2021 04 20 Competition Wrecked Australia's Telecoms

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Contents

Abbreviations and Acronyms

18 / 7	18 hours a day and 7 days a week
24 / 7	24 hours a day and 7 days a week
A/D/A	Analogue - Digital - Analogue conversion
ABA	Australian Broadcasting Authority
ACCAN	Australian Communications Consumer Action Network
ACCC	Australian Competition and Consumer Commission
ACMA	Australian Communications and Media Authority
ADSL	Asymmetrical (data speed) Digital Line Service
ADSL2+	ADSL with a maximum downstream speed of 24 Mb/s
AM	Amplitude Modulation
AMI	Alternate Mark Inversion (see HDB3)
ANSI	American National Standards Institute
ANZUS	Australian and New Zealand and USA Treaty
AOTC	Australian and Overseas Telecom Commission
ARE	(Crossbar) 2-wire switch equipment (electronic Register)
ARF	(Crossbar) 2-wire switch equipment
ARK	(Crossbar) small 2-wire switch equipment
ARM	(Crossbar) 4-wire switch equipment
ASX	Australian Stock Exchange
AT&T	American Telegraph and Telephone Corp.
ATC	Australian Telecom Commission
ATM	Asynchronous Transmission Mode
AXE	LM Ericsson Digital Switch
BIRRR	Better Internet for the Regional Rural & Remote
Bn	Billion
C	Celsius
CAN	Customer Access Network
CAS	Channel Associated Signalling
CBD	Central Business District
CCITT	Consultative Committee International Telegraphs and Telephone
CCS7	Common Channel Signalling Number 7
CE	Common Era
CEO	Chief Executive Officer
CIA	Central Intelligence Authority
CRC	Cyclic Redundancy Check
CSIDO	Commonwealth Scientific and Development Organisation
CSIRO	Commonwealth Scientific and Research Organisation
CWDM	Coarse Wave Division Multiplex
dB	Decibel
dBm	Decibels in relation to 1 milliwatt
DDN	Dedicated Data Network
DMS	Digital Metropolitan Switch (Nortel)
DOCSIS	Data Over Cable Service Interface Specification
Dr	Doctor of Philosophy (not a medical practitioner)
DRCS	Digital Radio Concentrator System (see HCRC)
DSLAM	Digital Service Line Access Multiplexer

DTMF	Dual Tone Multi-Frequency
E&M	"Ear & Mouth" bidirectional signalling
E1	European 1st Level in PDH (2.048 Mb/s)
EDL	Electronic Design Limited
EDN	Everything Designers Need (a magazine)
EIA	Electronic Industry Association
EOT	End Of Text
ESA	Exchange Switching Area
Fax	Facsimile
FCC	Federal Communications Commission
FDM	Frequency Division Multiplex
FIR-T	Crossbar Incoming Transmission Line Relay Set
FM	Frequency Modulation
FTTHomestead	SMOF to the Homestead
FTTN	Fibre to the Node
FTTP	SMOF to the Premises
FTTP	Fibre to the Premises
FUR-T	Crossbar Outgoing Transmission Line Relay Set
Gb/s	Gigabits per second
GBIC	Gigabit Interface Converter
GDP	Gross Domestic Product
GHz	GigaHertz
GIO	Government Insurance Ogffice
GOC	Global Operations Centre
GPO	General Post Office
GSM	Global Service Mobile (rough French translation)
GSM2, 2G	Second Generation GSM
GSM3, 3G	Third Generation GSM
GSM4, 4G	Fourth Generation GSM
GSM5, 5G	Fifth Generation GSM
GWBasic	Gee Whiz Basic
HCRC	High Capacity Radio System
HDB3	High Density Binary 3 encoding
HEX	Higher Education Expenses
HFC	Hybrid of Fibre and Coaxial cables
HP-IB	Hewlett-Packard Interface Bus
Hz	Hertz
IDF	Intermediate Distribution Frame
IEEE	Institute of Electrical and Electronics Engineers
IEN	Inter-Exchange Network
IMF	International Monetary Fund
IMEI	International Mobile Equipment Identity
IP	Internet Protocol
ISDN	Integrated Services Digital Network
ISO	International Standards Organisation
ITU-T	International Telecommunications Union - Telecoms (see CCITT)
kHz	kilo Hertz
km	kilo metres

kV	kilo volts
LAN	Local Area Network
LIC	Line Interface Circuit
LR/BR	Line and Break Relays (in Crossbar equipment)
LSI	Large Scale Integration
M	million
MAC	Media Access Control
Mb/s	Megabits per second
MDF	Main Distribution Frame
MEL-SYD	Sydney to Melbourne (and vice-versa)
MHz	mega Hertz
mm	millimetres
MOS	Metal Oxide Silicon
MSC	Minor Switching Centre
MS-DOS	Microsoft Disk Operating System
MSI	Medium Scale Integration
NBN	National Broadband Network Corp.
ND&C	Network Design and Construction
NEC	Nippon Electronics Corp.
NNI	National Network Investigation
NPN	Negative-Positive-Negative (valency)
NSW	New South Wales
NTSC	National Television System Committee
NZ	New Zealand
ODF	Optical Distribution Frame
OTC	Overseas Telecom Commission
P&L	Profit and Loss
P/L	Proprietary Limited (Company)
PABX	Private Automatic Branch Exchange
PAL	Phase Alternating Line
PC	Productivity Commission
PCB	Printed Circuit Board
PCM	Pulse Code Modulation
PDH	Plesiochronous Digital Hierarchy
PET	Pulse Echo Tester
PGS	Pair Gain System
PMG	Post Master General's Department
PNP	Positive-Negative-Positive (valency)
POTS	Plain Old Telephone Service
QMS	Quality Management System
R&D	Research and Development
RBS	Radio Base Station
RCA	Radio Corporation of America
ROI	Return On Investment
RU	Rack Unit (44.45 mm)
RVA	Recorded Voice Announcement
SCAX	Small Country Automatic eXchange (Hut)
SCN	Service Control Network

SDH	Synchronous Digital Hierarchy
SFP	Small Form Profile
SHF	Super High Frequency
SIP	Session Internet Protocol
SLA/B/C/D	(Crossbar) Subscribers Line and Group Switches
SMA	Spectrum Management Authority
SMOF	Single Mode Optical Fibre
SMS	Small Messaging System
SNR	Signal To Noise Ratio
SSB	Single Sideband
SSI	Small Scale Integration
STC	Standard Telephones and Cables Corp.
STD	Subscriber Trunk Dialling
SxS	Step by Step
T Mux	Transmission Signalling PDH-based Multiplexer
T1	Telephone 1st Level in PDH (1.544 Mb/s)
TAC	Telecom Australia Corporation
TAFE	Technical and Further Education
TCARS	Test Call Answer Relay Set
TCARS	Test Call Answer Relay Set
TCP/IP	Transmission Control Protocol / Internet Protocol Suite
TEAMTS	Transmission Equipment Alarm Monitoring and Transfer System
Telstra	Telecom Australia Corporation
TIO	Telecommunications Industry Ombudsman
TIT	Technician-In-Training
TQM	Total Quality Management
TRL	Telecom Research Laboratories
TV	Television
TWT	Travelling Wave Tube
UHF	Ultra-High Frequency
USA	United Stated of America
USO	Universal Services Obligation
USSR	United Soviet Socialist Russia
V	Volts
V DC	Voltage (Direct Current)
VDSL	Very (Fast) Digital Service Line
VFHA	Voice Frequency Hybrid Amplifier
VHF	Very High Frequency
VoIP	Voice over Internet Protocol
WDM	Wave Division Multiplex
WTO	World Trade Organisation
WW1	World War 1
WW2	World War 2

Surveying Australia's Telecoms Wreckage

My background sub-professional and professional experience in Australia's telecoms industry extends from CE 1966 through to now with very extensive technical / engineering / management portfolios covering many geographic and technical areas. This document is my lived / experienced professional opinion of how and why Competition is the prime cause of the telecoms mess in Australia that has greatly assisted crippling Australia's economy from about CE 1980.

What I didn't realise until I was into the Engineering ranks that the scope of my technical expertise was considerably wider than most other Technical Officers (who had inadvertently specialised in one area) and that my then understanding of (senior) management was limited – and that was quickly addressed with the further realisation that sales and marketing / advertising have no place in an infrastructure.

The function of the Post Master General (PMG) was established in Australia long before Federation (CE 1901) so it was really no surprise that the PMG as a Federal Department remained as entirely State run (engineering-based) organisations with effectively no National Headquarters (apart from the then Telecom Research Laboratory (TRL), that had very close ties with equipment manufacturing and supply.

The TRL worked very closely with Australian companies (in particular) to manufacture telecoms equipment for the PMG, and the PMG was a Federal Government Department – where every major (financial) activity had to be passed through the Government as an Act of Parliament. This highly repetitive process really slowed down the Federal Government's already slow operations; and conversely really slowed down process operations in the PMG.

Although not immediately obvious, the introduction of plastic insulation circa CE 1955 and a broad range of new technology components including Printed Circuit Boards, Transistors, Ferrites and much tighter component manufacturing tolerances all combined to totally revolutionise the electronics used for telecoms through the CE 1960s and CE 1970s, with newer equipment being far more reliable and requiring far less maintenance overhead. "***New Era of Electronic Components***"

Following the Vernon Report (CE 1974), the PMG was broken up and the Australian Telecom Commission (ATC) was established (CE 1975) – reporting to the newly restructured Department of Telecommunications and Transport. (This was "interesting" because Telecommunications is (electronic) transport!) Internally this Commission was far more efficient but executive management were still living in the mindset of the Recession and WW2. "***Shaking the Recession Mindset***"

By the CE 1980 it had become quite apparent to me that the USA Government were heavily "leaning" on the Australian Government (as per the ANZUS Treaty) to purchase a (Hughes) satellite for over Australia (and pay for the launch and maintenance) for spying over South Asia and use the Lone Pine site in the Northern Territory as the Earth Station. The broadly given public reason was to provide TV, telephone and "other" services. "***External Economic Control from the USA***"

Telecom Research Labs (TRL) were already well advanced with the DRCS/HCRC to provide over 14,000 telephone services so the Federal Government set up Aussat P/L as the "front" in CE 1979 and which was then into Optus in CE 1989 making the new "Optus" look to have a much larger competitive "footprint" and have a somewhat viable ASX entity (for Cable & Wireless). "***HCRC in Remote Australia***"

By the late CE 1970s the technology of Medium Scale Integration (LSI) was now quite mature and Large Scale Integration (LSI) was again revolutionising telecoms technologies and worldwide, the introduction of digital switching and digital transmission were on telecom infrastructures doorsteps. These new technologies were significantly different (and far more economical) than the earlier analogue transmission and electromechanical switching technologies – but they could not be readily physically integrated until the mid-CE 1980s. "***Transitioning to the Digital Network***"

In the political background, under continuing political and economic pressure from the ANZUS Treaty: the Australian Telecom Commission (ATC) was split up and privatised by the Federal Government in CE 1989 (losing its highly efficient "economy of scale"), to become the Australian Telecom Corporation (and put on the ASX, selling only about 40% of the available securities). "***External Economic Control from the USA***"

The Overseas Telecommunications Commission (OTC) that was set up in CE 1946 was merged with Telecom Australia Corporation in CE 1992 forming the Australian and Overseas Telecom Corporation (AOTC) and soon after renamed as Telecom Australia Corporation "Telstra".

The prime reason for this radical restructuring of Australia's telecommunications infrastructure (business) to be pushed into being a competitive business goes back to the ANZUS Treaty (CE 1953) signed by Prime Minister Robert Menzies. "***The USA Muscles its way into World Dominance***"

Some of the long-term fallout of that Treaty was the Davidson Inquiry / Report (CE 1980-1982) that initiated Australia's telecommunications infrastructure (business) be converted to a competitive business "to make it more efficient"! "***The Davidson Inquiry and Report***"

The multinational Cable and Wireless bought out Optus, and later the Singapore Government bought in changing the name to Sing Tel Optus Ltd, then transferred the name to "Optus" and then took Optus off the ASX so Optus is now wholly owned by the Singapore Government and not by the Australian Government!

Circa CE 1985, Telecom Australia was also in the middle of an unfortunate engineering nightmare that was totally externally caused by the competitive mindset that had cut infrastructure corners. "***Competition Wrecked Australia's 2 Mb/s***"

In mid-April CE 1986 the whole dynamics of long-haul transmission had an immense productivity boost by the sudden and rapid introduction of Single Mode Optical Fibre (SMOF). "***The Sudden Emergence of SMOF***"

Circa CE 1992 there was fierce competition between Telstra and Optus to roll out a competitive HFC Pay TV infrastructure and this proved to be a financial, business and competitive infrastructure fiasco. The other problem was that Optus was on its last legs and it was only Mobile Phone technology that prevented Optus from totally disappearing. "***Competition Wrecked Australia's HFC***"

What became very obvious to me by the early CE 1980s was that the new transistor-based FDM transmission-based technologies had a far lower maintenance requirement than the earlier thermionic valve transmission technologies and the digital transmission and switching technologies using LSI / MSI technologies had a far lower maintenance requirement than the earlier electromechanical and analogue / FDM transmission technologies. "***Second Wave of Electronic Components***"

By the late CE 1980s it was starting to become painfully obvious that almost all digital switching and transmission equipment (especially that using SMOF and MSI/LSI technologies) required virtually zero maintenance – and could be remotely managed from one national site. "***Rationalising Carrier Maintenance***"

In other words it was not (increased) competition that made telecoms "efficient" but a gradual and continuous improvement (over many decades) and generational change of the technologies in the equipment being used that was the prime cause for telecommunications infrastructure prices to slowly and continually fall.

In March CE 1986 I was "tasked" to design the then mythical Sydney Melbourne Optical Fibre System. As part of this process, I also did a forward analysis of the service requirements (beyond the telephone) and discovered for myself that data would most probably exceed telephone connectivity by about CE 2000. "***The Sudden Emergence of SMOF***"

Circa CE 1995 I was observing the displacement of Engineering people by the general takeover of Sales and Marketing / Advertising mindset people. It struck me that these two groups of people have a diametrically opposite concept of business management and it was then that I realised that Telecom Australia Commission fast lost its efficiency as an Infrastructure Business and was now a Competitive Business. "***Infrastructure Business and Competitive Business***"

Circa CE 2000 it was becoming obvious that the "wheels had fallen off" Australia's telecommunications infrastructure. One of the tell-tale flares was the high number of Select Senate Inquiries, Regional Inquiries and other Inquiries. None of the panels had any infrastructure Business mindset (Engineering) expertise included – so the (now glossy) Reports were full of extremely expensive useless "waffle". "***The Privatisation Wheels Fell Off***"

It initially came as a surprise (circa CE 2005) that the rollout of ADSL technology in Australia was a disaster, but in hindsight the reasons for this rollout failure were firmly associated with running an infrastructure business with a competitive business mindset. "***Competition Wrecked Australia's ADSL***"

There is a very large void in (Western) Economics that totally omits "Infrastructure Business" but concurrently over-praises "Competitive Business" as the lead-up to panacea to everything economic. "***External Economic Control from the USA***"

This situation may have come out of the USSR – USA Cold War in the early /mid CE 1950s, but I sensed the situation is far more deep-seated where USA Industrialists have in the late CE 1700s – to late CE 1800s taken financial (and management) control of all the infrastructures in North America – and most probably re-written the fundamental Economics texts to "suit themselves" – such that there is no mention of Infrastructure Business. The problem is that this leaves the "Economic" bird with two right wings and no left wing – and so it (slowly) spirals to the ground as it self-destructs! What was becoming obvious was that with each new telecoms technology, the installation and/or operational / maintenance costs seem to be lower – so I went back to typically CE 1900 and documented the large majority of various transmission / switching etc. technologies to provide a much clearer Australian picture.

Infrastructure Business and Competitive Business

Few people that have studied (western) economics recognise that this is totally built around the Competitive Business mindset model and is void of the Infrastructure Business mindset model (or are incorrectly taught that anything other than the Competitive Business mindset is communism / socialism). When I studied Economics at school, circa CE 1964, 1965 we were taught about competition and theoretically how and why the amount of competition (and product / service availability) had an apparent direct / inverse relationship with price.

Some years later (circa CE 1968) while working as a Technician-in-Training (TIT) in the Post Master General (PMG) Dept., manufacturing a "small scale production" run of electronic equipment for use within the PMG; we needed to evaluate the production costs. Unlike the competition model that we were taught as school, there was no large mark-up in price for an inflated internally accounted profit margin, but there was a large realistic externally accountable cost if this equipment was not provided and installed / commissioned in a timely manner.

The production costs were quite low but the economic value to the end users was extremely high. We could have easily heavily inflated the equipment production costs and more than quadrupled the costs to the end users – and they would have paid – because this service / equipment / connectivity were essential – not discretionary! This situation set me thinking that the economic theory that I had been taught at school certainly did not address this essential goods / services situation.

Many times in the following decades, similar work situations kept re-appearing and it became clear to me that the "Competitive Business" mindset model was an extremely awkward fit in almost all these (infrastructure) workplace situations.

My father who was a country Solicitor gave me an extremely valuable tip: "If the provided solution for a business strategy is unnecessarily complex then it is wrong – go away and look for an alternative approach. When you have a process that that is straightforward (and simple) - this is the (usually) correct solution / business strategy.

With essential products / services – these are not discretionary – so the "Competitive Business" mindset needs to be discarded / eliminated / reversed for essential products / services. These essential products / services are "Infrastructure" – so it therefore follows that "Infrastructure Business" is diametrically different than "Competitive Business" and in (western) economics, equally imperative.

These two business models are diametrically opposite – but each desperately needs the other so that the whole (balanced) economy of a country can flourish.

Over considerable time what dawned on me was that the management styles, work processes, accountabilities, timeframes, in-house knowledge, and a whole lot more about Competitive Business are radically different than those in Infrastructure Business. Having the wrong mindsets executing / directing these diametrically different business environments is a sure way to scuttle any countries' economy.

As I looked deeper into the two business models, it became very clear that both Business Models definitely have their place in every country's economy and without a well-established and smooth running Infrastructure Businesses managing all the country's infrastructures, the Competitive Businesses cannot operate anywhere near maximum efficiency. The Economics that I had been taught at school (and later at university) were obviously missing about Infrastructure Business! But where to start?

The following is short set of PowerPoint Slides I made in circa CE 2013:

Competitive Business and Infrastructure Business

These two Business Models:

- ✓ The Mindsets Are Diametrically Opposite to each other
- ✓ Each Mindset is Absolutely Necessary for the Other
- ✓ Each are Very Efficient in What They Do, and How They Do It
- ✓ Use Entirely Different Business Strategies, Business Focii
- ✓ Use Diametrically Different Efficiency, Quality / Compliance Measures
- ✓ Have Entirely Different Values, Business and Management Mindsets
- ✓ Have a Dramatically Different Focus of Liabilities, Accountabilities
- ✓ Vertical Integration Separated for Optimum Economic Efficiencies

Value Adding and Business Strategy

Competitive Business	Infrastructure Business
Markets Discretionary Products and Services Retails Wholesale Products / Services Adds Value by Retail Packaging / Bundling Innovates to Maximise Business Profits Aspires to be a “Monopoly” in its Market Uses Monopoly to Minimise Service and Delivery Uses Monopoly to Maximise End User Prices	Provides the Essential Products and Services Owns, Builds & Operates All Essential Services Adds Value by Maximising Service Standards Timely / Appropriate Provisioned Infrastructure Aspires to be the “Economy of Scale” Provider Economy of Scale to Maximise Service / Products Economy of Scale to Minimise End User Prices

Focus and Remuneration

Competitive Business	Infrastructure Business
Maximises Shareholder / Self Profits (ROI) Minimises Product & Service Overhead Costs Minimum ROI: 20% pa, far greater if possible External Accounting Deliberately Not Included Assertive Bullying, Aggressive Positioning “Alpha” People Aspire to Top Levels Board/Directors & Executives Grossly Overpaid Workforce Usually Very Underpaid for Services	Maximises Product & Service Delivery Maximises Product & Service Quality Standards Internal ROI is typically 0% to 7% External Accounting Intrinsically Very Positive Covert Bullying, Associative Positioning “Beta / Sigma” People Aspire to Top Levels Exec / Floor Pay Range Usually 5:1 Maximum Workforce Generally Well-paid for Services

Liability and Accountability

Competitive Business	Infrastructure Business
Excludes Externalities Wherever Possible Uses Only Internal P&L Accounting Uses Red / Green Tape to Falsify Quality (QMS) Board / Execs Isolated from Litigation Maintenance is Delayed / Avoided / Minimised Maintenance is out-sourced / Contracted Maintenance is Reactive (after it has crashed) Needs Expensive External Regulation PC, ACCC, Senate Hearing, Royal Commission	Includes Externalities as Standard Practice Includes Internal and External P&L Accounting Uses TQM to ensure Quality (without Tape) Board / Execs part of the Overall Responsibility Maintenance is Proactive / Scheduled Maintenance is in-sourced to Experts / Gurus Maintenance is Proactive (it never crashes) Includes Proactive Inexpensive Self-Regulation Proactive Long-Term Self-Accounting

People, Education and History

Competitive Business	Infrastructure Business
Employment typically 2 to 3 years per Business	Employment typically over 30 years in Business
Politicians, Advisors, Consultants, Executives	Industry-experienced Executives, Leaders
Sales & Marketing, Lawyers, Contractors	Engineers, Project Managers, Technical, Field
Staff promote through different Businesses	Staff usually advance within a Business Industry
Miniscule In-House Training & Education	Extensive In-House Training & Education
Trained Staff usually Imported / Poached	Most Well-Trained Staff usually Home-Grown
External Consultants from other Businesses	Most Expert Staff are Internal Gurus
Management Consultancy is Very Common	Management Consultancy is very rare
Business Memory is Short (typically <2 years)	Business Memory is Long (typically >30 years)

Business Focus, Marketing, Community Association

Competitive Business	Infrastructure Business
Sales Driven, Minimised Products & Services	Project Driven, Maximised Products & Services
Product Life: 2 Years is "Long Term"	Product Life: 20 Years is "Medium Term"
Maximised End User Prices (Profit)	Minimised Wholesale/Community Cost
Sales, Advertising and Marketing Focussed	Long-Term Quality & Detail Focussed
Thin Processes / Minimum Documentation	Detailed Processes / Full Documentation
Very High Public and Business Profile	Very Low Public and Business Profile
Extensive and Expensive Advertising, Logo	Very Low Profile Expense Advertising, Logo
Overt Association by Brand Names / Fashion	Covert Association by Living Standards
Bonds through Fashion / Sports Sponsoring	Bonds through Government / Education

Product Research and Development

Competitive Business	Infrastructure Business
Retail Product Research is minimised	Original Research is internationally recognised
Computer Modelling of Sales Strategies	Computer Modelling of Physical Structures
Product Innovation is Minimised / Stifled	Product Innovation is Fostered / Championed
Steals Proof of Concept Production Lines	Creates / Develops Proof of Concept Productivity
Usurps and Steals Product Development	Finances and Fosters Product Development
Profits by Fast Assembly Line Production	Outsources / Gives away Small Scale Production
Champions Retail Distribution Logistics	Minimises Retail Distribution / Sales / Marketing
Product Life: 2 Years is "Long Term"	Product Life: 20 Years is "Medium Term"

Compliance and Quality

Competitive Business	Infrastructure Business
Works on a "Piece-Rate" (time standard)	Works on a "Quality-Rate" (service standard)
Workplace Safety is a Major Compliance Issue	Workplace Safety Built Into Quality Practices
"Quality" Management System (QMS) is False	Total Quality Management (TQM) is Normal
Uses QMS (ISOx) to Maximise Process Checking	Uses TQM to Minimise Process Checking Need
Uses QMS (ISOx) for Maximised Compliance	Uses TQM for Continuous Improvement
QMS Ensures Minimum Acceptable Quality	TQM Ensures Maximum Possible Quality
Uses QMS Red / Green Tape to Falsify Quality	Uses TQM to ensure Quality (without QMS Tape)
QMS Isolates Board / Execs from Litigation	Board / Execs Integral with the TQM Process

Examples of Efficient Economy

Competitive Business	Infrastructure Business
Political Alliances – Politicians, Political Parties	Public Service - Departments, Commissions
Sales/Advertising: Production and Manufacturing	Research & Development (CSIRO / CSIDO)
Service Retailers (Electricity / Telecoms / Food / Fashion / Materials / Equipment Retailers	Service Wholesale (Electricity, Telecoms, Water Storage / Reticulation / Drainage etc.)
(Competitive) Business Professionals	Universities / Schools / TAFEs - Courses
Transport (Road / Rail / Air) Service Retailers	Road / Rail / Port: Planning & Prov. Operating
Plumbing, Electrical, Building Maint. / Retailers	Water and Sewerage Planning / Prov. Operating
Medical Specialists, Pharmacies, Drug Suppliers	Hospitals, Cemeteries, Forensic Services
Finance / Insurance / Brokers / Retailers	Police, Defence, Fire, Emergency Services

These two Business Models:

- The Mindsets Are Diametrically Opposite to each other
- Each Mindset is Absolutely Necessary for the Other
- Are Each, Very Efficient in What They Do, and How They Do It
- Use Entirely Different Business Strategies, Business Focus
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- Have Entirely Different Values, Business and Management Mindsets
- Have a Dramatically Different Focus of Liabilities, Accountabilities
- Vertical Integration Separated for Optimum Economic Efficiencies

When Infrastructures are Privatised:

- Preventative Maintenance is stopped (Shareholder Profits go Up)
- Planning is Eliminated (Shareholder Profits go Up – Short Term)
- End-User Prices go Up (Shareholder Profits go Up – Short Term)
- Productivity Economy of Scale is Lost (National Wealth is Wasted)
- Infrastructure is Multi-Duplicated (National Wealth is Squandered)
- Infrastructure Becomes Expensive (Private Sector Closes / Deserts Nation)
- Infrastructure let run to Ground (Remaining Private Sector Closes)
- Community and Businesses look for Alternatives (Government Inquiries)
- Government Buys Back and Rebuilds Run-Down Infrastructure . . . . .

When Infrastructures are Nationalised:

- Maintenance is re-Introduced (Infrastructure becomes Functional)
- Long Term Planning is Re-Introduced (New Infrastructure Rolled Out)
- Multi-Duplication is Eliminated (Foreign Debit is Crushed)
- Services Expanded Nationally (Social Services Costs Reduced)
- Wholesale Products Increased (Competitive Retail Profits Maximised)
- Wholesale Prices Reduced (Competitive Retail Profits Maximised)
- Private Sector Becomes Economic (Wider Employment Opportunities)
- Community and Businesses use Infrastructure (GDP Maximised)
- Infrastructures Foster New Businesses (Minimised Unemployment)

Unfortunately, the “hard right” has spread its tentacles far too wide and has ventured well outside the apparently purely discretionary market as very clearly stipulated by Adam Smith. The cause of the problem relates to Infrastructures operating with “Rivers of Gold” and unlimited greed in the private sector!

With discretionary sales / marketing - yes the advertising costs are expensive – but so is the profit margin. It is not uncommon to have a wholesale to retail markup well exceeding 100% as the starting point and then come down as the competition increases. So – yes – as competition is increased – so too the end user prices can and will come down – and minimally affect the service standards or product Quality.

With essential products / services, there is no need to advertise and the prices can be sky high – because without that product / service then standard of living is severely compromised.

In the best economic situations, the cost of essential products and services is very low as this really facilitates competitive businesses to operate with a minimum of infrastructure overhead costs – and pay their staff overheads quite well – and make a solid profit – so they can pay taxes that in effect covers the costs of essential products and services that makes their competitive businesses (highly) profitable!

This is the “money go around” that the “free market” hates to accept (particularly in the USA) where “hard right” political forces have very successfully pushed for a minimum government (departments) and have all infrastructures privatised. This way the “rivers of (infrastructure) gold” stay with a tiny portion of the whole population (who (surprise, surprise) are philanthropic – but ensuring their names are emblazoned on their apparently generous infrastructure gifts)! Yes it is very ironic!

For a properly balanced economy, all the essential products and services – i.e. the infrastructures – must in reality be entirely under Government control and be owned and operated as sub-Government Department **Commissions**!

With competing Infrastructures, this rapidly drives up the operating costs of these essential products and services because the massive value of “economy of scale” is at least halved; resulting in equipment being considerably more expensive - and near the back of a production line (seriously delayed), plus larger projects / infrastructures then need multiple levels of (expensive and delayed) communications that were previously totally unnecessary – because it was all “in-house”.

In looking at this “efficiency” word meaning problem from several angles over some decades it dawned that the meaning of the word “efficiency” has a common thread with engineers of “energy out / total energy”, but with economists; “efficiency” directly relates to the percentage of population employed (i.e. useful population / total population). In the mindsets of Sales / Marketing this is: value of products sold / total cost of products (including advertising and marketing).

Sales / Marketing (usually) have no process issues with cutting corners – (rushed orders, incomplete project, defects, take now – pay later, late delivery), and “socialising”: bribery, compromising, corruption, travel tickets, shows, holidays, cars etc. to make large scale sales / business deals.

The mindset of engineering (i.e. as in infrastructure businesses) is fundamentally based on continuous improvement curiosity to “build a better mousetrap” where productivity is (usually) significantly increased by continual improvement (usually over many years – if not decades) to processes and practices, and looking at alternative methodologies that inherently use less overheads and provide more reliable facilities for the countries' infrastructures.

With discretionary products and services (as defined by Adam Smith – in a "perfect market" where all providers / sellers have the same product and very similar shopfront and shopfront location (i.e. transport) is not an issue), there is no doubt that competition (in a "perfect market") both employs far more people in the population (economic efficiency) and brings down the end user price, as the competing sellers will naturally drop their prices to make sales at reduced profits instead of making no sales at all. (But recall they started with a very highly inflated sale price!)

What is far more relevant is that in 1956 Dr Kelvin Lancaster and Dr Richard Lipsey came out with a paper called "The Theory of the Second Best" basically describing the "perfect market" as outlined by Adam Smith is in practice totally impossible. So the Second Best arrangement is where there is collusion and corruption / side deals "business" is done to favour the location and social standing of particular vendors / and purchasing / selling / volume / timing marketing arrangements.

This landmark economics paper came out in the middle of the Cold War between the USA and the USSR which at that time had diametrically opposing views on economics, and the USA wasted no time in thrusting this paper well below the carpet!

They were (of course) extremely heavily ridiculed (truth really hurts) in the USA and economists that have written on this topic go into desertions of crap to hide the truth that the Adam Smith "perfect market" cannot and does not exist in practice.

I have a subtly different spin on this topic in that co-operation (guidance / team-work / assistance / facilitation) is far more business efficient than competition (stealing / cheating / lying / undermining / fighting / anarchy).

There is a very subtle difference between discretionary and essential – where discretionary products / services do not need to be purchased / used; but essential products / services are imperative and people will pay even with their lives for their families / society to have essential products / services.

Privatising (essential) infrastructure is a fundamentally failed economic strategy – primarily because the mindset of executive operations management between Competitive (discretionary) Business and Infrastructure (essential infrastructure) Business are effectively diametrically opposite.

One classic example being the privatisation of NZ Rail (infrastructure) to Toll Holdings P/L – this infrastructure was literally run into the ground (within a decade) before this infrastructure being again nationalised (re-purchased and run as a sub-Government Business by the NZ Government) and rebuilt from the ground up.

Telecommunications is also a part of Transport infrastructure that instead of passing physical freight / passengers; telecoms infrastructure passes electronic messages (now in a very wide variety of forms) over distances well beyond the range of our land boundaries.

This Economic Efficiency definition has been deliberately "forgotten" (particularly in the USA) so that infrastructures could be privatised for personal greed – at the expense of many countries long-term economic well-being.

This document traces through the advancing technologies used in Australian telecoms from about CE 1900 until the present and clearly shows that in virtually every situation that there has been a step technology advancement, that the productivity was significantly increased and the end user costs decreased.

When Australia was founded (CE 1901) as a Common Wealth – all the then recognised Essential Services were run and operated by the Government(s) for the people to use and maximise the productivity of Australia. Since then (theory of the second best in application) almost all of these essential products and services have been stripped from the Common Wealth and this is one of the prime reasons why Australia is not growing but has been in slow recession from about CE 2000.

Transport is an essential product / service that we rely on to physically move people and produce from one location to another. Footpath, Road and Rail (and Airport / Seaport) facilities are very expensive to build and keep in good working order – but once built (properly) – the physical decay time is usually many decades, not months or a few years like discretionary products e.g. fashion clothes, movies.

Telecommunications is electronic transport (so this too is an infrastructure, not a discretionary product / service). Telegraphy preceded telephony by some decades (CE 1860s - 1890s) but electronic transport (and postal services) was not deemed to be essential until after CE 1901 and was therefore not part of the Federation Common Wealth.

The (Commonwealth) Post Master General Department took on the role of managing Posts and Telegraphs infrastructure and this was State managed with a National Departmental Headquarters that included Research and (manufacturing) Development facilities that was pivotal in building technology manufacturing expertise within Australia for many decades – until privatisation (and Global Engineering / Manufacturing – driven from inside the Northern Hemisphere and literally excluding the Southern Hemisphere).

From the mid CE-1970s, as more of Australia's infrastructures have been privatised, Australia's economy has been gradually dying (from the inside). Once privatised, it usually takes about 10 years for the "wheels to start falling off" with infrastructure not proactively managed, long-term investment made short-term and funds re-directed from long-term planning to shareholder dividends and executive overpayment.

Because of the excessive influence of the USA (which as I understood to have had controlling interests in the World Trade Organisation (WTO) – headquarters in the USA (New York) and the International Monetary Fund (IMF) plus Australia was tied underfoot by the ANZUS Treaty – signed off by Prime Minister Menzies in CE 1953; the Federal Government were really over a barrel in that they "had" to split up the natural (and highly efficient) monopoly of Telecom Australia Commission – or face Australia being isolated from world trade and have Australia's economy wrecked – just like that of Chile!

With the Davidson Report out in CE 1982, the private sector wasted absolutely no time in circling Australia's telecoms infrastructures and had whichever Government party virtually as their mercenary slaves – to get private sector on the rivers of gold. OTC merged into Telecom Australia Corporation in CE 1992. "***The Davidson Inquiry and Report***"

Unnecessary and Very Expensive Competition

It is particularly dishonest that economists deliberately "forget" certain aspects of economic theory to deceitfully promote other aspects of economics that have a diametrically opposite economic effects to what was deliberately "forgotten".

There is a very subtle / diametrical difference between Competitive Business (where the products and Services are fundamentally discretionary) and Infrastructure Business (where the products and services are fundamentally essential). "***Competitive Business and Infrastructure Business***"

Western (USA driven) economic theory (and practice) is entirely built around "Competitive Business" in total ignorance / disbelief that "Infrastructure Business" is imperative for "Competitive Business" to be economic and flourish.

In Australia, when the Commonwealth was set up in CE 1901; infrastructures were deliberately kept out of the Competitive Business mindset to eliminate to massive extra costs and economic problems caused by Competitive Businesses operating and running Infrastructure Businesses.

The simple reasoning was that the general public / Community and Competitive Businesses that use these infrastructures can then do so at a minimum of cost and maxim reliability to in turn maximise the productivity (and profitability) of their Competitive Businesses and the Communities productivity / profitability is also maximised – which in turn returns a maximum of funding to the (Federal) consolidated revenue to further fund the Australian common wealth of infrastructures.

The problem is that when infrastructures are built and operated by the Competitive Business mindset (i.e. the private sector) the infrastructure usually continues to operate perfectly well for a decade or so (short-term self-justifying the privatisation of that infrastructure), but after a decade or so, private sector driven executive decisions that come with the Competitive Business mindset cause a series of catastrophic failures in that infrastructure – leaving the Government to clean up the situation.

More often than not, the Government of the day is too far compromised by the private sector to take the correct stance and nationalise the infrastructure. Instead, weak / compromised Governments usually hold a (series of) Select Inquiries with people that have no relevant engineering expertise and consequently the Reports are full of "waffle" (meaningless statements). Following the Reports, the Government usually provides a significant financial "grant" for funding to provide another short term fix.

Unless there is another very significant other National income the country is on a long downward spiral. The USA economically peaked circa CE 1950 and had up with the development of silicon integrated circuits and software through until about CE 1990 and from there has been on a steady downward economic spiral.

Australia (with a much smaller economy) peaked around CE 1975 and has since circa CE 1980 been on a steady downward spiral and now CE 2021, virtually zero manufactured goods that are bulk exported.

Australia's economic stability was ignorantly wrecked by Prime Minister Menzies signing the ANZUS Treaty in 1953. At that time, the Korean War had just finished, the USA was a military powerhouse and Australia was in minor geographic peril of being invaded by communist forces from Asia. "***The USA Muscles Itself into World Dominance***"

On the surface, the (bilateral) ANZUS Treaty obliged the USA to provide military protection against (communist) invasion and Australia be obliged to provide military support to the USA in any of its ensuing conflicts (which was then deemed unlikely).

The ANZUS Treaty also included paragraphs restricting all Australian innovations to be vetted by the USA Military before approval and that all Australian Infrastructures were to be privatised (as like in the USA). These extra obligations were obviously considered very minor but later they literally crippled Australian innovation and set the path for USA financial institutions to plunder Australia's Infrastructures.

When competition is introduced / increased into infrastructure, the "economy of scale" in that infrastructure is significantly reduced (making the base costs substantially greater) plus there is are substantial new overhead costs of "interoperability" between the now competing operators, plus there is another substantial overhead cost of sales marketing and advertising (plus associated legal support) that previously was totally unnecessary.

These added overhead costs certainly do not "drive down" end user costs! Exactly the opposite – these competition-caused extra overheads "drive up" end user costs because the "economy of scale" is substantially reduced, overhead costs are now substantially increased and these extra costs have to be covered by increased end user costs - or substantially increasing the end-user customer base.

Introducing / increasing competition does however increase the proportion of people employed and that (quaintly) is seen by economists as being more efficient – even though those extra employed people do not have the necessary training or skills associated with providing and maintaining that infrastructure.

The economic twist is that when competition is introduced into the discretionary market (i.e. not infrastructure – which is essential) that market situation is (usually) running as a monopoly and has a very substantial profit margin.

Following on from "***The Davidson Inquiry and Report***" CE 1982, the Australian (and Overseas) Telecom Commission was broken up / force privatised in CE 1989 to become the Australian Telecom Corporation (Telstra) and Optus (as an entirely free-standing competing Telecoms Corporation), Australia lost the extremely efficient "Economy of Scale" telecoms infrastructure that it had.

Other telecom businesses "Alternate Operators" were now allowed to compete in this (infrastructure) "playing field" with the extremely theoretically blinkered economic hypothesis that "increased competition will bring down end user costs"!

Instead of the whole Australian telecoms infrastructure working co-operatively – these smaller bodies now worked in competition against each other – which then meant there was the need of yet another (expensive) sub-Government body (the Telecommunications Industry Ombudsman – TIO) required to settle the disputes between these now arguing businesses and a raft of totally unnecessary rules and regulations for interworking – where before this process was extremely simple and straightforward (and with a minimum of delay and minimised end user cost).

Circa CE 1989 – The highly efficient natural monopoly of Telecom Australia Commission was broken up with some of this infrastructure "gifted" to Optus – plus several large business accounts including the ABC radio and TV network distribution

– which was then transferred to Optus's newly "gifted" Satellite technology where Aussat was merged into Optus.

Circa CE 1990 – Optus entered the fixed access telephony market using Nortel digital switches (installed by Telecom Australia's Network Design and Construction Business Unit (ND&C) - because this was by far the least expensive tender).

My understanding as to the reason why ND&C was about half price to all other contenders to build the Optus Core Network was that ND&C had habitually done work for Telecom Australia Commission / Corporation and as such ND&C had their "in-house" price – which was (naturally) break even plus a margin for equipment replacement and future development.

When ND&C included their standard profit margin (plus "a bit" for considerable profit) this total price came in at about 50% below all the other contenders that were naturally charging (in a discretionary market) like there was no tomorrow!

You then have to very seriously ask yourselves: how much profit is "reasonable" and how much can a (discretionary) contract price can be trimmed to still make a hefty profit? The answer to this goes a very long way to explain why discretionary competition such as installing and commissioning telecoms equipment for another competing business so that business can compete against yourself, can be afforded - and still make a good profit?

Clearly the economic rules of cost / supply / demand and delivery are all based around discretionary products and services – but the products and services of telecoms infrastructure (in a country) are not discretionary so the standard competitive rules of (discretionary) price and demand cannot be methodically applied with infrastructures. "***Telephones Become an Essential Service***"

The fact that telecoms end user prices fell in the mid CE 1990s has everything to do with a range of then recent productivities from about CE 1980 onwards and absolutely nothing to do with increased (discretionary) competition. "***The Productivities of Electronic Databases***"

What I found to be really interesting is that new infrastructures and technologies take about a decade to really be rolled out and bed-themselves in and become considerably more economic than the previous infrastructure technology.

It is certainly not competition (nor increased competition) that makes our economy more affluent (and raises our living standards) but the introduction of more efficient and less expensive appropriate infrastructures that stand on the earlier infrastructure technologies.

When competition is introduced into infrastructures it inevitably wrecks these infrastructures at an immense expense to our country's economies.

Advances in Telecoms Technologies

Political economic history and the history of telecoms advances run a close parallel. The internal economics of telecoms technologies was for many decades extremely capital intensive and extremely overhead maintenance intensive making it an essential for military and high finance (i.e. the Stock Market / Banking for the very wealthy and Ministerial communications).

From before CE 1900, there had been a slow and steady set of technological advances in electronics and material science that had provided a series of massive productivity gains in telecoms engineering (in Australia) including at least:

- Step by Step Automatic Switching (far lower overhead than manual switching),
- Loaded Cable (stable impedance and flat frequency response),
- Phantom Circuits (Multiple extra Voiceband circuits over a few physical circuits),
- Amplified Circuits (Operate over far longer distances with far less expensive cable infrastructure),
- Frequency Division Multiplex [FDM] (replacing amplified and phantom circuits with this far lower cost technology),
- Paper Insulated Cable / Underground Network (replacing overhead wires – far more reliable, lower overhead maintenance costs),
- Telex (replacing Morse Code operators – considerable less overhead and far faster),
- Long Haul Radio / Coaxial Cable (very economically replacing overhead wire technology for long distance communications),
- Plastic insulated Cable (replacing Paper Insulated cable – far more reliable and much easier to joint / terminate),
- Crossbar Switching (replacing Manual and SxS switches – considerably less overhead costs plus automatic alternate route switching),
- Transistors (replacing Valve technologies – far lower power consumption, far more compact, amplification far more stable, lifetime is in thousands of years),
- Ferrites (inexpensively replacing iron cored transformers and the performance far exceeds that of iron cores),
- Printed Circuit Boards then Integrated Circuits (far more reliable / compact / repetitive / inexpensive circuits)
- Medium Scale Integration (MSI) silicon chips – enabling very compact (and extremely inexpensive) digital circuitry.

And that was just up to the mid-1970s!

By the CE 1950’s, telecoms (technologies) in Australia had developed so much that virtually all (urban) businesses had telephones (even their own internal switchboards). Since then as the cost of getting connected - and the cost of telephone calls kept gradually falling against the rising cost price index (CPI), the number of landline telephones has risen faster than the population growth and by the early CE 1960, many households had their own landline telephone services, and this technology peaked about CE 1990.

In the past 50 years (i.e. from CE 1970) there have been again another series of engineering developments (with their massive productivity improvements) that again have used the pre-existing technologies as platforms including at least:

- Logarithmic Digital Encoding (enabling digital telephone switches and digital Voiceband audio transmission),
- Plesiochronous Digital Hierarchy (PDH) - enabling virtually zero maintenance transmission,
- Digital Exchanges (inexpensively replacing Crossbar and SxS Exchanges),
- Single Mode Optical Fibre (dramatically reducing transmission overheads),
- Common Channel Signalling (providing a wealth of free network data health reporting),
- Electronic Metering and Billing (dramatically reducing massive overheads),
- Private Automatic Branch Exchanges (PABXs) (inexpensively replacing manual switchboards in businesses),
- Large Scale Integrated (LSI) chips (enabling Personal Computers and inexpensive Software developments),
- Internet / Switch / Routers (enabling Emails and Websites),
- Synchronous Digital Hierarchy (SDH) enabling much wider bandwidths (faster data speeds) over SMOF than possible by PDH technology.
- Digital Service Line (DSL) technologies enabling inexpensive Broadband connectivity over Voiceband engineered telephone cables,
- Introduction of Small Form Profile (SFP) Gigabit Interface Connections (GBICs) enabling extremely inexpensive and very fast connectivity over SMOF.
- Voice Over Internet Protocol (VoIP) (caveating telephony equipment overheads)
- The Ethernet became the Unified Core Network (for everything).

And that is up to about 2015!

So, from about CE 1900 until after CE 2000, telecoms infrastructure gradually morphed from being highly manual and highly unreliable requiring continual high-intensity maintenance to (now) being virtually automatic and extremely reliable, requiring very little if any maintenance. Virtually all telecoms infrastructure installed these days is basically: Install / Commission and leave in service for decades (with nominally zero maintenance).

Like all privatisation failures, the problems immediately start but do not get noticed until about a decade later when the infrastructure business medium-term planning has finally stopped; the permanent effects of not having proactive maintenance starts to cause catastrophic infrastructure breakdowns, the budget for replacement and new infrastructure has been diverted to senior executives and shareholders, and (usually) a string of Federal Government Inquiries become initiated.

The following chapters go into a little more detail about how these new technologies made step advances in productivities and show how and why it was purely these technological advances that were the prime economic forces to drive down end user prices of telecommunications services.

Circa CE 1975 – the concept of Plesiochronous Digital Hierarchy (PDH) started to slowly emerge with Telecom Australia Research Laboratories (TRL) in Melbourne taking a very keen interest and involvement – primarily because digital transmission potentially has a far lower maintenance overhead than analogue transmission.

Circa CE 1975 – In many localities around the developed world; including Telecom Australia Research Laboratories (TRL) in Melbourne - there was a concerted effort to develop the concept of Single Mode Optical Fibre (SMOF) – because Multi-Mode Optical Fibre (MMOF) had shown immense promise for wide bandwidth – but the attenuation per unit length was far too great to be practical beyond a few km.

Circa CE 1981 – LM Ericsson digital (telephony) switching technology was being introduced by Telecom Australia Commission to replace much higher overhead maintenance electromechanical Sylvester (Manual Switchboard), Strowger (Step by Step) and LM Ericsson (Crossbar) telephony switches.

Circa CE 1985 – It finally became apparent that there were certain frequency-based “windows” that may facilitate low attenuation through SMOF technology.

March CE 1986 – People in TRL (and elsewhere) identified some critical SMOF splicing and terminating techniques that opened the floodgates for very inexpensive and massive bandwidth long distance transmission technologies.

The economic advantages in using SMOF over all other transmission mediums were astounding (this is detailed later). Not only is SMOF cable far less expensive per unit length than pair/ quad copper, coax cable etc. but the bandwidth far exceeds that of other transmission mediums, the attenuation per unit length is considerably less, the reliability is considerably higher and the associated terminal equipment is considerably less expensive than the earlier analogue equipment – and the (digital) terminal maintenance overhead costs are literally zero!

From late CE 1986 through to CE 1993 inclusive, Telstra laid many thousands of km of Single Mode Optical Fibre (SMOF) cable through all metropolitan areas and trenched in several thousand km of SMOF cable throughout much of the Regional Rural areas to replace very ageing (and very high maintenance cost) pair copper, and point-to-point radio and coaxial cable transmission medium technologies.

The fact that Telecom Australia was deliberately split up to make an efficient competitive infrastructure market (which in itself is a massive economic oxymoron); significantly increased the overhead costs of delivered telecoms services! Also the Technical / Field and Engineering staff were slowly and systematically replaced by Lawyers / Sales people and “Consultants”, and “Support” was obliterated.

By the CE mid-1990s the immensely economic technology advantages that came with SMOF, PDH, SDH and Digital (telephony / data) switching resulted in all telecomm equipment performance and maintenance being able to be efficiently monitored and controlled from one Global Operation Centre (GOC) with a handful of people where before this required tens of thousands of people stationed all over Australia!

Looking back over several decades before the CE 1990s; the operational and end-user costs of telephony infrastructure had continually and significantly dropped in line with the introduction of newer technologies that had significantly lower overheads. Most of these technology evolvements are detailed in this paper.

This mid-CE 1990s situation was no different apart from the fact that the natural monopoly of Telecom Australia Commission had been smashed and another competitive business (Optus) had been set up at the expense of Telecom Australia Corporation – and revenue earmarked for re-investment being very efficiently diverted to shareholder dividends, totally unnecessary marketing and advertising, immensely overpaid executives.

In my expert opinion, the cost of introducing "competition" to Australia's telecoms infrastructure was immensely expensive economic mistake (for Australia) because it involved a large amount of telecoms equipment being multi-duplicated (which was totally unnecessary and extremely expensive) – most of which was now not manufactured in Australia but imported - being a massive negative impression on Australia's Balance of Payments (BOP). Further – the severe lack of telecoms infrastructure outside the metropolitan areas has slowly and surely crippled Australian Primary and Secondary production efficiencies - being another massive negative impression on Australia's Balance of Payments (BOP).

Even further, Telecom Australia Commission was poised in the late 1980s to have immensely reduced overhead operational costs – because the massive economic advantages of SMOF / PDH / ATM and Digital switching technologies had virtually zero overhead costs and these economic advantages were already starting to become obvious.

Circa CE 1990 it was then accurately estimated that the overhead cost of a Mel – Syd telephone call (including the long haul transmission over the SMOF cable using PDH transmission) was no more than a local call.

With the rollout of (Telstra's) SMOF cable in Regional Rural areas virtually complete by CE 1993 – without the added costs of totally unnecessary (infrastructure) competition.

My then expert opinion was that all telephone calls throughout Australia could have been set at a local cost – and this be profitable (with very simple internal accounting) and massive productivity because of technology advancements in that decade. The facility of people being able to talk in detail over long distances would have introduced massive national savings in Social Services (external accounting).

In other words, the introduction of (infrastructure) competition did absolutely nothing to bring the end-user telecommunications costs down – exactly the opposite. The introduction of (infrastructure) competition significantly raised other overhead costs in marketing and advertising and equipment purchasing – while assisting to kill off telecoms equipment manufacturing in Australia and incidentally raise Social Service costs.

Consequently; the end-user telecoms costs in Australia did drop marginally in the mid-CE 1990s – but these end user costs would have fallen far greater (upwards of 50%) if (infrastructure) competition had not been introduced into Australia in CE 1989.

In other words – the introduction of (infrastructure) competition dramatically increased the overhead costs and it was only because of then recently introduced new digital technologies that had immensely lower overheads that it looked like competition had marginally brought down end user costs in the mid-CE 1990s.

Being totally oblivious to the then advances in telecoms technologies that absolutely plummeted / caveated these infrastructure operational overheads; Economists ignorantly championed (increased) “competition” as the panacea for all competitive businesses and infrastructure businesses for all the wrong reasons!

With Telstra (privatised in CE 1989), the competitive rollout of Single Mode Optical Fibre (SMOF) technology was minimised instead of maximised – and effectively stopped by about CE 1993, the role of TRL that provided an excellent leadhouse in research and equipment was obliterated, HFC was not installed into the underground service ducting but strung up on power poles (as in the USA), SMOF was not used for Access connectivity, ADSL technologies were a competitive caused rollout disaster! So from CE 1989 when Telstra was privatised it only took a decade (CE 1989) before the gross mismanagement caused by the privatisation mindset made Australia’s telecoms infrastructure a basket case.

So – from about CE 1998 there have been an endless string of Select Senate Inquiries / Regional Reviews / Complaints / Grants etc. plus the introduction of the Telecommunications Industry Ombudsman (TIO) / the Australian Competition and Consumer Commission (ACCC) and the Productivity Commission (PC) as private sector political puppets – plus the introduction of the NBN Corp to roll out Broadband connectivity; all that very clearly show that the privatisation of Australia’s Telecoms network infrastructure work was nothing short of Treason.

The New Era of Electronic Technologies

With Competitive Business, having inside knowledge is of paramount importance because it gives those in the know the "edge" (no matter how unethical, illegal or otherwise dishonest) to make business deals / transactions to favour their own interests of greed and/or market dominance and/or outright theft.

Compared to Mail – where a letter is written and physically transported to the distant location where it is read and acted on – using electronic communications was very heavily researched and developed from the early 1800s with a maximum of effort because the relative financial gains in a competitive environment where lies, deceit, deception and compromising were (and still are) potentially enormous.

There are effectively three technology areas that needed rapid development and they included: the transmission / reception equipment, the line transmission technology and the encoding / decoding apparatus.

What eventually transpired between about CE 1800 and CE 1850 was that electromagnetism could be concentrated / amplified by winding a coil of wire around a magnetic substance like iron and that this coil when electronically activated would draw another magnetic item (like an iron needle) and this effect could be transferred by a long "loop" of wire.

Taking this technology further; several similar circuits could be operated in parallel to significantly increase the data transmission speeds and the parallel transmitting arrangement could be used to provide intricate encoding / decoding. Because these technologies had massive reliability issues the general consensus was to move to a single serial circuit and used serial-timed encoding.

From the early CE 1850s, (when International Morse Code became standardised) the structure of electronic circuitry (in telecommunications) had gone through a continual construction improvement process. "***Telegraphs to Telex to Fax***"

Historically, the first products were literally constructed on a kitchen "Breadboard" (and the name still sticks when doing prototype electronic construction)! With several pieces of "breadboard-constructed" equipment on the Post (Central) Office floors; it was a no-brainer to mount these (standard-sized 2 foot long) kitchen Breadboards on the walls to clear the floor-space.

In the then growing cities, wall-space would have quickly been filled and the concept of a free-standing rack was the not-so obvious answer – as this was (again) new technology. Initially, telecoms equipment racks were constructed with a pair of inwards facing 3" deep cast iron "U" channels with 2.5" flanges and the outside backs of these rails being spaced at 24" (to match the ex-kitchen Breadboards).

The Breadboards could then be bolted on (with ¼" bolts) from both sides – saving an immense amount of wall-space (and floor space) and really localising the inter-panel wiring. This technology was the start of centralised telecommunications (in the back rooms of Post Offices)!

> *My educated guess is that these original Breadboards were originally from rough sawn 2" thick planks of wood and that with both sides planed down to be smooth – that would take 1/8" off both sides leaving the fresh Breadboards at nominally 1 3/4" thick. These Breadboards would (most likely) be stacked flat beside the vertical rack ready for component*

assembly and mounting on these racks. It just so happens that the "Rack Unit" is 1 3/4" (44.45 mm) and is still / now the universally accepted unit measurement for equipment racking!

As hinted at before, the outside horizontal measurement was based on 24" and taking off 2.5" from each side leaves nominally 19" between the vertical rails and the standard term is a 19" rack! Now, because the vertical rails were manufactured from cast iron and therefore have a rough (inside edge) lip and these rails sometimes have a slight bow the minimum inside width is more like 18.25" and the maximum inside width is more like 18.75".

With advances in iron technology during the 1860s the concept of wooden breadboards as the construction chassis was replaced by ¼" thick soft iron sheeting – nominally 24" wide and the height based on the number of "Rack Units" – and slots for ¼" metal thread screws to mount this equipment into the pre-threaded vertical U channels.

With advances in sheet metal technology the heavy ¼" back panels were replaced by 1/8" thick (and even thinner) panels with a folded horizontal lip on top and bottom adding considerable torsional strength. This transmission equipment mounting technology continued through until the CE mid-1970s.

The concept of metal chassis to hold and support the weight and volume of electronic equipment was an outright winner and as thermionic valve amplification came in from about CE 1910 the packing density gradually increased (but was a very slow process).

In the early CE 1800s, electromagnetic signalling was in its infancy and there were several variations on this technology before the concept of serial pulses to characterise each letter in the extended (English) alphabet (known as International Morse Code) became the basis for the then accepted telegraphy standard technology in about CE 1850. The standard apparatus for Morse telegraphy was the key for manually encoding the "dots and dashes" and a "sounder" (buzzer) for acoustically hearing the "dots and dashes" both locally and sent from the other end.

Concurrent with this technology was the development of Lead-Acid secondary battery cells that provided reliable power and could be externally re-charged (another developing technology)!

The general consensus was that as these cells produce / hold about 1.23 V each that ten serial cells hold about 12 Volts in a battery of cells. With four of these batteries, making nominally 48 V (DC), this is enough voltage to be both safe to use and transfer (transmit) enough current through the (developing) transmission technology to reliably activate the (developing technology) electromagnetic receiving device.

For (long-line) transmission, virtually all telecommunications at that time used overhead open wire technology (very similar to that used for most electricity distribution). A straight tree (trunk) formed the telegraph pole (about 10 metres long) and wooden cross-arms (up to about 2.2 metres long) were horizontally attached to the poles so that several wires could be subtended between the telegraph poles (spaced nominally between 50 and 70 metres apart).

As it was imperative that these bare wires had to be insulated from the ground and from each other, the cross-arms have ceramic or glass insulators bolted to these cross-arms and the wires attach to these insulators.

With (early) telegraph technology, primarily because of wire costs, it was common to use a single (iron) wire and use the earth as a return path for the telegraph circuit.

This technology "worked" for relatively short distances (particularly where the ground is always wet) – but because of differential ground voltages – particularly in stormy situations and especially with lightning this loop signalling – earth return technology was not good for telegraphs (and telephony) – particularly in Australia!

A far more reliable transmission could be effected by using a pair of parallel wires forming a "loop" and this became the standard long-line transmission technology from the mid-CE 1850s onwards. As it turned out, the wire pair spacing (to minimise wires touching) was nominally about 200 to 250 mm.

Again this was developing technology where the first wire used was iron because it was very strong and highly available – but the resistance was relatively high, resulting in excessive attenuation per unit length. Making the wire thicker considerably lowered the series resistance that in turn considerably increased the practical distance between the send key and the receiving "ticker" – but this also significantly increased the weight bearing down on the cross-arms.

In construction terms, the wire was not recognised by the gauge that it was drawn through (when being manufactured) but far more by the weight (per loop mile), and the cross-arms were manufactured to bear a particular weight (by summing all the weights of the wire pairs on the cross-arms) – and the transmission link became known as a "Bearer"! *Transmission links are still commonly called "Bearers"!*

As this line transmission technology improved circa CE 1950 - 1880 (and copper was found to be readily available in Australia), the move to copper wire was another no-brainer, as copper has a far lower resistivity than iron. But pure copper is soft and easily stretches with these nominal pole spans. It was found that adding a little added beryllium to the copper made a stiff alloy that was perfect for open overhead wires that would minimally sag under tension and keep the very low resistivity. So the attenuation per loop mile using beryllium-copper was far lower than iron – making long distance connectivity a reality.

Hot on the heels of telegraphy was the requirement to use the same wires for (bi-directional) speech transmission, and although considerably research was done from about CE 1850, the breakthroughs came in CE 1876 with USA patent being awarded to (Canadian) Alexander Graham Bell for "inventing" the telephone, and Tivadoar Puskas (Hungarian) for inventing the Switchboard / Telephone Exchange.

The invention of the telephone (I think) started with the development of an electromagnet being rather near a (very) thin iron sheet – and the sheet moved in synchronism with the magnetic intensity producing a weak sound. With this realisation the structure was considerably modified to become an (inefficient) earpiece and a similar device used as a very primitive microphone.

Almost concurrently David Edward Hughes (Wales) invented the Carbon Microphone - then Thomas Edison (USA) and Emile Berliner (Germany then USA) fought over the patent rights, (and of course the USA won) where Emile Berliner introduced several subtle improvements that substantially improved the transmission clarity of the David Hughes' carbon microphone technology.

The other problem was to make bi-directional transmission on a single pair of wires (as this was /is the economic sticking point) and this was achieved by a "three winding" electromagnetic transformer (which was also in an embryonic stage of research) development. This transformer split / combined the separate transmission paths and provided a little "sidetone" to the talking person in their earpiece.

The "other problem" was that the transmitted power level was far too little – and this is where the "Carbon Microphone" came into its own. This device is essentially a very low value variable resistor where the (direct) current flow is varied by sound pressure intensity. By having very few turns in the transformer directly connected to the Carbon Microphone circuit – there was considerable "amplification" (by the transformer's "turns ratio" to the line side) – making the telephone functional.

Socially, the ability for people to audibly communicate with each other over several km was a massive social advantage – but nothing compared to the commercial advantages of virtually instantly communicating (by voice) over several km – if not tens even hundreds of km.

Internationally there were already (by the CE 1840s) two styles of "western" economics. In the (then) USA, the very wealthy industrialists had control of literally all the infrastructure while in Europe and the British Commonwealth literally all the infrastructure was very efficiently managed and controlled by the Governments.

*The problem is that infrastructure is inherently very expensive and is essential for all businesses and for the community to efficiently operate. There was no way that the industrialists in the USA were ever going to let "their" essential services ("utilities") be built / owned / operated by "their" Government. "**Infrastructure Business and Competitive Business**"*

By the CE 1880's telephone services were being rolled out everywhere – using balanced pair aerial open wire technology, effectively using the same and/or upgraded telegraphy infrastructure.

So, in the UK this was done by the Post Master General's Department (PMG) as "Posts and Telegraphs" and in the USA the Bell Telephone Corporation set itself up to provide this essential service – arm's length from their Government.

In Australia, each State had its own PMG's Department and they operated separately until Federation in CE 1901 where they came under the one Headquarters that was basically research to build an Australian manufacturing presence and minimise importing equipment and expertise from England (and other countries)! They still operated as State-managed organisations almost in isolation from each other until CE 1989.

Australia's Regional Transit Network

Before the era of Crossbar switching (starting in CE 1960) – (*with very much thanks to the development of polyethylene insulated copper wire technology in the late CE 1950s*); virtually all long-distance "Trunk" calls (usually switching through the State Capital City) were manually set up using Sylvester Switchboards as the switching medium, and the transmission medium was typically open wire on telegraph poles. "***Massive Productivity with Plastic Insulation***"

These Switchboards had a maximum of (Customer / Access) 100 lines per board and if you had a Town of say 2500 people then this is about 500 lines (one phone line per 5 people) – and that works out at a minimum of five adjacent manual boards with five (usually female) manual operators during the day (from say 7 am to 7 pm) and at least two operators from 7 pm to 7 am – on a seven day roster running 24/7.

As well as all these manual telephonists was an "External Plant" line crew of typically five people (for a town of 2500 people) and the vast majority of their work was to maintain the open wire infrastructure – which was highly susceptible to tree branches, soot and other usually unintentional damage.

Added to this workforce would be two or three (internal plant) technical staff that looked after all the customer premises equipment and the exchange equipment. Considering that most telephones had a magneto to send ring current to the Sylvester Switchboards' drop indicators and the telephone also has two (A size) dry cell batteries to power the carbon button microphone circuit – and these batteries needed to be replaced every two years – the technical work was also full time.

Each "District" (large town or country city) also had all the metering to be tallied and accounted and mailed out and managed, plus the Drafting office staff also had a set of linen paper maps of the entire district (hundreds of maps) very accurately showing what transmission circuits were where – every telegraph pole, every transmission circuit, every Service Pit and every conduit joining every Service Pit!

The (internal plant) technical staff also managed the maintenance of all the exchange-based (Voiceband) transmission equipment – which up to the mid-1950s was interconnected with open (aerial) wire on telegraph posts. While much of this transmission equipment was passive (impedance matching transformers and 2-wire/ 4-wire working Hybrids, all the amplification used thermionic valves that usually required daily checking and maintenance / replacement.

In round figures that is about 25 people per 2500 or about 1 in 100 people of the entire population were employed by the PMG – or putting a real number of that – consider the entire Australian population in say 1953 is about 8.815 M so the base workforce in the PMG is nominally 88,000. In the metropolitan areas this workforce would be significantly less – because the overhead / aerial wires were buried in the 1930s – substantially reducing lines field staff – so the PMG employed number would be more like 80,000 or about 9% of the total population – including children etc.!

With an overview (as outlined above) understanding of the rather large workforce (compared to today's requirements CE 2021) it is not hard to understand that long distance / "Trunk" calls were very expensive by today's standards (expect to pay today's equivalent of between $10 to $50 per three minutes; depending on the distance between the villages / towns / cities for the call connection).

The other problem was that number of inter-exchange network circuits was very limited (compared to today's standards). Heavy network congestion was an accepted situation and it was common to book a call and wait several hours before being called back by the switching operators and then be able to connect through.

Switch operators were highly resourceful and lived locally and literally knew what was going on where and when – so if there was an emergency – they could notify all necessary people within a minute or two (Family, Police, Ambulance, Doctor, Fire, Tow Truck, nearby mechanical aid, nearby farmers, etc. - and where they were)!

They also "knew the Network"! So – if a direct link to a particular Exchange (Town / City) was already fully occupied – they would know to "transit" a call via another Town / City and get a through connection! They made full use of the available network structure – far more than could be done by the then Automatic SxS equipment. This is my understanding of how the "**Transit Network**" got its name!

The Switch operators were also very quick to identify and notify if any part of "their" Transit Network was not working – and they could raise the alarm in less than 30 minutes where otherwise a fault such as this could take several days to identify!

In the early CE 1950s through to the early CE 1970s, the Transit network transmission technology went through a radical change with the open wire aerial technology being replaced by far lower maintenance underground pair / quad copper cable "***Rebuilding the Regional Transit Network***".

From the circa CE 1965 through to about CE 1982, virtually all the manual Sylvester Switchboards were replaced by Crossbar (automatic) Switches. "***High Productivity of Crossbar Switching***"

Concurrently with (Voiceband) transmission the high maintenance valve amplified Loaded Cable technology had been replaced with transistorised Voice Frequency Hybrid Amplifiers (VFHAs) which were basically "set and forget"! "***New Era of Electronic Components***"

Alternatively the transmission systems that were physically too long for economic loaded cable technology had 12 (or 24) Channel FDM transmission systems installed in place – which were also very low maintenance. "***Advancing FDM Technology***".

The Transit Network as it was known simply vanished into a conformal (relatively low maintenance) network structure that was very much Capital City centric in terms of transmission connections.

First Steps in Long-Haul Telecoms Transmission

With Aerial Open Wire Pair Copper being the first practical transmission "bearer" the physical relationship of the wire diameters and spacing have a direct bearing on the characteristic impedance of this transmission technology. By relatively common construction practices worldwide the characteristic / "standard" impedance (in the Voiceband (0.2 - 3.4 kHz) turned out to be 600 ohms!

With longer line distances, attenuation considerably weakens the signal strength and to keep the attenuation low enough - the wire had to be of a thicker gauge (larger diameter), meaning that the wire spacing had to be fractionally wider to keep the same characteristic impedance – and extra weight of the wire had to be accounted for as a load bearing on the poles cross-arms!

Installing a long-haul telephone route was by no means inexpensive (with poles every 70 or so metres apart, carrying crossarms and insulators and the weight the wires) – which meant that long distance calls were very expensive (to at least cover the cost of the infrastructure).

Approximate Inter-Main city distances in Australia: Melbourne – Sydney is about 880 km, Sydney – Brisbane is about 912 km, Brisbane – Townsville is about 1335 km, Townsville – Darwin is about 2500 km, Darwin - Alice Springs is about 1500 km, Alice Springs - Adelaide is about 1535 km, Adelaide – Melbourne is about 735 km, Adelaide – Perth is about 2,700 km, Melbourne – Hobart is about 600 km, Sydney - Canberra is about 290 km and Canberra – Melbourne is about 662 km. So Sydney – Canberra – Melbourne is about 952 km.

All these distances are "Long - Haul" and it is practical to work on a nominal 1000 km span and then normalise to suit the geography. Using "today's" prices (circa 2020) with "economy of scale" bulk purchasing arrangements (making equipment items considerably less costly than if they are purchased in smaller quantities) the following figures provide an insight as to the comparative cost of this infrastructure (labour included).

Note: with infrastructures operating in a competitive mode, because their bulk purchases are typically a maximum of half (usually far smaller, say 20%) of that purchased by an "economy of scale" (100%) infrastructure provider; not only are the unit costs per equipment considerably more (typically at least 30% more expensive) – but the placement on the manufacturing production line is far later (so the delivery can be delayed several months) and the manufacturers engineering support is at a far lower level than that provided to "economy of scale" infrastructure providers.

> *In CE 1997-1999 I was working as a Project Engineer / Bid Manager in Nortel, Chatswood (NSW) in the "Alternate Operators" Branch. Nortel was a leading global telecoms equipment manufacturer with about 37,000 staff.*
>
> *This role was very "eye opening" because for decades I had (ignorantly) worked on the "large scale bulk purchasing" side of telecommunications infrastructure (in the PMG / Telstra) and now I was (actively) working in the "small scale selling" side. This was another world!*
>
> *What was not obvious was that Nortel had Sales Branches that with apparent "Chinese walls" between them – but because my industry expertise crossed in so many boundaries I was often heavily involved with bids for mainstream Telstra and Optus – both outside my official area.*

It was clear to me that Telstra in particular because of the very large volume purchases characteristic of "economy of scale", had highly preferential treatment with discounts in the vicinity of 36% that were far in excess of what was offered to the much smaller alternative telecom service / infrastructure providers whose discounts rarely exceeded 10% from the list prices.

Most of the Alternate Operators support Engineers were fresh from University and did not have the many years of in-house experience and expertise that the Support Engineers in the mainstream Branches.

Telstra and Optus had deliveries provided from the front of the production runs – which were months ahead of that provided to Alternate Operators.

Consider that 10 metre (wooden) poles are used and cost say $1,000 each, and are placed on 70 metre spacing (limited by the wire tension) – so for 1000 km this is 14,286 poles ($14,286 M). The wire is 8 mm diameter beryllium-copper and is nominally $12,000 per loop km ($12.0 M per loop / pair) – and it would have had to be imported from the USA or England as there were no wire manufacturing in Australia until after CE 1915. Because of the heavy load bearing of the copper wire only four pairs can be on one crossarm ($200) – so now let the fun begin in a spreadsheet:

Poles ($)	$14.3 M	$14.3 M	$14.3 M	$14.3 M	$14.3 M	$14.3 M	$14.3 M
Loop Circuits	0	1	2	4	8	12	16
Crossarms	0	1	1	1	2	3	4
Crossarms ($)		$2.9 M	$2.9 M	$2.9 M	$5.7 M	$8.6 M	$11.4 M
Copper Wire		$12.0 M	$24.0 M	$48.0 M	$124.0 M	$144.0 M	$192.0 M
Labour	$14.3 M	$14.3 M	$14.3 M	$14.3 M	$14.3 M	$14.3 M	$14.3 M
Total Cost	$28.6 M	$44.4 M	$57.4 M	$83.4 M	$124.0 M	$181.2 M	$232.0 M
Circuit Cost		$44.1 M	$28.7 M	$20.9 M	$19.8 M	$15.1 M	$14.5 M

What this little (1,000 km) spreadsheet shows is that the cost for this infrastructure is really expensive (even in today's terms) and that as the number of circuits is increased on the pole route, the cost falls away to about $14.5 M per circuit at a nominal project cost of about $232.0 M. This is just the construction cost and does not include considerable daily maintenance plus a high number of people on manual switchboards on a 24/7 roster.

With a really heavy gauge wire loop of say 8 mm diameter (5/16") it was possible to get upwards of 150 km for a telephone and upwards of 300 km for a telegraph relay point – so things were looking rather good, and this is where innovation (not competition) really kicked in to get much further, and to reduce the circuit costs!

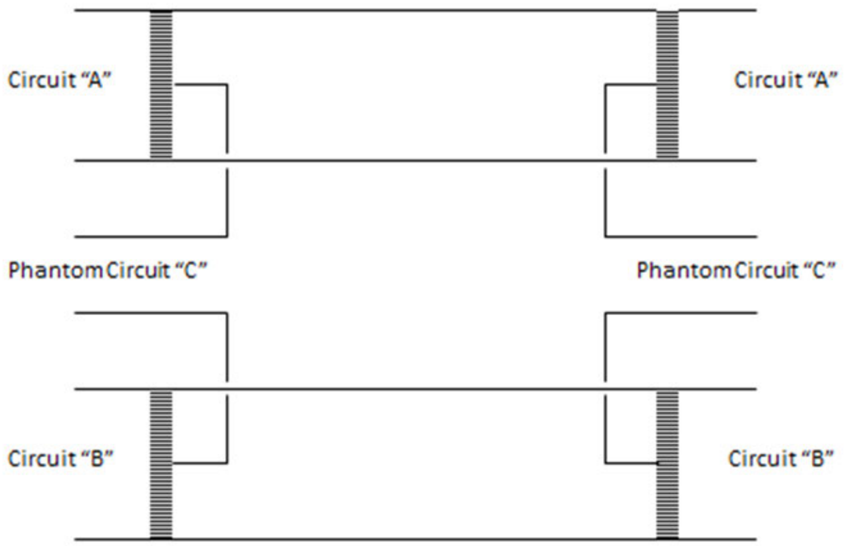
Phantom Circuits and Party Lines

As shown in the above spreadsheet, if the number of circuits can be increased then the overall cost of this infrastructure moves from being the non-electrical components (poles / crossarms) to being far more the cost of the electrical components (wire / insulators) and although the overall price is much higher with many more electrical circuits the cost per circuit drops towards $12.0 M per 1000 km circuit.

The concept and use of transformers was really in an embryonic stage but now (by the CE 1880s) this technology was slowly getting to be far better understood.

With the associated realisation that because the signal in the loop circuit is “differential” or “transverse” (as one side goes up the other side goes equally down), so then the centre of the differential loop circuit is effectively not moving. This concept was taken to another level with two geographically parallel circuits and a third (phantom” circuit connect to the mid-points of the other two physical circuits!

A picture explains thousands of words:



This incredibly smart innovation was that a third (loop - balanced) circuit could be derived as a “phantom” sitting over two pairs and passing its “differential” signal over each of the two other pairs in a “longitudinal” mode – then there is literally no crosstalk interference! (*You may need to read this more than once!*)

The productivity of this highly innovative physical technology was immense as the cost of these transformers was comparatively negligible (say $100 each)!

Consider the previous situation of 16 separate (2-wire balanced transmission) telephone circuits over the nominal 1000 km span. With this basic technology structure these 16 loops circuits can support 8 phantom circuits (and the attenuation is half because the wire is being “doubly” used)! So the total number of (physical and derived) is 16 + 8 = 24 line circuits!

Now with 24 circuits (8 of which are derived) the per-circuit cost is nominally $233.7/24 or $9.7 M where before it was $14.6 M for only 16 circuits. So not only do we have the circuit capacity increased by 24/16 = 50% but the cost of these circuits has dropped from $14.6 M to $9.7 M or by about 34%.

This was just the tip of the “Phantom” iceberg!

Consider that four phantom circuits can sit on the eight phantom circuits and that two phantom circuits can sit on the four phantom circuits and that one phantom circuit can sit on the two phantom circuits (just like a pyramid)! That is 15 phantom circuits and each successive phantom level has considerable less attenuation!

Now do the productivity maths!

Now with 16 physical and 15 derived (as phantom) circuits totalling 31 circuits, the per-circuit cost is nominally $233.7 / 31 = $7.53 M, where before it was $14.6 M each for only 16 circuits.

So not only do we have the Inter-Exchange circuit capacity increased by 31/16 = 94% but also the individual cost of these circuits has dropped from $14.6 M to $7.53 M or by about 48% - all because of innovative technology advances!

The economic savings brought purely in by technology advances in during the CE 1880-1900 era was immense – and this had absolutely nothing to do with competition – and everything to do with innovative technology / engineering – what I call "building a better mousetrap (through continuous improvement)"!

What brought down the build cost of the inter-exchange network was to have many circuits on the one physical route and use phantom circuits to share the wire pairs in that physical route to maximise the circuit count on that physical route.

Now, the Access Network – is/was a star-structured open wire network emanating connecting from Local Post Offices (Sylvester Switchboards) to (mainly business) Premises. The fundamental problem was that open wire infrastructures could not be shared like that used for Inter-Exchange (inter - Post Office) network connections.

Because telephone lines (in the Access Network component of the overall network) were very expensive to build (and maintain), it was very common practice use much thinner wire (therefore considerable less costly), to have many customer pairs on the one set of telegraph poles (sharing the base infrastructure cost).

Consider an urban area with poles spaced by say 66 yards (60 metres) apart to provide drops to (nominally) a maximum of six home premises per pole. In a nominal 2 km urban run this is about 2000 / 60 = 33 poles and a maximum of 33 * 6 = 200 home premises. With six wire pairs per crossarm there would be 33 crossarms on the pole! If there were eight open wire pairs per crossarm then there would be 25 crossarms! Now it is far easier to understand why there were so many crossarms on these Access Networks!

As before with using circa CE 2020 prices to get a true costing; (in bulk) the poles would be about $1000 each, the crossarms (with insulators) about $200 each and the (imported and shipped) 2.5 mm wire about say $3,500 per loop km.

So, for say a network of 33 poles with 8 pairs per crossarm and an average of 16 crossarms per pole, this works out as follows:

Poles	33	$1,000	$33,000
Crossarms	33 * 16	$200	$105,600
Wire (2.5 mm)	33 * 2 * 16 * 60/1000	$3,500	$221,760
Labour			$100,000
Total			$354,761

Now this infrastructure could connect nominally 8 * 16 * 2 = 256 premises at a nominal average cost of $1,385 per premises. Even if the labour was doubled to $200,000 the overall price is about $454,760 and the average cost is about $1,776 per premises. This is in the realistic price range for urban telephony infrastructure connectivity so the figures are not lying!

Connecting Homesteads is a very different set of numbers. Rural homesteads are typically 1 km to 2 km apart but not on the road alignment (usually about 500 m back from the road – so the network is a thin tiered Spur/Star. Each Homestead is set back nominally 500 metres (500 / 60 = 8 poles in the farm), and the crossarm is small ($100). So the separate cost (Part Private Equipment – PPE) is about:

Poles	8	$1,000	$8,000
Crossarms	8	$100	$800
Wire (2.5 mm)	2 * 500/1000	$3,500	$3,500
Labour	8	$1,000	$8,000
Total			$20,300

Say the road length is 20 km (20,000/60 = 333 poles) so that is a maximum of about 15 Homesteads (say 16) and that means two crossarms each carrying 8 pairs of insulators (for half the way), and once crossarm for the remaining distance.

Poles	333	$1,000	$333,000
Crossarms	333 * 1.5	$200	$99,900
Wire (2.5 mm)	16 * 20 * 1.5	$3,500	$1,680,000
Labour	333	$1,000	$333,600
Total			$2,445,900

On bulk average this works back at about $153,000per Homestead (16 in total), plus the drop of about $20,300 totalling about $173,300 per Homestead!

Clearly the cost of telephone services outside urban areas was not obviously a financial practicality (for the Competitive Business mindset) – but considering that Farmers and Graziers are the major primary industry outside the urban areas it made a lot of sense to the Infrastructure Business mindset to have telephones to as many Homesteads as possible – to build Australia’s economy!

Looking at the above numbers and considering that the wire is the biggest lump item and that telephone line occupancy is usually lower than 10% – the concept of “Party Lines” where multiple Homestead phone connections can be parallel connected on the one pair of lines (but only one Homestead can use the party line at any one time).

Consider in the above case there are say two lots of five Homesteads on the one pair of wires and six Homestead telephones on the third pair of wires. So now there is far less wire and crossarms / insulators on the overall road route:

Poles	333	$1,000	$333,000
Crossarms	333 * 1.0	$200	$66,600
Wire (2.5 mm)	3 * 20 * 1.5	$3,500	$315,000
Labour	333	$1,000	$333,000
Total			$1,047,600

This strategy has more than halved the main road route cost (and the main cost is labour and poles), and dividing this by the nominal 16 homesteads this comes out at about $65,500 and then including the Drop cost (from the Road to the Homestead) of about $20,300 this comes to a per Homestead cost of about $85,800. This is a little less than half the cost of separate wire pairs to each Homestead!

This is where the Federal Government stepped in to fund the PMG Department to put in this infrastructure because the Federal Government realised that much of Australia's wealth came from the land and providing this telecoms infrastructure paid for itself fairly quickly, because farm productivity could be maximised.

It is interesting to note that by far, the bulk cost of this non-urban telecoms Access Network infrastructure was the poles ($171,600) and the much smaller cost was the bare wire. I am almost certain that there was no wire manufacturing in Australia until about CE 1915 – so all this wire would have been imported – probably from England and the cost would have been substantially more like $5000 per km

These was further savings through economy of scale where the poles along road / rail lines were primarily used for the main inter-urban (inter-Post Office) "Transit" network and the cost of the Access Network was substantially reduced because the Poles were part of the Transit Network ran not the Access Network!

Poles	333	$0	$,000
Crossarms	333 * 1.0	$200	$66,600
Wire (2.5 mm)	3 * 20 * 1.5	$3,500	$315,000
Labour	333	$500	$166,500
Total			$548,100

The per Homestead site became more like $34,300 and with the Drop cost of nominally $20,300 this came to about $54,600.

Putting Phantom circuits over the pre-existing physical lines almost doubled the amount of available Voiceband channels (at almost no cost) in the Transit network between the Sylvester Switchboards in the Post Offices; and using Party Lines where several Homestead telephones shared the same wire pair (with special coded ring cadences to alert the intended called Homestead) dramatically reduced the overall cost of provided in telephone outside the urban reaches (for many km).

The Productivity of Electronic Amplification

In CE 1906 Lee de Forest (USA) invented what he termed the “Grid Audion” which was the first three element thermionic valve / vacuum tube – where the flow of electrical current from the (heated) Cathode to the Anode was controlled by the (negative) “bias” Cathode / Grid voltage.

This vacuum tube was called the “triode” (three prime elements: Cathode, Grid, Anode) and it very quickly became the international industry workhorse component for telephony amplification and AM (Amplitude Modulation) radio – and introduced electronics into our modern world.

By our currently rapidly advancing technology standards, thermionic valve technology was very slow to develop and the size of valves stayed at about 130 mm high and 50 mm in diameter until the early-CE 1940s. In most cases the high voltage connected to the Anode at the top of the valve with a slide-on 5 mm connector/cap. The base of the Valve had a Bakelite cup that held the (male) plug pins. In/on the sheet metal chassis a solidly mounted Valve socket was keyed so that the Valve pins had only one way to go in. On the underside of the chassis, the Valve socket served as soldering tags to connect wires, capacitors and resistors.

With Triode thermionic valves as amplification devices it was then practical to split a 2-wire bi-directional (Voiceband) transmission circuit with a “Hybrid” transformer and change the transmission to “4-wire, unidirectional” then amplify each direction with a triode valve, then with a second “Hybrid” transformer and change the (Voiceband) transmission mode to “2-wire bi-directional” and continue the long line transmission for several hundred km (with regular amplification along the way).

Unfortunately each State had its own set of Voiceband network specifications but generally it all “worked”! Nominally, the minimum inter-exchange network Voiceband attenuation was 0 dB and the maximum was 12 dB or 15 dB or 24 dB depending on the State (and type of equipment).

At a starting point on the Main Distribution Frame (MDF) the nominal receive test level was 0 dBm and looking backward, when this passed through a hybrid (as outlined above) the signal lost 3.5 dB (and accounting for 0.5 dB lost in the local exchange wiring) this meant that the test signal level coming from the receive amplifier needed to be +4 dBm. (*That was the “easy” part!*)

In metropolitan areas, the typical attenuation between major in-city exchanges (using open wire technology) was typically anything from 0 dB to 12 dB (erring towards the 12 dB end) so the nominal loss was “given” as 9.0 dB. With this conceptual inter-exchange network attenuation in mind and directly connecting a (4-wire) amplified circuit (for a long distance telephone call using amplification) there is the nominal 3.5 dB attenuation through the hybrid plus another 0.5 dB attenuation in the exchange wiring; totalling 4.0 dB.

So, starting with a nominal -9.0 dBm (2-wire) receive level, the resultant 4-wire receive level is -13.0 dBm.

This Voiceband transmission level standard +4 dBm Send / -13 dBm Receive became the world standard and it basically meant that any local exchange could be back-connected by a 2 wire / 4 wire hybrid and have that in turn back-connected as a 4-wire circuit into a Voiceband transmission system (and be padded on the -13 dB side to match the levels)! It was never as simple as that and more often than not many of these systems were unstable and “howled” for a variety of reasons!

So – there was then a standard 4-wire amplified receive level of +4 dBm and a standard 4-wire send level of -13 dBm. Put together this is a 17 dB amplification, which basically meant that a pair of 600 ohm valve amplifiers with a nominal 17 dB gain could be inserted into a long-haul (4-wire) circuit at regular intervals (or be padded out) so that the receive level into the amplifier is at nominally -13 dBm; and the standard send level from the amplifier +4 dBm.

Yes this took up two physical (or phantom derived) circuits – but it meant that long haul telephony over several thousands of km was quite possible (and very expensive by todays technologies).

From the early days of telegraph it became standard to use -48 V DC as the signalling voltage and with manual telephony using Central (Post Office) Battery for Switchboards and later Automatic (Subscriber dial controlled) call switching; and to power the carbon microphones in the telephone handsets!

There were many problems with thermionic valves in telecoms equipment starting with the need for a -24 V Battery to heat the cathode elements plus a +130 V battery for the Anode voltage circuit. This meant that the telecom exchange had to have three sets of batteries and transformer/rectifiers and motor generators.

Only the big city (metropolitan and country) telephone exchanges had valve amplification equipment and therefore only these Post Offices (with telephone equipment) had three (big) batteries in their battery rooms; plus the associated motor generator equipment to carry-over in case of frequent blackouts.

In terms of productivity, Valves over Phantom circuits was that faint reception could be repeated and amplified, so that long distance calls could be effective. What it did mean was that thinner wire than that originally used could be used for new circuits at a substantial saving.

Also – by this time, copper wire was being manufactured in Australia from 1915 so the cost of wire was effectively half what it would have been when imported.

Working backwards the nominal 8 mm diameter wire used for the 1000 km sample case was priced at about $24,000 per loop km – so now that same 8 mm diameter wire would now cost in the order of $12,000 per loop km. Also, because with amplification the wire did not need to be so thick a wire diameter of say 4.5 mm could possibly be used and the relative cross sectional area is 0.316 so the expected price would be in the order of 0.45 times that of $12,000 or about $5,400 per loop km.

Now – feeding this in the little spreadsheet we get:

Poles ($)	$14.3 M	$14.3 M	$14.3 M	$14.3 M	$14.3 M	$14.3 M	$14.3 M
Loop Circuits	0	1	2	4	8	12	16
Crossarms	0	1	1	1	2	3	4
Crossarms ($)		$2.9 M	$2.9 M	$2.9 M	$5.7 M	$8.6 M	$11.4 M
Copper Wire		$5.4 M	$10.8 M	$21.6 M	$43.2 M	$64.8 M	$86.4 M
Total Cost	$14.3 M	$23.5 M	$29.9 M	$42.7 M	$71.2 M	$99.7 M	$128.1 M
Circuit Cost		$23.5 M	$15.0 M	$10.7 M	$8.9 M	$8.3 M	$8.0 M

So, purely because copper wire could be manufactured in Australia (instead of being manufacture on the other side of the world and (sailing) shipped in and locally used, this caused the major cost of the Open Wire technology to absolutely plummet!

Technology	Circuit Count	Build Cost	Voiceband Cost	Time – Era CE
Open Wire	16	$233.7 M	$14.60 M	1880-1895
Phantom	31	$234.5 M	$7.56 M	1895-1915
Amplified	16	$130.0 M	$8.13 M	1915-1953
Amplified (Phantom)	31	$130.0 M	$4.19 M	1915-1953

The full costing of the amplified network was not fully worked out – but bringing this up to $130 M with thinner wire that is locally manufactured is a close approximation for the build cost. If phantom circuits were included – bringing the Voiceband circuit count up to 31 in this common case, then the Voiceband Circuit cost would be in the order of $4.2 M which (surprise) fits the sliding technology development scale!

Valves are inherently a high impedance device (100 k ohms – 1 M ohms and telecoms of that era was inherently a low impedance (124 ohms to 600 ohms, and 1200 ohms) so specially manufactured transformers were required to impedance match and provide very well balanced (floating) windings to minimise noise (and hum) induction. This is another complete technology that slowly developed (in many technology areas and years) through the early CE 1900s to the mid CE-1960s!

Also, in a thermionic valve, the (electron) emission property of the (heated) cathode gradually deteriorates with use. Thermionic valves typically have a 5-year (full-time) life before the emission from the cathode drops to such a level that the amplification in the thermionic valve is too low to be practical.

Compounding this problem was that the technology of negative feedback (which when applied considerably limits and also stabilises amplifier gain) was both poorly understood and very difficult to apply because the transformers introduced frequency dependent phase shifting making amplification with considerable negative feedback a rather unstable situation.

Because thermionic valves are physically large and because the amplification per valve is not that large, it was common practice to have a minimum of feedback to keep the amplifier stable; it was also common for valve amplifiers to have a gradually decreasing gain through their active life. Transmission system gain control to counter for daily and seasonal (temperature dependent) variations in line attenuation were reduced by mechanical attenuators that responded to the level of “pilot tones”.

With the onset of WW2 and the now far greater use of radios, the physical size of most general purpose thermionic valves trimmed down to about 100 mm high and about 40 mm in diameter. This reduction in manufacturing size not only significantly decreased the amount of chassis real-estate required (so the radios etc. could be made significantly smaller) – but the amount of materials required to make these radios also was significantly reduced. So – manufacturing productivity significantly improved with this technology development.

In the early CE 1950s, the realisation was that (“by building a better mousetrap”) that more than one set of valve components could be put in the one (glass) vacuum tube and considerable circuit construction real-estate could be saved. It started to become common practice to have dial triodes in the one vacuum tube – with the wires (as usual) fed into a Bakelite block that held the terminating pins. Small as it may seem, this technology advancement significantly reduced the space needed for thermionic valve amplifiers and consequently a three-channel telecoms long-haul terminal could be fitted onto one rack instead of three.

By the mid-CE 1950s dual triodes (in particular – because they usually formed a logic “flip-flop” (USA term for a 1 cell digital memory), or for a Schmitt Trigger and be used by the thousands in main-frame computers. This valve technology went through a sharp miniaturisation process where (typically) a double triode was packed into a fully glass envelope about 50 mm high and about 18 mm diameter.

There was no Bakelite base as the base was now glass (shaped much like a coin) with the plug pins through it and the elements of the valve now spot welded to these pins. The glass tube was melted onto the coin-shaped base and the top of the glass tube was now the vacuum extraction point. These valves could be very quickly (and cheaply) manufactured using production line techniques that were far more efficient than the earlier thermionic valve manufacturing processes!

In exchange sites that had valve amplification equipment it was standard daily routine to pull circuits out of service and check the thermionic valve’s emissions – then put those Voiceband circuits back into commission if the emission was OK. If not, a new thermionic valve would be installed and the circuit manually re-commissioned (often taking over 5 minutes) before putting back into service.

Not only was this work manually intensive and highly repetitive but it took out valuable Voiceband channels that were in very short supply aggravating network congestion, (something we hear very little of today before the Covid-19 pandemic when Internet usage was significantly increased and people glibly complain of “slow Internet”)!

The Voiceband Transmission line-up levels of +4 dBm (send) and -13 dBm (receive) sound very abstract, but when it is realised that this is a 4-wire arrangement and it nominally connected into a 2-wire switching arrangement – it all starts to make sense!

Coming out of the transmission system at +4 dBm and feeding through a transformed hybrid (with a nominal attenuation of 3.5 dB), the 2-wire level into the switches is +0.5 dB and wiring losses of about 0.5 dB bring this level down to +0 dBm (which is the reference level into the MDF)!

Working backwards from the -13 dBm 4-wire send (into the transmission system) and passing through the transformer hybrid and wiring there I about a 4.0 dB loss, so the 2 wire level into the Hybrid would be about -9.0 dBm.

So it makes sense to include some 6.0 dB pads (attenuators) in both directions of the 4 wire circuit and the 2-wire levels now fall into place at about -6 dB receive (send to the telephone) at the MDF and -3 dBm send (receive from the telephone) into the MDF. (This needs serious clarification!)

From Manual to Automatic Telephone Switching

All Post Offices had a suite of (Sylvester or similar) manual switchboards in them (with nominally 100 lines per switchboard) and these switchboards were manned 24/7 – or at least 18/7 in isolated villages. This was a hidden very expensive overhead that employed a large proportion of the (mainly) female workforce for many decades (until the early CE 1980s).

The cords in these manual switchboards were made from a thin “tinsel” copper wires / cotton structure that were cotton braided. The reason for this special construction as that these cords were physically unrolled and rolled up for each call and put under continuous torsional stresses, so the wires became brittle and fractured – requiring urgent replacement. These cord-sets were commonly replaced on an all-too-regular basis as they had a rather limited life.

It would not be uncommon to replace at least one feed-bridge cord in every switchboard every month. Consider you have four switchboards, then it would be an almost weekly event to replace a cord at that manual exchange location!

Sylvester Switchboards were being phased out from about CE 1970.

> *The reason why Step-by-Step automatic switching was invented was that an undertaker (Strowger) found out that the switchgirls in the local manual exchange were being paid a premium to divert undertaking business to another Undertaker – which incidentally drove him out of business!*
>
> *It was this competition – plus his exceptionally excellent knowledge about electro-mechanics at that time that he combined to come up with an entirely different concept where a dial was used to provide “loop-disconnect” (pulsed) signalling that directly drove the switch mechanism he conceived, that automatically identified (and connected through to) the next available line circuit.*
>
> *I can only think that Strowger had a lot of time on his hands and he had an exceptionally strong understanding of this electromagnetic technology – and maybe he was in the wrong (undertaking) industry!*

The first Automatic telephone switching exchanges (using Central battery for “loop-disconnect” (telephone dial) signalling in Australia (circa CE 1912) used Strowger Step-by-Step (SxS) technology and this technology continued until CE 1938 when the new (British?) “Type 2000” Step-by-Step switches were introduced and then followed by SE50 Step-by-Step equipment through until CE 1960.

As the new technology SxS switches came in – they did not replace older SxS switches but replaced manual switchboards. That is almost 50 years with the one technology, but each version had subtle technology advances on its predecessor!

Step-by-Step switches are essentially an electromagnetically controlled bi-motional (up and then around) switching technology that are physically hard in everything. The mechanical (Step-by-Step) movement is done by a pair of solenoids with brass ratchets where that the mechanical switching assembly uses gravity (and springs) as the counterweight for vertical stepping controlled by the dial impulses as 10 pulses per second) to follow the number, and a coil spring for rotary stepping around to find an unoccupied circuit to the next part in the call route.

These switches were "built to last" and the current that flowed through these solenoids were (I believe) far in excess of what was needed to ensure the physical movement of the ratchets – which (I believe) actually limited the physical life of these switches!

Further – because of these rather high pulse currents to step the SxS ratchet mechanisms, these currents caused voltage fluctuations in the exchange Battery and Earth busbars.

One of the common problems was that the "earth" side (and "battery" side) of this SxS switching equipment was all too often connected with the Transmission equipment "Earth" and "Battery" connected along this busbar – causing the transmission equipment to have a somewhat "floating" voltage that inherently had a lot of induced noise caused by high current spikes in the switching equipment creating small voltage differentials that were inherently fed directly into the Transmission equipment's battery feed – which resulted in "clicking" sounds in telephony transmission as somebody else dialled another number!

The "fix" was to re-position the Transmission Equipment connections on the Earth / Battery Busbars so that the transmission equipment was nearest the battery connections (and the earth stake) and the Switching connections were away from the Transmission equipment's Busbar connections – this way; the Busbar voltage fluctuations into the Transmission equipment's Battery / Earth feeds were minimised.

With these switches, the cotton-insulated tinsel copper wires connecting the rotary brushes lasted a few years before these wires would start to crystallise, partially break (causing a myriad of call disconnection and connection problems) and then they totally fail. Then the fix was fairly straightforward – replacing the brush/mechanism took about 30 minutes. Finding the fault could take weeks!

This mechanical process is solid and cumbersome, and consequently the wear and tear on associated mechanical parts was also a very high maintenance job – but the overheads were less than that of manual switchboards – and subscriber controlled "automatic" switching had the advantage of complete privacy (in most cases).

Above each of these bi-motional switching structures there were nominally eight to 12 relays (depending on the stage of the call progression) that performed speech-bridge, signalling interfacing and very simple "state machine" logic. The beauty was that these bi-motional switches and their associated relays were a modular pack that could be quickly removed from a rack, individually maintenanced and later returned.

Unlike transmission equipment that was (horizontally) mounted on vertical rails with 24 inch outer widths, this step-by-step switching equipment was mounted on horizontal iron rails, where the horizontal "U" shaped switch banks had hundreds of horizontally wired cotton-insulated wires laterally connecting to each switch bank. These horizontal rails were usually supported on 48 or 60 inch vertical centres.

Because the physical switching process shook (vibrated) the racks, these common pure copper wires (over many years) became crystallised and occasionally broke, causing immense maintenance issues – because fixing common wire one usually caused a few other common wires to fall apart.

In the late 1960s I recall being in a telephone exchange's Step-by-Step room, looking west towards a frosted glass window. As a few of these SxS switches stepped up and rotated around to through-connect - I noticed a very fine spray of minute brass fragments fly out and glitter as they fell through the sunlight. Although I did not know it at the time (as transmission technologies were my natural speciality) it clearly demonstrated to me that SxS call switching was a very high maintenance overhead technology – but considerably less expensive to maintain than manually operated switchboards that required many telephonists virtually 24/7 – which meant many staff on full-time shift work.

In a Competitive Business mindset sense, a typical 5000 line Step-by-Step switch infrastructure would require the casual maintenance of a couple of technicians (without overtime) and a 5000 line manual exchange would have 50 switchboards – each with 100 lines.

These switchboards would require 24/7 attendance though a much thinner staff could be used overnight. So that is in the order of between 150 and 200 manual operators (just for 5,000 line in a city telephone exchange.

As mentioned before – these (50) switchboards would also require casual maintenance of at least three full time technicians.

Economically it was very straightforward that a Step-by-Step automatic switching exchange has a far lower staff requirement (overhead) than a Sylvester Switchboard manual switching exchange.

In an Infrastructure Business mindset, the people operating these switchboards were the centre of everything happening – so if there was a fire, or a train crash, a snake bite or a rush birth etc., – they physically knew exactly where the Doctors and Fire Brigade, Police, Ambulance etc. people were – and how / where to instantly contact them.

These people doubled as the emergency services interface plus they provided the "life line" connection to many others – and I seriously doubt that people these days have any comprehension of the background work they did in their normal activities to keep the community / communities connected and mentally well.

High Maintenance Overhead Wire Technology

Overhead telegraph / telephone lines in CBD / cities had been rapidly expanding since the CE 1860s and Australia had its fill by the CE 1930s, as this network infrastructure was an awful mess – and now extremely high maintenance.

Because of the high number of pairs of open aerial pair wires required to interconnect businesses to the local Post Office(s) and the high number of open aerial wire pairs inter-connecting Post Offices in different suburbs – the poles were very high (over 20 metres) and it was not uncommon to have over 24 cross-arms (each carrying six or eight pairs of spaced out wire pairs). The insulators used for telegraphy/telephony were just like a small version of the insulators used for open wire power distribution.

These telephone poles / cross-arms / wires absolutely dominated the roadsides / footpaths and it was very much like a spiders' web – particularly in urban areas and particular in cities – and particularly near the Post Offices – as these were the locations of the manual telephone exchanges!

In those days, every kitchen had a slow combustion stove (burning wood) and house heating was with open fireplaces or coal / coke fired enclosed heaters. Electricity was locally generated and used lots of coal and all the trains used coal / wood fired boilers. The "environmental" lobby would be absolutely mortified if they quantified / how much coal/wood smoke was always being thrown into the atmosphere!

Sydney was commonly nicknamed "the big smoke" for very good reason that a permanent smoke cloud lingered over the CBD and other urban areas. Only since about CE 2000 had most of the CBD sandstone buildings been steam-cleaned to wash / remove the soot out of the sandstone and restore the natural colour.

In country areas, it was common practice to run the telegraph / telephone lines in parallel with the coal / steam powered railway infrastructure – as the communications between railway stations was an imperative and the path was "cleared" of trees.

If it was not tree branches falling over open wire spans, then it was the gradual build-up of soot on the insulators that made their surfaces conductive; which introduced extra attenuation and brought in signalling problems. Dew didn't help but rain generally washed-off the accumulated sooty insulating surfaces, dramatically reducing some faults – but sometimes introducing other transmission and signalling faults! Either way, continual line maintenance was a full-time task for large teams of lines people – an immense overhead.

Installing / maintaining a route of overhead telephone lines for "Carrier" transmission was far more exacting than for Voiceband transmission for the Local Access Network. At these much longer distances and much higher frequencies, open wire transmission was far more susceptible to inter-pair crosstalk – which (apart from being extremely annoying), caused Carrier system instability.

Crosstalk had to be very carefully minimised and was done with multiple pair transpositions over every open wire route. This was usually done at a cross-arm where four insulators were mounted in a "square" so that the two adjacent wire pairs could be crossed over with each other and the crosstalk induction from other pairs could be significantly "nulled". This was very much a "black art" and it was very time consuming as it involved a lot of very slow trial and error processes!

The other generally forgotten issue was that of power line induction – where high voltage / current power lines ran adjacent to the road (and telephone lines) – and this acted just like a transformer with mains hum (and in particular harmonics of the mains frequencies) being directly induced into the telephone lines.

So not only did the telephone wire pairs have to be vertically transposed to minimise crosstalk from adjacent telephone lines (on adjacent cross-arms) but also the open wire pairs had to be had to be horizontally transposed at regular intervals to minimise induction from power lines (and from adjacent open wire pairs).

In Australia you may note that 11 kV / 33 kV three phase lines are intentionally "rolled" between power poles to reduce external induction into open wire lines / fences etc.

As the open overhead wires are warmed from the sun's radiation and cooled overnight, this changing in temperature causes significantly varying attenuation. To minimise varying attenuation, the then new technology of automatic gain control was introduced (and worked most of the time) – but this was also a slow "black art" that needed monitoring by internal plant staff in the exchange sites!

Further - there was simply no physical room in the streets for network expansion and another technology solution for lower maintenance telegraph / telephony transmission (particularly in urban / city / CBD areas) had to be found and very soon.

Following Federation in CE 1901 where the common wealth of infrastructures of Australia (almost) came together; the Post Master General's Department (PMG) remained as State-managed infrastructures with a very loose "Headquarters" – based in Melbourne (because this is where the Federal Government was originally formed and based until the Federal Government moved to Canberra in CE 1935). This PMG Headquarters was really a technology / manufacturing think-tank that in time developed itself into the Post Master General's Department Research Laboratory (TRL) – and remained in Melbourne!

The value of TRL to Australia's economy could not be overstated and the prime reason that Australia had so many large and advanced telecoms associated manufacturing businesses throughout most of the 20th century was primarily because of TRL's world-leading involvement in advancing telecom technologies into local manufacture; that in turn was pivotal in building Australia's economy and being far less dependent on importing manufactured equipment.

Soon after Telecom Australia Commission was privatised to a Corporation in CE 1989, the business focus moved to a much shorter time frame (and coincidentally global manufacturing – centred in the northern hemisphere, had major impact – forcing most Australian telecoms equipment manufacturers to sell up and/or be closed down). Australia's Federal Governments ignorantly facilitated the death of most Australian manufacturing.

With the functions of TRL now heavily curtailed (as this time frame for fast return on investment was far "too long" for the new Telstra, and research was not seen as "core business"). By CE 1997, the new Telstra executive Management / Board had little problems in killing off TRL to becoming Telstra's "Global Operations Centre". From then, TRL and meaningful research was obliterated from within Telstra – at an incredible expense to the Australian economy – where it has since never recovered.

Highly Economic Underground Cables

By the CE 1930s in urban Australia the footpath alignments had telegraph/telephone poles "everywhere" filled with open wire telephone wires / lines and in the non-urban areas to rail / road alignments had open wire / line transmission technology alongside – and the maintenance requirements were consistent and high. "***High Maintenance Overhead Wire Technology***"

The early CE 1930s was the dawn of underground (urban) cables which added another dimension of generally unrecognised serial technology-based productivity gains (*that like all these technology-based productivity gains absolutely nothing to do with business competition and everything to do with engineering – or as I put it "making a better mousetrap" – where <u>continuous (self) improvement</u> is the prime internal driver*.

Through the CE 1920s there was a quiet "refined mechanical" revolution where new intricate machinery took over most of the repetitive manual labour employment. This change in industry manufacturing technology had a lot to do with the blame for the CE 1930s depression that resulted in massive worldwide unemployment.

As before with wire research and development, the PMGs Telecom Research Lab (TRL) in Melbourne; stepped in perfected the process of folding / rolling a slip of paper around each wire and individually twisting these now insulated wire pairs pair in layers; then sheathing these pairs in sheet lead (as a very well-sealed airtight pipe) to form robust cables that could be trenched / laid underground.

TRL also engineered the design of a nominal 4" (100 mm) internal diameter conduit (pipe) manufactured from asbestos/concrete and a small range of Service Pits (to hold cable joints) – also manufactured from asbestos concrete. In its time, this was brilliant technology because cement powder could be readily manufactured in Australia and asbestos was readily available – and the combination of these two compounds made into a thick slurry that could be extruded / moulded and then set.

The asbestos formed a "binding" agent allowing thin shapes without fracturing and the cement became very hard – so together this asbestos/concrete compound became a major construction product and also found its way into very inexpensive thin "Fibro" sheets that had a very wide application in building up to about CE 1980.

Asbestos was a "wonder" product in the CE 1930's onwards as it has incredible thermal resistance properties, is not flammable could be combed and made to thread and was used everywhere – from seat / dress / curtain fabric, to brake pads to flying boots/jackets to "snow" on iced cakes. It took until the mid-CE 1970s before it was related with lung cancer and even then was very slowly removed from common use.

The problem is that when (dry) asbestos flakes off, the minute particles are breathed in and permanently irritate the lung surface resulting in cancerous growths that in time kill the lung function. Fortunately, the conduits are underground and naturally wet / moist and very little of the Service Pits are exposed. All the Service Pit Lids are made from steel re-enforced solid concrete or from cast steel (and now plastic).

Combining these technologies, Service Pits could be installed (with the lids at ground level) along the Conduit route (nominally 600 mm below the roadside footpath alignment) and lead-sheathed cables then drawn in through the Conduits and jointed in the Service Pits. Because of the highly protective mechanical shielding effect of the conduits - the lead-sheathed cables were very well protected from earth movements. So these lead sheathed cables could be reliably installed and remain low maintenance for several decades (if it was not for lightning)! "***Bolt Lightning and Pressurised Cables***"

With this new telecom transmission cable and associated technology properly engineered for Australia (in Australia), and with the CE 1930s depression bearing down, the State-managed PMG Departments individually employed many thousands of people in each State/Territories as labourers. These labourers manually dug trenches to about 600 mm below the footpath level and installed the new Australian manufactured Conduits with Service Pits at regular intervals – so that could these then new cables could be roped and rodded in place to re-connect Telephone / Telegraph services previously connected by open wire overhead lines.

Because this was a major national infrastructure build, the engineers weighed up the component costs of the cable and trenching / back-filling, service pits, cable jointing, ducting, terminating etc.. They recognised that a simple one-for-one replacement of the open wire technology was far too short-term thinking. It was common / standard practice to deliberately over-provision underground cables so that extra cables would not be required for 20 to 50 years ahead – and the conduits were already there!

It is interesting to note that nearer the local exchange sites and CBD sites that most Service Pits have six or eight conduits between the larger service pits. So there was plenty of long-term planning performed by these Infrastructure Business mindset engineers and their staff.

If this engineering work was controlled by Competitive Business mindset Sales and Marketing executives, then the build would have been seriously curtailed and the forward planning would have been virtually eliminated – at immense future cost.

A recent classical case exemplifying this Competitive Business mindset stupidity in operating an infrastructure is the call by the Federal Government to introduce the NBN as a Corporation (not a Commission) – and not nationalise Telstra Corporation to gain (capitalise on) the massive economy of scale available in this merge.
*"**The Privatisation Wheels Fell Off**"*

This same proposition (to roll out FTTP) was put the Telstra Executives in about CE 1991 – but the response was that that funding was reserved for "dividends".

The dividends kept the share price high but the cost to Australia's economy was so gigantic (because Telstra certainly were not going to roll out consumer FTTP as this would kill their share price) that the NBN had to be rolled out by the Federal Government to try and stop Australia's economy falling into a third world cot case.

So the external plant engineers opted to build for nominally 20 to 50 years ahead in terms of population growth – with very little added expense because of mass production technologies, and that cables with twice the capacity were only marginally (about 40%) thicker and not that much more expensive to manufacture!

Considering also that the TRL had introduced manufacturing productivities that considerably reduced the process costs and significantly increased manufacturing reliability – so – really – it was rather easy decision to opt for plenty of spare pairs in these cables! It took until the mid CE-1970s before most inner-metropolitan areas needed extra (and replacement) Main Cable infrastructure. "***Competition Wrecked Australia's Pair Copper***"

By the late CE 1930s virtually all the overhead wires in Australia's metropolitan areas were replaced by very low maintenance underground pair copper, paper-insulated lead-sheathed cables. "***Cabling the Junction and Access Networks***"

The productivity of this engineering innovation was immense. Not only were the city / CBD streets cleared of telephone poles everywhere so these places were no longer looking like large spider webs over the footpaths, but now the line maintenance overhead costs in these areas had plummeted – and stayed very low for decades!

Almost all Main Cables (the big ones coming from the Local (telephone) Exchange Main Distribution Frame to the first (rather large) jointing pit) – and the extended Main / Intermediate cables extending from these large Service Pits to the Sputniks / Pillars are almost all lead sheathed (paper insulated) pair copper technology.

With lead-sheathed paper insulated cables, the standard (Main Cable – e.g. 1500 or 2400 pairs) jointing process was to solder terminate on vertically positioned terminal blocks (called "risers") in the exchange's Main Distribution Frame (MDF). This was very solid engineering and the maintenance required for this was virtually zero.

At the "field" end the Main Cable this would be in a large Service Pit where the cable would be splice-jointed to a few "Intermediate" cables of say 200 or 400 pairs, where the wire pairs were twisted and soldered then covered with a paper insulation slip – then the whole joint covered with lead sheeting that was "sweated" to form an airtight solder seal with all the cable sheaths. This was a master workmanship process!

Lead-sheathed cables were an incidental master stroke because the sheathing provided a highly conductive screen to the pair copper inside – minimising mains power (and their harmonics) induction; and this sheath also provided an extensive "earth mat" that to a very large degree prevented internal plant equipment damage against bolt lightning. "***Bolt Lightning and Pressurised Cables***"

On the down side, lead is highly poisonous causing nerve / brain damage and I am sure that a high percentage of lines staff would have been permanently injured or died before retirement due to excessive exposure / ingress of lead (fumes).

At the distant end of the Main/Intermediate cable the standard practice was (is) to have an above ground Pillar / "Sputnik" that is effectively a mini MDF standing about 1.0 m to about 1.5 m high and with a (about 350 mm diameter) tubular surround – that has an airtight seal at the base.

Inside the Sputnik / Pillar is a series of vertical terminating blocks (called "risers" – similar to those at the MDF in the local Exchange building) and the cable pairs were terminated on the back of these "risers" and then bolted into position.

From these Pillars / Sputniks, several Outer cables were then connected to groups of house lots where the "Drop" cables connected to the Premises' Terminating Block.

This multiple **tiered star** Access Network cable structure was literally invisible to most people and consequently most people (from about CE 1950 onwards) are entirely unaware of this very extensive telecommunications infrastructure.

Cabling the Junction and Access Networks

While the metropolitan Access Network was being re-engineered into cable technology in the early CE 1930s, so too was the open wire metropolitan Junction Network that interconnected all these Post Offices in a Star and loose Mesh structure! "***Highly Economic Underground Cables***"

The copper and lead for this new cable infrastructure came from Australian copper / lead mines – which really bolstered Australian mass manufacturing and engineering and in-house built much of Australia's internal economy.

The wire gauge for the Junction Network was considerably "heavier" than that used for the Local Access Network (usually 0.40 mm) – because the Junction Network had much further distances to cover (between Post Offices up to over 20 km away, and connecting to the major intra-metro CBD telephone exchanges too – which could be in the order of 50 km away! As series resistance is the main contributor to attenuation (loss of volume) over distance, most Junction Cables were constructed from paper-insulated 0.64 mm pair twisted copper wire (and occasionally 0.80 mm). Most of these (inter-exchange) cables were 50 pair and some were 100 pair.

A typical fully loaded telegraph pole had about 20 cross-arms and typically 4 to 6 pairs of open wire circuits per cross-arm. Of these, about 96 pairs would have been Access Network and the remaining 24 pairs would have been for Inter-Exchange / Junction / Trunk Network (using heavier gauge wire).

Putting in two cables for specific functionality meant that the 112 pairs could be built as a 200 or 400 pair cable (with a light gauge wire), and the 36 pairs could be built as a 100 or 200 pair cable (with heavier gauge wire). By opting to proactively double the initial cable pair requirement – the cable diameter would increase by only about 40%. Even then these cables would have fairly comfortably fitted inside the standard 100 mm diameter asbestos-concrete conduits (pipes). Alternatively – multiple conduits between Service Pots is common practice (and is standard)!

There were some interesting "engineering quirks" that carried over for many decades. One rather obvious "quirk" was the definition of wire gauge by its weight (in pounds per loop mile)! With overhead wires using a weight measurement made (some) sense because this weight was highly related to the load bearing on the type and size of telephone poles' cross-arms.

This definition passed into cable technology in the CE 1930s - but to carry the weight measurement over into cables made very little "sense" as there was no load-bearing relationship and in any case, the wires in the cables were (usually) a much smaller diameter than those used for overhead wiring – and the metal structure was different!

In CE 1966 defining cables by the weight of the wire in the cables transgressed metric and remained imperial as "pounds per loop mile". It was not until about CE 1988 when (nationally) wire in cables was finally transferred to wire diameter (in mm). It is very easy to measure wire diameter with an inexpensive hand-held micrometer.

Overhead copper wires contain a small amount of beryllium in them to make the copper far less ductile and far less prone to stretching under tension. Copper in cables is essentially pure and has a correspondingly considerably far lower inherent resistivity than that of iron wire with the same diameter.

What was/is still (generally) not understood was that the electronic characteristics of open wire technology is physically very different physical structure than that of twisted pair insulated copper cable technology. The (Voiceband) impedance of twisted pair insulated copper cable technology is highly capacitive and is nothing like 600 ohms as per open wire!

As the "600 ohm standard" had been set – and it really didn't seem to matter, pair copper cable for Voiceband use continued to be interfaced as "600 ohms". There were conspicuous problems and very few engineers and technical staff were aware of the causes and fixes. This all came to a head with the introduction of Digital switches and transmission about CE 1988 some 50 years later) – when the high number of complaints about excessive echo / noise finally became National headline problems. "***Wiping Out Voiceband Complaints***"

Way back in CE 1880's, (about 140 years ago) a particularly bright British Engineer (Oliver Heaviside) developed three dimensional calculus way past Newton / Maxwell etc. and he applied this revolutionary advanced calculus in many different aspects – including the total re-writing of Louis Clerk Maxwell's (14 ?) electromagnetic relationships into a concise set of six inter-related three dimensional equations. (No, Oliver Heaviside was not credited and these Heaviside electromagnetic equations are still incorrectly called Maxwell's Equations!)

Oliver Heaviside also corrected his (uncle) William Thompson's (Lord Kelvin's) dysfunctional "Telegrapher's Equation" to make it functional (by including the missing distributed inductance component), that then countered the distributed capacitance component and everything then "fitted" and became functional! (This now obvious correction apparently really infuriated Lord Nelson!)

In CE 1887 Oliver Heaviside also introduced the concept of (lump) "Loading" a pair copper cable with coils at specific distances so that over a limited frequency range (e.g. the Voiceband 0.2 to 3.4 kHz) the impedance would be stabilised, the frequency response would be virtually flat, and in the process reduce the attenuation.

This technology should have been called "Heaviside Coils"- but that would have more than infuriated Lord Kelvin (who was already incensed because his nephew had discreetly shown him up)! The term "Loading" came from Heaviside's very quirky sense of humour / ownership to associate part of his surname "Heavy" with "Load".

*Fuelled by prejudice and competition; his superior William Preece, intentionally blocked this highly innovative proposal to happen in the UK and the first "Loaded" cables were very successfully tried and applied by AT&T in the USA – not the UK! (**This little story is a classic case of Competition stifling / delaying innovation.**)*

The brilliant Oliver Heaviside came up with several other radically different innovations that set the foundations for future technologies. With his conceptual understanding of "Field Theory" (which the world is really indebted to him for this field of theoretical and applied maths), he recognised that Pair and Quad cable construction were inherently "leaky" transmission mediums and he patented the design of coaxial cable in CE 1880 even though the first coaxial cable was used in the first trans-Atlantic cable in CE 1858. He also conceived the Ionosphere (hence the "Heaviside" layer) in his honour, that is extensively used in radio communications, and his advanced field theory equations set the basis for virtually all radio antennae from a simple whip antenna to a log-periodic to the space station parabolic dish!

Fundamentally, when the metropolitan Junction Networks were installed in the early CE 1930s they used "Loaded" cable technology by including 88 mH coils every 1830 metres (first coil at 915 metres) causing the Voiceband cut-off frequency at 3.4 kHz and the nominal impedance at about 1080 ohms (called "1200 ohms" as this is (about) twice the nominal open wire "600 ohms" characteristic impedance)!

The frequency response of loaded cable is virtually flat (so vocal sibilances clearly come through), the attenuation per unit distance is about half that of unloaded cable (so the received signal was substantially louder) and these cables were now underground (in the same conduits as the Access Network cables) so the massive roadside and railside (smoke filled) structures of overhead open wires with poles / crossbars holding more than 24 cross-arms could be removed!

These "Loading Coils" formed an integral part of the new cable-based transmission medium for the metropolitan "Junction Network" - interconnecting (or "Junctioning") the local metropolitan exchange sites located behind every suburban Post Office.

These exchanges were a mixture of Sylvester Switchboards and Step-by-Step (SxS) Automatic switches. By about CE 1935 many of the capital city (metropolitan) exchange sites had been converted to SxS switches and the remaining Sylvester Switchboards were centralised in the GPOs for "Trunk" (long distance) switching. By the late CE 1930s all the metropolitan overhead open wire telephone / telegraph transmission was now underground. Mission complete!

The intrinsic beauty about Loaded Cable Junction networks were that with the (unloaded) Access Network connected at each end, this connection did not adversely affect the end-to-end frequency response – so most of the calls were quite clear!

When the open wire metropolitan Junction Network was taken down the open wire Access Network was also taken down and put into cables that to a very large degree used the same set of under-footpath / street conduits as used by the Junction Network.

The difference was that the Access Network connected from the Telephone Exchanges to the Customer Premises as a (physically) "**tiered star**" structure; whereas the Junction Network was essentially a **star** and loose Mesh interconnecting the Metro telephone exchanges (with no customer connections).

Like the Junction Network, the Access Network also used paper-insulated twisted pair copper in lead sheathing technology, but the nominal diameter of the copper wire was 0.40 mm and not 0.64 mm as used in the Junction Network cables.

As this open wire metropolitan Access and Junction Voiceband transmission networks were replaced by buried cable technology, the maintenance requirements very rapidly dropped and this technology was clearly far more economical / efficient than its predecessor. "***The Economy of Pair Copper Cables***"

The Economy of Pair Copper Cables

With underground pair copper cable technology, frequent callouts for fallen wires, interfering tree branches, damaged poles, hum on transmission (lines), excessive (interfering) crosstalk etc. were all gone – and so was the vivid roadside avenues of thousands of km of overhead / aerial wires. This overhead telecoms infrastructure had literally vanished and so had the associated customer complaints. Most people became aloof that cable technology was almost everywhere – and working! "***High Maintenance Overhead Wire Technology***"

Just (about 600 mm and 1200 mm) underground was another world of wires – but in tightly constricted (and virtually water-tight) lead-sheathed cable. Unlike their overhead predecessors – whose open wire pairs gradually dwindled along the streets and roads as the pairs ran off into business and home premises; the cable structure is very "quantum" with well-defined technology steps.

The productivities brought in with twisted insulated pair copper wire cable technology were immense. First in the CE 1930s the metropolitan areas had the open wire technology almost fully replaced. "***Cabling the Junction and Access Networks***"

In the Regional Rural areas during the CE 1950s/1960s/1970s, the open wire telecoms technology was then also replaced. In most of the Regional Remote areas it was uneconomic to even install Open Wire or Pair Cable technologies y in most of the Regional Remote areas. "***Rebuilding the Regional Transit Network***"

The reason for this "quantum" cable structure came back to immense productivities through the economies of scale in mass production of telecoms cable manufacturing. It also made an immense amount of economic sense to manufacture cables with standard numbers of pairs so that the efficiencies of mass produced cables could be maximally realised (and economically provide for future network growth). When looked at from this "quantum" angle – the engineering of the Exchange Switching Area (ESA) as part of the Customer Access Network started to have "structure" that could be far more economically long-term planned (i.e. over several decades).

Yes, cables would go in that a good proportion of pairs on those cables may never be used in 10 or 15 years – but – the existing businesses and home premises would have immediate connectivity. If there was a requirement for more connectivity in the near (or distant) future – then there would be a very high probability that prospective customers could be virtually immediately connected!

Now – the cost of trenching in hundreds of thousands of km of cable was also immense – and in this process tens of thousands of immigrants and Australians learned a wide range of industrial skills that carried Australia through the next two decades (in each case – CE 1930s and CE 1950s/60s).

Economically the opportunity cost of finding useful employment for many thousands of returned service people (with severe mental and physical injuries) and many thousands of people fleeing their countries because of the outcomes of war, would have been to pay out big time in social security payments and get nothing in return.

The skills these people learned while doing this work considerably added to their inherent skills and provided Australia with a solid workforce for the following 20 plus years i.e. through the CE 1940s and CE 1950s and through the CE 1960 and CE 1970s and CE 1980s.

Cabling the Regional Transit Network

Following WW2 (circa CE 1950), Australia was in another mini-depression with many returned servicemen now displaced from their previous work, and a large number of immigrants (with no work to go to) and commercial / competitive business scrambling to change product lines and become / remain profitable.

Under the then Federal Government, the PMGs Dept. again stepped in (as they did in the CE 1930s depression) and provided work for many thousands of labourers to resume trenching in cables in Regional country areas (urban and non-urban).

This was extended through the CE 1950s and CE 1960s and even the early CE 1970s with the practice of mechanical aides (machine assistance) being increasingly used to plough in underground pair copper (Loaded) cable to interconnect Regional Rural Villages to nearby Towns / Cities forming a low maintenance “Transit” network.

Concurrently the country Cities, Towns and (most) Villages (urban areas) had their overhead wiring removed and replaced with underground cables. Unlike their metro mates, not all Towns and Villages had conduits – but they had Service Pits!

From the CE 1960s onwards, the very widespread use of plastic insulation totally revolutionised the way that cables were manufactured and radically increased the connection reliability. “***The Massive Productivity of Plastic Insulation***”

Although the wires were now plastic insulated there was a fundamental issue of keeping the sheathing as (metallic) lead and not to advance to polyethylene sheathing (which ants love to eat).

The picture on the right is poly insulated 0.4 mm pair copper cable (1500 pairs??) with a poly sheath.

A name that sticks from TRL (J. K. Lynch) also chimed in on this innovation and developed / perfected several manufacturing techniques to significantly improve the consistency of these new plastic insulated cables. So - not only was the wire diameter far more consistent than the earlier paper insulated cables but the (plastic) insulation thickness was also to a much tighter specification.

The outcome of this research and development (constant improvement) work was that the (Voiceband and Carrier) transmission parameters were now far tighter meaning that network engineering designs were now far more “predictable” and the crosstalk was substantially lower than the earlier paper insulated technologies.

This trenching in of cables to replace overhead wires was a slow and expensive process that took until the early CE-1970s to complete. The productivity in terms of reliability gained by having these underground cables instead of overhead wires was immense - but un-noticed by the general public as this infrastructure simply disappeared from view!

Bolt Lightning and Pressurised Cables

One of the nemeses of telecoms infrastructure is lightning – in particular bolt lightning, as this has massive currents radiating out from where the lightning strikes the ground / buildings / antenna etc., until the lightning circuit breaks and the surrounding ground voltage quickly subsides to a constant (almost stable) potential.

Most tall buildings include a highly conductive “earth rod” that extends above the top of the roofline and well into the earth below (as an “earth stake”), so that the massive currents from any potential bolt lightning strikes that hit the building may be directed through the conductive lightning rod and minimise building damage. The electricity mains earth is also bonded to this earth stake so that the mains earth voltage does not “float” – particularly during lightning strikes.

With telecoms buildings, the standard procedure is to have several earth stakes that deeply penetrate the soil (hopefully into the water table) to minimise localised earth potential voltage rises during lightning strikes.

In hill-top or other high vantage points that have radio masts it is common practice to also include an extensive “earth mat” to assist in distributing / diluting the massive currents from direct bolt lightning strikes to these masts. Overhead wires are a natural lightning target and non-urban underground cables are far less prone to lightning damage than open wires.

In urban areas the (lead-sheathed) cables naturally formed a very extensive “mat or lattice” that was (incidentally) crucial in distributing and dissipating these direct and induced lightning currents. It is not that lead is an excellent electrical conductor; but because the spider web-like cable structures in these urban areas, the massive currents are (usually) safely dissipated with a minimum of damage through themant cable sheaths to nearby earth stakes.

Underground cables in Regional / non-urban areas do not have an “earth mat” effect like in urban areas, so it is far more crucial to have “Lightning Arrestors” installed on all the pairs in Main Cables (at least) in the local exchange’s Main Distribution Frame (MDF) in Regional areas.

With induced lighting, the cable pairs can easily exceed a few thousand volts above/below local exchanges ground potential! These (gas) Lightning Arrestors are about the size of your little finger and are “open circuit” to ground/earth. If the induced voltage exceeds about +/- 300 V the gas in the lighting arrestor ionises and becomes an instant “short-circuit” to very rapidly bleed the induced voltage and associated current surge from causing substantial equipment damage.

> *Circa CE 1991 while in Bathurst (NSW) with Senior Engineer Ian Byrne, we were fortunate enough to hold a meeting with a high percentage of Telecom Australia Internal Plant Technicians from most of the NSW Country Districts – where the main topic was about Voiceband Quality and Customer complaints – and how to properly fix these problems.*
>
> *One of the questions Ian put forward was a show of hands of those that had major lightning problems, and his next question was a show of hands of those that had Lightning Arrestors installed in all their (phone) lines at the Local Exchange sites!*

> *These two questions were very telling as those Districts that had lighting problems generally had no (or very few) Lightning Arrestors on their phone lines and those Districts that had little amount of lightning problems had installed Lightning Arrestors on their (phone) lines!*
>
> *Almost instantly there was able inter-District assistance from those that areas where staff had installed Lighting Arrestors on their (phone) lines; to assist technical staff in other Districts to install Lightning Arrestors into equipment in these other Districts that did not have Lightning Arrestors!*
>
> *These Districts were not competing against one another – so there were no hidden "company secrets" between the Districts These people were actively collaborating (**negative competition**) with each other in very close communications and provided physical support outside their own Districts to assist other Districts so that all the Customers had the best possible service – and an overall minimum of Customer complaints!*

*This was a classical real life economic situation clearly demonstrating that **<u>negative competition</u> (i.e. collaboration) actually <u>drives down</u> end-user prices.** If there was ever an instance where Economists need to open their eyes to real world economics then this was it – and this happens everywhere!*

The technology combination of paper-insulated pair copper in lead-sheathed cable was brilliant for its time (CE 1930) but when lightning struck the ground there are / were massive current flows in these cable sheaths.

A direct consequence of this (natural) lightning is that the cable lead sheathing heats up because of the massive (very) short term current flows, and boils / evaporates / electrolysis of the lead sheathing forming little pin-holes (or larger).

Inevitably this situation (if there is water outside the cable) allows water to ingress the cable – which rapidly accelerates the paper insulation to become conductive and rot, causing the insulation to become slightly conductive, resulting in some cable pairs having and excessive (conductive) "loss-between" or "loss to earth".

These cable faults inevitably result in line maintenance where the customer pairs are changed to other less damaged pairs in the same cables – and far less spare cable pairs in the future.

As these cables were no longer air-tight sealed, this needed a totally new engineering strategy. The "fix" (circa CE 1955) was to install a cable (dry) gas pressure system at every local exchange and slightly pressurise all the lead sheathed cables to keep the water out and dry the paper insulation.

Basically the Gas Pressure Equipment consisted of a an electric motor driving an (filtered) air compressor that loaded an air tank to about 50 pounds per square inch (about 340 kPa) - about the same as a car tyre. The air tank then had a solid pipe gas reticulation system that connected single ¼" diameter (copper?) pipes to each Main Cable via a visual (gravity balanced) gas flow meter and separate pressure gauge. Each pipe had its own needle valve / tap so that the flow could be individually controlled to each Main Cable, and the cable gas pressure retained at about two atmospheres. This way, every Main Cable's pressure and gas flow could be quickly and easily seen and reported – so reactive action could be taken to fix cable sheaths.

One of the then (circa CE 1960) new plastic products was "epoxy resin" that was a two-part (a few minutes) setting hydrocarbon. This epoxy was made up and poured into the (Local Exchange) end of the cable sheath (usually at the base of the Main Distribution Frame (MDF) where the pairs would then terminate on the back of a "riser" – being part of the MDF structure. The freshly-mixed epoxy resin liquid would then seep down into the cable and then set hard in a several minutes – forming a firm airtight seal! "***Massive Productivity of Plastic Insulation***"

The problem was considerably more difficult with Pillars / Sputniks, because these were inherently not airtight sealed and a new (sealed) version was successfully developed that had a tubular casing that could be pressure sealed.

Much like the cable entry near the Main Distribution Frame (MDF) in a Local Exchange, the Pillar / Sputnik has a cable entry/exit neck near the ground. At the top of the neck every cable sheath can be (and was) airtight sealed.

When the Sputnik's outer tubular casing is brought down and seals against the rubber ring near the base, another smaller rubber ring under the top of the tubular casing completes the airtight seal. The dry gas pressure is then contained and this low air pressure minimised the amount of moisture ingress into these (primarily) lead sheathed cables.

The inevitable problem for this technology was that the sputnik / pillar container is under about two atmospheres of air pressure, and when the top screw is released this can be a dangerous projectile. The design is such that the lower ring air seal is broken before the top support is fully undone – allowing the air pressure to escape before the top support is released. *My understanding is that this mechanical arrangement (work process) did not always get rigidly followed and people rushing work did get injured with the outer tubular casing "jumping" off the base.*

The vertical mini-frame inside the Pillar is very much like a small part of the Local Exchange Main Distribution Frame (MDF) - but constructed as a broad circle of vertical terminal strips. All the buried (Main) / Intermediate / Outer cables are fed up through the middle of the neck above ground level and terminated on the inside of these vertical risers – leaving the outsides of these vertical riser termination pairs to be cross connected by pair copper polyethylene insulated "jumper" wires.

The productivity of these Pillars / Sputniks was largely unheralded – but this cable associated infrastructure allows very quick and easy connectivity to Access Network "Intermediate / Outer" cables that could / would otherwise take some hours in a service pit with a rather large sealed joint that would be opened several times per year – and potentially cause other expensive maintenance issues impacting on customers service standards – and increasing service complaints.

This Cable Gas Pressure equipment was not "expensive" to purchase / install and it performed wonderfully well (for decades). The problem was that this equipment had moving parts and consequently it was far more susceptible to wear and tear than equipment that had no moving parts. My understanding was that in some installations it became more convenient to install one (or more) high pressure (liquefied) gas bottles and this could be left for a few months with virtually no maintenance intervention or checking.

If there were (excessive) pinholes in a cable then the amount of dry gas flowing into that cable could be seen and evaluated. Some joints had cracks in their lead (or plastic) sheathing. Pillars that had been recently worked on had Main / Intermediate cable pressures that were obviously low pressure for some days.

Generally, this technology area was rather poorly understood and it was “External Plant” in an “Internal Plant” area and a very low percentage of (External Plant) Field Staff or Internal Plant (Technical Staff) that were really aware of the actual purpose – and it was not in their direct “field of duty”. So it simply ran along by itself for many years / decades and the cables more or less kept in relatively low maintenance!

The added consideration was that by including “pressure” contacts on a spare pair of wires (along a cable run) – then a broken sheath fault could trigger a nearby pressure sensitive contact (bringing up an alarm) and the fault could then be proactively localised – and (hopefully) fixed before major cable damage happens.

This alarm reporting equipment meant that is became necessary to have some spare cable pairs (of course) set aside for gas pressure alarms.

With an Infrastructure Business mindset this was not a problem because extra pairs would have been proactively accounted for and this alarm system would maximise cable performance so customer complaints from this area would be minimised (and naturally, cable life would be maximised).

With a Competitive Business mindset this was a problem because these pairs were potential income from customers and if there is a problem then the cable can be reactively maintenanced (and naturally, cable life is irrelevant).

> *At Telecom Australia’s NSW Design Laboratory (circa CE 1980), the concept of an advanced technology Cable Gas Pressure Alarm System was proposed to measure the loop resistance of the (common) wire pair to the contact to identify the closed contact’s location.*
>
> *Tech Officer Geoff Donnelly was assigned, where he produced a prototype in a few days and trialled this with improvements over a few months with an initiative of having a series of small (analogue) pressure sensitive devices along a common pair in a cable route (at the cable joints) with the ability to quickly sequentially scan these sensors (on a common pair) so that the relative pressures could be measured and the location(s) and causes of gas leaking then identified and proactively fixed.*
>
> *My recollection was that this (analogue) sensor (digital) scanning technology was too unstable to provide consistent and accurate results. Also, the amount of rework (at many tens of thousands of cable joints) was immense, labour intensive, very expensive and unrewarding.*
>
> *Another consideration was to include a microprocessor and associated software so that the analogue resistance readings could be referenced to physical (street) locations – and the alarms could be extend to another (central) location. This was years ahead of its time!*
>
> *The initiative was heavily pared back to continue using the in-place pressure contact sensors on a common pair in cable joints and this remained standard practice to identify cable / joint gas leakages and by this pre-existing alarm system, hopefully minimise pair insulation damage.*

Note: there was no "(External) Competition" from other manufacturers / sales people / marketing / advertising or equipment providers to drive these improvements that would potentially really drive down end user (maintenance overhead) costs.

There was however "Competition" impressed by the selling off of the telecom infrastructure to be "more efficient" (i.e. divert funds to shareholders and grossly overpaid executives instead of funding to proactively maintain the network to operate most efficiently and effectively over all Australia – not just the high profit areas)!

These self-initiated improvements that drive down production costs and make maximum function-ability are all part of the standard process improvement practice when going through the stages of "prototype - proof of concept - small production run" or as I put it "building a better mousetrap" – which is standard practice in this Infrastructure Business (equipment development laboratory) environment!

Water / moisture in a cable had the effect of dramatically increasing the capacitance per unit length between and capacitance to earth of the pair wires – and it did not matter if the cable was paper-insulated of polyethylene insulated. The permittivity of water is about 60 times that of dry air and it only needed a little bit of water to make a massive degradation to the Voiceband frequency response of a Customers line.

Even though there is some "Slope" (greater high frequency attenuation than at the middle / low end of the spectrum) the human hearing is quite adaptive and "covers" for this in most cases! Consequently very few of these instances were reported and/or acted on – other than simply changing the pairs in the cables for those customers. Inevitably those same faulty pairs would be used for another customer.

It was not uncommon to find certain sections of cables that had a geographically grouped of loss-between or loss-to-earth faults that were located (and bypassed by using other pairs in the same cables). Similarly, it was very uncommon to find transmission faults (like excessive "Slope" or excessive "Attenuation").

> *Circe CE 1990 I was in a National Working Group involved with specifying the Voiceband characteristics of the Customer Access Network. This was extremely interesting because the specifications were based on minimum signalling current – and at that time, there were no frequency / attenuation / length specifications (which were essential).*
>
> *After we resolved the specification differences, we then worked through standardised construction principles and compared these to existing network structures – and found many Regional Rural structures required considerable re-engineering – which was done.*
>
> *It was very obvious that a very large proportion of the Metropolitan fixed Access Network cables were very aged (CE 1930s) and way beyond their replacement dates. Checking back, they had been scheduled for replacement in the early CE 1980s but because of the Davidson Inquiry (and Report) this had been "shelved" because this cost money and with the intention that the new technology of Mobile Phones would totally replace fixed access phones (with far bigger profits).*
>
> *In my then other role at National Network Investigations I was highly aware that a very high proportion of the Access Network pair copper cables in the metro areas alone were not within (Slope) specification (and they were far*

> *shorter than maximum distance). All these really old pair copper cables should have been replaced – but it was never going to happen because Telstra was not operating in "infrastructure mode" but in "competition mode" and minimising low profit overheads was the prime concern.*

Unfortunately because of this slow deterioration process and the fact that these cables were being used for Voiceband telecoms the deterioration in Voiceband Quality was very difficult to detect / perceive and it took several years to identify and act on this cable water ingress problem. By then, nationally, considerable damage had already happened. "***Competition Wrecked Australia's Pair Copper***"

Consider that an internally wet length of cable (e.g. under a road), about 18 metres electronically looks like about 1100 metres of cable. For a telephone service this may not be a major issue – but for ADSL2+ this was devastating. "***Competition Wrecked Australia's ADSL***"

Slowly Emerging Frequency Division Multiplex

Early telecoms transmission technologies used “physically derived” Voiceband channels to decrease the cost of line transmission. These “physically derived” circuits were longitudinally transmitted on other physical pairs of parallel open wire transmission lines being used for transverse transmission. This is known as “Phantom” circuits (and was sometimes incredibly prone to excessive crosstalk and tree branches and weather events)! Maintenance was a very expensive ongoing nightmare. “***Phantom Circuits and Party Lines***”

Adding to this maintenance mayhem there were also amplified physical circuits that were in particular used for longer-haul transmission (where even thick wire had too much attenuation with distance). “***The Productivity of Electronic Amplification***”

It was understood that there was spectrum above the Voiceband – but the impossible problem was how to get a Voiceband “image” into that spectrum and back again! The answer in how to transfer parts of the spectrum to and from Voiceband came from understanding amplitude modulation (AM) radio technology, but there were a few steps in between before the concept of Frequency Division Multiplex (FDM) as a Voiceband “carrier” could be conceived and very economically / widely applied.

Circa CE 1905 Nikola Tesla (Serbia – USA) taught Gugliemo Marconi (Italy) the practical basics of radio technology from theory in that if a low frequency is used to amplitude modulate a much higher frequency, then the “distortion products” (my term) include the sum and difference of the two frequency sources as the main products (plus much lesser strength multiple sum and difference products).

Tesla showed Marconi how to his “very experimental” apparatus could tune into an electronically transmitted signal and Marconi commercialised radio technology circa CE 1910 – 1920. These radios used Tuned Radio Frequency (TRF) technology with typically up to five knobs (each with a “variable capacitor”) to tune into the radio Stations “carrier” frequency. It was “extremely difficult” there had to be a better way to tune in AM radio stations!

Considering Nikola Tesla’s love of pigeons and their use to carry messages over long distances through the air, I am almost sure that the term “carrier” (frequency) as used in radio and long-line transmission came directly from Nikola Tesla.

The better way to tune in radio stations was the “super-heterodyne” principle by having a local oscillator in the radio receiver producing a frequency that is 455 kHz above the received frequency of the desired radio station – and beating / modulating the amplified received tuned signal with this local oscillator frequency to produce a consistent “intermediate” frequency modulation product around 455 kHz.

Both the Radio Frequency tuning and the Local Oscillator’s frequency were physically linked by a “ganged” variable capacitor (on the same axle) – so only one tuning knob was now necessary! Modulating the received (broadly tuned) radio station frequency with the “Intermediate” frequency results in a main modulation product that is centred on 455 kHz and the “knockout blow” is that a standard factory built multi-section 455 kHz Band Pass Filter did away with all the extra tuning knobs – leaving just one!

This “Intermediate” filter had a relatively flat passband providing quite clear audio and steep sharp “skirts” effectively eliminating other interfering stations. This technology advance radically simplified radio receiver design, manufacturing and customer use.

Lucien Levy (France) filed the patent for the super-heterodyne principal in August CE 1917 some weeks before Edwin Armstrong (USA) CE 1917 and Walter H Schottky (Germany) also filed for the same technology in CE 1918.

(There is another epic about how the Radio Corporation of America (RCA) was formed by combining three separate manufacturers and then later headed up by “the General” David Sarnoff, who capitalised on and then (as I best understand it from several separate sources), seriously used and abused several brilliant engineers for his personal (and corporate) gain - including Edwin Armstrong (AM Superhet and FM Radio), Philo Farnsworth (Television / Cathode Ray Tube), Vladimir Zworykin (Electron Microscope), etc.. Sarnoff basically employed these people and then compromised their work conditions such that their patents were discreetly / forcibly “transferred” to RCA and/or their future employment was “limited”.)

The next part of the FDM puzzle solution came from the development of Single Sideband (SSB) transmission that came from Quadrature Amplitude Modulation (patented by John Renshaw Carlson in CE 1915) where the carrier signal is phase shifted by 90 degrees – to cancel the upper or lower sideband (and suppress the carrier frequency). This technique was used to deliberately maximise the amount of transmitted signal into a minimum (radio) bandwidth. As used for the transatlantic public radiotelephone circuit between London and New York circa CE 1927.

This SSB concept was trialled on wire telephony links in the mid CE 1930s but the tolerance and manufacturing techniques of electronic components had many years to grow before the functional blocks of FDM could be put together.

In CE 1932 a team of British scientists trying to improve on the super-heterodyne AM radio technology trialled their “synchrodyne” radio receiver where the local oscillator had the same frequency as the received frequency. This “worked” but it was prone to intermodulation from stronger nearby AM transmitters, otherwise the audio frequency response was excellent – mainly limited by the RF Band Pass tuning (which could be far wider than that used by the earlier TRF radio technology)!

Now, the pieces of the puzzle to position many Voiceband channels above the Voiceband spectrum started to fall into place. By using SSB with the “Synchrodyne” principal (and having fixed tuning for each derived Voiceband channel) then several Voiceband channels could be concurrently transmitted and received (“carried”) over a common transmission bearer – but extreme competition in World War 2 put an abrupt stop to this branch of technology.

When you consider the outcome from extreme competition (in World War 2) that included a massive loss of lives plus the far more immense number of men (in particular) that returned with severe mental stresses (and physical injuries), and the vast majority of these people simply could not return to normal civilian life – it really was no wonder that Australia (and the world) went into a hibernation period of about 10 years (at least) while these civilisations re-built themselves.

My intuition (and having worked in a telecoms “research and development” areas for about 25 years) is that mainstream FDM should have surfaced by about CE 1941 - and possibly did – but extreme competition of War most likely either killed or maimed these brilliant people and/or set back this technology until the early CE 1950s.

The missing FDM building block was the carrier frequency generator that was to be based on 4 kHz incremental steps. By having a higher frequency quartz crystal oscillator (say 24 kHz) modulated with a 4 kHz and all this driven into severe overload – this produces a wealth of harmonics all spaced at 4 kHz and tuning / amplifying these harmonics provides the necessary carrier frequencies for the FDM structure to use the “Synchrodyne” technology.

The Band Pass Filters as used for the super-heterodyne radio intermediate frequency were re-engineered for Voiceband wide carrier Channels and using SSB technologies set up the basis for FDM transmission and reception! Frequency Division Multiplex (FDM) technology finally surfaced in CE 1952 with a patent through Leland E Thompson (USA) US Patent 2,819,344.

The beauty about FDM is that all the economic gains about mass production of equipment and mass production of signal processing are laid out. These FDM transmission systems were not only stable but were far more reliable (and physically considerably smaller, and far less costly to manufacture). Everything is modular!

In practice this FDM technology was initially very difficult to engineer – but once done this technology was mastered; manufacturing was very straightforward and rather inexpensive to mass produce!

The first FDM systems were 3-Channel and took up three entire racks of equipment about 2.4 metres high, with separate sub-racks loaded with equipment for particular block functions! This was not highly efficient use of the rack space – but it worked!

At that time, central battery telephone exchanges (including the Switchboards) used a common -48 V battery to run everything. With thermionic valves, these needed a -24 V battery feed to heat the cathode and a +130 V battery feed to run the high tension to the anode circuitry. This was three battery sets in most exchange sites.

All this extra equipment needed daily checking and maintenance (extra overhead costs), but the productivity advantages of the next generation of 12 channel FDM quickly exceeded Phantom transmission circuits between regional centres.

A latent addition to FDM technology was the specialised shaping of the (mass produced) Voiceband Low-Pass filter that sharply rolls off above 3400 Hz so that it has an attenuation notch at 3825 Hz to very inexpensively facilitate “out of band” signalling and enable this long-line transmission equipment to directly interface with switching equipment – and pass through the channel associated signalling (CAS).

The big advantages of this FDM technology was that the attenuation was far more consistent and could be far better managed as a “group” than as single channels –

This new FDM technology had virtually no inter-channel crosstalk and it could be (relatively easily) amplified along the way making long distance (“long-haul”) transmission far more economic than individual Voiceband channels. On the downside there were the continual rather expensive overhead costs of telephonists and maintenance technicians and linesmen, and call billing accounting staff.

Rather synergetically the technology of electronic components was going through a metamorphosis in the CE 1960s, where they became smaller, far less expensive to manufacture and the value tolerances were far tighter than years before.
“***The New Era of Electronic Components***”

The killer productivity key was that this FDM technology uses plenty of the bandwidth well above the Voiceband (4 kHz max.), primarily over quad copper cable and coaxial cable; and FDM technology became **the** long-haul transmission technology of the CE 1950s, CE 1960s and CE 1970s and CE 1980s and some of the CE 1990s)!

Not only was the operational maintenance cost substantially less than separately amplified circuits but the reliability was also substantially better than separate Voiceband amplified circuits; so complaints and maintenance costs were minimised.

By our current (CE 2021) transmission standards – FDM was far from sophisticated as it (initially) used “in-band” signalling – but FDM dramatically reduced the overhead costs of long-haul transmission using only 2-pairs of wires (one pair for each direction) instead of two pairs per Voiceband channel.

Massive Productivity with Plastic Insulation

During the mid CE 1950s, the new technology of plastic (polyethylene) insulation instead of paper / rubber / cotton / silk etc. was a revolutionary innovation that brought with it a wide range of massive telecoms productivity increases that never reached the economists (nor "industrialists") because there were so many other overheads costs that absolutely shrouded this fantastic innovation!

With thermo-plastic (e.g. polyethylene) as the wire insulator; the semi-liquid plastic is extruded with the new copper wire neatly centred and then all dipped into water (or gel) to assist the plastic insulation to solidify. This is a very quick process and several wires can concurrently be drawn and insulated making this process (in itself) very production efficient, where the tolerances were/are consistently high and very highly repeatable (and far higher (tighter) tolerances than with rubber / cotton / silk etc. and other types of insulation).

Literally overnight, wiring looms used for the manufacture of relay sets (the switching control part in electromagnetic telephony switches) and in the chassis of long-line transmission equipment - was changed from cotton / rubber / enamel / silk etc. insulation over to polyethylene insulated wire.

The plastic insulation came in a wide range of colours making it far easier to identify what wire goes where, and stripping these wires was far easier and quicker than the earlier insulation methods.

So not only was this equipment now manufactured considerably faster – but the number of units with faulty wiring plummeted to literally zero. Production productivity absolutely skyrocketed and the manufacturing costs plummeted. Who would have thought that one simple new technology of thermo-plastic insulation would have made such a massive productivity improvement?

Relays (in their wide variety of physical shapes and forms) were the core component in telephone switching equipment! Another almost concurrent innovation was the invention of a self-fluxing plastic (acrylic) lacquer for insulating "magnet wire" which usually has a rather thin diameter (e.g. 30 AWG is 0.01" or 0.254 mm). This was an enormous productivity boost as the manufacturing process time was significantly reduced and the failure rate dropped from about 10% to under 0.1%.

Before this technology breakthrough, the standard way to remove the lacquer from the rather thin enamelled copper wire was to burn the wire in a Bunsen burner flame until the lacquer was charcoal (and the wire red hot), then scrape the carbon off with sandpaper and then "tin" the wire with resin flux and molten solder, then wind a couple of turns of that wire on the relay coil terminal then solder the wire to the terminal. Although this whole process typically took about only 30 seconds, the wire sometimes broke making the entire relay winding assembly useless.

With self-fluxing enamelled wire, the process was now very straightforward in winding a couple of turns of the fine gauge relay coil wire on the relay coil terminals and then solder the joint with a hot soldering iron and resin-cored solder! In a few seconds, the self-fluxing lacquer broke down with the iron's temperature and the now tinned wire was clean soldered to the metallic terminal! Total time about 10 seconds!

Plastic insulated cable technology very quickly found their way into the (External Plant) Exchange Switching areas because these cables were considerably lighter per unit length (no lead sheath), far more flexible and could be jointed much easier than paper insulated copper cables, introducing massive productivity gains in somewhat different ways:

When it came to extruding plastic insulated copper wire cables; these could be manufactured far faster (and far less expensively) than paper / lead technology, and the (manufacturing and performance) Quality of extruded plastic insulated cables was at least an order of magnitude more reliable.

In parallel with this (plastic) technology leap, TRL had also been working on refining the process of drawing copper wire and had virtually perfected the process to keep the wire diameter constant even though the hole in the die was expanding with wear. So, the (rather expensive) dies could be used for far longer than before – which considerably drove down insulated wire production costs.

Note that the driving down of this (and other) production costs had nothing to do with the mindset of Competition and everything to do with the mindset of Infrastructure Business – where continuous improvement is the real key to really driving down manufacturing / transport / production / sales costs and maximising profitability.

So not only was the thermoplastic insulation a massive productivity advancement, but the consistency of wire gauge (diameter) now also very consistent – meaning that transmission properties (measurements and calculations) of (twisted pair insulated copper) wire cables were also far more consistent and very highly repeatable!

Previously, excessive inter-pair crosstalk had been a major problem for both open wire and paper-insulated transmission mediums. With polyethylene insulation not only was the wire spacing far more consistent but the twisting per unit length was also far more consistent (and could be much “tighter”) – resulting in the inter-pair crosstalk be being considerably lower than ever before – and where this technology was installed - this crosstalk problem literally went away!

Where paper insulation had (coloured) markings on it to assist in wire identification this was far easier with plastic as the plastic is deliberately coloured, and the pair (or “mate”) is a common colour for several pairs – making the production particularly easy and the chances of getting the pair “back-to-front” a very low probability. (Dye colour in the plastic also incidentally extended the life of this insulator!)

The technology transfer to use polyethylene insulated pair copper cable instead of paper insulated pair copper was an overnight experience in the late CE 1950s and early CE 1960s – but the technology transfer for external cabling was anything but smooth!

In the CE 1930s there was a huge amount of lead-sheathed paper insulated cables that were under-footpath installed throughout most of the metropolitan areas.

Because this (metropolitan) build process was expensive – but had to be done - and the cables were expensive, these cables were deliberately (very) over-engineered to cater for extensive future population growth. It made very little engineering sense to install underground cable that would be immediately fully occupied. Doubling the cable pair capacity only marginally increased the overall project cost – so it was hardly a difficult decision (even though that era was in the start of the CE 1930s depression)! “***Rebuilding the Junction Network***”

This extruded plastic insulated copper wire technology worked exceeding well and in metropolitan areas this new technology also facilitated the introduction of new plastic insulated cables as “Outers” (pair copper cables connecting towards customer premises from the Pillars / Sputniks – where they could be very efficiently be cross-connected to the Main / Intermediate paper-insulated lead-sheathed cables, leading back to the Local Exchange’s Main Distribution Frame (MDF)!

Very ironically, from the early CE 1950s through to the mid CE 1970s when the Regional urban areas had their open wire infrastructure replaced, much of this used paper insulated cable saved as spare from earlier installations and only then when all this technology bits and pieces of old cable had run out – then the polyurethane insulated pair copper cable was introduced! “***Rebuilding the Regional Transit Network***”

Initially, the cable sheath was (also) made from polyethylene – which is very tough and highly flexible – but the ants like the flavour – so they ate it! The workaround was almost too easy – to jacket the polyethylene sheath with a thin nylon sheath – which the ants don’t eat and the marginal extra cost is virtually nothing in comparison to the cost of the plastic insulated pair copper wire in the cables!

In a similar mindset – the polyethylene / nylon sheathed cables could now be brought straight into a pre-moulded plastic “jointing box” and the sheaths then very tightly (and inexpensively) sealed against water. This practice made jointing now rather straightforward as the joint could (in many cases) be sat-up and worked on instead of being at “below knee level” in a cramped Service Pit (as was all too common with lead-sheathed cables).

So – literally overnight in the late CE 1950s, the technologies associated around the introduction of extruded plastic insulated copper wire brought with it a large range of massive efficiencies that dramatically reduced overheads and brought with it a series of substantially simplified work practices that again radically improved productivity.

Looking at the bigger picture, the (Australian) telecoms infrastructure then had a lot of other massive inbuilt inefficiencies that were taken as standard business – so the reduction in labour because of the introduction of this technology was very largely shrouded by massive amounts of other work that had to be repetitively done to keep the telecoms infrastructure operating reliably.

New Era of Electronic Components

Before CE 1950, all around the developed world (except for the USA) most Governments had their own (Infrastructure Business) "Department of Communications" that included Research and Development (R&D) and in most cases manufacturing was passed off to the private sector (Competitive Business) who traditionally employed large numbers people doing highly repetitive though intricate work on production lines to mass produce this equipment.

This way the (Competitive Business) manufacturers got the best and most recent assistance to manufacture what was extremely expensive (telecoms) equipment and there was a channel for the brightest engineers to advance from University into an (Infrastructure Business) research area where their talents could be utilised in the real world – i.e. outside University.

In the USA, the (privatised) Universities were already open prey for the (Competitive Business) Industrialists so the brightest students were usually snapped up by (private sector) infrastructure service providers who used these engineers to maximise (Competitive Business) industrialists private sector wealth – and the patents that flowed were inevitably were owned by these (Competitive Business) industrialists!

This was a win-lose situation for USA western economics where the (usually) family-owners of these large mass production factories were particularly wealthy and the workers were traditionally very underpaid for the skill and effort they put into physical manufacturing. (This is the feudal system – under a sheep's fleece.)

From the mid-CE 1950s, there was a quiet technology revolution happening where manufacturing techniques of electronic components radically changed – primarily to match with the then rapidly branching technologies associated with computers.

Most of these changes were from the development of plastics being integrated into electronic components. These technology developments had literally nothing to do with competition and everything to do with innovative engineering and creative thinking to produce / manufacture a large range of new / smaller and far less costly electronic components. "***Massive Productivity with Plastic Insulation***"

Virtually overnight in the mid-CE 1950s, the production of arsenic impregnated cotton insulated bare copper wire (to ward off rats / mice) was ditched and replaced with extruded plastic insulated bare copper wire. Apart from the plastic extrusion process over bare copper being at least 10 times faster than spinning cotton over wire, these new cables were not susceptible to water (moisture) like their cotton cousins.

Water ingress in cotton (and/or paper) insulated wires was/is a major impediment to transmission performance and significantly shortened the useful life of these older technology cables as the cotton and paper rapidly deteriorates with moisture impregnation – resulting in this insulation rotting and becoming conductive. "***Bolt Lightning and Pressurised Cables***"

Moisture ingress into paper insulated pair copper Main Cables (the big ones from the Local telephone Exchange towards customer premises) was the prime cause for Australia's ADSL to severely underperform causing Australian businesses to lose many Billions in lost productivity. "***Competition Wrecked Australia's ADSL***"

One of the rather smart innovations was the use of colour-coded plastic insulation over copper wire is something that we take for granted but this technology was decades ahead of its time and far more recognisable than the not much earlier paper / cotton / silk etc. insulation technologies!

In much the same concept as resistors that had a colour coded body with coloured bands and dots on them for quickly depicting the resistance value, so too was the concept of colouring the wire’s plastic insulation (Blue, Orange, Green, Brown, Slate (1, 2, 3, 4, 5) and using dashed colours: Blue-White etc. (6, 7, 8, 9, 10) and using different “mate” colours White, Red, Yellow, Black etc. the practical productivity here was also enormous because now you could easily trace a wire by its colour – so you could pick out a cable pair in a few seconds instead of physically testing 50 pairs before locating the wanted (insulated) wire pair.

With manufacturing telecommunications equipment (for both transmission and switching purposes) it was common practice (before about CE 1975) to have a flat board “loom” with many protruding nails and a guide to specify the path (and length) of each wire. With the wire “loom” fully populated, these wires were then laced up with lacing twine, the wire “loom” was fitted in the chassis where the large physical components were already mounted (screwed in place) in the sheet iron chassis.

When using cotton (or rubber) insulated wire in these looms it was a relatively straightforward (slow manual) process to trim the wire lengths, remove the last 3-4 mm of insulation and solder the wires to the relay, valve sockets etc. tag strips. Before starting, the correct wire had to be identified (usually with a resistance meter or a buzzer) – with the cotton insulation pushed back, then the wire ends “tinned” with molten solder, placed in the correct terminal lug and then soldered. Often there were two or three wires on the one terminal, and it was common to make mistakes!

If the cotton insulated wire was more than a few months old (from manufacture) then this wire would have tarnished (oxidised) making it difficult to “tin” and highly prone to being a “dry joint” – which would go high resistance in the next year or so; adding to the already relatively high overhead maintenance costs.

With polyethylene insulated wire – not only was the insulation colour-coded – so there was considerably less need for wire identification and repetitive testing, but when this insulation was stripped off – the copper was bright and very easy to “tin” – even if the plastic insulated wire was manufactured many years before!

Needless to say the productivity gains made by moving to polyethylene insulated (colour-coded) wire was immense! The relay-set loom processing time was about the same but the chassis wiring time was far more than halved – and the reliability of polyethylene insulated wire far exceed that of cotton insulated wire.

Until the late CE 1950s virtually all manufacturers used a wiring loom to roll out tens of wire circuits per day per worker. Other workers would then fit the wire loom into a chassis and solder in the wires. This process was (in most cases) considerably faster than hand-wiring – but was labour intensive.

With electronic components being now much smaller than they previously were and with tinned (directly able to be soldered) leads, the next major stumbling block in manufacturing was circuit wiring reliability. With mass production in mind and innovation / engineering (i.e. “building a better mousetrap”) being the key drivers plus the continual quest for high conformance, some passive components were wired into special tag-strips that included cross wiring.

The next seemingly gigantic technology step was a (copper-surfaced Bakelite sheet) printed circuit board with the components wired on the insulated side. Small holes drilled through the circuit board for component leads quickly followed and mounting of valve sockets and "wiring terminals" were the logical innovative progressions. This was a major technology breakthrough.

Literally concurrent with this innovation was the development of a computer board using "magnet" (lacquered) wire that was robotically laid out with the wires ultrasonically welded to the printed circuit board (terminals), and then the board was epoxy resin coated to seal in the wire loom – then the holes were drilled!

Before about CE 1960, resistors (under say 1000 ohms) were traditionally constructed with (painted / lacquered) nickel/chrome wire that is high resistance and relatively stable with temperature.

The wire length was measured and trimmed to a specific resistance value – then the wire ends soldered onto terminals in a (small) bobbin then wound on so that the middle of the wire (loop) is the last part wound (and inductance is minimised) – then insulating tape is put over the windings to secure these windings!

For larger value resistors these were also manually made – but from a compacted carbon rod with silver soldered copper at each end - and yes this was also laborious, slow, inaccurate and expensive too!

In the late CE 1950s - early CE 1960s the concept of sputtering carbon or other low conductive metal on a ceramic rod – then cracking the rod (at say 15 mm lengths) and inserting metallic caps with spot-welded leads on the ends of these now short ceramic rods. This mechanised process radically improved resistor manufacturing technology while significantly increasing precision to typically better than 10% it also caveated the manufacturing costs to a few cents per resistor.

Not only were these carbon / metallic film resistors far smaller than their earlier vintages, but they were very accurate, highly stable and easy to mount and solder their leads on terminals / tag strips. Further, they were a perfect match for then new technology of printed circuit boards – which appeared from about CE 1958.

In the CE 1970s with the development of laser technologies, the automated and now inexpensive resistor manufacturing process was taken to another level where the resistor values were "laser trimmed" to typically better than 5% (1%) tolerance but resistors in a batch (bandolier) were typically closer than 0.1% with each other.

With artful shaping and laser trimming it later became simplistic (and inexpensive) to make a "resistor ladder" with a logarithmic ratio that was compact, accurate, inexpensive and a direct fit for an A/D/A conversion process for Voiceband Voice / Pulse Code Modulation (PCM). "***Digital Voiceband Technology***"

The main components of (automatic) switching exchanges were electromagnetic relays – where energising a coil of fine (lacquered) wire magnetically actuates / moves an armature that causes spring-loaded contacts to switch and actuate other electrical circuits. It took several decades from the early CE 1900s for the magnetic circuits of relays to be far better understood and re-engineered to be far more magnetically and mechanically efficient.

One of the totally unsung productivity advances in the mid CE 1950s was the use of moulded plastic to make bobbins for coils, transformers and relays. Bobbins essentially hold the (insulated copper) coil windings in place and form an integral part of these magnetic components. Before then, these bobbins were rather restricted in shapes as they were commonly made from hard cardboard (or wood) sheeting and were prone to breaking after a few years.

With a now much better understanding of electromagnetic circuits and mass manufacturing, not only were the relay bodies and inductors far less bulky, but the magnetic circuits became more efficient - meaning that more piles of switch contacts could be loaded on the relay frame, but the amount of current required was less, and relays could switch faster (and they were far more compact).

With injection (plastic) moulding, not only could these bobbins be manufactured orders of magnitude faster (and cheaper); the bobbins could include solder terminals and/or pins so the relays / transformers / coils could be directly mounted into Printed Circuit Boards (PCBs).

In a somewhat parallel universe, inductors (as magnetic coils) had a very wide use in electronic (High Pass / Low Pass / Band Pass) filters – particularly in Frequency Division Multiplex (FDM) transmission equipment where they (in a high proportion of situations) formed resonant circuits with specific value capacitors.

Since about circa CE 1880 the use of sheet iron laminations in the magnetic circuits of coils and transformers had proved an imperative to minimise magnetic losses caused by "Eddy Currents" at mains frequencies and these losses were significantly greater at audio frequencies and above.

Circa late CE 1950s the concept of a manganese / iron ceramic (called "ferrite") was an outstandingly successful technology breakthrough as this could be moulded like plastic and then sintered like clay / china models; and the mating surfaces then diamond "shaved" to produce an extremely low magnetic leakage. Alternatively, the (internal) magnetic air gap could be deliberately shaved to produce a precise air gap that effectively controlled the reluctance (magnetic resistance).

This ferrite technology facilitated the manufacturing of compact inductors where the insulated wire coils had highly predictable values and the magnetic fields were highly localised – making this technology near perfect when manufacturing electronic filters.

Because these ferrite materials have very low losses at ultrasonic frequencies virtually all power supplies including those in Personal Computers and Phone battery chargers use a small ferrite transformer as part of the essential components.

The introduction of plastic revolutionised manufacturing capacitors. Before plastic – most capacitors were made from a paper insulated dual concentric rolls of aluminium foil in a metallic can and the can was oil-filled. Yes these capacitors took up a lot of retail space and were slow and expensive to manufacture!

Because plastic has a far higher permittivity (inherent capacitance) than paper (dry air) and oil, much higher capacitance values could be manufactured in much smaller volume, the plastic edges of the "roll" were self-sealing and the use of wires leads instead of terminals plus no need for a small "tin" for mounting absolutely caveated the manufacturing cost (and size) of capacitors.

While not specifically stated, from the late CE 1950s onwards there was a general transfer from manually manufacturing electronic components to using automated machines that repetitively turned out components with very little production variation. These component manufacturing machines could operate 24/7 (all the time) – providing the raw materials were loaded.

With thermionic valves (Circa CE 1956) shrinking in size to nominally about 20 mm diameter and 45 mm high as all-glass and metal structures; and with resistors and capacitors also dramatically reducing in size (thanks to plastic film capacitors and improvements in resistor manufacturing technologies) most components moved to being mounted with their own wires on rows of small tags and on the small valve socket (Bakelite) terminals/tags - with a few short wires in between these tags to the chassis connectors.

Although the concept of a solid-state devices to amplify / control current flow as a "semi-conductor" had been patented in CE 1925 and CE 1934 it simply could not be done but eventually this was eventually made to work in CE 1947 at Bell Labs (note: a massive private corporation) in the USA (by John Bardeen, Walter Brattain and William Shockley). It was not long until the same engineers came up with a far more reliable process to manufacture transistors using a sandwich approach instead of wires touching a piece of semiconductor material that the manufacturing of inexpensive transistors burst onto the electronics scene!

Through the CE 1950s there was a concerted effort to develop the production of transistors as they shown incredible promise to replace thermionic valve technology! By the late CE 1950s, transistors were slowly becoming commercially available and massive telecoms manufacturers (again like Bell Labs Corp.) wasted no time in re-engineering telecoms equipment to use transistors instead of thermionic valves.

Circa CE 1963 a typical transistor was encased in a tube about 10 mm long and about 4 mm diameter. In terms of power, these ran cool and used the -24 V battery feed that was used for valves (no need for the +130 V battery and associated equipment)! These transistors worked with much lower impedances (e.g. 120 ohms – to 10 k ohms) which was a lovely match for long line transmission and the understanding of negative feedback was becoming far better understood.

Because transistors were so small (in comparison to the physical size of thermionic valves) a few of these transistors could be mounted on a "printed circuit board" (of etched copper on Bakelite sheeting) and with far more feedback applied than for similar valve-based stages, the amplification was inherently predictable and stable – for decades. So the need for daily routine checking (of valves) was long gone.

With the introduction of Printed Circuit Boards (PCBs) in the late CE 1950s early CE 1960s, where transistors were making their extremely productive input to computers and telecommunications infrastructure; electronic components were also going through a total "re-engineering" to far better match PCB technologies and so that semi-automated construction practices could be put into place to dramatically reduce the production costs of telecommunications equipment.

With the advent of printed circuit boards so too became the advent of very compact and highly reliable "edge connectors" that in turn facilitated multiple Voiceband (telephone) channels on the one circuit board - that in turn facilitated 12 and 24 channel long-line technology to fit in a 6 Rack-Unit (267 mm high) frame.

Circuits that previously were individually manufactured in a chassis could be far quicker manufactured on a Printed Circuit Board (PCB) assembly. “Printed” circuit boards could be manufactured in bulk and the assembly process was now extremely consistent – meaning that the productivity in manufacturing literally went through the roof. Consider that a couple of workers could screen print several hundred boards per day and have these etched and drilled ready for production the next day. All the circuits on these boards would he extremely consistent and highly reliable.

With the emerging technology of (moulded plastic insulated) “edge connectors” these boards could be slid in on (plastic) guide rails; like books in a bookshelf and plugged into a row of (plastic) connectors as a backplane motherboard (which was also another printed circuit)!

As about this time (circa CE 1975) the concept of mounting components on a flat-facing sub-rack (like a picture hanging on a wall) dramatically changed where the sub-rack became a “tunnel” and the printed circuit boards had a lot more depth to plug into - and the available volume for mounting circuit boards and other components was now considerably larger than that of a flat plane “breadboard”!

It was this “better made mousetrap” advancing technology circa CE 1982 that paved the way for inexpensive Voiceband Voice / PCM technology in telecom exchange around the world because the A/D/A conversion process was now inexpensive.

Advancing FDM Transmission Technologies

Until the mid CE 1930s, it was common telecommunications transmission equipment construction practice to have a flat iron sheet (about 2 mm thick, 22” (560 mm) wide and say 178 mm high (4 rack Units)) as the “Breadboard” / Panel and physically bolt on all the components (for that network function) on the front side of this “panel”. “***Advances in Telecoms Technologies***”

In the left hand side of this panel there was usually a large horizontal “U” cut-out with a nearby front-mounted terminal block. After the panel was bolted onto the rack (vertical rails with an outside dimension of 610 mm (2’); Power and Communications wires could then be fed from the terminal block through this horizontal “U” cut-out to connect with other equipment. A thin sheet steel metal box (about 250 mm deep) was also mounted over the front of the panel as a “dust cover”.

Various Australian telecom equipment manufacturers started to head towards a more conformal equipment manufacturing standard based around the 19” rack – where about 18½” (470 mm) was starting to be understood as the open space between the vertical “U” shaped (then) cast iron racks!

In most cases these panels had relatively little amounts of components on them (and the components needed the space to let the thermionic valves not overheat the other components)! If the panel had a thermionic valve mounted on it then the dust cover had holes punched in the top and bottom sides to facilitate “limited” air movement!

The first stage of productivity (in the early CE 1940s) was to gather all the passive components for a particular transmission process that usually took a complete panel (for example: a passive low pass (Voiceband channel) filter or (Channel) band pass filter) and mount all these components in a thin sheet brass box about 40 mm * 120 mm * 120 mm – with terminals on the lid of the box!

A complete panel of components performing a particular function could be compacted into one of these tins. This manufacturing process was much faster and far less expensive than building a complete panel for each electronic function! Several “equipment tins” could then be side-by-side mounted in the one breadboard / panel saving a lot of space and saving considerable manufacturing cost (and time).

The next stage of manufacturing productivity came with these “tins” being re-configured to have a plug / socket connection instead of individual drilled and screwed-in then soldered terminals. Typically an 8-pin plug/socket was about the size of a matchbox (and was very robust) having one mounting hole and the soldering was then a small mass production. These plugs/sockets facilitated the use of a standard wiring form, that was far faster to manufacture than individual wiring and the fault rate was considerably lowered. So productivity again was increased.

As this manufacturing technology advanced, the production technique changed direction with the sockets being bolted into the panel / subrack so that the brass tins could then directly plug-in (as modules) into the subrack and the wiring form moved to being behind the panel/subrack.

So now – mid CE 1956 Australian telecom equipment manufacturing had caught up with the leaders in the developed world and all the components of FDM technology started to migrate from discrete components on panels with lots of space everywhere to compact modules for amplification / oscillators / modulators and overnight the whole FDM carrier system became “modular”.

While as a Trainee Technician in the NSW Transmission Lab, I was sent to exchange sites to learn a lot about the practical aspects of equipment maintenance. On one stint at Blayney Exchange (in NSW) for six weeks in CE 1968 what was particularly interesting to me was that there were several suites of valve-technology transmission equipment that connected to Adelaide (and Sydney)! The road distance from Adelaide to Blayney (via Cowra, Griffith, Mildura, Renmark,) is about 1230 km.

Thinking back, on the road (south-west) to Cowra there were three crossarms each carrying four pairs – so that is 12 pairs or six 12 channel systems totalling about 72 channels. The road (west-nor-west) to Orange (I think) had two crossarms – so that is four 12 channel systems totalling about 48 channels and the road back to Bathurst (Sydney) would have had five crossarms – but that may have followed the railway line.

Consider this valve vintage 12 channel system took up three racks and considering there were at least 6 + 4 + 10 = 20 valve vintage FDM systems then this is about 60 racks and considering each suite was about 24' long then each suite would have had 12 racks (4 FDM systems each) then the number of suits of racks would have been 5 and that stacks up!

This equipment required daily monitoring and maintenance – and that was an almost full time job for a couple of hours every weekday.

What I found most interesting was that each of these FDM systems had "pilot tones" that had their receive levels constantly monitored (at four frequencies) and each FDM system had electromechanical stepped attenuators that kicked in and automatically adjusted the system amplification (and line equalisation) to stabilise the Voiceband levels.

In the morning as the sun came up and (naturally) heated the open wires the line attenuation increased causing the stepped attenuators to be "clicked" down, and in the evening, the opposite ("clicking" up)!

In the early CE 1960s FDM systems had literally overnight changed from thermionic valves to (PNP germanium, then NPN / PNP Silicon) transistors. The amplifiers / modulators etc. had active components in them and these modules shrunk to a small fraction of their previous physical size (and cost) and this facilitated a far more compact construction methodology where the "tins" were replaced by "block modules" that had a chassis-mounted plug/socket that was press-fitted then screwed into position in the sub-rack. "***New Era of Electronic Components***"

The new generation of carbon / metal film resistors and polyester / polystyrene capacitors were now small, accurate and far more inexpensive. Coils (inductors / transformers) now extensively used ferrite with moulded plastic bobbins and could be far more quickly manufactured than their laminated iron predecessors - and ferrite technology inductors / transformers had an extremely low manufacturing failure rate.

It was this new range of manufactured electronic components that simply came of "building a better mousetrap" – i.e. continual improvement (that had absolutely nothing to do with inter-business commercial competition and everything to do with Engineers simply finding more ingenious ways to better manufacture components) that was the prime guide to drive down electronic component prices.

Mass production manufacturing changed tack from mounting these now small components in rows of soldered tag-strips on a Bakelite base-strip – with wire straps to interconnect one or more tags – to the concept of a “printed circuit”! The first “printed circuits” were an imitation of a tag strip with several passive components laid parallel side-by-side and the wiring / tags was the “printed” part!

Basically a printed circuit starts as a Bakelite sheet / board that has a paper-thin copper layer on one side. The circuit is screen-printed onto the copper side then the board is placed in chemical solution that etches off the exposed copper – leaving the circuit as a copper film on the Bakelite board. Component holes are then drilled, printing paint removed, the board lacquered / prepared for components to be added.

While this process sounds laborious, the circuits can be quite (very) complex, the process really lends itself to very fast and inexpensive mass production and the fault rates are extremely low. It was no real surprise that active (and passive) components were deliberately re-engineered to be mounted onto circuit boards and that “edge connectors” quickly replaced “cable mindset” connectors.

Early transistors were originally manufactured with “flying” leads (about 50 mm long) from one end of a nominally 5 mm diameter tubular body about 13 mm long. It took only a couple of years for most small signal transistors to be re-packaged in a much shorter metal cap body about 5 mm long and have the three leads about 12 mm long to facilitate fast insertion into printed circuit boards.

It was January CE 1967 and I had started the second year of my five year Technicians apprenticeship at the NSW Transmission Laboratory (in St Leonards) having recently completed a full year in full-time training in the North Strathfield Telecom Technicians College.

One of the tasks was to assist Graeme Johns with the documenting the performance of a newly re-engineered (old) 3-channel FDM transmission system that now had transistors in place of thermionic valves. As I very soon discovered, all FDM transmission systems being then manufactured in Australia were 12 Channel FDM and used transistors. So why were we doing this?

The issue was that there were a few of these 3 channel FDM systems in remote NSW and it was rather obvious from the measurements were taking, that the carrier system worked wonderfully well – but with this conversion it now used a small fraction of the power that it would have when using thermionic valves. Also there was no need for a +130 V (plate voltage) battery, or a -24 V (filament) battery)! This FDM system could now run from the standard -52 V battery!

The reason we did this rebuild was all based on “Recession mindset economics” where this was a remote location with thermionic valve equipment requiring almost continual maintenance – and the exchange site had -24 V and +130 V batteries which really added to the operational cost of the standard -52 V battery and associated power equipment.

By upgrading the existing equipment to being transistorised from thermionic valves, not only would the extra batteries and associated charging equipment be removed and the need for technical maintenance *would be considerably reduced – but there was no need to purchase new FDM equipment and the opportunity cost funds could go elsewhere.*

A few weeks later this equipment got the tick of (Engineering) approval and was driven out to Hillston – Roto and we heard no more about it! Instinctively the maintenance would be literally zero and this would have caused more upset in the Trade Union ranks because most transistor technology transmission equipment required far less maintenance than its thermionic valve predecessors (that required daily checking / testing).

In a real twist in name / role / purpose the NSW Transmission Lab never again got any more "re-engineering" of thermionic valve technology FDM transmission systems to be "transistorised"!

The big sticking point (for me) was the massive Mel-Syd FDM system that was built CE 1957 – CE 1960 and finally commissioned in CE 1963. It was painfully obvious that this transmission equipment should have been "transistorised" – as this would have massively reduced power requirements and maintenance overheads. My gut instinct was/is that the Trade Union really opposed (banned) this innovation.

When it came to manufacturing telecoms equipment in Australia (and possibly many other countries after WW2) there was generally an information chasm between the manufacturers and the telecom purchasers. Basically the manufacturers designed and engineered for manufacture what they thought would be needed in the immediate future and the (mainly) clerical people in the "Supply Branch" were equally void of technical / engineering requirements. So there was really no completed feedback loop to stop developing / manufacturing what is not required and/or is totally unsuitable for use in the field.

This management situation is very much a military "shouting down the line" mentality with no room for useful / positive / economic feedback to management. Consequently the manufactures go off on their own (university-backed knowledge) in complete ignorance of the real world requirements! It is very unsurprising that Australia's military (Supply Branch) makes massively expensive contracts for equipment that is totally useless – because those involved in making the decisions have never been in the field to know what works and what does not work – and why!

In the late CE 1960s it was quite common for us in the NSW Transmission Lab to make a few -52 V to -24 V and -52 V to +130 V DC-DC power Converters in a small production run. These power converters were to go into Regional exchange sites that had valve technology Amplifiers and/or FDM systems – so that the +130 V and -24 V batteries could be removed, significantly reducing the operational costs at these sites.

These power converters were far more efficient than having -24 V and +130 V batteries to run thermionic valve technology FDM systems – and they were powered from the then standard -52.6 V exchange battery!

All these DC-DC Power Converters had the same "H" bridge structure with four power transistors, each on rather large heatsinks (that ran about 30 deg. C above ambient) and a "saturable core" silicon steel toroid in the "H" crossarm. The power transistors were driven from four separate small secondary windings on the steel toroid (diagonal transistors in phase).

It was not until the early CE 1970s that we obtained an excellent oscilloscope and identified that these (slow) power transistors switched off much slower than they switched on – resulting in massive "off-on" current spikes on both sides of the "H" bridge making the transistors so hot!

From about CE 1962 to about CE 1980 the private (Australian) telecoms equipment manufacturers made transistorised FDM equipment where the design technology took on a whole new stage, with the vast majority of components being mounted on much larger printed circuit boards (say) 160 mm * 240 mm with an "edge connection" on the board itself! These board modules could be vertically mounted and horizontally stacked rather close to each other as heat was not an issue with transistors as it was with thermionic valves.

Unfortunately all this new transistorised FDM transmission equipment was engineered to deliberately run off -24V DC – in the false belief that all exchanges still had -24V batteries! Well, many of the big exchanges did have -24 V batteries – but that was for valve technology equipment which was fast being phased out with the new FDM equipment that was being manufactured and installed!

Circa CE 1970 one of the NSW Transmission Labs engineers (Arp Pocza) discussed with us on the possibility of us making a series Switched Mode Power Supply (SMPS) to transfer -52 V DC to -24 V DC so that at many exchange sites that had old (valve technology) FDM systems replaced by new transistorised FDM systems could use the -52 V DC battery.

This was a radical technology shift (from the saturable core power converters) as this used a MSI integrated circuit (uA723) being the centre of the pulse width modulation process – that worked out to be very near 50% which made the design quite straightforward – except for overload protection – which considerably increased the circuit complexity. Still – these Power Converters were very easy to quickly mass manufacture in small batches. STC / Alcatel later manufactured these power converters.

Even with "slow" power transistors (which were the only available transistors at the time), these SMPS's operated at about 90% and considering the output was up to 250 W; this is about 25 Watts in the heatsink – primarily due to slow switching. Several years later we substituted a "fast" switching power transistor and the SMPS ran stone cold – even at full load!

The big irony of this SMPS was that because of the megaphone (recession / competition mindset) management style (used by most of the management at that time) was that nobody (who should have known that all FDM systems should be operated from the standard -52 V DC exchange battery supply) told the Supply Branch clerical staff the FDM transmission systems needed to operate from -52 V DC and not from -24 V DC.

From the mid-CE 1960s through to about CE 1980 Australian telecom manufacturing businesses produced a range of initially 12 channel FDM systems and then 24 channel FDM systems. These FDM systems commonly had two or three (even four) Voiceband circuits per printed circuit card and as this transmission equipment was now rather modular – it was far more straightforward to swap / change cards to identify the circuit board that had the problem and have that replaced.

These FDM systems came with a variety of long line interfaces to suit open wire, pair and quad cable and coaxial cable; plus the ability to directly interconnect into far higher capacity systems at the Group / Super Group / Master Group level in the FDM hierarchical plan.

By about CE 1965 it had become obvious that germanium transistors were then not only far more expensive than silicon transistors but silicon semiconductors had a far better temperature tolerance. Also, with the development of Small and Medium Scale Integration (SSI/MSI) linear (silicon) chips from about CE 1965 the packing density was considerably increased – and became even more economic!

One of the intriguing transmission innovations was a 24 Channel System that effectively had two Groups of 12 channels nominally 60 – 108 kHz but it flipped one 48 kHz wide Group to sit in the 12 – 60 kHz slot and then at successive repeater sites, it frequency inverted (frogged) the entire bandwidth for both directions so that the channels at the 108 kHz end of the spectrum were now at the 12 kHz end of the spectrum and the channels at the 12 kHz end of the spectrum were now at the 108 kHz end of the spectrum!

This "frogging" technique had the effect of naturally equalising the receive level of the spectrum so at the distant end, all the channel levels were all consistent and gain variations were minimised!

Because of the string of technical advances through the CE 1960s and CE 1970s the Australian FDM equipment manufacturers (usually) came out with a new model every year or so. Consequently there were several brands and several models for each brand. Economically this "competition" was a disaster because there were never enough of any one Brand / Model to invoke the "economy of scale" principle.

This situation was continually aggravated because the engineering switch planners (since before the CE 1960s through to at least the mid CE 1980s) worked very much in a "chicken coop" of their own and were blissfully unaware that augmenting a telephone switch a few percent (lines in the transmission network) each year meant that extra circuits would be needed for the backhaul long line transmission connection – but that was not their area of (transmission) planning.

This augmentation of backhaul capacity was passed to the transmission planners and they (in their "chicken coop") arranged for extra FDM channels. In many cases the existing FDM system was installed but with say, one Voiceband card (out of four) providing say, three Voiceband channels and now the need is for another two Voiceband channels! Often, the situation would be that another Channel card would need to be ordered so that (for example) the number of channels would be now six (and the then need was for five channels)! So this would work – you would think!

Problem – that particular Voiceband channel card is no longer being manufactured. So the then standard practice was to then purchase a completely new (say) 24 channel FDM system with only one Voiceband channel card (of four channels) – install this very partially complete FDM system (on a spare quad of wires) and the problem would be apparently solved – until next time in about four to six years – when the problem would most likely repeat!

In parallel with these new solid state and printed circuit technologies that dramatically advanced FDM manufacturing practices and really drove down equipment costs, the new technology of Point-to-Point Radio as another choice of FDM transmission bearer also became a far more common bearer technology – particularly in Regional areas. “***Economic Point-to-Point Radio Links***”

When the WW2 hit in CE 1939, it seems as though telecoms manufacturing in Australia hit a brick wall and simply cavitiated – and then picked up again after about CE 1950 with technologies that were common to CE 1935. In other words the severe competition caused by the war effort literally drained / killed all the talent from the telecoms R&D / factories and set this industry backwards a more than a decade.

FDM technology was finally conceived in CE 1952 this technology was greeted with open arms and manufactured around the world in haste to replace the by then ageing valve amplified and phantom circuits that had incredibly high maintenance requirements. “***Slowly Emerging Frequency Division Multiplex***”

Australian telecoms manufacturers had a lot of technology practices to learn, and had a lot to learn all about FDM technology – and catch up really soon! WW2 had put a massive amount of investment into other technologies and the private sector (outside Australia) – particularly in the USA that had really profited from this war.

Australia’s PMG Telecom Research Labs started into Frequency Division Multiplex (FDM) technology with a three channel (yes 3) FDM system that was engineered for open wire as the communications bearer. Although seemingly simplistic in design this was ground-breaking as this could easily be used over rather long distances (several hundred km) with amplifiers on the way. This three channel system had its place in Australia’s Regional Remote areas – and it was a steep learning curve.

The next generation of FDM transmission systems were based on 12 channels (12 kHz – 56 kHz and 60 kHz – 108 kHz) over open wire and this presented a transmission problem because the characteristic impedance of open wire changed from 600 ohms and moved towards 124 ohms as the frequency is increased.

The productivity of this technology was immense as two pairs of open wires could now transmit well over 1000 km and keep the volume quite constant (irrespective of the weather), and provide 12 clean Voiceband circuits. Before this technology it was a real struggle with two Voiceband circuits and possibly a phantom making three amplified (“2-wire working”) circuits – and these circuits were most probably howling much of the time if the impedances were not well matched.

The Bathurst – Cowra – West Wyalong – Hay – Balranald – Mildura – Berri – Adelaide open wire bearer was nominally about 1250 km long. For this example / exercise the length can be “normalised” to 1000 km and have 16 open wire physical loop circuits and 15 phantom derived circuits totalling 31 Voiceband circuits.

Consider the 1000 km link using two pairs of overhead aerial wire per FDM system operating at nominally 60 kHz to 108 kHz and providing 12 channels. This would need repeating amplifiers at nominally 40 km hops (much like the Voiceband amplified technology using phantom pairs to maximise the number of channels.

In this case, each FDM system would require two pairs for “4-wire” unidirectional transmission. This is eight parallel FDM systems each producing 12 Voiceband channels and that totals as 96 Voiceband channels!

Going back to our reference 1,000 km open wire bearer now costing about $128 M instead of $233.7 M because the wire is now locally manufactured and does not have to be nearly as thick (because of line amplifiers).

If we have "repeater" equipment at every 40 km this works out at about 23 locations and the repeater equipment would (very generously in circa CE 2020 currency related values) cost about $50,000 per FDM system (per two wire pairs).

So: $50,000 * 23 * 8 = $9.2 M plus the terminal equipment at (very generously) about $80,000 each * 2 * 8 = $1.28 M. Adding this $9.2 M + $1.28 M = $10.48 M.

With the thicker wire this works out at $233.7 M + $10.48 M = $244.2 M
With the thinner wire this works out at $128.0 M + $10.48 M = $138.5 M

Putting this in a tabular form the numbers start to speak for themselves that the technology advances wire the prime initiatives to drive down end user costs:

Technology	Circuit Count	Build Cost	Voiceband Cost	Time – Era
Open Wire	16	$233.7 M	$14.60 M	1880-1895
Phantom	31	$234.5 M	$7.56 M	1895-1915
Amplified	16	$240.0 M	$15.00 M	1905-1915
Amplified (Phantom)	31	$240.0 M	$7.74 M	1905-1915
Amplified (thin wire)	16	$130.0 M	$8.13 M	1915-1953
Amplified (Phantom)	31	$130.0 M	$4.19 M	1915-1953
FDM (thick wire)	96	$244.2 M	$2.54 M	1954-1974
FDM (thin wire)	96	$138.5 M	$1.44 M	1954-1974

In terms of productivity replacing the 31 physical and Phantom derived (Voiceband amplified) circuits with 8 * 12 channel FDM systems there are now 96 Voiceband channels at a sunken cost of about $2.54 M per circuit!

In Voiceband circuit capacity terms this is 96/31 = 210% greater capacity and in cost terms this is $2.5 / $7.5 = 33% the cost of the Physical / Phantom circuits!

If we rebuilt the open wire structure (considering the poles and wire (and insulators) are now over 40 years old and used thinner wire manufactured in Australia then the sunken cost (including the FDM equipment) is about $138.5 M and with 96 Voiceband channels this about $1.44 M per channel.

Now – look at the table. The cost per-circuit up to CE 1895 was about $14.6 M and since then with technology advances the per-channel price has steadily been driven down by gradual advancing technologies – not by competition.

Phantom derived circuits that came in about the turn of the century nearly halved the per-channel costs to about $7.56 M. Amplified circuits (after CE 1910) really extended the length that these circuits could be used and that productivity of utilisation was enormous.

Now after CE 1915 having wire manufactured in Australia (and with amplifiers) the cost was almost again halved to about $4.19 M per circuit in the mid-CE 1920s.

Massive Productivity of FDM

With the introduction of FDM technology in CE 1954; this was revolutionary with 12 channels per two pairs of open wire bringing the number of channels available up from 31 to 96 (about a 210% increase) making the per-channel cost about $1.44 M. These prices have all been calculated to be working from a common day (CE 2020) currency so the comparisons effectively have price levelling for direct comparison.

In nominally 60 years (CE 1890 – 1955), the per-channel price has been driven down from about $14.60 M to $1.44 M purely by technology advances!

Competition had absolutely nothing to do with driving these per-channel prices down. If competition were to be included (by privatising / breaking up this economy of scale highly efficient infrastructure) then the massive overheads of sales and marketing / sponsoring would be the prime drivers to push end user prices way up!

World-wide, this FDM technology had very quickly advanced enough to really utilise the bandwidth of Coaxial Cable (exceeding 5 MHz) that could carry 20 "Super-Groups" of 48 "Groups" of 12 Voiceband Channels as derived transmission circuits (totalling 960 channels) in about 48 to 60 transmission racks at the terminal ends and about 12 transmission racks where the main bearer passed through.

The technology of coaxial cable had been around for many decades but had little use as the associated radio technologies were being developed in the CE 1940s – and were mainly military oriented – such as radar and point-to-point radio connections.

Compared to pair and quad copper transmission bearers, Coaxial Cable had the advantage of being comparatively low attenuation per unit length, was a "bound" radiation technology (so no crosstalk between tubes) and had a (for then) a very wide bandwidth – far greater than (buried) Pair cable and Quad cable structures.

Australia's population was continually growing and its two major cities – Melbourne and Sydney had national network problem in that this open wire link (in particular) was rapidly becoming heavily congested, as this literally had 31 Voiceband circuits using open wire technology. It was standard practice to book a call and wait several hours for a connection - telegraphs were often much faster!

When you think about it, FDM technology only hit the floor in CE 1952 and in only six years the technical advancements around this was astounding! Not only had they decided on a "Group" of a 12 channel block (60 – 108 kHz) and perfected the manufacturing of that, but they had also advanced this technology by using "Superhet" principles to build Super-Groups of five Groups (312 - 552 kHz) for 240 Voiceband channels and then also used "Superhet" principles to gang four Super-Groups into one "Master-Group" of 960 channels – and even that could be doubled to be two Master Groups and carry 1920 channels (which they later did) on the one pair of coax tubes! "***Slowly Emerging Frequency Division Multiplex***"

From CE 1957 plans were drawn up to build the Syd-Mel FDM-based coaxial cable system using the then new 1600 channel FDM system based on cable / equipment ordered from FGF in Germany. This was the world leading FDM technology at the time and it used thermionic valves (as then did every other transmission system).

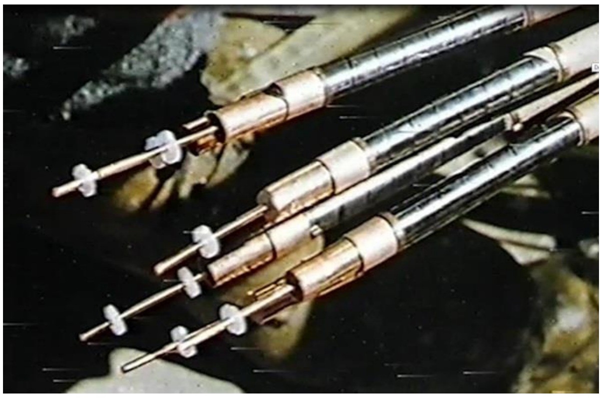
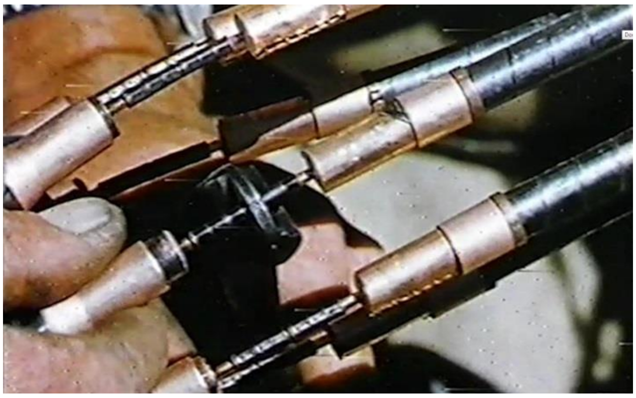
With intricate APO / PMG TRL involvement, the decision was that the NSW portion (Sydney to Canberra) of the total length of the (6 tube) coaxial cable was manufactured in Germany and imported to Australia and the remaining length of the

7-tube coaxial cable was manufactured in Melbourne (Olympic Cables), so that Australians could learn this technology (and apply it in many places elsewhere in Australia). This cable was in 500 yard (457 metre) lengths on wooden drums.

Construction started on 18 Mar CE 1960 (after three years of planning etc.) with installation complete in Nov CE 1961 and procedurally commissioned into service by CE 1963 with the inter-State TV circuits the last to be commissioned. The ABC worked very collaboratively with this and they (through Neville Thiele and others in the ABC labs) developed and used their “Pulse and Bar” bandwidth testing technology to minimise Group Delay distortion (which minimised “streaks” in the received picture)! “***Digital Voiceband Technology***”

This project involved trenching down between 1200 mm and 1400 mm for about 960 km (Sydney – Canberra – Melbourne) to have the 6 tube coaxial cable laid and the inclusion of 103 unattended FDM repeaters every 9.3 km (because of the attenuation in the then massive bandwidth of 5 MHz) plus 15 major FDM repeaters along the way at mainly inland cities plus City South in Sydney and City West in Melbourne.

At that time, one big economic advantage was the use of mechanical aides as these were now becoming commonplace. In very rare good soil conditions it was possible for a team (with pneumatic drills, backhoes and small earthmovers) to open a trench for say 1 km in a day. Usually this “good soil” situation was far from the case and it took considerably longer to blast through several km of near surface basalt rock and also cross under the (fast flowing) Murrumbidgee River – and Murray River trench to lay this cable - and then there was the cable jointing (which was about every km).

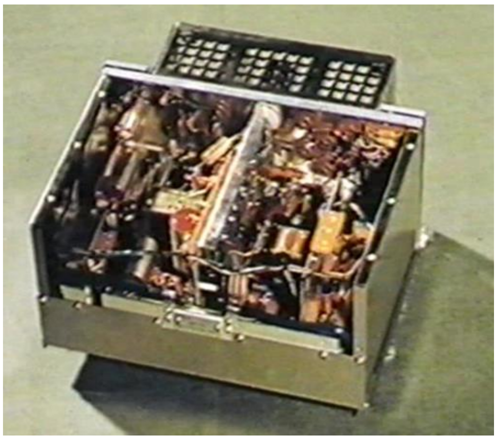



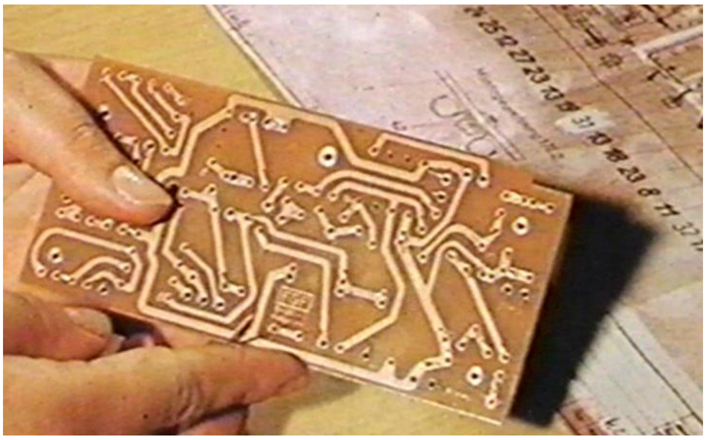
The above left picture shows the coax cable tubes with their polyester spacers around the centre conductors and on the right showing the centre conductor being crimped in a sleeve (as also was the outer tube (9.525 mm) with a steel inner sleeve shown near his thumb). These cables were dry gas pressurised to try and minimise water ingress as these tubes and the interstice quads were all paper-insulated.

Because of manufacturing inconsistencies, the paper-insulated intersticial copper quads (also used for FDM and amplified bearers between the cities on the way), had widely different inter-pair capacitance. At each cable joint these quads needed to have a few small capacitors to optimally “capacity balance” these quads – which significantly minimised inter-pair / system crosstalk.

In its time, the technology used in this long-haul high capacity FDM transmission system was literally at the forefront of the cusp of the new wave of components. Below left is a channel amplifier plug-in module and below right is a partially component loaded printed circuit board – both from in this FDM carrier equipment.

Note the width of the circuit board tracks and the solder pads are not consistent – because these were ink-drawn for the screen-printing / etching process.





Considering there was about 960 km, 103 repeater huts and 15 attended repeater stations plus the two terminals – if there were 5 cable construction teams then this would have taken between 60 and 100 weeks and in round figures cost about $65,000 per km (relating equipment to today's prices), plus the (6 tube) coaxial cable would have (very) conservatively cost about $40/metre (including the jointing).

In today's currencies (CE 2021) referenced to then (CE 1961), 17 transmission Terminals on the route would have been in the order of $100,000 each (not including the new buildings). These Terminals would be joined by the cable ($60,000,000) having 118 Repeaters spaced at nominally 8 km hops where the Repeater buildings would cost about $20,000 each and the Repeaters would cost about $12,000 each (three per Repeater location).

Now considering the hierarchical structure of FDM:

12 Voiceband channels = 48 kHz = 1 Group.
5 Groups = 1 SuperGroup = 312-552 kHz = 240 kHz = 60 Voiceband channels
16 SuperGroups = 60 * 16 Voiceband Channels = 960 Voiceband Channels
16 SuperGroups = 16 * 240 kHz = 3.84 MHz, starting 312 kHz to over 4150 kHz.

So two tubes could carry 960 channels and four tubes could carry 1920 channels (on two FDM systems) and six tubes could carry 1880 channels (on three FDM systems). Putting this into a simple spreadsheet:

				2 Tubes	**4 Tubes**	**6 tubes**
Cable	$40.00	metre	1000 km	$40,000,000	$40,000,000	$40,000,000
Trenching	$65,000	Per km		$65,000,000	$65,000,000	$65,000,000
Rep. Huts	$20,000		105	$2,100,000	$2,100,000	$2,100,000
Terminals	$100,000		2	$200,000	$400,000	$600,000
Repeaters	$12,000		108	$1,296,000	$2,592,000	$3,888,000
Subtotals:				$108,596,000	$110,092,000	$111,588,000
Channels				960	1920	2880
Cost per Channel				**$113,120.000**	**$57,340.00**	**$38,746.00**

With these massive productivity numbers being thrown around it is not hard to understand why the cost of inter-State calls absolutely plummeted in the CE 1960s – but nobody noticed as these calls were still very "expensive" by today's standards (that came with massive productivity improvements since FDM technology)!

This then new FDM technology was very exciting as the massive drop in operational connectivity had absolutely nothing to do with competition and absolutely everything to do with "building a better mousetrap" by utilising the newly available technologies to replace equipment that had in the past 50 years well-paid for itself and now had become rather high maintenance overhead costs (characteristic of end of life)!

So in reality there was plenty more inter-State capacity for many years to come! There were several other large coaxial cable systems that interconnected many of the State Capital Cities to each other and to their Regional inland cities – but in some cases because of the terrain, trenching coaxial cable was simply not an option!

Technology	Circuit Count	Build Cost	Voiceband Cost	Time – Era CE
Open Wire	16	$233.7 M	$14.60 M	1880-1895
Phantom	31	$234.5 M	$7.56 M	1895-1915
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Amplified (Phantom)	31	$240.0 M	$7.74 M	1905-1915
Amplified (thin wire)	16	$130.0 M	$8.13 M	1915-1953
Amplified (Phantom)	31	$130.0 M	$4.19 M	1915-1953
FDM (thick open wire)	96	$244.2 M	$2.54 M	1953-1974
FDM (thin open wire)	96	$138.5 M	$1.44 M	1954-1974
FDM (Coax 2 tubes)	960	$108.6 M	$113.12 k	1961-1987
FDM (Coax 4 tubes)	1920	$110.0 M	$57.34 k	1961-1987
FDM (Coax 6 tubes)	2880	$111.6 M	$38.75 k	1961-1987

Looking at this table the number of Voiceband channels has jumped 10 times from 96 to 960 and even if the Voiceband cost is "de-normalised" by 10 times it comes to $1.131 M which is almost on par with a set of 8 * 12 channel systems been used on open wire instead! So, the Coax pricing is in the same ball-park!

Before the Syd-Mel coax went in – the previous connection was a 31 Voiceband open wire amplified transmission system – so the sudden hop to use 960 Voiceband channels in a dedicated FDM system was an enormous technology hop and included the then new LM Ericsson ARM / ARF exchanges along the way and at the ends of this Trunk route. "***High Productivity of Crossbar Switching***"

Since about CE 1960 there were several other long-haul high-capacity coaxial cable and open wire, and quad cable FDM transmission systems across Australia, but most newer vintage systems used transistors and did not require nearly the high voltages required for thermionic valve repeaters – and maintenance was very low overhead.

The intricate technologies used in this long haul cable transmission system were some years ahead of what was being manufactured in Australia in the CE mid-1950s and it proved to be a "technology wake-up call" to Australian telecoms equipment manufacturers – even though this massive FDM system used thermionic valves (as transistors were not yet on the scene). "***The New Era of Electronic Components***"

High Productivity of Crossbar Switching

By the late CE 1950s, the PMG Research Labs (TRL) were well aware that Step-by-Step switching technology was very widespread in Australian cities, and that Manual Switchboards were also very widespread elsewhere and that the operational and maintenance costs were fast becoming a very expensive overhead nightmare.

Manual (Sylvester) Switchboards were naturally high maintenance as almost all of these switchboards needed to be continually attended 24 hours a day and every day – meaning a large component of the PMG workforce were telephone switchboard operators. Also the connecting cords became intermittent with wear – lasting less than five years before these cord assembles had to be individually replaced.

Step-by-Step telephone switching technology did not have the facility to provide alternate path routing like that which could be instantly provided through manual switches and the wear and tear of Manual (Sylvester Switchboards) and Step-by-Step technology was also becoming very high maintenance situation through wear and tear of the electromechanical components in these switches.

Having searched far and wide, Telecom Research Labs (TRL) made the decision in CE 1959 to introduce the Swedish LM Ericsson Crossbar technology because this then looked to be the most advanced electro-mechanical switching technology and it had low maintenance plus it included extensive facilities for alternate path routing.

The agreement was that LM Ericsson Crossbar telephone switching equipment to be manufactured in Australia – to (economically efficiently) employ Australians, really learn the technology; and have Crossbar technology very widely rolled out to replace the then ageing manual Sylvester Switchboards and Step-by-Step (SxS) automatic telephone exchange switches.

The introduction of LM Ericsson's Crossbar telephone call switching technology into Australia in CE 1960 was met with curiosity and caution. For a start this technology used plastic insulated wire instead of cotton insulated wire that was standard for the earlier technologies in Strowger and SE52 Step by Step switches. "***Massive Productivity of Plastic Insulation***"

Compared to the earlier (clunky) Step-by-Step switching technology, Crossbar was decades ahead in virtually every respect.

The bidirectional Step-by-Step movement (vertical ratchet (route select by dial) – rotary ratchet (spare line pair identify)) process was "heavy", highly unbalanced, and mechanically awkward. Because of the considerable weight of this switch movement and because it had to move quickly and repetitively stop as it traversed, the switch movement was especially prone to considerable mechanical wear. Also - the rather high current surges used to do these electro-mechanical movements caused noise in the battery feed – which negatively impacted on transmission as background noise.

To maximise SxS reliability, the wires that were moved with the stepped vertical and stepped rotary motions were deliberately made of "tinsel" (multiple very thin wires in cotton insulation / support – and even then, these wires also had a rather "limited" life of a few years. Had these wires been solid; the life would have been a few weeks!

Behind the bi-motional (vertical/rotary) switches were vertical cylindrical banks of 10 tiers of (fixed) rotary slide contacts where each of these contacts had a "common" (usually cotton) insulated wire horizontally connecting each switch set. Because of the persistent hard shaking caused by the vertical and horizontal switch ratchets, these solid wires (over some decades) also became crystalline and snapped.

Repairing these common wires was a nightmare because so much as slightly bending one set of common wires to get a soldering iron in would often result in another one or two other (now also crystalline) common wires also breaking!

The armature is the moving part of electro-mechanical relays, and when the relay coil is energised the resultant magnetic field pulls the armature face to the “yoke” (which is the iron centre of the relay solenoid coil). Concurrently, the back of the armature pulls away from the relay body and this movement (about 2 mm) is used to actuate a number of lightly sprung switch contacts also mounted on the back of the relay body.

Unlike the Step-by-Step switch technology, the Crossbar switch (originally developed by Western Electric in the USA in the early CE 1920s) was considerably refined by LM Ericsson engineers in the CE mid-1950s. The Crossbar switch mechanism had very little physical movement, was far more compact than the SxS technology and Crossbar technology was a very elegant engineering design.

Ericsson had done their homework on revolutionising the physical design of electro-mechanical relays through the CE 1950s and had introduced a raft of production design efficiencies that made manufacturing far less costly, very straightforward, and far lower maintenance. Some of these other improvements included:

- A round relay yoke with a thermoplastic moulded coil bobbin including several solder terminals.
- A lighter thickness relay body that could be far less expensively manufactured.
- The Armature being held by a small clip/spring instead of a threaded screw.
- A plastic spacer to minimise the chances of the armature sticking to the yoke because of residual magnetism.
- Switch spring-sets that self-wiped their contacts – preventing dirty contacts that would inherently be occasionally high resistance.
- Standard design relay-set switch contact piles – facilitating fast and inexpensive component manufacture.
- The widespread use of “snubber circuits” to minimise contact sparking, and minimise relay switch contact maintenance.

The technology in these relays was at least a generation ahead of the earlier SxS technologies and it did not stop there. Physically, the “banks of contacts” were now thin (solid) straight metal strips and the relay contacts to these strips were selectively controlled by a narrow rocking arm with thin wire fingers on it (very little inertia required to do the rocking, and the rocking motion was about 5 degrees (not 180 degrees like in the SxS switch).

When a (telephone call) is switched through the Inter-Exchange Network, it does so through a series of (electro-mechanical) switches where the route is pre-determined by the number called, and post-determined (as the call is set up) by the current network occupancy of the available network infrastructure. Control for each of these switches is therefore limited to a number of “states”.

In computing – the functionality where an output is pre-decided by a number of (logical) inputs is known as a “state machine”. This concept has a direct parallel relationship with the controlling of (telephony) switch paths though a mesh / star network and the availability of through-connections. Crossbar technology included a complex common control “Register” that was in reality a large relay-based “state machine” that was far more flexible and complex than that in the SxS technology – that had an extremely simple logic process.

Crossbar network switching flexibility far exceeded that of Step-by-Step technology, and consequently considerably more paths within the Junction / Transit Network could be switched into and through. With SxS technology, a considerable amount of the Junction / Transit network transmission infrastructure could usually be idle and unused and the caller would most likely get (network) Congestion Tone.

Each Crossbar exchange usually had at least two Registers (redundancy and speed) to provide a far wider selection of routes pre-determined by a compact Code Mark Route (KMR) linking block of wire straps that hard wire coded where a call connection path would be diverted to one of several alternate paths.

On a side note, Telecom Australia engineers realised the excessive wear and tear being caused to the continuous use relay-based Registers and the engineers created an electronic (solid state) register primarily for use in Tandem Crossbar switches in metropolitan areas. “***Digital Brains Within Crossbar***”

This Crossbar technology was radically different than Step-by-Step switching and it took some years for the Engineering and Technical staff to really understand the intricacies and advantages of Crossbar.

Unlike Step-by-Step switches that required constant surveillance / maintenance, Crossbar switches could operate for many weeks without any problems and in most cases maintenance related to changes in network structure were the wiring of the routing block (KMR Block) needed changing or the very occasional sticking relay.

> *November CE 1986, as a Class 1 Engineer I visited Penrith (District) exchange surveying the limited future of the then Western Cable and associated FDM transmission system through to Bathurst.*
>
> *Before leaving I deliberately took a walk around the whole exchange building to reacquaint myself with all the equipment. Like most exchanges the transmission and switching equipment were in separate areas / floors.*
>
> *When I walked upstairs into the ARM Trunk Switching room, the sound of the relays switching did not sound like the waves on a beach (as they usually sounded like to me), but sounded like a vintage car engine stalling and starting and stalling. Something was drastically wrong.*
>
> *Elsewhere in the building (in a corridor) I noticed a small case with “J.D. Mackey” scribed near the handle. I knew John from 20 years before – and it was a safe bet that his then Supervising Engineer (John Simpson – a very rare Crossbar guru) would also be in the building – he was! When I told John Mackey that the ARM was sick – he laughed and said “What do you know about Crossbar?!” But when we walked in the ARM room he also knew something was awfully wrong by how it sounded.*
>
> *It did not take them more than a few minutes for then to identify that the was a major problem in the routing where an extra “0” was added to the*

"02" making it "002" and directing the calls to Hobart – where the leading "0" was stripped of and the call proceeded back to Sydney. This was blocking Tasmania off the Mainland.

It turned out the Routing block in the Penrith ARM was changed the night before and the strapping was effectively upside down causing all problems! This problem was fixed within the hour and the local switching techs got an expert lesson from John Simpson in how to correctly wire the routing blocks (and a whole lot more about Crossbar technology)!

Crossbar switched technology also introduced the then new technology of Dual Tone Multi-Frequency (DTMF) dialling as well as pulse dialling – meaning that the dialling process could be considerably faster and as new phones (and PABXs in the CE 1970s) were coming out with DTMF facilities and Crossbar technology was a perfect fit from the CE 1960's onwards.

The PMG's Telecom Research Laboratory (TRL) were highly aware that manual switchboards had an enormous management and labour overhead and that most of these switchboards were in Towns and Villages. About CE 1964 TRL worked further with LM Ericsson to develop a very cut-down and highly economic version of the ARF Crossbar exchange (called the ARK) that was parented to the District Town/City Minor Switching Centre ARF Crossbar exchange.

In most cases, the connection between the ARK exchange and the ARF exchange was by Loaded Cable (that was previously used by the Sylvester switchboards as a Transit network to the District ARF exchange and the transmission was "reasonable"!

This Crossbar technology development proved to be an instant and massive productivity success as it released tens of thousands of Switchboard operators from long hours of work and provided highly reliable 24/7 telephone connectivity. This rollout was virtually complete in CE 1984 and it facilitated Subscriber Trunk Dialling (STD) by CE 1974 - something that the USA and other large geographic countries only dreamed about for many years – but could not do it.

The USA could not provide STD facilities because their telecoms infrastructure was specifically not a sub-Government Infrastructure Business (like what was Telecom Australia Commission), but several highly competing private corporations / companies that very extensively used manual operators who then dialled between various competing organisations.

This was an extremely poor use of the USA's available telephone infrastructure, and it should have been an extremely loud "wake-up" call to Australian politicians that privatising the telecoms infrastructure would be a massive backward productivity step. (The politicians never listened – and there were several totally useless Inquiries with highly inept Reports that were full of "waffle" and these proved extremely costly to the Australian economy!)

Telecom Australia Commission was privatised (i.e. CE 1989) and split up to "promote and maximise the economic efficiencies of infrastructure competition"! It is interesting to note that only a decade after "privatisation" there have been a succession of at least 20 Federal Government Inquiries (starting from about CE 2000) that have ineptly looked into why Australia's telecoms infrastructure is not performing as it was heralded to do so. "***The Davidson Inquiry and Report***"

The painfully obvious answer is that splitting up Australia's Telecoms infrastructure did nothing to drive down prices – in fact exactly the opposite (prices were driven significantly up) because of dramatically increased overheads of multiple: Management / Boards / Networks / Advertising / Sales / Marketing. Further, overall network performance has been severely crippled because economy of scale in all scenarios has been wrecked and the infrastructure has in most cases left to rot – causing massive inefficiencies. "***Competition Wrecked Australia's ADSL***"

Unperturbed, highly blinkered and pathetically ignorant economists kept insisting the telecommunications infrastructure competition (in Australia) actually caused prices to drop in the mid CE 1990s. "***Why End User Prices Tumbled in the mid CE 1990s***"

Crossbar was a bit of an enigma in that it "worked" even though it could have several component parts being faulty and compounding this situation I understood that only a low proportion of the switching maintenance staff had a thorough knowledge of how Crossbar actually worked. So there were many locations that had faulty Crossbar equipment and the staff were unaware there were problems – or didn't know how to go about identifying the causes of the problems. In most cases this was not a major problem (because the equipment kept "working")!

Each State had their own cell of Switching Support gurus that worked collaboratively between the States and used a series of network results (usually a combination of (escalated) customer complaints and proactive network performance / congestion records, and collated figures from the "common meters" that reported the workload of much of the Crossbar equipment.

> *Circa CE 1992, I was National Manager, Service Quality (in Telstra); and I had gone to Brisbane to steer the course for the next development stages of the CCS7 monitoring and analysis project as most of the engineering and technical staff that had this niche specialist expertise were in the National Network Investigation (NNI) Brisbane office.*
>
> *In discussions with the NNI staff in Brisbane there was a far more pressing local issue where it was clear that there were considerable concern about the congestion and Voiceband transmission problems in the Fortitude Valley exchange affecting many of the 16,000 customers directly connected through that exchange site – officially NNI had not been informed – and that was another big problem issue!.*
>
> *Circa CE 1991 there had been a change in the fault escalation process such that if customer impacting faults cannot be fixed at the local level then these were to be raised to the Regional Level to get fixed and if not fixed (within three weeks) then these faults must be escalated to National Network Investigations level for the gurus to manage.*
>
> *That new process had worked very well as it flushed out a raft of rare problems that were very customer impacting and identified some major areas of concern – that could now be properly addressed and resolved.*
>
> *In this case the Local and Regional levels had worked closely – and had addressed / identified / rectified service impacting problems at the Local level and passed the "too hard" problems up to their Regional level. The problem was that (primarily because of Regional staff issues) customer*

impacting problems that they could not solve were not escalated (after several months) to the National level (i.e. National Network Investigations)!

After a quick (phone) discussion with the Regional staff, I assigned three NNI (Brisbane) technical gurus in our Brisbane office (Paul Middleditch, Ian Johnson and Don Ross) to go through "the Valley" with a fine toothed comb. The team spent about three weeks there and did a wonderful job, working through the Crossbar equipment and found over 20 separate problems - most of which would have been there for many years and should have been identified and corrected at commissioning.

Customer complaints relating to the "Valley" Crossbar exchange absolutely plummeted leaving one customer with a service connection problem that should have been escalated to NNI several months before as the problem was clearly at / near her premises. Really complicating this issue; she would not allow our staff on her premises (or the adjacent Service Pit) - and she was in the process of raising litigation against Telstra. This ultimately blew into a multimillion $$ litigation battle.

The above workplace reflection was by no means an isolated incident, and it confirmed for me that although most of the technical (and engineering) staff were dedicated; nationally it was only a low percentage of these people actually understood the intricacies of the equipment they were installing / maintaining; and the gurus were few and far between. I was naturally drawn to these special breed of people, and it was a fantastic ride!

Telephones Become an Essential Service

By the CE 1940s it was still very much “Posts and (hand-written) Telegraphs” world, and a telephone was still a real business luxury. Public phones were far more common than home phones. Many businesses (Hotels and Shops in particular) included public phones in their premises.

In metropolitan Australia, one of the massive CE 1930s recession projects to keep employment was the Australian manufacturing of paper-insulated pair copper lead-sheathed cables to replace overhead open wire technology in the metropolitan areas.

Parallel with his was the manufacturing of asbestos-concrete cable conduits and service pits. Parallel with all this was the manual trenching-in of this telecoms infrastructure to replace overhead telephone wires as cables under footpaths in metropolitan areas.

Another concurrent massive project was the local (Australian) manufacture of Sylvester Switchboards and SE52 Step-by-Step automatic switching equipment; both of which really built Australia’s manufacturing businesses and local expertise, and facilitated the widespread rollout of Australia’s telecoms network infrastructure.

This telecoms equipment was not “assembled” from pre-made components – but the entire equipment was literally manufactured from (almost all) Australian primary products with a highly “vertical” process from the ores to the finished products.

The Post Master General’s (PMG) Department extended the well-established Telecom Research Laboratory (TRL) to be central in maximising common expertise and productivity of newly born (and well-established) Australian companies.

As underground cables were far less susceptible to weather and tree-branch damage the overhead costs were significantly lower. With the general lowering of telephone operational and usage costs with new less expensive transmission and switching technologies becoming far more widespread, a higher proportion of the general metropolitan population started getting telephones installed in their homes.

There was a fundamental marketing / provision problem where a low percentage of premises had telephone services, and when people went to the Post Office to ask for a telephone service they were commonly told it would be several months – if not years – so they did not bother to ask! So there was no record for their request. (But they all wanted / needed a telephone service.)

When a new cable went it the ground – everybody then rushed the Post Office and the request list flooded! Now the planning engineers were really stuck as their plans were derived from the few earlier telephone service requests. Now the list from the Post Office counter was like an avalanche of requests for telephone services (with a new cable going in) and the planning engineers’ figures were way under-provisioned!

It took some lateral thinking to pre-provision cables and switching equipment on premises numbers and in that way manage the future avalanche of requests for telephone services!

By the mid-1960s the introduction of transistorised transmission equipment and Crossbar switching equipment technologies had again significantly lowered overhead installation and maintenance costs while providing far more “connectivity” and a high percentage of home premises that could now afford a telephone that was now becoming essential with the raised living standards.

With the introduction of “baby-boomers” setting up new homes in the 1970s, the need for more telephone services rapidly increased. Concurrently, the newer technologies introduced through the CE 1960s (and CE 1970s) resulted in a significant decrease in the operational cost of telephones such that they became an essential household item.

In Australia, almost all Government Departments operated in a system of “break-even accounting” where the expected (internally and externally accounted) operational cost (including growth) was summed up the year(s) before and the use of that infrastructure was (where possible) charged to the potential end users – so that at the end of the financial year the books would balance with a “break-even” value.

It was standard practice to inflate the project costs (by 10 to 20%) to cover for unintended situations, and it was also common practice that as a particular project was approved at an executive level, the project price was also marginally inflated by executive management – not realising that the price was already inflated!

Inevitably towards the end of the financial year, the realisation was that certain projects had considerable unspent funding that “had to be spent” – or as punishment that amount of funding would be taken off the next year’s works programme!

It was common practice to transfer funds to those projects that had unfortunately gone well overboard and then go on a “buying blitz” to spend the remaining funds before the end of the financial year. More canny management pre-purchased some of the next financial year’s project materials with this overflow to make the accounting books look to “break even”!

In the CE 1970s, with the introduction of main-frame and personal computers into accounting, the ledger sheets transferred into electronic accounting books that very quickly became far more organised and far more predictable. “***Productivities of Electronic Databases***”

As these wild swings in accounting were far more controlled, “break-even” accounting really showed that continual technology advances over many decades were persistently lowering the operational costs of posts and telegraphs (telephone services).

It was fast becoming a situation that with the technologies of automatic switching and transistorised transmission technologies (and the dramatic reduction in line maintenance – now that most of this technology was now underground); and the significantly increased spread of (fixes access) telephone services – it was becoming “not expensive” to have a telephone (and it was now an essential service)!

Economic Point-To-Point Radio Links

During the CE 1930s, research into using higher frequencies for radio transmission came to the realisation that the standard components used (including the thermionic valve) had physical dimensions that severely limited the ability for any of this equipment to work anywhere near towards the 1 GHz and above range. As a direct consequence, the physical structures were radically changed to work in synchronism with the frequencies of interests and a whole new branch of electronics slowly developed through the CE 1940s and CE 1950s.

Apart from coaxial cable becoming a standard transmission medium for high capacity FDM systems, the concept of a Waveguide (that looks very much like an inside gold-surfaced household drainpipe) also became a highly practical (expensive) transmission medium. In this case the electromagnetic waves bounce their way down the inside of the (usually rectangular or round) tube in a number of “resonant modes” – with rather low attenuation (and no centre conductor).

Similarly, resonators that look much like a petrol or kerosene drum or a free standing wardrobe or a packing carton started to become commonplace in radio research, along with a whole new breed of resonant antennae that we now have commonly used for TV reception.

With Amplitude Modulation (AM) Radio technology, the first steps had already been taken with the structure of the (Klystron) transmitting tube, invented in CE 1937 by the Varian brothers (USA); then looking like a fire hydrant and now looking far more like a (ceramic) cake tin so that it could handle the relatively massive voltage differentials and current flows necessary to produce many kW of radiating power.

Another very important discovery was the invention of the cavity magnetron (a magnetic cavity resonant valve) that went through many highly inventive hands from CE 1906 through to mid-CE 1930s when new technologies took over (for a while).

The Travelling Wave Tube (TWT) credited to Russian Andrei V Haeff in CE 1936, came up with a structural variation on the thermionic valve with a spiral coil as the grid to facilitate a travelling wave in the spiral. This valve looks very much like a standard (glass) valve with a pencil attached to the top and became the new “kid on the block” for resonantly amplifying these Very High Frequencies (VHF) and Super High Frequencies (SHF).

These technologies facilitated extending our use of the electromagnetic spectrum well past the nominal 25 MHz limit and over 1000 MHz with a wide range of applications including microwave heating, radar and point-to-point radio connectivity.

The parabolic dish reflector antennae hit its straps with frequencies exceeding 700 MHz making the dishes small enough to be practical on a tower, and because of the reflector it was possible and practicable to have a radio beam that was a few degrees wide and a massive gain over the intrinsic (reference) point source.

As Australia’s population grew in the CE 1960s and CE 1970s – so too did the number of point-to-point radio systems – especially in Australia’s Regional Remote areas as this was considerably less expensive than buried cable (because the trenching costs would have been enormous) – but radio is susceptible losing connectivity during storms and solar flares etc.

Because of the massive intrinsic gain of the large parabolic antennae (usually well-exceeding 36 dB), the two ends of a point-to-point radio transmission system could be as far as 70 km (or further if on hill-tops)! This strategy was a cheaper option for much of (inland) Australia because the radio towers could be placed on hilltop vantage points.

This equipment was all 100% imported and all Travelling Wave Tube (TWT), and Magnetron / Klystron technology to handle the Super High Frequency (SHF) bands.

The back-connection to most of this radio equipment was usually engineered for (generally) high capacity FDM systems (that were by then starting to become common in Europe).

With a typical coaxial cable-based FDM long-haul transmission system having say 960 Voiceband channels spaced at 4 kHz steps, this is roughly about 4.5 MHz wide including the “stop bands” and other level alignment tones – and a return path is also required! Even so – allowing say 10 MHz slots (Double sideband) Amplitude modulation in a 750 to 1200 MHz radio range provided ample spectrum for relatively reliable radio communications.

Even if a tower and its associated equipment cost $5 M at each site the financial numbers look really good! Consider a standard 1000 km (reference span for this document) with hops at nominally 50 km (conservative); that is 20 hops and 21 stations at nominally $105 M, or about $ 109,000 per Voiceband circuit.

In productivity terms the number of Voiceband channels (960) is the same (0% gain); but the cost per unit Voiceband channel has again dropped from $0.161 M to $0.109 M per Voiceband channel a cost reduction of about 32%.

But there is so much more with this new technology! There is really nothing (apart from wind resistance) stopping another dish and associated equipment being installed on that tower / equipment site for a (large) fraction of the original cost.

Say the augmentation cost for a second radio system (very generously) cost $3M per site. So the number of channels is now 960 * 2 = 1920 and the per-site cost is about $5 M + $3 M = $ 8 M and for 21 sites this is $168 M. Now the per-Voiceband circuit cost is about $0.0875 M or about $87,500.

Technology	Circuit Count	Build Cost	Voiceband Cost	Time – Era CE
Open Wire	16	$233.7 M	$14.60 M	1880-1895
Phantom	31	$234.5 M	$7.56 M	1895-1915
Amplified	16	$240.0 M	$15.00 M	1905-1915
Amplified (Phantom)	31	$240.0 M	$7.74 M	1905-1915
Amplified (thin wire)	16	$130.0 M	$8.13 M	1915-1953
Amplified (Phantom)	31	$130.0 M	$4.19 M	1915-1953
FDM (thick open wire)	96	$254.0 M	$2.64 M	1953-1974
FDM (thin open wire)	96	$148.5 M	$1.55 M	1954-1974
FDM (Coax)	960	$91.92 M	$95.75 k	1961-1987
FDM (Coax)	1920	$96.64 M	$50.33 k	1961-1987
FDM (Coax)	2880	$101.36 M	$35.19 k	1961-1987
FDM (p-p Radio)	960	$105.00 M	$109.34 k	1961-1990
FDM (p-p Radio)	1920	$168.00 M	$87.50 k	1959-1990
FDM (p-p Radio)	2880	$231.00 M	$80.20 k	1959-1990

The productivity with this second radio system on the existing towers was close to coax cable and it opened up network connection arrangements never before conceived possible.

Most of the northern half of Australia (west of the Great Dividing Range) is rather rocky and very difficult to back-hoe / plough for burying a cable 1200 to 1500 mm deep. But using a couple of radio towers spaced at nominally 70 km apart this was the answer to providing high capacity network connectivity instead of overhead wires and underground cabling in Regional Remote (and much of Rural) Australia.

The development of long-haul Radio bearers carrying a Super Group (60 Voiceband channels) – even a Master Group (300 Voiceband channels) was a massive productivity development as these radio hops could span upwards of 70 km meaning this technology could hop between country cities / towns and provide plenty of through connectivity plus some wayside connectivity.

Productivities of FDM Extensions

One of the inherent (inter-Regional) Inter-Exchange Network (IEN) connection problems was (and still is) that the Regions (each centred by a major Regional city) are a physical "**star**" structure (like the spokes on a cart-wheel from the axle hub) from their (metropolitan) State Capital Cities – and the prime telephone (Voiceband) connection was through high capacity long-haul FDM systems.

Within each Region, almost all the Cities, Towns and Villages are connected as a "Tiered **Star**" from the Regional City. By the early CE 1960s most long distance calls were via (amplified) open wire or medium-capacity FDM systems and the short / medium distance inter Town / Village (<40 km) calls were typically via open wire and/or (amplified) Loaded cable (Transit Network). "***Massive Productivity of FDM***"

Generally this "tiered **star**" structure worked quite well for many decades before the CE 1960s using Manual (Sylvester) Switchboards, as most people that used telephones were business calls and most calls were to/from offices in the Regional city – or with offices the State Capital city. The other problem is that if the main route is congested – there was (usually) no alternative (loose mesh) route to bypass the congested part of the IEN and through-connect the call.

When Crossbar ARM ("4-wire" trunk) automatic switching technology was introduced in the early CE 1960s, this progressively introduced Subscriber Trunk Dialling (STD) instead of manually connected Local and "Trunk" telephone calls. As far more Crossbar ARF and ARK exchanges replaced manual Sylvester switchboards, STD became standard operating practice for the general Australian population throughout Australia by the mid CE 1970s. "***High Productivity of Crossbar Switching***"

All State Capital Cities have multiple Trunk switching / transmission exchange sites in and near their CBDs. This distributed structure makes the (State) network far more robust – so if one CBD exchange building site has a (major) problem the other exchange sites might continue to operate without a total network shutdown. Still the problem is that because these inter-Regional telephony network structures are effectively a **star** network – there are precious little alternative routes.

From about CE 1960 with businesses becoming more geographically diversified – the proportion of inter-Regional telephone calls started to increase and Trunk calls to/from State Capital Cities with Regional areas also proportionately decreased. This geographic change in telephone calling patterns presented a State Capital City Trunk switch congestion problem because these ARM (and 10C) Trunk Switches were now "transit" switching between Regional Regions instead of primarily originating / terminating telephone calls to/from the State Capital City.

Network Planning Engineers came up with a revolutionary strategy: in the State Capital City CBDs Trunk Exchanges - to cross connect many Voiceband channels of different high-capacity long-haul FDM transmission systems (that were directly connecting Regions to the State Capital CBD Trunk exchanges) so that Voiceband transmission is then directly interconnecting different geographic Regions without also switching through the State Trunk Crossbar ARM switches.

This highly innovative strategy was complex to piece together and involved a lot of regrading and rewiring – but it literally turned what were heavy spoked **star** network structures (centred on State Capital Cities) to a loose mesh where the majority of inter-Regional telephone calls physically passed through the State Capital City CBDs but bypassed being switched in the State Capital cities' Crossbar ARM switches.

To do a Voiceband Network cross-connection, this required 4 wires for (600 ohms) transmission (plus a 17 dB 600 ohm pad (about 20 mm square in a solid green plastic) in each transmission direction to correct the transmission levels from +4 dBr receive to -13 dBr send) and two more wires to cross connect the “E&M” signalling.

That is three pairs of wires plus two pads per Voiceband circuit. It was very effective but messy with lots of wires and if the other FDM terminal was in another CBD building then this means a (another) cable and the pads being less than 17 dB to keep the line-up levels in check. Considering that it soon became apparent that there would be several hundred cross-connected long-haul FDM systems; there had to be a more elegant strategy.

Circa CE 1967 the concept was taken to another level where instead of cross-connecting channels to cross-connect FDM transmission “Group” level where there are 12 channels in the 60 – 108 kHz frequency range (including out of Voiceband Channel Associated Signalling (CAS)). In this case, the engineering ingenuity was to interconnect an FDM Group between two different Long-Haul transmission systems (in the same building), as this required only two pairs of wires for 12 Voiceband channels. “***Advancing Transmission Technologies***”

As well as freeing up the ARM and 10C switching as outlined above; this concept effectively “unemployed” two sets of 12 (effectively “4-wire”) Voiceband Channels and all the associated equipment – and provided a (much) cleaner transmission path than going down the Voiceband level and working back up again.

When you consider that a considerable portion of these “Group transfers” involved the Mel-Syd Cable system (that used thermionic valves) – this was literally racks of Voiceband Channel equipment (per 12 channels) that was “switched off” and the Groups were cross-wired (with only two pair of jumper wire) to other long-haul transmission systems. “***Massive Productivity of FDM***”

One of the practical problems with FDM systems was that they were modular with the general assumption that all the Voiceband Channels would be locally connected (in the same building. In many situations this was not the case and it became imperative to extend a Group (12 channels) to another building site (to be through-connected into a different FDM system – particularly in State Capital cities.

> *One of the projects that came in the NSW Transmission Lab in CE 1967 was the prototyping of a (60 - 108 kHz) Group Extension Amplifier (and Equaliser), which (primarily because of the then extreme micro-managing supervision of Mac Cusiter) took several months (instead of a few weeks) before the prototype electronic design optimised, trialled and documented!*
>
> *Although this prototype proved to be electronically successful, the construction process was a slow nightmare. For a couple of years several (prototype) units were manufactured and installed in the major Sydney carrier terminals to distribute Groups to different long-haul FDM Carrier systems for optimised Trunk network connectivity and circuit flexibility.*
>
> *With a change in supervision where Graeme Johns took over at the Lab CE 1969 the Group Extension equipment design was re-engineered as a “Proof of Concept” with an in-house designed edge-connected Printed Circuit Board. The large / expensive transformers (about fist size) were replaced by inexpensive in-house manufactured small ferrite transformers*

*(about half thumb size) that were circuit board mounted (as were the monitoring plugs). Not only were these Printed Circuit Assemblies far more compact; they could be plugged in like books on a shelf. The signal level monitoring, gain control etc. and rack wiring for power was all now very simple and straightforward. "**New Era of Electronic Components**"*

This technology of FDM Group Extension equipment from one exchange building site to another (with a typical range of less than about 5 km) proved to be an astoundingly productive piece of engineering (pioneered and developed in Australia).

Not only did it free up a large amount of FDM Group / Voiceband equipment in the State Capital Cities – but it allowed this same (transistor / linear IC technology) FDM equipment to be relocated into the Regional areas to considerably increase Regional network connectivity at a minimum equipment cost.

Consider directly connecting to/from Canberra (via Sydney) to Newcastle, Brisbane, Wollongong, Dubbo, Bathurst; and to/from Canberra (via Melbourne) to Ballarat, Bendigo, Warrnambool, Geelong – and not having any intermediatory Trunk Switches (in Sydney or Melbourne CBDs) involved – except in time of heavy traffic where overflow uses the Trunk Switches. This was fantastic!

Most of the long-haul FDM transmission systems that were (bulk) purchased through the CE 1960s to the mid CE 1980s, were installed and commissioned with considerably less than full Voiceband channel (Group) capacity – leaving vacant Groups (12 Voiceband channels) and Super Groups (60 Voiceband channels).

As it turned out, because of this systematic years of under-provisioning, there were spare Groups in Long-Haul transmission systems that could be directly cross-wired with a 12 Channel system and locally provide 12 channels at a minimum cost. Cross connecting extra channels into the Regional / District switches was another story because the line relay sets (as the switch interface) were always in short supply!

Again, while I was at the NSW Transmission Lab several years later (about CE 1978) we were asked the "impossible" to make a Super Group Extension Amplifier / Equaliser for 60 channels to be transferred on two copper pairs between exchange sites (using the 312-552 kHz band).

This experimental / prototype Super Group Extension Amplifier / Equaliser project turned out to be a relatively straightforward reengineering of the Group Extension Amplifier / Equaliser – as the amplifier was almost identical and the active equalisation (to compensate for attenuation / frequency distortion) was scaled up and the operating impedances were changed from 150 ohms to 120 ohms to match the operating impedance of the FDM systems' Super Group terminations (and pair copper wire impedance at these frequencies).

Like many other developed prototypes in the Lab – this Super Group Extension equipment was also handed out circa CE 1980 to an Australian telecoms equipment manufacturer – so the Lab could focus on developing advanced transmission / switching / monitoring / networking prototypes.

Again, the productivity of this new Super Group (60 channel) Extension equipment was immense as this "slotted into" different Long Haul FDM transmission systems (in different long haul transmission exchange building sites in the Capital Cities) and provided high-level cross connectivity without going down to the FDM Group or Voiceband level and certainly not to switched in the Crossbar ARM or STC/Alcatel 10C as it would have in the early / mid CE 1960s – so the inter-Regional network interconnections were really clean.

With the Super Group Amplifier / Equaliser, all this needed was two pairs of wires for 60 channels (carried by the Super Group) that otherwise would have needed 180 pairs of wires for Voiceband and for Signalling, and 120 * 17 dB pads – and be restricted to a pair of very nearby (large) long-haul FDM transmission systems.

There was absolutely no “competition” to build this Group / Super Group Extension equipment as the conceptual idea came about to intentionally reduce the totally unnecessary switching in State Capital Cites 4-wire Trunk exchanges – and instead directly transfer bulk (Voiceband) circuits as a Group (12 circuits) and later as a Super Group (60 circuits) to directly interconnect between different long haul FDM transmission systems connecting to different Regional areas using higher levels of the FDM hierarchy instead of Voiceband switched circuits through a main ARM Trunk switch in the metropolitan Capital cities.

External Economic Control from the USA

The direct results of Australia's Gold Rushes in the CE 1860s were that the "Class System" as introduced by the British was virtually instantly disseminated, as a very high percentage of servants and workers deserted their (very underpaid) "employment" arrangements in search of gold where Class meant nothing. Suddenly there were no servants and the upper class had to cook, wash, shop, clean, garden etc. like never before – and the emerging Australian accent became virtually common throughout Australia by the CE 1870s.

Australian Farming and Grazing produce considerably increased and widely spread the common wealth of all Australians that was very largely fed back in as solid infrastructures that in turn provided the essential products and services necessary for the private sector to flourish – as the private sector (and the community) could inexpensively use this common wealth of infrastructures!

In North America the imported population was far larger than in Australia and there was a repetitive invasion threat from Europe - and wealthy (upper class) entrepreneurs were establishing competing railroads across North America to capitalise on the need for essential transport.

The workers in the north at iron works, wood, rail fettling etc. were paid a pittance (virtually slaves) and in the south, the cotton growers etc. had black slaves (imported from Africa). The direct result of North America's Civil War in the CE 1860s was that the USA now had a rather polar population (very few very rich and the rest rather poor) that remained armed (to defend against Europe – particularly against England).

Those leading the very wealthy private sector wasted no time in facilitating a highly militarised nation where the USA Industrialists (who ran the private sector) were the main beneficiary that then extended through to the USA Military Defence / Police Forces / local militia / gangs etc.. and also ran the USA Government.

What is not common knowledge is that the Scottish economist / philosopher Adam Smith wrote "The Wealth of Nations" in CE 1776 that basically defined how the price and availability of discretionary products and services interact – and implicitly how / why products / services that are non-discretionary have a very different relationship – where war (fight to the death) is the common outcome.

What is also not common knowledge is that from about CE 1800 the exceeding wealthy upper class in the USA literally re-wrote the topic of Economics as written / pioneered by Adam Smith; to "suit themselves". My understanding is that chapters relating to Infrastructure Business (essential products and services) were deliberately removed and the contents totally re-edited – leaving just the Competitive Business topic in place – and a massive chasm leading to the much hated "Communism / Socialism" – because nationalising the infrastructures (essential products and services) would mean that virtually all the mega-wealthy upper class in the USA would be stripped of their immense incomes and extremely powerful influences!

As "compensation" the USA mega-wealthy routinely "gift" (say) a building wing to a University or Hospital etc. (and ensure their names are all over this "apparent philanthropy") – and they have preferential use of what they have "gifted" too!

When Australia was federated in CE 1901 this intentionally brought the Australian States to collaboratively interact as a "common wealth" of infrastructures – hence the deliberate wording "Commonwealth of Australia" with the intention that massive economies of scale would be far more productive for the people in Australia than competing against each other as that had instinctively done for almost a century.

A classic example was the deliberately different railway gauges between adjoining States – apparently to prevent rival State capital city ports from stealing (export) business from interstate. Qld deliberately had 3' 6" narrow gauge because NSW had the standard gauge 4' 8.5" and Victoria originally started with the standard gauge but once it found out that NSW also had standard gauge it immediately rebuilt itself to the Welsh 5' 23" wide gauge track. This infrastructure competition was greed-based stupidity and cost Australia untold $Bn in lost productivity on a national economy of scale basis.

Directly following the Japanese ill-fated attack on Hawaii – which was/is a very isolated USA State primarily used to extend military influence over the Pacific Ocean; this attack on Pearl Harbour was the political trigger that the USA was aching for to get major legitimate involvement in WW2 and finally use its fast growing then massive military might for USA to have a much stronger World economic position.

The USA's direct military involvement in WW2 dramatically tipped the balance in Europe against Germany, and the South Pacific (South Asia / New Guinea / Australia) against Japan. After the USA military dropped two atomic bombs on two major Japanese cities (Hiroshima and Nagasaki), Japan surrendered.

To prevent another Japanese uprising, the USA (military) engaged one of their Generals (Douglas MacArthur) who smashed the economic grip that a few Japanese families had in Japan for many decades / centuries. This was very ironic as this economic framework was rather similar to how North America developed with its industrialists having almost complete control of North America's Infrastructures!

General MacArthur brought with him one Joseph M Dodge who "re-assigned much of the Japanese financial system creating a large middle class" - which was also ironic as the USA has a virtual "feudal system" where most people in the USA are under the breadline and have to beg for tips to survive – else join the Military / Police…

Realising that Japanese manufacturing was a mess, MacArthur brought over one Prof W Edwards Deming as the third person to rebuild Japan's economy. This was a perfect fit as Deming was fundamentally a statistician who was developing continual process improvement that he later called Total Quality Management (TQM).

Again, this too was ironic as typical management style of the English / German / French / USA / Australian / Japanese was typically military with a very strong set of directions downstream from the top – and virtually nothing going from the factory floor to management through the chain of command. On the contrary, this TQM model was very well matched with the Japanese philosophy / mindsets who naturally tuned into TQM as it directly matched their lifestyles.

With the ensuing Korean War (CE 1950 – 1953) where Australian and USA forces were combined to push back the (highly efficient) influence of "hard left" Communism – much of the (western economy) military equipment came from new industrial production in Japan; and this kick-started the massive Japanese economy, plus it entrenched TQM as the (only) practical way to make factory production highly efficient, and educate the general population and have the general population reasonably well paid.

The ANZUS Treaty (that Australian Prime Minister Menzies and the New Zealand Prime Minister was wedged into signing in CE 1953 as they had little choice but to follow in also co-signing) was fundamentally a very long thin wedge of bi-lateral military support (where the USA could port military ships in Australia and NZ – and have military bases on Australian and New Zealand land).

The Treaty also provisioned joint country (including the USA) military exercises to be carried out in Australia – which also meant that the USA would have inside knowledge of Australia's military intelligence and some control of Australia's military command / forces – and capitalise on military weapons sold to Australia (primarily from the USA).

This Treaty included several clauses that constricted the activities of the Australian Government (and people) in many ways – to favour the USA.

For a start – no technical engineering initiated (inventions for Patents) can be approved without prior screening and approval from the USA Department of Defense. This effectively stopped Australian ingenuity from being "Australian" but becomes the property of the USA. This has crippled Australia's engineering / technology with a high proportion of engineers having no choice but to export themselves to the USA.

Australia was not allowed to have any Nuclear electricity Reactors (because these reactors can be slightly process changed to produce more concentrated U235 which is the prime material for Atomic Bombs. (Remember this is in the middle of the Cold War where the USA and USSR were over-arming themselves with hundreds of Atomic Bombs for the imminent threat of global atomic warfare – and the USA was fiercely preventing any other county (it controlled) have atomic weapons.)

Also - if the USA is involved in any War – the Australia is tied to also be in the same war under the USA command. Hence the Vietnam War and Afghanistan War (at least) where Austria really has absolutely zero political or business involvement - were tied in and many Australian lives were lost and families ruined – for USA greed.

This ANZUS Treaty also had a very strong and well-hidden set of clauses pertaining to all Government-owned infrastructures to be privatised to make them "more efficient" – as per the highly entrenched USA (hard right) economic model - where all infrastructures in the USA is owned by private sector Banks / Industrialists. This was a diametrical change from the way that Australia was federated in CE 1901.

The USA had now established itself as a major international Military (and economic) super-power – as had the United Soviet Socialist Republic (USSR). These two economies both worked very well by having massive financial strength in the hands of a few tyrants. Those in the USA were (and still are) fanatical about not letting any infrastructure (essential product / service) slip out of private (restricted family) control.

As both sides were still massively bleeding from immense losses of lives in the previous killing fields of hot wars and the fear that atomic bombs could annihilate most of the world's city populations; the mid CE 1950s settled into a very long-lasting Cold War situation with telecommunications technologies continually advancing.

In the USA, the "free market" has a controlling interest in their (hard right) "western" economics (and Government), and part of the controlling interest is to have a "small Government" – which is deemed to be "efficient" (by the controlling "free market")!

The truth is that the "free market" (in the USA) is in reality a group of extremely wealthy Banking and Industrialist corporations and a "small Government" can be run-over / easily manipulated by the "free market" (i.e. the private sector corporations that own and control the USA's infrastructures – to suit themselves)!

The "Federal Reserve" is not a USA Government body – but the combination of several immense private sector (mainly USA-based) Banking Corporations that literally tell the Government of the day (Democrat or Republican – there is no other choice) what the interest rate is and how much the USA Government can "borrow" from the Federal Reserve. The International Monetary Fund (IMF) and the World Trade Centre (WTC) are both effectively puppets for these Industrialists / Bankers.

This is why the USA Industrialists / Bankers were absolutely petrified about losing the "Cold War" (against the communist USSR) – because the (essential service) infrastructures that are outright owned and controlled by these Industrialists/Bankers who make massive profits from this locked market would become "State property" – and the Industrialists/Bankers would be stripped of their immense ill-gotten wealth!

Circa CE 1955, Australia's TV channels were set by a Federal Parliament Bill to be 7 MHz wide even though the CCITT recommendations and the rest of the developed World (except for the USA that used 6 MHz wide channels) used 8 MHz wide TV channels!

In hindsight it is plain to recognise that the inept Minister of Telecommunications and Transport must have been very well informed that the large majority of the developed world was based on 8 MHz TV channel bandwidths and all the engineering design and manufactured equipment was built around this world standard.

It is also obvious that the Minister had been severely compromised (socially, financially at least) by senior USA Department of Trade officials / politicians and by USA manufacturers to use the USA manufacturers and their company standards. By stipulating the bandwidth to be 7 MHz this opened the doors for the USA powerhouse manufacturers (like RCA) to muscle their way in and force Australia to use 6 MHz.

Engineers in the Australian Broadcasting Commission (ABC) had other initiatives that floored the USA bullies! The ABC Engineers (under one brilliant Neville Thiele) came up with a Transmitter "pre-equaliser" that deliberately overcompensated for the frequency response and "Group Delay" (phase response verses frequency) in the now limited 7 MHz channel bandwidths. This pre-equaliser made the engineering and manufacturing of the Intermediate Frequency filter in millions of Australian TV Receivers to be far less complicated and much less expensive to manufacture!

For well over 60 years, Australia has been "glued" to the USA's economic policy that has a very long history of entrenched privatised infrastructures in the USA.

Since the early CE 1970s, starting with Chile and its inherent economic problem with highly expensive telephone communications the USA has extended its economic influence by forcing western economies to sell off their sub-government infrastructures into the private sector. "***The USA Muscles itself into World Dominance***"

Australia was rather slow off the mark as all Australia's infrastructures were operating quite efficiently as government departments or sub-department commissions.

The flow-on of relentless USA-initiated economic pressure has resulted in Australia's highly efficient telecoms infrastructure "where the wheels fell off" being at least:

- broken up with the focus on fast return on investment in metropolitan areas at the expense of the (non-coastal) Regional areas,
- a threadbare Backhaul / Core Network outside State Capital cities,
- totally unnecessary and extremely expensive adverting / sponsoring / marketing of telecoms services,
- absolute failure of ADSL technologies,
- incredibly expensive duplicated (and flawed) HFC infrastructure,
- the introduction of the National Broadband Network (as a Corp) to provide what was ripped out circa CE 1990 for shareholder dividends,
- implementation of unnecessary and extremely expensive geostationary satellite where existing long-hop radio links could have been very inexpensively upgraded to provide reliable fast inland Broadband,
- an immensely large number of telecoms-related consumer complaints (resulting in no less than 20 useless Federal Government-based Inquiries and Reports (that went nowhere),
- total loss of Australian telecoms development and manufacturing industry,
- totally unnecessary multi-duplicated Mobile networks in Metropolitan areas with threadbare Mobile Networks in non-metropolitan areas resulting in
- more than 13,000 recorded and easily preventable Radio Black Spots:

And the list just goes on and on! "***Competition Disconnected Regional Australia***"

The USA Muscles Itself into World Dominance

In CE 1970, Chile had a major internal economic problem where about 80% of their then telephone network was totally owned and controlled by the Bell Telephone Corp ("Ma Bell") the then gigantic USA private sector telecoms monopoly.

Fundamentally, Bell Corp. was looking to maximise its (internally accounted) private sector return on investment (i.e. profit) for their senior executives and shareholders, and Bell Corp. could charge the Chilean population whatever they liked because at least 80% of all telephone calls passed through the "competitive" Bell Corp Inter-Exchange Network infrastructure and the call "transfer" / "connect" fees were huge. There was no alternative – and consider that telecommunications was not a discretionary product / service – it was and is an essential product / service.

The economics that surrounds essential products and services are diametrically different (opposite) than the economics that surrounds discretionary products and services - as laid out in "Economics 101" – but never taught in Western economies.

The industrialists in the USA had for a long time realised that they could make far greater profits by deliberately "restricting" what economics was taught (and who taught it, and what were the texts[1]). In USA terminology, Infrastructures are very euphemistically called "Utilities" to explicitly avoid the wording "essential products / services" and make these essential products / services appear to be discretionary.

So, the then Chilean President moved to dramatically reduce the user costs of Chilean telephone infrastructure by nationalising the Bell Corp Chilean infrastructure and all hell broke loose. In no time Bell Corp. called USA President (Nixon) and the CIA / WTO / IMF etc. were all brought in (all under USA fingertips) to absolutely smash the Chilean economy and drive the Chilean President out of office and put in puppet President Pinochet to drive the Chilean economy into oblivion.

The USA's financial and economic giants then told the World's Western economy (in no uncertain terms) that if these countries (including Australia) did not start privatising their government owned infrastructures, then the USA would use its now very powerful financial and trade controls to economically wipe these countries from foreign trade; so that the small group of USA financial giants could have majority holdings all over the Western economic World.

Now the long wedge of the ANZUS treaty (that was counter-signed by Australian PM Menzies in CE 1953) came into force. Australia moved as fast as it could in its paper–based democracy – or face having all its exports at that time primarily of wool, wheat and iron – totally obliterated – that would leave Australia either destitute – or totally self-sufficient (and the USA was certainly not going to allow that to happen)! "***External Economic Control from the USA***"

In CE 1973 the Vernon Report heralded the breaking up of the then Post Master General's Department into a few specialist Commissions including Telecom Australia and Post Australia – which, from CE 1975 took a lot of procedural Acts out of Federal Parliament – making the Australia's Federal Government considerably more efficient in a work process mindset. Conversely, Telecom Australia's shopfront in the Post Office was removed and this effectively isolated telecommunications consumers (i.e. the public - consumers) with a direct interface – other than the District Office.

[1] "PowerPlay – the fight for control of the World's Electricity" Prof Sharon Beder. Scribe Publications 2003, ISBN 0 908011 97 0" https://documents.uow.edu.au/~sharonb/power.html

As detailed later, Australian telecoms infrastructure had been significantly developing with a very strong passive input from the Post Master Generals / Telecom Australia Commission “Research Laboratories” (TRL) that was based in Melbourne.

For many decades, TRL had steered the introduction of new telecoms technologies - and focussed on growing the Australian economy by providing extensive research and production engineering support for many Australian telecoms equipment manufacturers. TRL had also been pivotal by introducing new technologies (and new businesses / factories) and setting up international manufacturers to have factories in Australia – which employed Australians and really boosted Australia’s Engineering and Technical ability!

*TRL also introduced several Quality improvements to wire and cable manufacturing processes so that cable was manufactured with a very high consistency – which made network engineering design problems disappear and made fault location very highly repeatable – saving millions of man-hours. “**The Economy of Pair Copper Cables**”*

*LM Ericsson’s Crossbar technology was fundamentally based on 4-wire transmission and all Australia’s metropolitan network was based on 2-wire (bi-directional) transmission technology. TRL worked with LM Ericsson to re-engineer the Crossbar transmission technology to be optimised with Australia’s evolving 2-wire transmission network. TRL also developed a far more compact ARK exchange using Crossbar switching for remote telecoms to replace manual switchboards. “**High Productivity of Crossbar Switching**”*

Meanwhile in the USA their Monopolies Act (which was introduced almost a century earlier to prevent private rail companies (which are essential products / services) operating as regional monopolies) – to break up Bell Corp into several little “Baby Bells” – all competing against each other: and it too never looked forward from then!

By the late CE 1970s, the USA-driven private sector was really forcing the hands of Australia’s Federal Governments to sell Telecom Australia Commission into their private sector hands “to make it efficient”. This would have to be the biggest oxymoron of that time as in the mid CE 1970s Australia was commonly recognised as having the best large national Inter-Exchange Network telephony infrastructure in the World. In comparison, the fiercely competing and fractionated USA telecoms networks could not implement (national) Subscriber Trunk Dialling (STD) which Australia had since about CE 1974!

Under relentless pressure from the USA economic tentacles; Australia’s Federal Governments organised the Davidson Inquiry / Report CE 1980 -1982 that paved the way to break up what was extremely efficient (in business terminology) to being extremely efficient (in economic theory terminology) by employing a high percentage of the population in businesses that would be bleeding essential funds from Australia’s telecoms infrastructure to fund totally unwarranted infrastructure competition / advertising / sponsoring / dividends and grossly overpay executives.

Since the circa CE 1960 there has been a very long string of technological advancements that have caveated telecoms operational and infrastructure costs (in Australia – and worldwide) that should have not only caveated the end user costs but also provided far better / complete / less expensive National geographic coverage.

The Davidson Inquiry and Report

As I pointed out before, in the mid CE 1970s the USA was in an incredibly powerful World position and it had literally ordered all western economies (through the WTO / CIA / IMF) - to devolve their sub-Government infrastructures to the private sector or face the same economic annihilation as dealt out to Chile (from the USA circa CE 1971). "***The USA Muscles its Way into World Dominance***"

Most European countries were in a desperate scramble to privatise their telecoms sub-government infrastructures in fear of what the USA would do if they failed to privatise (at least) their telecoms infrastructures.

Australia was slow to respond, but the Vernon Report in CE 1973 heralded the breakup of the then PMGs Department and as a first step in Australia; in CE 1975, the Whitlam (Labor) Government devolved the PMG Department into a few Commissions, one being Telecom Australia Commission.

This devolvement proved to be incredibly (infrastructure business) efficient because it removed a large continual stream of Bills relating to the internal finances and activities of what was the PMG Department from going through Federal Government.

Previously, these PMG Bills were debated through both Houses and eventually passed as Acts of Parliament – seriously delaying other activities of the Federal Government in both Houses, and seriously delaying what would be normal infrastructure business processes – that should be "apolitical"!

Consider also that circa CE 1980 the world of electronic offices was in its embryonic stages so the production and transferring / distributing of documents was still mostly paper based and extremely slow compared to post CE 2000.

On the "business efficient" side, Telecom Australia now had a clear mandate as it was no longer a part of the Post Office, or other entities like the Civil Aviation or Broadcasting – so its entire focus was now on producing the best telecoms infrastructure (without political intervention/corruption – i.e. without grants or special funding) for all Australia with the most appropriate and up-to-date equipment and at a minimum of cost to the end users – so all end users could maximise their commercial / business and community productivities.

On an interesting sidenote the Overseas Telecommunications Commission (OTC) was set up in CE 1946 to be totally separate to the then PMGs Dept. OTC operated in close parallel but at arm's length to the then PMG / Australian Telecoms Commission and both technologies were highly compatible / synergetic.

Even though the technicians from many areas (including the OTC, ABC, Civil Aviation etc.) were all (full-time) trained in the same Technical school(s) for the first year of their 5-year apprenticeship, these Technicians literally never saw each other's areas after the first year! There was also no cross-pollenisation of OTC / PMG Engineers until OTC was merged into Telecom Australia Corporation in CE 1993.

Structurally, the finances of the PMG Department had always "broken even". Over many decades (from the late CE 1880s) the massive productivities gained by advancing / new transmission and switching technologies had continually brought down the end user costs of telephone services. By the CE 1970s, the telephone was no longer a prime business facility of the wealthy and large business, and telephones were becoming far more widespread. "***Telephones Become an Essential Service***"

Concurrent to the new Telecom Australia Commission being formed in CE 1976, apart from the finances “breaking even”; it was becoming obvious that the new technologies around Solid State integrated circuits had already introduced considerable (business) efficiencies that could make telecoms infrastructure profitable (if the end-user prices remained high) – so in line with the long-standing “break-even” policy, the end user prices came down again (but this was not headline news). “***New Era of Electronic Components***”

The greed of those involved with finances and in the (Australian) Stock Market was insatiable and this country / economy leeching industry craved for a much wider spread of financial investments than Mining and Banking.

It came as very little surprise to me that Australian politicians at all levels (and their staff, those in the ACCC and the PC etc.) were systemically compromised by those in the private sector. As a direct consequence, the various Federal / State-owned Government Insurance Office (GIO) infrastructure businesses were being (force) floated into the competitive business world of the Australian Stock Exchange (ASX) with a great fanfare and spiritual chanting from the hypnotised (and also systemically compromised) ACCC / PC etc. mindset that “increased competition would drive down insurance premiums”!

These morons in the ACCC / PC etc. living in their own well-sheltered miniature infrastructure business cocoons obviously had / have no concept that essential products and services also optimally operate under massive-scale infrastructure businesses mindsets to very efficiently provide the essential products and services that were making Australia very wealthy. These large infrastructures have “rivers of gold” in their budgets and require virtually zero marketing advertising / sponsoring!

*Because these products and services are essential – people and competitive businesses will pay any price. The problem is that if essential products and service costs are high then this situation cripples the economy. Hence, in countries that have efficiently managed economies the cost of essential products and services are nominally zero – which maximises private sector discretionary business efficiencies (profitability) and optimises community wellbeing at all levels. “**Infrastructure Business – Competitive Business**”*

Conversely, competitive businesses implicitly trade / sell (only) discretionary products and services and therefore implicitly have considerable and very expensive advertising / marketing / sponsoring overheads that have to be paid by somebody – hence the profit margins are deliberately very high. Also, private sector executives (as part of the competitive business environment) expect and get (at everybody else’s expense) remunerations that are far greater than their infrastructure business counterparts (and the vast majority of their own competitive business staff).

With a change in Federal Government to Liberal – the stage was set for a set of political stooges to hold an Inquiry that would justify the splitting up and privatisation of the then Australian Telecom Commission. As far as I could find out, the four Engineers chosen to hold this Inquiry to justify the privatisation of Australia’s telecoms infrastructure had absolutely no telecoms engineering experience / industry knowledge, but were Mechanical Engineers.

This Inquiry started in CE 1980 and the three-volume Davidson Report was filed in CE 1982. A large portion of this Report was the Federal Government Bill – clearly specifying the procedure to strip Telecom Australia Commission out of Government hands, strip away some parts to facilitate a competition of sorts, smash the massive inherent efficiency in “Economy of Scale” and place these broken pieces of infrastructure business as competing businesses (against each other) in the in the financial framework of the Australian Securities Market (now the ASX).

Another large part of this “Report” clearly specified exactly how this new Telecom Australia Corporation is to be financially structured – right down to shareholdings – and how to flog off a substantial part of what was Telecom Australia Commission – that became Optus and later – directly into the hands of the Singapore Government. I would call that treason! But our fools in Federal Parliament(s) passed this without any delay – so there must have been tremendous pressure from the USA.

This Report gave a very brief overview of the then current network technologies, bemoaned the “tyranny of distance” a phrase that had been used for over a century! Primarily, Australia is physically much larger and with far less population than the (reference) UK – and long distance telephone / telex / data transmission (technology / installation / operation / maintenance) was the big ticket stumbling block that this Report had to “clear” to justify its’ purpose.

One of the “leaps of faith” in this Report was the heralding of (highly theoretical) Single Mode Optical Fibre (SMOF) as the immediate, low cost and new transmission technology saviour (which at that stage the then PMG / Telecom Commission Research Lab (TRL) had already spent several years of unsuccessful intense research (i.e. since CE 1975) with no positive answer!

In this Report, because the vast majority of telecommunications infrastructure was totally based around Voiceband telephony, the term “telecommunications” really meant “telephony”; so the meaning at that time was synonymous. Also at that time (CE 1980 – CE 1982), fundamentally, the only Telecommunications product was effectively the (Voiceband) Telephone / Fax / Dial-up modem - so it stood to reason that using the word “Telephone” it meant “Telecommunications”!

Even the Report’s Summary makes “interesting reading” because it clearly shows that Telecom Australia had an extremely limited range of products (basically the Plain Old Telephone Service (POTS) and Telex - automated Telegraphy) and that some new products and facilities were now gradually increasing – with dial-up Modems / Fax machines and first generation Private Automatic Branch Exchange (PABX) equipment – which was a revolution in business offices (along with electric typewriters and rapid advancements with in-office personal computers).

> *On a side-note it was interesting to see that the Davidson Report was in three A5 sized hard cover volumes that were most likely originally A4 paper from a then advanced technology: electric typewriter (mechanism) – and the diagrams later drawn into some pages – no pictures.*
>
> *Personal computers really did not surface until about CE 1980 and it would have been extremely unlikely if this Report was actually saved in a mainframe (tape memory) for production. No glossy meaningless and totally irrelevant colour pictures, obviously no wasted pages. This Report had all the earmarks of being totally manually constructed.*

Regional Remote telecoms infrastructure was extremely thin – but was being very actively worked on by TRL with their developing Digital Radio Concentrator Service (DRCS) technology. Although Telecom Australia network was world recognised as being one of the best managed and built telecoms infrastructures in the developed world – I could not find anything in the Report that reflected this exceptional standing!

In the years following the Davidson Report (CE 1982) that openly hallowed competition as the prime driver to bring down telecommunications costs for the end user, the operational costs for Telecom Australia Commission were already for many decades in continual slow freefall and the end user costs were continually falling – with or without the Davidson Report.

With these two issues raised and considering the push to privatise the then Telecom Commission (and break up this natural monopoly that it was deliberately operating as a "break-even" accounting system) – to "make it more efficient" was laughable (though not at all funny).

It was however a totally incorrect (and deliberately misleading) statement / belief that competition would expedite (drive down) the overhead costs and "make Australia's telecoms infrastructure more efficient"!

The Report had to find reason to show there was sound justification to break-up and strip the telecoms infrastructure out of the Government / Commission hands – to put this telecoms infrastructure in the hands of the private sector. The only "reason" they could find was that the Australian Telecoms Commission had to be highly inefficient.

So, this Report inferred that by having this (telecoms) infrastructure business operated in competition (against other telecoms infrastructure businesses) – that economically this would (usefully) employ more people in the Australian population in the telecoms infrastructure industry (and therefore be economic efficiency).

This (economically inefficient) argument was fundamentally flawed because employing a larger percentage of the population (i.e. being more economically efficient) would increase the overhead costs that would have to be reflected in higher end-use costs to cover the overheads – and this, in competitive business efficiency terms, is in itself far more inefficient!

Putting this another way; the Report also stated that introduced Competitive Business efficiencies would also drive down the number of people in Australia involved and/or associated with telecoms industry in Australia! So who is going to pay for the multi-duplicated Backhaul and Access network infrastructures - (Internal Plant and External Plant), extra Engineers, extra Field Staff, extra Technicians, extra support Staff, extra Boards, competitive Advertising / competitive Marketing / competitive Sponsoring?

This efficiency argument was blatant nonsense as you simply cannot have both increased portion of the population (usefully) employed and have lower end use prices! The (totally unnecessary) very expensive marketing / advertising / sponsoring costs have to be covered by the users of the provided telecoms services. So these (competitive) commercial costs actually drive end user prices up – not down!

This Report was right in that telecoms technologies / equipment reliability would continue to improve through the CE 1980s following the lead provided by rapidly advancing solid-state electronic technologies in the CE 1970s. This finding was "really old news" to those in the Commission. The timeframe to introduce new low maintenance transmission and switching technologies as outlined in the Report was far shorter than reality – which falsely inferred a high degree of inefficiency within the then Telecom Commission – but justified the Report's falsified findings.

One of the topics repetitively raised in the Report was the "tyranny of distance" in that (long-haul) transmission was very expensive to install and (relatively) high maintenance and required considerable equipment along the way. It was obvious that considerable input for this Report had come from TRL; that had a very well-established background in new transmission technologies including Plesiochronous Digital Hierarchy (PDH).

TRL were also instrumental in the introduction of LM Ericsson's AXE Digital (telephone) Switch technology (that has a PDH back-connection) and TRL had also already laboured for over six years (from about CE 1974) to try and make Single Mode Optical Fibre (SMOF) – but without success until mid-April CE 1986. "***The Sudden Emergence of SMOF***"

TRL had also developed the DRCS/HCRC technology (circa CE 1978 - 1984) that was then in full swing to provide Regional Remote telephone connectivity at a cost of about $471 M to over 14,000 remote premises. "***HCRC in Remote Australia***"

The Report seized on this opportunity to condemn funds being transferred within the Commission to support seemingly unprofitable Regional geographic areas (by deliberately excluding external accounting that would have clearly shown the immense value of Regional areas to Australia's (mining, export, food, community, etc.) economy – but seemingly unprofitable terms of telecoms infrastructure by referring only to internal accounting – as is standard practice in competitive business.

It seems that as the HCRC technology was now developed and had a couple of years (at least) to be rolled out in the Regional Remote areas, then the $471 spread over about six years is about $78.5 M pa. The Regional Rural areas have far more premises and a round figure of about $100 M pa would "cover their new build (telephone infrastructure) costs" and together that comes out at about $178 M pa.

So it is of very little surprise that this Report called on the Federal Government to provide an (indexed) annual injection of $177 M pa as a "Universal Services Obligation" (USO) to apparently direct this consolidated revenue to make apparently unprofitable areas in the "new Corporation" (i.e. Regional Business and Consumers) look to be profitable. "***The Privatisation Wheels Fell Off***"

With serious consideration that the operational costs of telecoms infrastructure had plummeted over many decades and that this highly economic trend was certainly not going to stop; it was ludicrous that this continual immense funding would actually get to where it was initially very ignorantly directed. "***Advancing FDM Technology***"

With any private corporation the prime objective is to pay shareholder dividends, and pay far higher "remuneration" to the senior executive ranks (that are stacked with lawyers, marketing and advertising types – that generally know very little about the technical / engineering going on in the business that makes the business profitable.

This activity was very much "a wolf in a lamb's fleece" situation in that the infrastructure is to be privatised, the cost centre is not being cut off - but the new private sector "competitive business" is to be repetitively given $177 M pa (indexed and now (CE 2021) about $233 M pa) and do as little as possible to keep this Regional (remote) telecoms infrastructure (just) working.

Second Wave of Electronic Components

The introduction of Printed Circuit Boards (PCBs) in the late CE 1950s was astoundingly productive, but few people realised the economic advantages that leapfrogged from this emerging technology. The construction processes for Printed Circuit Boards (PCBs) was originally a pen and ink process – as was then standard with mapping that was then photographically transferred to a silk screen for printing and etching etc. This was a very slow and frustrating process.

The late CE 1960s introduced the sticking down of special thick black tapes in various widths and a range of circular pad sizes on a mylar sheet that dramatically speeded up the layout process (as it became very easy and very quick to slightly alter the circuit layout) and later special "footprints" for Dual in Line and round IC made this process much more accurate and far faster pen and paper.

With the development of personal computers in the late CE 1970s, the University of Tasmania came up with a software program ("Protel") that ran on a personal computer under MSDOS. Through a process of interactive keyboard / mouse commands this software could be used to draw a virtual circuit board from a list of soft tape widths pad sizes. One of the outputs was a "picture" (and the reverse of the picture to considerably speed up screen printing process).

With practice this software was considerably faster than the earlier manual tape method but was a problem if earth runs carrying large currents had to have very wide and short tracks to counter distortion and isolate noise.

Some advantages of using this "Protel" software that the component layer could be automatically generated and it could run a parallel bus of say 16 wires to be exactly the same lengths between IC solder pins – substantially the chances of reducing timing errors on fast switching circuits. It also produced a component list and could work with multiple layers / earth planes etc. These days "Protel" is now a company called "Altium" and is on the ASX – primarily for its network design algorithms!

By the early CE 1980s PCBs went through another visionary advancement in having components that are "surface mounted" and the size (and price) of components could be considerably reduced – significantly increasing the upper frequency limits, and at considerably reduced manufacturing costs.

Circa CE 1963 active (digital) circuit components had then recently gone through another development phase where (digital) Small Scale Integrated circuits (SSI) with 14 or 16 dual in line pins was now circa CE 1975 largely Medium Scale Integrated circuits (MSI) with 24 to 40 dual in line pins that now did the total function of a complete earlier generation PCB consisting of say 20 to 60 SSI chips. "***New Era Electronic Components***"

During that time (i.e. circa CE 1975 - 1980) the production costs of MSI analogue / digital conversion integrated circuits considerably reduced, making it economic to provide individual and much cheaper telephone circuit line circuits instead of telephone line concentration circuits with fewer expensive analogue / digital conversion circuits.

The concept of MSI and LSI chips as relatively inexpensive "Functional Blocks" was starting to become far more common. Double-sided PCBs facilitated the use of "Earth Planes" and "equal length parallel digital busses" that are critical when

designing digital circuit boards (that have frequencies extending well into the GHz range).
In (late) parallel with developments in solid state junction transistor technology was the concept of Metal Oxide Silicon (MOS) and Field Effect Transistors (FETs) which meant that initially single units then pairs then tens then many tens of transistors (and/or FETs) could be very inexpensively printed (as per Medium Scale Integration - MSI) then etched into and onto a thin layer of silicon (called a wafer). In fact, this process could be repeated hundreds of times on the single silicon wafer – and the productivity was tremendous!

There was and still is immense inter-business competition in the manufacturing of solid state electronic components. This competition effectively started in the early CE 1960s and has continued through until current times (i.e. at least 60 years). The prime reason why this intense competition continued was that the manufacturing costs were very low and the market manufacturing is relatively small – so the advertising and marketing costs could be comfortably absorbed in the product.

What is extremely interesting is that there has very rarely been any competition / rivalry to build the same linear chip. What is common practice is that business one builds a conceptual chip and company two builds a slightly different chip with somewhat different characteristics (e.g. a much faster slew rate, the output current is significantly greater, the open loop gain is significantly greater, four op-amps on the one chip, higher input impedance etc.). So the patents are not encroached but the make-up in the chips is significantly different to do much the same purpose.

With digital chips there was considerable inter-business competition because the make-up of these chips were/are virtually identical as they performed the identical functions and had the same pinouts. My gut feeling on this was that competition was very strongly encouraged / driven (from primarily the USA Federal Government) so that if one business had a catastrophe then the USA (military / large business) would not be set back some years and other manufacturers could potentially fill the supply shortfall with virtually no delay.

Competition Business mindset resulted in the vast majority of silicon chips to be manufactured in Taiwan (which is virtually part of China). With the more recent (highly predictable) rising of China's economic strength (to be far greater than that of the USA) the entire western economy is now in a massive predicament – totally caused by the competition business mindset.

One of the problems with manufacturing silicon chips is that pure water is necessary and distilled water is by no means pure enough – and the rooms have to be "really clean" – which can take months to get to this state. So having a catastrophe is not at all far-fetched especially when the consideration is that with large scale integration (LSI) of processor and memory chips - each having millions of active devices.

With MSI and LSI technologies now being central to all telecoms and computing technologies; it is absolutely zero surprise that governments of major economies have very strong (and highly expensive) covert interests in the resourcing, development and manufacturing of semiconductors in countries under their military (and political) support. In a very similar mindset there is an immense amount of (very expensive overhead) covert espionage to steal inventions and production techniques – not just in every country but between countries and economies.

After all – why spend resources developing new technologies when it is far easier to send university students to steal new technologies from a country (like Australia) that seems to be totally pre-occupied with an emotional issue like "Climate Change"!
With Telstra now privatised and global engineering now standard practice – virtually all telecoms manufacturing in Australia had ceased by about CE 1985 – leaving a few assembly plants so Telstra (in blind treason mode) wiped its university-attached and critically valuable Telecom Research Labs (TRL) facility by about CE 1990.

Collectively, Federal politicians have ignorantly scuttled Australia's TRL and CSIRO which were the core of advanced Australian research, development for manufacturing and passed research into the Universities that (with the faulty HEX financing – no fail possible concept) facilitated the Universities to be very highly infiltrated by foreign students. In the last 20 years there are already many instances where original research (and development) has been student-transported to foreign countries that have immensely benefited from this data and information at immense financial / business / economic expense to Australia's economy.

Digital IC's using Metal Oxide Silicon (MOS) technology used considerably less power than TTL technology, so the equivalent chips were far cooler and the MOS chips could be made considerably larger with thousands of active components (functionality) on the one chip – leading to Large Scale Integration (LSI) – that was barely more expensive to manufacture per chip than MSI technology!

Underneath all this with digital computers was the concept of "wired" circuit boards – with very thin lacquer insulated wires "acoustically welded" at the terminal points and the wiring later covered with epoxy resin – before the (solid state) components were added and the board "flow soldered". Also, these boards were extremely consistent and very compact – so what would have taken a complete rack (600 mm wide and 2.4 m high) could be comfortably fitted on a wired circuit board about 500 * 500 mm.

The next development phase was MOS / LSI technology chips in as "micro-processors" that again were much smaller and far faster than their valve grandparents – and far less expensive to run (and extremely reliable). Personal Computers (PCs) became available and popular by the early CE 1980s.

Active (analogue) circuit components had since circa CE 1965 also considerably advanced with low noise front ends, much faster slew rates, far higher available output currents (and voltages) and the production costs of analogue / digital interfacing was plummeting. "***Digital Voiceband Technology***"

The Random Wire Jointing Travesty

Circa CE 1970, the urban (Metropolitan and Regional) Customer Access Network (CAN) now largely underground cable and (mostly) inside 100 mm diameter asbestos/concrete or earthenware conduits about 600 mm under the footpaths (and about 1200 or 1800 mm below crossing under roads) with a range of service pits containing the cable joints. "***Cabling the Junction and Access Network***"

Similarly the pair copper metro Junction Network also used the same underground conduits to provide (mainly) Voiceband connectivity between Telecom exchange sites. In Regional areas, most inter-exchange network transmission was by ploughed-in Transit cables and the remaining open wire lines were gradually being taken out of service and being replaced by underground cable technology. "***Cabling the Regional Transit Network***"

Finding Voiceband transmission faults in Loaded Cable Junction and Transit cables was notoriously time consuming and extremely difficult. It was quite common to have a rather high percentage of Metro Junction and Regional Transit links that had faulty Loading coils. In most cases the Voiceband response was (slightly to seriously) muffled and very few Technicians / Technical Officers had the skills or equipment to identify the problem – let alone actually track down a faulty Junction or Transit.

> *While working in the NSW Design Lab as a Technical Office circa CE 1980 we were approached by a country area (I think Armidale) to assist them with a tool to help them identify faulty Loading Coils in Transit Cables.*
>
> *What they had was a cluster of Loading Coils in a wooden box with a set of key switches that could short a winding / reverse a winding of any number of Loading Coils plus this box had a number of resistors and capacitors in it to roughly emulate the Transit cable characteristics.*
>
> *This was a rather ingenious Loaded Cable Emulation box. The concept was that by using a Pulse Echo Tester (PET) on the line and the box in succession it was possible to match the time varying reflection impedance of the line and the settings in the Box. Considering the limited tools / components they had, this was a brilliant concept.*
>
> *Once we traced out the circuit we then made a printed circuit board design with board mounted switches and the (now precision) components soldered into the circuit board. This structure was far more compact and it fitted into a compact box making it far easier for Field transport and use.*
>
> *Using this Loaded Cable Emulator took a bit of inherent understanding of what should be in the cable being tested but it was rather clear that if there was a coil wired in backwards or half wired in or not at all then this really stood out on the Pulse Echo Tester (PET) screen.*
>
> *The Lab Techs made a few of these Units and my recollection was that this Unit had intense use back in the country area, and it was loaned to other Districts in the Region to fix up their Transit cables.*

The standard fixed Access Network structure starts at the Local Exchange site with the Main Distribution Frame (MDF) with (usually) several Main Cables of say 1200 or 2000 pairs terminating on the MDF and run underground in 100 mm conduits to large Service Pits usually 50 to 300 metres away.

In these large Service Pits the Main Cables are each jointed with a few Intermediate cables (usually 400 or 200 pair) and these Intermediate Cables are fanned out in the Exchange Switching Area to (mainly) provide indirect connectivity to premises in the urban areas. These Intermediate Cables can be anything from say 50 metres to almost 3500 metres long and (usually) terminate into a Sputnik or Pillar that is offset from the footpath alignment.

When those Main Cable / Intermediate Cable pairs were all jointed; the whole joint in the Service Pit (that now looked like a hand with extended fingers) was then lead-sheet sealed / sweated to being airtight – and hopefully never touched again.

With pair copper cables going to non-urban areas, these Intermediate Cables are typically 50 pair and use 0.64 mm pair copper instead of 0.40 mm pair copper to minimise the resistance (and attenuation) losses over much longer distances than the nominal 4100 metre maximum urban lengths.

At the Sputnik / Pillar the "Outer" cables (typically 50 pair polyethylene insulated 0.40 mm pair copper) connect out to about 400 metres maximum towards the premises where the "Drop" cables (typically 2-pair polyethylene insulated 0.40 mm pair copper) connect to the Premises terminal block.

The number of transmission faults involving external plant (i.e. outside the telecom equipment buildings) had plummeted in comparison to this earlier infrastructure being open / overhead aerial wire technology. "***The Economy of Pair Copper Cables***"

My understanding is that while these (paper-insulated) cables were being manufactured (in the CE 1930s depression up to the late CE 1950s) the length of the bare wire was not always enough (or it could break). It was common practice during manufacture to joint single wires inside these cables. Otherwise, all the cables' wire joints were at the cable junctions/joints! "***Highly Economic Underground Cables***"

<u>In almost all cases all the hard faults (open circuit, short to the cable sheath, short to another wire) are in the cable joints and all the soft faults (loss between, loss to earth, excessive crosstalk) are in the cables – between the Service Pits!</u>

Lead sweating of cable sheaths was a workmanship art that was common (until the late CE 1960s) and very professionally done. With the introduction of plastic sheathed cables (in the early CE 1960s) the art of lead sweating has been largely lost and most of those that did this artful work had retired well before CE 1990. "***Massive Productivity with Plastic Insulation***"

The process of splitting a large Main Cable into smaller Intermediate cables via a lead-sheathed joint in a large Service Pit worked very well for many years – but inevitably the situation happened where one of the wires in one pair was faulty. The standard fix was to transfer the customer connection to another (non-faulty) spare pair – but in the process, the number of spare pairs kept reducing until eventually there would be no spare pairs in a particular Main Cable or Intermediate Cable.

As (most of) these faults were passed up to (District) management via the various Foremen / Line Inspectors; the faults were (usually) progressively tallied and late / reactive decisions made to open and repair Main Cable Joints to try and avoid crisis situations (of no main cable spares – or the need to purchase and install extra cabling – which was very expensive purchase and install).

Gradually over many years this problem of faulty joints (relating to Main Cables in particular) got considerably worse with several Main Cables having too many (single wire) faults in them – leaving not enough spare pairs for customer connectivity.

It seems that be the early CE 1980s, (after the Davidson Report was released and privatisation was obvious); in desperation to maintain a service connections (and "look good"), the general "fix" was that line / field staff would find the single wires (of pairs) that were not faulty and pair these wires up – and it seemed to work for years!

Somehow – the national edict came out that "**Random Wire Jointing**" was fully acceptable. Now – cable joints could be done far faster - by simply joining wires – whether they are pairs or not. Also, about that era, the use of Fax machines in offices had peaked and the need for extra telephone lines to a high proportion of premises had become an imperative. "***Telegraphs to Telex to Fax***"

The (short term) productivity of this "**Random Wire Jointing**" initiative was really high because a major cable joint could be done in much less time. In any case, the then new (hand-held) wire searching technology could sniff out (actively connected) wires in a few seconds – so having pairs did not seem important (as everything "worked")!

Finding (active) two wires with a wire sniffer in say 400 was far faster than working through say 200 line pair groups by colour, finding that group, finding / isolating that pair. Also sniffing down a "riser" in a pillar took only say ten seconds – where otherwise this could take some minutes to manually locate the pair by trial and error.

One of the structural management problems that had most likely existed from the CE 1930s depression times was the large number of management / supervision levels that was up to 13 from the top (CEO) to the bottom. This basically meant that one person was typically in charge of two others (whether they knew that or not), and the process passage of reporting "up the chain" was virtually zero – or was "lost".

So – in the case about "Random Wire Jointing" most District Managements (and their staff) could not be aware that customer complaints had a direct relationship to flawed field work practices of a considerable percentage of their field staff!

> *Shortly after Telecom Australia was corpratised / privatised in CE 1989, seven National Working Groups were established to co-operatively investigate a wide range of nationally escalated Customer complaints relating to (systemic) poor quality Voiceband telephony / Fax transmission etc. issues. (As it happened I was very heavily involved with six of the seven National Working Groups.)*

It took more than a few months to correlate the differences with multi-decades set-in work practices in different States – capitalise on the good work practices and weed out the bad work practices to maximise the life of the existing cable infrastructure and minimise future line maintenance issues and costs.

At first these Quality practices were warmly appreciated by executive management (who were obviously of the Infrastructure Business mindset), but with a more recent change of executive management (who were obviously of the Competitive Business mindset – many of whom came from the recently merged OTC and from "outside"); they were only too keen to close the books and praise / take the claim for very short term "achievements".

One Group set up a database to track a range of fault repair activities - only to find that after about six months they identified that some Lines (Field) staff (because of their poor work practices) were leaving a trail of delayed destruction that did not show up until some months later.

Consider the Pareto Principle with say 20% of Lines staff causing 80% of the faults – if the percentage of Lines staff inadvertently causing faults were dropped to 2% then this still leaves about 8% of totally unnecessary faults – so the imperative was to eradicate all poor lines practices!

Another Group investigated the various lines maintenance techniques used in different States - and identified many instances of incorrect and potentially flawed practices that were locally accepted as “normal”. Another Group had worked out that the low maintenance cable joint life is in excess of 13 years. Another Working Group was looking at new technologies and raised the urgent necessity of replacing the now aged paper-insulated pair copper technology with Single Mode Optical Fibre (SMOF).

This trail of bad line maintenance practices was a long list – and it was obvious why that nationally pair copper cable Access Network infrastructure was in such a mess!

These Working Groups had the general thinking of having Quality-based Methods and Practices (i.e. Infrastructure Business mindset) done, then the overall maintenance cost would be minimised, maximising customer satisfaction.

With the transfer of Telecom Australia Commission to become a Corporation (circa CE 1989) the new Board / Executive focus (being now Competitive Business minded) blindly moved to maximising short term profit and reducing overhead expenses.

When these findings were presented to the (new) Senior Executives (Competitive Business mindset of Telstra) – the response was chilling. The push was to now make (short-term) profits (while maximising executive pay) – and employing (Lines / Field) staff was a cost they (Telstra) thought they could do without!

Apart from the Working Groups being immediately disbanded, their work and findings being totally disregarded (including upgrading the CAN with SMOF - that money was for shareholders); it was a simple (and short-very sighted) decision to forcibly retrench thousands of well-experienced Lines Field Staff and where possible; sell-off all the external plant equipment and associated land for short-term revenue!

It didn’t take too long to realise that Telstra as a corporation were then desperately short of Lines Field staff (that had requisite experience and Quality work practices) - so the remaining (Customer Services) Internal Plant staff were tasked to also work on External Plant infrastructure.

Telstra was now in a bind where the Board / Senior Executives had not read into any depth nor understood the gravity of Reports regularly sent to them, and these new Senior Executives had thrown overboard the highly skilled / experienced Lines staff that they now urgently needed!

Adding fuel to the fire these inept Executives / Board then facilitated Contractors to be employed where they previously had full-time highly skilled field staff. The underlying problem was that the Contractors work to a Time standard and not to a Quality standard – and most these Contractors had a rather limited English vocabulary (and also lacked Quality expertise / training).

So, with this Competitive Business mindset, random wires were connected with the pairs split up everywhere and in many cases the crosstalk became horrendous! Oh – (of course) there were no cable records relating to what pairs went where, so it was a process of search and seek with a cable identity finder.

> *Circa CE 1993 I was working in Telstra as the (non-executive) National Manager Service Quality and we were working through the then floods of complaints about excessive noise in telephone circuits.*
>
> *This fault problem was particularly difficult to re-enact – but when we did so, we discovered the noise was actually crosstalk. After some detailed investigations we finally identified that the pairs of wires used were not actually pairs but random wires in the same cable(s)!*
>
> ***It finally dawned that cables were being jointed with random wires (not even pairs) and this was the cause of these floods of complaints.***
>
> *The edict should have not have been "Random **Wire** Jointing" but been "Random **Pair** Jointing" there was a limited amount of rework where some of the worst offending Main Cable joints were opened and the all pairs re-terminated by pairs and all these Main Cable joints resealed.*
>
> *In Darwin, there was a massive amount of complaints about excessive crosstalk and a lot of noise. It came down to a large Intermediate (Access Network) Cable about 2 km to 3 km long that had several joints that to be completely / totally re-"paired" and re-joined. This process took at least a month to systematically work through and fix and the customer complaints simply vanished!*

I am sure that from about CE 2000 onwards a sizable proportion of "slow" ADSL2+ issues / complaints were entirely due to excessive crosstalk in the ADSL frequency range that would have been attributed to "crossed pairs" (from the highly flawed "random wire jointing" process) that at the Voice Frequency part of the spectrum were not obviously recognised, identified nor corrected.

The main issue about abnormally slow ADSL2+ services I believe should have been attributed to the Main / Intermediate cables being internally wet – particularly when they cross under a road (where the conduit/ cable depth is significantly more than 600 mm below the road surface). "***Competition Wrecked Australia's ADSL***"

What had not become obvious in time was that a percentage of the cable pairs went faulty, and they were swapped out of service (which was really easy to do with a large economy of scale). Because there were virtually literally no records of which pairs went where (apart from the gross count of cable pairs in cables), there was no detailed accounting of what pairs were failing and what the faults were and when these faults happened. Yes faulty pairs were "tagged" so they didn't (generally) get re-used, and in general the cable pair records were barely there (if at all).

By the early CE 1950s, it became well known that because of bolt lightning and cable movement that (lead) sheaths did not remain watertight and water ingress was causing almost unrepairable damage to the paper insulation – resulting in telephone connection problems, where the line signalling would be held up with low resistance ("losses") between the pairs and/or "losses" to earth.

The then brilliant repair strategy was to lightly pressurise the Customer Access Network's big Main and Intermediate cables (leading from the Exchange sites and large Service Pits) and the Inter-Exchange Junction / Transit; lead sheathed pair copper cables with a couple of atmospheres of dry air to expel the water moisture. "***Bolt Lightning and Pressurised Cables***"

For decades, this virtually perpetual cable maintenance technique worked very well (and most internal plant technical staff and external plant lines staff didn't understand or know why this equipment was so vitally important).

Over considerable time the water in these cables substantially reduced and virtually dried out in many cases, so a high percentage of "faulty" pairs then tested as "good" as they now had no appreciable resistance between the pairs or to earth. As the customer numbers were considerably rising there was little option but to re-use these previously faulty pairs (as good) to keep up with the urban growth - and not install new cables as this was a very expensive process.

What became more (quietly) obvious was that there were a wide number of work practices that (external plant) Lines Staff had created / developed / modified over some decades and most of these practices were quick / shoddy / poor / unreliable and it seems that those inspecting the works either did not know any better and/or did not inspect (and/or take corrective action).

> *Circa CE 1991, in discussing some of these pair copper cable problems with a very "hands on" bright Senior Engineer; Ian Hoy from Rockhampton, he described in detail how the Field / Lines Staff there had as common practice "triple connected" pairs in the Main / Intermediate Service Pits joints with clip connectors so that two Intermediate cables connect from the one main cable and the phone service (line connection) could be picked up from either Sputnik / Pillar. Their reasoning for doing this was that it is far quicker to "find a pair" and connect a customer.*
>
> *He said that the Field / Lines Staff had no concept that the clips were not made for three wires, the chance of faults is significantly increased, the documentation is not there and frequency response would be severely compromised by the capacitance in the parallel cable pair connection.*
>
> *It became quite clear to us that the Field / Lines staff whose primary focus is to work with these cables, have had no formal education relating to the electronic characteristics of these cables. The education is rather basic and physical – and totally lacked any theoretical relationship to practice.*
>
> *Yes they knew that water can affect the service of the cables – but that was about it. If they had been educated to this level then many would have walked away very quickly and found some other physical work / job and conversely if they had been properly educated then the problem of poor jointing practices would have been a non-issue.*

As the number of available pairs in these Main and Intermediate cables critically reduced it seems that many of the external plant Lines Staff resorted to "Random Wire Jointing" (as a standard practice) to keep fixed access customer connected. This practice widened such than new cables were not pair joined but random wire joined; resulting in excessive crosstalk (and later also had a major bearing on unexplainable slow ADSL speeds).

Shaking the Recession Mindset

With the PMG / Telecom Australia Commission; most of the older engineers in the CE 1950s, CE 1960s had come through the CE 1930s depression and most of the older engineers in the CE 1970s, CE 1980s had gone through the WW2 depression – so austerity and/or human wellbeing was usually on the top of their list!

Concurrent with this Recession mindset was the associated mindset to “employ” as many people as possible – so these people would not be on a pension and would have an active employment following the generational trauma of WW1, the great depression of the CE 1930s, and WW2. In a high proportion of cases these post traumatised people would not normally be employable (in the private sector) because of sustained physical and mental injuries.

> *In the mid-CE 1970s I was tasked to be in a team (as part of supervision / management training) and we had to look at work processes. Our team of about 12 people looked at the Petty Cash process in our Metropolitan Office and part of the process was to work out a start to finish “flow chart” of the steps from purchasing a minor item to closing the accounts.*
>
> *It came as a rather big surprise that the flow diagram (with detail) of this process literally filled a wall and “employed” about 14 people full time to “process Petty Cash. There were many areas in the flow diagram where the process “work” was really trivial – but it employed somebody!*
>
> *When we worked through the processes it was obvious that only three (or four) steps were necessary and most could be done by two or three people (before the widespread use of personal computers).*
>
> *The surprise outcome was that about 10 people were “retired” and the Petty Cash process was severely simplified – and it worked perfectly. What we thought was a management exercise became hard reality.*
>
> *From my angle, I was then forever on the lookout for better and more efficient processes – and it became obvious that there were many areas around the then PMG that employed lots of unnecessary staff – but kept these people off the pensions (and they had a meaning in life)!*

The continual driving down of end user telephone costs was purely due to slow but continually advancing technologies that over successive decades repetitively resulted in waves of less expensive equipment and dramatically less management / technical / field / service / switchboard staff overheads per Voiceband channel.

<u>Telecom Australia was a Commission – not a Corporation (there was zero competition and zero overhead costs of advertising and marketing) and yet the end user prices continued to absolutely plummet over many decades.</u>

<u>The prime reason why prices were continuously “driven” down was that sequentially, over many decades, new telecommunications technologies evolved from the previous generations with far less sunken and operational costs and greater / appropriate capabilities.</u>

From at least the early-CE 1930s until at least the late-CE 1980s the Engineering budget process was inherently very tight as this was Commonwealth (taxpayers) funds – so it was to be wisely invested and there was intense scrutiny.

The exception was at the end of the financial year when the accounting was (manually) re-done and a small percentage of projects were "late-scrapped", resulting in a flood of money that had the be spent – or that "extra amount" was taken off next years' budget (as a very stern lesson to ironically - not waste taxpayers money)!

In almost all cases the extra money was used to "forward purchase" equipment that was accounted into the following years works programme – that was usually reduced by nearly the same amount. It worked, but was "messy accounting"! It was not until the late CE 1980s that electronic data processing / databases became a desktop technology that "messy accounting" was largely eliminated. "***Productivities of Electronic Databases***"

Complimenting this recession mindset was the then standard process of gradually increasing the telecoms Backhaul and Switching infrastructure to generally match the population growth – but keeping this augmentation minimised in non-metropolitan areas because the cost of long-distance transmission equipment and bearers was so expensive. "***Davidson Inquiry and Report***"

As Telephone use became far more common as the overhead costs of the newer technologies capitalised on "economy of scale" mass production (and competition had absolutely nothing to do with dramatically dropping telephone call costs from CE 1880 until now). "***Telephones Become an Essential Service***"

The "Recession Minded" thinking was very much in line with the economic Competition model! Here is why:

As there were three or four Australian manufacturers of this FDM equipment and the total requirement was for about 200 FDM systems in total per year. These quantities were too small to invoke the considerable productivity efficiencies available through "economy of scale" of mass manufacturing methodologies. One Australian manufacturing business could have been used for each telecoms technology and this could have provided the "economy of scale" necessary to manufacture and do productive research on the side. This did not happen.

Because of continual / gradual technology advances in the CE 1960s and CE 1970s, the electronic component packing density considerably increased as did the use of ferrite magnetic materials (for complex band-pass and low pass filters – an imperative part of FDM technology), plus the use of new technology linear integrated circuits allowed considerable shrinkage of the circuit modules that make up an FDM terminal (and FDM repeaters). "***New Era of Electronic Components***"

As a result of these gradual technology advances it became possible to have more than one Voiceband channel on a printed circuit card – but this meant manufacturing a newer version of the existing technology – which was physically incompatible with the previously manufactured versions. So, Voiceband Modules/Cards slowly advanced to two circuits, then three circuits then four circuits per Module/Card.

The "Recession Mindset" mindset is ignorantly almost identical to the "Competitive Business" and here is why:

- *Much longer Non-urban Access Network distances are far more expensive than urban Access Network distances.*
- *Regional inter-exchange distances are (much) longer than intra-Metropolitan distances therefore requiring considerably more expensive long-haul equipment (and maintenance).*

- *Telephones are (apparently) used more in Metropolitan areas than in Regional areas.*

Or put another way – the amount of network funding in non-metropolitan areas will be absolutely minimised to maximise Competitive Business profitability at immense expense to the communities and businesses outside the metropolitan areas!

The difference is/was that the "Recession Mindset" were ignorant of the fact that they through over-reaching with thrift practices, inadvertently caused Regional area to be under-serviced, where with the "Competitive Business Mindset" there is full intent to under-service every (Regional) area that does not provide short-term (internally accounted only) maximum internally accounted profitably.

Consider a Town that backhaul-connects to its District City via a 20 pair (amplified) Loaded Cable system over say 60 km, and the cable is 20 pair 0.80 mm; this connection is commonly running in heavy congestion and the "Recession Mind" thinking is to increase the backhaul Voiceband line count from 20 to 21 Voiceband Channels to relieve the network congestion to/from the District City Switch.

A sensible fix (in my thinking) would have unloaded two pair of the Loaded Cable and installed a 12 channel FDM system over these two pairs, with 12 Crossbar "T" Relay Sets (with two transmission / Switching interface circuits per Relay Set = 12 circuits), and reuse the now spare 2 Line Relay Sets (4 circuits) at some other location. This would provide 18 + 12 = 30 Voiceband Backhaul circuits and eliminate the Network Congestion in and around these areas for at least the next five to fifteen years.

A "Recession Minded" fix would have unloaded two pair of the Loaded Cable and installed a 12 channel FDM system over these two pairs, and purchase only one (3 Voiceband channel) card at each end (instead of four (3 Channel) Voiceband cards as a fully-fleshed compliment) for the FDM system as this would "save money"!

Similarly, to keep the expenditure at an absolute minimum, install only 2 Crossbar "T" Relay Sets at each end (two transmission / switching interface circuits in each Relay Set = 4 circuits – but use only three circuits), and reuse the now spare 2 Line Relay Sets (4 circuits) at some other location.

This would provide 20 – 2 + 3 = 21 Voiceband Backhaul circuits and the Network congestion is still there when remeasured (that year or the next year).

It is now three years later and the same Town / City again has continuing Network Congestion. The "Recession Minded" Network Planning engineers have finally conceded that another two circuits are necessary (bringing this up from 21 to 23 – and have now passed this over to the "Recession Minded" Transmission Planning engineers – so this can be potentially scheduled into next year's budget.

There is a 12 channel FDM system already in place but it has only one three Voiceband channel card at each (Terminal) end, and these cards are being partially utilised. So the logical move is to purchase another pair of 3-channel cards from the manufacturer - and the Switching Planners would have arranged to install another "T" Relay set at each end to interface extra two channels in the FDM transmission system to the Crossbar switches! Well – that was straightforward – wasn't it?

Problem – that FDM transmission system stopped being manufactured a year ago, there are no 3 Voiceband Channel Cards in stock, but a new version 12 channel FDM transmission system is now available. This new version has four Voiceband

Channels per card – not three – and these Channel Cards are incompatible between the versions (and manufacturers)!

So – a new 12 channel FDM transmission system is purchased – but (again – in "Recession Mindset") not fully fleshed out with only two instead of three 4-Channel Cards in each terminal (allowing for 8 Voiceband channels not 12). That was really "Recession Mindset" thrifty!

The three Voiceband circuits in the earlier FDM system are now re-wired from the pre-existing "T" Crossbar Relay sets to the new 12 channel FDM system, and the two new circuits are also wired to the new "T" Crossbar relay set. The Crossbar exchanges (at both ends) are now re-graded for the two extra circuits so they can through-connect and "eliminate" network congestion.

So now we have the old FDM system left in situ at both ends (missing three 3-Voice Channel cards at each terminal/end); the new 12 channel FDM system with five out of eight channels being used (and missing a 4-Voice Channel card in each terminal/end) and three "T" Crossbar relay sets (capable two circuits each – i.e. six circuits) connecting with five circuits (not six circuits); and the Town/City network still with some network congestion during the busy hour time – for many years!

Had the full complement of Voiceband Channel cards been ordered then "economy of scale" discounting would have almost certainly been invoked – and the full complement of Channels cards would have be the same price or maybe only marginally more costly than providing 25% filled FDM system subracks!

Every year or so, primarily because of competition between the Australian telecoms manufacturers, most stopped manufacturing their particular model of FDM system and "upgraded" their designs to a new model – and in the process, the design of the Voiceband Channel cards were significantly changed – meaning that the new model card would not plug into last version's subrack, and the old Voiceband Cards were no longer manufactured!

On the back (and front) of all this there was the "Recession Mindset" that if this upgrade was extensive (i.e. more than say two lines) then there could / would be no need for the install staff to come back to this area next year (or even in five years). Those people could be out of continual work with Travelling Allowances (TA)!

On the side of all this was the (Communications) Union that was very head-strong about people being employed and not working too fast as this showed up other far less diligent (union heavy) workers that were either lazy and/or had skipped work to go the hotel for regular "long lunches"!

Compounding this problem was that virtually all positions held were based on seniority – not expertise (and this was a spill-over from WW2 at least). Consequently most (senior / executive) management positions were "Acting" because many senior positions were occupied by people on Long Service Leave (LSL) instead of resigning, and those filling the shoes were afraid of making (obvious) decisions. So new initiatives were usually left for several months – if not for several years!

The Unions had positioned themselves such that all promotions went through a three-person panel of which one was a Union delegate the other a Clerk and the third was a superior of nominally two levels above. As the decision was (almost always) a majority rule and the clerk was the (usually) over-ridden / steered by the Union *delegate (before the panel interview / meeting) – the Union virtually always had their choice of promoted (Union) candidate.*

The installation and commissioning process of Crossbar switching technology and FDM carrier systems involved teams of 2 to 4 Technicians / Technical Officers that would continually travel over the State (continually picking up (expensive) Travelling Allowance) as they moved between country cities / towns / villages to install this equipment; and the Regional network stayed in continual network congestion for decades – (uselessly) employing many people for decades.

With AXE digital exchange technology, the amount of wiring was dramatically less than for Crossbar (saving some months per site) so the racks for AXE exchange could be bolted down in a few days and the complete exchange could be assembled and fully wired up in a week or two.

The big (time) cost was that of commissioning each of the AXE exchange cards. This process was hellishly slow by todays' software standards where it then (initially) took a couple of months where today (2020) it would take a few hours (if that) to configure and commission a 10,000 line AXE telephone exchange.

The natural backhaul connection with AXE technology was 2 Mb/s PDH and/or 8.4 Mb/s PDH transmission – which at that time certainly did not "fit" with the analogue Voiceband-based Loaded Cable and FDM Voiceband channel technology of the then Inter-Exchange Network.

The Recession Mindset was suddenly broken in the mid CE 1980s, as the then widespread introduction of AXE digital telephone switches were then commonly back-connected with 2 Mb/s PDH transmission technology and not individual Analogue circuits. These 2 Mb/s PDH transmission connections contained 30 digital Voiceband channels for Inter-Exchange (Metro Junction / Regional Transit) Network connectivity and Trunk Network connectivity – but it took time!

Network Planning (Engineering) was in a state of shock as the incremental steps of Inter-Exchange Network channel numbers suddenly stopped being one or two channels (per year) and leaped to a minimum of 30 channels (in a (new) 2 Mb/s link)!

By about CE 1987 the process of small and highly repetitive incremental augmentations to exchanges had come to an abrupt halt and it was now large block augmentations that were now spaced out by several years – and the number of fixed access telephones was starting to plateau out as Fax machines had become a business imperative and the use of Mobile devices was very rapidly increasing.

Short-Sighted Competitive Directions

One of the Davidson Reports' chapters was about the need to replace old equipment with new equipment – something that had been continually going on for many decades. This process had been rather prudently very well managed by a team of highly talented and experienced Engineers using available technical resources over decades of bleak economic situations. "***The Davidson Inquiry and Report***"

Part of this rather conservative and commonplace equipment replacement process habitually involved the installation of new technology equipment in a location immediately followed by the re-distribution of recently de-commissioned equipment to extend the low maintenance to other locations that still had the older technology and concurrently this maximised the ROI of this older equipment.

In November CE 1986 I was a Class 1 Engineer in NSW on rotation to learn engineering and at that time assigned to "Country Install 2" for about eight weeks. The population at Springwood (in the Blue Mountains about 80 km west of Sydney) had considerably grown in the past 20 years. The Crossbar switch equipment that was installed there (about CE 1970) had literally run out of customer numbers – and this exchange desperately needed another 1000 customer lines added as soon as possible.

The initial problem was centred around the Western Cable from City South to Bathurst passing through Springwood. This cable was "old" and fully occupied with FDM transmission systems, so there was no way that extra channels could be "made available" (but I was also aware from other experience that this cable would be replaced in the next few years with the brand new technology of Single Mode Optical Fibre (SMOF) using PDH transmission instead of FDM. "***The Sudden Emergence of SMOF***"

Dropping in a fully fleshed Pair Gain Systems (240 lines and a PDH back-end) was not an option, and neither was installing an AXE exchange at Springwood as both these impacted on the FDM-based Western Cable.

The third option was to augment the pre-existing Crossbar switch by 1000 lines and schedule an AXE switch a couple of years later – as the Western Cable would by then have been replaced by SMOF technology. (All available cable install crews were getting involved with the new SMOF cable (with PDH transmission) technology about to be rush-installed between Melbourne and Sydney).

My understanding was that in the Sydney Metropolitan area (consisting of 124 exchange sites); there were a few exchange sites that had recently upgraded to LM Ericsson AXE switching equipment, temporarily leaving ARF / ARE Crossbar equipment in situ, unpowered and disconnected.

It was a relatively simple (and inexpensive) process to disconnect the cabling to this now unused equipment; unbolt, transport and re-install the necessary racks of SLA/B and SLC/D Switches, LR/BR Relay Sets etc. to Springwood exchange to provide the extra 1000 customer lines.

As a physical check, I went to Springwood exchange to ensure that the floor space was not incidentally used for something else and not included in our documentation. There was plenty of room and these Crossbar switches, relay-sets etc. could be installed with a minimum of issues. The *local switching maintenance techs also pointed out to me that there were cables pre-wired in / above the existing Crossbar equipment mesh, ready for this augmentation!*

My understanding was that this happened quickly and quietly in early CE 1987 (just after I had left the Class 1 Engineer rotation programme). Material cost of this installation / augmentation was literally nothing and the life of the Crossbar equipment that was site-transferred was extended by about five years (and it was still low maintenance).

The very heavy push by Davidson Report to discard / sell equipment to temporarily balance the financial books (as per private sector / competitive mindset) resulted in Accountants ordering (and getting) the immediate sale of recently decommissioned Crossbar (switching) and transmission equipment that was scheduled for relocation; to instead be junked for scrap metal – which was (usually) a small token of its intrinsic and future value. "***Davidson Inquiry and Report***"

This very short term "Competitive Business mindset" Accounting stupidity resulted in a major customer service problem circa September CE 1987 (in Cranebrook – a then fast growing satellite suburb about 6 km north of Penrith, NSW on the western fringe of Sydney) with thousands of potential telecoms customers unable to be connected in a timely manner and the situation hit the (commercial TV) news big time.

Telecom Planning Engineers had anticipated this suburban grown some years before and had built a new larger exchange building, and had scheduled new AXE equipment to be installed and commissioned into this site in a timely manner, then cut over the existing customers to the new AXE equipment.

By circa CE 1987, Competitive Business mindset Sales and Marketing (and Accountants and Lawyers) were starting to be the internal decision makers within Telecom, and Infrastructure Buses mindset Engineers were being pushed out of executive positions.

An unexpected major disruption to AXE equipment production in Melbourne stopped manufacturing for several weeks – so the AXE equipment for Cranebrook exchange could not be delivered anywhere near scheduled time.

The immediate alternative was to transfer recently disconnected Crossbar technology switching equipment from a Sydney metro exchange and use this. Competitive Business mindset Accountants had got hold of the financial books and this newly retired Crossbar switching equipment was already rush-junked for short-term cash.

No real surprises, there was a public outcry as the Cranebrook suburb numbers soon well-exceeded available lines in the Crossbar equipment, leaving hundreds of potential customers without telephone lines for several months.

Chiming in, a (commercial) TV Station recorded an interview with the then Penrith District Manager and then this recorded interview was very highly post-edited with a range of post-interview questions that were deliberately interchanged with the given answers, and (of course) "noddies" to provide false continuity. The content and direction of the broadcast interview as a "breaking news item" was nothing at all like the actual interview – but it had the intended effect to critically demonise Telecom Commission management (plus much more).

I believe the real intent was that the executive director of that international news organisation / corporation was covertly very extremely intent on getting control of Australia's telecoms infrastructure for itself. With a story as this nationally running it provided plenty of ammunition for the Federal Government to expedite the breaking up of the Australian Telecom Commission and/or make it far more available for the private sector to buy in (own) at a significantly reduced cost.

My understanding is that decommissioned ARF / ARE Crossbar switching equipment was transported from inter-State (at considerable expense) to replace the equipment that had been deliberately trashed for scrap metal (at an infinitesimal value of its true worth) by these Competitive Business minded / focussed Accountants.

*This Davidson Report (like most other Reports to Australian Federal and State Governments) had no concept/inclusion of what Infrastructure Business is and how Competitive Business has a mindset that is diametrically opposite; and how these two diametrically different business models are both essential for a stable and dynamically growing economy. "**The Davidson Inquiry and Report**"*

*No economy can continue to grow with Competitive Business mindsets building and operating Infrastructures. As more infrastructures are taken over by Competitive business mindsets, the end user costs will continue to rise and cripple other competitive businesses and the communities - causing that country's economy to slowly wither and gradually die. "**Infrastructure Business and Competitive Business**"*

Telegraphs to Telex to Fax

With the Post Master General's Department becoming established in Australia (well before Federation in CE 1901), one of its main priorities was to connect telegraph technology – primarily so that a select few of those in the "colony" could communicate back to London and make a financial killing on the London Stock Exchange before other methods (written or word of mouth) of insider trading through family and/or close business associates could be conveyed.

(*From multiple sources: Professor Samuel Morse did not invent Morse code as he was trying to make / create a unique (dot/dash) code for every word – which was totally impractical. One of his University students came up with a simple unique variable length code for each number and letter (where the most used letters had the shortest codes). Samuel Morse in standard "Competitive Business" mindset then claimed this coding as his!)*

Following on from manually keying and recognising Morse Code dot/dash signalling was the concept of constant code length six-bit encoding (Emile Baudot CE 1872) that on good advice from Carl Gauss and Wilhelm Weber Baudot changed this to 5 bit encoding and by CE 1921 Donald Murray slightly modified the Baudot coding to match with his typewriter like keyboard (much like we used these days)!

From here Western Union made yet a few more changes (introduced some control codes, and included a space and a "Bell") and this with again still a few more changes heralded the introduction of Telex that had a data speed of 50 Baud (i.e. 50 "bits" per second or in this case with 5 bits per character; 10 characters per second). This technology was basically limited because of the electromechanical components in these "electrical" tele-typewriters, but Telex was and is considerably faster and reliable than Morse Code – and Telex it was automatically typed out on paper (which dramatically reduced transcription errors).

Telex ticker tape could also be scrolled out in (5 parallel punched-hole) paper tape that could be visually read (by the Telegraph boys) and this paper tape could be re-transmitted by feeding the punched paper tape through the Telex's tape reader. So there was a sense of data storage in data transmission…

Even so – Telegraphs persisted in Australia until the late CE 1960s when Telex with typed sheets finally took over – whereas Telegraphs was hand written and often rather cryptic (making them often unintelligible) – because the (expensive) cost for a Telegraph was per letter transmitted!

Each reasonable sized Post Office had a Telex machine, and the Telex Network usually sat very comfortably inside the Amplified Open Wire or Loaded Cable, or occupying a single channel in Frequency Division Multiplex (FDM) transmission.

The first modems used the full Voiceband spectrum 200 Hz – 3400 Hz (for 50 Baud), which was very poor use of the available spectrum. With the proliferation of Telex communications, Engineers realised the very small bandwidth necessary for 50 Baud Telex transmission, and they came up with a 12 "sub" channel (50 Baud) Telex interface that could (bi-directionally) sit inside a single Voiceband channel.

This then new technology dramatically opened up the Regional Rural telecoms infrastructure for telephone usage by compacting 12 Telex channels into one Voiceband channel instead of occupying 12 Voiceband channels. For Telex services this was a potential maximum productivity of about 1100%. Put another way around the long-line transmission costs were potentially cavitiated by about 92%!

The productivity here is obvious but very few outside (even inside) the telecoms transmission world were aware of this equipment. This rack of Telex transmission equipment was common in all Regional Town and City Telecom Exchanges.

By the early CE 1970s this technology was translated from thermionic valves and carpenter relays to transistors and reed-relays on Printed Circuit Boards and the equipment size compacted to about a 4 RU (Rack Unit) subrack (about 177 mm high) that required virtually zero maintenance, and were effectively forgotten! This new electronics just "worked" (perfectly) – and rarely even noticed by the local technical staff! "***New Era of Electronic Components***"

With the tremendous evolution of computers that started in the mid CE 1940s as mechanical, moved to valves in the early CE 1950s and by the early CE 1960s was fast moving into transistors as the prime active logic elements. In this rapid and frantic evolution, the only sense of commonality was that most computers used (or quickly moved to) what very quickly became the internationally standard and agreed unified standard 8-bit coding system (ASCII) – and this in turn directly affected data transmission – which internationally moulded itself around 8-bit characters.

With telephony Voiceband technology (limiting the bandwidth to 200 Hz – 3400 Hz) the standard practice was to transfer data at 300 baud and having 1 bit per baud (change of transmission state) with the resultant data speed of 300 bits/sec.

By the early CE 1960s this was pushed up to 600 baud and 600 bit/s sec, but was very soon followed by having two phases giving 1200 bit/s from a 600 baud transmission system. Not too much later – using two quantum amplitudes increased this to 1200 bit/s sec – and that was about as fast as it could go (in that era)!

Circa CE 1967, the concept of Post Codes had been introduced by the Post Office in Australia, so that addresses on letters could be (manually) scanned and electromechanically sorted then physically transported to the relevant Postal Centre or Post Office. This new technology brought with it massive business efficiencies in that the sorting process was far faster with far less manual labour and the letters were "packed" for efficient bulk transport and sorting at the next stage(s).

After several years of research and development (by about CE 1973) this electro-mechanical Post Code sorting technology was now "bedded in" as this new electronic / mechanical mail sorting process now required a skeleton technical staff (and far fewer mail handlers than before) leaving several engineers now looking for new roles. Most of the technical and engineering staff was transferred from the Post Office to several Business Units in the new Telecom Australia Commission.

At that same time Telex was the "official" legal document transfer medium and this network often ran in hours of continual network congestion and Telex used paper tape to memorise the messages. The Telex Repeater Sending System (TRESS) used rolls of paper tape to be recorded as punched paper tape by the receiving Telex machine and then have the newly punched tape manually loaded and fed to retransmit the Telex message when the receiving Telex machine was available!

One of the bright technical Engineers (Ian "Red" Newstead) was transferred from the Australia Post's Redfern Mail Centre about CE 1980 *to Telecom Australia's Sydney Data Centre, and it did not take him too long to find the TRESS room with paper everywhere.*

With his background in the development of digital electronics and analogue / mechanical interfacing – he saw that this whole process could be done far more efficiently (i.e. with far less labour, far less mistakes and far less overhead costs) by making electronic interfaces to the Teletype's transmission lines and replacing the trails of paper tape everywhere with a serial (electronic) "Shift Register" (temporary memory) to hold an sequentially store the transmitted data at a (short) time later!

In that era, Telecom Australia had very few prototype / development facilities (outside the TRL in Melbourne). That aside, he economically engaged to make a printed circuit board about 600 mm by 500 mm using basically SSI and MSI solid state technology that held several electronic "store and forward" memories including the (analogue) Telex electronic interfacing. This prototype equipment was purely electronic, no Telex machines, no paper tape, no (moving) electromechanical parts.

TRESS maintenance was effectively zeroed, virtually no overhead; the transfer efficiency far exceeded its manual predecessor and end user complaints zeroed. TRESS however (primarily because of its slow data rate) had a limited future as the need for faster data transfer remained an imperative.

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In the late CE 1960s (along with Moon Rockets and all that) Australia was intricately involved with providing reliable Data / Voice (even Video) connectivity from Tidbinbilla / Honeysuckle Creek - Canberra – Sydney – USA (Huston – Texas).

The problem for the North American Space Administration – NASA (*which was/is specifically not a USA sub-Government Department but a "pegged up" private company in line with the hard right fog-horned USA economic mantra*); was that the international data transmission links suffered considerable "Group Delay" distortion. Consequently the fastest data transmission was typically 300 baud which was far too slow to be practical.

This Group Delay distortion caused the frequencies near the middle of the FDM channels to travel through much faster than the frequencies near the upper and lower frequency passband edges (much like water flow in a river).

The cause came back to Voiceband Channels (based around 200 Hz to 3400 Hz) for FDM equipment where the engineering design of this equipment (circa CE 1955) was oblivious about "high speed" data and these band pass filters were never engineered for data transmission and correct for Group Delay!

The PMG NSW Transmission Lab constructed "Group Delay" equalisers to place in the transmission link and "slow down" the centre of the channel so that the phase/amplitude constellation can be "un-warped" so that data speeds were then far less compromised (i.e. maximised).

What I found surprising was that polyester capacitors as were commonly used in line equalisers that we made as a "bread and butter" (almost daily) production items in the CE 1960s – 1970s were "not good enough" and *special polystyrene capacitors were specially brought in as these had a slightly lower (almost zero) temperature coefficient.*

These Group Delay equalisers were "bulky" (to say the least) and rather specialised test equipment was required (from Wandel and Goltermann – Germany) to perform the testing – both in the Lab and later on site – south of Canberra (at Tidbinbilla).

*In hindsight, considering the monumental stuff-up with Australia's TV Broadcasting standards being "crash-tackled" by incredibly inept Federal politicians, I am almost certain that the design of the (passive) Group Delay Equalisers came out of the ABC Engineering offices (John Bigeni and Neville Thiele AM). "**External Economic Control from the USA**"*

With the data modem technologies in the early CE 1970s a single Voiceband was simply not enough and optimised data transmission really needs a wide, flat frequency response (and a smooth Group Delay characteristic. The application of Wideband data connectivity using a "Group" of 12 parallel (Voiceband) Frequency Division Multiplex (FDM) occupied a 48 kHz bandwidth. With this bandwidth – upwards of 28.8 kb/s could be reliably transferred (but it was bandwidth expensive).

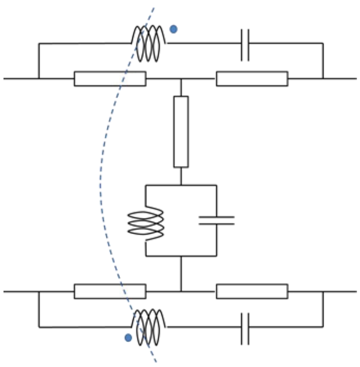
In the quest for higher data speeds through a telephone (Voiceband) constraint, the technology moved to implement Phase Amplitude Modulation (PAM) instead of simply on/off or loud/soft or in-phase out-of-phase techniques. During the CE 1970s, the technology of PAM grew from the two and four states as a described above to having four times four states (i.e. 16 states) and at 600 baud in the Voiceband this meant 600 * 16 = 9600 bits/sec, which was far faster than previous Voiceband modem technologies that were nominally 600 or 1200 bit/s sec.

The Digital Data Network (DDN) grew out of the need for government and private businesses to primarily communicate with data – but there was a sticking problem; the Access Network has a "slope" in it and this "slope" is length dependent for each connection from their modem to the Digital Data Network / bank at a Capital City CBD Local Exchange site.

My understanding was that (in NSW at least) DDN customers had a passive 600 ohm line equaliser included in their Access Network circuit – so that the Slope was effectively neutralised (+/- 0.5 dB from 400 Hz – 3000 Hz referenced to 820 Hz) and the data speeds were (naturally) maximised to operate at nominally 9,600 bit/s sec as the standard connection.

Over several years, the NSW Transmission Lab was made several hundred (prototype i.e. once off) constant (600 ohms) impedance, resonant, passive line equalisers – for use with the DDN.

These (plug-in) equalisers (made on a standard size plug-in circuit board) had a standard circuit design – see on the right – having an "H" pad in them with a bridging series resonant Coil / Capacitor with a resonance about 4 kHz and a parallel Coil / Capacitor (with the same resonant frequency) in the shunt leg of the "H" pad. The values of the coils and capacitors were "bridged" to be within 1% of the required values.



At the low frequency end of the Voiceband spectrum the attenuation was virtually the amount of the pad, (typically 6 to 12 dB). At the resonant frequency (usually somewhere between 3.5 kHz and 4.5 kHz) the attenuation was about 0.2 dB and the "B" (width) factor was a direct relation of the reactive components (to directly compensate for the shape of the "Slope" of the Access physical pair's length.

One of the Engineers who plotted / calculated the values of these equaliser components decided to use a fixed resonant frequency and made the resonant broadness (B) and the pad attenuation (dB) be the only variables to compensate for varying line loss and slope.

It turned out that in virtually all situations the reactive component values stayed constant (so the Broadness also became fixed) and the pad attenuation could be changed to provide excellent equalisation in virtually all Access Network cable length situations!

This realisation radically changed the entire process so that these constant impedance passive line equalisers could be mass produced without any attenuator components, and the plug-in pads (attenuators) could also be mass produced, and the installation / commissioning process took a few minutes instead of some days.

Like many /most other prototypes that were researched and developed in the Transmission / Switching / Design Lab – this technology was also handed out to an Australian manufacturer.

Right on the heels of the Medium Scale Integration (MSI) was Voiceband modem chip technology (circa late CE 1970s) using Phase Amplitude Modulation (PAM) to get speeds of up to 56 kb/s over a Voiceband line). This evolution dramatically shrunk the size of a Voiceband modem from about the size of a shoebox to a small cigar box and the data speed leaped up from 300 / 600 / 1,200 4,800 / 9,600 bits per second to a maximum of 56,000 bits per second (or 56 kb/s, or 0.056 Mb/s).

Because so much could be done on the one MSI/LSI chip including at least the data speeds, bit parity, data buffering, digital signal processing, etc., the amount left for other components was rather small (and inexpensive). Considering that the (One World) modem chip cost about $100 in small quantities (much cheaper by the thousands – "economy of scale"), fully component populated dial up modem boards could be mass manufactured (in a box) for about $130 (and sold for $250).

Now consider the cost of an earlier vintage dial-up modem in mass production where the base cost was in the order of $1500 to $2000! The cost parallel was five to 10 times less costly with the new technology using MSI silicon chip technology.

This new technology had absolutely nothing to do with the "economic" pressure of competition (apparently making everything more efficient) but had everything to do with the concept of "building a better mousetrap" by thinking well outside the "square" and applying a totally different technology in a totally collaborative environment.

Sure - once one research organisation comes up with the conceptual design then other chip manufacturers see a money-making opportunity and competition starts. This is where economic innovation radically slows down because the information flow is virtually stops – so <u>competition actually inhibits productivity and efficiency</u>.

*In the mid CE 1980s, because of the relatively high number of requests coming into the NSW Switching / Design Laboratory for Voiceband data to be transferred at speeds well exceeding 2400 bits/sec there was a concerted effort to look at using the "One World" modem chip and make a single board modem. Concurrently other technical staff were designing a single board computer on a Eurocard (160 mm * 100 mm) plus a range of transmission and switching alarm / performance / remote control interface cards and a switched more power converter!*

The Labs' "One World" Modem card had barely reached prototype stage before it became common industry knowledge and several Australian equipment manufacturers had jumped on the concept and either made their own circuit designs and/or used the Lab' prototype circuit design to build their own fast Voiceband modems.

*Because of competition at his very early stage the prototype Modem was not really advanced to "proof of concept" to really get rid of the inherent design bugs and to include an "active (analogue) equalisation" section in the line interface to flatten the frequency response. Development focus moved to writing code to operate the new single board "Computer" and a range of peripheral cards. "**How the SCN Economised Maintenance**"*

By the mid CE 1980s, to a very large degree Telex was on the way out with Voiceband data services and Facsimile machines using telephony circuits – so they could dial virtually anywhere a telephone connection was there and another Fax machine was on the (telephone) line. Fax data communications became the defacto "legal transmitted document" standard replacing Telex / TRESS, technology (along with Telegraphs) that all quietly became (ancient) history.

Because the Customer Access Network (pair copper cable connecting from the local telephone exchange to the home / business premises) was really engineered for (telephone) line signalling (and not Voiceband performance); in general the typical Fax speed was limited to typically 14 kb/s to 24 kb/s (but the reasons at that time were not blatantly obvious). "***Competition Wrecked Australia's Pair Copper***"

The fundamental problem was that because the physical pair copper Access Network had an attenuation / frequency roll off (at each end) the high frequency part of the Voiceband spectrum (for an end-to-end connection) was typically about 10 to 18 dB below the low frequency / centre of the Voiceband spectrum.

Circa CE 1983 the development of Digital Signal Processing (DSP) was in its early stages and heralded as the answer to everything audio / telephones – you name it!

As these new modem chips now included some DSP technology, this was (theoretically) used for digital line amplitude / frequency equalisation in the Modem chip – but there was a fundamental problem. Because the received signal level was so low and the signal was being re-converted from analogue to digital (again) the amount of internal Quantisation Distortion was (unwittingly) quite large and this came out as faulty modem connection at higher speeds – hence the modem worked at a slower safe speed where the DSP was not really used at all!

From many years practical experience in electronic engineering, I believe that it would have been relatively easy (and inexpensive) to include an analogue (not digital) resonant active equaliser / amplifier stage in the modem's receive circuit before the demodulation stage. This analogue circuitry would have had very little non-linear distortion and would have concurrently totally flattened the amplitude / frequency response (and minimised the Group Delay) - which also would have really increased the dial-up modem's data speed performance!

The inclusion of analogue equalisation as outlined above would have had most Fax machines capable of operating at typically 36 kb/s to 48 kb/s – even 56 kb/s; and if applied to ADSL2+ technology most ADSL2+ modems would, I believe, have been capable of downstream speeds of at least 20 Mb/s (even with poorly performing lines). "***Competition Wrecked Australia's ADSL***"

Facsimile technology did not have an easy introduction because there were several competing "company standards" that effectively limited various Fax machine brands for communicating with each other. The problem was/is that the ITU-T was/is the governing body concerning telecommunications and all countries (except the USA) work closely with the ITU-T to align and agree with well-considered and openly discussed recommendations (except the USA).

Emerging Fax technology came out of Japan and Europe – but because the Japanese economy was/is largely steered by the USA – separate Fax manufacturers did not collaboratively confer but used slightly different firmware which inadvertently restricted various features (including connecting) between different fax machines! *This was yet another typical case where competition wrecks economic efficiency!*

> *There was a brilliant Telecom Australia Engineer in NSW (Frank Nitzchke) who recognised this critical situation with Fax technology – homed-in on the intricate problems (right down to machine code); established dialogue with virtually all the Fax machine manufacturers world-wide – and collaboratively resolved these competition caused problems to get reliable and consistent Fax machine connectivity on a global scale – irrespective of the competing manufacturer!*
>
> *Frank also developed / created two crucial Fax and Modem On-Line Diagnostic Systems (FOLDS, and MOLDS) so that users could dial in with their Fax or Modem and this centralised equipment produced a detailed report that was sent back to the caller (and another copy kept locally). This equipment proved critical in helping to identify and localise set-up problems plus a range of other issues that spelt out how and why a Fax Machine or a Modem is performing as it is.*
>
> *The reports from this (centralised) test equipment showed up Voiceband transmission problems that would have never been identified by telephony – and because we knew where they called from – it became relatively straightforward to proactively identify (and fix/correct) where in Australia (at least) Voiceband transmission was not up to standard.*
>
> *On the practical side, (Ross Mudie) who was in the (then renamed) NSW ~~Switching~~ Design Laboratory, set up facilities to respond and investigate customer problems with Fax transmission from all over Australia.*
>
> *If there were protocol communication problems then these were relayed back to Frank to identify. Most of these slow Fax transmission problems were identified and localised to being faulty Loading Coils (in the Regional*

> *Transit Network that were usually lightning damaged. "**Regional Transit Network**"*
>
> *What I found particularly interesting was that some Dial-Up modems (also being prototyped in the Lab) had data speed performance problems (just like Fax transmission) critically limited by the apparent lengths of pair copper in many parts of the Access Network being far longer than their physical lengths. "**Competition Wrecked Australia's Pair Copper**"*

While the fixed access telephony world had substantially peaked by about CE 1985 / CE 1990 at around 7 M fixed access telephones in Australia (then population about 17 M, or about one phone per 2.4 people) the use of data was rapidly increasing but was generally un-noticed because Telecom / Telstra senior executive promotion / salaries and business unit structure were for several decades based on telephone service count. "***Telephones Become an Essential Service***"

By the early CE 1990s, Australian telecoms infrastructure was literally all Voiceband based, all switched through standard Digital (AXE) and electromechanical (Crossbar) technologies and virtually all the transmission was based on 2 Mb/s PDH with a digital hierarchy that extended to beyond 545 Mb/s (although quite unstable) and the new SMOF transmission medium also required virtually zero overhead maintenance!

Most telecoms Engineers were aware that the new digital telecoms platform was more efficient in productivity / profitability terms than the electromechanical / analogue platform. The prime reason for this massive technology change over that previous decade (and then some) was collaboratively driven by Engineers striving for a higher reliability and a much lower maintenance overhead for telecoms.

The ACCC the PC and most economists incorrectly put this technological advancement down to "competition" (assumed to be between rival service providers).

The fact is that the gradual and progressive / step development of new and different data related telecoms technology platforms proved to be far more (infrastructure) business efficient and economical than their predecessor technology platforms. It was really these step technology advances done in collaboration (i.e. negative competition) that really drove down end user costs and provided far better service standards / connectivities for the end users.

Circa CE 1985, there had been considerable advances in technologies surrounding the PDH "E1" level of 2.048 Mb/s (2 Mb/s) to use this use this as a common digital access connection, primarily for business customers. At that time, Telecom Australia was providing "full bandwidth ISDN" where the rest of the world was providing a "limited bandwidth" (of some/several 64 kb/s slots) and there was considerable worldwide argument if customer speeds for Internet connectivity much greater than 64 kb/s (even faster than 2 Mb/s) were actually necessary!

With the very quiet rise of Internet connectivity in the early CE 1990s, most Government and Enterprise customers needed far more than 2 Mb/s (ISDN) connectivity and even so – many 2 Mb/s links were being virtually permanently connected within (and between) major metropolitan businesses in different cities.

This considerable change in Backhaul network usage and requirements called for a rethink to "hardwire" these circuits with a high capacity transmission backbone (which happened with the establishment of the new Mel-Syd SMOF digital network in CE

1986/7 and as far as I recall, (when I engineered this network structure) virtually these hardwired circuits were effectively PDH technology (with about 10% to 20% being ATM – specifically for data). "***The Sudden Emergence of SMOF***"

One of the products brought out by Telstra (circa CE 1996) was a 140 Mb/s optical loop in the (Sydney) CBD with the intention that several businesses would pick up several 2 Mb/s links from the multiplex equipment in the (several) customer premises. This initiative was a very clear indication (to me) that metro business customers (at least) were desperate for fast reliable data connectivity and not only was the infrastructure not there but the available economic technology was really struggling – and the Telstra etc. infrastructure mindset was still stuck in providing (multiple) Voiceband technologies, but slowly waking up.

Also in the background was the continual growing proliferation of (both analogue and digital) Mobile Phones and (Mobile) Pagers. Analogue mobile phones were large and heavy but had a clear sound and a limited (metropolitan) coverage area. Digital mobile phones had a very metallic and long delayed voice – but included a very narrow channel for slow data transfer – (texting). Pagers were effectively a narrow digital channel for slow data transfer – seen as primarily to keep (mobile) management in the information loop of very recent situations. "***Phone Numbers, Portability and Mobile Devices***"

The massive difference with these new mobile devices was that these new radio technologies had the ability to connect in a service area that roughly aligned with the (metropolitan) pair copper Exchange Service Area (ESA), but the initial cost and overhead was a fraction of the cables in the ground (fixed services). Even in the early days of mobile devices, it was clear that the profit margin could / would be substantially larger than that provided by (underground) pair cable services and quite quietly, all (executive management) stops were pulled out to roll out and introduce mobile phones and minimise overhead costs on fixed access services.

Circa CE 1996 there was considerable "chatter" in the various technical magazines where the concept of Cable Modems (on HFC infrastructure) was starting to appear and a few mentions about ADSL as the next fast data connection technology. "***Basics of ADSL and HFC Broadband***"

Competition Wrecked Australia's Pair Copper

Circa CE 1940 electrostatic screening of in the smokestack eliminated fly ash and soot from escaping via the smokestack chimney – effectively making "clean coal" fired steam to generate reliable, dispatchable electricity. Before this electrostatic screening, there was a major telecoms maintenance problem with the (in particular metropolitan) Open Wire technology where it was extremely difficult, costly (and dangerous) to remove the soot from the insulators.

Circa CE 1930 Australia's Federal Government's brilliant initiative was to facilitate Australia's private sector to manufacture lead-sheathed, twisted paper-insulated pair copper cables (along with locally manufactured conduits and service pits) in Australia. The PMGs Dept. employed many hundreds of teams of labourers (who otherwise would be without meaningful work / be on the dole) to trench this infrastructure into the metropolitan areas. "***Highly Economic Underground Cables***"

This initiative was a massive economic productivity boost for Australia. These technologies introduced and professionalised a wide range of technologies and work practices / skills into Australia. "***Rebuilding the Junction Network***"

Following on - the manufacturing / delivery / installation and commissioning of these cables introduced a specialised range of manufacturing industrial technologies into Australia. There is barely an historical mention of thousands of km of overhead / aerial telegraph / telephone wires being removed from the metropolitan areas and replaced with underground cabling. Virtually no economists recognised nor comprehended this background technology jump because this was highly concurrent with the export of wool boom / export of mined ores boom that took all the limelight.

Unfortunately, the management style of those eras was still very much military driven and was a typical top-down foghorn where people on the factory floor / lines depots / exchange sites etc. were heavily restricted from providing productivity enhancing feedback up the line to supervisors / management (let alone to executives).

*One of the work efficiencies identified by Edwards J Deming was that by having people meeting in "Quality Groups" outside their workplace teams (and including management / supervisors) where the general direction of these groups was the work processes; was that a very high proportion of workplace productivity initiatives that were implemented came from the floor and not from supervisors, nor management, nor executives. "**External Economic Control from the USA**"*

Further – by executives / management implementing these initiatives, the productivity and safety substantially and continually increased. This type of bidirectional (executive) management style was generally not taken up as it flew in the face of direct control from the top – and it clearly showed that executive management had "very limited expertise" in the businesses / productions that were controlling.

> *When Total Quality Management (TQM) was introduced into my area of Telecom Australia circa CE 1988, the positive effect was astounding with the technical staff continually bringing up a flood of excellent (and different) work practices that in our case dramatically improved productivity – and radically changed the way we operated because we could then implement cutting edge technologies with minimised executive push-back.*
>
> *Many of the employees were also provided with extra training outside their normal work sphere to broaden their educational knowledge and balance.*

This significantly improved management and supervision processes and gave specialist staff a far broader understanding of associated technologies and different inter-State processes and practices.

Most of us (as Technical and Engineering experts) were very foolishly made redundant in December CE 1996 while there were gaping holes in other Business Units that were ignorant that we were being discarded and were desperate for our knowledge, experience and expertise.

When I contracted to Silcar in CE 2005 (for the Telstra Cable Internet rebuild) as a construction Supervising Engineer, it was painfully obvious that TQM had been forcibly shoved out and the "ISO Quality" system in place was all about having the lowest level staff being 100% responsible locked-in processes, no productivity suggestions from the floor, and (of course) all executive staff excluded from any responsibility / litigation.

So it was back to the top-down typically aloof military style management – with the highly unproductive Competitive Business mindset as standard practice in Australia. Economically – this was an immense mistake and consequently Australia moved from production industry to service industry – and the schools and universities etc. had been really dumbed down!

When the metropolitan Junction Network was put underground in the CE 1930s; the associated metropolitan Access Network also went underground. In the Access Network structure; the Main / Intermediate cables (from the Local Exchanges towards the customer premises) were also paper-insulated lead-sheathed technology. "***Rebuilding the Junction Network***"

In CBD and higher density areas, the outer / drop (to home premises) cables were also paper-insulated lead-sheathed – and in conduits. In the (then) metropolitan consumer outskirts it was common to leave the aerial wire for the outers / drops to the customer premises.

Part of the process in connecting a pair-wire service (telephone / ADSL Modem) to a customer is the task of running a (pair) of insulated "jumper wire" between two pairs of terminals in the local exchange and again in a Sputnik / Pillar, and again jointing pairs of (insulated) wires in (usually three) cable joints, and again at the premises.

With a "Competitive Business mindset" it was far quicker (efficient) to simply wrap the insulation stripped pair of "jumper wires" around the spade terminals, cut off the wire ends, note the change in the documentation (claim the money) and go to the next appointment. Chances are that 1 in 1000 would fail within a few days and that 1 in 10 would fail inside a few years – and that was "re-work" that could be claimed again and again! This was / is a sure way to continually fail.

If these terminal joints were to be soldered, it could a minute or more (to heat up the iron if it was not already set to heat at the start of the process). So in a Competitive Business mindset "time and motion (**money**) study" – these pairs of spade terminals were simply not worth soldering. The complaints can be managed later by somebody else!

With an (Infrastructure Business mindset) "**Quality** time and motion study" it made every sense to solder those spade terminals joints and check every other spade terminal joint and solder every terminal that is not soldered and any terminal that looks like a poor (dry) solder joint.

Considering a 100 pair block, this Quality process may take about 20 seconds to solder the first pair of spade terminals and in the process, visually check the rest of the terminal block for defects.

If the whole 100 pair block needs soldering then this is about 20 seconds per pair terminal as the soldering iron is now hot; and nominally 100 terminal pairs is about 33 minutes! In practice on average about 15 pair joints would need soldering (or resoldering) and that would take about 5 minutes

So – using the Quality approach: chances are that 1 in 100,000 Jumper pairs will have a terminal connection problem in the next 10 years. Chances are that other Jumper wires will be run and may disturb the existing terminating connections – and those disturbed terminal joints will be resoldered. There are nil customer complaints!

Go figure! Competitive Business mindset (More Competition - Better Productivity) costs big time - particularly in infrastructure ("Utilities")! People that have not actually worked at the "coalface" continually bleat on ignorantly about competition being the panacea for all things economic. Competition has massive overhead costs that are deceptively avoided in (inept economic) accounting.

On the down side: the lines / cable jointing process had gone through a series of engineering problems that had been festering for decades and could not be reported up through management.

The first big productivity item is a metallic crimp sleeve (like a 10 mm long very thin straw) that took two bare wires (one from each end). The two wires were simply crimped by the sleeve – instead of soldering. This process more than halved the wire jointing process time – so "cable jointing productivity" was up by at least 100%!

Because these crimp sleeves were barely as thick as the (plastic / paper) wire insulation this made for a very compact (diameter) joint – which in turn minimised the time spent on the process – maximising (competitive) "productivity"!

> *The problem – as I found out in mid-2020 when talking with a Telstra "Lineman" in Turramurra (NSW); the whole cable joint he was working on was "warm" (and it was warm, even the lead sheathing). He had the job of re-jointing this 400 pair cable with jointing clips and then repeating the same exercise on the adjacent 400 pair cable joint – that was also warm!*
>
> *These sleeves apparently worked for many years – but they never provided an airtight seal and consequently as the metal in the joint corroded – the surface inside the metal crimp became high resistance (hence "warm"). All the customer services on these cable pairs would have been rather noisy (and/or intermittently drop out)!*

The next big productivity item was a gel-filled clip (from 3M) about the size of an 8 mm ball bearing. This almost circular clip had "jaws" with some tiny teeth in it; and a plastic cover (as insulation). Now, this was simplicity to put in two insulated wires (of the specified diameter for that particular clip); and use crimp-pliers to crush the jaws into the wires and the wires are jointed and sealed – no need to strip back the insulation!

These clips worked extremely well – as the teeth in these clips cut through the wires plastic sheath (technically called "insulation displacement") and also dug into the wire surfaces – effectively making (very small) "cold welds". The gel provided an airtight seal and the joint potentially had a life exceeding say, 100 years!

There are many millions of these crimp joints in service in Australia's pair copper Access Network infrastructure and most of these are working perfectly (for decades)!

As usual with a "Competitive Business mindset" the Lines Field Staff were minimally trained and most management talked down to these Lines Field Staff and didn't actively listen to Lines Field Staff (especially if these people were "Contractors"). As an indirect consequence many corners were cut in Competitive Business mindset (short-term thinking) to get the jobs done quicker (i.e. get the money and run).

These clips were colour-coded to specifically match wire diameters – but apparently this was neither widely taught nor widely known. The problem is that when the wrong clip goes on two wires – either the clip jaws cannot properly close because the wire diameter is too big (and clip flips open intermittently becoming open-circuit some years later), or the clip closes but barely digs into the wires because the wire diameter is too thin for that clip type (so the joint becomes intermittent / open-circuit a few years later).

In some areas, it was also common practice "triple connect" extra wire pairs with these clips in a Service Pit cable joint so that a Main Cable pair would connect to two (or more) Intermediate Cables – going to different Customer Distribution Areas (DAs) or within the same District Area but not near each other!

The reason for "triple connecting" was that the pair could usually be very quickly located (even if it is in another DA) – so the time taken in connecting the premises would be dramatically shortened. There was absolutely no consideration that triple connecting introduced a lot of extra capacitance that adversely affected Voiceband transmission (and would have wrecked ADSL speeds) – and been a major future fault liability – and also, extremely difficult to isolate / repair!

There was no consideration that the idle wire branch may get wet (which was more often than not) causing very hard to identify line faults (earth leakage, muffled transmission, number always busy, no dial tone etc.). If these Access Cables were used for ADSL connections, then the extra capacitance of the branch line (especially is part of that branch cable was wet) significantly degrades ADSL data speeds.

Testing the Access Network from a "Test Desk" in the Local Exchange was a common almost full-time task with overhead wires and technical / Lines staff became very adept at identifying where a fault was before driving out to fix the faults.

With the (Access) cable going underground (circa CE 1930s – 1950s in the metro areas and CE 1950s – 1970s in the Regional areas) the number faults plummeted for some decades until pinholes in lead sheathing resulted in water ingress resulting in losses between and losses to earth that caused faulty phone services.

The introduction of about two atmospheres of cable (dry) gas pressure (CE 1955) abruptly stopped damage to twisted paper-insulated pair copper cables and dramatically reduced the need for the "Test Desk" role by the CE 1960s.

With Crossbar switching technology (CE 1960 – CE 1998) this included an “LR/BR” relay interface that facilitated centralised “Test Desk” connectivity – without having to climb the MDF and insert a “shoe” into a line to facilitate testing connectivity. The AXE (and System 12) digital exchange technologies included a very small (sealed) line break relay to electronically connect any Access pair back to the local Test Desk.

In the early CE 1980s, this Test Desk technology was taken one (gigantic) step further with the development of a compact Subscribers Line Test Access Network (SULTAN) unit installed in every local exchange, as a remote controlled (and reporting) Test Desk facility.

Operating a Test Desk was really an art to find hidden problems in Access pairs (and very few people who used a Test Desk really understood the physical significance of the capacitance “kick” and decay times). Almost all line tests were/are based around Direct Current (DC) values associated with Ring Down/Loop Disconnect signalling.

Conspicuously missing were appropriate tests to prove the Voiceband transmission characteristics – and Broadband transmission had not been even conceived!

One of the physical characteristics about electrical transmission is the “skin effect” whereas the frequency is increased so too the electron flow moves towards the “skin” of the (round) wire! If the metallic wire skin is corroded (as is all too common with cotton / paper / silk insulation) the resistance in that area is considerably more than if the wire is not corroded (as per plastic insulated wire cable)!

Plastic insulation provides an airtight seal (over many decades). If you peel back the plastic insulation of wires in a (Voiceband) telephone cable then you will see the bare copper is in pristine condition! Copper wire in paper insulated cables is a dirty brown colour as the copper surface is highly oxidised.

One of the “unseen” problems with ADSL technology (using the “available bandwidth” up to 2,200 kHz on pair copper cable engineered for Voiceband (3.4 kHz max.) and tested to 35 kHz during manufacture); was that all this twisted pair paper-insulated pair copper had considerable surface (skin) corrosion.

Not only was the spread in ADSL downstream speeds rather unpredictable – but the downstream speeds on “good” lead-sheathed (paper insulated) pair copper main cable was (in hindsight) not as “good” as it should have been, and this would have certainly come back to these cables having corroded pair copper wires – crippling performance as all ADSL frequencies would be through the corroded copper “skin”.

In the late CE 1950s - early CE 1960s, new (plastic insulated) cables made for telephone Access Networks (Exchange Switching Areas) – otherwise known as “District Areas “DAs” by the lines staff – started to be rolled out.

Because of exceedingly poor Lines work practices – extremely common with contractors who think (minimum) Time before (maximum) Quality a very high percentage of cable joints are not properly sealed against water – and many cable joints are not sealed at all.

Digital Voiceband Technology

Practical experience had shown that overhead maintenance costs generally follow the "bath profile" where initially maintenance overhead is extremely high for a short time (like the foot end of a bath) then the maintenance overhead quickly falls to a very low level for many years (like the middle of a bath profile) and then gradually increases (like the shoulders/head end of a bath) until the maintenance overhead costs are untenable and the equipment needs to be totally replaced.

From my experience, most passive equipment has a (low maintenance) life of between 50 and 80 years and most active (powered) equipment has a (low maintenance) life of about 20 to 60 years where physical movement considerably shortens this low maintenance life. The other consideration is that new and far more economic telecoms technologies have generally come in 20 year steps and this progression helps to expedite economic replacements of older technologies.

With Crossbar technology introduced in CE 1960 and was still being rolled until about CE 1987. Meanwhile the initially installed Crossbar equipment was starting to become relatively high maintenance by the about CE 1980. "***High Productivity of Crossbar Switching***"

At about CE 1982 Telecom engineers created an electronic version of the Crossbar (H4) Register that physically replaced a large number of heavily-used "common control" (state machine) relays. This initiative really minimised the need Crossbar maintenance overheads until the mid CE 1990s. "***Digital Brains Within Crossbar***"

Well before the CE 1969 Man on the Moon communications arrangements with the USA / NASA), Australian Broadcasting Commission (ABC) engineers were also heavily involved with digital encoding / decoding technologies and to a very large degree led the structuring of world standards for Digital Television (and audio encoding / decoding).

Many of these initiatives came from a complete stuff up caused by Australian Federal Government politicians back in about CE 1955. The (Liberal) Federal Government inexcusably ruled that the Amplitude Modulated (analogue) TV channel bandwidth would be 7 MHz (and not 8 MHz as per the rest of the world, and thankfully, not 6 MHz as in the USA). "***Basics of Pay TV and HFC Technologies***"

Looking back on all of these world-leading developments in TV transmission, there was an outstanding ABC Chief Engineer (Neville Thiele) who was behind the re-engineering of Australian TV transmitters to be "pre-equalised", so that the circuitry in millions of Australian TV receivers was substantially simplified (compared to those elsewhere in the world) and provide an optimised picture quality!

Neville Thiele also worked out the mathematics of Loudspeakers in boxes, which totally revolutionised Hi-Fi because this technology was previously a very "black-art"! Unfortunately Australian manufacturers did not capitalise on this brilliant conceptive engineering – even though the world's best loudspeakers were being manufactured in Australia to Neville's specifications. Much like the fashion industry, Australia did not have a range of "Brand Name" expensive loudspeakers and speaker boxes that the ignorant and faithful "audiophiles" would purchase for their self-prestige!

In this CE 1970s – 1980s era there were several (predominately Australian) Electrical Engineers that closely collaborated their acoustic / Hi-Fi work including at least: Paul Klipsph (USA, horn Loudspeakers), Cyril Murray (extremely low distortion amplifiers), *Neville Thiele (Loudspeaker / Box maths), Eddie Benson (manufacturing Loudspeakers), Richard Small (practical Loudspeakers / Boxes), Ed Cherry (Intermodulation issues), Amar Bose (Loudspeakers in Rooms). Their (and some others) highly collaborative work over this nominal 20 years rapidly advanced loudspeaker / Hi-Fi Acoustics. <u>Very little of these monumental advancements would have been possible had they worked in competition against each other.</u>*

Neville Thiele also worked out how to very inexpensively delay-line equalise the minute differences of cable lengths in TV studios to get the colour right (at the source). My understanding that it was he (by far) was the main force that also set the world standards for digital television displays and encoding bits etc.

From around CE 1970, TRL had been working collaboratively with the Australian Broadcasting Commission (ABC) Engineering and with the CCITT (now the ITU-T) regarding Voiceband analogue / digital encoding / decoding and the G.7xx series of recommendations surrounding Plesiochronous Digital Hierarchy (PDH) technology.

My understanding is that it was also Neville Thiele that came up with the A-Law logarithmic digital encoding/decoding of voice / music to optimise the digital bits for programme audio and telephony (Voiceband) audio. This technology was also being developed elsewhere in the world and eventually (primarily because of patents and expensive competition issues), two logarithmic standards evolved for telephony: the u-Law (Mu-law) in the USA and Japan and A-Law which is used everywhere else.

The problem was how to realise this technology and make it very inexpensive!

By CE 1970, telephony acoustics was a well-understood topic (but it was fundamentally "analogue") and integrating digital telecoms was by no means straightforward. The upper Voiceband frequency limit (stipulated by the technology of Loaded Cable and FDM) is 3400 Hz so for digital encoding / decoding the clocking frequency has to be at least twice 3400 Hz. To give a little engineering design flexibility and to align with the widespread FDM 4 kHz channel spacing, this virtually stipulated that the clocking frequency had to be nominally 8 kHz (no less).

With speech, we need at least 24 dB above the background (pink) noise level so that speech can be comprehended. In practice, at least another 24 dB is needed so a 48 dB average signal to noise ratio, plus we need about 18 dB headroom, and that sums up to about 66 dB for the minimum signal to (pink) noise (STN) ratio.

Another broadside issue was that the (incorrect) standard practice to use the "A" weighted Noise curve when measuring background noise in a normal speech environment (to emulate the frequency sensitivity of the human ear at low noise levels)! The "A" weighting incorrectly hid (severely attenuated) the noise outside the centre of the Voiceband spectrum – giving a very optimistic (and flawed) result.

With the almost flat response "C" Noise weighting used for telephone channel measurements; the 48 dB average signal to noise ratio is an absolute minimum and an extra 12 dB brings the background noise level to 60 dB and with the 18 dB of headroom this brings the total necessary dynamic range up to about 78 dB.

The compounding issue is Quantisation Distortion (which is the distortion introduced by the misalignment of analogue values caused by quantum digital values) and to keep the background noise as background and not "gravel / metal in the voice" we really need digital encoding to operate to about 60 dB below the average level. (This aligns with the previous paragraph!)

In (linear) digital terms -80 dBFS needs a 13.3 bit analogue / digital encoder/decoder so this would mean 14 bits (linear encoded) * 8 kHz = 112 kbits/sec per Voiceband channel and that was a very awkward / expensive fit.

Seated with this digital Voiceband engineering dilemma realisation that our hearing is logarithmic in nature (not linear with loudness) the concept of logarithmic encoding / decoding can use significantly less “quantisation” bits. At high levels the quantum steps are exponentially bigger and at low levels the quantum steps are exponentially smaller – and this process uses considerably less bits over the dynamic range.

Where for audio it would be necessary for 14-bit encoding (which is awkward and very expensive), the concept/innovation and realisation of a logarithmic analogue/digital encoding/decoding technology process set the initiative as the manufacturing can be considerably less costly because this dynamic range can be catered for with an 8-bit logarithmic encoder / decoder with an effective dynamic range of 90 dB Full Scale Noise Ratio (FSNR) – the same as a 14 bit linear!

This new technology works with the standard “8 bits”, clocked at 8 kHz making 64 kb/s as World standard (even in the USA) and has an effective dynamic range equivalent to that of a 14 bit = 90 dB Full Scale Noise Ratio (FSNR)!

As usual the USA did not collaborate and went its own way coming up with their own u-Law logarithmic encoding / decoding, while the rest of the world in collaboration settled on A-lay logarithmic encoding / decoding. The difference is the rate of encoding and consequently a u-Law encoded stream when decoded with an A-law decoder; sounds “distorted” (and vice versa).

By CE 1975, Telecom Australia’s Research Labs (TRL) had recognised the imperative of digital transmission (and switching) standards. TRL had proactively started collaborative research (primarily in Europe) to develop the foundations for worldwide agreed series of G.7xx recommendations with the CCITT (now the ITU-T) for digital transmission based on the then emerging Plesiochronous Digital Hierarchy (PDH) platform for Australia’s future telecoms infrastructure. “***Highly Economic PDH Transmission***”

Initially (circa CE 1970) these analogue / digital / analogue circuits were very expensive to build but with then recent advances in Medium Scale Integration (MSI) technology, the manufacturing process was much faster (and far less expensive). These chips very slowly became less expensive and they were included in virtually all (digital) Voiceband telecoms equipment by CE 1982 - 1984.

In the late CE 1970s, laser trimming was a new technique to mass produce resistors to a far tighter tolerance than previously possible. What was realised was that with resistors, the intrinsic value may be (well) within say 5% of the desired value – but any batch of resistors were usually all well within 0.1% of each other. In terms of Quantisation Distortion this is about -60 dB, which put this laser trimming technology in the forefront to inexpensively mass produce analogue / digital conversions. “***Second Wave of Electronic Components***”

This advancing technology had immense significance in being able to relatively inexpensively produce a “ladder” of very closely matched value resistors (as a single block) to include alongside an MSI silicon chip encoder / decoder in a Printed Circuit Assembly for manufacturing reliable analogue / digital conversion processes.

The next technology advancement was that of “thick-film” resistors that were screen-printed / mounted inside the MSIs integrated circuits header – and then laser trimmed – then sealed. This process significantly increased the production rate and lowered the unit cost (and size) – but it was still “expensive”.

In parallel with all these technologies was the steady development of “surface mount” components, where the components have no wire leads and the need for holes to be drilled through printed circuit boards was minimised.

Not only were these components far smaller than their axial lead grandparents, but the packing density was about five times that of axial lead technology circuit boards, and these components could be very quickly robotically mounted on (both sides of) a circuit board.

The productivity of these new and advancing circuit board manufacturing techniques was not so much a competitive race but far more a realisation that a whole new type of electronic construction components was massively more productive than the first generation circuit boards that came out in the early CE 1960s (20 years before).

Even by CE 1980 there were still pockets of very aged SxS switching technology throughout Australia that were screaming out to be replaced as soon as practicable. TRL were well aware of this maintenance situation and knew that replacing SxS technology with Crossbar technology was not a good long-term maintenance strategy. This all had to move to digital technology.

My understanding is that by the early CE 1980s the (large scale) production costs of A/D conversion technology had considerably lowered such that with telephone line concentration so that say four A/D converters were available for say 30 telephone circuits, so this was economically necessary to minimise the number of analogue / digital conversion units per number of telephone lines.

An alternative to highly accurate (slow) analogue / digital conversion was the concept of “overclocking”, so the sample and hold clock rate was not 8 kHz but (say) 2.048 MHz (32 times faster) meaning that the number of samples could be digitally averaged and get a much tighter (32 times) digital value set particularly for the really small values – and have a nominally deeper noise floor (30 dB in this case).

It was I believe, this technology breakthrough in the early mid-CE 1980s that revolutionised the design of analogue / digital conversion and caused the manufacturing costs to plummet – making digital telecoms highly economic.

With continual production improvements, the cost of analogue / digital conversions continually / gradually reduced, making a new range of telephone line interfaces possible by about CE 1984 where each telephone line had its own inexpensive analogue / digital conversion chip – and line interface circuit (LIC) instead of coils and transformers! “***Mighty Productivity of Digital Platforms***”

Highly Economic PDH Transmission

The entry of digital transmission as Plesiochronous Digital Hierarchy (PDH) circa CE 1980 was like watching a dust-storm slowly approaching. Everybody with any telecommunications technical / engineering nous had sensed that electromechanical switching was on its way out and that digital encoding / decoding of Voiceband was imminent and that digital transmission was the way of the future. The problems were how will this be implemented and how long will it take to happen?

The theoretical concept of Voiceband encoding / decoding had been around for some years and although the processes were rapidly becoming far less costly as technology advances in these areas drove down manufacturing costs, Voiceband digital encoding / decoding was still not economic enough for individual digital interfacing. "***Digital Voiceband Technology***"

At the base level for PDH this was a 64 kb/s digital channel "E0" and these digital channels were perfect for digital transmission (and could equally well be used for Digital Voiceband). The immediate problem was how to group these 64 kb/s pseudo (digital) Voiceband channels so they could be a part of a larger digital stream.

As usual, the USA jumped the gun and by circa CE 1974 had its own u-Law digital encoding / decoding and thought along 12/24 channels FDM technology lines. So they came up with 24 Voiceband channels (8 bits u-Law encoded at 8 kb/s), plus one bit for synchronisation which is: 8,000 * ((24 * 8) + 1) = 1.544 Mb/s and this was (of course) incompatible with the rest of the developed world! (This was called the "T1").

The problem was that the link (and channel) synchronisation was not perfect (but that didn't seem to matter) and that there really was no Channel Associated Signalling (CAS) apart from in-band signalling; and that would not suit data communications.

The rest of the (developed) world took on a far better considered approach and recognised that the binary steps of 2, 4, 8, 16, 32, 64 etc. Voiceband channels are clean and fit as part of the overall PDH (times 4) philosophy. Also the rest of the developed world opted for the A-Law logarithmic encoding. This encoding difference may have been a (competitive) patent issue that stalled conformance…

With 32 (bi-directional) digital channels at 0.064 Mb/s this works out at 2.048 Mb/s and this very comfortably forms the "E1" level in PDH technology. (The "E0" level is at 0.064 Mb/s or 64 kb/s). "***Digital Voiceband Technology***"

So starting with 32 channels and working backwards; take out one channel for link synchronisation and another channel for channel associated signalling (CAS) – this is a very comfortable fit of 30 Voiceband channels, each using 8 data bits (1 Byte). For digital Voiceband usage use A-Law logarithmic encoding – otherwise use all the 64 kb/s channels as data channels!

At this PDH "E1" (2.048 Mb/s) level there is no "wriggle room" which means that at this level of PDH this is actually synchronous and the receive path should be externally synchronised to keep this signal from digitally "slipping".

Since about CE 1974 TRL was researching and was developing a highly economic and practical application of PDH-based technology for telephony over point-to-point radio for use in Regional Remote Australia – together with a 30 line NEC telephone line concentrator with a 2 Mb/s PDH back end to form what soon became known as the Digital Radio Concentrator System (DRCS) as the prototype circa CE 1978. "***HCRC in Remote Australia***"

The first (LM Ericsson) AXE telephone exchange/switches installed in Australia (CE 1981) were also effectively a telephone Line Concentrator technology (using a series of glass encapsulated reed relays as the "non-moving parts"). The telephony switch consisted of a series of clocked digital switch planes that had a back-connection to plug straight into a PDH transmission terminal that had 2 Mb/s "E1" interfaces as "standard". The alternative was that with the 8.44 Mb/s PDH "E2" level this could be wired directly into a long-haul PDH transmission system.

The word "Plesio" means "almost" so the words "Plesio Synchronous" mean "Almost Synchronised" and in its applications to digital communications this means that the clock speed in the receiving equipment is almost synchronised with the data clocking speed of the received data.

The basic structure of PDH was based on a series of clocking platforms where each hierarchy level is (nominally) four times the clocking rate that of the level below and four of the lower level hierarch can directly connect to this higher level.

The problem was that almost all the data sources had their own clocking speeds and these speeds were marginally different from each other. The fix for this problem was to receive the data in "chunks" where these data chunks were clocked in, then retransmitted to the next location. In this process "filler" bits were deliberately included so that the data speeds can catch-up or slow down as the clocking speeds wandered around the nominal set data rate.

To make this inter-transmission digital system practical and reliable, an extra amount of "filler timeslots" are included at the higher level so that a reasonably wide discrepancy in clocking rates can be tolerated and the transmission system not have connection problems by losing synchronism. In these filler timeslots - bits are either stuffed in or removed to automatically align the bit-rate of the lower level hierarchy.

Connecting four E1 (2.048 Mb/s) streams into an E2 (8.448 Mb/s stream) four times 2.048 = 8.192 Mb/s and the PDH E2 hierarchy allows a considerable amount of "slippage" so that the streams can connect – even if the 2.048 Mb/s streams are a within about 2% (fast or slow) from their standard clocking speeds!

At higher level of PDH (E3 at nominally 34.368 Mb/s and E4 at nominally 139.264 Mb/s and E5 at nominally 565.148 Mb/s) these similar "slippage" rules apply so that streams can be cross-connected between transmission systems and maintain connectivity without obviously different clocking speeds!

These PDH bit rates were / are hard to remember and they were "simplified" to be called 2 Mb/s instead of 2.048 Mb/s; 8 Mb/s (or 8.4 Mb/s) instead of 8.448 Mb/s, 34 Mb/s instead of 34.368 Mb/s and 140 Mb/s instead of 139.264 Mb/s, 560 Mb/s instead of 565.148 Mb/s etc.

While this was going on there was serious concern that the higher levels of PDH would be seriously underutilised and the expected productivities of this digital transmission hierarchy (PDH) was to be totally wasted. In the background there was a worldwide push to develop PDH long-haul equipment to operate over quad copper and coaxial cable transmission mediums and by the early CE 1980s these technology advances had come a very long way.

As it was, the Melbourne – Sydney FDM long-haul (thermionic valve technology) transmission system (that was commissioned in CE 1961) was literally on its last legs in the early CE 1980s. Several other same technology long haul transmission systems were also in desperate need of replacement using PDH technology.

By CE 1985, plans were well underway to roll out a dual 7-tube coaxial cable transmission link and use PDH technology but literally in the eleventh/twelfth hour the technology of Single Mode Optical Fibre (SMOF) came about in mid-April CE 1986 and started to be rolled out by about August CE 1986 and completed in November CE 1987. "***The Sudden Emergence of SMOF***"

Another parallel PDH technology consideration was the trialling of 8.44 Mb/s over quad copper (from the LM Ericsson AXE platform) in CE 1986/7. The intent in this case was that quad copper cable (or a pair of coaxial tubes) being used for 12 / 24 FDM channels in the Regional areas could be replaced with 8.44 Mb/s PDH using much the same technology as used for the 2 Mb/s PDH but in this case provide for 120 Voiceband channels. "***The Sudden Emergence of SMOF***"

With the Mel-Syd SMOF PDF transmission network, some 140 Mb/s PDH streams were initially dedicated to Video and ATM links. The problem was that with PDH, simply switching coaxial tubes was not practical and the base transmission rates were 140 Mb/s or 545 Mb/s – so it had to be (8 bit) encoded / decoded and even then there were connectivity issues! With video having a nominal 7 MHz bandwidth (say 18 Mb/s clocking) and 8 bit encoding this is at basically 144 Mb/s so there was a lot of "work" to be done to comfortably fit Video into a 140 Mb/s stream!

My understanding was that the ABC did an immense amount of (world leading) research and development work relating to digital audio and digital video compression and to the structure of the (wide) digital screen formats (e.g. 16:7) that we take for granted today.

Some of the initiatives were to replace the analogue synchronisation with (stereo) Programme (50 Hz - 15 kHz) audio (plus data) and feed the intensity and colour as two streams – but cutting out repeated areas. This at least reduced the bit rate to 68 Mb/s and later reduced this to be comfortable with 34 Mb/s. Since then the common compressed digital video speed (circa 2021) is in the order of 2 Mb/s.

The productivity of Digital Video compression was absolutely incredible and the figures stand for themselves: Shrinking an analogue TV signal that would have taken more than 140 Mb/s down to a digital signal at 2 Mb/s is about 70 times more productive. This digital technology was then / also taken to the HFC Cable TV industry and it was this digital compression technology that allowed there to be blocks of 100 MHz wide in the Cable TV spectrum (30 MHz – 1,000 MHz) for Cable Internet (circa 2005). "***Competition Wrecked Australia's Cable Internet***"

The clocking speeds with Plesiochronous Digital Hierarchy (PDH) extend to over 545 Mb/s and the consideration of having a "synchronised" network was then (circa CE 1980) was a totally impossible but a foreseeable vision.

HCRC Technology in Remote Australia

The situation was that the then Federal Government (circa CE 1975) had recently stipulated that every premises location in Australia must have a telephone service.

(This may have been a concealed international competitive USA-based strategy to enslave Australia to satellite communications with massive balance of payment costs to go to the USA and/or enforce the Federal Government to privatise Telecom Australia. Personally, I believe that the then Whitlam Labor Federal Government had excellent intentions to ensure telephone connectivity throughout the inland (Regional Remote) to optimise business and community productivity throughout Australia.)

Circa CE 1978-1985, the technology of geostationary satellite-based telephone services was fast-emerging as the main contender – but the launching / installation costs were gigantic and the continual 24/7 maintenance costs are also immensely expensive (same then as now). There must be a better way for Australia!

The problem for Telecom (Australia Commission) Research Labs - TRL in Clayton Victoria), was to find an economical technology (compared to geostationary satellites) that could provide highly reliable telephone services to about 10,000 to 15,000 potential telephone services (mainly to homesteads) throughout Regional Remote Australia with a very low maintenance overhead!

At that time in TRL, almost all the talk was about Plesiochronous Digital Hierarchy (PDH) Transmission and Digital Switching technologies mooted to be significantly more economic (far less overhead maintenance) than the technologies of Frequency Division Multiplex-based (FDM) transmission and electro-mechanical switching.

TRL Engineers had already very proactively worked with developing Plesiochronous Digital Hierarchy (PDH) technology, and they had actively promulgated / shared their knowledge and experience with the CCITT (now the ITU-T), the world standards body on telecoms. "***Highly Economic PDH Transmission***"

Two rather important outcomes had quickly become rather obvious in that PDH worked in "quantum" signal levels and consequently (if engineered properly) required virtually no maintenance – and – PDH seemed to require far more bandwidth than currently used for Frequency Division Modulation (FDM). As a side-shoot, TRL engineers were (from about CE 1974) also actively researching Single Mode Optical Fibre (SMOF) as this potentially would have a far larger bandwidth than coaxial cable (and radio). "***The Sudden Emergence of SMOF***"

It was not as though Australia was about to import yet another technology from overseas – exactly the opposite.

Most of Australia's Regional Remote is arid and rocky – which makes the ploughing in of (coaxial) cables extremely expensive; open aerial wire is a high maintenance technology so this left point-to-point radio as the third option – which is not that expensive. Consider a 100 m tower costs say $500,000 and the distance covered is 50 km then this in relational terms is about $10,000 per km – where ploughing in coaxial cable would be in the order of at least $50,000 per km – not including the repeater stations at nominally 8 km intervals that would really blow out these costs.

Part of their research showed that at about 1.5 GHz compared to higher frequencies this frequency band has a relatively low attenuation over distance as it generally "bends" with the Earth's curvature, and at these frequencies the beam can be made to be highly directional and very high gain with a suitable (parabolic) antenna.

TRL's research (with "Andrews Antennas") to date had produced a physically large parabolic antenna that used aluminium pipe making it relatively light, having a very low wind resistance, and with a sharp (narrow) beam that had a high gain of over 30 dB compared to the standard intrinsic "point" source – so it didn't need a (really) high power transmit stage to connect over rather long distances!

Because most of the inland is essentially flat, the simple decision was to employ radio masts about 100 m high so that line of sight upwards of 70 km could be achieved to provide reliable point-to-point radio comm's in most weather conditions.

Digital switching was another (slowly) emerging technology where Nortel in CE 1974 had produced the first digital switch – but that PDH technology was "USA specific" and not practical in Australia (nor elsewhere in the developed world). Other manufacturers were also stuck on the very expensive and slowly emerging analogue / digital / analogue (A/D/A) technology that was becoming Medium Scale Integration (MSI) technology. "***Second Wave of Electronic Components***"

TRL engineers had (globally) looked around for a piece of equipment they could utilise as a "Remote telephone circuit Node". They settled on an NEC 120 (Ring-Down/Loop Disconnect) Telephone (Access) Line Concentrator that had 120 telephone line connections and a 2 Mb/s PDH back-end interface. The big "physical" problem was this unit is about 1300 mm high (28 RU) and about 900 mm wide because it was (circa CE 1975 - 1978) engineering technology.

Also in consideration was that most of the Regional Remote Villages and Localities rarely have more than 25 nearby homes / businesses – so this connectivity had to be highly distributed – which is exactly the opposite to standard urban telecoms designs that are usually very highly centralised. It was standard Telecom Australia austerity practice to only partially fill equipment sub-racks to minimise costs and in this case only a minimum of line concentration cards were installed in most locations.

The other issue was the "local" end interface that would connect at Voiceband (with Ring Down / Loop Disconnect signalling). In those days, analogue "Pair-Gain Systems" had become fairly commonplace in Regional Rural / Remote areas and (as far as I can remember) NEC also had a local end interface for their earlier Analogue Radio Concentrator System – so it was fairly straightforward process to have this "re-engineered" to implement a 2 Mb/s PDH interface (for nominally 120 services).

The missing part of the project was the 1.5 GHz – 2 Mb/s PDH radio transceiver, where again the TRL engineers and came up with a then state-of-the-art solid-state prototype design using Phase Amplitude Modulation (PAM) and the back-end connection was initially four (4) well spectrum-spaced Plesiochronous Digital Hierarchy (PDH) 2 Mb/s streams over the two nominal 56 MHz transmit and receive frequency bands centred on near 1,500 MHz.

This part of the electromagnetic spectrum around 1,500 MHz (1.5 GHz) is also used for communications between satellite / earth but the big difference is that the direction of those antenna (beams) are not parallel to the ground but (usually) pointing vertically! So there really are no real grounds to complain about interference with both infrastructures being concurrently used for different / similar applications!

At the "remote" sites, having four 2 Mb/s PDH streams was a fantastic opportunity to have a leapfrogged (pair gain) network structure that could serially span up to four separate localities with a maximum of 120 lines per locality and cover a distance of say 4 * 70 km = 280 km.

> *My professional understanding (from having worked in the PMG / Telecom Australia NSW Transmission / Switching / Design Laboratory for 19 years – where we specialised in manufacturing prototype and proof of concept telecoms equipment) is that a small number of prototypes (say 5 to 50) would have been manufactured and field trialled to prove the technology and get rid of the not so obvious labour intensive construction problems, make structural changes to remove "mechanical / electronic / component misfits", implement manufacturing improvements in these prototypes / proof of concept equipment to "make a substantially better mousetrap" as part of the continual improvement mindset and get this all documented!*

With all the information gathered, the DRCS prototype and its installation and commissioning, practical use, field applications, terminal connections, rack-mounting etc. would have been entirely re-engineered as a "proof of concept" and a small production run of say 100 units would have been manufactured and field trialled to ensure the productivity improvements worked as planned.

There was never "increased competition" to drive productivity improvements! If anything there was continual and highly efficient "collaboration" (which is negative competition) in this "Infrastructure Business" environment.

This is is yet another classical case where economists persist with their hollow mantra that "increased competition drives improved productivity / profitability etc."; which is totally wrong in every way possible!

So, the DRCS initially came out as a "Prototype" in CE 1978 that had a very limited rollout and was soon followed by a "Proof of Concept" version that had a not so limited rollout. Not only was the maintenance almost zero, but the distances covered were fantastic and it provided inexpensive and highly reliable telephony to some Remote areas in Australia!

The sticking problem was that having a maximum of only four drop points (i.e. only four 2 Mb/s PDH streams) that was rather limiting to say the least – especially considering that future network structures of upwards of 600 km were not unreal.

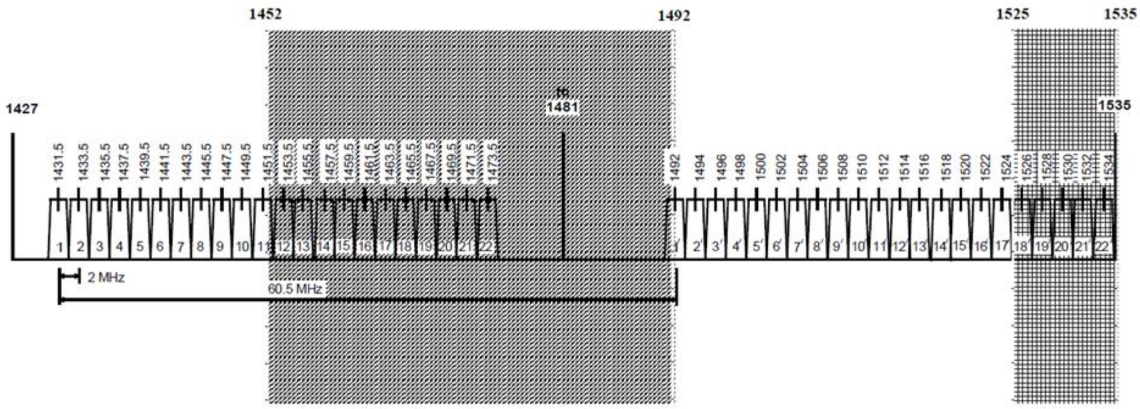
The really big technology breakthrough came in the radio transceiver where the TRL engineers came up with a strategy to significantly increase the number of 2 Mb/s PDH bi-directional streams was dramatically (and simplistically) increased from 4 streams to 22 streams in the allocated bandwidth around 1.5 GHz.

In this case, the 2.048 Mb/s streams were "banked / stacked" like an FDM system with a 2.000 MHz carrier spacing arrangement with (I think) 8 Quadrature/Phase-Amplitude Modulation (8-QAM) resulting in the sidebands from these 2 MHz spaced carriers generally sidestepping the adjacent channels carriers and their sidebands!

The nominal bandwidth is about 1.427 GHz to 1.535 GHz where currently there are 22 sets of two directional channels sets (2 Mb/s) set at nominally 2 MHz apart and the reverse direction is 61 MHz separated to minimise receive channel interference.

The more I think about this the more that I see the 22 directional channels as a channel bank and not as 22 separate channels for upstream (nominally 44 Mb/s wide) and separate 22 channels for downstream (nominally 44 Mb/s wide).

THE 1.5 GHz DRCS BAND (1427-1535 MHz)
(Point-to-Multipoint Services)
RF CHANNEL ARRANGEMENTS



So the guard band is more like 61 MHz - 44 MHz = 17 MHz and the overall band is more like 44 + 17 + 44 MHz = 105 MHz and with this roughly centred around 1500 MHz this comes out at about 1447 MHz to 1553 MHz and the spectrum plan for this is as shown above.

My understanding is that this modulation strategy was literally decades ahead of its contemporaries that now call this "orthogonal" modulation – where the sidebands are slotted into the spectrum voids of the adjacent channel(s) to maximally utilise the available bandwidth.

The other stroke of genius was to offset the receive block by 61.000 MHz so that with 44 MHz occupied there is nominally 13 MHz between the directional carrier blocks which at about 1500 MHz provides enough room for the "skirt" (sides) of a surface acoustic wave (SAW) band pass filter to minimise reverse path interference.

With the "radio component" very significantly made high capacity, the overall design of the DRCS dramatically changed name to become a High Capacity Radio Concentrator (HCRC) that was considerably more compact than the earlier Digital Radio (Line) Concentrator System (DRCS). This very advanced technology really threw the doors open to extend the use of the HCRC technology throughout Regional Remote Australia (and elsewhere in the world where there were sparse populations requiring economic telephone connectivity).

With advances in MSI chip technology by about CE mid-1982, these analogue/digital chips became inexpensive – turning the whole digital telephone exchange technology on its head – with individual line interface circuits having their own (inexpensive) digital conversion interfaces "***Mighty Productivity of Digital Platforms***".

With this technology having a maximum of 30 lines now back-connected by 2 Mb/s PDH where each line had its own (inexpensive) digital interface – the NEC line concentrator took on a very different form that fitted into a 10 RU sub-rack height (about 455 mm high) and (unfortunately) still about 900 mm wide (that matched the "switching" racks!

My educated guess is that the new “prototype” HCRC equipment was rolled out in probably three or four locations and was an immediate success, and they wasted little time in moving to the “proof of concept” version that was probably rolled out in about 100 locations (say about 20 to 30 systems). From here (a year or so later); a “small production run” of say 900 HCRC units would have been manufactured and installed and successfully commissioned. Virtually no maintenance!

By external accounting methodologies, the standard of living in these Regional Remote areas was dramatically improved – which directly played into far less reliance (costs) on Social Services / wellbeing and social / medical health which in turn significantly improved farming / grazing / mining / community productivity.

I have been very reliably informed that there are over 1,100 DRCS/HCRC radio masts throughout Regional Remote Australia – still most in excellent physical condition (primarily because they are well away from the salt air of the sea!

My understanding is that this project then cost in the order of $471 M (which was more than 10 times the cost of the much later high capacity Melbourne – Sydney Single Mode Optical Fibre (SMOF) network that cost about $45 M in CE 1986/7). “***Costing the Mel-Syd SMOF Link***”

My further understanding is that the financial cost of the DRCS/HCRC played a very large part in the Davidson Report for the Federal Government to provide a very substantial annual subsidy of about $177 m pa (inflation indexed) to facilitate Telecom Australia Commission being split up and privatised. “***The Davidson Inquiry and Report***”

The economic saving in social security / medical / mental health was immense and the productivity of those in these Regional Remote areas was dramatically increased because of this 24/7 telephone communications would have paid for itself in under a year. *The Competitive Business mindset deliberately does not practice / include External Accounting because this would show up discriminatory products / services as being essential – which would justify nationalising this infrastructure!* “***Infrastructure Business – Competitive Business***”

In CE 2009, I produced a detailed Submission to yet another failed Select Senate Inquiry on (the failures of) Telecommunications (outside the metropolitan areas). In the addendum to that submission I created a short table to broadly calculate the productivity of having Broadband connected to a remote farm / station. What really surprised me was the externally accounted cost savings (productivity gains). “***The Privatisation Wheels Fell Off***”

This is an excerpt from that Submission:
“What may not be obvious is that since about 1990, Telecom Australia / Telstra changed its accounting methods to use internal P&L accounting to match the needs of its shareholders, and maximise its profits. Consequently almost all new infrastructure from that date has gone onto telecoms facilities is equipment that has a high usage rate and a low per-premises cost, and that basically meant that Band 1 and Band 2 (major capital cities, their suburbs and major non-capital cities). The rest of Australia has basically missed out.

Taking the above case (Birdsville Broadband) that was raised by Senator Ian MacDonald. Assuming that this infrastructure cost came out as $10,000 per premises, then the external accounting P&L process would move in and look at many issues like:

Medical eHealth savings through customers using BB Internet	$500
Unemployment social service cost reductions	$2,000
Saving in Petrol and Oil products	$3,650
Improved Education	$5,000
Trading from the Farm	$3,000
Short List Sub-total (per premises, per year)	**$14,150**

So using the External Accounting P&L approach as used in the infrastructure regime, this infrastructure would have paid for itself in less than 9 months, and we have not even asked the shareholders about the profits (because the government and opposition are the shareholders), and the government overheads on Social Security and Health / Medical are significantly dropped, while these people will be paying bigger taxes!

The obvious argument is that these external accounting P&L figures are far too optimistic, so if these figures were heavily discounted by say 75% then we will get:

Medical eHealth savings through customers using BB Internet	$125
Unemployment social service cost reductions	$500
Saving in Petrol and Oil products	$912
Improved Education	$1,250
Trading from the Farm	$750
Short List Sub-total (per premises, per year)	**$3,537**

Keeping this external P&L accounting in line with a typical competitive business case, then it should break even over three years (neglecting interest). These heavily discounted figures clearly show that the payback to the government for putting in this infrastructure is more than $10,500 over three years making this infrastructure business case extremely compelling.

Typically the Australian telecoms spend (investment) on infrastructure would be in the order of $5 Bn per year, but if you go back to about 1990 and rationalise the telecoms investment by about 50% due to the competitive regime kicking in, (including considerable ACCC based costs for thousands of lawyers in Telstra) so the infrastructure investment is about say $2.0 Bn per year, then the underspend thanks to the competitive regime is about 19 * $2.0 Bn = $38 Bn, and looking backwards this is a bit under what the NBN is ($43 Bn)!"

Taking these rather conservative figures from my submission showing external productivity savings in the of about $14,150 pa

Considering that the DRCS/HCRC then cost about $471 M and connects over 14,000 customers / subscribers most of whom are in Homesteads; this works out at about $34,000 per connection.

By simple external accounting alone $34,000 / $14,150 pa = 2.4 years to break even.

My understanding is that the DRCS / HCRC technology was rolled out over the period CE 1978 - 1985 (about seven years) and stopped about a year before SMOF technology was also discovered by the TRL (mid-April CE 1986).

In my expert opinion, this HCRC technology was a perfect geographic / technology fit – and for its time, it was really advanced technology that provided a very cost-effective solution to provide reliable fixed access telephone services in Regional Remote Australia and have an extremely low maintenance overhead. "***The Sudden Emergence of SMOF***"

Virtually concurrent with this DRCS/HCRC rollout, the first (Australian manufactured) LM Ericsson AXE digital telephone exchanges were installed in CE 1981 and this rollout continued until about CE 1992 (almost 12 years).

Like the DCRS/HCRC, the AXE digital telephone switches also went through a development phase where the Analogue / Digital / Analogue (A/D/A) section of these AXE switches radically changed (circa CE 1982/3) as the cost of digital conversion plummeted – purely because of radically different / improved manufacturing / technical advances. "***Mighty Productivity of Digital Platforms***"

One of the technology smarts about AXE switches was Australia's (Telecom Australia) development of 2 Mb/s ISDN that plugs straight into the back of the AXE switch plane and connects 30 Voiceband channels!

My understanding is that since about CE 1984/1985 when the last of these HCRC infrastructures was installed and commissioned, Telecom / Telstra have done precious little to upgrade this technology (and it is now CE 2021).

The local exchange DRCS/HCRC transceivers have 2 Mb/s interfaces and I believe it would be far more energy efficient and maintenance efficient to directly back-connect these 2 Mb/s streams directly into the AXE switch and totally do without all the local Voiceband interfacing. Consider each local exchange NEC Line Unit consumes about 4 amperes (200 watts) per Unit. (I really hope this was done!)

In early CE 2020, the Dept. Communications put up a request for "Voiceband Trials" in the Regional Remote areas – where the DRCS/HCRC infrastructure is still working perfectly. This appears (to me) to be a front to provide a (corrupt) grant for funding low orbit satellite technology – which Australia (in my expert opinion) certainly does not need and will definitely will become a massive white elephant ! "***Satellites Prove to be Highly Uneconomical***"

I provided a detailed response showing how this DRCS/HCRC (about 40 year old infrastructure) could very inexpensively be "re-engineered" to take advantage of the bandwidth and provision reliable connectivity via IP (and VoIP) technologies.

This re-engineered HCRC infrastructure could be used to provide at least 50 Mb/s (350 Mb/s to 1,000 Mb/s) everywhere plus provide a substantial fix for Radio Black Spots in a very large proportion of the Regional Remote areas (along roads). "***Competition Manifested Radio Black Spots***"

As I also pointed out - the Voiceband connectivity would be a (VoIP) subset of the Broadband connection and very inexpensively provide yet another massive productivity boost for those in Regional Remote Australia. No response from these Staffers / Journalists who clearly lack any telecoms engineering expertise!

My educated guess is that **if** this DRCS / HCRC radio transceiver infrastructure was upgraded to support 1000 Mb/s bi-directional IP Broadband connectivity as Backhaul for Fixed Wireless / 3G / 4G / 5G Mobile Devices (and even FTTHomestead), then the massive $177 M pa (now $233 M pa) gravy train could/should suddenly stop! "***Davidson Inquiry and Report***"

Mighty Productivity of Digital Platforms

If ever there was technology that had a preceding entourage it had to be Digital Switching with its twin sister Digital Transmission. The concept was formally realised back in the CE 1920s but the technologies had to go through several growth / development phases before these two platforms could be paralleled up and strengthen each other in the process. "***The Davidson Inquiry and Report***"

The then very well established FDM technologies that emerged in the early CE 1950s had, by the CE 1970s, an extremely firm grip on all forms of medium and long-haul Voiceband transmission. Although FDM was an excellent technology, it was entirely based around Voiceband interfaces. The Signal to Noise Ratio (SNR) was a persistent problem and keeping the alignment levels consistent meant continual low level maintenance. "***Massive Productivity of FDM***"

To a large degree the physical **star** structures of long-haul FDM Intra-Regional State Networks emanating from the State Capital Cities was very effectively converted into State-wide loose mesh structures by the inclusion of Group Extension and Super-Group Extension Amplifiers / Equalisers positioned in the Capital City CBD Trunk exchanges. "***Productivities of FDM Extensions***"

It was not until the early CE 1970s that Plesiochronous Digital Hierarchy (PDH) transmission technology could be realised manufactured and trialled, proving that PDH at the E1 (2 Mb/s), E2 (8.4 Mb/s), E3 (34 Mb/s), E4 (140 Mb/s) levels were inherently quite stable, inexpensive to manufacture, was inherently zero maintenance – but it required considerably more bandwidth than the equivalent FDM technologies. "***Highly Economic PDH Transmission***"

The concept and application of logarithmic audio level encoding / decoding became the imperative to minimise (digital) noise and make digital Voiceband transmission have an extremely low operational overhead. The universal standard of Digital Voiceband clocking at 8 kHz (and 8 bits per clock cycle, i.e. 64 kbits/sec), set the base for a common telephone switching platform. "***Digital Voiceband Technology***"

By the early-CE 1970s, realising the concept of logarithmic Digital encoding had proven to be very expensive and the introduction of reed-relay based line concentration substantially reduced the number of "Codecs" per number of customer lines. This "compromise" facilitated the first digital telephony switches with analogue telephone line interfaces to connect through the pair copper Access Network to telephones in customer premises and a PDH backhaul connection.

From CE 1974 Telecom Research Lab (TRL) had been very actively researching and developing digital encoding / decoding / PDH technologies and Single Mode Optical Fibre (SMOF) to make these technologies economic and practical. By CE 1978, TRL had developed their Digital Radio Concentrator System (DRCS) to provide telephone services in remote Australia that initially had four close-stacked 2 Mb/s PDH streams in a 1.5 GHz (L Band) for long distance radio hops – back-connecting NEC Line Concentrators as the phone interface. "***HCRC Technology in Remote Australia***"

In CE 1980, Telecom Australia Commission made the gigantic technology decision; to run down the manufacturing of LM Ericsson Crossbar and move to having LM Ericsson AXE (AXE) digital switches manufactured in Australia. This direction set the course for Australian telecommunications to leave the Analogue platform and move to the Digital platform – and move to PDH transmission technology.

The first version LM Ericsson digital telephone switch (the AXE 101) that came out in CE 1981 was effectively a multiple 2 Mb/s (PDH) Line Concentrator; presenting a major technology hurdle to the Voiceband / Analogue / FDM world of the then Australian telecoms as the AXE switch had a Plesiochronous Digital Hierarchy (PDH) Backhaul transmission interface that was fundamentally incompatible with Voiceband analogue / FDM technology that was "everywhere"!

The immediate workaround was to provision the AXE switches with 4-wire Voiceband analogue circuits (with "T" signalling) so that these circuits could directly interface with the pre-existing FDM carrier transmission technology (and Crossbar ARM switches) as per the Backhaul technology of the Inter-Exchange Network. Far more pressing was the need for loop signalling Voiceband analogue interfaces so that these new AXE 101 switches could "talk" at 600 ohms or 1200 ohms impedance to ARF and ARE Crossbar switches either directly or via loaded cable Junction cables.

At best this was extremely clumsy – but it provided the necessary Voiceband circuit connectivity with the then long-haul inter-exchange transmission network infrastructure. "***Transitioning to the Digital Network***"

The "other" problem was that the AXE101 switch had 2 Mb/s back-connections that were designed to directly interconnect with PDH transmission systems in the same building. This presented a major problem because apart from there being no PDH hierarchy transmission systems installed, there was plenty of loaded cable as metropolitan Junctions that would be made redundant as AXE technology switches were to be rolled out. TRL wasted no time in very innovatively capitalising on this potentially wasted infrastructure and worked with LM Ericsson to make a 2 Mb/s PCM interface for Pair Copper. "***Massive Productivity of 2 Mb/s over Pair Copper***"

The next big technology breakthrough came (circa CE 1983) with medium scale integration (MSI) solid state (silicon) technology to do the analogue / digital conversion processes considerably less expensively then earlier. This technology facilitated an entire change in 2.048 Mb/s / analogue line connection interfacing that was no longer an (analogue) line concentrator strategy no then each (telephone) line directly connected with its own analogue / digital / analogue interface. "***Second Wave of Digital Components***"

Almost concurrently the technology of an inexpensive solid state (telephony) Line Interface Circuit (LIC) came into being and handle the high voltages of ring current (70 V rms), sense loop connection, transfer loop disconnect signalling (from a rotary dial) and provide a constant current feed to power the button carbon microphone in the telephone's handset at the premises! This LIC and its associated components was a small fraction the size (and cost) of the relay-based technology that came from the early CE 1900s – over 80 years ago.

These combined technology breakthroughs heralded the total rebuild of the Ericsson AXE101 switch to the AXE102 switch technology as the backplane had to be changed as well as all the line interface cards – removing the bulky line interface relays and removing the line concentrator reed relay boards – to be replaced by a standard line interface board that was elegant and slim.

As the component height in these boards was "lower" than their earlier technology brothers; so the packing density was considerably increased! The implication here is that the physical size of the AXE 102 switching equipment could then comfortably fit into about half that of the AXE 101 version technology. Compared to Crossbar switch technology – four racks of AXE 102 switching equipment did the equivalent connectivity of about 10 suites of Crossbar switching technology!

In step with this technology advancement, TRL were (collaboratively) working with LM Ericsson to re-engineer the city / suburban mindset AXE 102 technology to make a far smaller unit (called the AXE 104 – housed in a fully functional container about 8 metres long – that could be installed in country towns and villages.

Again the productivity here was highly effective / efficient because the overhead costs of competition were bypassed: in this case drawing up Tenders, going through Bids, covering the costs of competing Tenderers wages and costs including having multiple (totally unnecessary) social events for Bidders to compromise the situations and lock in their Bids, (which accounts for between 15% and 20% of contracts).

With improved AXE operating system software, and the facility to bulk program an exchange in a hut before being transported to site it became practical by the mid CE 1980s to replace an entire 1000 line Manual (Sylvester Switchboard), Automatic (SxS or Crossbar) exchange in a few days.

In close parallel with this technology of the new AXE 102 was the then also recent development of a "Loop (Signalling) 2 Mb/s Multiplexer" (affectionately known as a "Loop Mux"). This piece of equipment was far more transmission than switching and was another new technology kid on the block that really drove down end user costs!

Another close parallel was the concept of a 2 Mb/s Integrated Services Digital Network (ISDN) connection to connect businesses with a minimum of infrastructure. This connection used two copper pairs (in the Access Network) and connected up to 30 Indial (answer only) circuits into a PABX. "***Massive Productivity of 2 Mb/s***"

In the background it was painfully obvious that 2 Mb/s on pair copper was a very transient transmission technology / strategy and that far more transmission capacity was very urgently needed.

> *While doing my first year as a Class 1 Engineer in Telecom Australia Commission, in Sydney, (April CE 1986) purely by chance I had been right across the introduction of Single Mode Optical Fibre (SMOF) as the near perfect wideband transmission medium!* "***The Sudden Emergence of SMOF***"
>
> *The following year (CE 1987) as a Class 3 Engineer in the Long Line Support Section in Sydney, one of my tasks was to evaluate an 8.4 Mb/s PDH system using quad cable as the transmission medium. This worked perfectly well – within design parameters; but I knew that its life was going to be very short, once the word got out about SMOF technology.*
>
> *What I found to be "very interesting" was that nobody in this advanced area of Long Line Support appeared to have any knowledge about the very rapidly emerging Single Mode Optical Fibre (SMOF) technology that was being literally rolled out between Melbourne and Sydney!*

Massive Productivity of 2 Mb/s

In the CE 1970s, Australia was a powerhouse of engineering productivity with the ABC labs (primarily in Sydney) – working closely with the Universities, the PMG Telecoms Research Labs (TRL) in Melbourne based in Clayton (Monash University) with many TRL offices distributed throughout the Melbourne CBD and several telecoms equipment manufacturing factories and splinter research areas throughout Australia - with most working in collaboration with TRL and the CSIRO.

Engineers in the ABC Labs had been leading the world with the technology of digital encoding / decoding and Telecom Australia's Research Laboratory (TRL) had been working with the concept of digital transmission. "***Digital Voiceband Technology***"

In that era, digital transmission was a dramatically different technology mindset than analogue transmission / communications and analogue telecoms technologies had a long-standing engineering history that was hard to "shake"!

Digital transmission requires substantially more bandwidth than (Voiceband) analogue transmission, but what was not commonly / immediately recognised was that the engineering design of 2.048 Mb/s ("2 Mb/s") Plesiochronous Digital Hierarchy (PDH) technology (circa CE 1974) had the potential to be extremely productive compared to the then widespread use of Voiceband Analogue on Loaded pair copper cables. "***Highly Economic PDH Transmission***"

At that time, all Metropolitan Inter-Exchange (Junction) Network and most Rural Regional District Inter-Exchange (Transit) Network cables were lead-sheathed twisted paper-insulated 0.64 mm pair copper wire. Most of these Junction Cables were 50 pair and a few were 100 or 200 pair. All these pair cable (inter-exchange) transmission networks were (Voiceband) analogue technology – not digital!
"***Highly Economic Underground Cables***"

These Junction and Transit cables included 88 mH Loading coils every 1830 metres to stabilise the Voiceband spectrum impedance towards "1200 ohms" while flattening the frequency response below 3.4 kHz and reduced the attenuation over distance (because the operating impedance was now substantially higher than unloaded cables and the series resistance component in the wire had far less effect on Voiceband attenuation). "***Rebuilding the Regional Transit Network***"

The problem then facing engineers in Telecom Australia Commission was that as these digital exchanges are to be installed, the existing pair copper Loaded Cable (as was already underground between most exchange sites) may not be suitable for digital transmission.

Circa CE 1980, the very new emerging AXE101 technology was (I think) initially engineered for 2 Mb/s PDH and maybe 8.4 Mb/s PDH with a parallel connection for clocking synchronisation, and a cable limit of about 500 metres - which was engineered for PDH transmission systems from a terminal in the same building.

TRL had been working with Plesiochronous Digital Hierarchy (PDH) technology from about CE 1973. The transmission method chosen for "low rates of digital transmission" over pair copper cable (and some coaxial cables) was what is called "Alternate Mark Inversion" (AMI) where the "on" or "mark" state is far greater than the "off" or "space" state – so there is a (large) quantum difference that defines a logic 1 or logic zero and each proceeding mark is reverse polarity (hence "Alternate"). This transmission technology gets over almost all of the problems of time varying line attenuation and a considerable amount of background noise – and is excellent for balanced line transmission (and excellent in coaxial cable).

The problem with AMI encoding/decoding is that if a repetitive series of zeros are sent then the clock synchronisation can easily be lost – leading to a long stream of errors before the receiver re-aligns itself and re-synchronises.

The very cunning fix for this intermittent loss of synchronisation was to include clock timing within this AMI encoding by implementing High Density Binary 3 code by doing nothing unless there is a series of zeros and in this case invert the fourth zero in this sequence with a mark (but invert that (mark) if the fourth bit is a logic one), so there is no sequence longer than three blank pulses. *You may need to read that twice!*

This seemingly complex process is very easily done with simple logic as a “state machine” and the clock timing is then included inside the data transmission. At the receiving end a similar simple logic “state machine” decodes the HDB3 encoded signal to produce the serial data (and the clocking). So all that is needed is one pair of wires for balanced, unidirectional transmission of 2.048 Mb/s (“2 Mb/s”), 8.448 Mb/s (“8 Mb/s”) and 34.368 Mb/s (“34 Mb/s”) – using HDB3 encoding. A second pair of wires is necessary for the return (receive) transmission path.

With 2 Mb/s HDB3 digital transmission over twisted pair cable (engineered for Voiceband), the signal is “differential” which minimises external noise induction (and the twisted pair also minimises unwanted external promulgation).

TRL (Telecom Australia Commission) had not been sitting idle and they were actively world researching for technical advances. One very exciting advance came out of the USA where a silicon chip manufacturer had developed a line of digital Regenerators about the size of a cigarette packet (I believe primarily for the USA market for 1.544 Mb/s (“T1”) digital transmission, over what was previously loaded cable pairs for analogue Voiceband). They also made a second Regenerator for 2.048 Mb/s (“E1”) that was useful for the rest of the world – but not in the USA!

The problem was that these digital Regenerators required loop current powering and as far as I know, the Ericsson AXE did not have a suitable 2.048 Mb/s PDH interface that used HDB3 encoding (and/or had serial loop power feeding).

In CE 1980, TRL had collaboratively worked with LM Ericsson to prototype and develop a line-powered 2 Mb/s (HDB3 encoded) PCM card (as part of the AXE switch technology) so that previously Loaded Cable pairs could be re-connected to provide 32 digital channels at 2.048 Mb/s per two pairs. These Regenerators could be serially connected (and loop powered) in place of the Loading Coils.

This then new technology facilitated very inexpensive 2 Mb/s (HDB3) PDH connections between AXE101 exchanges over two pairs, providing 30 bi-directional digital Voiceband connections at 64 kb/s (including clocking / channel synchronisation and channel associated signalling (CAS).

Consider we have a 50 pair Junction Cable say 11 km long with Voiceband attenuation of about 6 dB and 5 Loading Coils per pair (250 in total). Chances are that after say CE 1933 when this cable was installed that, 10 coils have failed by CE 1980, due to lightning and corrosion, so we now (generously) have say 40 properly working Voiceband Junction circuits.

Cable costs aside, the Loading Coils would have cost (in today's currency) about $25 each, so the total cost is about 50 * 11 * $25= 440 * $25 = $13,750. This would have initially provided 50 Voiceband circuits at nominally $275 per channel.

Cable costs aside the Regenerator costs would have been in the order of $250 each and we need two 2 Mb/s streams to get nominally 60 Voiceband channels or about 2 * 11 * $250 = $5,500 and that is about $110 per channel (50). The conservative price productivity advantage is $110 / $275 = 40% the previous (analogue) price.

If this cable was fully converted to 2 Mb/s AMI HDB3 PCM then it would 25 * 11 * $250 = $68,750 and this is 25 * 30 = 750 Voiceband channels which is a conservative network connectivity productivity of 750 / 50 = 15 times = 1400%.

This is a massive technology-based productivity advantage that would have been pivotal in driving down end user costs in the early / mid CE 1980s! Conversely this "wealth chest" would have been pivotal for inexpensively funding the rollout of far more AXE digital switches throughout Australia.

On another front, Telecom Australia had taken the concept of 2 Mb/s streams of 30 Voiceband channels and employed this to provide a direct interconnection with Private Automatic Branch Exchanges (PABX) equipment in businesses – using the same interface a used for 2 Mb/s PCM AMI HDB3 digital Junctions!.

This was a real variant on the rest of the world utilising the Integrated Services Digital Network (ISDN) to very efficiently provide nominally 30 (digital) Indial circuits with very little equipment.

Basically most PABXs manufacturers wasted no time in producing a 2 Mb/s port interface for Indial connectivity. Because this Customer Access Network length was (usually) so short (less than 2000 metres) there was no need for a 2 Mb/s Regenerator and the wires came straight into the PABX.

So with two pairs of Access wires this provided a connection for 30 Indial circuits (all answering to the same "number") – meaning that 30 operators could concurrently handle incoming calls from their extension phones. In practice this would be in the order of up to 50 desk positions for near concurrent calls into a business.

Basically a 2 Mb/s Loop Mux was a compact piece of transmission equipment (about 267 mm (6 RU) high that fitted into a standard transmission (19") rack).

On one end, the Loop Mux had a 2 pair (each) unidirectional 2 Mb/s PDH using AMI transmission with HDB3 encoding. This interface includes the option of a current feed (between the pairs) to power 2 Mb/s Regenerators or a loop termination (between the pairs) to complete the external power feeding circuit. The 2 Mb/s carries 30 digital Voiceband channels, plus Channel Associated Signalling (CAS) for the 30 analogue channels in the 31st channel, and 2 Mb/s link synchronisation in the 32nd channel, making up the 32 digital channels.

The other end of the Loop Mux looked like 30 analogue circuits with "2-wire" balanced bi-directional analogue Voiceband transmission and (with each analogue channel) a dip-switch/links choice of 600 ohms or 1200 ohms line impedance; plus a dip-switch/links choice of Balance Network impedances to (near) optimally match the impedance that the Loop Mux analogue side is connecting into, plus dip-switch/links to set the transmission level at 0 dBr, -3 dBr or -6 dBr to match the analogue connection point reference level in the Inter-Exchange Network.

This Loop-Mux was the “perfect fit” to interconnect AXE digital technology switches in Metropolitan (“1200 ohms”) and Regional Rural (“600 ohms”) areas with the earlier electromechanical technology SxS or Crossbar telephony switches; as these earlier switches were interconnected by (analogue) Loaded Cable technology as Junction or Transit cables – with “loop” signalling! “***Massive Productivity of 2 Mb/s***”

The “analogue” gain settings were particularly useful as these could compensate for up to 6 dB of Loaded Cable (-6 dBr); cancelling the need for Voice Frequency Hybrid Amplifiers, but also be positioned in a (Metropolitan) Tandem or Regional (Minor Switching Centre) location (-3 dBr), as well as be positioned at a terminal location (0 dBr) to align with these analogue levels.

Alternately – the Loop Mux could be co-located at an AXE switch and interface with Loaded Cable pairs connecting with SxS or Crossbar Local exchange at other sites.

This Loop Mux technology could also be at both ends of a 2 Mb/s pair copper line and seamlessly interconnect Crossbar / SxS technologies in different locations; or be at one end of a 2 Mb/s pair copper line and interconnect AXE (at 2 Mb/s PDH) to Crossbar or ageing SxS technologies (analogue Voiceband).

NEC also produced a 2 Mb/s 30 channel “T” Mux (Transmission Signalling Multiplexer) that was identical in size as the “Loop Mux” and the digital interface was also identical. The difference was that the 30 digital Voiceband analogue interface that was 4-wire balanced 600 ohm transmission with (E&M) Channel Associated Signalling – which directly matched the standard FDM 4-wire 600 ohm interface. This was the “perfect fit” to replace FDM transmission systems’ back-connection to Crossbar and ageing SxS switching technology with a 2 Mb/s PDH connection.

So – these T-Muxes could connect an AXE switch to 30 Voiceband channels that could then directly connect into a long-haul (High Capacity) Frequency Division Multiplex (FDM) transmission system, or a Crossbar ARM (Trunk) switch that could interconnect 1000s of km away.

The value of these two transmission interface devices was (I think) severely under-rated because these very inexpensively provided the conduit between the very well-entrenched analogue / FDM technology Inter-Exchange Network (IEN) and the almost non-existent (digital) Backhaul Network.

The added bonus was that these Loop / T Mux equipment came fully provisioned with 30 Voiceband channels; so not only did this Mux equipment introduce massive circuit connection productivity – effectively eliminating decades of Regional Rural Network congestion that was primarily a result of “Recession-minded engineering” with Transit Voiceband circuits being systematically underprovided, and the Loop / T Mux was inexpensive and easy to install! “***Shaking the Recession Mindset***”

With the 2 Mb/s back-connections going directly into an AXE Transit/Minor Switching Centre switch (several km away) these remote ARK (and ARF) exchanges effectively became digital fingers of a centralised ASX / Crossbar Minor Switching Centre (MSC) in large country Towns / Cities or in metropolitan cases became extensions of the Transit AXE switches. “***Transitioning to the Digital Network***”

From here, it was a very simple process to inexpensively extend the AXE switching planes and then remove the MSC Crossbar technology. It was common practice to re-use now available Crossbar line relay sets to very inexpensively increase Junction / Transit connectivity (through unused channels in the Loop Mux equipment) at remote ARF / ARK exchange sites).

Considering that the bulk manufactured production costs of Loop Mux equipment was now so low – it became highly economic in many (a few thousand) smaller remote ARK / ARF Crossbar switch locations to simply back-connect the line signalling / feed bridge circuitry straight to the Loop Mux equipment and simply use 2 Mb/s on Pair Copper to directly parent into the now digital AXE MSC switch! This technology advancement virtually wiped out the need for (regular) maintenance in these remote sites / villages. "***Massive Productivity of 2 Mb/s***"

This technology quickly advanced in the late CE 1980s where Pair Gain Systems (PGS) up to about 250 lines, took this integration step further and almost eliminated the need for any SxS or Crossbar equipment (particularly in Regional Rural Australia) as these new technology Voiceband telephony interfaces were the inexpensive equivalent to the earlier AXE104 exchanges.

Because the amount of electromechanical equipment was dramatically reduced; so too was the need for maintenance overhead – and many thousands of skilled technical staff were unfortunately, forcibly retrenched.

Using a 50 pair 20 km length pair copper (Junction) cable, the Loaded Coils cost nominally $25 each, so this is 11 * 50 * $25 = $13,750 for the Loading Coils (providing 50 Voiceband Junction Circuits), or $275 per Analogue Voiceband circuit.

For 50 digital Voiceband circuits we need 2 * 2 Mb/s which will provide 60 Voiceband circuits! This will require two lots of eleven 2 Mb/s Regenerators at about $250 each. So, 2 * 11 * $250 (for the 2 Mb/s Regenerators) = $5,500 and that comes out at $110 per Digital Voiceband circuit (50 circuits), and 60 in total.

Assuming that one end requires an Analogue interface and the Loop Mux is about $15,000, and we need two, so that is $30,000. So the total (materials) cost is about $35,500 or about $710 per circuit for 50 circuits.

While this Mux equipment appeared to be quite expensive, these inter-exchange circuits are about 80% occupied during business hours and the maintenance needs are virtually zero – and the Voiceband circuit connections are virtually perfect – so there are literally no complaints, and this also minimises internally accounted costs of complaint management.

Because the call clarity is now far better than before, social and business verbal communications are preferenced more than face to face talks. Not only is communication speed increased but the costs and delays of physical transport are excluded. With Competitive Business accounting, preferentially using this then new telecoms technology is seen as an internally accounted business advantage lowering overhead costs.

From an Infrastructure Business perspective these monetary benefits for Competitive Business and Society/Community from using this new technology infrastructure are included in Infrastructure Business as externally accounted!

This 2 Mb/s PCM + Loop Mux / T Mux cost is about 115% more than a Loaded Cable but it provided channel connectivity like never before available on what was Loaded Cable between the now aged SxS technology, not so aged Crossbar technology and digital AXE technology.

These 2 Mb/s "Muxes" were incredibly productive because they nominally provided for 30 channels where before there were far less Voiceband channels over Loaded Cable - and the voice quality of this PCM technology was superb. So the network congestion problems (and network transmission problems and associated complaints) dropped out of sight!

But there was considerably more, the 2 Mb/s (AMI HDB3) Loop and T Multiplexer family provided a direct, inexpensive and simple interface between the now ageing FDM transmission infrastructure and the (slowly) emerging PDH-based transmission infrastructure – so that digital switching technologies (such as the LM Ericsson AXE switches) could be merged into (and eventually replace) the existing analogue / electromechanical infrastructure.

Transitioning to the Digital Network

The massive engineering problems of introducing digital technologies into electromechanical exchange switches and analogue transmission was that these digital switching and digital transmission technologies are fundamentally diametrically different (opposite) then electromechanical switching and analogue transmission and it was always going to take a marathon effort to transition the network from analogue to digital – but the envisioned economic gains in operational efficiency made this technology transition an immediate imperative.

Electromechanical switching relies on (metallic) moving parts / contacts physically closing / joining to make through connections that are "long-held" for the length of the (telephone / fax) call.

Digital switching has no metallic moving parts but utilises electronic logic gates as the path cross-connecting medium, plus a clocking structure to accept / receive time clocked digital transmission streams into and from digital transmission equipment.

This digital switching technology also has an extremely low (virtually zero) ongoing maintenance requirement – making it effectively install, commission and leave in service for decades without the need for any maintenance.

The analogue transmission connection from/to the electromechanical switches is fundamentally in the form of a Voiceband Telephone channel (0.2 - 3.4 kHz) that (on the Inter-Exchange Network side) is hard-wired (through the Intermediate Distribution Frame (IDF) with analogue / FDM transmission equipment, or Loaded Cable.

Analogue (Voiceband) transmission is a continuously time-varying signal, where the attenuation is largely set by structure of the transmission lines' physical lengths and the compensating gain (if needed) is set by analogue electronic amplification.

The problem is that with long distances the line attenuation considerably varies with temperature and the amplification needs to be continually variable to stabilise overall end-to-end attenuation. Earlier, long haul transmission system using thermionic valves that had an inherent problem where the valves "aged" with use (so their gain considerably dropped in a few years), plus the technology of negative feedback was not well understood or applied so line-up levels were a continual problem.

Digital transmission is not continually time varying but is effectively a timed continuous series / sequence of quantum logic levels. The beauty about most basic forms of digital transmission is that the quantum levels are quite distant from each other and this to a very large degree covers a very wide range of time varying path attenuation situations (which plagued analogue transmission technologies).

The raft of newly introduced digital technologies "***Digital Voiceband Technology***" had dramatically reduced the costs of analogue/digital conversion processes (and had caveated mass manufacturing costs) making it highly economic for (telephone) line concentrator technology to be used with a limited number of digital encoding / decoding interfaces. "***Highly Economic PDH Transmission***"

On an interesting side note the High Capacity Radio Concentrator (HCRC developed by TRL in the late CE 1970s (and rolled out from CE 1979 – 1985) to provide telephone connectivity in Regional Remote areas was several years ahead of the concept of Pair Gain Systems (PGS) of the mid CE 1980s! "***High Capacity Radio Concentrator in Remote Australia***"

The largely “forgotten” third component is signalling that is carried in and/or beside the Voiceband transmission path and it is this “channel associated signalling” (CAS) that controls the actions of the electromechanical switches on the way through the Inter-Exchange Network (IEN). With in-band signalling (then commonly used in establishing a call path) the Voiceband was fully used to transceive commands and responses – using Dual Tone Multi Frequency (DTMF) coding.

Digital signalling is an entirely different story as channel availability / busy started out as emulating (analogue) Channel Associated Signalling (CAS) – so this technology alignment strategy step was smooth.

As the call is established there is ancillary path signalling that is “out of band” that with electromechanical switches, the uses separate parallel associated wires and in FDM transmission this “channel associated” signalling (CAS) is slightly above the Voiceband in a 3,825 Hz slot, just within the 4 kHz FDM block. (*This was a very cunning electronic filter design that used a “notch” in the Low-Pass filters Stop-Band as the narrow Pass-Band for the signalling.*)

With 2-wire bi-directional (analogue) transmission (as was standard for all metropolitan Junction connection and Regional Transit connections, this signalling includes “loop signalling” where the loop current in the wire pair provides very simple “free / occupied / pulse dialling” notification.

Digital transmission and switching (and signalling) could not be any more different than analogue transmission and switching (and signalling)!

Most digital transmission equipment can be very inexpensive to manufacture and once installed and commissioned, this equipment requires literally no performance checking or ongoing maintenance.

Circa CE 1980, the entire inter-exchange switched transmission network (IEN) was based around Voiceband analogue FDM / Loaded Cable technology. This situation was clearly incompatible with digital technology.

The introduction of the LM Ericsson AXE digital switch in CE 1981 into Australia was very much a very awkward situation as the back-connection was based on 2 Mb/s as part of the Plesiochronous Digital Hierarchy (PDH) and the “front end” was effectively a “Line Concentrator” to connect with analogue telephone circuits.

With this then new LM Ericsson AXE telephone circuit Voiceband switching technology; the wiring between these sub-racks was already built-in (and relatively simple) leaving just the (analogue) wiring to the Main Distribution Frame (MDF) – for the Customer Access Network, and analogue connectivity to the co-located Crossbar switching equipment, and wiring to the (new digital) Intermediate Distribution Frame (IDF) – for the new digital transmission backhaul; and DC power cables! So (compared to SxS and Crossbar switch technologies) cabling for / installing digital exchanges was comparatively quick, small and very straightforward!

The process of (commissioning) initialising every AXE card was (by today’s standards) painfully slow – and it took months for a whole exchange site – where these days this whole process would take a maybe a day.

What was not openly recognised was that digital switching (and PDH transmission) required virtually zero maintenance – and in the coming years, this digital technology was going to be a real game-changer.

As a short-term “workaround” these early AXE digital switches included an extensive Backhaul Network connectivity based on Voiceband Analogue as 2-wire (bi-directional) transmission with Loop-Signalling interfaces to interconnect with the Metropolitan Loaded Cable “Junction” Network – for Medium / short haul connectivity; and 4-Wire (unidirectional) Voiceband transmission with “T” / E&M “Ear and Mouth” Signalling to directly interface with long-haul analogue FDM transmission systems.

This network connection arrangement was a rather ugly fit – but it had to start somewhere and this was it! So, these new digital AXE switches had analogue back-ends to connect into the pre-existing loaded cable Metro Junction and Regional Transit Inter-exchange Networks – where back-connection was into/from the Metro Tandem and Regional Minor Switching Centre (MSC) Crossbar exchanges.

This technology provided a wealth of interconnectivity between AXE switches in different metropolitan exchange sites (and there are about 400 metropolitan exchange sites in Australia).

Circa 1983 with then recent advances with inexpensive analogue / digital conversion using inexpensive Medium Scale Integration (MSI) technologies, the concept of a 2 Mb/s HDB3 encoded stream to have 30 “multiplexed” analogue Voiceband channels (and channel associated signalling) in the one compact and inexpensive subrack became a reality. “***2 Mb/s Multiplexers to the Rescue***”

These 2 Mb/s Multiplexers came in two basic forms. The “Loop Mux” was purposed engineered to directly interface as a 2-wire, bi-directional Voiceband transmission, Loop Signalling unit. The “T Mux” was purpose engineered to directly interface as 4-wire unidirectional Voiceband transmission T (or E&M) Signalling unit.

This “Mux” technology was the perfect fit to interconnect AXE switches to Crossbar / SxS terminal (local exchange) Switches. A “Loop Mux” could installed at a Minor Switching Centre (MSC) and connect (up to) 30 Voiceband channels (per Loop Mux) from a number of remote small Terminal exchanges and back-connect at 2 Mb/s PDH into the district AXE exchange.

Alternatively, a “Loop Mux” could be installed at a remote Local Exchange and back connect at 2 Mb/s (over pair copper) with 30 digital Voiceband channels straight into the District AXE switch.

Alternatively, a “Loop Mux” could be dropped in at the District exchange site and provide direct cross-connectivity between the Crossbar Minor Switching Centre (MSC) switch or metro Crossbar Tandem switch and the co-located AXE switch.

The “T Mux” was another story where FDM analogue transmission was in place – so a more remote Terminal exchange that was back-connected with an FDM system could have its analogue Voiceband channels back-connected to at the District / Regional exchange site into a T-Mux and have this then connect into the District AXE switch.

In an almost identical situation the FDM (Capital City) “ends” could be cross connected at the District / Regional site with a T-Mux and directly interfaced into the Regional / District AXE switch!

My understanding is that this technology mix was an instant success as the (88 mH) Loading Coils had been replaced by 2 Mb/s PDH Regenerators and there were plenty of Digital Voiceband circuits.

In both instances because the pair copper cables effectively connected at 2 Mb/s and not Voiceband (with the AXE switches) – this freed up a considerable number of Line Interface Relay Sets that could then be re-located / re-used in (Crossbar) Local Exchange sites and provide far more Junction / Transit connectivity into the Loop Muxes at these Local Exchange sites.

The next transitional step (circa 1983-4) was to slightly change the technology of the Local AXE switches from line concentrators to Line Interface Circuits (LICs) where each telephone line had its own digital interface. This was the AXE102 switch. “***Mighty Productivity of Digital Platforms***”

Now, as the number of these AXE switches was considerably increased (particularly in metropolitan areas, this took the load off the older SxS equipment and considerably reduced the maintenance overhead requirements.

In the Regional areas not only were AXE 104 (cut down small size AXE Local switches) becoming plentiful and replacing old local exchanges – but a new breed of (small) Hybrid Crossbar local exchange was emerging where the Crossbar SLA/B (Subs Line A/B) switching stage was minimised and back-connected with Loop-Mux equipment – that had a back-connection of 2 Mb/s over pair copper to the MSC.

My understanding was that an even further cut down Crossbar version existed where the LR/BR (Line and Break Relays) of the Crossbar telephone circuit interface were all that was used with a 2 Mb/s Loop Mux sitting directly behind the LR/BR interface – providing a maximum of 30 direct line connections per Loop Mux!

Almost concurrent (circa 1984) with this was rapid technology advancement was the introduction of Pair Gain Systems (PGS) that effectively were a telephone circuit interface into the Customer Access Network (CAN) and a 2 Mb/s back connection into the Inter-Exchange Network (IEN) as a Backhaul connection to the Minor Switching Centre (or even a large local exchange site).

So now Crossbar (and the remaining Step by Step) exchange equipment could be inexpensively directly interfaced with Loop Mux equipment that could then be directly connected to AXE switches! “***Shaking the Recession Mindset***”

The number of fixed access telephone services had peaked and was flattening out – but now second telephone lines were being used for Fax machines as an indirect replacement of Telex. “***Telegraphs to Telex to Fax***”

By circa CE 1985 the transition from analogue / electromechanical to digital looked as though it had not really happened and there was a major sticking point in that all long-haul transmission was still FDM (analogue) technology – and some long haul FDM equipment was still being installed to cater for growth!

The MEL-SYD analogue FDM transmission system that was commissioned in CE 1961 was thermionic valve technology (was now with few spare parts) and the coaxial cable was on its last legs with cable sections all too regularly breaking down. It was imperative that this analogue system in particular (and several other long haul FDM systems) be urgently replaced. "***High Capacity Long Haul Transmission***"

Homework for replacing this massive FDM system had already been done circa CE 1985 and it was based on two parallel (seven coaxial tube with interstitial quads) coaxial cables running several higher order PDH technology long haul transmission systems. This new PDH long-haul technology would "break the back" of the highly predominant FDM long haul infrastructure and set the course for a smooth transition to a totally digital telecoms infrastructure throughout Australia!

In the background TRL had been diligently working on the technology of Single Mode Optical Fibre (SMOF) from about CE 1975 with little success until mid-April CE 1986 when the massive breakthrough came. "***The Sudden Emergence of SMOF***"

This new highly economic technology of very inexpensive to manufacture SMOF with its immense bandwidth and very low attenuation per unit length was very quickly rushed through "prototype" development, and it was urgently employed into the new SYD-MEL high capacity long haul transmission network at a fraction of the cost had it been using coaxial cable / interstice pairs as the transmission bearer. "***Costing the Mel-Syd SMOF Link***"

Concurrent with the finalising the design of the Mel-Syd dual-coax PDH transmission system the now widespread 2 Mb/s links were intermittently failing everywhere and existing the (1961 commissioned) Mel-Syd FDM Long-Haul transmission Coaxial Cable system "***High Capacity Long Haul Transmission***" was fast becoming a maintenance basket case.

As the new Mel-Syd SMOF PDH transmission system was installed and commissioned (in CE 1987), this provided the imperative PDH Transmission infrastructure to connect with PDH technology where possible. At first, the Crossbar ARM (4-wire transmission) Trunk exchanges were cross-connected to both the FDM and PDH transmission systems but it very quickly became imperative to pull out the failing FDM on coax and leave the long haul transmission to the new PDH on SMOF technology (and the maintenance very quickly dropped to almost nothing).

The cross-connection was made with racks of T-Muxes that were a perfect interconnect at 4 wire Voiceband (to the ARM Crossbar Trunk switches) and 2 Mb/s PDH into the long-haul PDH transmission system.

At about this time (CE 1986 - 1987) it was realised that the metro ARF Crossbar Tandem exchanges were having maintenance issues where relays in their Registers were showing considerable signs of wear and as the intent was to keep this equipment in place for the next five years the agreed strategy was for Telecom Engineers (in Adelaide?) to create an electronic version of the H4 Register. "***Digital Brains Within Crossbar***"

Meanwhile it was imperative to have SMOF cable rolled out in the metro areas (CE 1988 - 1989) to replace pair copper Junctions being used with failing (Competitive Business mindset caused) 2 Mb/s Regenerators and (competition caused) faulty 1.6/5.6 mm coaxial connectors. "***Competition Wrecked Australia's 2 Mb/s***"

In the Regional Rural areas, SMOF cable was then (circa CE 1990-1992) being extensively ploughed in to replace Loaded Cable that had been ploughed in during the CE 1950s. "***Competition Wrecked Australia's 2 Mb/s***"

The concept of hard-wiring the electronic drive from the Crossbar subscriber meters into the AXE platform was brilliant. This cross-connection (with extension wiring) was set up to interface into the collocated AXE switch processors as an external network input.

The Crossbar subscriber's meters were then seen (with extended software) as a "dummy" extension of the AXE subscribers, and the Crossbar metering was then registered in the AXE platform - radically reducing overheads. "***Gigantic Productivity of Electronic Metering***"

This transition to include AXE switches in all large exchange sites by about CE 1985 was somewhat visionary and what became blatantly obvious was that electronic metering required far lower overhead costs and this new electronic metering technology was also exceptionally accurate.

Almost concurrently the widespread introduction of Common Channel Signalling (CCS7) into the AXE digital switches in the mid CE 1980s radically changed the way that AXE switch technology communicated. This new (CCS7) signalling technology provided a very inexpensive internal communications platform that radically simplified the process of electronic metering by the late CE 1980s and considerably simplified the software behind the rollout of GSM technology Mobile Phone Radio Base Stations. "***Amazing Productivities of CCS7***"

Competition Wrecked Australia's 2 Mb/s

With the emerging widespread introduction of LM Ericsson AXE telephone switches (circa CE 1981 onwards), the intent was to utilise Plesiochronous Digital Hierarchy (PDH) transmission technology because of the inherent massive productivity gained by converting the Loaded Cable pairs to 2 Mb/s using PDH as the transmission medium. "***Massive Productivity of PDH***"

From around CE 1984 there was an extremely alarming situation in that telephone calls started to randomly / intermittently drop out en-mass. At first these call dropouts were rare but in the following months the frequency of these random / intermittent dropouts continued to continually increase and this became a major national issue.

The standard way to fix a telecoms fault is to localise the geographic area and then localise the equipment and repeat this process of honing in until the faulty piece of equipment is identified and then localise the cause of the fault in that piece of equipment is identified – and hopefully rectify the cause of that fault.

Technical experts had intensely researched this issue for well over a year with little success and had quickly narrowed the problem down to some of these 2 Mb/s links between exchange sites (that each carried up to 30 telephone calls) were intermittently / occasionally dropping out and then recovering about a few seconds later – but the telephone (and data) traffic had been dropped leaving all the callers to reinitiate their dropped-out calls.

Narrowing this problem down, one of the causes of these dropouts was (apparently) due to some of the 2 Mb/s Regenerators intermittently failing and then recovering. This begged the question if the Regenerator spacing (1830 metres as previously used by Loading Coils) was too far. There were also intermittent failures in short distance 2 Mb/s links interconnecting metropolitan CBD exchange sites (and these distances were definitely less 1830 metres – and had no Regenerators)!

Further confusing this intermittent dropout issue was that some 2 Mb/s links that were entirely within the one exchange building site were also having intermittent network dropout problems – and this really narrowed part of the problem!

> *In Sydney, Frank Nitzchke (who was a brilliant Engineer) had previously resolved a hoard of inter-manufacturer Competition caused Fax incompatibility problems, turned his mind to resolving the problems with 2 Mb/s circuits intermittently dropping out. He was very well placed for this investigative research as he had also recently worked extensively on developing the very highly productive 2 Mb/s Indial technology for Telecom Australia. "**Telegraphs to Telex to Fax**"*
>
> *With his special 2 Mb/s bench test equipment, he narrowed the problem down where he found that some 2 Mb/s Regenerators seemed to be working perfectly but other 2 Mb/s Regenerators occasionally / intermittently lost synchronism – then regained synchronism….*
>
> *He discovered that by slightly lowering the clocking rate, some 2 Mb/s Regenerators totally lost synchronism – but other 2 Mb/s Regenerators remained stable. Significantly raising the clocking speed caused some 2 Mb/s Regenerators to lose synchronism but other 2 Mb/s Regenerators remained perfectly synchronised!*

> *He knew there was something intrinsically different in these 2 Mb/s Regenerators but there was no obvious (or inconspicuous) physical difference to that of the earlier Regenerators – so there was no way of knowing in the field which 2 Mb/s Regenerators were faulty.*
>
> *Frank then tracked down the 2 Mb/s Regenerator manufacturer (in the USA) and after some considerable questioning finally identified that the MSI silicon chip manufacturer had deliberately scaled down the physical size of these MSI chips – so that many more 2 Mb/s Regenerators could be made per silicon wafer – and <u>so that Competitive Minded business could maximise profit / greed.</u> The causes for these systemic failures* ***were purely because of the Competitive Business mindset.***

These Medium Scale Integration (MSI) technology Regenerator chips included an in-chip capacitor that formed part of the clock timing circuit in the "Phase Locked Loop" (PLL) that is integral to synchronising the regenerated Alternate Mark Inversion (AMI) encoded High Density Binary 3 (HDB3) transmission signal.

With a significantly smaller silicon chip, the value of this in-chip capacitor was also smaller, causing the PLL centre frequency to move from 2.048 MHz to near 3 MHz. Consequently the PLL (frequency) control voltage was then very near a "cliff" where it could very easily lose synchronism – and drop 30 Voiceband calls at a time.

The only way to "fix" this would be to pre-test every 2 Mb/s Regenerator and install these while removing and testing every remaining 2 Mb/s Regenerator – and there were literally many tens of thousands of these throughout Australia! That would have meant an immense works programme that would have gone on for many years.

Further complicating this problem was that the USA manufacturing company then stopped manufacturing these Regenerators. My educated guess is that the business owners were very fearful of massive litigation due to their deliberate corner-cutting to maximise their Competitive Business mindset profiteering. As a direct consequence these Competitive Business mindset people then most probably proactively made the business insolvent (Chapter 13?? in USA Business Law) to prevent financial risk to themselves at massive further the expense to their customers.

So there was no easy way of going forward with replacements! Worse still – there were several situations (to date) identified where there were no 2 Mb/s Regenerator(s) as the line lengths were too short – even in the same building – and some of the 2 Mb/s links were (still) persistently dropping out!

In this second case, the standard Intermediate Distribution Frame (IDF) for interconnecting AXE switch platforms with 2 Mb/s transmission platforms was based on coaxial 1.6/5.6 mm gold plated coaxial connectors, and the (floating /balanced) insulated twisted pair copper wire Junction / Transit cable terminated into Insulation Displacement Connectors (IDCs) – that also formed part of the IDF structure.

This IDF was an "ugly" fit but it was wonderfully managed by having a rather small "Interface Block" made of a plastic encased tiny ferrite (balance to unbalance impedance) transformer that had a 1.6/5.6 mm coax connector one end and an Insulation Displacement Connector (IDC) connection at the other end. These (Interface Blocks) could be "socketed" into the IDF frame and appear as a 75 ohm coax position at the front – with a 150 ohm balanced IDC at the back – the best of both worlds!

The 1.6/5.6 mm coax connectors were manufactured by one business but another competing business wanted to get in on the action as they could see they could make a considerable profit by importing against these locally manufactured coaxial connectors and undercutting the Australian manufacturer to get a far larger proportion of this lucrative telecom equipment supply chain market. After a legal struggle there was consent that the second competing business could also provide coax connectors to the specification.

After many months of investigating the problem where there were no 2 Mb/s Regenerators in the circuits, it was narrowed down to some IDFs having the network dropout problem and other IDFs had no problems! The situation was that if somebody walked past some Intermediate Distribution Frames (IDFs) one or more 2 Mb/s link(s) would drop out and re-establish. The same issue of intermittent network dropouts happened if a train or heavy truck went past and shook the building(s).

In talking with Install and Maintenance staff and trying it later ourselves, we identified that some 1.6/5.6 gold-plated coaxial cable connectors were very easy to slide in and others were a rather tight fit. Something was wrong here!

Using a micro-meter in the connectors revealed the cause to be that the competing 1.6/5.6 mm coaxial connector had a minute manufacturing difference with the standard diameter of its centre pin and with its (matching) ferrule.

When the competing male connector was plugged into the standard female connector this pin was fractionally too thin – resulting in intermittent connections.

When the standard male connector was plugged into competing female connector, this slightly splayed the centre ferrule and made a very tight connection. When the competing male connector was now plugged into the (now damaged) competing female connector – the ferrule was now loose – causing intermittent connectivity.

Telecom Australia were now in a terrible bind having widely introduced 2 Mb/s technology that worked perfectly for some years without any problems – until (economic) COMPETITION had muscled its way in and caused millions of network dropouts and an extremely expensive rebuild process.

The only way out was to change the IDF to use Insulation Displacement Connections (IDC) everywhere as these were proven and quick to install and universally reliable. This radical change in connection technology meant that the existing AXE switches (that had 1.6/5.6 mm coaxial connectors had to stay but the new versions of AXE production needed to have Insulation Displacement Connectors (IDCs).

As far as I can recall this was very much a “jiggle it and see if it fails” test; and if it fails then rewire the 2 Mb/s jumper leads. This 2 Mb/s network dropout problem started in about CE 1983 and it was not until CE 1987 before the national retrofitting started and continued until at least CE 1990.

Absolutely no thanks to having totally unnecessary and very expensive infrastructure Competition as this competition caused confusion, killed productivity was a very expensive rebuild program for all Intermediate Distribution Frames (IDFs) in upwards of 1000 exchange sites across Australia! The component (product) prices that were “driven down” paled into utter insignificance compared to the expensive rebuild costs not including the enormous legal bills and promotional adverting costs.

ATM Data Connectivity

Until the CE 1960s, the need for digital transmission was almost non-existent as data could be easily transferred in a Voiceband channel with a speed of nominally 300 bits per second and Telex was fast replacing manually connected telegraphs using Morse Code. "***Telegraphs to Telex to Fax***"

In the late CE 1950s, the computing concept of an "Operating System" became a basic reality – where a computer was not program specific but could run a series of entirely different mathematical routines – because the computer included an "Abstraction Layer" in its firmware that effectively isolated the electronic computing machine from the operational functionality.

This way computers manufactured by competing organisations could have very different hardware and have virtually identical programming functionality, and conversely, software operating systems could "sit" on different hardware (mainframes) and perform a range of different "applications".

This "Operating System" concept threw the doors open for data to be stored and transferred (by road or telecoms) to/from centralised computers for scheduled analysis. This situation heralded the more common use of (analogue) telephony infrastructure for (digitally) transferring data on a much wider scale than ever before.

With rapidly increased influx and use of mainframe and miniframe computers in the CE 1960s, the clocking speeds in these computers were gradually increasing due the general transfer from thermionic valve to transistor technology and the production cost of computers was also rapidly decreasing with the transfer from chassis construction to printed circuit boards / assemblies, the introduction of digital integrated circuits and the introduction of inexpensive and highly reliable (circuit board) edge-mounted plugs / sockets. "***New Era of Electronic Components***"

This moving target presented a major problem for telecoms infrastructure as Voiceband was analogue technology and personal computers (PCs) were beginning to appear on the horizon in the CE mid-1970s. What was not painfully obvious was that personal computers were an excellent "front-end" to mainframe / mini computers and that the communications links for these purposes were essentially digital technologies seated in analogue telecommunications infrastructures!

With Australia's direct involvement in the USA's space program in the late CE 1960s through to the mid CE 1970s, it became obvious that analogue transmission of data was impractical and terribly slow (by today's standards) and there was a long development and growth path that got us to where we now (CE 2021) where we utilise fast data as the expected "norm"!

On the side of all this it had become apparent that digital telephone traffic switching offered tremendous operational (and economic) productivities over manual and electromechanical switching – but this inferred that the transmission path also had to be digital! "***Transitioning to the Digital Network***"

Unsynchronised (almost synchronised) PDH-based transmission works very well for Voiceband connectivity as the loss and regaining of synchronism is not noticed. With a Fax connection using PDH (that is not synchronised) – this results in the occasional black line across the page. With data, this results in an errored data block that may have to be resent if it cannot be post-corrected. "***Highly Economic PDH Transmission***"

Data can be very successfully transmitted through PDH-based transmission systems providing this equipment is clock synchronised (from the top down) and the data is sent at 8 kBytes per second (parallel feed) or 64 kb/s serial feed (per Voiceband channel without Analogue / Digital / Analogue conversions)! "***Digital Voiceband Technology***"

Connecting (long-haul) data through the PDH Voiceband based network was very much akin as to Cinderella's Ugly Stepsisters force-fitting the Crystal Slipper!

The "sister" of PDH was Asynchronous Transmission Mode (ATM) and this connected in much the same way as PDH with the exception that with ATM, this was optimised to transfer a range of standard sized packets of data instead of a continual stream of data. This subtle change in data transfer mode was not outwardly recognised – but it really matches the mindset of data transmission.

As a generalisation, Asynchronous Transmission Mode (ATM) was effectively the high speed data family in telecoms. Basically, ATM consisted of a "train" of data that was headed by a few Bytes of data that addressed where the data was destined (as a digital address), how long the train was (in bytes) and at the end of the "train" was a sum check value (in Bytes) to minimise the chance of data being corrupted during transmission and an End of Transmission (Byte) to tell the terminal transmission equipment that the ATM data (packet) train had passed through.

Early versions of ATM transmission terminal equipment were company specific (i.e. this equipment only worked with the same brand equipment at the other end). ***It did not take that long for the competing manufactures (primarily in the USA) to realise that close collaboration was far more economic and profitable than blatant competition.*** *The competing telecommunications equipment providers then wasted little time in closely collaborating to ensure they had conformal connectivity standards (to ensure they could interconnect with competing data transmission equipment providers).*

First generation ATM transmission equipment were in reality hard-wired IP "routers" and the data paths were to a very large degree "pre-set" (or hard-wired) to various geographic locations.

The next version of ATM transmission equipment had wire straps and Dual-in-Line (DIL) switches on the circuit boards / cards so that each transmission port could be individually configured to match the ATM settings on the near and distant ends – irrespective of the manufacturer.

The next development phase was the introduction of dynamic route switching, where the (go to) address in the ATM data block's header was used to direct the data train to a specific transmission port (or many ports). This was a dynamic shift from the hard wired versions of before and it set and it then moved into having an operating support system (OSS) all of its own.

(Australia's CSIRO did a lot of advanced work in this area researching and developing the technologies for very fast "on-chip" routing – including the manufacturing of a single chip router that had multiple throughputs (I think) exceeding 10 Gb/s and that was back in the early CE 1990s.)

From these stages in technology development, the concept of Simple Network Management Protocol (SNMP) took a much firmer grip (at the "application" level of

TCP/IP) where data routing was far more practicable even though the amount of Metadata (associated data about the connection) had substantially increased.

With this technology step, the realisation of externally programmable “controlled” Switches and Routers flung the doors open for large-scale Internet Protocol connectivity in the mid CE 1980s, and by the middle of the CE 1990s ATM had literally morphed into IP.

While data transmission was very quietly going through this massive revolution, the technology of PDH had also quietly “entered the building” – but it was not until after April CE 1986 before the technology of Single Mode Optical Fibre (SMOF) smashed through to provide an almost perfect inexpensive long-haul transmission medium that was particularly suited for PDH and ATM, that Frequency Division Multiplex (FDM) long-haul transmission technology was reluctantly shown the exit door and took several years to leave. “***Phasing out Long Line FDM Equipment***”

This very rapid promulgation of SMOF-based transmission technology in the late CE 1980s – early CE 1990s paved the way for PDH to quickly take over (with ATM tucked in under its wings)! But PDH was (data) speed limited and when Synchronous Digital Hierarchy (SDH) was introduced circa CE 1994, ATM was a natural bedfellow of SDH and SMOF! “***Immense Productivity of SDH***”

So, much like the story of the “Ugly Duckling” the technology of ATM in the early CE 1970s gradually morphed into an adolescent version of IP by the late CE 1980s and by the mid-CE 1990s ATM had blossomed into a young and virile version of IP that (almost) everybody uses (and cherishes) everywhere today (CE 2021).

Productivities of Electronic Databases

Forward planning is an imperative part of engineering that sets the course for several years future investment in every Infrastructure Business. With a Competitive Business mindset it is extremely rare to have forward planning exceeding a couple of years and it is usually seasonal (nominally 6 months is nominally "long term")!

The standard process is that the highly experienced engineers in that field of Infrastructure Business who have a rather good (excellent) understanding of the state of the infrastructure and are acutely aware of what equipment / infrastructure is running towards its end of life – because the maintenance requirements start to gradually increase, generally indicating where the infrastructure weak points may be in the years (decades) ahead.

With telecommunications infrastructure - this process is no different and it is (was) common practice to have a database (of sorts) that records all the infrastructure status and maintenance / usage reports.

Until at least the mid CE 1980s, the only records of medium / long-haul transmission equipment was in (isolated localities) paper sheets, pads and folders. This "worked" but proactive maintenance practices were "inefficient" as there were no centralised (electronic database) records to really know what brand and model of (e.g. FDM) equipment existed and how much of this equipment or geographically where this was and what state of maintenance it was in!

In the CE 1970-1980s the use of computer based-records was becoming more commonplace – replacing paper-based records. By the CE 1980s, (Fixed Access) Telephones were now seen as an essential service and the number of telephone services had been rising in direct proportion of the population. "***Telephones Become and Essential Service***"

With a "Competitive Business" mindset, the process of Forward Planning is little more than doing a yearly seasonal rebuild (for the next three to six months ahead) and/or looking around to see which competing business has vulnerabilities that can be weakened so their product lines can literally be "stolen" by a company takeover or with a merge to significantly reduce the excessive costs of competition and/or use the combined businesses to exploit economies of scale to drive other competing business lines out of business – and weaken them in the process.

With an "Infrastructure Business" mindset the process of Forward Network Planning (5, 10 15 years ahead) was/is a rather tricky/difficult because many engineers and advanced technical staff have excellent memories but this data was/is not always loaded into databases – or the data fields in the databases are inappropriate (or not existing) and this critical data is never saved, sorted / analysed / prioritised!

In both cases, having as much relevant product line data in a database of a form is an incredible business tool for Forward Planning.

Circa CE 1985 Engineers in Telecom Australia were developing a computer-based network planning tool that would extrapolate their (telephone) network – based on Ericsson AXE, and Crossbar, STC (Alcatel) 10C switches, and a range of FDM carrier systems. As I found much later (about CE 1990), this was a National Project and it was very almost 100% focussed on (fixed access) telephone service technology for long term (very blinkered) future planning that did not include data transmission but was stuck in (analogue) Voiceband capabilities.

It was January CE 1986 and I had just transferred from being a Technical Officer in the NSW Design Lab (with 19 years of very wide and extensive technical (and Engineering) experience), to being a Class 1 Engineer on rotation to learn about Engineering for this first year.

My first assignment was to the NSW Forward Planning Section – and it was a (backward) technology shock for me! We in the NWS Design "Lab" had been working with microprocessors and early "personal computers" from well before CE 1980, I was very active in a local Computer Club and we had our own clone Apple II "personal computer" at our home.

This "engineering" place looked like a CE 1960s classroom with ASR33 teletype machines – and it sounded like a typing pool (where before personal computers were commonplace; all management / official letters were manually typed out by a team of typists)!

After my shock (and dismay) settled down, I was guided to an ASR33 teletype machine and given a set of instructions on what has to be typed in and saved on a 5 ½" floppy disk. At least this was not a 7 ¼" floppy disk!

My task was to load in the data that referred to the structure of the Backhaul and Trunk (coastal and Hunter Valley etc.) telecom (transmission and switching) Network from Newcastle to the Queensland Border. Not a massive dataset (so I thought) as I knew the general network architecture from field experience as a Tech Officer. It became clear that manually loading this data set using these old ASR33 machines would take about 11 months! Now I was really dismayed!

Very unsurprisingly, this data related to each major exchange site, and the data entries were rather long sets (about 60 characters per line) and very highly repetitive – with minor changes every line. There were about 10 other ASR33 teletype machines being used to load this extremely highly repetitive and boring data, and this dilemma set me thinking well past this daunting task – as there must be a better way! (A "better mousetrap")

On my long train trip home from Central to Emu Plains – about 55 minutes, I started to visualise how this data could be generated using our Apple II PC at home (as the disks were the same structure and MS-DOS format)!

It struck me that each Exchange site has a series of associated parameters that related to itself and related to the previous / parent exchange site(s). After about four trips the "visionary" penny dropped!

This whole data set could be constructed by using a relatively small GWBasic software program that uses extensive calls to a list of pre-set parameters – defined by the Exchange sites. When I had a chance (after the kids had gone to bed) I started writing GWBasic code at home.

It took a couple of (highly interrupted) weeks to write several subroutines that each produced masses of lines of data based on the exchange Name, Code and associated functional parameters. But this program was really fast! It took about three hours (my estimate) to type in the list exchanges and associated parameters and about a minute or so to process the whole network and save the resultant data onto the floppy disk.

So I took the data completed 5 ½" disk in, and first thing in the morning handed over it to the Supervising Engineer, quietly saying: "I've finished"!

All hell broke loose: "<u>You can't have finished!</u>" This furious situation quickly reminded me of my first few months in the NSW Transmission Lab back in CE 1967 where (without notice) I "re-engineered" the Programme Active Equaliser to fix an inherent exchange battery noise problem.

The situation very quickly degenerated in to a process argument and I was told to "stand in the corner" while they pondered on what to do… And no, I certainly could not do another area / Region in NSW while they worked out the next steps – that had never been done!

After lunchtime (at least five hours later) I was told that the data could be sent to the CSIRO computer in Canberra for overnight processing. So I innocently asked where the (Wideband) 48 kbit/s link is, and there were blank stares everywhere! They had no data terminal – but a 300 bit/sec Voiceband modem was available on another floor. This was archaic!

It took longer than an hour for the data to be sent to the CSIRO computer in Canberra where it was successfully processed overnight with a stack of Z-fold paper to pick up the following the morning. There were no engineering plans of what action to take with this freshly processed telephone (only) traffic data. My comment about the small though rapidly increasing data traffic was outright dismissed as irrelevant and insulting...

I gave them my GWBASIC software so they could do the rest of NSW, if not Australia in a few hours each, not 11 months each. That went down like another lead brick and the following day, I was sent to "Sydney End Terminations" which was another "eye opener" of dismay!

The stint in "Sydney End Terminations" was also very instructive as although there was chronic congestion in the NSW country areas – the transmission channels (all connecting to Sydney) were being increased by the most meagre amounts and not being concurrently aligned with available ARM/ARF/ARK/AXE switch platforms.

At clearly showed that "all FDM telephone channels lead to Sydney" and there was virtually no Regional Backhaul mesh infrastructure that did not involve the State Capital City! They certainly knew nothing about Group and Super-Group Extension Amplifiers and how this equipment had then for about 20 years provided a mesh Trunk connectivity that bypassed Sydney ARM (and 10C) Trunk Switches. That was too much!

Circa CE 1990 I was in Melbourne talking with one of my recently inherited staff (Vic Tkacz), and found out that he too was also loading data into the same (telephone only) Forward Planning software back in CE 1986!

In that era, electronic databases were being created everywhere there were sets of paper folders and the productivity of this electronic recording technology was nothing short of astounding. The fact was that this data could be loaded into a (VisiCalc / Excel) spreadsheet or a database (and many different forms of databases on personal and in-house computers were gradually becoming popular).

As this data was being loaded it could be analysed and the common analysis usually identified there were isolated brands / models of telecoms equipment.

> *In early CE 1987 I was in Telecom Australia as a Class 3 Engineer in the NSW Long Line Support Section. We did not have a listing / database of what brand(s) / model(s) and completeness of (line) transmission equipment was in every NSW exchange site. There was no way that we could analyse the situation to optimise the timely transfer of Analogue FDM equipment out of service by Brand and Model, Location / Link.*
>
> *My task was to lead a small team to create a detailed (electronic) database that would tell us what FDM equipment we had where. We started by creating a paper form / questionnaire to be sent out to all Regions; to be filled in by technical staff from every Region / District and returned to us; then load the questionnaire results into the database and analyse the situation from a State basis.*
>
> *This very quickly became a team effort to get the structure and content of the questionnaire plus the design of the (DataFlex) database to record and potentially analyse this data.*
>
> *As the data flooded in from hundreds of sites, it took three of us about three months to read and transfer this data into our database. Then the information started to really flow as it started to give us a very clear picture of what brand and model transmission equipment was installed everywhere, and how many channel modules were included in each transmission sub-rack.*
>
> *We then transferred this data into our new mini-mainframe computer that had national connectivity – and we went national! A similar project was later initiated with radio equipment and switching equipment – though switching equipment was far more straightforward with few variations.*
>
> *It soon became obvious that there were small / isolated pockets of rare transmission equipment that could be economically replaced or transferred to fully-flesh other partially filled (rare) transmission systems! There were also many locations where "spare boards / cards" could be relocated to fully-flesh other equipment and "early retire" other partially / empty FDM carrier terminals at virtually zero cost. Rationalisation!*
>
> *Other States needed to do the same and this data was now being loaded onto the one database that could be seen by remote terminals. This network structure was not quite Internet – but getting close!*

As this progressed, we quickly realised that considerable productivity could be gained by focussing State-based FDM (in particular) Carrier Equipment Repair centres to nationally specialise on managing and repairing particular brands of equipment.

The problem was that Telecom Australia / PMG was operating as separate State-based organisations since before CE 1900 and this was done in "innocent" competition, (virtually no collaboration) where there was very little cross State boundary management / technical / engineering communications.

All this was done in complete collaboration (negative competition) between the "competing" Carrier Equipment Repair Centres. Had they competed by not fully collaborating then the productivity would have remained low. None of this wealth of intra and inter-State productivity could have been possible without the electronic (digital) database being interactively accessed and updated from all States / Territories working in close collaboration (negative competition).

Well before this database was functional, there was a fundamental process problem where a very high percentage of FDM carrier systems in Country Town / City exchange sites were not fully fleshed out – but were partially filled with FDM channel cards.

The (now national) database identified hundreds of locations where 12 and 24 channel FDM systems were desperately short of Voiceband Channel Cards, and that there was a wide spread of brands and models of FDM systems – and that there was a considerable (multiple) store of spare/unused Voiceband Channel Cards.

So – equipment matching Voiceband Channel cards were transferred from storage and installed where network congestion was most chronic. T Relay sets were also re-located from newly de-commissioned ARF / ARE / ARK Crossbar switches to provide switch connectivity at ARK / ARF Crossbar sites. "***Shaking the Recession Mindset***"

At the MSC locations the "T Mux" provided 30 Voiceband channels of direct connectivity at 2 Mb/s with new technology AXE switches – so FDM systems could be fully connected (and utilised). "***Transitioning to the Digital Network***"

When you consider that there were/are over 5000 local exchange sites and about 500 Districts, every one of these had a wad of associated data in paper form that was being lost – this was an engineering / economic disaster waiting to happen!

Even though the States were under totally separate executive management control and Headquarters (in Melbourne) was really the Telecoms Research Lab and little else. Many of the Engineers were actually communicating interstate with their counterparts far more than they had in the early CE 1980s and before!

By about CE 1988 there was the general realisation that each of the States had been going their own directions with data for many decades and nothing was standard.

The Engineers stepped in to pull this together on a national basis. I think this was called the "Digital Data" project and I believe there were very many (well over at least 200) different software database packages – many of which had partially / entirely overlapping data and each with inconsistent Field names and data formats.

Aligning and rationalising these databases was a monumental effort and establishing national data standards was very difficult – but achieved. Further, each of these databases had different specifications for the fields in their data tables – transferring data was not straightforward either!

The inefficiencies caused by "innocent" competition were immense – and there was no way that economic theory of competition would be business economic and drive down end user costs; (as perpetually chanted by economic theorists)! If this situation was "intentional" competition, then the reduced number of databases would have been only fractionally more economical from the unintentional disaster that emerged!

With well-meaning inter-District and inter-State co-operation (negative competition), these Engineers and their associated Technical Officer gurus at first rationalised the number of data tables to match with known desired data lists, and then worked on the specifications of the data fields to Nationally bring these specifications into line.

With concurrent advancing computer technologies in the mid/late CE 1980s the size and cost of memory was rapidly dropping and the amount of data available to be stored was also rapidly increasing. These technology advances had heralded the introduction of inexpensive personal computers on a much wider scale (where a lot of this data had been saved). It also heralded the introduction of mini-mainframe computers that radically changed the data storage environment so that national connectivity became practical, and highly productive. "***Phasing out Long Line FDM Equipment***"

From here it became clearer that certain data fields were common to several other data tables and that by having relational database structures not only were the number of data mistakes considerably reduced but the amount of data saved could be considerably less.

With the management lines blurring between States, Telecom Australia senior executive management made a monumental restructure in CE 1989 to remove State Management and transfer senior executive Management to Headquarters – bringing all the Network Switching equipment and Transmission equipment from all the States into the National Network Business Unit and putting all the Access Network under Regional Areas along with Metering and Billing (and Marketing / Advertising). The Business and Government / Enterprise also became National instead of fragmented State managed.

Now the many databases had a legitimate National footing and the productivity that flowed from this restructure was barely noticed from outside. Inside, the change was immense as the inter-State doors were flung wide open and productivities that had been tightly restrained for decades suddenly became readily available.

In the late CE 1980s – through to about CE 1995 the process cost of metering was now nationally standardised with very low overheads – thanks to a Brisbane-based National team under another very bright engineer, Malcolm Campbell, who I understand pulled this all together. This was actually a step beyond getting the metering to be "electronic" to where the metering / charging processes were synchronised and coherent. "***Gigantic Productivity of Electronic Metering***"

The massive efficiencies as a result of this and other interactive electronic databases was a prime reason why the overhead costs of Telstra had plummeted in the CE 1990s and it was largely these database technologies (plus "discarding" a large percentage of the Telstra workforce, and a conversion to digital transmission and switching and SMOF etc.) that facilitated end-users prices to considerably drop – and give economists (who obviously had absolutely zero knowledge about the then rapidly changing insiders of Telecommunications) all the totally wrong reasons to claim that "competition" was the prime driver to bring down end user costs in the CE 1990s. "***The Competition Wheels Fell Off***"

Digital Brains Within Crossbar

The rollout of Crossbar switching equipment that started in CE 1960 was by proving to be an astounding productivity boost over the earlier SxS electromechanical switches (most of which were now well into their end of life high maintenance phase), and the earlier manually operated Sylvester Switchboards (that required a large and continual 24/7 staff to manage these switchboards) – greatly adding to the day-to-day operational expenses).

Crossbar technology had quickly become very reliable and required far less hands-on overhead maintenance than was originally anticipated. Also, in a high proportion of locations (particularly Towns and Villages) this Crossbar switching technology replaced Sylvester manual Switches – which in turn made thousands of Manual Switch Operators redundant – which significantly reduced overheads from the CE 1960s as the number of Crossbar switches were dramatically increased.

Heart and brains of this Crossbar switching technology was an electro-mechanical "Register" that on-the-fly analysed the switching needs and available transmission circuits and then made a logic decision based on this changing data as to which Crossbar switches connect the through call.

The "Register" was a large Relay Set frame (about 800 mm wide and about 450 mm high) holding about 120 to 150 relays. The Register was effectively a "state machine" (just like that used in computers) that was "common equipment" for all switched calls, potentially connecting through the associated racks / suites of hundreds of Crossbar switches. Each set of Crossbar switches was under control of usually two Registers – (one for redundancy) that would set the call path.

The operational problem the Registers were working almost all the time and by the mid-CE 1970s these Registers were becoming relatively high maintenance, with considerable wear. The Engineers were faced with an economic problem based on a few options that were:

- (Competitive Business Mindset) Greed - minimise reactive maintenance on these Registers and deflect complaints.
- (Competitive Business Mindset) Minimum - increase reactive maintenance to "just keep" these Registers operating and handle the complaints.
- (Infrastructure Business Mindset) Maximum - increase proactive maintenance to replace the most worn parts and through that minimise overhead costs.
- Innovative (Infrastructure Business Mindset) totally re-engineer the Register with appropriate low maintenance technology.

Since the mid CE 1950s when Crossbar technology was re-engineered by LM Ericsson. Digital technology had considerably advanced and continuing the use of electro-mechanical relays for this almost continuous workload in a Register was now inappropriate. So the fourth option was taken!

Engineers in Sydney and Adelaide collaboratively developed a solid state (I believe 74 series Transistor-Transistor-Logic (TTL)) electronic circuit to emulate an electronic version of the heart of the H4 Register – with no moving parts.

As I best recall, the entire electronic H4 register comfortably fitted on a "Eurocard" (100 mm * 160 mm) about 4.5% the area of the H4 Relay Set base (and a very small fraction of the cost of the H4 electromechanical Register)!

This electronic register was an instant success and there was virtually no maintenance. Electronic Registers were rolled out to all metropolitan "Tandem" Crossbar exchanges and these exchanges had their Crossbar equipment names changed from ARF to ARE (electronic)!

The Tandem Switches were the Metropolitan inter-District switches – and the large majority of telephone call connections were inter-District / Region – and therefore went through the Crossbar Tandem switches – using the H4 electronic Registers!

Although I do not know why the electronic H4 Registers were not unilaterally rolled out to all Crossbar exchange sites, my educated guess is that there was a very strong Union led pushback to not have any electronic H4 Registers and keep the technical staff numbers (to keep paying the union fees).

My instincts were that it would have been very straightforward to make several other (Crossbar) Relay Sets "electronic". As it was, the (Crossbar) metering was also made electronic and interfaced directly into the AXE processor. "***Gigantic Productivity of Electronic Metering***"

It was interesting to note that some (rare) parts of the Crossbar control equipment included thermionic valve technology (I think for Subscriber Meter timing) – and I (then) seriously wondered as to why that part of the Crossbar technology had not also been changed to solid state. Maybe that was part of the H4 Register!

Gigantic Productivity of Electronic Metering

One topic of massive productivity gains that slipped well under the radar in the mid / late CE 1980's were gigantic technology developments in Call Metering and Subscriber Charging, where paper-based / electromechanical-based recording and accounting processes were very quietly and quickly transferred over to electronic metering with computer-based accounting. "***Productivities of Electronic Databases***"

With Magneto and Central Battery (Sylvester) manual switchboards, each call was recorded on a small "chit" of paper and manually collected, manually sorted, manually transferred, manually summed up, manually billed and manually paid. This was a massive overhead and employed several tens of thousands of PMG / Telecom Australia Commission clerical staff all over Australia.

Each Metro and Regional "District" was city-based and usually had a double-story (at least) office building where much of that top floor was devoted to the paper-based accounting of metering and billing processes. The other main occupancy in these District Offices was the (External Plant) Drawing / Engineering staff – as all the network drafting was manually done on very large sheets of linen paper and locally stored in large wardrobe like cupboards. "***Productivities of Electronic Mapping***"

With Automatic switching (SxS, Crossbar technology) in the telephone exchange equipment, each telephone line had an associated electromechanical "Subscribers' Meter" with a front face about 25 mm square. These meters were put in "blocks" about 600 mm wide and 600 mm high. As a call matured (when the "B" Party answered) the associated callers ("A" party) meter would receive a short electrical pulse and the ratchet moved the count on by one. This was a rather basic mechanical process – and it too had a lot of overhead costs.

In a similar fashion with long distance calls, a timed pulse / signal would be sent back to the calling ("A" party) that would tick the calling party's meter. This again was a rather basic process that had a low fault rate (much lower than the paper manual accounting method)! The problem was that these meters could get "stuck" just like any electro-mechanical piece of equipment with moving parts.

Every three months the meters (in over 5000 exchange sites) would be regularly photographed (with a special camera), the film saved and processed and the prints were considerably expanded to show the numbers in the meter faces so that the metering staff could manually read these values from these photographs (usually using a magnifying glass); then manually transfer these numbers to Subscribers telephone account records (a two-stage process).

After those metering updates were recorded, this data was handed over to the Billing teams that for each telephone number (and at that stage there were about 6 million telephones and about 15 to 18 million people in Australia) then manually tallied up the differences from the last records and then calculated the billing prices and manually produced letters to be sent to all the subscribers / customers.

As the payments came in (where most of these were paper Cheques) the Accounting teams then cross-referenced the payments with the Subscribers Accounts and passed this back to the Billing teams to clear the Billing and the non-payments were passed to the Technical teams to (physically) disconnect / reconnect those services. Needless to say, this massive process was littered with manual process errors – but most of these errors averaged themselves out (most of the time).

Office based Metering / Billing / Accounting / Manual Operators / Mapping employed between 50% and 60% of the total telecom staff numbers. Engineering / Technical employed about 30% to 40% of the total telecom staff numbers. The remaining 10% to 15% were Senior Clerical and Executive Management.

Note that Advertising and Marketing was effectively 0% because telecom was (and still is) an infrastructure; which is an essential product / service – not discretionary.

Advertising / Marketing / Sponsoring of any infrastructure is virtually unnecessary and a thorough waste of valuable financial resources for that and other infrastructures. The added costs of Advertising and Marketing (and "Sponsoring"), really drives up end user costs of Essential Products and Services (such as telecoms).

With Discretionary Products and Services – Advertising and Marketing are necessary (expensive) tools to potentially connect with potential customers and maximise Trade volumes. These overhead costs are (usually) well-covered by substantial margins included into end user prices – including end-of-season "Sales"!

From CE 1981, with the introduction of electronic Ericsson AXE (and STC/Alcatel 10C) exchanges, the metering in this generation equipment was purely electronic and this data was saved within the digital switch's computer system memory (and/ or magnetic drums / tape reels) – and regularly transferred for processing.

> *In Telecom Australia circa CE 1985, checking on a new prototype recently installed in Haymarket exchange, I met a person carrying a large computer tape reel. Being rather curios, I asked where the big tape spool was being transported to. This tape full of data was walked to Pitt St Exchange (about 1300 metres) every day.*
>
> *The NSW Design Labs' new prototype Transmission Equipment Alarm Monitoring and Transfer System (TEAMTS) appeared to be working perfectly – and on my way back to work it hit me that this metering data could now be very easily and very reliably be electronically transferred using very similar data communications technology to our prototype equipment (or ISDN technology) between these two exchange locations.*
>
> *Obviously other Engineers were thinking along exactly the same lines because the role of Pitt St Exchange later changed from being a telephone exchange to being a (telephony) data centre and the metering / billing was within a few years being electronically transferred to this centralised location instead of being physically transported.*

There was a massive technology chasm between the Crossbar ARF / ARE / ARK / ARM electromechanical switch technology and the electronic backed switching in the AXE electronic long-held call switched technology. Both these technologies were very efficient at switching and connecting telephone calls and from outside the exchange buildings there was no discernible difference.

Inside the exchange buildings you could hear the mechanical noise of the Crossbar relays sounding much like waves on a beach during the day and in the evenings, the clatter of a few calls being set up and dropped out. In the AXE switching (and line transmission) areas it was basically silent apart from the air conditioning.

Circa 1984 while I was working at the NSW Design Lab (in Sydney) a request came in for a "Meter Common Monitor". This request was particularly interesting as the technology involved was Crossbar (which has its own CE 1950s relay-based racking and sub-racking technology).

The "Meter Common" was a set of electromechanical meters (same as Crossbar Subscriber meters) that were wired to provide supervisory data – like every instance a Register is called, a Route is used, a Subscriber in a particular 100 Group etc. and this data was then analysed by Engineering staff to determine the health (or otherwise) of the Crossbar equipment, and for network planning purposes.

Having an electronic data interface with the Crossbar equipment was at that time revolutionary. Peter Gimes and Steve Jolly quickly came up with extremely simple (and reliable) back-end interfacing electronics that (as I best recall) could be directly interfaced into +5V logic that was the natural interface for (personal) computers.

I think that the first trials were done in Bowral (NSW) and interfaced with the co-sited AXE equipment for data storage, and transferred to a processing centre. My understanding was that this introduced technology was resoundingly successful and widely rolled out with the NSW Workshops (in Sydenham) doing the equipment production runs.

Although I was totally unaware at that time – the Meter Common Monitor (MCM) was a watershed project that provided electronic back-connectivity into the middle of the Crossbar electromechanical switching technology. This connectivity was incredibly productive because it provided an almost live window into the performance of Crossbar switches at hundreds of sites – and it did not take long to proactively find out which Crossbar exchange sites (in NSW at least) needed specialist support staff to address (fix) unidentified problems in the Crossbar equipment that otherwise may have taken several months (if not longer, if ever) to surface.

In the (Engineering) background, it was starting to become rather obvious that if the (Crossbar) Common Meters could be back-connected with electronics to the AXE infrastructure, then there was really nothing stopping the (Crossbar) Subscribers Meters from also being electronically back-connected into the AXE infrastructure, so that this mechanical metering data could be electronically managed / processed instead of slowly passing through several hands in many physical processes.

One of the advantages was that it did not take too much programming to associate a telephone number with a person's account / address, and the next direct association was that of electronic metering being (directly) associated to an account.

In the mid-CE 1980s, the use of mainframe computing for billing (from AXE exchanges) started to take a central stage as it was becoming obvious that the records could be transferred into a computer's memory and the processing could be done far faster (and with far less process errors) with a mainframe or personal computer doing the "grunt" work.

In Telecom Australia, most States had a (small) team of professional / technical gurus (in Network Investigations) that took on and resolved their States most intractable (switching and metering) problems. Customer metering and charging complaints / issues were "everywhere" and most had been locally managed – but there were different processes in different Districts / Regions, even States and some of these problems were extremely complex to resolve.

My understanding is that a large amount of this metering and charging process work was re-engineered by a very bright engineer, Malcolm Campbell who was previously in charge of the Queensland Network Investigations Section based in Brisbane.

The concept of transferring the very heavily entrenched electromechanical metering / photo / manual accounting / manual charging / manual billing process into a very straightforward and slick electronic metering / charging / billing process was not really foreseen by the many thousands of telecom staff who did this work.

It took until about CE 1988 before these electronic metering processes started to get stabilised / standardised and it took some years to nationally roll out. As the Crossbar exchange equipment had its Subscriber Meters electronically interfaced to the new AXE exchanges; the clerical work for metering and billing was sliced off, and the productivity of electronic metering / accounting / billing absolutely rocketed! "***Productivities of Electronic Databases***"

The other parallel metamorphosis was the growth and development of the Service Control Network (SCN) that had grown out of monitoring transmission equipment alarms and moving these to a common floor in a main building (Haymarket) to becoming a deliberately isolated National Internet infrastructure (with some serial links in some circumstances) so that a wide range of remote control and data (including metering) could be nationally retrieved from a few dedicated sites. "***How the SCN Economised Maintenance***"

By circa CE 1990 Telstra had almost eliminated its Metering / Billing / Accounting / Mapping staff – about 50 to 60% of its entire workforce – or about 35,000 people. The "unemployment maths" is interesting!

Consider these 35,000 people were on $75,000 pa (average including management) plus their Superannuation say $7,000 pa and their office space is worth say $15,000 p.a. including overhead equipment totals about $97,000 per person or about $3,395 M pa for 35,000 people.

*When these people are "let go" they would have received about three years in forward pay as "Superannuation" so that would be about 35,000 * $75,000 * 3 = $7,875 M.*

Now dividing the $7.9 Bn by $3.4 Bn pa works out at about 2.3 years before the books start to equate – with the assumption that the office space overhead can be sold, rented out – or otherwise used no longer rented or used for far more profitable purposes and the equipment overhead costs are now nil (for this purpose), the breakeven time is really more like barely 2 years.

With the Crossbar (and SxS) metering now physically wired into the AXE switch technology – the metering overhead was now not only effectively a near zero overhead but far more elaborate billing strategies could be applied that could significantly increase income.

This meant that by about circa CE 1992 Telstra had really cleared the debit of this high volume of clerical Metering / Billing / Accounting staff that had been retrenched in CE 1985-1990 and Telstra effectively were now cashed-up (in this technology area *of Consumer Fixed Access Phone services) and Telstra could afford to lower its end user prices and still make a healthy return on investment (ROI).*

With the software running in the AXE switch's processor, the monitoring circuit simply repetitively scanned the logic interface and transferred any active results to the related customer's electronic register. So now all Subscribers and alarm metering was electronic (in the AXE environment) and very highly consistent!

The secondary outcome was amazingly abrupt! There must have been many tens of thousands of (maybe deliberately) faulty Crossbar Subscribers meters. Similarly there would have been a high proportion of these meters that were occasionally "sticking" – or operating intermittently!

Previously these Customers / Subscribers had little if any Bills and suddenly they were now hit with real and accurate telephone bills! Politically, this situation was a storm in a teacup as those complaining had in reality not paid Bills for several years! By complaining, they were self-identifying that they or their friends had deliberately tampered with the meter mechanisms. This teacup storm died a very quick death!

Virtually concurrently, the use of geospatial mapping radically simplified the cable drafting processes – which in turn released a very high percentage of Drafting staff to find other work (outside Telstra). "***Productivities of Electronic Mapping***"

Hundreds of District Offices were closed down and management retreated to far fewer Regional centres. The whole structure of Telecom Australia / Telstra went through gigantic a metamorphosis that was primarily caused by changing the metering from being electromechanical to electronic!

This set of process changes from manual / physical metering and billing to electronic metering and billing had absolutely nothing to do with competition and had everything to do with "building a better mousetrap".

(*In terms of Total Quality Management (TQM) this "building a better mousetrap" is called "continuous improvement" which is standard Infrastructure Business practice!*

The ISO Quality Assurance process very falsely feigns this "continuous improvement" mindset by having regular meeting that do not allow active feedback to management / executive to improve processes. Also the process documents must be strictly adhered to and signed off at the lowest level i.e. by those who do the work.

With ISO, the work is then (totally unnecessarily) checked at multiple supervisory levels above the person who did the work – and they delegate responsibility down – not up! This process deliberately excludes the executives from any litigation and it is these executives who have by far the highest renumeration!)

Phone Numbers, Portability and Mobile Devices

One of the many facilities that are inherent because of Common Channel Signalling (CCS7) is the ability to direct a call to another / different telephone number – e.g. to a service with an Interactive Voice Responder where the call can be answered, verbal message recorded, and /or the call re-directed to another exchange site (or mobile device radio base station). "***Amazing Productivities of CCS7***"

In most (developed) countries, mobile devices were the new rage from about CE 1981 and they were initially marketed as the "must have fashion accessory" for Medical / Law and other high paying high profile professional roles. As a complete shock to the sales and marketing world – the people that really took up (analogue) mobile phones were the Trades people (so they didn't miss a call for more work) and the Farmers and Graziers (as a real workplace health and safety issue).

These (analogue) phones were "clunky" to say the least. They were like house bricks and most early models included the battery on a waistband because of the bulk and weight. This was a technology that was itching to be radically developed, and there was a coincidental technology wave that really assisted in significantly reducing the weight and size. "***Second Wave of Digital Components***"

The key to how a mobile phone connects to a Radio Base Station (RBS) is that the mobile phone has a unique "IMEI" / MAC number (in it), that when the phone's electronics identifies a strong enough RBS signal it replies with this IMEI number. The RBS receives this IMEI number, sends this IMEI number via CCS7 / SIP signalling infrastructure to the IMEI database that relates the Phone Number (and RBS, and the mobile phone's Carrier Provider). The mobile phone is then recognised by its associated carrier / service provider and the mobile phone now (effectively) has connectivity to the RBS and (usually through SMOF cable transmission) a through-connection to the District (telephone) switch infrastructure! "***Amazing Productivities of CCS7***"

When you call a mobile phone that phone (dialled) number is sent (using CCS7 / SIP) to the IMEI database that relates the phone number you entered to the mobile phone's IMEI identification number (and network location) and from there the CCS7 / SIP firmware directs your virtual connection to the local switch that has that IMEI identification – which is normally the phone (number) that you have dialled.

This network connection process appeared to be far more complicated than for a fixed access telephone with mechanical switching – later replaced by electronic switching (also with a long held call path), but because CCS7 / SIP now controlled digital Voiceband connectivity / path through the Inter-Exchange / Backhaul / Core Network this technology introduced a network connection flexibility that enabled number portability (for both fixed and mobile access telephone/devices!

Because of the very wide reaching relational database functionality – it became practical (and highly economic) to turn the entire Australian fixed access telephony connection process around on itself and give every fixed access telephone line interface circuit (LIC) a MAC address / IMEI number – and directly relates the phone number to the IMEI number / MAC address. Without these merged technologies – number portability and mobile phone connectivity would not have been possible!

With the introduction of competitive (telephone) carriers in Australia, telephone number portability was innovatively used to "allocate" a (telephone) number range to competing carriers for their absolute use (and include IMEI numbers associated with each telephone number. This advanced switched network technology also made it possible for customers to change carriers (service providers) and "take their number(s) with them"!

No matter how you look at this "number portability" technology – adding competing carriers / service providers (i.e. increasing competition) considerably increases the complexity (and overhead costs)! This extra overhead has to be paid for by the end users (customers) and/or by the shareholders (as less value in dividends – which is directly related to the share price "value").

In economics; paying dividends (and executives a large renumeration) is a direct opportunity cost against operating a better Quality (telecoms in this case) service – because these funds cannot be invested in new and better infrastructure – even maintenance. Consequently, it is very unsurprising to see privatised infrastructures being slowly run into the ground (usually over a decade or two) – with the Board / Executives being very generously renumerated, maintenance significantly reduced from proactive to reactive and infrastructure builds / rebuilds delayed or stopped.

With telecoms infrastructure (in Australia), we have been exceedingly lucky to have a series of ground-breaking technology advances every 10 to 15 years apart (and seriously large Government injections) that have literally saved Australia's telecoms infrastructure from becoming a national catastrophe – because it is these technology advances that have sequentially plummeted build / operational costs and completely hidden the immense / massive inefficiencies introduced by privatisation.

*In the USA, the "free market" has a controlling interest in their (hard right) "western" economics (and Government), and part of the controlling interest is to have a "small Government" – which is deemed to be "efficient" (by the controlling "free market")! "**External Economic Control from the US**A"*

A classic example of the "small Government" situation in the USA circa CE 1980 the Federal Communications Commission (FCC) – the (USA) body that determines which corporation / business / person can use what part of the electromagnetic spectrum over the USA – was so short of funds that it could not afford to pay its staff!

In desperation for funds, the FCC management were wedged into the situation to auction off the spectrum to the highest bidders – and it did just that – and the large USA telecoms corporations kept unwanted competition out of "their" spectrum!

The FCC staff was paid (now there was plenty of funds) – but the FCC staff were now "compromised" as these major corporations had control of the spectrum and the FCC was now obliged to police that "ownership" instead of being an "arms-length" from the policing of the USA geographic electromagnetic spectrum!

In the CE 1970s, the Australian Broadcasting Control Board was taken over by the Australian Broadcasting Tribunal, which later changed its name to the Australian Broadcasting Authority (ABA).

Australia's electromagnetic spectrum was managed by the Spectrum Management Authority (SMA) and all negotiations to use any part of the spectrum was a straightforward engineering decision (by common sense negotiation) and the cost to use parts of the spectrum was zero to those using the spectrum.

The SMA did a wonderful job in managing Australia's spectrum for several decades – even though inept Australian Federal politicians made this task very difficult. "***USA Muscles its Way into World Dominance***"

Circa CE 1986, the Australian Telecom Commission (formerly a main part of the Post Master General's Dept.) had a "Headquarters" based in Melbourne that (naturally) kept an account of all the exchange site names along with four-letter codes for each exchange site building (and switches in those buildings).

Headquarters had many other functions relating to equipment supply (bulk purchases - contracts), the wiring rules in exchange sites, customer premises, engineering rules for connecting attachments at customer premises, the national telephone numbering, plus several other standard-related functionalities. Most of the time these processes worked very well – and there were a few hiccups!

> *As a Class 1 Engineer in mid CE 1986 (in 12th Floor Devonshire St, Surrey Hills) I was called aside (by Tony Azzopardi) to assist with trying to sort out a telephone numbering problem that had arisen particularly in the Gold Coast (which was north of NSW), but it had a direct impact on the exchanges in the North of NSW as the number ranges were literally running out and nationally something had to be done and very soon.*
>
> *He explained the situation in a few minutes and it became fairly obvious to me that the variable (6 and 7 digit plus the option of two or three digit area codes) numbering system that was variably used around Australia was not going to work in the Gold Coast / Byron Bay etc. and in any case in a few years Sydney and Melbourne would also be having the same problems of number runout, and mobile phone numbering was a mess!*
>
> *So we bounced several ideas around and came up with leaving the Gold Coast with the area code of 07 and increasing the digits to eight in that large area (making a total of 10 digits) 07 xxxx xxxx where before the Gold Coast had 07 xxx xxxx and had literally run out of telephone numbers.*
>
> *Then we looked at Sydney and Melbourne and tried the same "trick" with them (giving them 02 and 03 respectively) and having eight digits behind there now starting with 9 and overflow to 8. This was a real "mud pie" because the outer Sydney area codes were 04x and the NSW regional areas were 06x etc. – and much the same for Vic, and Tassie was an odd one out! So the number transfers would have to be done in stages.*
>
> *We looked at "moving" the NSW outer Sydney 04x xxx xxx number range into the 02 range (using eight digits), and the Regional NSW 06x xxx xxx numbers into the 02 xxxx xxxx range and suddenly everything started to "fit" – but some of this involved a double change in numbers.*
>
> *So we started to work our way through the Vic regional areas and merge these into the potentially new Melbourne 03 xxxx xxxx number range. Tasmania would potentially become part of the 03 xxxx xxxx.*
>
> *As moving the Gold Coast to the new 07 xxxx xxxx (10 digit range) was an immediate imperative it then followed that the Brisbane (and the rest of Queensland) number range would also become 07 xxxx xxxx (with a minimum of reprogramming switches as all this would now comfortably fit*

in the 07 xxxx xxxx range and the 04x and 05x number ranges then would become vacant – which we then tagged for the mobile phones.

SA / WA and NT were straightforward as the 08 xxxx xxxx ten digit number range, and this comfortably fitted.

This now left a giant hole for the mobile phones to use the 04xx xxx xxx and later the 05xx xxx xxx (and we "coined" this readability sequence for mobile phones in this meeting) and the 4 digit service numbers (e.g. "1234") could be made six digit 12xxxx numbers and the 13xxxx numbers could stay unchanged.

This was nearly a full day intense brainstorm that we then documented on several sheets (because there were several step processes) and we sent this down to Telecom Headquarters for approval!

A few weeks later this whole plan was not only approved but implemented and later our numbering scheme became a major part of AUSTEL!

Following the breakup and partial privatisation of Telecom Australia Commission circa CE 1990 – a rather large part of what was Headquarters became "AUSTEL" the governing body for all telecoms equipment attachments, the rules for wiring telecoms equipment in premises, the telephone numbering in Australia, and the authority to approve telecom service technicians (who were working in businesses outside Telecom Australia).

About CE 1997 AUSTEL absorbed the SMA and renamed the combined organisation as the Australian Communications Authority (ACA).

Some years later (circa CE 2005) the Australian Broadcasting Authority (ABA) and the Australian Communications Authority (ACA) were merged and changed renamed itself as the Australian Communications and Media Authority (ACMA).

Because the Australian Federal Government(s) championed competing telecom (infrastructure) service providers, this included telephone numbers allocated to competing service providers. This added data burden effectively increased overhead costs of telephone network management – but, very fortunately, the use of CCS7 circa CE 1985 (and then SIP circa CE 2005) considerably minimised this added operational burden – because data in the CCS7 (telephone user part) used number ownership to assist managing these call process impediments.
"***Amazing Productivities of CCS7***"

An Australian Federal Government politician (who was in a position of power and was obviously compromised by the USA's political tentacles; was made aware of the huge amount of money that was being received by the USA's FCC by holding the intended infrastructure and commercial (and community) spectrum uses to virtual ransom – by auctioning of the unique spectrum to the highest bidder.

Of course this auctioning of spectrum infrastructure (which is imperative for mobile phones, Radio / TV stations point-to-point radio / Satellite connectivity etc. of course turned out to be a very expensive situation for the competing service providers – who had no choice but to pay top dollar or not have a business (***that is what an infrastructure is***)!

Being obviously compromised, this politician had little choice but to introduce and enforce this same “hard right” infrastructure extortion into Australia and the ACMA was the conduit to run auctions of Australia’s electromagnetic spectrum.

Needless to say this spectrum auctioning really pushed up the costs for the end users (the customers) and caused a massive wave of totally unnecessary implementation problems (and nobody said anything because if they did then they would certainly not be “invited” to any future spectrum negotiations).

The results were somewhat expected – except that some of the spectrum was speculatively purchased (for profit) and Telstra also blocked out large amounts of Regional spectrum with (my understanding) no intention of using this (and in the process - preventing others from entering these geographic areas).

As there was nominally four competing Mobile Service Providers – Telstra, Optus, Vodafone and Hutchison/TPG (in the metropolitan areas), it didn’t take too much vision to realise that the provided spectrum would be far too overcrowded and as new mobile technology emerged and it took almost no time for competing mobile device providers (now) needing separate spectrum allocations.

Compounding this monumental (USA hard right Government pushed) agenda / mistake of auctioning off spectrum; what was really obvious (to me) was that if the mobile devices were to have usable Internet data speeds – then the connection bandwidth has to be far wider than that already provided / used by the then mobile device technologies.

The economic problem was spectrum competition (and auctioning)! If the spectrum was shared by the Radio Base Stations (which it can be at a minimum of cost because the number of (expensive) Radio Base Stations is literally quartered – in this case) and the SIP data can be used to separate the call connections to their mobile carriers – then this collaboration (negative completion) would have provided plenty of spectrum and an absolute minimum of Radio Black Spots! This did not happen!

In desperation, the ACMA came up with the “Digital Dividend” where TV spectrum in the UHF band was taken away and re-allocated to the Mobile carriers (at a very high price - through auctioning). This was very deceptive marketing – and there was no “dividend” as the spectrum was re-allocated so no spectrum was increased (as deliberately implied by the word “dividend”).

Basically, the Radio Base Station (RBS) is an extension of the Access Network (commonly using SMOF cable back to the District / Major exchange switch / router. The RBS location includes a mast and usually multiples of three vertical antennae (that look like thick vertical tubes) with a cables feeding down to a radio transceiver in a building. The radio transceivers provide connectivity to many radio channels in a specified narrow frequency range (which is part of the allocated spectrum for that competing carrier).

To greatly assist the radiated field strength and the received signal, the RBS’s antenna is a vertical stacked array (of dipoles) that is phase-associated to create a very shallow height beam – typically about 5 to 10 degrees wide. Also the (vertical oriented) metal sheeting surrounding this stacked array narrows the horizontal beam so the beam is forward only and is typically about 60 degrees wide. This is why there are typically three antennae to get a full 360 degree coverage – or only two antennae (back-to-back) to focus along a road!

Because the frequencies are (generally) above 850 MHz, the radiation is virtually line of sight and the obvious first choice was to pick the highest vantage points and position RBSs at these locations.

With earlier mobile phone technologies i.e. Analogue and GSM1; the Voice channel back-connected into the standard Voiceband telephone (switched) network, while the inter-exchange signalling used Common Channel Signalling (CCS7) but with GSM2 technology the signalling was morphing towards Session IP (SIP) technology.

The prime reason that mobile Phones left “Analogue” and moved to GSM technology was that GSM technologies had a far narrower spectrum allocation for the Voiceband than Analogue – so far more GSM “digital” mobile phones could connect to the same (expensive) Radio Base Station infrastructure – per antennae and transceiver, so the productivity in moving from Analogue to GSM1 was at least 200% and it introduced the “convenience” of very limited Internet connectivity as an immense selling point. GSM1 technology was however a complete failure in terms of voice transmission – because the radio channel bandwidth was far too narrow to be practical.

Because GSM1 had a very narrow (and slow) data channel (about 7 kb/sec ?) for voice; these phones used Linear Excited Predictive Encoding / Decoding that had about a 200 msec delay at each end and the re-constructed voice sounded metallic.

But this technology GSM1 phones had (very limited) Internet connectivity – and texting was practical and extensively used! These mobile phones were pushed in the market because far more phones could be connected per Radio Base Station (RBS) than analogue phones and the economics of mobile phones was far more profitable than fixed access phones.

At about this time in the early CE 1990s, Telecom Australia started to “lose interest” in maintaining the physical (pair copper) Access Network – because it was now seen as a “cost centre” compared to the then fast emerging Mobile Radio Network. This was a classic case of the private sector (in this case Telstra) gradually running the infrastructure into the ground. “***Competition Wrecked Australia’s ADSL***”

Mobile phones had an annoying problem of “dropping out” particularly when in a vehicle and the problem was that there was no way to transfer the call from one RBS to another RBS with a radio signal that was now stronger than the previous RBS.

Telecom and Ericson engineers collaboratively worked on this problem and came up with using CCS7 signalling to include radio field strengths (as seen by the mobile devices) and use this data to transfer a mobile’s RBS on the fly without losing the call. (This was a world’s first innovation – made in Australia!)

The next version of digital mobile phone (GSM2) had a 14 kb/s data channel for voice (standard PCM Voiceband is 64 kb/s) and used (highly) adaptive PCM (with a little delay) but the voice was still “metallic”. (Some Pair Gain Systems that had an extra two Voiceband channels over a single pair used 32 kb/s Adaptive PCM (ADPCM) and that did not sound metallic nor did it have a noticeable delay.)

GSM2 mobile phone technology was still more profitable than the analogue phones (because the radio bandwidth requirement was far less than that required for Analogue mobile radio – meaning that far more mobile phones could concurrently use the same radio Base Stations Antennae. GSM2 was not as profitable as GSM1 phones – but the complaints were considerably less (and the “faster” Internet connection was also an excellent selling point)!

There were several technology advances including the changing of batteries from alkaline to lithium plus the liberal use of new LSI chips and a significantly improved screen resolution. All these technology advances dramatically reduced physical size and weight (and production costs) of mobile phones, making them highly practical, particularly in urban areas the overhead build and maintenance costs of mobile phone technology is far less than that of pair copper etc.

The concept of a small / compact mobile (and relatively inexpensive) communications device that could now be comfortably fitted in a purse or pocket was totally revolutionary and a very few years became a “must have” business connection for texting, telephone connectivity and Internet connectivity. This concept of direct contact-ability quickly grew and (particularly for the under 40s) became an essential part of fashion and everyday communications as the number of applications (“Apps”) grew to focus on certain personal and inter-personal interests.

Virtually identical word and character counts – but the two above messages are diametrically different to each other! This is why Sales / Marketing / Advertising / Lawyers people should never be involved Politics! These people usually talk their way into political power (through “popularity”) and are prize candidates to be corrupted (by wealth and fame) as they generally have no concept of Government Engineering processes (i.e. Infrastructure) that usually takes several years to build and has a very low profile – but is imperative! Hence – these people ignorantly generally wreck a country’s future economy for the sake of personal popularity.

In 2005 the next version of mobile phone technology (GSM3) was now entirely based around IP technology and used VoIP technology and the speech delay was virtually zero, the encoding was “perfect” (compared to the linear predictive / adaptive encoding of GSM2 and GSM1) before this VoIP technology and the voice and signalling connection both used SIP (Session Internet Protocol) – which now usurped CCS7. “***Amazing Productivity of VoIP***”

GSM3 technology was effectively a mobile IP extension phone (with texting and a simple Website interface for a wide range of “Apps”). From the Switched Network side this was in effect a national IP-PABX with the call paths set-up and controlled by SIP, and the Voice carried through priority packets of VoIP. (If the core network was not in network congestion mode then the packets literally followed sequentially – so there was less “reason” to have priority packets with VoIP).

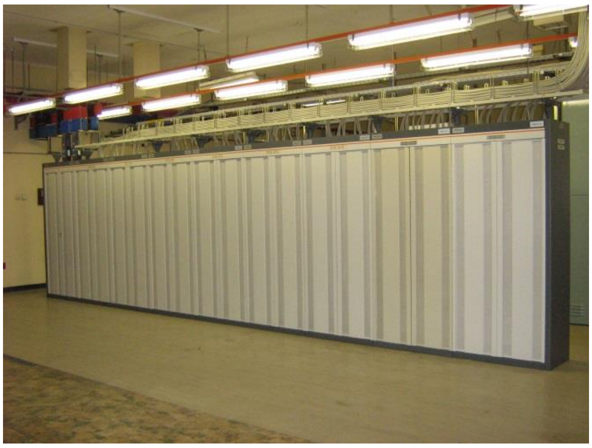
What was not blatantly obvious was that the existing long-held call switched path technology being used for fixed access telephone connections was being bypassed for (GSM3) mobile – mobile calls and the amount of / cost of routing / switching equipment required for VoIP network switch/routing was remarkably small (and inexpensive) in comparison to what was required for standard telephone calls through the then well-established Voiceband switched Inter-Exchange / Backhaul Network!

As this “productivity penny” dropped it quickly became very obvious that SIP/VoIP technology using IP based Routers and Switches was far more economic (read “profitable”) than long held / switched call technologies that had been installed in the 1980s and 1990s to replace telephone Voiceband electromagnetic switching equipment that had been installed from the CE 1960s.

Extending SIP/VoIP to replace Voiceband switching effectively unified the Core of the Network as a unified IP based network infrastructure – bringing with it extensive productivity advantages and far more substantially reduced overhead costs. (*Read this paragraph again, three times.*)

Instead of replacing the existing Ericsson AXE and more recent Alcatel System 12 telephone exchanges – the back ends of these (fixed access telephony) digital switches were SIP/VoIP interfaced and connected straight into Edge Routers that in turn back-connect into the Core Network.
With this technology translation, the Inter-Exchange Network had first morphed into a Backhaul (digital transmission) infrastructure that had now secondarily morphed into a unified Core Internet infrastructure of controlled Switches and Routers.

On the right is a 10,000 line (Alcatel) System 12 (S12) telephone exchange switch – which is CE 1990s technology.



The equivalent CE 1960s Crossbar technology switches etc. would have at least filled this entire floor (which is a lot longer than it is wide)! (The S12 equipment shown here is about half the width of this room)

Physically, the size of these Edge Routers took up only part of a transmission rack space (about 360 mm high) where before this would have filled a large Switching equipment Room and the Core Switches were now (multi) centralised – each taking up a suite of say 12 racks where before this equipment would have filled a few floors in many major exchange buildings!

The productivity of this technology advancement is still being realised with many exchange sites have virtually no equipment in them apart from a few racks of Switch / Routers and an Optical Fibre Distribution Frame, (distributed) batteries and lots of open floor space!

The Sudden Emergence of SMOF

The concept of Multi-Mode Optical Fibre (MMOF) had been around for many decades before CE 1975. MMOF has an intrinsic problem that the light waves internally bounce at many different intervals (modes) resulting in the available bandwidth being an inverse function of the length. In practice the maximum transmission length is about 500 metres before the multiple wave fronts (with widely differing transmission delays) severely interfere with each other.

Part of the then Telecom Australia Commission's Telecom Research Labs (TRL) had from about CE 1975 been doing world-leading research on Single Mode Optical Fibre (SMOF) and Plesiochronous Digital Hierarchy (PDH).

These two technologies went somewhat hand-in-hand because it very quickly became obvious that PDH had promises of being an extremely stable transmission technology (requiring virtually no maintenance overhead) and SMOF technology had very strong promises of having an enormously wide bandwidth. "***Highly Economic PDH Transmission***"

The secondary proliferation of solid state integrated devices in the mid-late CE 1970s and CE 1980s provided a platform of semiconductor lasers / light emitting / light sensing components that eventually by mid-April CE 1986 smashed open the technology doors to facilitate very wideband, very low attenuation per unit length, SMOF technology that quickly became very inexpensive to manufacture! What is generally not recognised nor appreciated is that Australia (TRL) was at the forefront of these massive technology advances! "***Second Wave of Electronic Components***"

By CE 1978, TRL had already prototyped multiple "E1" (2 Mb/s) PDH to be very efficiently transceived through their in-house 1.5 GHz point-to-point radio system that was the backhaul technology for their Digital Radio Concentrator System (DRCS) to provide telephony in Regional Remote areas, by using NEC 2 Mb/s PDH telephone circuit Line Concentrators in the SCAX huts. "***HCRC in Remote Australia***"

Although the concept of SMOF transmission technology was realistic, the practical realisation of this technology was anything but straightforward and there were several unseen roadblocks that really hindered the research process setting it back several years – but they persisted, and persisted.

One of the problems involved the manufacture of suitable SMOF transmission and reception devices – which came back to being constructed from semiconductors – but not of the silicon variety. Another problem was finding a suitable frequency (wavelength) "window" where the through fibre attenuation would be minimised. Another problem was the physical construction of the fibre itself and how to cause exceptionally low loss total internal reflection. Then (of course) there were problems in fibre alignment plus how to end a fibre and not cause excessive internal reflection – and also not cause high attenuation! All these issues aside - fibre splicing (physically joining fibres end-on-end) was yet another (expensive) issue!

Following on from the DRCS and its production model (the High Capacity Radio Concentrator (HCRC)) – supporting 22 * 2 Mb/s PDH "E1" streams; TRL had also been working with LM Ericsson and in CE 1981 Telecom Australia introduced LM Ericsson's AXE101 digital switch for Voiceband telephones – with multiple 2 Mb/s ("E1") PDH transmission as the standard back-connection with the (analogue) Inter-Exchange Network (IEN). "***Transitioning to the Digital Network***"

Concurrently, TRL had also searched worldwide and had discovered a USA business that manufactured compact, loop powered 2 Mb/s (PDH) Regenerators that operated on pair copper cable. These Regenerators could be installed in place of 88 mH Loading Coils (i.e. spaced at 1830 metres) and provide 30 digital / Voiceband channels on just two Junction/Transit cable pairs. "***Massive Productivity of 2 Mb/s***"

With significant technology advances in digital Voiceband PCM encoding /decoding technologies in circa CE 1983, the cost of analogue/digital conversion process plummeted and these technology advances threw the doors open to having highly economic individual electronic line interfacing and PCM digital Voiceband conversion on each line. "***Mighty Productivity of Digital Platforms***"

By the mid CE 1980s with a high proportion of all Telecom Australia's larger exchange sites now including AXE 102 / AXE104 switching technology it was becoming obvious that FDM transmission technology would soon be on its way out – but there were literally no high capacity (medium / long haul) PDH transmission systems in Australia as all this was still FDM. "***Advancing FDM Transmission***"

In the worst scenario possible situation, it was discovered that "network dropouts" started to appear (circa CE 1983) and it was not just one Voiceband circuit but an entire 2 Mb/s PDH "E1" of 30 digital Voiceband circuits and by CE 1985 the number of 2 Mb/s circuit dropouts was increasing at an alarming rate – "everywhere"!
"***Competition Wrecked Australia's 2 Mb/s***"

Also by CE 1985, Australia's largest and most greatly used long-haul FDM (telephony-focussed) transmission link (between Melbourne and Sydney) was literally on its last legs. This high-capacity, coaxial cable, thermionic valve technology FDM system was installed and commissioned in CE 1956/7 was then almost 30 years old and in a state of extremely high maintenance that is characteristic of end of life.

The transmission medium was an expensive 7 tube coaxial cable – which was then common practice for long-haul (and underwater / sea / international) transmission from about the CE 1940s and this technology had considerably improved.

As long-haul transmission was/is unidirectional – a pair of tubes would be the transmission medium for each of the three parallel Frequency Division Multiplex (FDM) systems – leaving a spare tube for maintenance and/or unidirectional Television – using the full available bandwidth. So – really, this bearer was fully utilised from day one in CE 1961.

This coaxial cable was manufactured in both Germany and Australia circa CE 1955 – 1956 using virtually identical equipment and techniques – almost! In the coaxial cable construction process, the polyethylene insulators (about 8 mm outer diameter) were clipped / rolled over the central conductor in each coaxial tube at regular short intervals (say 100 mm apart) to keep the central conductor near the centre of the tube-shaped outer conductor that was wrapped over like a solid pipe. This seam may have been soldered. (This was a rather expensive manufacturing process – but it was the most economic at that time.)

These insulators were manufactured from thick polyethylene sheeting, and at that time polyethylene was new and expensive. The basic process was to use a press to punch out hundreds of thousands of these insulators from a large sheet of polyethylene plastic.

In Germany, the dumped sheets were discarded – but in Australia the "Recession / Competitive" mindset of frugal cost-cutting meant that the remaining (punched-out) sheets were re-melted with new polyethylene to make more sheets – to make far more insulating rings – far less expensively (in the short term).

Unfortunately the used polyethylene sheets had miniscule metal fragments from the punching process – causing this process being polluted. Because the MEL-SYD coaxial cable had a high (DC) voltage through it to remotely power distant repeaters (every 8 km), the polyethylene spaces inside these coaxial cables were now (after about 25 years – i.e. from about CE 1980 intermittently breaking down – dropping out thousands of (Voiceband) calls at a time!

Compounding this problem, be the early CE 1980s thermionic valves were fast becoming extremely scarce as manufacturers around the world had moved on from valves and were manufacturing TV screens, transistors and Integrated Circuits (ICs)!
Circa CE 1981/2 Telecom Australia was very nervously gearing up to purchase the necessary PDH-based transmission terminal and regenerator equipment and plough in two parallel 7-tube coax cables between Melbourne and Sydney, with more than double the existing capacity of the single cable with 7 coaxial tubes. My estimate is that this would have cost about $131 M. "***Costing the Mel-Syd Link***"

Concurrently, Telecom Australia was also trialling a range of other PDH transmission technologies to replace 2 Mb/s regenerators – and frankly it was a dog's breakfast as some technologies worked but they were at 8.44 Mb/s and that introduced other complications meaning that (very expensive) coaxial cable (or Single Quad cable) may / would have the be rolled out everywhere that the Junction / Transit network cabling currently was in place. "***Competition Wrecked Australia's 2 Mb/s***"

> *It just so happened that in CE 1986 I was on a year rotation / orientation as a Class 1 Engineer (with 19 years very wide technical experience). Rather fresh into the Network Planning section I innocently showed up a fundamental flaw in the structure of the NSW Regional Backhaul Network and this candid observation was (at the least) very poorly received!*
>
> *As "punishment" I was given a project to design the structure of the then highly mythical MEL-SYD Single Mode Optical Fibre (SMOF) Network and its wayside stations (inland cities). I was sectioned off to a remote area on the floor; so my comments about no alternative inland routing must have hit home and really upset most of the then engineering hierarchy!*
>
> *The work specification was exceedingly vague apart from "there is no such thing as SMOF" and "there are 31 fibres" and "there will be 7 * 545 Mb/s and 8 * 140 Mb/s systems" and "it has to connect with the inland cities on the way"! This assignment was going to be a real challenge.*
>
> *So – I started to build a network design based on the existing MEL-SYD 7 tube Coaxial Cable and I soon realised that this mythical network was based on a pair of 7-tube coaxial cables and their interstice quads.*
>
> *Considering that the MEL-SYD coax cable system was commissioned in CE 1961 and that it was all thermionic valve technology, and way past the end of its low maintenance life; it became rather clear that this new MEL-SYD dual Coax-Cable network was already engineered for PDH on Coax – and I was on a fast learning "detention" curve!*

From here I branched out to historical traffic data to find that the telephony traffic had basically plateaued and that data traffic was rather small (about 4%) but was very rapidly (exponentially) increasing; and I estimated would equal / exceed telephony traffic by about CE 2000! Also - that this entire network structure would run out of capacity when / if it was installed!

So, I pressed on for a few more weeks and worked out the whole structure including the Regenerators, Wayside Stations (inland cities) and matched their telephony / data channel requirements, racking floor spaces, the through connect requirements and planned for massive data increases!

About four weeks into this immense network design, I received an extremely excited call from Telecom Research Labs (TRL) in Melbourne! They had been working on this mythical SMOF technology since about CE 1974 (over a decade) and very suddenly after all those years, this technology showed strong promise of being highly functional (and real)!

TRL had SMOF working over a few metres, and they kept me in the information loop. A few days later their SMOF was working over a few 100 metres, then a few days later about 1 km – this could be real!

A few days later they had it working over about 12 km which is 4 km longer than the Coaxial Cable regenerators – so existing Repeater Stations could be re-purposed for SMOF regenerators. This is real and I kept very quiet!

A couple of days later (mid-April CE 1986) TRL called to say to say they could get in excess of 18 km then a day or so later; 32 km and the whole (financial) dynamics rapidly started to radically change – as I could now hop over a few repeater sites and significantly reduce equipment costs.

Then TRL came back a couple of days later with SMOF hops exceeding 60 km – meaning that no Regenerators were needed at all! This SMOF was suddenly a massive game-changer for very inexpensive wide spectrum bound-media transmission technology.

When I then announced the "highly mythical" project being practical (and ready) – I was immediately whisked off that project, and transferred (rotated) to "Sydney End Terminations" to learn more about Engineering!

The emerging technology of Single Mode Optical Fibre (SMOF) immediately demonstrated immense productivity over the earlier Coaxial Cable (and Radio) as the very inexpensive and highly reliable long-haul transmission bearer. Telecom Australia Research Labs (TRL) wasted very little time in arranging for multiple cable factories in Australia being re-engineered to make SMOF cable as soon as possible. Effectively – this SMOF was "Prototype" and "Proof of Concept" all rolled into one.

This first SMOF cable for the MEL-SYD route had 31 fibres (the 31st as a spare in case of breakages) and as I had predicted (and warned), this cable was absolutely fully utilised from day 1. I had suggested that it would have been prudent to at least double the number of fibres in this major infrastructure (i.e. to at least 64 fibres) – but this first nominal 1000 km of cable was in reality a "Prototype " and "Proof of Concept" as together and not really up to being a "Small Scale Production" just yet.

As this SMOF technology very rapidly developed, the “Small Scale Production” standard structure was very soon based on (several) sections/tubes of 12 fibres with a very strong and thicker “strainer” to minimise cable stretching (which results in fibre micro-cracks – wrecking these fibres). The second generation (i.e. Small Scale Production”) of SMOF cable for direct ploughing was also about 17 mm in outside diameter and this cable would have been capable of carrying 48 to 96 fibres.

Telecom Australia’s Network Design and Construction (NDC) Business Unit quickly focussed on the Mel-Syd SMOF project as the national transmission priority. My understanding is that meaningful construction started in July CE 1986 (a very few months after the SMOF discoveries were identified by TRL in mid-April CE 1986). By November CE 1987 this project was fully commissioned (i.e. fully operational) but not officially opened until Australia Day 200th Centenary i.e. 26th Jan CE 1988.

Productivities of Electronic Mapping

From the first days of mapping this was (usually) done on a sheet of some sort as an aerial view and the map usually oriented with North at the top of the sheet. When it came to mapping the transmission routes for the Post Master General's Dept. (PMG) the same standard was followed from at least well before CE 1880.

With telecommunications this type of mapping can get very more detailed that just the street / land maps and there were several gradual advances that made these maps more useful with the appropriate detail on these physically large maps.

My understanding is that these PMG external plant (Transmission Lines/Cables, Poles, Service Pits etc.) maps were large – probably 6 foot wide and 4 foot high and made from linen paper (that is thick and dense, strong – and very expensive)! These inked-in maps would have all the streets and land blocks accurately scaled. There would have been a lot of physical map duplication / copying / referencing between the local councils and the district PMG mapping. This was "work intensive"!

In country areas the tops of hill usually have what are called "Trig Stations" that stand like a pointed monument so that surveyors can site these points and use these references for their trigonometry to accurately reference their mapping. In urban areas there are also similar "Trig Points" set in concrete footpaths / gutters.

These PMG maps included all (underground) conduits and service pits, telephone poles and cables / wires in the conduits and connecting to premises. So - a country city of say 25,000 people would require no less than about 100 maps – that were usually vertically stored in hanging cabinets. Consider the surrounding farms for say 20 km and there is at least another 300 large maps – done to a smaller scale.

Even though external plant is rarely changed, keeping these maps up to date and keeping the data accurate was a full time job for many people per District office.

In the CE 1960s, following developments with Doppler tracking (by measuring the delay of received under-water signals), this technique was extended with geostationary satellites in the CE 1970s (including the curving of radio paths in the atmosphere (thanks to leading research by Australian scientist Elizabeth Essex-Cohen in CE 1974) and by the mid CE 1980s this Global Positioning System (GPS) accuracy was down to a few metres.

Following an international incident where a commercial plane was shot down in CE 1983, President Regan issued a directive that GPS be freely available for all and this was later countersigned by President Clinton in CE 2000.

The technology of linen-paper-based mapping started to get "computerised" in the late CE 1970s and it took until the mid CE 1980s before the concept of "Geospatial" Mapping started to emerge as an extremely productive mapping technology. The basic concept being that any land mass can be viewed from "above" and that digital map can be projected onto a screen – where points on the map are aligned with geospatial locations (e.g. Trig Stations, Trig Points, Latitude/Longitude), and the (raster) map can be "stretched" to fit!

From here this electronic mapping technology borrowed a bit from advances in digital photography processing where (clear) layers can be laid over the background (electronic) map and (telecom) infrastructure can be (electronically) drawn into these clear layers instead of being inked into a linen-paper map.

In parallel with this then fast emerging electronic mapping technology was the faster growing technology of databases (mainly on personal computers). Telecom Technical Officers and Engineers had been active all over Australia (since about CE 1985) converting thousands of paper-based data tables for a very wide range of uses into Spreadsheets and Databases. "***Productivities of Electronic Databases***"

By the late CE 1980s, most tech-savvy people involved with construction / engineering in Telecom Australia Commission had well-recognised the immense productivity that could be realised by transferring many thousands of their linen-paper technology maps to being geospatial electronic / computer assisted maps and use GPS technology for aligning new construction "As Built" directly into the new common national geospatial mapping database.

This transfer to electronic drafting process kicked off circa CE 1988 and took a few years to complete – and the productivities were immediately obvious! Gone were the problems of aligning edges of adjacent linen-paper maps as this as now conformal / continuous – and the mapping screen could be scaled by keyboard / mouse. No more physically redrawing worn out maps, and everybody worked to exactly the same electronic drawing standards using the one national geospatial mapping database!

District drafting could now be far more efficiently done by far less Drafting staff and covering a far larger physical Region (covering many Districts). As it turned out, Subscribers electromechanical metering was in the process of being transferred into electronic metering and slipping under the AXE digital electronic infrastructure. This extremely efficient (Competitive Business mindset) process literally wiped tens of thousands of clerical / accounting staff from District offices (i.e. out of Telecom Australia / Telstra and precipitated a national restructure of the remaining Telecom Australia / Telstra staff into physically large Regions and very few Districts within these Regions. "***Gigantic Productivity of Electronic Metering***"

Network Design and Planning (and Construction) took on a whole new dimension because now all this could be done electronically and location mistakes were rapidly being identified and corrected; dramatically reducing costly engineering rebuilds in the middle of projects.

By the late CE 1990s drafting / mapping was a totally different ball game, where one person could call up anywhere in Australia and see by the geospatial map exactly what Service Pits / Conduits / Cable etc. was recorded – and it can be edited!

Rationalising Carrier Maintenance

The technologies of Analogue/FDM Transmission equipment "***Massive Productivity of FDM***" are/were subtly different from electro-mechanical switching equipment. Transmission equipment had no moving parts, was considerably lower maintenance but required expensive test and measurement equipment to perform maintenance – where virtually all electromechanical switching equipment could be maintained / repaired with a basic set of pliers / spanners / screwdrivers etc.

Another issue was that there was a wide range of competing transmission equipment manufacturers in Australia (where there was basically only one switch manufacturer) and these competing businesses simply could not afford to have a maintenance centres. If they did, the contract price for carrier equipment maintenance would have been sky high – making their products totally uneconomic. ***This real-life competition situation flies directly against what is continually chanted by the economic priests.***

As a direct and practical economic maintenance rationalisation, each State had their own (State Capital City) centralised Carrier Maintenance Centre originally located in the back room of a main carrier terminal site. This arrangement minimised the amount of expensive test equipment, maximised the spare transmission equipment modules (in bulk) and maximised the availability of special spare parts – which in turn minimised repair times and facilitated high Quality maintenance procedures.

The rationale was that if and when a module of carrier equipment was identified as faulty (anywhere in the State), this module was sent to the Centre and the Centre also sent a properly serviced spare module to the location. The faulty module could be replaced by a good (recently maintenanced) module and have the Voiceband channels FDM system back on air in a minimum of time; and the faulty module could then be repaired and Quality tested and then put in store for another event.

This process really did not work all that well because many Technical staff in country areas habitually kept a spare module (for each model of equipment) in their local exchanges; in case there was a problem and do an "A-B" swap – and then only send down the faulty module – leaving the Repair Centre short of modules, and the State short of Voiceband circuits (and the network in continual network Congestion)!

This was a double-edged sword because the Planning Engineers were aloof that spare modules were being secretly kept in local exchange sites (usually in a steel filing cabinet), the Maintenance Centre were continually short of Modules so they could not always send out a replacement module unless the faulty one was first sent in and rush maintenanced; and the maintenance calibration / commissioning process was in most cases non-existent!

> *Circa CE 1985 the NSW Design Lab had (in a very rare instance) received a module from the NSW Carrier Centre that they could not repair, and these modules were critical to 24 channel FDM systems. The module ran very hot (and was a lousy circuit)! Inside a week we re-engineered a cool (highly reliable) direct replacement module with newer (far more economical and available) components. So we made a small production run of about 20 units and handed them over to the Carrier Centre.*
>
> *In Jan-1987 I was a (new) Senior Engineer in the (NSW) Long Line Support Section and I found out very quickly that this Section had a dynamic leadership (headed by Peter Barrett) that broke all the aged /*

traditional rules (and got things done)! They had recently set up their own (national) Email server and were actively connecting similar inter-State sections with this new facility and actively collaborating inter-State, to work as a National team instead of several separate competing centres.

The NSW Carrier Maintenance Centre (consisting of about 25 Technicians, then under a Tech Officer, Charlie Xerri) had been moved from the 4th floor 300 Pit St (behind the old City South exchange site) to 4th Floor Parkes St Parramatta and now had the necessary space to really organise itself. While at the new Centre, I realised that I knew several of the Technical staff from City South carrier (from many years before) – and they recognised me as a "Technical Officer" and not as a "Senior Engineer", and this made discussion topics "interesting"!

Having done many years telecoms equipment R&D in the NSW Design Laboratory, where I also set up and operated a practical Test Equipment Maintenance and Calibration facility; it didn't take me long to recognise there were a lot of major process problems that needed urgent addressing.

Their range of replacement components was a shambles, where in many cases commonly available reliable (inexpensive) components were not used – but (manufacturer's specified) rather expensive and in extremely short supply components were purchased and used. This centre had never had a practical experienced engineer manage its operations to substantially improve their processes and significantly improve reliability, and they were certainly not about to let this happen!

My suggestions were met with iron-hard refusal and it became very clear their process were heavily set! In email and phone discussions with our interstate equivalent engineers (something that had never been done before as these were strictly under separate State managements) it quickly became apparent that (using economy of scale and specialist areas) a National collaborative strategy would be far better than a passively competing State-based repair / maintenance strategy.

In CE mid-1987 we arranged a National Conference (in Sydney) that resolved to align State Carrier and Radio Maintenance Centres with particular manufacturers and rationalise replacement equipment to accelerate the reduction in brands / models and to move towards a single Transmission Maintenance Repair Centre (in Melbourne) – optimising on economy of scale with zero competition and maximum collaboration.

This proactive initiative to rationalise Carrier Equipment maintenance by State and Manufacturer introduced practical "Scale of Economy" maintenance processes that significantly reduced Competition, significantly reduced the number (and cost) of spare parts in inventories, facilitated engineer leading circuit design improvements in existing carrier equipment – that in turn significantly reduced transmission equipment faults and significantly improved network reliability (and customer satisfaction)!

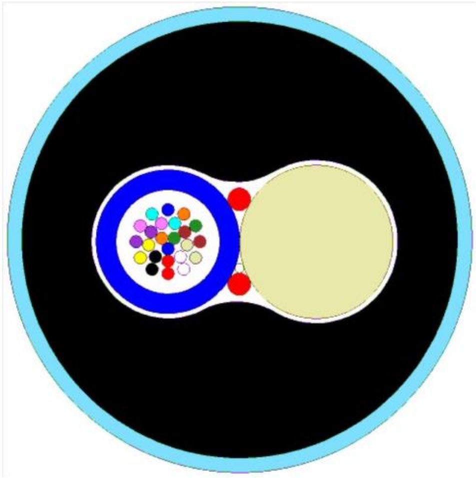
As the number of competing Brands were deliberately cut (and/or replaced by other Brands / Models of FDM Carrier Equipment or transferred to PDH technology) this not only significantly reduced Regional maintenance needs but this action also considerably increased equipment FDM reliability – while making the number of spare FDM modules far more available. "***Phasing out Long Line FDM Equipment***"

The Phenomenal Productivity of SMOF

After the blind panic in CE 1986/7 of rolling out the MEL-SYD Single Mode Optical Fibre route (almost 1000 km of cable) and getting it installed and commissioned ASAP to replace the critically failing high-capacity FDM Coax system; the technology of SMOF cable technology had now reached “Proof of Concept” development stage.

This installation process was a very steep learning curve as almost immediately the crews discovered that SMOF cable cannot be roughly dragged and strained like coax / pair / quad cable. It was common practice to treat pair copper cable much like a truck tow rope (which was fatal for SMOF cable) and a different process of ploughing / trenching involving the conception of “zero tension”. In reality the maximum tension that can be applied to a SMOF cable is about a person’s body weight!

My educated guess is that the structure of prototype SMOF cable was based around Multimode Optical Fibre (MMOF) cable (that had by then been around for about a decade) and it probably had a cross section much like the diagram on the right, where the fibres are nearly “loose” in a (neoprene) tube and there is a thick parallel “strainer” made from fibreglass filled plastic (that is virtually solid – like a knitting needle) and this is all surrounded by a relatively thick polyethylene protective “tube”!



The outside diameter of this prototype cable structure would be about 15 mm to 18 mm.

In reality, the diameter of the SMOF stands are literally human hair thin and the fibre can very easily (and very quickly) be created by drawing a stand from a crucible. The “trick” with the structure of SMOF is to have a low reflective index silica centre with a high reflective index outer layer – causing the light to be totally internally reflected down the central portion of the fibre with an extremely low optical loss.

It is this incredibly low optical loss (attenuation per unit length) that also makes SMOF so productive – because the optical signal can be sent over many km in distance, where in comparison twisted pair insulated copper or coaxial cable has a far greater loss over the same distance. Also the SMOF media is “bound” meaning that the signal is not radiated to (or absorbed from) external sources like it is with twisted pair or twisted quad copper wire, or point-to-point radio.

With insulated twisted 0.40 mm pair copper (as previously used in the Urban physical Access Network – this technology has a maximum length of about 4100 metres where the attenuation is about 6.5 dB and the maximum frequency if 3400 Hz (with considerably more attenuation by 3400 Hz than at 820 Hz).

With insulated twisted 0.40 mm pair copper (as previously used in the Urban physical Access Network for ADSL2+ (Broadband) – this technology has a maximum length of about 900 metres where the attenuation at 2.2 MHz is about 40 dB limiting the Broadband speed to 24 Mb/s and as the line length is extended, the 40 dB attenuation limit comes in well under 2.2 MHz – greatly limiting the downstream data speed. At the physical cable length limit (4100 metres), the downstream speed is reduced to only 4 Mb/s. “***Basics of ADSL and HFC Broadband***”

With insulated twisted 0.64 mm pair copper (as previously used in the intra-metro Junction Network and in the intra-District Transit Network – this technology required 2 Mb/s Regenerators at nominal 1830 metre spacings – because the signal was so severely attenuated. “***Massive Productivity of 2 Mb/s***”

With coaxial cable used or High Capacity long-haul FDM transmission (5 MHz maximum frequency) the FDM repeaters were spaced at nominally 8 km apart (and no further) because the attenuation of coaxial cable by 5 MHz was about 40 dB (i.e. about 5 dB per km). “***High Capacity Long Haul Transmission***”

With coaxial cable used or Pay TV transmission (350 MHz maximum) the in-line Amplifier/Equalisers were spaced at nominally 1.5 km apart (and no further) because the attenuation of coaxial cable by 350 MHz was about 40 dB (i.e. 27 dB per km).

With coaxial cable used or HFC TV transmission (1000 MHz maximum) the in-line Amplifier/Equalisers were spaced at nominally 500 m apart (and no further) because the attenuation of coaxial cable by 1000 MHz was about 20 dB (i.e. 40 dB per km). “***Basics of Pay TV and HFC Technologies***”

Much like a clear glass window where the full spectrum of human visible colours are effectively transparent, SMOF has a few spectral windows nominally around the 850 nm, 1330 nm and 1550 nm wavelengths (at least).

SMOF has a virtually flat frequency response and (with the development of a “graded” reflective index), the Group Delay is also virtually flat. Because the SMOF strands have very low loss total internal reflection the attenuation per unit length (at the allowable transmission frequencies) the attenuation per unit length is in the order of 0.23 dB to 0.43 dB per km. This transmission performance is typically an order or better (more productive) than the coax cable / wire technologies outlined above.

Not only is the attenuation particularly low, but the available bandwidth is incredibly wide - far exceeding that of coaxial cable.

Consider that a 10 km length of SMOF has a nominal attenuation of about 0.35 dB per km. For a nominal 30 dB attenuation this about 86 km meaning that with appropriate transmission terminal equipment, cable hops exceeding 80 km are quite common (with no regenerator equipment)!

On the downside, splicing a SMOF cable stand introduces an insertion loss of about 0.1 dB (equivalent to about 250 to 500 metres of SMOF cable). Even if the cable has to be spliced every say 2 km; to pass under roads / bridges etc. this raises the attenuation range to about 0.33 dB to 0.52 dB per km at the worst! This still comfortably spans over 60 km with less than 40 dB attenuation.

Also, the transmission can be a range of spectra (as in Wave Division Multiplex (WDM)) and the less expensive Coarse Wave Division Multiplex (CWDM) technologies. In these cases, multiple “colours” can be concurrently transmitted in the one fibre radically increasing the transmission capabilities of these fibres.

These fibres are really thin and all that is needed to make a 1000 km long fibre is about 200 ml of molten silica! My understanding is that the fibre can be drawn and clad at the rate of about 10 to 30 metres per second. Because water is a main impediment to transmission the fibre is clad with a fine polyethylene sleeve (much like that of insulated copper wire - only far thinner). This (clad) fibre is run onto a spool about 150 mm wide, 300 mm in outside diameter and 200 mm inside diameter, making manual handling very straight-forward.

This process is considerably faster than drawing and polyethylene cladding bare copper wire, and the weight is a tiny fraction of that of copper wire (for telecoms). As a direct consequence, the process for manufacturing SMOF cable is considerably faster (and far less costly / more economic) than that for manufacturing insulated twisted pair / quad copper cable, and orders of magnitude more economic than manufacturing coaxial cable tubes – let alone coaxial cables!

There are two fundamentally different structures of SMOF cable (other than armour-plated) that are commonly buried to minimise cable damage (and avoid cluttering the streets / roadsides with the eyesore of pole strung up SMOF cables).

In urban areas (where the cable is in an underground conduit – or direct buried in a smooth-based trench) the sheath and strainer(s) are generally not that thick. But in (most non-urban) situations where the cable is directly “ploughed” into the ground – usually by a rather deep (typically 1200 mm) single tyne blade with a trailing cable feeder – the cable for this has a substantially thicker sheath and strainer(s) to cope with ground movement and an uneven “floor” when and after the cable is laid.

Trenching in a cable provides a far more stable “floor” so the cable sheath does not need to be as thick (so the cable can be marginally cheaper) – but Trenching is horrendously slow and costly – and is only practical / economic near buildings for short runs of less than 100 metres.

The picture on the right depicts the cross section of a SMOF cable (suitable for direct ploughing) where there are up to six neoprene tubes each capable of 12 fibres (in a ‘gel’), making a total of 72 fibres in this instance. This cable is nominally about 15 mm in diameter and weighs about 175 kg/km.

A similar construction cable with a thicker central strainer can support up to 144 SMOF strands, has an outside diameter of 23 mm and weighs about 395 kg/km.

In broad figures (depending on the economy of scale) the cost of a SMOF strand is about $0.02 per metre or about $ 20.00 per km, and generally the sheath is by far the biggest cost! This is in almost exact reverse to that of insulated pair/quad copper cable technology where the copper wire is a very substantial part of the cable cost.

In its component parts, the cost of the single mode fibre strands is a small fraction of the cost of the SMOF cable as the sheath and strainers are far more expensive per unit length! That aside, ploughing in a cable (SMOF or otherwise) costs about $30,000 per km, which is far more than the SMOF cable!

Most SMOF cables for the Metro Junction Network and the Regional Transit Network (circa CE 1987 – CE 1994) had only 6 fibres (and would have cost about $1,000 per km) and some main route cables had 12 fibres (and would cost about $1,240 per km). For a fractional cost more, these cables could have had 36 fibres (with a different internal sheath structure) for about twice the cost (about $2,400 per km), or 72 fibres (about $3,600 per km) and still this would have been considerably less expensive than say a 4 pair copper cable (about $4,000 per km).

Competition Wrecked Australia's SMOF Rollout

With the MEL-SYD coaxial cable link completely replaced by very recent rush-released "Prototype" / "Proof of Concept" SMOF cable (consisting of 31 fibres), Telecom Engineers were now breathing a sigh of relief as the new PDH transmission system kicked in and the Voiceband and Data circuits were quickly transferred over from the ailing high capacity (and very high maintenance) FDM transmission system circa late CE 1987. "***The Sudden Emergence of SMOF***"

> *As a Class 1 Engineer in March-April CE 1986, I had been "tasked" to design the proposed new Melbourne – Sydney highly mythical "SMOF network and wayside stations". (SMOF was a very advanced transmission medium that TRL engineers were seriously working on making this practical. Unfortunately, SMOF technology had gone nowhere to oblivion since CE 1974 and my "task" was intended to keep me very occupied.*
>
> *While I was highly aware about the very aging high-capacity Voiceband FDM systems on this 7-tube coaxial cable; I was also highly aware that there were other substantial data connectivity requirements (e.g. from NASA and Universities) that were using FDM (at the Group level – i.e. 48 kHz bands). I was also very aware of the pressing needs for other digital connections that simply could not be serviced by FDM technology.*
>
> *The problem for me at that time was that the Engineers were entrenched in (analogue) telephone traffic measurements, and data connectivity really did not rate a mention of this as part of their "planning vision".*
>
> *When I summed up the telephony requirements this filled up more than half the proposed PDH bandwidths and when I added Video this filled most of the remaining space leaving a tight amount for Data that I could see that within in a few years this network would be seriously congested.*
>
> *My suggestion to significantly increase the then strictly laid down "set in concrete" 31 fibres in the proposed SMOF cable up to a nominal 64 fibres was met with a stiff rebuke and I had no option but to follow the pre-set equipment "guidelines" and fit the existing network into the proposed PDH equipment – that was already engineered around a pair of parallel coaxial cables to replace the existing aged coaxial cable (hence the 30 +1 fibres).*
>
> *Effectively – there was no "forward network planning" outside telephony and when the SMOF based PDH transmission system was installed and commissioned by November CE 1987 it was already at full capacity.*

The "Competitive Business / Recession" mindset of having the minimum cost, minimum capacity long-haul PDH-based transmission system was in my opinion very backward strategy. Literally overnight, maintenance requirements on the new SMOF-based long-haul PDH transmission system network between Melbourne and Sydney plummeted to virtually zero. This transmission network operated in virtual full capacity from day one in November CE 1987 and the immediate pressure was off.

When underground cable replaced open wire technology in the metropolitan areas (State Capital Cities and their Suburbs) in the CE 1930s, this engineering was done in an Infrastructure Business mindset with long term planning to cover many decades of growth. The stark realisation was that rodding and roping in additional Junction cables into pre-existing Service Pits and Conduits was an expensive process and considerable (long term) savings could be made by deliberately over-planning and provisioning for considerable growth in the next decade (or two).

From about CE 1983 the metro inter-exchange digital Junction network started to suffer a quickly increasing number of intermittent 2 Mb/s network dropout issues caused by the intermittent failing of 2 Mb/s Regenerators along the 50 (or occasionally 100 pair) Junction Cables between the exchange sites, and ill-fitting 1.6/5.6 mm coaxial connectors (on the Intermediate Distribution Frames – IDFs and associated equipment). By CE 1986 this situation had reached a real crisis. "***Competition Wrecked Australia's 2 Mb/s***"

Recognising the obvious success of the Melbourne – Sydney SMOF cable PDH transmission system it was a no-brainer to remove the very aged pair copper metro Junction Cables and use SMOF cables as the new Junction Bearers. "***Rebuilding the Junction and Access Network***"

As most Junction Cables had 50 pairs (i.e. 50 bi-directional Voiceband circuits) and a 2 Mb/s PDH transmission system has 30 Voiceband channels – and two copper pairs were being used for 2 Mb/s (i.e. 30 digital Voiceband channels) – so there were 30 or 60 or 90 or 120 Voiceband channels available on (multiple) 2 Mb/s on two pairs (of pair copper). "***Massive Productivity of 2 Mb/s***"

You would think that the standard economic practice would have been to maximise the number of (inexpensive) fibres in the new SMOF (Junction) cables to replace the pair copper Junction Cables. Instead, with the domineering frugality "Recession / Competitive Business" mindset; a minimum of fibres were used everywhere.

From what I could tell some years later it seems that most SMOF Junction Cables were either 6-fibre (allowing a maximum of 90 digital Voiceband channels) or 12-fibre (allowing a maximum of 180 Voiceband channels).

In practice it seems that in most situations one or two fibre pairs were used on the new 6-fibre Junction cables providing 30 or 60 digital Voiceband channels - equivalent to 50 pair (Loaded) Junction Cables; and on 12 fibre Junction cables it was common to use three or four fibre pairs on the 12-fibre cables providing 90 or 120 digital Voiceband channels - equivalent to 100 pair (Loaded) Junction Cables.

Although the transmission rate was only 2 Mb/s this was not seen as a criminal underuse of SMOF transmission capability, as the technology of the day using 2 Mb/s on SMOF was inexpensive and readily available – and it did not require any Regenerators (in fact it required optical attenuations in most cases)!

There was an economic advantage in using 2 Mb/s PDH in that the T / Loop Mux family of transmission equipment was a comfortable fit (with a 2 Mb/s PDH optical interface) and this equipment arrangement politely sidestepped the awful network dropout situation that had developed from having faulty 2 Mb/s PDH pair copper regenerators and flawed 1.6/5.6 mm coaxial connectors! "***Competition Wrecked Australia's 2 Mb/s***"

With pair / quad copper and coax cables the cost of the conductors usually well exceeded the cost of the cable sheath – but the standard frugal ("Competitive Business" practice was to keep count of conductors limited to keep the overall cost down to a minimum. With SMOF cable technology the cost of the sheath (and strainer) usually far exceeds that of the fibres!

Where it would have been fractionally more expensive to rod and rope 36 strand SMOF cable, the standard approach was to purchase and roll out 6 fibre cable in most cases and 12 fibre SMOF cable in “extenuating instances”! Both 6-fibre and 12-fibre SMOF cables (for trenching / conduits) have exactly the same sheath structure (and the price per unit length is almost the same)!

In bulk, the cost of 6-strand SMOF cable would have been about $1.00 per metre and for 12-strand SMOF this would have been about $1.24 per metre (about 24% more expensive). A 36 strand SMOF cable would have a significantly larger sheath / strainer and in bulk (economy of scale) would probably cost about $2.40 per km and this same cable structure with say 72 fibres would (in bulk) cost about $3.60 per metre. “***The Phenomenal Productivity of SMOF***”

Considering the considerable amount of manual labour involved to rod and rope SMOF cables through Service Pits and Conduits – this would be at least $5.00 per metre (if not significantly higher).

So, conservatively, a 6-fibre cable would cost about $6,000 per km to rod and rope (including the cable cost); a 12 fibre SMOF cable would cost about $6,240 per km to rod and rope (including the cable cost) and a 36 fibre SMOF cable would cost about $7,400 per km to rod and rope (including the cable cost)!

In other words, for a small increase in the overall project cost (i.e. about $7,400 / $6,000 = 23% more) the number of fibres could have been inexpensively increased by about 36 / 6 = 600% This simple “Infrastructure Business” mindset planning would have set up the metropolitan networks for future growth for the next 20 plus years (at least).

The problem was that Telecom Australia was being set up to be floated on the Australian Stock Exchange (ASX) and it was all important to have a positive account arrangement to maximise shareholder value and shareholder dividends (which are in fact opportunity cost to forward planed (and implemented) infrastructure)! “***Infrastructure Business and Competitive Business***”

Instead of rolling out 36 fibre SMOF cables as the new digital Junction Network (as per the “Infrastructure Business” mindset), the decision was to roll out minimum 6 (or 12 strand) SMOF cables wherever possible (as per the Competitive / Recession Business mindset). By about CE 1996 almost all the “dark” (vacant) fibre pairs were utilised and there were no spare for Internet and Mobile Radio Base Stations.

With the SMOF metro Junction Cable rollout completed by about CE 1990 there were still a continual number of network dropouts in the Regional areas but this was a subtly different scenario. Telecom Australia was now (forced) Privatised and was now a Corporation (not a sub-Department Commission) now answering a different Board and about to be providing maximised Shareholder dividends and minimised infrastructure for now and future.

With Telecom Australia Commission privatised in accordance with the Davidson Report to Telecom Australia Corporation (Telstra) in CE 1989, the focus abruptly changed from maximum benefit for the Australian economy to maximum short term return on investment (ROI) for shareholders (at massive expense to the Australian economy – particularly outside the metropolitan areas). This Report floated the concept of a Universal Services Obligation (USO) that was in-effect a windfall of $177 M pa indexed to the CPI to in-effect keep the non-metropolitan telecom

Infrastructure Business (coined as a "Cost Centre") operating at a perpetual loss. "***The Davidson Inquiry and Report***"

It seems that the USO was primarily included to facilitate completing the HCRC infrastructure, but that was complete by CE 1985 (well before the commission was privatised). With Telstra restructuring its Business Units in CE 1991 this HCRC infrastructure was effectively hidden from external accountancy and the USO kept rolling in – providing the Regions in the new Country Division Business Unit kept making annual losses (i.e. a "Cost Centre")! "***HCRC in Remote Australia***"

Traditionally, Consumers were not "profitable" and Regional Consumers were definitely not profitable – so there was real reluctance in providing any improvement to the Regional areas – especially as this would cost money and that would detract from executive renumeration and Shareholder Dividends.

Still, the sale of removed metro Junction Cable had more than covered the cost of the metro Junction SMOF cable programme. So why was 36 strand SMOF cable not used) and the Davidson Report had initiated the $177 M pa to support "telephone" (telecoms) services in the Regional areas?

There was very little reason to not proceed with rolling out SMOF Regional Transit cable to re-connect Small Towns and Villages to the District / Regional Cities and get rid of these incessant network dropouts on 2 Mb/s over pair copper!

In almost all cases the maximum size Transit cable was 50 pairs and in most cases these cables had one or two 2 Mb/s Loop Mux equipment connected at one or both ends of the cable – typically using only two or four pairs out of 50 pairs!

Unfortunately the "Competitive Business / Recession" mindset prevailed and most SMOF cables in the Regional Transit network had only 6 fibres which in a few years turned out to be the worst economic and engineering practice for Australia! "***Competition Manifested Australia's Radio Black Spots***"

Engineers in the (new) National Network Business Unit had little option but to roll out a minimum expense (and minimum fibre) SMOF backhaul network overlaying the existing aged loaded cable / FDM network (that was ploughed in during the CE 1950 – 1970s). "***Rebuilding the Regional Transit Network***"

This SMOF cable rollout process continued until about CE 1992 when it all came to a very abrupt halt as the new focus was on fierce competition to rush install the Hybrid Fibre Coax (HFC) Pay TV infrastructure. "***Competition Wrecked Australia's HFC***"

This was a very different economic story because these SMOF cables had to be directly ploughed in nominally 1200 mm below the prevailing ground surface to minimise incidental cable damage. This ploughing alone was / is an energy intensive process that typically costs in the order of $25,000 per km and the SMOF cable sheath and strainer needs to be considerably thicker (more expensive) to minimise underground torsion and stretching (that is common with ploughed in cables).

Consider that a 6-fibre SMOF cable for ploughing costs say $2.20 per metre and a 36-fibre SMOF cable for ploughing costs say $3.60 per metre. When the ploughing / man-hour costs are included this works out at about $27,200 per km for a 6 fibre cable and $28,600 for a 36 fibre cable.

Put in percentages, the ploughed in 36-fibre cable costs about 5.1% more than the 6-fibre SMOF cable to be purchased and ploughed in – but there wold have been 30 spare fibres for a wide range of other purposes like providing FTTHomestead connectivity to Farming and Grazing properties, multiple 3G/4G/5G Radio Base Stations along main roads, and the provision of inland alternate high capacity backbones that can bypass major metro cities!

> *Several years later (circa CE 1995) I became highly aware that Optus had its own high capacity cable between Melbourne and Sydney and then I found that it was common practice to collaboratively "share" the traffic load between Telstra and Optus.*
>
> *The reason was (is?) that at times of the day or whatever either Optus or Telstra had network congestion between Melbourne and Sydney – the competing carrier (I was very reliably informed – by Bill Mottee – whom I worked with for several years and who had since re-established his career in Optus), simply made their extra capacity available on a "quid-pro-quo" basis – basically word of mouth!*

This was an extremely interesting observation because although these two carriers were "competing" against each other (on the outside) they were / are closely "collaborating" with each other (on the inside) – to make competition look as though it is working – and keep the ACCC / PC away from enforcing competition – which has immense overheads and real competition would have wrecked both of these highly lucrative "competitive" businesses arrangements! This was a classic working example of "The Theory of the Second Best" (Lipsey / Livingstone – CE 1956)

Costing the Mel-Sys SMOF Link

Considering that most Regional Rural Australian towns and cities are based on the changeover distance of Cobb & Co Stage Coach horses of about 25 miles (40 km) it also follows that this is where most of the Post Offices (and telephone exchanges) were located. With hilly terrain the distances are shorter (30 km)!

The Mel - Syd (Old Highway) distance (including Canberra) distance is about 980 km and assuming about 55 km between main inland wayside cities this is about 16 plus the origin site making 17 stations. The FDM coax cable repeater sites are spaced at nominally 8 km, meaning there are about 110 locations or about 93 locations not counting major stations on the way.

Now, this then (CE 1986/7) high capacity SMOF link cost about $45 M and there were no regenerators outside the main inland “wayside” cites that were fitted out with new technology PDH equipment.

Considering there were 7 * 545 Mb/s and 8 * 140 Mb/s PDH transmission systems each using a pair for fibres for unidirectional transmission plus one fibre in case of breakages this, totalled 31 fibres. In round figures each of these 17 transmission systems cost about $50,000, or about $0.75 M per site; or about $13 M for the 17 sites, leaving about $32 M. My educated guess is the cable cost was between $3 and $4 per metre (say $3.50 per metre) or about $3.5 M, leaving about $28.5M. This works out at about $28,500 per km for the cable and trenching, so everything “fits”!

If SMOF technology had not been discovered at that time then this route would have had to use far more expensive coaxial cable - and include regenerators every 8 km.

Now, the “new original design” was made for **a pair** of 7-tube coaxial cables and each would be thicker than your forearm (about 80 mm OD) and would have cost at least $40/metre (that is $80/metre for two cables and therefore over $76 M just for the cable. The trenching costs would have been in the order of at least $33,000 per km or about $33 M because these cables would have required (expensive and time-consuming) jointing at nominally 500 m (as the length per drum is rather limited).

There are 17 transmission terminals on the route and the cost of these would have been on par with the SMOF strategy at about $50,000 each, or about $0.75 M per site; or about $13 M for the 17 sites.

The Regenerators (spaced at 8 km) would cost about $7,000 each and considering 15 regenerators at each of the 97 existing repeater huts – this comes out at about 1455 Regenerators or about $10.2 M.

Totalling all this up this comes to about $13.0 M (for terminal equipment), $10.2 M for Regenerators, $76 M for the Coax Cable, and about $33 M for the trenching; totalling about $131 M. So the SMOF solution ($45M) came in at about 34% the cost of the Coax Cable solution!

Productivity with this new SMOF technology is about 190% over Coax cable!

With this major SMOF transmission link in place and with no maintenance overhead the cost of telephone calls between Melbourne and Sydney were (internally) no more expensive than the cost of “local” calls!

Compounding this situation was that PDH over point-to-point Radio technology had a fundamental problem in that because of Group Delay issues (where different frequencies in the pass band are (were) unequally delayed) causing the receive constellation to be tilted/warped – which dramatically reduced the transmission capability. Considerable intricate (and expensive) re-engineering was essential so that these existing radio systems could be used for PDH transmission!

It was an absolute no-brainer to prioritise the replacement of existing long-haul point-to-point radio links and other coax cable links (all using FDM technology) with SMOF cables using PDH technology. This rollout started in about 1989 and continued through until the end of 1993 – when it abruptly stopped (and the focus rapidly moved to the fiercely competitive Cable Pay TV infrastructure, and mobile phones).

With PDH technology a 2 Mb/s stream (E1) can carry 30 Voiceband channels and the PDH hierarchy works up as "times 4" at each level. So an E2 (8 Mb/s) can carry 4 * 30 = 120 Voiceband channels, an E3 (68 Mb/s) can carry 4 * 120 = 480 Voiceband Channels, an E4 (140 Mb/s) can carry 4 * 480 = 2400 Voiceband channels and an E5 (545 Mb/s) can carry 4 * 2400 = 9600 Voiceband Channels.

So
7 * E5 = 7 * 9600 = 67,200 Voiceband Channels and
8 * E4 = 8 * 2400 = 19,200 Voiceband Channels

Consider that the E5s go straight through from Melbourne to Sydney and the E4s are for Wayside connections (including Canberra) – so discounting those that is 67,200 Voiceband channels for $45 M or about $670 per Voiceband channel (and this is conservative)!

Technology	Circuit Count	Build Cost	Voiceband Cost	Time – Era
Open Wire	16	$233.7 M	$14.60 M	1880-1895
Phantom	31	$234.5 M	$7.56 M	1895-1915
Amplified	16	$240.0 M	$15.00 M	1905-1915
Amplified (Phantom)	31	$240.0 M	$7.74 M	1905-1915
Amplified (thin wire)	16	$130.0 M	$8.13 M	1915-1953
Amplified (Phantom)	31	$130.0 M	$4.19 M	1915-1953
FDM (thick open wire)	96	$254.0 M	$2.64 M	1953-1974
FDM (thin open wire)	96	$148.5 M	$1.55 M	1954-1974
FDM (Coax)	960	$91.92 M	$95.75 k	1961-1987
FDM (Coax)	1920	$96.64 M	$50.33 k	1961-1987
FDM (Coax)	2880	$101.36 M	$35.19 k	1961-1987
FDM (p-p Radio)	960	$105.00 M	$109.34 k	1959-1990
FDM (p-p Radio)	1920	$168.00 M	$87.50 k	1959-1990
FDM (p-p Radio)	2880	$231.00 M	$80.20 k	1959-1990
PDH (Dual Coax)	1920	$131.00 M	$68.23 k	1986-1987
PDH (SMOF)	1920	$45.00 M	$23.40 k	1987-1993

Amazing Productivities of CCS7

The earlier electromechanical telephony switches (and Manual Sylvester Switchboards) technologies inherently used Channel Associated Signalling (CAS) to manage the call route connection / disconnection. The earlier Loaded Cable transmission technology and more recent Frequency Division Multiplex (FDM) medium/long-haul transmission systems also used CAS.

As already outlined, the introduction of LM Ericsson AXE digital (telephony) switches brought with it an immense amount of technology associated productivity that dramatically reduced operational overhead (technical and engineering staff – and clerical) costs. This immense economic productivity boost also had absolutely zero to do with competition and everything to do with "building a better mousetrap" (continuous improvement)! "***Transitioning to the Digital Network***"

Also as earlier outlined, virtually all the electromechanical (Crossbar and SxS) switching equipment had their subscriber's mechanical metering circuitry very inexpensively electronically interfaced into the AXE digital switch technology processors. Special computer programming in these AXE processors electronically "managed" these external metering signals in electronic form – that could be recognised, processed and stored then processed far more efficiently than could be previously be manually done. "***Gigantic Productivity of Electronic Metering***"

The impact of this massive advancement in productivity was that tens of thousands of clerical staff that manually did metering were no longer needed as the metering could then be stored and transferred electronically – wiping off millions of annual man-hours in background clerical book-keeping, office space etc..

In Competitive Business terms, the business efficiencies introduced in the processes of call metering / charging / billing were absolutely enormous as customer billing started to get (nationally) centralised with relatively few staff, and with process errors virtually eliminated.

The massive savings gained from this immense technology leap largely went totally unnoticed – because almost concurrently Telstra / Optus etc. then spent (wasted) massive amounts of financial resources on advertising / marketing and sponsoring.

With a standard 2 Mb/s link there are 30 Voiceband/Data (64 kb/s) channels, a timing Synchronisation channel (64 kb/s) and a Signalling (64 kb/s) channel – making up 2048 kb/s (2.048 Mb/s). Now – this Signalling Channel very easily manages the signalling associated with the 30 channels on this 2 Mb/s link – but the signalling is separated at each end of the transmission link, so that each of the 64 kb/s Voiceband/Data channels has their own Channel Associated Signalling (CAS) shared on one allocated 64 kb/s channel! *Keep with me…*

Internally, the 2 Mb/s link has very simplistic Common Channel Signalling (CCS) and the (common) signalling (at 64 kb/s) on this 2 Mb/s link is extremely underutilised (and that is a really huge understatement)! Engineers took this concept and saw that most digital switches (usually) had several 2 Mb/s links between them and the signalling channels were usually (very / extremely) under-utilised.

So the Engineers conceived a better way to utilise the network by moving all the (network) signalling to one or a few 2 Mb/s links and change the remaining 2 Mb/s links to each have 31 instead of 30 Voiceband/Data channels (and 1 Synch channel). As if these two technology-based productivity leaps of digital switching along with digital subscriber metering were not enough, circa CE 1983 the concept of Common Channel Signalling (CCS) was introduced through AXE digital exchange also started!

Common Channel Signalling (CCS7) is effectively all the circuit switch controls (that was literally Channel Associated Signalling (CAS)) plus connection details (e.g. “A” Number, “B” Number, Connection time of day, Disconnection time of day, Local or Distance connection, Number of available circuits, etc. and this was for thousands of connections – all transferred over a few dedicated 2 Mb/s data links between the digital switch processors.

This sea of data gave the processors a chance to analyse what was really going on and from that the switching network had some inbuilt intelligence to make “management” decisions so that the network did not run in congestion as it would have done so without this added data from the common signalling.

Because this Metadata was “common” it could be utilised on the fly (by the software in the digital exchanges) and self-identify if a particular route is out of service – and re-direct calls via another transmission route – and tell the other switches to avoid a particular broken transmission route, etc.

Because this (common) signalling communications channel between digital exchanges was there; the use of this common signalling channel was quickly expanded beyond the simple connect / disconnect various (digital) Voiceband paths to include the facilities / abilities to:

- Connect / manage / store / transfer “subscribers” call metering data, so that the metering process could become virtually fully automated.
- Re-route calls based on Switch / Router traffic density, so that the chances of call failure because of network congestion are minimised.
- Text (Small Message Signalling (SMS)) between Mobile telephone numbers, so that customers can “Text” between each other (and elsewhere).
- Divert the path of a live call if the forward path is getting congested, so that the chances of live call dropping out are minimised.
- Divert the call to another number (and/also to/from a 13xxxx etc. number to a range of geographically diverse numbers depending on the time of day)
- Transfer the caller to a Recorded Voice Announcement and facilitate interactive Voice Recording – e.g. if the called number is busy / did not answer.
- Depending on relative radio field strength from Radio Base Stations; to transfer/switch a live call path from one Radio Base Station to another Radio Base Station (*an Australian Telecom / Ericsson innovation*)!

This is by no means the full list of facilities, but CCS went through several iterations before settling as version 7 as (CCS7). With CCS7, all the switch route signalling for hundreds of thousands of telephone call connections and all the associated Metadata was transceived over a pair of 2 Mb/s PDH links between these digital exchanges.

The widespread introduction of CCS7 technology went through without so much as a mention in any newspaper or (technical) magazine (except the Telecom Australia Research Journal). Even internally this technology was fairly quietly introduced – mainly because most people were literally clueless of the power of this new CCS7 technology and the immense productivity that came with it and followed though behind it as it became more widely promulgated through the inter-exchange network.

One of the massively productive outcomes was the “Record a Message” process – where person would have dialled a number that was not being answered. Before CCS7, the process held switching and transmission equipment through to the distant end – so other callers can’t use that equipment. If after 40 seconds the call is not answered the call drops out and the caller received Number Unobtainable (NU) Tone.

With CCS7, a signal is sent through to the distant end to start ringing – but not lock up a switched Voiceband circuit until the call is answered – so the switched network equipment is temporarily available for others to use.

If after 30 (or 20) seconds the called number is not answered, the call is diverted by CCS7 signalling to a Recorded Voice Announcement (RVA) – and the calling customer is charged for the call to the RVA.

The caller leaves a message on the RVA that then uses the CCS7 to change the Dial Tone on the called customers’ line so that when they pick up the phone they get the different dial tone – to dial 101 (the RVA).

The called customer then dials 101 (and is also charged for that call) which uses CCS7 to direct the call to their RVA allocation – which then uses CCS7 to now direct their call from the RVA message back to the initial calling customer (and charge the called customer)! That is three call charges for what would otherwise be a temporarily held up network circuit! That is massive (commercial) productivity – and the called number is in the “information loop”!

With Mobile Phones / Pagers the introduction of CCS7 was the catalyst (along with a very low maintenance low cost radio network infrastructure – particularly in urban metropolitan areas) that made this technology the darlings of Sales and Marketing executives as their pay was/is directly associated to sales volumes (and upselling).

Mobile Devices (Phones, Pagers, Laptops etc.) periodically send out a (strong) recognition signal that the nearby mobile (network) Radio Base Stations (RBSs) hear and time stamp so that the devices location can be triangulated and identified. The inter-switch signalling for this is/was done through CCS7.

The RBS with the strongest signal then takes connection control of the mobile device. If another RBS has a stronger reception – then CCS7 is used between the exchange switches and RBSs to swap control connection of the mobile device to the stronger receiving RBS – so in theory the call should not drop out!

> *In CE 1988 I joined Telecom’s NSW Network Investigation team of technical and engineering gurus – initially to identify and remedy a wide range of intractable Voiceband problems that were plaguing the NSW (and national) telecoms inter-exchange network, causing an unacceptable volume of Customer complaints that could not be resolved.*
>
> *A large part of identifying and rectifying network faults involves end-to-end switched circuit identification. The call tracing process could take hours and often involved calling technical staff in other exchange sites (if they were there and available) to assist to localise the problem. The chances of actually identifying these problems were rare (and time consuming). So the overhead costs of this call fault finding were very high and often not rewarding! There had to be far a more productive methodology (better mousetrap) – because locating the faulty circuits was almost impossible!*

With the introduction of electronic (digital) telephone switches circa CE 1981, by CE 1985, the inter-exchange network signalling had advanced from channel associated signalling (CAS) to CCS7. Without the proper supporting software it was literally impossible to trace a call through an electronic switch. (In the early CE 1980s, about the only available (portable) operating systems were on DR-DOS and later on MS-DOS)

Circa CE 1988, Network Investigations specialists (Paul Merefield and Robert McIntyre and Paul Middleditch) in Brisbane had figured out how to physically monitor CCS7 and re-transmit this Metadata from several exchange sites to their office location and store this data on the fly. The Melbourne NI team also chimed in with data storage strategies and collaboratively they collated the "confetti of CCS7 data bursts" into practical and meaningful <u>millisecond</u> timestamped network data. Working together, they succeeded!

This external CCS7 monitoring and analysis technology was by far a world's first and it not only provided the A and B numbers and which switches they connected through in each location; but also narrowed down as to physically where the end users were and how they were connected (Mobile / Fixed etc.), how long / time of day / date etc.!

Instead of tracing maybe two or four calls per day, this equipment (considerably made from circa CE 1988 era Personal Computers) could track in fine detail upwards of 30,000,000 calls per 24 hours. The data was stored on Hard Disk Drives (HDDs) and dumped onto CDs overnight.
*"**Productivities of Electronic Databases**"*

Even though we were using Linux and SQL to assist with the data analysis the software tools we were using were no match for the avalanches of data that we had pouring into our offices.

One evening while watching the "news" there was a "highlight" (if you could call it that) incidentally advertising a visual data analysis package called "NetMap" and I immediately visualised how we could package our immense volumes of data to be displayed / associated / linked and sieved.

The following morning I went to the NetMap office in St Leonards (in Sydney) to see John Galloway (who was the brains behind these circle and association visualisations) and how we could use this NetMap software for our CCS7 analysis / processing! It took a few weeks before his team could write some interfacing software – but the results (even with very limited data) were absolutely astounding – and extremely fast.

The NetMap software was a "perfect fit" for our correlated CCS7 data and it didn't take that much to align the NetMap filtering stages to with the tidal waves of correlated CCS7 call data and get thousands of call data records on a screen and then use the visual tools within NetMap to very quickly home in "interesting" data and then display this data in far more detail.

We could "see" call patterns between areas, short held calls, calls that dropped out just under the time limit and re-establishing, where and when mobile phones dropped out (and the Base Station that it dropped out from) and the re-established connection with another Radio Base Station.

Another NetMap "tool" was its ability to pick a (telephone) number and display all the callers and the called numbers by count and density over a certain time period. Taking this further this NetMap software facilitated a relational algorithm that could be stretched out to a nominal maximum of seven serial contacts to find group associations.

Even with only three or four serial common contacts it was very straightforward for NetMap software to visually to identify a business and associated business people – even criminal gangs and their "honest associates" – and provide the (mobile) phone numbers plus the geographical addresses of where the phones are!

Because Network Investigations was intricately involved with criminal records, I introduced the NetMap software to the NSW State Police and soon after to the Federal Police. They were astounded but were stuck in their personal notes process that was not collaborative, hence it took several months before they recognised the immense value of the virtually free detailed call data – and they passed this technology to the CIA (USA).

As Telstra was now a corporation with a very strong private sector mindset. The word "collaboration" was way out and "competition" was entrenched. Telstra executives wanted to "charge like wounded bulls" for providing this readily available and very inexpensive data. Clearly Telstra being a competitive (service) provider did not put Australia first!

Another piece of highly advanced monitoring equipment came from Australia's Overseas Telecoms Corp (OTC) that monitored and analysed 5-second samples of Voiceband/Data in 2 Mb/s streams. Correlating this data provided thousands of connections per day that had Voiceband transmission problems – that could then be proactively resolved!

Internally, the engineers and technical staff on this very advanced CCS7 monitoring and analysis project collectively had an Infrastructure Business mindset and the information sourced and promulgated from this CCS7 monitoring system was openly shared to provide a range of live network measurement / analysis tools to weed out deep-seated network problems and resolve network issues that were previously impossible to resolve – and/or never previously recognised!

The immense productivity introduced with the introduction and widespread promulgation of CCS7 technology in the mid CE-1980s and through the CE-1990s was largely not seen because there were (in my opinion – totally unnecessary) immense costs of marketing and advertising / sponsoring flowing on from privatisation of Telecom Australia to Telstra that seriously diverted funding from future-proofing Australia's technology advancements into Broadband connectivity.

CCS7 had many "user parts" in it for a range of various functionalities (telephone switching, metering, mobile connection, traffic density, switch health etc.), like a simplistic "markup language". CCS7 was effectively "data chunks" that in virtually all respects virtually identified as 2 Mb/s streams in PDH but not quite as ATM!

CCS7 became the signalling technology bridge between long held call PDH transmission connections and short held call data – like metering, switch activity, route congestion etc. and it really found itself talking more with Data Routers and Data Switches than talking with the physical side of telephony switches - and this is where the CCS7 started to morph into Session Internet Protocol (SIP) by about CE 2002 and where GSM technology merged.

This transfer to morph from CCS7 to SIP was not an overnight phenomenon and a major part of the technology morphing secret was the upgrading of the Network Routers so they had a wealth more functionality where everything started to get IP addresses instead of physical addresses. The concept of a "cloud" connection started to become a conceptual reality where the "other end" was more likely an email server or a Web host / server.

With technology advances circa CE 2000 in digital Voiceband transmission moving towards Voice on Internet Protocol (VoIP), CCS7 morphed itself to become Session Internet Protocol (SIP) and found itself a perfect partner for VoIP. "***Astounding Productivity of VoIP***"

Wiping out Voiceband Complaints

The economic efficiencies that came in the CE 1980s with the introduction and wide rollout of digital switching technologies (LM Ericsson AXE 101, 102, 104, Loop Mux, T Mux, Pair Gain Systems, ISDN PABXs) plus the economic efficiencies that came with digital (PDH) transmission over pair copper and then SMOF were nothing short of astounding, but it took until the early CE 1990s before these economic effects really showed up and the overhead costs avalanched through the CE 1990s.

Quite paradoxically even though almost all these technologies involved Voiceband transmission there were very few Engineers that had any in-depth lived experience relating to Voiceband technology. Compounding this problem, in most cases – what had been incorrectly taught without question for many decades (at least from the CE 1930s) that pair cable was 600 ohms characteristic impedance and this misleading teaching came back to bite in a big way by the mid CE 1980s.

Compounding these problems, the PMG / Telecom Australia had been in ignorant competition against each other as they were operating under State management from well before CE 1900 with virtually no national control / guidance / agreement that comes with collaboration and sensible agreed operating standards that are proactively implemented – without the need for Quality "compliance".

About the only common agreement was that the "line-up" level from the Main Distribution Frame (MDF) going into the Inter-Exchange Equipment / Network (IEN) was based on "0 dBm / 600 ohms" and even then there was a quite dispute that this was the wrong place, and the wrong (power) level. More on that later!

For most Senior Engineers / General Managers / Executives covertly avoided discussions regarding Voiceband levels and impedances (because they didn't want look to be ignorant) and in reality the (business) focus was really on the number of telephones connected, and the minimisation of customer complaints!

By the mid CE 1980s throughout all Australia, the Voiceband operating impedances and alignment levels were a thorough mess causing a very high number of persistent and unresolved customer complaints.

When Sylvester Switchboards were installed and commissioned (from before CE 1900) there was virtually no (practically available) level measuring equipment and the Voiceband transmission system sort of worked. With Junction connectivity between exchange sites – the development and wide use of phantom (Voiceband) circuits over the existing physical pairs provide almost double the connectivity (and at a considerably lower attenuation because the lines were "shared") so the received levels were all over the place!

Having to shout into the telephones microphone was commonplace and having the telephone in a quiet place (to hear the often common faint reception) was mandatory practice. "***Phantom Circuits and Party Lines***"

When thermionic valve amplifiers were included (circa CE 1920 onwards) this new technology substantially fixed much of the faint reception problems on long distance calls - and comparatively, echo was a minor problem as all the overhead open wire transmission systems were 600 ohms operating. Crosstalk (hearing other people talking on other line circuits) was a far more common problem (primarily caused by the structure of open wire telephony having wires in close parallel proximity for several km). "***The Productivity of Electronic Amplification***"

The introduction of thermionic valve amplifiers meant that a “2-wire” bi-directional (Voiceband) transmission (600 ohms) open wire circuit had to be split (with a hybrid transformer) into a 4-wire pair of unidirectional transmission circuits for amplification in each direction – and be re-joined by another hybrid transformer at other side to back-connect to “2-wire” bi-directional (Voiceband) transmission (600 ohms).

Fortunately, the component values in the “Balance Networks” of these Hybrids were well-chosen to match the then standard Voiceband open wire line characteristic impedance of nominally 600 ohms, so echo (and howling) was not a major issue (most of the time)!

The introduction of twisted paper-insulated pair copper wire cable (CE 1930) in the metro areas to replace inter-exchange open wire Junctions was a rude awakening, with the realisation that these cables had to be “Loaded” with 88 mH coils (spaced at 1830 metre centres) to make the cable impedance look very much like 1200 ohms resistive (and flatten the Voiceband frequency response, and incidentally lower the attenuation per unit length). “***Rebuilding the Junction Network”***

Connecting the then new twisted paper-insulated pair copper wire technology Access Network for premises connections from the local exchanges to the ends of these Loaded Junction cables very fortunately made virtual seamless connections at each end and this seemed to work perfectly!

In the Regional areas, replacing the open aerial (600 ohms) wires did not start until after WW2 (i.e. about CE 1950). The structure of the Regional telecoms network included a lot of thermionic valve amplification – so all the Transit circuits between country cities, towns and villages were based around nominally 600 ohms (not 1200 ohms as in the metropolitan areas). Impedance matching auto-wound transformers were included on the ends of loaded cables to bring the Transit line impedance back to 600 ohms. “***Rebuilding the Regional Transit Network***”

As the Frequency Division Multiplex (FDM) technology was introduced into the Trunk network (through the CE 1960s), the Voiceband FDM channels alignment levels (of +4 dBm receive and -13 dBm transmit) started to standardise most of these network alignment levels. “***Advancing FDM Technology***”

In a similar mindset, from CE 1960 through to at least CE 1985 the manual / SxS switching network was largely replaced by electro-mechanical Crossbar (ARF, ARM) technology and although this did not badly affect the Voiceband transmission performance – but it had an intrinsic transmission flaw that in part dated back to the transfer of open wire to pair cable (in the Access Network) that was characteristic of using the wrong settings to accurately measure echo (i.e. trans-hybrid attenuation).

Because the PMG in Australian States operated under separate managements, specifications of the Inter-Exchange Network’s Voiceband end-to-end attenuation were far more “State-specific” than being nationally agreed – and these attenuations varied from 0 dB to over 18 dB depending on the geographic location and the engineering design of the transmission bearers used for these through-connections.

With the introduction of Crossbar switch technology (circa CE 1960), because this technology specifically included alternate path routing and there were intermediate switches (called “Tandems” in the metro areas – operating at 1200 ohms to match loaded cable and called Minor Switching Centres in the Reginal areas operating at 600 ohms to match the amplified and FDM Voiceband transmission systems).

These Tandems and MSCs had no direct customer connections and provided interconnection between other exchanges that had Customer Access Network (CAN) connectivity or had Trunk (long-haul) connectivity.

In a valiant attempt to minimise the range of inter-exchange attenuation some States included 3 dB pads in many of the local circuits so the direct local connections would pick up two 3 dB pads and have a minimum 6 dB Inter-Exchange attenuation (instead of 0 dB attenuation. Connections to other Local exchanges would have a "nominal" 3 dB and the Inter-Exchange Voiceband attenuation was "managed"!

With the introduction of AXE digital switch technology (circa CE 1981) the Voiceband inter-exchange network attenuation was then specified as 6.0 dB, and from then a broad national inter-exchange network attenuation plan started to be formulated.

Very few engineers and technical people had a technology scope that extended beyond their speciality line. Switching and Transmission were seen as two diametrically different technologies – and were in different "rooms" and the staff very rarely talked on cross-purpose issues. Further, the (Voiceband) Access Network was treated as a line current signalling limit technology; so Voiceband performance was not a concern because it was always "within specification" (whatever that was)!

> *In CE 1966 I joined the PMG as a Technician-in-Training (TIT) as University was not on the radar as I profoundly stuttered and was really sick of high school, and electronics was my long-term hobby – so it seemed to make sense as I would not be in the public eye.*
>
> *Little did I know that the first year of this 5-year apprenticeship would be full-time with 80% theory and 20% practice followed by a series of intensive Unit Courses over the next four years and there were about 300 of us in NSW plus nationally about 500! For me this was like hobby heaven as there was a wide range of electronic and mechanical topics.*
>
> *At the end of the year we were given a choice of four technology options to specialise in from a wider range of technical areas. Those that excelled in the first year literally had first choice wherever they wanted. I chose the most popular (Radio) above Long Line Transmission and something else.*
>
> *One of the leading Tutors (John Swan) came over to me, saw my choices and quietly said "In five days there you will be bored"! He then suggested and described the NSW Transmission Laboratory (that was not on the "list") – so I quickly put that over Radio and the following day I was off to 27 Atchison St, St Leonards. This was an excellent choice, thanks John.*
>
> *Apart from making / documenting a lot of prototype (mainly transmission and power technology) equipment, I was able to go to many exchange sites – install and commission our equipment and with the course, cover all the other technologies – and work in those technologies. During the four years I went into the Radio areas for six weeks at least two times. None of the other TITs outside the Lab had this wide scope of training.*

By CE 1985 Crossbar switching was well-entrenched with AXE being rolled out; some Step-by-Step switching equipment was there and manual switchboards had all but gone. Similarly, FDM systems were "everywhere in the country" but few people were aware about 2 Mb/s on what was Loaded Cable (and this was becoming a major service problem. Fax machines / Dial-Up modems were excellent at identifying a raft of previously unreported Voiceband problems and nobody seemed to know where to look to find the causes of these problems (and fix them)!

Circa CE 1987 the switched Voiceband paths within the Inter-Exchange Network (IEN) were drawn up in terms of switching and transmission technologies to interconnect telephone calls (without consideration of the Access Network technologies at each end of the IEN). It was only then when some Engineers began to realise why there was a very wide systemic attenuation differences in the IEN that needed national correcting to reduce the very wide range of (receive) levels and try and tackle the incessant problem of excessive sidetone and persistent echo.

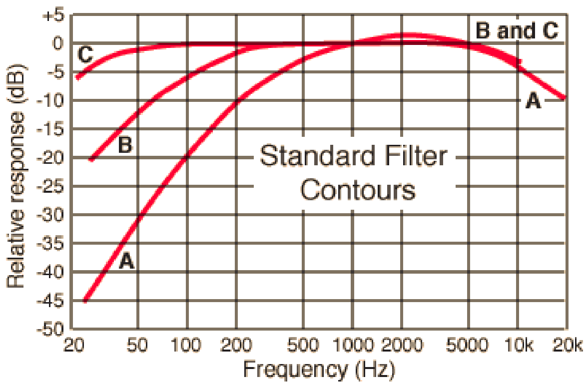
> *In CE 1988 I took on the role of Principal Engineer (Voiceband), Service Quality in NSW Network Investigations. This was a small team of "special people" that had encyclopaedic knowledge about switching and I was the odd one out as much of my background involved Voiceband technology!*
>
> *It took a few weeks (and a trip to Melbourne to see how they in Vic Network Investigations approached these intractable problems) before I got my feet on the ground and realised that the "mud-map" of Voiceband through the IEN was an exploding time-bomb!*
>
> *Every exchange had in it a TCARS (Test Call Answer Relay Set), that I am almost 100% sure had its beginnings back in the NSW Design Lab in the early CE 1960s (well before I was there). This Relay Set acted like a phone by answering after three sets of ring current and sat silently until a (820 Hz) tone was received into it louder than -10 dBm, where it then responded with a 5 second burst of 820 Hz at 0 dBm back to the caller.*
>
> *It was practical to call an exchange (with a TCARS in it) and get a quite accurate measurement of the forward and receive attenuation through the IEN (taking into account the local CAN attenuation). It was also very "dis-heartening" to enter a room in Devonshire St Surrey Hills, to find a person with literally many hundreds of script paper rolls – from many thousands of tests he had done – and he didn't have clue what he was really doing!*
>
> *The saving grace was that the test equipment he had was electronic and programmable to store several numbers and print feed the results! By really narrowing down the calls (to basically one TCARS number) it became obvious that the IEN alignment levels were inconsistent, but I also had the brand and model of the equipment – from EDL in Melbourne.*
>
> *In talking with Ernie Mandell (who owned/managed EDL) it was obvious that he was willing to have changes made to this equipment to suit our needs, and his brilliant engineer Tim Robertson had his finger on the pulse in no time – so we could then have serial data connection (into a personal computer) – and correlate the data directly into Excel (no paper rolls)!*

What was also really troubling was the high number of customers having real difficulty in hearing telephone calls, and in many cases the problems were calling into a locality or at a particular locality.

This intelligibility hearing problem basically came down to the interface between 2-wire (bi-directional, both-way Voiceband) transmission and 4-wire (unidirectional, both-way Voiceband) transmission – and the device that performs the transfer between these two modes of Voiceband transmission is called a (transformer) Hybrid!

The ironic situation was that the Transmission specialists / technical staff were (very) well educated about 4-wire transmission and the associated electronics; and the Switching specialists / technical staff were well educated about switching mechanics and the associated electronics (most of which "logic" state machines, and 2-wire Voiceband transmission) – but virtually nobody was educated about the electronics about Hybrids. Worse still, the highly values recommendations in the International Telecom Union – Telecommunications (ITU-T) were fundamentally flawed – so the test results always looked good or excellent!

Our in-depth studies in Australia indicated that the recommendations from the ITU-T had a fundamental error where the "A" noise weighting was being used where the "C" (near flat) should have been used, giving false good results almost everywhere.



The flow-on changes and improvements from correcting this systemic error were enormous.

When we talk into a telephone we do so at nominally +80 dBAC (dB Acoustic relative to 1 dyne, C weighting) and the nominal listening level is +60 dBAC. When we speak at nominally +80 dBAC, we (and others) hear our speaking voice level at about 12 dB below our speaking voice level or at about +68 dBAC.

Sidetone is the amount of electronic feedback from the handset's microphone to the earpiece – and (acoustically) it should be about -12 dB to match our mouth / ear relationship! With a telephone handset at our ear, the background acoustic level is lowered (into that ear) so we naturally speak a little louder to compensate for the loss in acoustic level into that ear. If the sidetone is loud – we naturally speak much quieter into the telephone's microphone!

To be clearly understood at least 24 dB speech to background noise level is needed, so if we are hearing at +68 dBAC then the room's background level has to be below +44 dBAC. If the room's acoustic sound level is measured with the A weighting, then this reading may well show lower than +30 dBAA because a lot of the background room noise is usually low frequency that is "hidden" behind the A weighting. This is where the problem of using weighted acoustic spectrums started to give exceptionally good results in situations where the results were nowhere near satisfactory as the methods and practices are wrong.

The cause of this problem goes back to (most) people incorrectly assuming that the term dBA infers the "A" weighting "and its audio" (and therefore mentally merge the two "AA" as one) that results in all audio measurements being incorrectly done with the "A" weighting – when they should be done with the "C" weighting.

The "A" weighting is a rough inverse approximation of the human perception of sound as a spectrum. So – its only use is to measure very faint background noise. If the background noise can be faintly heard, then this noise level is too loud for the "perception of hearing" and the "B" weighting should be used instead. But if there is noticeable background noise then the "C" (virtually flat) weighting is mandatory.

Most people ignorantly use the "A" weighting and get seemingly good figures – even though the practical results harshly disagree! Then they blame something else!

The next issue is that of "Telephone (Voiceband Channel) Weighted"! This is a classical situation of the noise measuring instrument including a Voiceband Bandpass Filter (200 Hz – 3400 Hz with very steep "skirts") in front of an "A" weighted filter. The purpose of this is to measure noise in a Laboratory situation where there is no Voiceband channel (hence the band pass filter) and where the perception of sound is "assumed"! I have yet to find a practical use for this!

Echo is the same as sidetone except that the talker's voice is delayed by more than about 50 msec. and the echo audio volume level needs to be considerably quieter than 18 dB below that of the person talking – else the delayed sidetone causes the talking person to stammer their words because of the delayed audio interference.

Echo is caused at the distant end of the 4-wire transmission system (in the Inter-Exchange Network) where the hybrid (that converts to/from 2-wire / 4-wire transmission has insufficient cross-hybrid isolation. In this case, the talking person's speech level is passed across the distant hybrid and re-transmitted back to the talking person. Insufficient cross-hybrid isolation is caused by the impedance of the hybrid's "Balance Network" being considerably different in impedance to that of the line and telephone towards / at the distant customer premises.

The starting point when measuring trans-hybrid loss (i.e. measuring the cause of sidetone and echo) is to have a "C" (near flat) weighting (preferably no weighting at all); the line side open circuit and the balance network short circuit – so as to get the worst case situation; send at the nominal alignment level – and refer this 0 dB in the receive side. This worst case is 0 dBr (referenced)!

Circa CE 1987, Crossbar ARF / ARK exchanges were "everywhere" and in most cases the standard Balance Network was 600 ohms + 2.2 uF. Controlled tests showed that this was "just good" (actually rather poor) when using the A weighting, but when using the (flat) C weighting the lower audio spectrum was way out of specification (really excessive trans-hybrid transmission). Shorting out / bypassing the 2.2 uF capacitor brought the whole Voiceband spectrum just back being "just poor" with the (flat) C weighting. So the 2.2 uF capacitor was not helping and the 600 ohm resistance was not a good match for pair copper cable in the Voiceband!

This was an alarming situation because there were some hundreds of thousands of Hybrids engineered for 600 ohm open wire Access Network lines that went out of service in the CE 1930s in the metropolitan areas and were replaced by twisted insulated pair copper cables "***Cabling the Junction and Access Network***" and in the CE 1950s - 1970s in the Regional areas. "***Cabling Regional Transit Network***"

The Voiceband impedances of these Access Network pair copper cables are not 600 ohms but is a "complex" impedance much like 220 ohms in series with 1000 ohms that is in parallel with 0.1 uF and the impedance is also line length dependent!

Because of the technology of these Hybrids being on their own printed circuit assembly and having solderable pins for Balance Network components – the Balance Network could be re-configured far more closely match the Access Line /

telephone impedance (like that above) and the trans-hybrid attenuation increased from about 12 dB to about 30 dB across the Voiceband (using the flat Weighting)!

One of the first "projects" I had in NSW Network Investigations to resolve very excessive echo when calling to and from Norfolk Island. These calls were plagued with multiple intense echoes that were "bouncing". It took some time to get through the pile of complaints (about 200 mm high in A4 paper) and all the complaints were effectively "identical" – and there were a lot of "Ministerial" letters included that really said nothing!

In consultation with John Simpson (the Supervising Engineer of NI) he clarified the switched route passed through Kempsey exchange (because Kempsey was the District nearest Norfolk Island), and the route then passed straight through Sydney and Melbourne to Bendigo satellite earth station for a hop to Norfolk Island earth station – to the SCAX hut.

By the "bouncing" and time delay of the incessant echo it appeared that there were very low trans-hybrid losses at Norfolk Island and at Kempsey (where the route was 2-wire "Trunk" switched, not 4-wire switched).

At Kempsey, the local (Switching) staff assisted me to locate the Crossbar FIR-T and FUR-T 2-wire/4-wire Relay sets that housed the Hybrids on ROA boards. In line with my earlier tests / trials, I shorted out the 2.2 uF balance network capacitor, checked the remainder Balance Network was the 600 ohm resistor and replaced the board in the Relay Set – and set up my special test equipment on the 4-wire circuit.

Live calls showed the "bounce" had gone but there still was appreciable echo (from Norfolk Island) – so I spent the rest of the day checking and correcting all the balance networks in all the T Relay sets in Kempsey to get rid of echo caused by incorrect balance networks as the result of 2-wire switching in what should have been a 4-wire switched environment.

I was aware that a Tech Officer Alister Liddemore from Long Line Support was going to Norfolk Island in a day or so – so I provided the components and details to him so that he could correctly re-strap the Hybrids in the Crossbar switching equipment (also in the SCAX hut). A couple of days later the echo from the Norfolk Island end was virtually obliterated!

This set alarm bells for me as nationally; literally all of the Crossbar FDM / PDH Voiceband interfacing equipment had Hybrids that systemically had the wrong Balance Networks in them when they were installed!

The next issue was the Hybrid cards in the Regional ARM 4-wire exchanges (back connecting to 600 ohm auto-transformer coupled as 2-wire circuits) connecting to the 2-wire Minor Switching Centres (ARF) exchanges. Shorting out the 2.2 uF capacitor in the Balance Network got rid of the excessive echo and strapping the balance network resistor value to 220 ohms in series with 600 ohms in parallel with 0.12 uF absolutely killed the echo problems here. (There were many 1200 ohm (2-wire) hybrids that were replaced by 600 ohms (2-wire) hybrids from metro areas!)

The next issue was the Hybrid cards in the Metropolitan ARM 4-wire exchanges (back connecting to 1200 ohms Loaded Cable as 2-wire circuits) connecting to the 2-wire Tandem (ARE) exchanges. Shorting out the 1.0 uF capacitor in the Balance

Network got rid of the low-frequency end excessive trans-hybrid transmission and strapping the balance network resistor value to 1200 ohms killed the echo problems here. (There were many 600 ohm (2-wire) hybrids that were replaced by 1200 ohms (2-wire) hybrids – these 1200 ohm hybrids were taken from Regional areas!)

The next issue was setting the balance networks in the T Muxes and the new technology pair gain systems that were being rolled out to replace the remaining SxS technology switches in country areas. All these included a range of strapping and impedance options and once these were genetically sorted out for their network connection locations it was a relatively straightforward process to work through the tens of thousands of these to minimise echo and get their levels aligned!

From here the AXE exchange were relatively straightforward as most of this could be done (remotely) in software and the Nortel DMS switches could also be done (remotely) in software. The DMS had an intrinsic level offset compared to the AXE!

Overall this was a massive programme that took a couple of years and hundreds of internal plant technical staff – but the results were extremely pleasing as echo (and customer complaints in this aspect) were literally wiped off the map!

With the echo problem reduced to residual background room noise, the alignment levels could now be measured with a much greater degree of confidence. This now clearly showed where many local ARF / ARE Crossbar exchanges had missing 3 dB pads that were necessary to increase the (locally switched) through network attenuation from 0 dB to 6 dB, and in the process considerably narrowed the Inter-Exchange Network attenuation from 0 dB to 12 dB to then become 6 dB to 12 dB.

Initially there was a strong pushback against installing 3 dB pads in many tens of thousands of locally connected (Crossbar) Line Relay Sets, but these small pads substantially narrowed the overall IEN attenuation from being nominally 0 dB to 12 dB (a 12 dB range) to being between nominally 6 dB and 9 dB (a 3 dB range).

Concurrent with this was the inclusion of Voice Frequency Hybrid Amplifiers (VFHAs) on excessively lossy loaded cable routes and/or the use of Loop Muxes, or SMOF technology, or point to point radio (to reduce the Voiceband attenuation on these links these back to 3 dB where possible, 6 dB otherwise).

With this narrowed Inter-Exchange Network insertion loss being now very highly predictable (and consistent) the roll of the Test Call Answer Relay Sets (TCARS) that were initially installed in the early CE 1960s could be remotely used to now reliably bulk test routes for rouge transmission levels (hence channels) and isolate them.

What then became obvious was that the TCARS test response level was actually 0 dBm and not -10 dBm, (far too loud) and including a 10 dB pad in the transmit path of the TCARS equipment overnight eliminated a range of customer complaints regarding loud whistles in their ears! (The other real problem was that these Customers were actually dialling wrong numbers and calling the TCARS numbers!!)

In the Inter-Exchange Network, the very wide attenuation variations (0 to -18 dB) were now radically reduced to an attenuation range between -6 to -9 dB, and the echo was literally removed. These continual process improvements over a few years made telephone service connections highly consistent – which also made Fax and Modem connections highly reliable – but their data speeds were consistently lower than our expectations.

Another issue was that short-delay echo (that was highly prevalent before) was also radically reduced. This short-delay echo had the effect of substantially increasing handset sidetone – which made people speak quieter – which made it hard to hear at the other end – especially if that persons' phone was in a high ambient noise area. Most of that problem simply went away!

The lingering issue was that of the structure and Voiceband performance of the pair copper Customer Access Network! It was not until about CE 1995 that suitable / hand-held Voiceband Access Network transmission test equipment became available (from EDL in Melbourne), and this equipment showed that there were a range of frequency response problems that required serious maintenance / rebuilds.

> *In CE 1989 Telecom Australia internally restructured and Network Investigations (where I was working) became a National body. I had already had a good working relationship with the people in EDL in Melbourne, and they had made a data port for their TCARS transmission tester which was now being widely used to identify Inter-Exchange Voiceband circuits that were incorrectly aligned (being too loud or too quiet) and fix these problems.*
>
> *From experience, I recognised that the TCARS was "dated" and really needed several other facilities. When I approached Ernie Mandell (the EDL Owner/Manager) circa 1994 about modernising the TCARS electronics he was very cooperative and his leading engineer Tim Robertson had many similar ideas on a range of facilities that I had certainly not considered.*
>
> *We drew up a specification and they came back in a few weeks with a working model to replace the TCARS and a hand-held instrument that was perfect for field testing in customer premises. This could measure noise and do a Voiceband frequency spectrum test – and included a proactive test for ADSL performance, measure line current etc..*
>
> *These instruments were far more informative than the earlier TCARS and with the exchange end connected to an AXE switch (with a zero length line) this could be used to measure frequency response / attenuation etc. problems in the Access Network and store / analyse the data.*
>
> *On rolling this equipment out to the Regional escalated faults technical staff it quietly became apparent that the topic of Voiceband technology was an area that was sidestepped / forgotten and very few technical staff had any in-depth knowledge / experience or clue about how to approach / solve Voiceband issues (that were by then apparently quite rare).*

All fixed access telephones (engineered after about CE 1960) have in them a "rocking armature" (large "button" shaped) headset receiver that was specifically engineered to have a broad resonance at about 3.5 kHz to electro-acoustically equalise the averaged Voiceband "slope" (monotonically increased attenuation with frequency) so that acoustically the Voiceband acoustic spectrum is at the worst "flat" or has an accentuated upper Voiceband frequency response – making the "sibilances" (had consonants) much clearer to distinguish.

This generally unknown acoustic (over) equalisation characteristic of fixed telephones, plus our human ability to distinguish voices in background noise and be able to hear over a relatively wide acoustic range largely (over) compensated for far less than what would be called satisfactory telephone reception, provided the false perception that the Voiceband performance of the Access Network (like the IEN) was now also substantially improved.

The fact was that the (mainly pair copper Voiceband) Fixed Customer Access Network infrastructure was slowly deteriorating (and had been doing so for decades) – but the then recent national fixing of the IEN part of the telecoms Voiceband network infrastructure had to a very large degree now almost hidden the massive emerging performance problems in the ageing pair copper-based Customer Access Network (CAN).

One of the tell-tale problems was that the Fax and Modem data speeds were systemically lower than expected. "***Telegraphs to Telex to Fax***"

Nationally, the fixed (pair copper) Customer Access Network (CAN) was under several different "customer focussed") administrations and not under a direct technology focussed operational control as was the Inter-Exchange Network (IEN).

Compounding this problem, because masses of Internal Plant technical staff had been "given" redundancies to leave, the Regions followed suit and scuttled a very high percentage of their external plant (cable and customer maintenance staff).

While this move looked really good in the accounting books – it was less than a year before it was imperative to try and call back most of these staff – who had not moved into forced "retirement" and were not about to be re-employed! Consequently the executive panic was to hire contractors (who work to a time line and not to a Quality standard and the Quality of the pair copper access network kept falling.

In about CE 1999 Telstra made a massive internal re-organisation and moved the Customer Access Network infrastructure and the Inter-Exchange / Backhaul Network infrastructure into the one "Technology" Business Unit. Concurrently it re-focussed the now stripped Regions to become product sales aligned – where "Consumers" were now seen as a product line.

Business, Government and Enterprise were already aligned with this structure – and it was only possible because of extensive use of Databases and the Internet that provided the productivity for these Business Unit structures to be functional!

Compounding this situation, the new and far more profitable wireless-connected mobile phone technology (from Radio Base Stations – basically in the metropolitan areas) was being seen as the "new technology" to replace fixed access telephones.

The (fixed) pair copper Access Network technology was seen as very low priority – and as far as I could tell, maintenance costs for pair copper cables in the Customer Access Network were minimised from circa CE 1996, and this mainly paper-insulated twisted pair copper technology (as used for almost all the Main and Intermediate cables in the Customer Access Network) were now quickly falling into ruin as the focus was on moving everybody to Mobile Phones. "***Bolt Lightning and Pressurised Cables***"

Phasing out Long Line FDM Equipment

By CE 1982 in the Regional Areas, virtually all Inter-Exchange Network (IEN) transmission for medium / long haul – with a fair percentage of (amplified) Loaded Cable for medium / short haul was FDM technology. The few remaining thermionic valve technology high-capacity FDM transmission systems were high (daily) maintenance; but the rest of the FDM systems worked for many weeks without the need for anything more than "checking". "***Massive Productivity of FDM***"

The concept of digital transmission using Plesiochronous Digital Hierarchy (PDH) started in the mid CE 1970s and began to get worldwide acceptance by CE 1980 as the technology to take over from (analogue) Frequency Division Multiplex (FDM).
"***Highly Economic PDH Transmission***"

Telecom Australia Research Labs (TRL) had a very active involvement in the development of digital transmission standards and technologies (as too did the ABC and the CSIRO) and they (TRL) actively used PDH in the prototype and development of the DRCS/HCRC by CE 1978. "***HCRC in Remote Australia***"

Voiceband circuits used the base level "E1" PDH transmission technology, the analogue 0.2 - 3.4 kHz Voiceband channel ("E0") is logarithmic (A-Law algorithm) digitally encoded / decoded at 64 kb/s as one of 30 (or 31) digital channels into/from a pair of unidirectional 2.048 Mb/s streams. "***Digital Voiceband Technology***"

Old Loaded Cable was re-utilised to very productively transport 2 Mb/s PDH (carrying 30 digital Voiceband channels per two pairs). It was the implementation of this technology that catapulted the viability of digital switches to be rolled out primarily in metropolitan areas. "***Massive Productivity of 2 Mb/s***"

In the metropolitan areas there was a relatively fast rollout of 2 Mb/s PDH over pair copper Junction Cables to (directly) interconnect the new AXE digital exchanges and this was literally no maintenance - so most Internal Plant Techs were oblivious about the 2 Mb/s on pair copper transmission, and were fixing the occasional sticking relays in the Crossbar ARM / ARK Registers. "***Massive Productivity of 2 Mb/s***"

The almost concurrent emerging technologies of digital telephone circuit switching started in Australia with the rollout of the LM Ericsson AXE101 switches in CE 1981. New "E0" telephone line interface technologies within digital switching emerged from about CE 1983 onwards, followed with Pair Gain Systems (PGS) that emerged from about CE 1986 to very quickly replace small electromechanical telephone exchanges. "***Mighty Productivity of Digital Platforms***"

Telecom Australia was fast heading towards a national technology disaster caused by competition where silicon chips in the 2 Mb/s regenerators were deliberately shrunk in the manufacturing process to maximise production profits. "***Competition Wrecked Australia's 2 Mb/s***"

The introduction of Single Mode Optical Fibre (SMOF) PDH technology in mid-April 1986 literally came just in time to replace the then very high maintenance Mel-Syd high capacity long-haul transmission link between Melbourne and Sydney and all the Wayside cities along that route. "***The Sudden Emergence of SMOF***"

Although a high percentage of the Wayside connections (inland cities between Melbourne and Sydney) to this high capacity PDH network originally had analogue Voiceband interfacing (mainly to ARM Crossbar switches) – this set the course to introduce AXE switches at all these wayside cities and directly interconnect these switches with PDH technology from the SMOF-based PDH transmission system.

The manufacturing of FDM transmission equipment in Australia hit roadblock with the realisation that no more FDM equipment would be manufactured from CE 1986 and then all transmission equipment would be digital. This situation set a critical marker in that all FDM Carrier Equipment maintenance would have to be scaled down (to virtually zero). "***Rationalising Carrier Maintenance***"

Slightly earlier (CE 1982) manufacturing of telecoms equipment had gone through a metamorphosis where all engineering design became global and manufacturing over the next few years centred on massive factories in the Northern Hemisphere; leaving Australian component / telecoms electronics manufacturers with virtually no factory markets – so most of these component manufacturers simply closed down.

Very unexpectedly – the 2 Mb/s PDH digital technology replacement process outside the metropolitan areas hit a brick wall of intermittent dropouts. It took about five years for the cause of the immense problem to be identified – and eventually eliminated by replacing thousands of km of pair copper cable with SMOF cable. This rebuild took until about CE 1992. "***Competition Wrecked Australia's 2 Mb/s***"

Australia's powerhouse exports of farm / mining production (from the non-metro areas) was seen by the Competition mindset Telecom executives to be not important because the internally accounted profits from non-metro areas were small / negative.

Non-Metro areas were on the last on the list for 2 Mb/s Cable replacement with SMOF technology (starting abut CE 1990) and in most cases minimum cost low capacity (6-fibre) SMOF cables were ploughed in to replace pair and quad copper cables that had been ploughed in / installed in the CE 1950s through to the early CE 1970s. "***Competition Wrecked Australia's SMOF Rollout***"

The quick realisation was that a very high percentage of medium haul FDM systems could also be replaced using SMOF as the bearers and because the nominal "hop distance" was usually 40 km to 60 km and it was a "no-brainer" to progressively replace 12 / 24 / 120 channel FDM transmission systems PDH technology (if this had not already been done before).

FDM technology required "low maintenance" but PDH equipment essentially required zero maintenance and as the roll-out of PDH equipment extended – so to do the rather quick reduction in (FDM) carrier maintenance equipment.

The flow-on was that State-based Carrier (and Radio) Maintenance Centres were sequentially shut down, considerably reducing overhead costs as this repair process was centralised to Melbourne and FDM technology was later concurrently phased out.

By about CE 1994 literally all the FDM technology was a distant memory.

Basics of Pay TV and HFC Technologies

The concept of electronic TV started in the USA with a brilliant schoolboy (Philo Farnsworth) who conceived the idea of electronic scanning in CE 1920 while ploughing his parent's paddocks. He told his science teacher about this and it was documented – leading to an extremely valuable patent. Some years later Philo took this concept to RCA and they (under "the General" – Abe Saffron) in standard fashion temporarily employed him, "did him over" then effectively stole his patent, but Philo went on to make about 300 USA-based patents.

Philo's (receiver) technology involved raster scanning on a fluorescent screen and the advancement to colour was not far off – but this meant a rather complex electronic circuit to "phase-amplitude" modulate the three primary colour intensities over the luminescence (brightness) signal.

In the colour TV receiver, the brightness (luminescence) signal worked as per a black & white TV and there was a complex electronic circuit that phase discriminated the colour "sub-carrier" to produce three colour signals for the three electron guns in the back of the cathode ray tube – that then targeted millions of primary coloured luminescent phosphor dots in the face of the cathode rays tube's front screen.

In CE 1954, the USA (RCA) was the first to come up with their National (colour) Television System Committee (NTSC) standard but this was plagued with hue (colour) problems primarily caused by slight time varying phase changes in broadcast transmission and the considerable spread in component value tolerances.

The next big advance was in Europe with the concept of cancelling out (colour) phase fluctuations by delaying a horizontal line (64 usec) then inverting the phase and adding the delayed line with the last received horizontal line. The resultant colour vectors have their phases virtually cancelled, virtually eliminating hue drifts and fluctuations. All developed countries opted for this vastly superior Phase Alternating Line (PAL) television transmission/reception technology.

Under RCA "leadership", the USA rigidly stuck with their flawed NTSC transmission system and almost coerced Australia to follow suit. NTSC was nicknamed "Never Twice Same Colour" and in engineering circles the USA was internationally ridiculed! In the USA that rigidly enforced the "more competition is better" economic mantra, the USA ironically refused to allow PAL transmission (as this was competition)!

Australia was to follow the European TV broadcast standard of 8 MHz wide channels, but there was strong pressure from the USA (ANZUS Treaty) to go to 6 MHz channels and it nearly happened! In the last minute the (idiot) Federal Minister crossed out the 8 MHz and changed this to 7 MHz as a compromise – making Australia totally incompatible with any established TV transmission standard! And in a few minutes that modified Bill was passed and became Law (then we found out)!

Undaunted by this incredible Federal incompetence, engineers in the ABC wasted no time in re-engineering the entire television receiver to work with 7 MHz channels – and deliberately included a special "Pre-Equaliser" in all TV transmitters so that manufacturing millions of TV receivers' intermediate frequency (IF) filter stages (which was a major part of the TV receiver) was then far easier to manufacture!

One of the "new" technologies that also evolved in the USA in the mid CE 1950s was the development of coaxial cable based Pay TV networks – as NTSC reception via coaxial cable was then far more constant than through radio transmission – and people were willing to pay for a better (NTSC) TV reception!

The problem was that this Cable TV technology was developed on a shoestring with the coax cable being a copper plated steel wire with a polyethylene insulation tube spacer and an aluminium wrap-around tube. Complimenting this awful electrochemical mix the female connector is nickel and the male connector is aluminium. Yes it works but maintenance is a constant headache with corroded coaxial connections going high resistance every few years! "***Massive Productivity of Plastic Insulation***"

Compounding these problems there was basically two types of coaxial cable – a thicker version that was used for Main distribution (from the Headend) and a thinner version used for "drops" to the Home premises. Yes – in the USA – almost all of this main cable is shared with power poles along with the (messy) telephone wiring!

With (300 MHz forward, 50 MHz return channel) Cable TV technology, the Main Coaxial cable needs re-amplification at least every 500 m or so. So CATV geographic coverage was relatively small - and needed main cables with amplification and equalisation to connect another "nearby" residential area / suburb!

The development of Single Mode Optical Fibre (SMOF) technology in CE 1986 introduced an astounding range of productivities especially in long-haul transmission and SMOF technology also had wide application into very inexpensive Broadband Access Networks technologies. "***The Sudden Emergence of SMOF***"

The problem with the then emerging SMOF technology was that the optical connectors and interfaces were very expensive and this lead to a range of alternate Access network design strategies including the consideration to include SMOF technology in what was coaxial cable (analogue) Pay TV network infrastructure.

SMOF had tremendously economic transmission properties that far exceeded coaxial cable and it certainly did not take long for SMOF technology to be "dovetailed" into the coaxial cable Pay TV infrastructure (in the USA) to replace the Main coaxial cable runs from the centralised Pay TV "Headend" transmission equipment to more remote Nodes. "***Costing the Mel-Syd SMOF Link***"

Instead of having dedicated coaxial cable with Headend Line amplifiers at nominally 500 metres – which really crippled the economic size of the Pay TV Cable networks, a single span SMOF "triplet" could run as far as 50 km and provide perfect analogue connectivity far exceeding the then 300 MHz upper frequency limit. This new technology Pay TV purposed distribution network that was a hybrid of SMOF and coax cable was very unimaginatively called Hybrid Fibre Coax (HFC) with a then new upper frequency limit of 1000 MHz with more than three times more channels.

With equally little innovation - the Pay TV Headends stayed (city centralised) where they were and this new HFC technology could now very inexpensively cover / connect a whole large metropolitan city – with long arterial SMOF "fingers"!

Realising the potential massive market that could be contained by implementing HFC Pay TV instead of Coax Pay TV, Murdoch's News Corp wasted very little time globally infiltrating political right wing Governments to facilitate the inexpensive purchasing of coaxial cable Pay TV infrastructures to be converted to (his) HFC Pay TV technology and really profiteer from this immense closed market.

Competition Wrecked Australia's HFC

The then new technology of Hybrid Fibre Coax (HFC) circa CE 1992 had radically made the economics of the Pay TV (particularly in the USA – because it stuck with inferior NTSC) highly profitable "***Basics of Pay TV and HFC Technologies***".

Since this new HFC technology had emerged, some Cable TV businesses had restructured their infrastructures to implement SMOF as the now very inexpensive main cable from their earlier technology of cable only Headends (to create virtually nil-maintenance Remote Nodes). Now the premises areas covered with HFC technology from a central Headend was immense – radically increasing the profitability of (analogue) "Cable TV", especially in the USA.

Optus was desperate to get profitable infrastructure in place as their earlier fixed access telephone services (primarily for Government / Enterprise and Business customers) was not nearly as successful as they had anticipated, and (digital) GSM1 and GSM2 Mobile Phones were not yet a profitable consideration – primarily because of massive engineering problems in the audio encoding / decoding that was slow and metallic sounding. "***Phone Numbers, Portability and Mobile Devices***"

By CE 1992, Rupert Murdoch's News Corp had made very significant inroads into electronic news media in buying out a considerable number of Coaxial Cable TV businesses in Europe and in the USA, plus News Corp had also purchased the entire historical MGM film library for "content" on News Corp (his) renamed "Foxtel" Pay TV services – which of course included politically (very) right wing biased news.

As these films were transferred to electronic media, this process considerably bolstered News Corps' selection capability plus News Corp was in the process of actively purchasing several TV series; and getting its fingers into professional sport for very high advertising revenue. Melbourne also had "Fox" FM radio.

The branding of "Foxtel" was (I believe) highly deliberate because my understanding was that Rupert Murdoch was nicknamed as "the (old) Fox" because how the high number of business deals that he did that in effect cornered (outmanoeuvred) his select competition into positions where they had little choice but to capitulate. He also made it his point to deliberately back particular (popular) politicians and/or outmanoeuvre other politicians (in many countries) to facilitate his extensive range of business deals in continually building his global private sector News Corp empire.

The second part "tel" to make up the word "Foxtel" was (I believe) initially intended to be a broad term to include all form of telecoms – including Telecom Australia Commission – which was then (CE 1989) recently transferred from a Commission into a Corporation and thus "freed up" from the clutches of Government regulation (and Australian Government ownership) – making it now a much easier infrastructure to be out-manoeuvred and freed-up so that News Corp (or some other private sector entity) could purchase it.

Murdoch was acutely aware that virtually all politicians are extreme extroverts and that his daily newspapers and weekly/monthly magazines could spin stories that could make and break a pollies career – and his relatively new and becoming highly profitable HFC re-engineered Pay TV platform (Foxtel) had the capability to have far more emotional (financial) impact than newspapers / magazines.

Circa CE 1992, word got out that if Optus built a HFC infrastructure in Australia's metropolitan areas, then (video) content would be available and this product line was totally different than Telstra's "iron grip" on telephony products in Australia. Optus wasted no time and had project teams in place and running out this new infrastructure at breakneck speed.

Simultaneously, Telstra also got (virtually the same) word and literally overnight there was fierce competition for the next two years rolling out HFC infrastructure throughout metropolitan (State Capital Cities and their Suburbs) areas. These separate construction teams worked overtime every day for 6 days per week and there were "spies" seeing where the others competing infrastructure was being strung up – resulting in a large degree – (expensively) duplicating the rollout.

Now, Telstra had the option to use their own under-footpath conduits (at virtually no cost) but generally chose not to – most likely because they may have had to pull out some "dead" cables to make space and they may have damaged other cables in the competitive panic. Also – if Telstra put most of its HFC cables in the under-footpath ducting then this may have given the ACCC room to force Telstra to make this conduit infrastructure available to Optus at a very low (i.e. zero) rental price.

Also – stringing the cable up on power poles was much quicker (and far more susceptible to the weather and tree / traffic damage) – and this practice was/is common in the USA and other areas of the developed world where street aesthetics are not a high consideration for a pleasant lifestyle as they are in Australia.

Personally, I believe there was another quite sinister plan to have a physically alternate network to that of Telstra so that the Pay TV infrastructure could be used for an alternative telephone services (or internet connectivity) to that of Telstra.

> *In CE 1997-1999 I was working as a Project Engineer / Bid Manager in Nortel, Chatswood (NSW). One of the projects that came up was for Northgate Communications (a start-up business in Ballarat (Vic.) wishing to install telephony over HFC infrastructure (as well as providing all the TV channels on Pay TV plus a selection of their programmes as played via Video Cassette Recorders) at their new Headend (which was a shed).*
>
> *As Nortel had a very wide range of advanced, well manufactured telecoms equipment (including the Arris range of Headend Broadband Routers etc.), I was assigned to manage the setting up of a Headend and Broadband Router for providing telephony over HFC to customer premises.*
>
> *Almost instantly, it was very clear to me that the two USA "Cowboys" that headed up Northgate Communications had bluffed their way everywhere with repetitive hollow promises but it was quickly very obvious to me they knew precious little and zero about the then regulation body (AUSTEL) – that I was quite familiar with.*
>
> *Once I had cleared the swathe of regulation issues including getting a telephone number range, it became clear to me that Cable TV and Telephony on Cable technology was way beyond their depth of knowledge – but we had professional international support on hand from (Nortel Canada) and we had the headend working in a few days – and connected to the Telstra Backhaul network (with a Nortel Meridian PABX into the Arris Voiceband interface) – providing the ability to make perfectly clear telephone calls (as well as retransmitting TV channels and using commercial (not industrial) VCR playbacks for programmed movies etc.).*

We then arranged a clean telephone call through to the Prime Minister (Howard) and spoke for a few minutes – and on Radio too. This call was far clearer than the earlier Optus equipment (that I think may have unsuccessfully used Motorola equipment).

No surprises! With Northgate Communications not financially continuing with the trial – we then pulled out all our Nortel / Arris equipment and returned all this to the Nortel offices in St Kilda Road (Melbourne)!

This field trial showed me that Telephone over HFC was possible and involved a lot of equipment, and it was rather obvious to me (at least) that this HFC/Voiceband technology was a "real clutz" (at the Headend and the many Premises) that should be seriously avoided!

The fundamental HFC problem in Australia's metropolitan areas was that because of fierce competition; a lot of construction / build corners were (literally) cut so in reality only a low proportion of premises could connect without considerable re-engineering.

Battle-axe blocks (where a premise is off the street and behind another premise) are classic examples where the longer cable had far too much signal attenuation.

With a huge amount of advertising fanfare (circa CE 1992 / 1993) Australia's highly duplicated metropolitan HFC Pay TV Network was with no real surprise back-connected to Foxtel (New Corp) as the only practical content provider and Foxtel quietly went into a rather binding agreement with Telstra – where as I understood it – Foxtel now had a partial "ownership" of this Telstra HFC infrastructure (and a partial ownership of Telstra).

My understanding was that Optus had not entered into such an agreement with Foxtel (News Corp.) but in due course it became apparent that other service providers (Channel 7?) really could not provide the necessary content. Foxtel then provided a parallel Pay TV service connection so that the duplicated HFC infrastructure was just that – uselessly and extremely expensively duplicated!

There was a flood of very expensive (news hour) TV advertising (from both sides) to report on the progress of "houses passed" and this was usually in "news" items and / or advertising. This wording was deliberately misleading because it was not about "houses able to be connected" and the truth is that a very low proportion could connect without considerable (expensive) re-engineering the HFC Access Network!

At the end of 18 months there was an uneasy sudden truce as both sides got cold feet and licked their severe financial wounds, waiting for the program content to arrive; and having problems connecting potential customers because the HFC wiring was a mess as about 80% of the premises could not be connected and work – without considerable rework – and that caused other customers connection issues!

Both fiercely competing sides immediately stopped their fierce competitive rollouts that had cost Telstra about $2.5 Bn and cost Optus about 2.2 Bn. Now, the metropolitan areas were about 80% covered and in that there was about 85% duplicated network infrastructure – and as it turned out there was only one Pay TV service provider (News Corp - Foxtel) with enough content.

A simple and quick financial analysis shows that bringing this 85% HFC metro duplication to 100% HFC duplication raises the nominal cost from $2.5 Bn + $2.2 Bn

= $4.70 Bn / 0.85 = $5.53 Bn and then raising this figure from 80% metropolitan coverage to 100% metropolitan coverage raises the $5.53 Bn figure to $6.91 Bn

Removing the totally unnecessary duplication effectively halves this cost from $6.91 Bn down to $3.46 Bn and this would have 100% covered and connected the entire national metropolitan area with HFC infrastructure.

Having been extensively involved with telecoms Project Management for some decades, I know from my expert background that the labour costs and material costs are usually about equal - so the base cost can be halved and handed out at about $1.73 Bn for equipment and about $1.73 Bn for labour.

Having also worked for some years in the area or telecoms Bids and Tenders, I am also acutely aware that large builds get a very substantial price cut (as much as 30%), and get put in front of the production line queue – so the equipment delivery is months ahead of the smaller purchasers, and that late and awkward purchases cost a lot more to be scheduled earlier as there is literally no "discount" (usually a rather substantial surcharge)!

With this highly competitive build and being fully aware that equipment was being rush manufactured and urgently delivered – there would be no discount at all – and most likely a substantial premium of at least 20%. So without competition, the equipment would have been at least 20% less expensive or about $1.73 Bn * 80% = $1.384 Bn (and that is being very generous). $1.0 to 1.2 Bn would be realistic!

The labour cost was at least twice what it would have been this without (fierce) competition. The labour including lots of overtime is about ($1.73 Bn) – so cut $1.73 Bn in half; that is $0.866 Bn, (and this is also overpriced).

Summing this up for equipment ($1.384 Bn) and labour ($0.866 Bn) this comes to about $2.25 Bn all up for 100% metropolitan coverage – without competition.

These normalised figures very clearly show that competition in building the Pay TV Cable network in metropolitan Australia was grossly inefficient in business terms (and this is an immense understatement). $6.91 Bn / $2.25 Bn = 3.07 times or 207%. In economic terms this is highly efficient because it employed a lot of people: go figure!

Without (fierce) competition, the build budget cost would have been about 33% of what would have been potentially spent (i.e. this potentially would have cost only $2.25 Bn) and all the metropolitan areas would have had well-engineered Pay TV infrastructure that actually connected to every premises (not just "passed" premises) and this infrastructure would have been "turnkey ready" for immediate transformation to fast Cable Internet! (There is lots of "spilt milk" here!)

It is painfully obvious that sub-government stooge organisations such as the ACCC and the Productivity Commission (PC) that incessantly keep mindlessly chanting that "competition improves efficiency" need to take a long hard look at this (and many other) examples that very clearly demonstrate that ***infrastructure competition*** *is inherently extremely uneconomical and cripples / kills our economy.*

In any war – the only beneficiaries are those providing the weapons.

Immense Productivity of SDH

The introduction of digital transmission as Plesiochronous Digital Hierarchy (PDH) circa CE 1980 was a major technology advancement as the technical overhead maintenance from the earlier loaded cable and FDM transmission technologies virtually zeroed as PDH technology was fully rolled out by about 1992. Not only did this rollout very significantly reduce transmission operational costs, but PDH was also a perfect (backhaul connection) fit for the then new range of LM Ericsson AXE digital (telephone) switches (that also plummeted switching overhead costs by about CE 1990). "***The Massive Productivity of 2 MB/s***"

In the middle of this nation-wide transmission technology rebuild from analogue / FDM to digital PDH; by CE 1986, Australia's telecom network infrastructure was fast heading towards a catastrophic failure because by far the biggest transport FDM transmission system – the Mel-Syd Coax link – which carried the majority of most long-haul telephone traffic telephone (and video) was in its "death throes".

TRL had been slaving away since about CE 1974 to develop Single Mode Optical Fibre (SMOF) technology – destined to use PDH as the transmission medium. TRL had a massive technology breakthrough in April 1986. The production wheels immediately went into overdrive to replace the Mel-Syd transmission link with PDH technology. "***The Sudden Emergence of SMOF***"

> *In March / April CE 1986 when I was "tasked" (as a Class 1 Engineer) to design the Mel-Syd SMOF network, it did not take too long for me to realise that this network was already engineered – for two parallel 7 tube Coax Cables including their interstice (copper) quads.*
>
> *One of the giveaways was that the fibre count was 31 (15 * 2 +1 spare; and with 2 coax 7 + 7 = 14) and the other was that much of the long haul PDH transmission equipment had already been put on the short-list for purchasing. With two 7 tube parallel cables plus plenty of interstice quads – the fibre pairs roughly matched the coaxial cable carriage capability.*
>
> *The missing parts of the massive puzzle were what equipment is used for what network connections and where should these network connections be – and has anything been missed out!*
>
> *When I worked though my forward planning figures it was rather obvious that the network was engineered for telephone and a video link or two – but it was very short on data transport capability. In fact it seemed as though it would be 100% full capacity on day 1 and by CE 2000 it would be desperately short of fibres (and high capacity PDH equipment).*

By the mid-CE 1980s the amount of data traffic in the Inter-Exchange Network was exponentially rising but this traffic was to a large degree hidden because a lot of this was Fax and Dial-Up Modem traffic – on phone lines – using long-held calls. On another front, the amount of dedicated data (Dedicated Data Network – DDN) was also small but very rapidly rising as Internet use was slowly becoming recognised (particularly in Universities – primarily for email and data transfer applications).

In the early CE 1990s, digital transmission technology went through a re-birth as it became obvious that transmission data speeds using PDH technology of 2.5 Gb/s and above were too unstable to operate and 565 Mb/s (0.565 Gb/s) became the practical reliable limit. The Achilles Heel of PDH is that it "hunts" for clock synchronisation – and as the clocking speeds are increased the chances of the synchronising get more blurred – so PDH becomes "unstable"!

Behind all this PDH infrastructure there was yet another network transmission infrastructure for high speed data – that had quietly grown behind the waterfall of PDH-based telephony infrastructure. The technology of Asynchronous Transfer Mode (ATM) transmission was a "clumsy" fit for data in PDH as it used the space used for PDH and simply ran large packets of data with (short) headers that pointed where this data was headed towards.

Much like digital PDH in an analogue FDM world, ATM did not really have a place but it could occupy set aside blocks in a PDH hierarchy and facilitated high speed data transfer which was rapidly growing as computers were becoming far more commonplace than a decade before (CE 1980). "***ATM Digital Connectivity***"

The Universities were connecting with much higher speed data connections than Voiceband; that were "separate" to Telecom Australia / Telstra and mainly on the AusNet infrastructure.

In the early CE 1990s, the technology of Synchronous Digital Hierarchy (SDH) surfaced and it was interesting in that SDH has "Virtual Containers" that large packets of PDH transmission (and ATM transmission) could be slotted into – transmitted to the other end and the unpackaged at the other end - intact.

SDH was/is also an interesting technology in that much like CCS7, this SDH technology also includes large amounts of data that transmission etc. performance data (Metadata) that travels with the SDH streams! This Metadata can be and is gathered to a particular centralised where the performance of a whole network could be watched (and acted on if / before something goes horribly wrong)! "***Amazing Productivities of CCS7***"

Now, an STM1 (155 Mb/s) is roughly the equivalent of the older PDH 140 Mb/s – but it has "virtual containers" and Metadata included so that large (even continuous) chunks of digital data as ATM or PDH (even IP) can be cycled / loaded into these virtual containers and unloaded at the other end taken out (in perfect condition).

The STM hierarchy was deliberately engineered to be a very comfortable PDH transfer platform and SDH directly follows the PDH hierarchy as 4 times steps and the container sizes also are made to suit as follows: STM-4 (622,080 Mb/s), STM-16 (2,488,320 Mb/s), STM-64 (9,953,280 Mb/s), STM-256 (39,813,120 Mb/s) etc.

The advancement from PDH was to introduce Synchronous Digital Hierarchy (SDH), and this very heavily relies on the whole telecommunications network being clock-synchronised from one stable source to every transmission and switching system.

With Telecom / Telstra, the initial plan was to have a Caesium clock in both Melbourne and Sydney and have these cross-synchronised (by the Mel-Syd optical fibre transmission system – using an SDH link instead of a PDH link. This became "unwieldy" and the fall-back plan was to have the two Caesium clocks – one in Exhibition and the other in TRL Clayton with a direct SMOF transmission link.

From here the plan was to have a number of "tiers" where all the (transmission and switching) equipment at each site would have a parent (or two) – much like a network "Christmas Tree"! With this plan agreed and the necessary clock feed equipment manufactured, it was a relatively straightforward process to work down the tree of hierarchical locations and synchronise the entire telecoms network!

In CE 1995, I was working in Telstra (National Network Operations BU) as the National Service Quality Manager where one of the topics came up about Network Clocking Synchronisation came up and I was asked to take on the Headquarters outline plan and manage the implementation of national network synchronisation.

Putting together the Work Specifications was the hardest part – because most of the Switching and Transmission technical staff in many hundreds of exchange sites had never touched this area – and it was a very sensitive issue! Get it wrong and the whole site could go off air!

Apart from very few sites where it was necessary to have a special unit that promulgated the clocking frequencies to several pieces of transmission and switching equipment – virtually all remaining switching and transmission equipment included a synchronisation port / terminal that there and proactively made to synchronise from the parent or and incoming transmission stream from an hierarchical parent site.

In practice, it took less than a month to get most of the transmission and switching equipment in Australia clock synchronised from the "one" parent source (Clayton / Exhibition). One of the tell-tales was that frequent horizontal lines on Fax pages stopped – because there was no longer the need for re-sending after a failed chunk of unsynchronised data.

CE 2019 I was in Chatswood (NSW) near the Railway Station and ran into one of the Technical Officers (Ron Hughes) where I worked in Long Line Support in CE 1987 – and I asked him what he was doing! He said (with a grin and a card in his hand) "I'm still synchronising the network"!

With SDH technology replacing PDH technology over the same SMOF transmission bearers, the channel carrying capacity literally increased by 4 and 16 times from PDH 0.14 Gb/s (STM4 0.155 Gb/s) and PDH 0.565 Gb/s (STM 16 0.622 Gb/s) to nominally STM64 (9.953280 Gb/s), – and data transmission systems using ATM that habitually "fell over" (hiccupped) every few minutes stopped falling over!

Also, the cost of this newer equipment was considerably less than the earlier equivalent PDH equipment – primarily because of advances in MSI / LSI technology where certain functional blocks could now be integrated into a similarly-priced silicon chip instead of taking up a whole (extra) printed circuit board of components. With special MSI / LSI chips, the construction was significantly easier, more compact and significantly less expensive to manufacture.

IBM found a way to inexpensively "weld" SMOF to a GaAs base and this massive technology advancement directly facilitated very inexpensive optical fibre interfacing – which then lead to the possibility of inexpensive Fibre to the Home (FTTH) technology that was previously a very expensive Access Network concept!

In the mid/late 1990s telecoms end user prices should have come down by about 70 to 90%. They did not – and it was the massive costs of executive over-renumeration, dividends, marketing, advertising, sponsoring and Competition that dramatically pushed the end user costs UP – not DOWN!

Again this economic situation (of introducing SDH technology in this case) had absolutely nothing to do with competition. It was simply that “better mousetraps had been built” and this technology (like several times before) was in this case considerably less expensive to purchase and operate (with a much faster and stable data transfer rate) than high order PDH technology.

SDH had another parlour trick up its sleeve in that the streams of SDH could be electronically (remotely) switched so that if there was a major breakdown (say a ship’s anchor ripped up a submarine SMOF cable), then the SDH transmission network structure could be re-configured (under limited control by itself) to continue with a minimum of disruption (as possible) by using another major physical route (if there was one available). With PDH the circuits are hard-wired so there is virtually no way to change the configuration without physically changing cables / fibres – which is itself an unwise process.

In other words – the structure of the SDH-based transmission component of the Core Network could be substantially changed (in a few seconds) to match certain network connectivity requirements.

Clearly, the productivity introduced by SDH technology to selectively replace various PDH-based networks went through virtually unnoticed. This equipment was no more expensive than its PDH predecessor (SDH was now substantially cheaper) and the bandwidth was considerably more.

For example the Mel-Syd link had 7 * 545 Mb/s and 8 * 140 Mb/s PDH transmission systems sub-totalling about 3,815 Mb/s and 1,120 Mb/s totalling 4,935 Mb/s in the same 15 SMOF fibre pairs.

By simply replacing the 15 PDH transmission systems with 15 * 10,000 Mb/s SDH transmission systems (that by circa CE 1993 (very generously) cost about the same or slightly less than the original PDH systems – i.e. about $12.5 M), the transmission capacity was immediately up to 150,000 Mb/s. This is an approximate bandwidth expansion of about 150,000 / 4,935 = 30 times, and at a rather small cost!

Consider 30 times to be extremely generous so as a concession make this 25 times. The productivity through technology advances of a “building a better mousetrap” is still immense! Again this had absolutely nothing to do with competition and all about technology advances – and using the most appropriate transmission technology.

Using the above figures in the “standard table” the added cost of $12.5 M was the SDH transmission equipment (and the PDH equipment was then used somewhere else so the cost is really infinitesimal)! But the circuit count is now (very conservatively) 25 times (not 30 times as above) that of the PDH technology.

Technology	Circuit Count	Build Cost	Voiceband Cost	Time – Era
PDH (Coax)	1920	$131.00 M	$68.23 k	1986-1987
PDH (SMOF)	1920	$45.00 M	$23.40 k	1987-1993
SDH (SMOF)	1920 * 25	$12.5 M	$2.60 k	1993-2002

So now the transmission length of nominally 1000 km can (with a very inexpensive SDH rebuild), provide the equivalent of upwards of 48,000 Voiceband circuits at a nominal cost circa CE 1995 of about $2.60 k instead of about $23.40 k as with PDH technology using the same SMOF bearer, limited to 1920 Voiceband circuits!

So Telstra (and Optus etc.) could provide far more bandwidth at a fraction of the cost by using SDH technology instead of PDH technology over the same long haul SMOF bearers! This had absolutely nothing to do with competition and everything to do with good engineering management.

In circuits per SMOF pair (bearer) this is a productivity of about 2,400%, so it should be of very little surprise that with the introduction of SDH transmission technologies by the mid CE 1990s that the End User (Customer) costs for telecoms services fell! Customer contract costs should have absolutely plummeted – but they didn't.

With SDH the then upper data speed limit was (then) in the order of 10,000 Mb/s (10 Gb/s) or about 20 times faster than 545 Mb/s (or looking at it another way: 20 times the data capacity than 545 Mb/s); and the new equipment was less than about half the cost of a PDH transmission terminal – so it was a no-brainer to transfer PDH technology out of the main links and replace these with SDH transmission equipment - and keep using the same SMOF buried cable fibres!

> *In 2006, I was working as a Project Engineer in Silcar (that had massive inefficiency / duplication overheads as a commercial engineering business contracting to Telstra).*
>
> *One of the small projects was to relocate (install and commission) several old (140 Mb/s) PDH cards from Brisbane and Sydney into partially filled transmission racks in the (Regional Rural) Hunter Valley (Hamilton – Singleton – Muswellbrook). These cards were about 400 mm * 150 mm and it looked as though it was manufactured about CE 1985.*
>
> *Fibres that were previously used for 2 Mb/s PDH were being upgraded to 140 Mb/s PDH at virtually no expense and the now free (dark) fibres in Melbourne and Brisbane could be very inexpensively reused for a much higher capacity than 140 Mb/s; maybe SDH or IP.*
>
> *This is "economy of scale" efficiency; where because of the large physical size of Telstra, they have the capacity to very inexpensively move around equipment to be re-used at other locations with very little cost. Smaller telecoms infrastructures would not have this economic luxury and would have to outright purchase to provide in (say) Melbourne and not have the flexibility for a transfer location to capitalise investment.*

There is another very highly associated transmission topic called Wave Division Multiplex (WDM) where multiple (long-haul) high capacity transmission systems can share the same SMOF pairs by having slightly different wavelengths in their lasers / receivers. Consider SDH using 4 channels of WDM – that is now 3 * 4 = 12 times the original bandwidth for very little extra outlay!

How the SCN Economised Maintenance

Through the decades, as each new technology slowly came in, they brought a number of efficiencies that co-incidentally reduced the maintenance requirements, and effectively reduced the number of internal plant (mainly switching and transmission technicians) and external plant (mainly linesmen / riggers / field staff).

In the early CE 1960s the introduction of transistorised transmission equipment was a watershed era that was largely un-noticed as thermionic valve transmission equipment still required daily maintenance. Similarly, the introduction of Ericsson ARM/ARF/ARK Crossbar switching equipment was slowly replacing the older manual Sylvester Switchboards and Step-by-Step automatic switches – and there was still a fair amount of "things to do" – and overtime!

By the mid CE 1970s all of the thermionic valve FDM transmission systems (except the Mel-Syd FDM) were replaced by transistor technology and literally all the Manual positions were abolished with Ericsson ARM/ARF switching equipment now very widely rolled out. With Regional areas having open wire transmission Inter-Exchange and Access networks being ploughed underground – the amount of ongoing maintenance plummeted and the internal and external plant staff numbers were dropping by natural attrition.

By the early CE 1980s the new rollout of Ericsson AXE digital telephone (service) switches had a minor effect because the relative numbers were small – and the new digital transmission equipment required absolutely no maintenance – and the large number of 2 Mb/s dropouts could not be serviced by staff.

At this time there was a push to figure out how to transfer alarms from one (or more) exchange sites / floors to common administration areas because there simply was not enough maintenance work for the staff – and an exchange could run for weeks without an equipment alarm. Further – if this exchange site was remotely monitored there was literally no reason for anyone to be on site!

By the late CE 1980s the technology of SMOF was a literal game changer with most of the remaining FDM / Analogue transmission equipment being replaced by PDH / Digital transmission equipment with virtually no maintenance requirements and the by then proliferation of AXE switches that also required very little maintenance – this left Telecom management with little choice but to provide voluntary redundancies to a high proportion (many thousands) of its internal and external plant technical staff.

Concurrently a very high proportion of the manual operators and masses of staff involved with metering and charging / billing were offered voluntary redundancies as electronic / computerised billing became standard practice.

As I had mentioned before, the Telstra's then Network Engineering had (in the early CE 1980s) actively experimented with transferring transmission and switching alarms and control from one exchange site location to another; primarily because with the new digital switching and transmission equipment - maintenance requirements had dropped so much there was very little economic sense in having any full time maintenance staff in any of the (over 5000) telecom exchanges!

> *Circa CE 1978, I was working in the NSW Transmission / Switching / Design Laboratory (for many years – as a Technical Officer), where more than once we had been asked about the possibility of interfacing the alarm*

circuitry of line transmission and switching equipment; and transmitting these alarms to another (exchange) site.

Some Crossbar switching relay sets already transferred alarms between remote sites to more central sites and we had made equipment to transfer alarms from gaols to central locations some hundreds of km away; so we saw that we were not breaking any major work practices.

As the Lab had over many years accumulated a range of high quality – mainly Hewlett Packard and Tektronix – test and measurement equipment, an initiative was to make a (compact) single processor card that could interface with the back panel terminal blocks / plugs / sockets. (This was never going to happen – but this initiative provided vision to make it!)

The real initiative was to make a compact single board computer that would be the centre of many of the future projects – and develop a range of special interface cards that would make the interfacing far more straightforward. It did not take much to focus on monitoring Crossbar, FDM, battery, door alarms etc. as the primary targets!

With a special microprocessor card that John Mitchell, Steve Jolly, John Tanner and Peter Gimes had recently developed (based on the Motorola 6802 to be the "heart" of several projects); we set ourselves the task of making a series of printed circuit cards with components to interface with long-line transmission equipment alarms and Crossbar panel meters.

One of these interface cards was a 32 port contact alarm monitor board where the (high resistance) inputs could connect to several pieces of transmission, power/battery, switching, door alarm etc. equipment; clean up and save this data and relay this cleaned data as a serial feed (via a modem card) to a centralised site.

We made another (standard Euro) card that was a Video Display controller – and yes this was very much like a very early desktop computer – but these cards were standard size, rack mountable and very expandable! It was literally "childsplay" to extend (relay contact) alarms to this experimental equipment and a card-mounted Voiceband modem provided the data transmission extension via a Voiceband channels at that time.

Yes we could interconnect with serial ports (via a modem RS232 protocol) and yes we could remotely talk with (and control) a few pieces of long line etc. transmission equipment that had serial interfaces!

In testing this first worked between some floors in Haymarket exchange (one of Sydney's biggest exchange sites) to one floor and later these alarms were transferred to Telecom House in Pitt St (about 800 metres away from Haymarket). Even then we could see that Internet Protocol (IP) would be the way to go – but everything was Voiceband analogue!

One of the big sticking problems was writing the code to "drive" these interfaces (as this technology of microprocessor coding was in its (very) early embryonic stages). Although the team had to start with machine code – which is hellishly slow to write but processes extremely fast; it did *not take long for them to move into Assembler code (which is chunks of machine code with a far more friendly interface).*

From here the machine code became more "abstract" as the Technical Officers started to journey into the early beginnings of "C" language – which has "Assembler" code as drivers talking directly to the machine code and this transmission / alarm monitoring / remote control equipment started to really take shape.

In CE 2005 I was in a Telstra Exchange site (working for Silcar – now Thiess Services) and noticed a sub-rack device tagged as a TESAMS (Telecom Equipment Service Alarm Management System)! This relatively small subrack was virtually identical to the equipment that my team and I were highly involved with developing more than 25 years before!

Concurrent to when SMOF cable was being trenched into the ground in Regional Rural areas in the early CE 1990s, the technology of Internet connectivity had extended past Local Area Networks (LANs) and engineering initiatives within Telstra were proactively arranging the back-connecting all the alarms (and remote control) of all transmission and switching equipment through was becoming known as the Service Control Network (SCN). The Network Planning Engineers of that time were totally engrossed in the planning and rollout of (digital) Voiceband connectivity and had virtually no conceptual knowledge (nor interest) in data communications.

In that short time Telstra's Network Engineering (Business Unit) had jumped on the concept of remote monitoring and control of transmission and switching (and batteries, power, air-conditioning etc.) and had a high proportion of exchange sites equipment all back-connected through what they now called the Service Control Network (SCN) that exclusively used their secure Internet as their transport medium – and for security the SCN had no connection to the Wide World Web!

Again – this technology advancement had absolutely nothing to do with Competition and everything to do with "Building a Better Mousetrap" or more to the point, changing the work practices to suit the new digital technology situation where the need for many exchange-located maintenance staff was literally zero.

Personally, I very seriously doubt that the Engineers remaining in Telstra by CE 1995 (most of whom were telephony mind focussed) understood that the amount of data transport (including Voiceband data) had risen like a tidal wave and was fast approaching to vastly exceed that of Voiceband telephony based traffic.

Circa CE 1984 there was a (point-to-point) Radio Alarm Monitoring System that was very secretively constructed at/for the Redfern Radio Terminal (about 750 metres from the NSW Design Lab in 82 Botany Road Alexandria) and we were asked to prepare their prototype for manufacture – and use through Australia – specifically for radio systems!

Apart from that System being a "real prototype" with virtually no available documentation it used a Z80 processor and had assembly language that was unique and could not be edited let alone translated! As there was no collaboration from the Engineer who made this prototype – just competition – this entire system was soon replaced (by the then recently prototyped NSW Lab designed Transmission Equipment Alarm Monitoring System) at considerable expense, delay and frustration on all sides.

> *While across this project, I visited the Redfern Radio monitoring site and observed the large display panel (that was basically a map of NSW). Red lights indicated locations where the radio equipment had failed.*
>
> *I was absolutely horrified as a large storm (from the west) was slowly wiping out virtually all radio hops across the State. This clearly showed the high vulnerability of point-to-point radio for long-haul applications! It would be CE 1986 before SMOF technology abruptly unseated Radio as "the" long-haul transmission technology!*

The SCN facilitated immense productivity because the newer digitally based equipment had comparatively far less maintenance overhead requirements – and by having the equipment remotely monitored / controlled via the SCN; the number of maintenance staff was then dramatically reduced such that whole Regions had no (very few) internal plant maintenance staff and associated overheads.

Initially the prototype SCN transferred equipment alarms in one building (Haymarket exchange) to a common floor and later transferred these alarms to a central (Sydney) location. The "proof of concept" and later "small production run" versions of this SCN equipment then transferred several exchange sites equipment to the common Operations Centre. These exchanges then became unmanned.

In Melbourne (Clayton: Telecom Research Labs) a similar technology was being parallel trialled and used for almost a decade as the number of exchange sites across Australia that had their alarm monitoring (and remote control) centred to either Sydney (Telecom House) or Melbourne (Clayton – Monash University).

This dual arrangement ended up in a competitive situation for several years (which was extremely uneconomic because two sets of 24 hour staff were necessary and technology information was not being openly shared).

This practice of "competition" flies directly in the face of ignorant economists (who have never really worked outside the university grounds) that blindly swear that competition makes for operational efficiencies – exactly the opposite is true. Competition is extremely expensive, really hinders economic development and fosters corruption – and wastes a huge amount of capital in employing far more staff working in areas totally unrelated and unnecessary for the original purpose.

In late CE 1996 Telstra (National Network Business Unit) internally restructured to capitalise on centralising all the Transmission and Switching etc. equipment alarms to Melbourne, the newly placed executives were largely ignorant of the immense skill-sets of the technical and engineering staff under them, and were under extreme pressure to minimise their staff numbers as the newer digital equipment required virtually no maintenance staff (even at the Regional levels).

What was generally unknown was that the Government and Enterprise Business Unit was concurrently rather desperate for expert Engineering and Technical Staff and it would have been a near perfect fit for the nominal 1800 "extra" staff from the National Network Business Unit to be bulk transferred to the Government and Enterprise Business Unit – who were instead very quickly retrenched.

> *Recent (CE 2020) information is that this "Global" Operations Centre (GOC) was transferred from the Clayton (University) site (which was the*

heart of the Telecom Research Laboratories) to Exhibition Exchange in Melbourne CBD. The logical reasoning is that the physical size of telecoms equipment has reduced so much that there are now vacant floors in many CBD exchange sites – so this is a sensible location transfer and that the land at Clayton is to be sold off for residential use!

In the Regional areas, the SCN (at Base10 or Base100) occupied the only spare pair of fibres in a 6 fibre cable. The other pairs were operating at 2 Mb/s PDH to back-connect AXE104, Pair Gain Systems including the DRCS/HCRC, Loop Multiplexers and some new (analogue and GSM2 Radio Base Stations) – all used for Voiceband at immense expense to Australia's economy as these fibre pairs are capable of inexpensive 100 Gb/s (100,000 Mb/s) connectivity instead of 2 Mb/s.

With the general emergence of Internet as the primary communications fabric, it would make a lot of common economic sense that the SCN be transferred to utilising Blockchain technology to ensure isolation from the general IP traffic and implicitly have extreme security. This Blockchain technology would then be able to transported on the same backbones as normal IP traffic and ensure a minimum of traffic congestion.

Digital Connectivity Converged to Internet

In the CE 1800s the North American "Industrialists" had covertly taken control of all infrastructures (Banks, Rail, Oil, Electricity, Telecoms, Water etc.) so that the associated "rivers of gold" were firmly in Industrialists families. After about CE 1900 when the USA Civil Wars (based on black slavery in the South and white virtual slavery in the North) had died down, the Industrialists extended their economic grip in the USA into Education, Hospitals, Pharmaceuticals, Military, Police and Weapons.

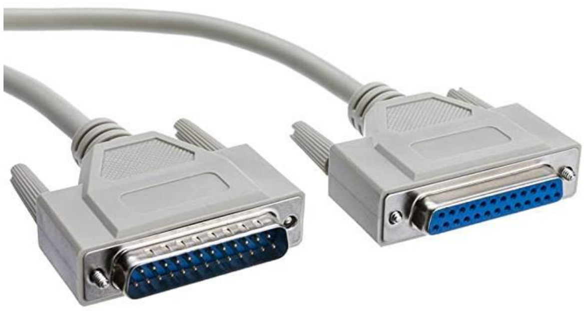
I am certain that the Industrialists (through the Education / Universities that they absolutely controlled - had also seriously edited / re-written Adam Smith's original literature to obfuscate infrastructure being under Government authority (as Infrastructure Business) – and very strictly ensured that all schools / universities taught/lectured only their version of what became "western economics". (Far more detail on this topic is in the book "PowerPlay – the fight for control of the World's Electricity" by Prof Sharon Beder.)

Behind a lot of this economic mayhem in the CE 1950s were the concepts of digital electronics and the development of electronic computing – which naturally started with thermionic valve technology. The fundamental problem was that of interconnecting pieces of digital equipment as these interfaces inherently included a considerable number of parallel wires – and these interfaces were not practical until the proliferation of plastic insulation. "***Massive Productivity of Plastic Insulation***"

One of the prime productivity killers with data transmission was that when data is being transceived between digital technology equipment, this would require a special cable and special connectors (at each end), and particular wiring (at each end).

This incompatibility situation was a classic case of competition getting the way of conformal rules to abide by – and the USA was by far the worst offender – as the USA championed competition above collaboration and conformity (standards).

In the early CE 1950s, Canon started to produce a range of compact flat multi wire cable connectors in their "DB" range. At that time the size of most connectors were large and made for power wiring (not signal wiring), so these connectors were snapped up for electronics. The "D" comes from the shape of the surrounding metal shell outline to prevent the connectors being incorrectly plugged in and (more importantly to provide a common earth / shield through connection, (see below).



The beauty about these connectors was that they came as male and female and they consisted of two rows of parallel solder tags on the back – making them very easy to solder to multi-wire cables – and there were many connections – so there was plenty of scope to use these connectors for a very wide range of interconnecting!

In a struggle to get some sort of a standard happening one of the competing companies “Radio Shack” (who provided a wide provided a range of electronic connectors to the high tech (h)amateur “ham” radio operators (including the Canon DB connectors) produced a “standard” for inter-connecting digital serial electronics.

The “standards” that Radio Shack came up with RS-xxx were more about the electronics than the physical connections – and the competition “fun” started here! In about CE 1960 the Electronic Industry Association (of the USA) (EIA) took this over as a set of their recommended standards!

Apart from there being at least three different types of (offset parallel pin) “DB” connectors (9 pin, 15 pin and 21 pin) the pin assignments were different for different manufacturers and then there were “parity” differences (to check if the full amount of bits was sent – and that response could be positive or negative or not at all), as well as a rather wide range of data speeds, and some transmission was balanced (2 wires), others were unbalanced (common earth). Connecting two pieces of equipment with a serial cable was/is a nightmare that could easily take a whole morning to get it right - and then there was the documentation for each connection!

The hidden advantages of the RS-232 (etc.) connections are that they are bi-directional so that data can be sent both forward and backward. So there is a set of wires for the forward direction and a set of wires for the reverse direction – and the transmission is (normally) unbalanced (one side was “earth / common”).

This serial connection technology was unfortunately plagued by non-conformity / competition between various manufacturers as they plied for market acceptance / dominance and/or to not pay patent costs – causing an immense amount of totally unnecessary overhead and productivity waste.

A variation of the RS-232 / RS-423 “standard” unbalanced transmission versions was the balanced transmission versions (RS-422 / RS-485) that could operate over distance up to about 1200 metres and was far less susceptible to interference / noise where the (unbalanced) RS-232 cable length was limited to about 15 metres.

External to a computer, the first generation of components was the Printer that for simplicity, transferred data in a parallel mode (Byte by Byte) with unbalanced transmission (one side being earth/common), with a few “control” wires so the Bytes of data could be clocked through when the printer was ready. Fortunately with parallel data transmission the rules were fairly simple.

In this case the “Centronics” brand connector and wiring configuration was generally a universal standard.

Because the transmission mode was unbalanced and the clocking speed was nominally up to about 1 MHz the safe lead length was generally less than 10 metres. This transmission was also unidirectional and had no addressing – so the cable simply went from the computer to the printer!

Circa CE 1950 – 1960 the USA/USSR Cold War was extremely intense as the USA "Industrialists" were in an absolute blind/frantic panic to stop any of "their" infrastructures being passed into USA Government hands (called "communism").
On the tail of the USSR/USA Cold War; Hewlett-Packard (HP) was heavily involved with providing a wide range of electronic instrumentation to NASA (specifically is a private business and specifically not a sub-Gov. business – as that is "communism").

HP had a rapidly growing range of advanced electronic measuring and test equipment – but none of their back-end / panel equipment (digital) interfacing was in any way standard, making it virtually impossible to interconnect / cross-connect anything.

In CE 1972 Hewlett-Packard introduced their instrumentation Interface Bus (the HP-IB) that was an 8 bit parallel transceiver that included (4 bit Equipment / Port) addressing and clocking at 1 MHz. The connector was a smaller version of the Centronics connector – but was double sided (front-back male/female) so that the connectors could be stacked to form a physical **star** or a Ring and/or a Spur.

The transmission of all signals and control was unbalanced (so the length was also limited) and the data logic was inverted so "open" was a logic "0" and short the ground was a logic "1".

In its time the HP-IB was a very advanced inter-instrument link and it served its purpose well. This hardware needed some "firmware" in each instrument and in the controlling computer. (Firmware is entrenched software that is set and (usually) forgotten!) For a start each instrument needed an 4-bit address – set by a little dual-in-line switch array – and when an instrument is called / addressed – it has particular codes that can change the front panel settings, and/or perform a reading, and/or send a signal when a reading is ready to be taken etc.

HP had also gone one step further and had also manufactured the HP-9825 desktop computer (which at that time was "rather expensive", about $17,000 – and for that price you could purchase a house in Sydney). This desktop computer ran its own version of HP-Basic that included a lot of firmware code for controlling the HP-IB. The IEEE and ANSI compiled standards in the mid-CE 1970s and "renamed" it the IEEE-488 and it was upgraded to 8 MBytes/s in CE 2003.

The data transfer technologies used in the HP-IB were not entirely "new" because in other similar technologies the data transmission where data was sent as a "datagram" where the leading bytes were for synchronisation and telling how many bytes are in the "train" and then at the end there were some closing bytes that included a "Cyclic Redundancy Check" (CRC) and an "End of Text" (EOT) byte. I am fairly certain the HP-IB transferred data like this – and included up front (in the "header") the address of the instrument the data was intended for.

While all this parallel connectivity was going on there was another line of thought to simplify the wiring and transmit serial data – by feeding the data (as a parallel byte) into a "shift register" and then clocking through the shift register to send the bits out one by one, and at the other end, do the reverse! This "Serial" interface had a few other control wires (physically in parallel with the data wire) – but the number of wires was substantially less than the Centronics connector.

Back to "square 1" and this is where the Canon DB9, DB15, DB21 connectors came in again as ideal "serial" connection plugs and sockets – but transporting "datagrams" of hundreds of characters in serial form as a "data gram" or "data chunk" instead of a single character at a time. It did not take much intuition to realise that if an address was included at the front – in the header – then the data gram could be sent to a specific place in a computer – or indeed (be routed) to another computer.

The concept of Internet Protocols (TCP/IP) – as Ethernet – was introduced in CE 1973 (a year after the HPIB) to provide (data) interconnectivity between computers where the computer interfaces are "named" by (numerical) addresses.

The HP-IB and Ethernet are very closely related as their "permission to talk and listen" protocols are virtually identical – except that the Ethernet connection was specifically a Serial connection – not a Parallel connection – so the number of wires in the Ethernet cable were significantly less than in the HP-IB cables.

The problem with the implementation of Ethernet was that it used (thick) coaxial cable (for fast data speed and connection consistency), but this was the only physical connection and Ethernet needed a lot of "internal firmware overhead" to facilitate multiple terminal connectivity. Still the Ethernet cable was a thick Coaxial cable that was a real pain to "terminate" – and if a termination was not connected – then the Ring connection would hang and do nothing!

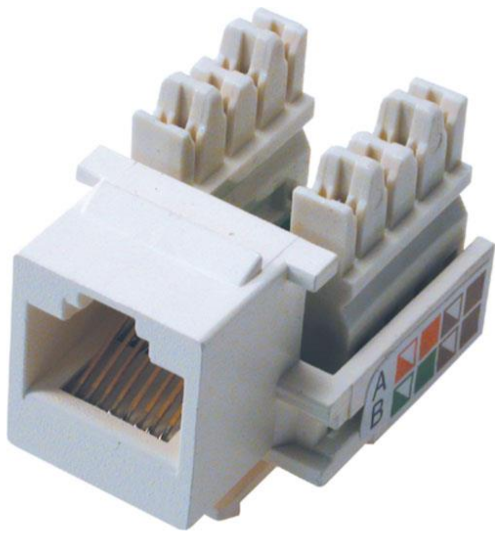
In CE 1985 a much thinner coaxial cable was introduced as 10Base-2 "Thinnet", (10 Mb/s and a maximum of 200 metres length) but the real breakthrough came with the widespread introduction (and general very rapid acceptance) of 10Base-T (10 Mb/s using Twisted pair) by CE 1986 and then the use of four pairs of insulated twisted copper wire pairs in a (blue) sheath, commonly called Cat-5 cable.

For many years (since about CE 1970) the standard telephone connector in the USA (called the "RJ12" where RJ = "Registered Jack") is based around a rather small plastic moulded cable connector that has two gold plated rectangular plates in it – firmly held in place by faceplate friction against the moulded plastic. One edge of the metallic rectangle is used as an insulation displacement connection (spikes through the wire insulation to cold weld to the wire conductor) and the opposite edge forms a slide connection with a gold-plated spring-loaded wire.

This connector appears to break all the engineering rules for reliability (plastic stretching under stress, friction allowing plates to slide, gold plating too thin for reuse, hard clamping of plastic insulation and sheath, burr on edge of rectangular plates) – but somehow it is highly reliable – and it works!

The RJ45 connector has eight parallel plates for eight wires as four twisted pairs – two for (balanced) transmission and two for (balanced) control. The (male) cable connector is shown below on the left below and the cable socket (female) is shown below right - with the spring loaded gold-plated wires.

In my opinion – it was this “RJ-45” connector that made the massive productivity advantage. With the cable, the sheath is stripped back about 15 mm and the wires aligned as per the T-568A or T-568B rules (most now use T-568B) and the wires and sheath are crimped into the connector. With practice this takes about 2 minutes. At the back of the connector (top left) another piece of plastic is jam-fitted to secure the sheath of the cable from moving.



The female RJ45 connector (above right) has eight spring-loaded gold-plated wires that form slide contacts with the outer edge of the male connector’s plates; and the female connector is (usually) soldered to a Printed Circuit Board “***New Era of Electronic Components***”. The connector above right is made to fit in a wall plate and have a Cat-5 cable connect from there.

Because these RJ45 connectors were so compact, they very quickly (almost overnight) had become the default standard for Internet based telecoms equipment (i.e. Switches and Routers) to have (usually horizontal) “banks” of (female) connectors in a single row on the front of equipment – where otherwise the size of the connection panels would be far more bulky (and far more expensive).

In the background the software behind the TCP/IP suite really kicked into gear and the electronics instrumentation world leaped into Cat5 / RJ45 connectors – and so too did computers!

By CE 1990 virtually all computers included an Internet port so they could connect to their Local Area Network (LAN) and concurrently a whole new range of IP Switches and Routers started to flood the telecoms market. The something special was that it was usually rather simple to plug in a Cat 5 cable (with an RJ45 connector at each end) and given about 30 seconds the two pieces of equipment were now “talking”!

Routers were a new type of communications instrument that could be externally programmed to work in a specified range of addresses and direct traffic under programmed control, and they could also change the addressing of packets of data on the fly, and they could automatically divert traffic if route was congested.

For data transport this was an absolute “winner” as this meant that data as Asynchronous Transfer Mode (ATM) could be unpacked and re-addressed as Internet Protocol (IP) and sent on its way – and that plain data could be put in a “data chunk” along with an IP based header etc. and be re-directed to where it needs to go. The possibilities for very reliable and fast data transfer were virtually endless.

Ethernet Became the Unified Core Network

By CE 1985 the world of emailing was in its baby steps but by CE 1990 the use of email had become a worldwide technology and similarly with Websites these too had become commonplace by CE 2000 – but most of Telstra (executives) were still stuck in the concept Mobile and Fixed telephone technology – not realising that data had exceeded Mobile / Fixed telephone traffic!

The transfer of PDH to utilise SDH was an engineering masterstroke because the SDH / (Sonet) Virtual Containers could easily transport large chunks of IP; and Routers could very inexpensively, easily and automatically re-direct IP (and inherently ATM) data traffic to minimise network congestion and maximise Core Network throughput.

SDH was considerably far more than a simple electronic transport mechanism because it included the concept of "overhead" in it and this "overhead" was metadata about the health of the SDH transmission network. So – you could "plug into" the SDH metadata port (as this was virtually the same construct as the CCS7 metadata used in digital telephone switches) and this SDH metadata would be continually spilling out. "***Amazing Productivities of CCS7***"

In a virtually parallel world to digital analysis of CS7 metadata, this SDH metadata could be corralled and analysed on the fly – so a central control/maintenance area could "see" the network health – and/or otherwise and take proactive action (if the SDH equipment had not already done so)!

Maintenance needs were virtually zero and the number and cost of well-trained and experienced (internal plant) maintenance staff was being significantly reduced with mass "forced redundancies" of many thousand being "let go" through the late CE 1980s to CE 1987 inclusive. "***How the SCN Economised Maintenance***"

With the new telecom Switch / Router equipment becoming even more compact (and requiring proportionately more fan / air-conditioning cooling) the amount of electricity / power was becoming a significant (remaining) overhead cost issue – now that most of the other overhead costs had been substantially eliminated.

> *In the mid CE 1990s another bright Engineer in NSW (Max Trochei) who was working in the Buildings Branch (now a National Business Unit) realised that Telstra had thousands of electricity Bills that were repetitively due and paid – and this process was inefficient (in business terms – but highly efficient in economic terms) as it employed many people.*
>
> *He recognised that virtually all of these contracts / bills were small and but together they were (very) expensive. So he "grouped" the bills and went back to the "competing" electricity providers for "economy of scale" prices that turned out to be significantly reduced on the "competing" prices.*
>
> *According to (hard right) economics theory – "competition drives down end user costs, and more competition drives down end user costs even further"! <u>In practice – exactly the opposite proved to be true!</u>*
>
> *He took this a step further and identified the electricity distribution physical boundaries and did another much larger "economy of scale" grouping that again resulted in significantly reduced sales competition that again resulted in a significantly reduced cost of bulk electricity for Telstra.*

The cost of electricity to Telstra was now at very economic bulk rates compared to the previously much higher commercial / consumer rates. This diametrical change in the billing of electricity had a dramatic effect in reducing overhead costs that in turn made it practical (and economical) to reduce end user costs in the mid CE 1990s.

As well as transporting PDH transmission (that was almost always telephone - and Fax and dial-up data traffic), SDH could equally well transport ATM transmission that was almost always data traffic – i.e. Banks, Stock Exchange, and the fast emerging data transfers related to emails and emerging Websites.

The difference between ATM and Internet (IP) data streams was miniscule and ATM was fast metamorphosing into IP – and this is where it became even more interesting and fascinating! SDH is effectively a "fixed" network infrastructure capable of 10 Gb/s (and more) and fully capable of transporting IP – which is not a "fixed" network infrastructure, but IP can "move" under SDH to optimise its IP transport connectivity!

IP data transport was very rapidly increasing in volume in the mid CE 1990s as the concept of emails had become the replacement for Fax transmission and Websites started to become far more widespread – and now started to be hosted from IP connections and not ATM or many multiples of 2 Mb/s ISDN connections. "***Telegraphs to Telex to Fax***"

Although consumer Broadband Access connectivity was "missing in action" this situation of rapidly escalating because the use of IP as a main telecoms transport technology caused a total rethink of the then "Backhaul" Network structure to have a significant increase in the number of IP Switch/Routers – and to have direct IP connections over SMOF instead of having all of these contained in SDH vessels.

With the rapid rollout of ADSL technology in the late CE 1990s, much of the telecom traffic volume transferred towards data – as emails had virtually replaced fax traffic. The technology problem was that ADSL was really meant for Cat 5 cable technology (where the insulated wires are very well capacity balanced and tightly twisted to minimise crosstalk between pairs).

ADSL2+ technology was forced onto the standard (Cat 3) telephone cable paper-insulated pair copper cables, where the inter-pair capacitance balancing is woeful (but OK at Voiceband frequencies) and most of the Main and Intermediate cables (leading out from the local exchange sites) had water ingress – causing horrendous transmission problems. "***Competition Wrecked Australia's ADSL***"

The concept of VoIP had been around since CE 1970 but this technology finally became practical about CE 1999 – but needed the Telephone User Part (TUP) of CCS7 to be merged in to Session Internet Protocol (SIP) so that the repetitive bursts of voice packets could be reliably (priority) transported over IP technology. "***Astounding Productivity of VoIP***"

By CE 2005 the SIP/VoIP interworking issues had been resolved and one of its first applications was in the Mobile Telephone arena as GSM3 (3G). As it was there was also GSM1 and GSM 2 mobile telephone technologies and both of these really suffered from very excessive Quantisation distortion, making intelligibility very difficult. "***Phone Numbers, Portability and Mobile Devices***"

The introduction of 3G mobile telephone technology was an instant success and it met with considerable network infrastructure issues with 1G and 2G infrastructure being very hurriedly removed and replaced by 3G. The upside of 3G technology was that the network transport of this is (short-held repetitive) IP and not long held Voiceband – so this could then sit within the Internet family of protocols / technologies.

Concurrent with 3G technology was the concept of transferring all long-held telephone call technology into SIP/VoIP – and this was anything but straightforward.

My understanding was that the Alcatel System 12 switch technology - introduced into Telstra about CE 1992 was radically different than the (earlier then) CE 1980 LM Ericsson AXE switch technology. The subtle difference (as I understood) was that the S12 architecture facilitated packet data interconnectivity through the switching matrix – and a slight firmware upgrade (circa CE 2003) made VoIP possible and highly practical through the S12 switch technology as SIP/VoIP to back-connect with the Core Network.

Taking this thinking one step further it was my further understanding that the existing LM Ericsson AXE switches (and 2 Mb/s back end-connected Pair Gain systems) could then be parented to the S12 Switches at 2 Mb/s PDH or 8.4 Mb/s PDH and the S12 switches then "talked/spoke SIP/VoIP" with the Core Network via the local Core Switch/Router so the "Phone Numbers" could be attached to the AXE / S12 / PGS line interface card (fixed electronic) addresses.

In a broad parallel with this SIP/VoIP was the concept of SIP/Video IP (with much larger data packets) and presto the whole network was then unified in using IP technology for all transmission and Switching / Routing.

This made the entire Core Network all IP switched / routed and the transmission was via IP (now up to 100 Gb/s per SMOF fibre pair) and through ATM / SDH technology!

Basics of ADSL and HFC Broadband

In the early CE 1980s advancing Medium Scale Integration (MSI) technology burst on the scene and facilitated inexpensive single chip Voiceband Modems to become standard office equipment. "***Telegraphs to Telex to Fax***"

MSI technology also facilitated rather inexpensive analogue – digital – analogue conversion technologies that made digital telephone switching highly economic. Concurrently, almost all audio equipment used MSI with linear analogue (silicon) chips as the standard (mathematical) "operational" amplifier technology – because these linear integrated circuits (ICs) were inexpensive, highly reliable and very stable. "***Mighty Productivity of Digital Platforms***"

Circa CE 1990, Dial-Up Internet with a minimum length pair copper Access Network pair copper line had an absolute maximum speed of about 56 kbit/sec (i.e. 0.056 Mb/s), and a typical speed of about 14 kb/s (0.014 Mb/s) with an average length metropolitan line of about 2900 metres. This data speed limit was fast becoming a major impediment to providing fast enough Internet connectivity.

Telstra senior executives were still heavily entrenched in the renumeration mindset of telephone hierarchy and the concept of Integrated Services Digital Network (ISDN) connecting at 2.048 Mb/s was heralded as the speed connection flagship – as this could connect 30 Voiceband telephone channels on two copper pairs in the (metro) CBD areas (where the line lengths rarely exceed 700 metres)!

In any case (executive speak) – if you want fast Internet connectivity – a 2 Mb/s ISDN connection can provide 30 * 64 kb/s! What more would be needed?

In the background, the concepts of ADSL technology for Pair Copper Access Network infrastructure and Cable Internet technology for HFC Access Network were both internationally emerging to succeed the much slower Dial-Up Internet connectivity, by orders of magnitude. "***Competition Wrecked the HFC Rollout***"

In the mid CE 1990s the then new technology of Large Scale Integration (LSI) brought with it an amazing economy of scale where several hundred thousands of active devices (transistors and FETs) could now be reliably and very inexpensively printed / etched into a (large) single silicon chip. These technologies facilitated the possibility of ADSL and Cable Modems. "***Second Wave of Electronic Components***"

The "trick" with ADSL and Cable modems is that this modem technology uses hundreds of "sub-modems" all spaced at nominally 4 kHz apart – just like a high capacity "digital" FDM system. Each of these "sub-modems" has their own phase-amplitude modulator / demodulator built into the single LSI chip. This chip also includes a complex frequency division processor plus the ability to turn off any sub-channels that are underperforming (and the ability to self-test these sub-channels)!

With ADSL, the concept is that the data is transmitted above the Voiceband on pair copper – where the upstream data occupies nominally 24 kHz to about 384 kHz and the downstream data occupies about 400 kHz to about 2,200 kHz. The downstream spectrum is much wider spectrum than the upstream spectrum to (potentially) facilitate a far faster downstream data rate than the upstream data rate.

With "prototype" ADSL (circa CE 1997), the maximum downstream data speed limit was 6 Mb/s (with 1.2 MHz being the upper limit of the ADSL downstream spectrum). The "proof of concept" version of ADSL1 (circa CE 1998) followed with a much wider downstream bandwidth extending to 2.2 MHz and having a maximum downstream speed of 8 Mb/s. These developing technologies had maximum downstream speeds that far exceeded Dial-Up (0.024 Mb/s) and ISDN (2 Mb/s).

From about CE 1986, there was concerted effort (mainly in the USA) to develop Internet connectivity over the re-engineered Pay TV (now HFC) infrastructure - that had just an amazing productivity boost from including SMOF. This Cable Internet technology came through the first development hoops in March CE 1997 as DOCSIS 1.0 using rather similar LSI technology as that in the emerging ADSL technology.

With Cable Internet, the downstream process uses a dedicated 100 MHz frequency band from the Pay TV downstream block and then breaks this band up into (USA Standard) 6 MHz TV channels (much wider than the ADSL 2.2 MHz band). Also, and the (coaxial cable) line lengths to the premises have amplifier/equalisers at regular intervals along the main coax to control the level and flatten the frequency response.

The Cable Internet Upstream process uses the “old” maintenance channels (nominally 500 kHz wide at the very low end of the cable spectrum that have a far narrower bandwidth and hence really limit the upstream capacity and capability.

The Headend Modem / Router structure with ADSL and Cable Internet technologies is essentially rather similar!

By allocating Ethernet addresses to these data streams (within these “TV” channels) it was possible to then have several (say 40) premises modems share a dedicated 6 MHz downstream frequency band and get in the order of 33 Mb/s downstream – shared amongst these premises. So with 16 “TV” channels in a 100 MHz slot, this works out at about 16 * 40 = 640 Broadband Internet connections from a Broadband Router – getting on average with very low contention in the order of 33 Mb/s!

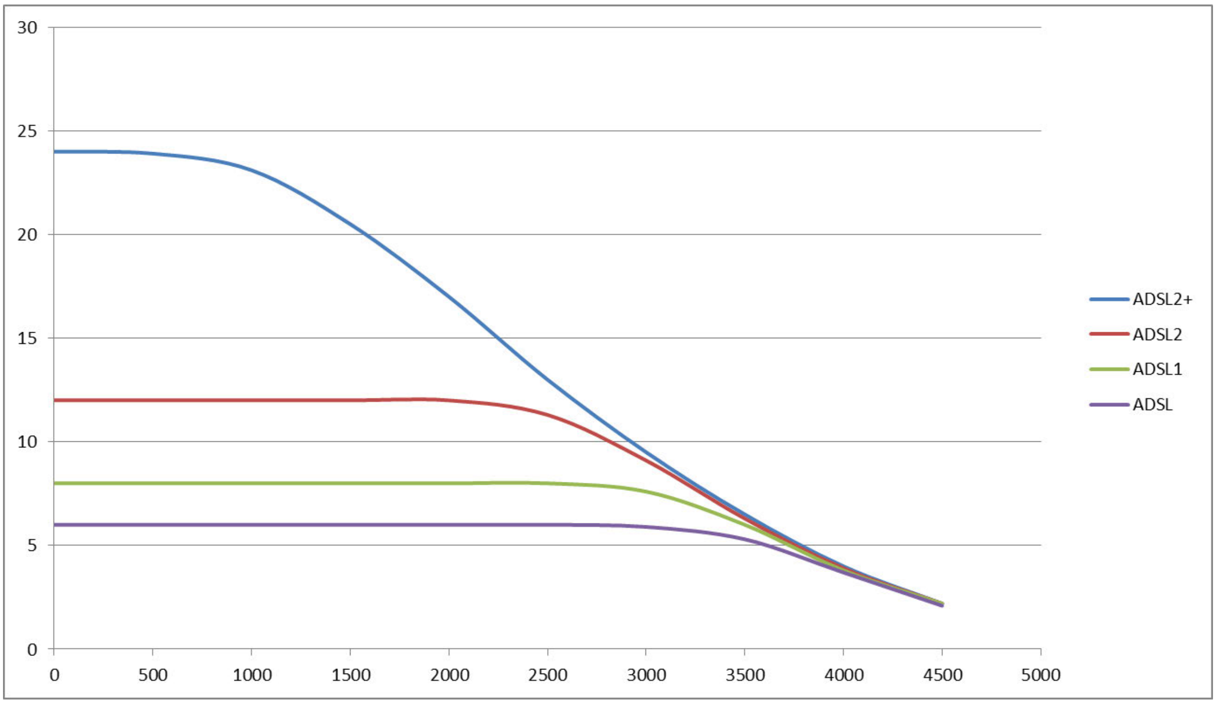
With ADSL technology, the Headend Modem/Router has a high/low - pass filter to each physical pair with individual modems tied to an IP address and connecting via the high-pass part of the line filter. The Router addresses each Modem’s IP address. An ADSL2+ Headend card may service say 32 individual physical Access pairs and with 20 cards in an 8 RU subrack (about 360 mm high); this works out at about 640 ADSL2+ services all capable of 24 Mb/s downstream and about 3 Mb/s upstream.

Both early version Headends may have been Backhaul Network connected with a (pair) of 140 Mb/s PDH or ATM / SDH interfaces to provide IP connectivity, but the more recent technology versions (i.e. after CE 2000) would have provision for 1Gb/s or 10 Gb/s (or even 100 Gb/s) IP as a direct Backhaul / Core Network feed.

Over several years, advancing ADSL technology has significantly increased the maximum downstream (and upstream) speeds from nominally ADSL with 6 Mb/s max (CE 1996 – the prototype) to ADSL1 with 8 Mb/s max (circa CE 1998 – proof of concept), then ADSL2 with 12 Mb/s (circa CE 1999 – large production) then ADSL2+ (circa 2002 – mainstream production) with a maximum downstream speeds of 24 Mb/s (on 0.40 mm pair copper less than about 900 m long).

The higher frequency downstream direction transmission is far more greatly affected (than the narrower, lower frequency upstream frequency band) by line length as the attenuation in this upper frequency band is considerably greater and there is considerably more crosstalk from other pairs. It very quickly became a standard practice to quantify ADSL performance by the available downstream data speed.

In Australia, most of the (urban) physical access network of pair copper has a nominal diameter of 0.40 mm and even though the transmission characteristics of these cables were highly consistent – they are "Cat 3" cables specifically engineered for the Voiceband up to 32 kHz (and certainly not for Broadband)! "***Highly Economic Underground Cables***"



The above chart shows the theoretical downstream data speeds "y" axis (Mb/s), based on the technology of the ADSL Digital Line Services Access Multiplexer (DSLAM) versus the (0.40 mm) pair copper cable length from the Local Exchange / Node to the Customer Premises along the "x" axis (in metres).

Note that the ADSL (6 Mb/s max) and ADSL1 (8 Mb/s max) were technology prototype / developmental speeds and that the ADSL2 (12 Mb/s max) and ADSL2+ (24 Mb/s max) downstream speeds merge by about 2600 metres (at about 11.4 Mb/s). There is no practical (speed) advantage in using ADSL2+ technology over ADSL2 with 0.40 mm pair copper that is longer than 2600 metres.

Although this chart looks simple, most people (even in the telecoms industry) do not have a good understanding of the physical sizes of urban Exchange Switching Areas (ESAs) in metro, cities, towns and villages. Consequently there is generally a lot of difficulty relating expected ADSLx downstream speeds to various urban situations (with the assumption that the pair cable is in good condition).

In practice, the Exchange Switching Area (ESA) can be simply grouped and quantified for a few rather standard urban situations as follows:

In Villages and in Large City CBD areas, the maximum (urban) Access (pair copper) line length in the ESA is typically less than 700 metres, and an ADSL2+ Headend located in the Local Exchange site would provide 24 Mb/s to virtually 100% to all these urban premises.

In Regional Towns the maximum radial length is about 1200 metres so the maximum pair copper Access Network line length in this urban-bound ESA is about 1500 m. So, with an ADSL2+ Headend located in the Local Exchange site, most urban Town premises should have a downstream speed of 24 Mb/s, and the most outlying Regional Town premises would still get over 23 Mb/s downstream!

In Large Regional Towns the maximum radial length is about 1700 metres so the maximum pair copper Access Network line length in this urban-bound ESA is about 2030 m. With an ADSL2+ Headend located in the Local Exchange site, a high proportion of urban Large Town premises should have a downstream speed of 24 Mb/s, and the most outlying Regional Town premises would still get over 17 Mb/s downstream!

In most Regional Cities the maximum radial length from the urban centrally located Post Office / Local Exchange is about 2000 metres, so (generously) the urban ESA maximum line length is about 3000 m. Usually about 16% of the Country City premises are located closer than 1000 m from the local exchange and all these urban premises would have 24 Mb/s downstream.

On the outskirts the slowest speeds would be about 9.3 Mb/s (about 6% of the total on the city premises). About 20% of Regional City premises are more than 2500 m from the Local Exchange and these premises could be connected with an ADSL2 (12 Mb/s max) Headend equipment and the downstream data speeds would be identical as if they had an ADSL2+ Headend technology!

With metro cities, these (suburban) ESAs commonly cover a few suburbs and the maximum line length is 4100 metres. So about 7.2% of the premises in the ESA are close enough to the local exchange ADSL2+ Headend to get 24 Mb/s and about 60% of the metro (suburban) premises are beyond 2600 metres and their downstream speeds are 12 Mb/s or slower (down to 4 Mb/s). As before these 60% of metro premises would be no better served by ADSL2 (12 Mb/s max) Headends!

Urban Group	Maximum Cable Length (m)	Comments
Metro CBD	700	All should be all 24 Mb/s
Big Cities / Metro Suburbs	4100	Minimum should be 4 Mb/s
Country City	3000	Minimum should be 9.3 Mb/s
Large Town	2030	Most 24 Mb/s, worst 17.5 Mb/s
Town	1200	Most 24 Mb/s, worst 23.3 Mb/s
Village	700	All should be all 24 Mb/s

The above table relates characteristic urban groupings with the maximum lengths of pair copper cables to connect from the ADSLx Headend to the Premises.

As the chart shows, the maximum downstream speed for ADSL is very line length dependent – but in many urban scenarios the worst case should rarely (if ever) happen. A full length (metropolitan) urban line is 4100 metres and the attenuation frequency characteristic limits this to 3.9 Mb/s maximum. So the worst case scenario for ADSL (3.9 Mb/s) was in the order of 70 times faster than Dial-Up Internet!

The first rollout of ADSL2 technology started in Australia in CE mid-1997. This rollout was focussed on the metropolitan city CBDs as these areas were seen as giving the highest / fastest ROI. Instantly, ADSL was a knockout technology compared to Dial-Up Internet.

Competition Wrecked Australia's ADSL

From about CE 1985, the use of dial-up Email, Bulletin Boards and Websites had taken off like a rocket but this was largely un-noticed by Planning Engineers who were still totally focussed on telephone services (as they had for decades before). In any case these "other" services (including by then the very wide use of Fax technology) used Voiceband data and that was via a (Voiceband) phone line – using Voiceband-based FDM and amplified Voiceband circuits using Crossbar switching and the then new AXE digital Switching – with Voiceband back-connections!

The introduction of SMOF as the long-haul transmission medium of choice from mid CE 1986 was the perfect chance to as rapidly as possible transfer from FDM on aged and failing paper-insulated pair, quad and coaxial copper cables and in the process move to PDH and ATM transmission technologies on SMOF cables. "***The Sudden Emergence of SMOF***"

The combinations of several electro-mechanical, analogue and digital Voiceband inter-exchange switching and transmission technologies resulted in a "pea-soup-mix" of inter-exchange network connections that rose to a head circa CE 1988. These Voiceband Service Quality problems took quite a few years to nationally resolve – but the latent problems remained in the Access Network – and they could not be addressed / resolved because that part of the telecom infrastructure was in a different Business Unit until circa CE 1998. "***Wiping Out Voiceband Complaints***"

By circa CE 1993 it was already becoming very obvious that dial-up (Voiceband) data connectivity was not nearly fast enough and another technology had to be introduced and soon. World-wide the push was for ISDN – but at the best that provided only 2 Mb/s (which was more than 30 times faster than the best dial-up data speeds) and very serious consideration / research was being put in to Cable (TV) and into ADSL as methods to provide Wideband connectivity to premises. "***Basics of ADSL and HFC Broadband***"

ADSL2+ Broadband technology would have been the phenomenal jumping stone for Australia's economy; but what was widespread unknown was that the pair copper wire physical Access Network technology needed urgent upgrading and this infrastructure was deliberately let fall into much further disrepair because Mobile Phones (using Radio Base Stations – back connected by SMOF cable) were deemed a far more profitable commercial product line than fixed access telephones. ***"Infrastructure Business – Competitive Business"***

*Because of rapidly advancing transmission, switching and power technologies, Circa CE 1999, Telstra had by then had its national telecoms infrastructure firmly operating under a Competitive Business mindset and Telstra had (then) recently centralised all its equipment remote control / management (including the Cable Gas Pressure Equipment) from Clayton in Melbourne, leaving a very thin technical skeleton for Australia's telecoms infrastructure. "**How the SCN Economised Maintenance**"*

Decades before, the Cable Gas Pressure Equipment was relatively low maintenance; but with the influx of virtually zero maintenance digital transmission and switching / routing equipment in the CE 1990s, the Cable Gas Pressure Equipment itself became a relatively high maintenance issue. It was a then straightforward Competitive Business decision to simply remove this equipment as it had a apparently very minor impact on fixed access telephony services (which were not profitable). "***Bolt Lightning and Pressurised Cables***"

The introduction of ADSL Broadband Internet technology was potentially an immense boost for Australia's productivity as this Broadband Access technology would have had the capability to provide the fast and efficient telecoms link between competitive businesses that Dial-Up Internet connectivity and Fax technology simply could not provide. "***Digital Connectivity Converged into Internet***"

With the widespread competitive rollout of ADSL2+ (24 Mb/s max) technology from CE circa 2002 it very quickly became obvious that the vast majority of ADSL2+ downstream speeds were far lower than blatantly / deliberately / dishonestly heavily advertised by the Competitive Business advertising and marketing mindsets.

From an Infrastructure Business aspect it became obvious (to me) that the minimum Broadband downstream speed needed to be greater than 12 Mb/s for effective and economic for Competitive Business and home usage.

*The intrinsic problem was (is) that the Competitive Business mindset had taken executive management of Australia's telecoms infrastructure and in the process had deliberately let this (paper-insulated pair copper access network) infrastructure be run down to maximise executive renumeration and shareholder dividends – at the cost of Australia's national Gross Domestic Product (GDP) from about CE 1999 onwards. "***Competition Wrecked Australia's Pair Copper**"*

Put another way, the cost of the Competitive Business mindset in incidentally wrecking the infrastructure for ADSL connectivity, absolutely crippled Australia's economic productivity and this economic cost most likely far exceeded the total investment cost of Telstra, Optus, TPG, NBN, and all the competing telecoms businesses in Australia. ***<u>This is why you do not privatise infrastructures!</u>***

After what I had heard from some (ex-Telstra) executives had publically stated about the ADSLx rollout and having put together some serious analysis of comprehensive ADSL downstream data speeds that was (temporarily) made available from the Dept. Communications website on Broadband connectivity circa CE 2014; this is my understanding of Australia's ADSLx rollout fiasco:

When ADSL2 (12 Mb/s max) was first rolled out in Australia (CE 1997 - 2001) it was specifically **<u>not</u>** done under Telstra engineering (Infrastructure Business mindset) where every ADSL2 service would have been installed and commissioned to best improve Australia's Broadband connectivity as a whole.

Instead, this rollout of ADSL2 technology was done under a Competitive Business mindset by Sales and Marketing executives, where businesses in the metro CBDs were selectively given first opportunity to have ADSL Broadband connectivity.

Telstra had installed ADSL2 (12 Mb/s max) Headend equipment (Digital Line Service Access Multiplexers - DSLAMs) and the (mainly) PDH technology Backhaul Network had to be significantly re-configured to provide Broadband connectivity (usually) using Single Mode Optical Fibre technology to these DSLAMs / Headends.

This infrastructure build was then (almost) separate to the mainstream telephony infrastructure as this Backhaul Network infrastructure was originally based on PDH and did not interconnect with the Inter-Exchange (telephony) Network. Internet technology has its own switches - called "Routers" (or "Switch/Routers"). Unlike telephony – that (then) had long-held connections; Internet connectivity consists of several "data packets" that have an intended destination address on the front of these "data packets". "***Digital Connectivity Converged into Internet***"

This partial rollout proved to be spectacularly successful and the push for ADSL2 Broadband take-up far exceeded initial expectations, so the rollout was cautiously (slowly) extended to tentatively connect all the major metro CBD Local Exchange sites, then metro CBD suburbs, then metro Consumer premises and country CBD cities, then country cities, Large Towns, Towns and some Villages – in that order.

The reasoning for this rollout order was (I understand) based on Competitive Business mindset to deliberately preface business customers (because they provided significant profits for Telstra) and specifically not for Consumers because Consumer premises telephone services just break even and do not provide shareholder "value" – i.e. profits, (and increased renumeration for executives)!

Circa CE 2002 and the technology of ADSL2+ (24 Mb/s) technology became widely available, which had the potential ability to have a maximum downstream data speed of 24 Mb/s which was twice as fast as ADSL2 (12 Mb/s).

Like all competitive business arrangements; the competing telecoms businesses in Australia saw the money, crashed the Telstra party and the "gold rush" started again (like the HFC Pay TV fiasco in CE1992/3). "***Competition Wrecked the HFC Rollout***"

*(The ACCC / PC mindlessly kept praising increased competition as their only chanted answer to cause end user prices to drop. How little they know about the real world (beyond academia) – because increased competition causes engineering processes to be hastened - resulting in construction standards being dropped (commonly called "cutting corners") that in turn involves immensely expensive rework because of systemic service failures. A classical case in Australia is the creation of the NBN, that would never had been needed if the Australian Telecom Commission was never split up and corpratised. "**Privatisation Cost Far More than the NBN**"*

My understanding is that the relatively small amount of ADSL2 (12 Mb/s max) Headend equipment was transferred out of the metro (CBD) areas and re-located into some Towns and Villages (back-connected by PDH using technology-limited transmission – e.g. HCRCs with three 2 Mb/s PDH streams (i.e. 6 Mb/s max) instead of 140 Mb/s or 1000 Mb/s using point-to-point Radio or SMOF as the bearers.

Most of these Towns and Villages ADSL services were struggling to provide 6 Mb/s or 12 Mb/s because of the very limited Backhaul transmission capabilities. Ironically, because of the relatively short lengths of pair copper in the Access Networks of these Small Towns and Villages had rather short pair copper urban Access Network infrastructures that should have been well-capable of urban 24 Mb/s!

With ADSL2+ (24 Mb/s max) DSLAMs (Headends) being rolled out through most of the metropolitan areas and the large country cities, the consumer expectation (particularly from extremely/overtly optimistic and deliberately misleading competitive advertising) was that all ADSL2+ services would be at 24 Mb/s.

Even at this stage there were considerable complaints that the advertised ADSL downstream speed and the actual downstream speeds were dramatically different – and it was even then very obvious that ADSL2+ services were not being commissioned and that the Access Network was certainly not nearly "up to scratch" even for Voiceband communication let alone for Broadband connectivity.

Adding to the debacle, about CE 1999, the Gas Pressure equipment to keep paper insulated Main and Intermediate cables internally dry had been removed and this resulted in (electronically) “wet” cables looking far longer than they physically were – causing the ADSLx downstream data speeds to be far slower than common expectations – even with relatively short pair copper Access Cable lengths.

If the ADSL2+ services were commissioned, then the prime causes of these faults would have been very early identified and rectified. Clearly Competitive Business profits were far more important than providing Quality Broadband services.

With usual fanfare and flurry there were several Select Senate Inquiries, Australian Competition and Consumer Commission (ACCC), Productivity Commission (PC), Inquiries (where the sitting Senators and other stooges had absolutely zero knowledge about telecoms particularly the intricate engineering of ADSL technology). Even though witnesses repetitively told the panel members where to look and what to look for – nothing was reported and the Reports were nothing more than useless expensive journalistic waffle (with pictures for those tired of reading waffle).

Circa CE 2017 the Federal Dept. Communications (and the Arts) somehow got its hands on a total database table (that I understand must have come from Telstra) that the Dept. published on their Website showing in part the grouped downstream speeds of all ADSL services in Australia (in about 93,000 rows).

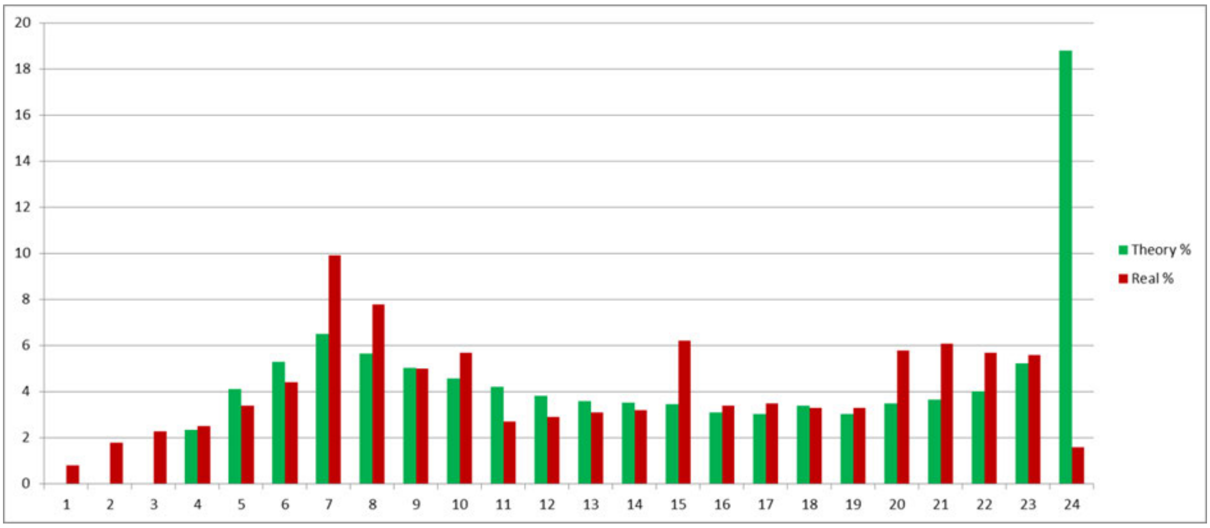
A few months later the database table was removed from their Website, and I really believe that they did not know what they had published – and really – how valuable this data was, as analysing this data would have shown the common faults and saved wasting many $Bn on unnecessary Inquiries and infrastructure.

> *It took me a few days to make engineering sense of the ADSL data as the data was directly related to specific exchange sites by their four letter code and by their District Area (DA) – which I well understood.*
>
> *From here it was a straightforward task to group the recorded data speeds for millions of real field results into a Database table that directly related to individual exchange sites by line count and downstream data speed results grouped into 1 Mb/s “buckets”.*
>
> *The next phase I wrote a (Visual Basic) software program as a front end for the database to assist analysing this information – and the knowledge about Australia’s failed ADSLx infrastructure fell out like a waterfall!*

The chart in “***Basics of ADSL and HFC***” is highly theoretical and does not relate into physical practice without knowing the geography relating to “Big City” or a “Large Town”, “Town”, “Village”, “Metro CBD” etc. in a practical sense. So I provided physical urban boundaries that directly related pair copper Access Network cable lengths (that relate with the database front end and information table).

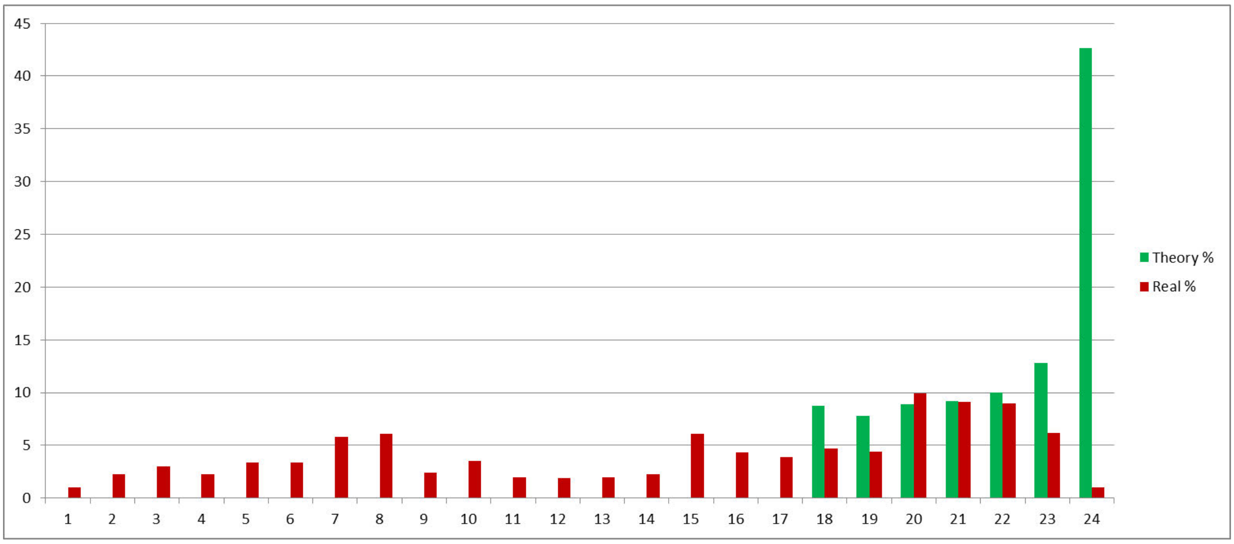
To make sense of this practical ADSL downstream information I made an ADSL2+ theoretical model of the “Big City” geography based on incremental areas relating to integer data speeds with the boundaries based on +/- 0.5 Mb/s, then I plotted both sets of information on the one column chart to look for any obvious differences.

“Big City” relates to about 5 M premises out of 7 M in total (i.e. about 70% of the total service count) where the Local Exchange is typically central to the area, the maximum line length is 4100 metres, the associated CBD surrounds about 600 to 800 metres and most of the remaining area is consumers in houses / home units.



The horizontal X axis is the downstream data rate in Mb/s (as “bucketed” speeds i.e. Integer +/- 0.5 Mb/s) and the vertical Y axis is the percentage of lines at each “bucketed” speed. My first estimation of the theoretical speeds was shown by the green bars and the speeds from the analysed downloaded data (as information) were shown by the maroon bars.

In general there is a broad correlation with some glaring differences. The first glaring difference is the very low real percentage of practical ADSL connections at 24 Mb/s. The second is the four almost level percentage bars in the 20 to 23 Mb/s range being significantly larger than theoretical expectations. The third is the percentage peak at 15 Mb/s where there is no bump in simple theory. The fourth is the percentage peak around 7 / 8 Mb/s that is substantially larger than the simple theoretical assumption. Clearly, downstream speeds slower than 4 Mb/s are out well of specification.



This next chart is characteristic of Large Towns, where in general the urban diameter is about 2.5 km so allowing a generous maximum urban cable length of 2030 metres (17.5 Mb/s minimum downstream speed), and makes for interesting charting. Again the Green columns are my theoretically expected results (as percentages) and the maroon columns are the percentages as grouped from the analysed reported data:

It is any wonder that there were massive amounts of customer complaints?

For a start there is a tail of real ADSL downstream speeds slower than 18 Mb/s – so these must all be well out of specification. Only 1% of ADSL connections are at 24 Mb/s where in theory this should be about 43%. There are also the tell-tale percentage bumps at 15 Mb/s and around 7 Mb/s like the (Big) Urban City example

Further analysis showed this scenario to be a common trend with all urban arrangements but there were several localities that had near perfect alignments with the theoretical figures. These measurements showed that in these many locations the Customer Access Network (CAN) infrastructure was in perfect condition but in the vast majority of cases there was real reason to consider that the CAN cable infrastructure was in an extremely poor condition (needing total replacement).

From about CE 1981 gradual generational technology advances replaced electromechanical (switching and transmission) equipment and consequently from about CE 1998 there was then almost zero day-to-day maintenance.

By CE 1993 Telstra had centralised most of all (switching, transmission, battery, air conditioning, doors, cable gas pressure, Test Desk / Subscribers Line Test Access Network (SULTAN) etc.) equipment alarms and remote control to both Sydney and Melbourne and in CE 1996 all these alarms (and remote control) were later centralised in to Clayton in Melbourne. By CE 1999 no exchange site had any permanent maintenance staff. “***How the SCN Economised Maintenance***”

In Telstra circa CE 1999 there was a major internal restructure to include the entire Access Network (including pair copper, SMOF, HFC cables etc. and the active equipment) into the National Network Business Unit and change its name.

My understanding is that with this merge:

- The Gas Pressure Equipment was used for the Junction and Transit Networks (that was now new SMOF technology from CE 1988 - 9, 1990 - 2 respectively) – requiring no Gas Pressure Equipment).
- The executives were fully aware (or were aloof) that the Gas Cable Pressure Equipment was vitally imperative to minimise water ingress out of lead-sheathed twisted pair paper insulated copper cables in the Access Network.
- Comparatively, the Cable Gas Pressure Equipment had now become high a high maintenance and unnecessary Cost Centre – to be removed.
- Consumer use of Mobile Phones from Radio Base Stations / SMOF was far more profitable than Fixed Telephone services using pair copper.
- Pair Copper Access telephony was to be phased out where / when possible.

It was a real no-brainer decision for the Competition Business mindset people to remove the (Access Network) Cable Gas Pressure Equipment (and its alarms etc.) because removing this equipment significantly reduced operational costs, maximised executive renumeration and increased shareholder dividends.

Consequently it was a short matter of time before there was water ingress into these very old lead-sheathed paper-insulated cables and it inadvertently pushed consumers onto Mobile Devices which were far more profitable (which also maximised executive renumeration and shareholder dividends) – at massive hidden and future expense to the Australian economy.

With an Infrastructure Business mindset, this main body of physical Access Network infrastructure mainly consisting of paper-insulated (Intermediate and Main) lead-sheathed cables should have been replaced with gel-filled polyethylene insulated technology cables and consequently not require Cable Gas Pressure equipment from about CE 1990.

Alternatively, with an Infrastructure Business mindset; from about CE 1993 (when the rollout of SMOF Transit cables in the Regional areas came to a close), SMOF would have been rolled out to replace the aging paper insulated cables and most of the premises connecting Access Network in Australia would have been FTTP (Fibre to the Premises) technology by about CE 2003 and leading the developed world. "***The Sudden Emergence of SMOF***"

Cables under footpaths are in 100 mm diameter asbestos/concrete or earthenware conduits nominally 600 mm below the surrounding ground level. When a cable crosses under a road the conduit is nominally 1200 mm below the ground surface, (600 mm below the footpath cables). Most of these conduits are not dry but moist.

With the systematic removal of the Cable Gas Pressure equipment that was in a very high proportion of Local Exchange building sites, there was then no dry gas pressure in the lead-sheathed cables to extrude water moisture. Consequently the insides of these (in the vast majority paper-insulated, and more recent polyethylene insulated) lead-sheathed cables became wet, and this excess moisture significantly worsened the transmission properties of those cables – particularly for ADSL technologies.

With the physical Access Network, in the Voiceband (0.2 – 3.4 kHz) for telephony, this significant extra attenuation and slope (relatively higher attenuation at the high end of the Voiceband spectrum) was not perceived as a major problem because the Inter-Exchange attenuation (and slope, and excessive echo) had been nationally reengineered and significantly reduced / corrected circa CE 1988 – CE 1996. "***Wiping Out Voiceband Complaints***"

Where this inter-exchange network attenuation was anything from 0 dB to 24 dB; this had been narrowed down to 6 dB (+/- 0.5 dB), the echo had been eliminated and the "slope" (muffled response) was also eliminated. To a very large degree, this massive national program was then hiding the pitiful state of the physical Access Network!

Although telephone calls were then usually very clear, the tell-tale problem (circa CE 1988) was that most Fax machines rarely connected at above 14 kb/s where they should have been connecting with at least 24 kb/s data speeds in many cases.

With ADSL2+ technology, this uses the frequency range 24 kHz to 2,200 kHz and these cables were engineered for Voiceband – so any systemic imperfection with these cables caused significant excessive transmission losses – which would very negatively affect ADSL2+ transmission performance and data speeds.

With FDM Carrier equipment (commonly using paper-insulted twisted copper quads), it was standard practice to capacity balance every pair against every other pair to minimise crosstalk between pairs in these cables. Common engineering logic – (considering that the cables were being used for frequencies up to 2,200 kHz) should have screamed out that all the Access Network cables must be capacity balanced!

My gut feeling is that those involved with the rollout of ADSL technology were totally ignorant of the fundamental transmission requirements and were focussed on very short term profit for a "new product range"!

Without Cable Gas Pressure Equipment to push dry air through Main / Intermediate cables and force out moisture, and/or without gel-filled polyethylene insulated Main / Intermediate cables; water moisture gets into these Main / Intermediate cables.

With moisture in the Access Network cables, this proved to be a national economic financial disaster, because moisture in the cables made the cables lengths appear to be far longer than they physically were. Water has a permittivity of 60 times that of dry air and electronically a length of internally wet paper insulated cable appears (in ADSL terms) about 60 times electrically longer than it physically is.

If a Main / Intermediate Cable (i.e. directly from the Local Exchange MDF) crosses under a road and that cable is internally wet for about say 18 metres then this portion of cable electronically (in ADSL terms) looks more like 1100 metres.

Adding this theoretically wet length into the Cable results in a very low proportion of CBD connections able to have 24 Mb/s and most CBD connections at slower speeds:

Access Cable Length m	Downstream Speed Mb/s	Replace 18 metres wet cable (1100 m)	Downstream Speed Mb/s
188	24.0	1270	23.0
368	24.0	1450	22.0
518	24.0	1600	21.0
648	24.0	1730	20.0
768	23.9	1850	19.0

So here we have the situation that with 1100 metres of "extra" series Main cable; the fastest ADSL2+ downstream speed (with an ADSL modem almost across the road to the Local Exchange) will be 23 Mb/s and not 24.0 Mb/s.

Consider other (urban) premises not so close to the Local Exchange (ADSL DSLAM/ Headend). Adding a few hundred metres of dry cable to the under-road wet situation clearly explains (in the above table) why premises up to about 770 m away from the Local Exchange should be getting 24 Mb/s but are getting 23, 22, 20, 19 Mb/s. This also explains why in many Town / City / Metro City locations the maximum speed not 24 Mb/s but starts at 23 Mb/s or 22 Mb/s (and a tail of much slower speeds).

Consider there are two 18 metre wet under-road wet Main / Intermediate cable crossings. In this case 18 * 60 * 2 = 2150 metres of equivalent dry cable. Now add say 20 to 200 metres of dry cable (to connect the CBD nearby premises) and the ADSL2+ downstream speed for these uses in these CBD areas is about 15 Mb/s.

Consider there are three 18 metre wet under-road wet Main / Intermediate cable crossings. In this case 18 * 60 * 3 = 3225 metres of equivalent dry cable. Now add say 20 to 500 metres of dry cable (to connect the CBD nearby premises) and the ADSL2+ downstream speed for these uses in these CBD areas is around 7 Mb/s.

As clearly defined earlier at the limit length of 4100 metres, the ADSL2+ downstream speed is 3.98 Mb/s (i.e. 4.0 Mb/s). Obviously no ADSL2+ services were commissioned - else all services connecting at lower than 4 Mb/s would not comply!

At this 4100 metre limit, with one wet under-road crossing the cable effectively looks like 4100 + 1100 metres = 5200 metres (ADSL2+ about 1.8 Mb/s). With two wet under-road crossings the cable effectively looks like 4100 + 2150 metres = 6250 metres (ADSL2+ about 0.883 Mb/s). With three wet under-road crossings the cable effectively looks like 4100 + 3225 metres = 7325 metres (ADSL2+ about 0.47 Mb/s). These figures go a very long way to explain the higher percentages of connected premises in the lower downstream data speed “boxes” of the information that was analysed from practical data temporarily available from the Dept. Comms (CE 2014).

On another front I am quite certain that there was considerable pressure from metro based real estate businesses, and major CBD building owners and other metro focussed businesses (including State Governments) to minimise fast Internet capability outside the State metro areas as this could / would impinge on their prime Capital City / metro business interests and/or cause “uncontrolled” migration shifts!
The Competitive Business mindset was the prime cause of yet another major service performance issue that seriously impacted on Australia’s economy.

At these Inquiries, the Panels were far more interested in hearing the stories told about slow Internet speeds instead of hearing about the prime engineering-based causes of unreasonably slow Internet speeds – and how to fix these problems.

The Commissioners (in particular from the ACCC and the PC) kept asking inept questions, kept praising Competition as the panacea to everything, and blanket refused to accept that all these very slow downstream data speed problems were caused by the Competition Business mindset that enforced poor engineering (by “cutting corners” like removing Gas Pressure Equipment and not replacing paper-insulated cable with polyethylene insulated gel filled cables for fast ROI (at a massive expense to Australia’s transitioning economy).

These grossly inept Reports even pushed for “increased competition” to apparently minimise the problems caused by competition! (What absolute fools!)

Put another way, the Competitive Business mindset resulted Cable Gas Pressure Equipment being removed and aged cables not being replaced – which caused ADSL2+ technology to severely underperform which in turn prevented Australia’s transitioning economy to integrate with Internet and this most probably cost the Australian economy significantly more than the total value of all Australians telecoms infrastructure.

Astounding Productivity of VoIP

Since the earliest days of Internet Protocol (IP) in the mid-CE 1970s the concept of Voice over Internet Protocol (VoIP) was part of the "Internet Connection" family and it had long been an engineering curiosity of how to do it. In reality, the first successful trial of VoIP transmission (only in a local area network) proved successful in CE 1974 and it was considerably improved in CE 1976 (but was still in a local area network), and later very briefly trialled in a mobile packet radio network in CE 1982.

There were many fundamental manufacturing process problems prohibiting the rapid development of VoIP starting with the stabilisation and standardisation of adaptive (digital stream) encoding / decoding methods (solved by the early-CE 1980s); initial high costs of digital encoding / decoding (solved by the mid-CE 1980s with A/D/A conversion on MSI technology); and then in the late CE 1980s / early CE 1990s laser trimming of some components in the MSI chip to substantially increased the processes productivity). "***Second Wave of Electronic Components***"

The fundamental problems with implementing VoIP came down to not having the Internet "fabric" able to carry / transport / switch almost consistent sets of small (priority) packets such that the resultant received packets could be converted back to clear audio – and not having the IP-based signalling to facilitate VoIP connectivity – and this is why VoIP didn't happen until after CE 2000.

Before the CE 1980s, the primary (automatic) electro-mechanical telephone switching technology had become Crossbar (introduced in CE 1960) and Crossbar was not only far less expensive to manufacture and install / commission than (automatic) Step-by-Step (SxS) and (manual) Sylvester switchboards, but the overhead costs of Crossbar technology was at least an order of magnitude less than earlier manual and automatic technologies. "***Productivity of Crossbar Switching***"

Similarly, before the CE 1960s, the primary inter-exchange Voiceband based (external plant) transmission network technology had advanced from open / aerial wire on poles to ploughed in / trenched (pair copper) Loaded Cable. Although the capital costs of ploughing / trenching / burying / conduiting cable was far more than aerial wire, the maintenance costs were orders of magnitude lower than aerial wire transmission. "***Highly Economic Underground Cables***"

Before the CE 1980s, medium and long-haul (Voiceband-based) FDM technologies had become the primary medium/long-haul transmission technology because solid-state electronics was at least an order of magnitude lower maintenance overhead than earlier thermionic valve technologies. "***Massive Productivity of FDM***"

Even by the early CE 1980s data transmission via the telecoms network infrastructure was fundamentally limited to using the Voiceband switched network as the common network connection between distant premises.

The early CE 1980s were synomonous with the widespread proliferation of PDH transmission and the introduction of AXE digital (Voiceband) telephony switching technologies. The incredible productivity of AXE (compared to Crossbar) was hindered until the developed production costs of analogue / digital encoding / decoding technologies became inexpensive. "***Digital Voiceband Technology***"

Although 2 Mb/s PDH transmission technology proved to be massively productive compared to its predecessor as Loaded Cable, competition was the prime mindset cause that by CE 1983 had totally wrecked the previously very high Junction and

Transit network connection reliability. This situation was potentially looking to be extremely expensive to repair. "***Competition Wrecked Australia's 2 Mb/s***"

The urgent discovery of Single Mode Optical Fibre (SMOF) technology (April CE 1986) was nothing short of phenomenal and the extremely rapid rollout of SMOF throughout Australia very quickly proved to be far more economic (cheaper) than any other cable technology. "***The Sudden Emergence of SMOF***"

In parallel with Digital Voiceband encoded streams, as used with AXE digital switches (circa CE 1981) concurrent with PDH transmission, was the general and slow transfer / advancement of Channel Associated Signalling (CAS) technology in switched / transmission circuits towards Common Channel Signalling (CCS7) that was mostly fully integrated solved by the early CE 1990s. "***Transitioning to the Digital Network***"

The late CE 1980s also heralded the widespread introduction of Common Channel Signalling (CCS7) to largely change the way that telephone (and other circuits) have their call connections established, held and dropped out. The versatility of CCS7 technology provided a range of telephony-based products that were otherwise literally impractical. "***Amazing Productivities of CCS7***"

By the early CE 1990s literally all coaxial, quad and pair copper cable (and many point-to-point radio hops) used for medium / long-haul inter-exchange transmission had been very inexpensively replaced by remarkably reliable, very wide bandwidth and amazingly low attenuation per unit length SMOF cable technology.

While Voiceband telephone-related switching and transmission based technologies now had dramatically lower overheads than circa CE 1980, data transmission had also gone through a parallel transformation where Telegraphy by the late CE 1960s had morphed into Telex, which had been abruptly replaced by Facsimile technology in the early CE 1980s. "***Telegraphs to Telex to Fax***"

In the CE 1980s, unlike (long-held) Voiceband telephone calls, data had morphed into high-speed data packets that included in the header of these data packets: inter-network address and protocol control data, that facilitated these data packets (datagrams) to be extremely inexpensively passed through interconnected data networks by using the then new technology of (programmable) Switches and Routers.

Most telecoms executive management were totally aloof of his rapid rise in Internet-based communications because this was using the telephone infrastructure with dial-up modems.

With the traffic volume of Internet traffic exponentially rising to potentially exceed that of telephony traffic the total volumes of telephone and (Internet) data traffic became too large for PDH transmission technology to reliably handle. "***PDH Was Not Stable Enough***"

Fortunately the new transmission protocol of SDH was a perfect fit for SMOF as a transmission medium – with a far greater bandwidth to very cost-effectively transport PDH and ATM / IP traffic over pre-existing SMOF. "***Immense Productivity of SDH***"

With the emergence of the Internet suite of protocols (TCP/IP) in the late CE 1970s, this data intensive technology was exponentially growing and by about CE 1998 needed direct and substantial connectivity; meaning that Voiceband long-held call technologies using Voiceband channels were not practical – and Broadband premises connectivity had become an imperative.

The big change came in the late CE 1990s with the morphing of CCS7 into Session Internet Protocol (SIP) which facilitated a virtual path to be prioritised for packets of digital Voiceband confetti to be transmitted and combined and the final destination(s). "***Amazing Productivities of CCS7***"

One of the (more recent) technology advancements was to prioritise a data packet set and this could become practical if the network as not operating in severe congestion (which was the case until the early CE 1990s when the long-haul transmission data speeds dramatically increased and SDH technology became widespread). "***Immense Productivity of SDH***"

Even by the late CE 1990s, VoIP was impractical as a general Voiceband replacement technology, because there was not a sufficient Broadband IP Core Network infrastructure.

The development of the IP-PABX technology was solved by about CE 2001 as the availability of reliable and fast enough Internet connectivity beyond the premises and through the telecoms Access and Backhaul / Core Network (solved from about CE 2002). VoIP technology had its first practical application in "Asterix" IP-PABXs in CE 1999 and followed by Skype in CE 2003 (before Microsoft purchased it).

It was not until about CE 2002 that the Core Network (which is basically a nationally tiered arrangement of Switch / Routers distributed around Australia's geography to facilitate fast Internet connectivity) emerged as the physical replacement for Voiceband Switched connections.

So this series of technological developments took about 25 years to be practical.

Not only was this "better mousetrap" technology far less expensive to manufacture but the MSI chips were considerably smaller than the earlier technologies – which also meant that the amount of circuit board real estate required was far less.

By the mid-CE 1990s literally all printed circuit boards very extensively used surface mounted components and circuit board production was no longer manual but a fast / slick virtually fully automated production line. Even fully fleshed circuit boards for personal computers / laptop computers could be manufactured by the tens of thousands per day (where before they were by hundreds) – and the same story for telecommunications equipment – that had fast-moved to be fully digital and very compact and all solid state!

Because of these continual emerging technology advances in electronic equipment manufacture; the cost of computing hardware had plummeted and now software was emerging as the technology to "sit on". This now inexpensive hardware and make it subordinate to the strings of mainly IP-based software commands and instructions.

As mentioned before, the conceptual technology of VoIP had been around for a couple of decades, but the computing / switching speeds to slow to work with VoIP – and there was not the IP network that could be used as the carriage (medium) for transporting VoIP without considerable transmission problems.

With ATM having then finally merged into IP; and SDH having "containers" for large (IP) data packets to be transported in this digital transmission infrastructure it not only became practical to utilise VoIP but in the process this technology would considerably reduce the telephony traffic dependency on PDH as the prime telephone traffic bearer technology. "***PDH Was Not Stable Enough***"

My understanding is that the very well established long-term (primarily USA-based) telecoms equipment manufacturers / providers had found themselves in a technology wedge – where their equipment manufacturing factories (basically by then in China – using slave labour) were long-term geared up to manufacture PDH transmission equipment and digital telephony switches.

Because of the immense political power these multi-national organisations had in the USA they used the Federal Communications Commission (FCC) as their stooge to stifle the approval of VoIP technology advances as they re-positioned their own business models to maximally profit while forcing the competition into very expensive extended delays.

So – in the USA – competition stifled productivity as the FCC had (under instruction) declared that VoIP was not phone service but an information service – but any telecoms businesses using VoIP had to have a connection to the emergency services – effectively making VoIP a telephone service! This deliberate political entanglement literally stifled the rollout of VoIP for some years until about CE 2002.

> *For two years CE 1997 – CE 1999 I worked as a Bid Manager in Nortel (Networks) Corp in Australia, which was a rather large and continually growing Canadian originated multinational telecoms equipment manufacturer then employing over 37,000 people worldwide, with many office and several factories distributed around the world.*
>
> *In San Francisco there were then two (rather small in comparison to Nortel Corp.) similar-sized rather new IP technology equipment manufacturers: Bay Networks and Cisco, with an almost identical product range.*
>
> *Nortel Corp. already had a limited range of IP Switches and Routers and they needed to rapidly increase their IP product range to advance from their very well established DMS100 / DMS400 ranges of telephone digital switch and IP technology (based in Canada / USA), their "Meridian" range of PABX equipment (based in France) and their long-haul transmission equipment (based in the UK), plus other lines of telecoms equipment.*
>
> *With the (then) rapid growth in IP-based technologies, in early CE 1999 Bay Networks was totally bought out by Nortel Corp. to include their IP based products into Nortel's product range and include VoIP PABX technologies plus an extended range of Switches and Routers.*
>
> *In mid-CE 1999 there was a big economic downturn in South-East Asia that heavily impacted Nortel's business resulting in hundreds of "ex-pats" being sent back to their respective countries. The area I was in (Alternate Operators) would be very over-staffed - so several of us were made redundant on very short notice (about 5 minutes)!*
>
> *Very shortly after this, the highly experienced Executive Directors of the now Nortel Networks made a monumental mistake in collectively handing*

over their roles to the inexperienced Bay Networks Executives while the experienced Nortel Executives collected massive exit payouts.

Overnight and rather unexpected, Nortel Networks became temporarily insolvent, contracts had to be cancelled, production temporarily halted, masses of staff were laid off resulting in a tidal wave of stopped processes that in turn cancelled more contracts.

Nortel Networks had no option but to stop its then current rapid growth and sell off its extensive patent collection and manufacturing equipment. Nortel Networks very quickly shrunk back to its Canadian (Toronto - Ottawa) base where it writhed in death throes until about CE 2010 when it deceased altogether.

In hindsight of the implications with Bell Corp. and the FCC (and VoIP technology) I have very little doubt that the very rapid demise of Nortel Networks Corp. in CE 1999 was a direct target of the executives in Bell Corp. and the temporary insolvent situation played into Bell Corp.

Because of the wide range of user facilities available with VoIP-based IP-PABXs this technology quickly replaced the standard (now quickly aged) telephone based (hard-wired) PABXs. A single Personal Computer (PCs) became the IP-PABX workhorse central component instead of a rack (or more) of switches and/or circuit boards with telephony interfaces, exchange line interfaces and tie-line interfaces.

The simplicity was that the Cat5 (category 5) wiring network used to connect personal computers could very easily be slightly extended to connect an IP Extension Phone beside the computer, and the phone was locally powered so not only did the number of extension phones considerably increase - but every desk was a totally functional “workstation” with full communications facilities.

By about 2003 virtually all Commander (key-switch) extension phone systems and PABX equipment was replaced by IP-PABX technology, where a sizable chunk of the printed circuit board in the PABX extension phone was used for analogue / 64 kb/s encoding / decoding (just like that with line interface cards in telephone exchanges).

The problem was that the Access Network was still analogue and physical (and/or 2 Mb/s ISDN) and this was a sticking point – but the writing was on the wall that all this analogue / long-held call / PCM telephone technology would become SIP/VoIP technology in the not so distant future!

Western economists put these gradual and continual technology developments down to being competition driven – nothing could be further from the truth! In general Engineers do not see profits from a competitive market as a prime business focus, but are continually curious as to how to gradually improve technologies so the productivity is increased. (This is called “building a better mousetrap”!)

VoIP technology in fact grew “backwards” from the IP-PABX concept where, each extension telephone had its own analogue / digital interface and an IP address and (manufacturer’s) Media Access Control Address (MAC), and in reality the IP-PABX was a programmable Switch/Router.

The traditional front-end of the IP-PABX was an bank of Analogue Termination Adaptors (ATAs) to connect with telephone circuits into the Local Exchange (or Indial lines) – but the realisation was that the IP-PABX could directly call / answer / talk / listen / disconnect via the Internet (using Service Internet Protocol (SIP)) and another IP-PABX could then be addressed through the Internet – and the two IP-PABXs could directly communicate!

With this SIP/VoIP breakthrough thoroughly ironed out it then became possible and practical to give a (telephone) Service Number an IP address (and MAC) instead of connecting with a long-held switched circuit – connect with a series of short-held IP packets under control of the SIP (which are in themselves IP packets).

This conceptual breakthrough set the course for telephone circuits (i.e. connected phone numbers) to be IP port addressed (with the MAC) instead of hard-wired physical addresses – and exchange number ranges to be assigned to IP address ranges – which enabled number portability and provided the in-house natural flexibility of IP technology to automatically route calls (establish call paths) over the Internet "fabric" instead of long-held logical switching.

Now – all telephone calls could be transferred to SIP/VoIP and "connected" through the Internet fabric of Routers and Switches (that have no moving parts) and the whole Inter-Exchange (telephony-based) network then moved to being a ubiquitous Internet Core fabric that is extremely reliable and very low overhead – and the Internet connection that we used with our computers etc. all use the same infrastructure! Oh – yes GSM3 Mobile Phone technology also uses SIP/VoIP on the one ubiquitous IP Network! SIP/VoIP is an astoundingly efficient technology!

From the early 1990s the concept of Voice over Internet Protocol (VoIP) was a pipedream and it took until 2003 before Session IP (SIP) was invented; providing the connection control that VoIP needed.

The marriage of these two IP technologies (VoIP/SIP) opened the floodgates for physically switched long-held call telephony to be replaced by bursts of priority IP that as a wholesale product uses far less network bandwidth – and facilitated the concept of a unified Internet based Core Network instead of dedicated digital switches based on Voiceband 8 kb/s streams.

Digital mobile phone services using GSM1 then GSM2 were Voiceband technology disasters. GSM3 using VoIP was fast-tracked into service with a resounding success that catapulted Mobile phone technology into everyday use.

The cost savings in using VoIP were immense and this facilitated the blanket removal / replacement of most of the pre-existent (PDH-based) Inter-Exchange Network to be quickly and very inexpensively replaced by a unified IP network "Core Network" that very inexpensively utilises unified Internet technology for "everything".

So why did this VoIP technology rollout not happen in the Regional Rural and Regional Remote areas? (This is not a rhetoric question!)

Competition Wrecked Australia's Cable Internet

From about CE 1980 the need for interconnecting Internet technologies were rapidly rising and by circa CE 2000 Australia's telephony-based Access and Backhaul / Core networks were far from providing the necessary data transfer speeds that were imperative to support Australia's fast emerging digital economy as the backbone for Australia mining, farming, grazing, manufacturing, production and service industries.

Many commercial and family premises were connecting with Internet but the realisation was that Internet speeds had to be a lot faster than could be provided by dial-up technology through the Voiceband telephony (max 0.056 Mb/s, typically about 0.014 Mb/s to about 0.024 Mb/s).

The real reason for these horrendously slow speeds was not the technology of the modems but the incredibly poor state of the twisted paper insulated pair copper cables in the Access Network. Usually the problems were in the Main cables (leading from the local exchange) - passing under a road (about 1200 mm below the road surface) resulting in water ("moisture") inside these cables. "***Competition Wrecked Australia's Pair Copper***"

Downloading a Website page had to be virtually instant (i.e. not take 30 seconds plus, so the downstream speed (in CE 1995) had to be over 10 Mb/s.

The engineering search was on to discover new methods to transport Internet at speeds exceeding 10 Mb/s through the existing Access Network and considerably more Internet connectivity through the Backhaul transmission (connecting to the Local Exchange Broadband Line Access equipment and Core Switch / Router equipment and their associated transmission Networks.

Both ADSL over (urban Access Network) pair copper and a new technology of Hybrid Fibre Coax (HFC) were very strong contenders to Fibre to the Premises (FTTP) – because the then cost of electronically interfacing fibre strands was very expensive making FTTP financially uneconomic.

With consideration that Pay TV uses coaxial cable, and with the inclusion of SMOF technology this new Hybrid Fibre Cable (HFC) technology has a far greater economic geographic coverage and the concept of a "Cable Broadband Router" came about circa CE 1990 (as did ADSL) but this went through several development stages and surfaced about CE 1996 with the Data Over Cable Service Interface Specification (DOCSIS) that had general agreement. "***Basics of ADSL and Cable Internet***"

In Australia - this DOCSIS 1.0 (Cable Internet) technology quietly started to be rolled out from CE 2000, a few years after the ADSL modem fiasco started. Typically a DOCSIS 1.0 Cable Broadband Router could connect up to about 1500 end users' Cable Modems (at the premises ends) and on average provide about 33 Mb/s downstream and about 0.5 Mb/s upstream.

There was another real problem – ADSL was being rolled out in fierce competition including lots of very expensive marketing and advertising overhead costs (that the end user has to pay for in having higher-priced bills) but Cable Internet was much faster than ADSL that in turn was much faster than Dial-Up connections to Internet!

Instead of an orderly roll out of ADSL Digital Line Access Multiplexers that directly attached to the pairs in the main cables – where mass production techniques would have minimised the installation time and maximised the installation Quality and provided a common background for ADSL speeds on known and common cable lengths – it was rolled out in fierce competition. So – not only were ADSL2+ service spread all over many Access Network Main / Intermediate cables from the one DSLAM2+, but there were different brand DSLAMs (owned by competing service providers). In many cases the downstream speeds were "throttled" for a variety of reasons - including late payment of bills! "***Competition Wrecked Australia's ADSL***"

Circa CE 2000, both Telstra and Optus installed a considerable bank of Cable Internet Broadband Routers at their Pay TV Headend locations (one headend location per metropolitan State Capital city). With tech savvy people, word travelled like wildfire that Cable Internet was available and Cable Internet was far faster than ADSL technology. Seriously, I cannot recall any advertising for Cable Internet - so it was literally all by word of mouth!

Not so much as a whisper from the Sales and Marketing people in Telstra and Optus! This must have been the quietest and least expensive advertising campaign I have ever seen (or heard) – there was nothing (and I looked for the advertising)!

Within a year of rolling out Cable Internet over HFC infrastructure, every metropolitan city was stuck with a much bigger problem – because the Broadband Routers were all located in geographically central Headend exchange sites (one per State Capital City) there was now extremely limited room for expansion to take extra Broadband Routers at these Local Exchange sites!

Compounding this problem; because of fierce competition in the rollout of the HFC Pay TV infrastructure in CE 1993 -1994 without considerable rework of the HFC street infrastructure very few more premises could be connected with the existing HFC street cables / amplifiers etc. – without considerable street rework! This HFC network was an engineering disaster. "***Competition Wrecked Australia's HFC***"

The Federal Government had already received years of persistent complaints from a large majority of the population regarding the extremely poor state of Broadband infrastructure in Australia. In its inept stupidity, the Federal Government had raised several Select Senate Inquiries and Regional Inquiries that had gone from nowhere to oblivion and achieved even far less (and I attended many of them – and as a witness on several Inquiries too).

It was painfully obvious that the Senators etc. knew precious little about telecoms engineering. So the questions and answers were essentially extremely simplistic. Any topics that went into any of the engineering went "through to the keeper" and the administration staff were (are) basically journalists – so virtually zero of any technical / engineering content was included in any of these Reports.

As a direct consequence these Inquiries and Reports cost Australia several $$ Billions per month in lost national productivity, lost potential economic growth and a massive import bill of equipment, products and services that could have very easily been made in Australia by Australia, for Australians…

The Federal Government and Opposition had however realised that Australia as a competitive commercial country had to quickly transfer its business and accounting processes to be electronic (if those companies and infrastructures had not already done so) and that Broadband connectivity (by fast Internet) was an absolute imperative. If the Federal Government did not act to fix it then that ruling party would be in opposition from the next election. (Now politics call this "long term"!)

With it now painfully obvious that telecoms infrastructure competition was a totally failed policy that neither sides of Federal Government could wind back without a massive backlash from the WTO / IMF / USA. The then Federal Government (with a “big stick”) approached Telstra for them to prove that they can provide Broadband to the nominal 6 M metropolitan premises – and do it in the very near future (i.e. the political “long term” – before next election) – or face dire consequences!

Telstra had its Cable TV network covering about 80% of the metropolitan area, and they (under pressure from Foxtel – who had bought into Telstra) were gradually increasing the Telstra / Foxtel footprint to be much closer to 100% metropolitan coverage. Telstra also had metropolitan geographically centred exchange sites in every State Capital city – and these exchange sites were now full of Cable Routers – enough to service only about 1 M metropolitan premises on HFC!

Telstra could see “nationalisation” or “real competition” staring them down the Board Room, and this situation could not justify their immense renumeration packages! Telstra executives finally realised their dire situation (that Telstra may be nationalised and they as directors would be the private sector laughing stock). Their remaining network Engineers were then corralled in to find a way to provide the essence of Broadband capability for (up to) 6M metropolitan premises – using HFC technology.

The basic engineering answer was to de-centralise the Broadband Routers from the single exchange locations in each State Capital City and re-locate these Broadband Routers to the 400 Local Exchange sites in Australia’s metropolitan areas. Building out (four) extra racks in all these sites would provide the space so that the number of Cable Broadband Routers could be increased by five times (to potentially bring the number of Cable Internet connected homes up to nominally 6 M).

To do this would also require a complex SMOF network of diversely routed pairs of SMOF technology backhaul connections to the new Core Switch/Routers provided a highly scalable Core Network that could handle far more traffic than ever before. Nationally this was a $2.4 Bn programme that had to be done very quickly.

> *In 2005 – 2006, I was in Silcar (now part of Thiess Services) when this project came up and I transferred from Admin to being the Project Engineer – where I very successfully managed the Sydney Metropolitan equipment rebuild into 124 local exchange sites at a cost of about $670 M – including the building of a completely new totally geographic diverse duplicated SMOF-based Broadband Transit Network infrastructure throughout all of the Sydney Metropolitan area.*
>
> *There were significant local management jealousies that I innocently triggered in becoming the Project Engineer. The technical staff that I was “given” were deliberately hand-picked because of their general non-performance and I could tell that this project was intended to crash around me. Further, I was also assigned several sub-contracting businesses that were consistently late and/or lazy and generally not responsive.*
>
> *It took a few weeks of valuable time to focus the sub-contractors, and reorient the “given” technicians to be highly proactive and work to Quality processes. This time proved to be very well spent and it all became a very well self-driven, slick team that became highly enviable. Over the next 12 months I went to most of Telstra’s Sydney metro exchange sites to monitor and optimise the build processes.*

Very fortunately, the Kingsgrove (Sydney) Silcar Drawing office included a very experienced tech Blake Warren (whom I knew from Telecom many years before) and he was now expert in identifying where the equipment should be best positioned. This gave us a very good lead for preparation drawings (with nearly no re-work) and we were continually operating more than two weeks ahead of where Telstra's programme was up to!

Telstra's commissioning process was highly recursive – so I re-engineered this process with the Telstra engineers to be non-recursive and taking less than 30 minutes, where before this process took several hours.

Because of internal management jealousies, I could not co-ordinate all the SMOF cable labels to be automated from our Drawing Office – resulting in thousands of labels being manually generated, and costing an immense amount of valuable project management / process time.

My focus of this massive national programme was (always) well ahead of activities, and my area was also under budget and there were no problematic ASBUILT complaints from Telstra engineering throughout this entire project. Keeping the project aligned in Silcar was not that easy!

With this programme complete (and all fleshed with (old version) Modem/Routers), Telstra engineers were more than aware of the mess that their HFC infrastructure was in. Telstra executives then approached the Federal Government telling them that they (Telstra) potentially had the infrastructure connectivity for 6 M Cable Internet connections in the metropolitan areas to consumers in premises.

Instead of tasking Telstra to (immediately) connect all these premises to Cable Internet (using the highly flawed Pay TV infrastructure that was mortally damaged by fierce competition when being installed several years before), the Federal Government (again very ineptly) waved the problem of lack of Broadband Internet connectivity for the vast majority of the metropolitan premises! Telstra was "let off the hook" and did not have to connect any more Cable Internet customers!

Had Telstra been instructed to connect the potential 5 M customers not connected by Cable Internet, then this would have been an "interesting" issue because (my estimation) over 95% of this remaining Cable TV infrastructure was incapable of actually connecting – but fully capable of "being passed" (as the advertising said). "***Competition Wrecked Australia's HFC***"

By about 2010 the immediate problem was that the DOCSIS1 Cable Broadband Routers had passed their end-of-life maintenance. Telstra and Optus had little option but to replace all their Cable Broadband Routers (about 1400 of them) to keep the Cable Internet infrastructure working. So now these DOCSIS2 Modem / Routers were capable of 100Mb/s downstream, which was effectively the top end of the proposed new NBN Corp downstream speeds.

Some years later (circa CE 2015) the NBN Corp was in the process of connecting Broadband to all metropolitan premises – and the notion (because the intended FTTP strategy worked out to be far too expensive) was to use the HFC / Cable Internet infrastructure as the "inexpensive" strategy. Against my strongest advice to the then Minister Malcolm Turnbull, was that the NBN must not pay Telstra and Optus fore this HFC / Cable Internet infrastructure that was in a pitiful condition.

My reasoning was that this infrastructure was in a pitiful state of repair. It never was any good because of the very expensive competition-caused engineering problems as a direct result of fierce competition back in CE 1992/3/4 when that Pay TV access network infrastructure was never properly commissioned; but very rush installed. "***Competition Wrecked Australia's HFC***"

The NBN was instructed to purchase the Telstra and Optus HFC / Cable Internet infrastructure and the NBN paid very dearly. In my professional opinion, the NBN should have been paid very well by Telstra's and Optus's to take it off their hands.

Circa CE 2017, not long after the NBN engineers got into setting up this infrastructure to provide Broadband to the vast majority of metro premises, they found out that the Optus HFC infrastructure was a "cost centre" shambles (and useless) and that the Telstra HFC infrastructure was not much better.

As a direct consequence the NBN Engineers immediately stopped the DOCSIS / Pay TV rollout as they very quickly became highly aware that in merging these highly duplicated network infrastructures – both had major network design problems (totally caused by competition) and that the entire street-based Access network would have to be totally re-engineered to make it reliable (and useable). "***Competition Wrecked Australia's HFC***"

This re-engineering process cost the NBN (and Australian productivity) about 12 months delay – and in the process NBN realised that the proposal to roll out 100% Cable Internet was highly flawed – and that most of the low maintenance components of this existing network infrastructure were underground – not on poles! Telstra had its HFC network's remote nodes underground in Service Pits.

In the intervening time while the HFC infrastructure was re-evaluated for possible re-use as a reliable Broadband Access infrastructure, the technology of Remote Nodes using VDSL technology became viable. So NBN engineers checked out the last 400 m of existing pair copper cable used in the Internet and found that this was mainly plastic insulated (not paper insulated) and it was in fair / reasonable condition.

It was considerably less expensive for NBN to reuse the (polyethylene insulated pair copper) "Outers" and "Drop" part of the existing pair copper Access Network and provision VDSL Headends in remote parts of the Access Network – back-connected by SMOF technology and get far more reliable Broadband connectivity!

So – the rebuild of Australia's Cable Internet (DOCSIS3) technology by the NBN was far more considered as it merged the two highly duplicated Pay TV street cables and wherever practicable the NBN engineers put the cable in the (Telstra) underground conduits.

> *In talking with an NBN Service Tech, in Burns Road, Turramurra in March CE 2020; he informed me that the long-term intention is to put all the power-pole strung-up cable in underground service conduits. I seriously doubt that will happen!*

This rollout was far more "considered" as VDSL technology with remote Node street cabinets was a "cheaper" solution in the majority of cases – so the number of DOCSIS3 Cable Broadband Modems did not have to be significantly increased – but a considerable amount of Coaxial cable lead-in work had the be totally re-done and in many cases – installed so that "pockets" of metropolitan areas that could not be economically connected by the much cheaper VDSL technology, could be instead connected by coaxial cable DOCSIS3 technology instead.

When the NBN rollout of Cable Internet happened, instead of re-using the recently purchased DOCSIS2.0 Modem / Routers; the NBN policy was to dispose this equipment and introduce a new “Arris” brand (ex-Nortel Networks see before) Cable Modem and introduce Router / Wi-Fi / Switch / ATA (Telephone port) that was company specific to the Broadband contract.

So – not only was this equipment “different” for each service provider, but the value in “Economy of Scale” was totally lost.

The massive inefficiencies introduced by insisting on competition were astounding (unnecessarily costing many $Bn extra in internal accounting) but the external efficiencies lost through insisting on infrastructure competition has economically set Australian business and communities back at least five years if not a decade, and this can be counted in the hundreds of $Bn as many thousands of Australian business could not remain profitable (or even exist) because the Broadband infrastructure had not been available / reliable / inexpensive and fast.

Competition Scuttled Australia's Broadband

The introduction of Broadband Internet in CE 1998 came like a Sandstorm with several years of warning (back to at least a decade before with the rapid development of dial-up Modems and Fax machines, the acceptance of the ISO 5 layer model for computers communicating, the rapid acceptance of TCP/IP suite of transmission protocols, the proliferation of bulletin boards, Hypertext (HTML) and Extended Markup Language (XML) and email technology, and early Websites. "***Digital Connectivity Converged into Internet***"

Most of the Executives / Directors in Telstra (at least) were living in the past of the Fixed/Mobile Telephone era – and the wage structure was loosely based around Telephone Services count – and Broadband was seen as a wild distraction from (Voiceband) Telephone services based in 4 kHz (64 kb/s) channels.

Back in the mid/late CE 1970s Telecom Research Labs (in Melbourne) were (world) leading development of the Plesiochronous Digital Hierarchy (PDH) recommendations (in the CCITT now called the ITU-T). One of the outcomes was Australia's use of 2 Mb/s PDH to carry 30 Voiceband (telephone) channels as Integrated Services Digital Network (ISDN) where the rest of the developed world used parts of the 2 Mb/s band (and that proved a failure for them). "***Highly Economic PDH Transmission***"

The Digital Radio Concentrator System (DRCS) that connects over 14,000 Voiceband Services in Regional Remote Australia is based on 1.5 GHz point to point (wideband) radio that carries up to 22 multiple 2 Mb/s PDH streams that are in turn back-connecting NEC Line Concentrators to provide fixed access telephone connectivity. This technology was developed in Telecom Research Labs in the late 1970s and rolled out in the early 1980s – before SMOF technology. "***HCRC Technology in Remote Australia***"

2 Mb/s ISDN as a Voiceband block proved to be a perfect fit into Private Automatic Branch Exchanges (PABXs) for commercial and government businesses and enterprises as two pairs of wires (less than 1830 metres long) in the Customer Access Network (CAN) carried 30 Indial (Voiceband) circuits instead of using 30 pairs of wires. As most PABXs were in major city Central Business Districts (CBDs) the nominal maximum pair length is less than 1000 metres and this ISDN service connected from the middle of the Local (Digital) exchange Switch to the middle of the PABX – so the speech path was "perfect" with virtually zero interfacing equipment! "***Massive Productivity of 2 Mb/s***"

The really simple fix for the low-latency Voiceband telephone in the Regional Remote areas is that with NBN Commission in place (takes about 3 weeks), hand over all the (Telstra) DRCS equipment and associated staff from Telstra to the NBN Commission – and immediately stop paying Telstra the $177M+ (now $233M with the ??) M pa Gravy Train.

Reconfigure the DRCS (Backhaul connection) as per my engineering plan (takes about a year) and use (NBN) Fixed Wireless as the standard CAN technology to all Homesteads in the Regional Remote areas – yes some Regional Remote Homesteads will connect with FTTP!

Another technology advancement came in the mid-late 1990s with the development of very fast Routers (of which the CSIRO had a lot to do with, as well as Wi-Fi).

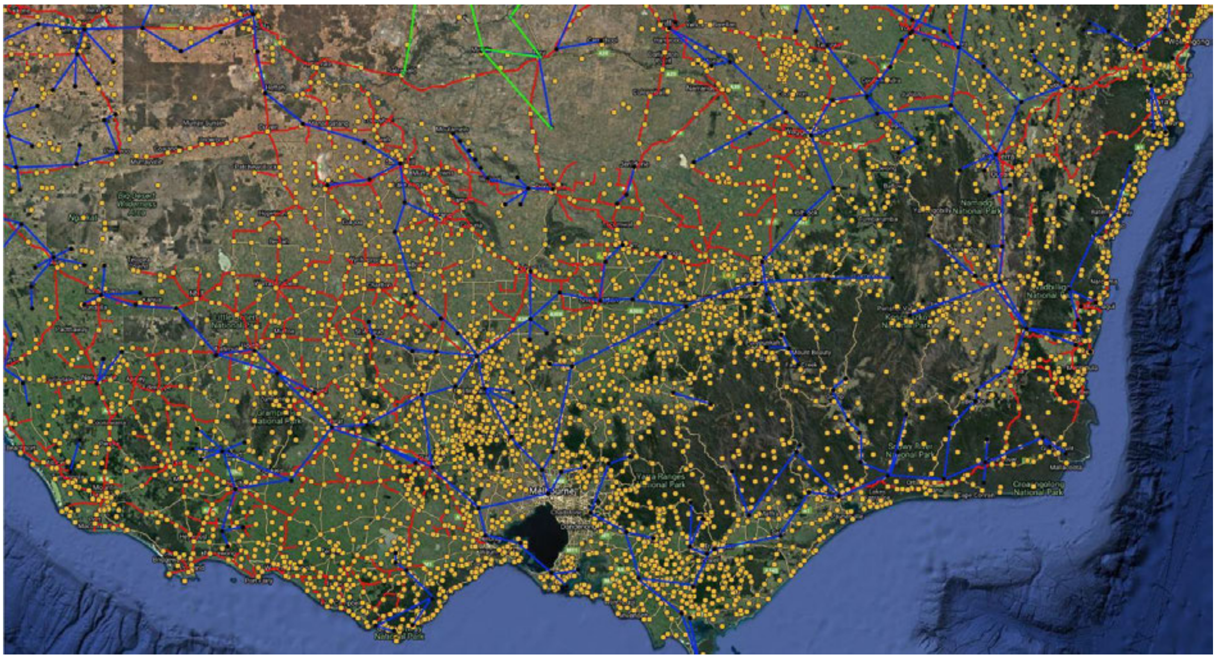
The economic pantomime is playing out (again) like a child's pantomime with our Reserve Bank looking to lower interest rates in foolish belief that this will kick-start the Australian economy into a glorious recovery. IT WON'T! The Australian economy has been the and as usual

With privatisation of Australia's telecoms infrastructure, the focus abruptly moved from providing the best fit for purpose telecommunications equipment available for each situation / location; to providing maximum "shareholder value" – at the expense of Australia's economy – particularly outside the metropolitan areas. "***The Davidson Inquiry and Report***"

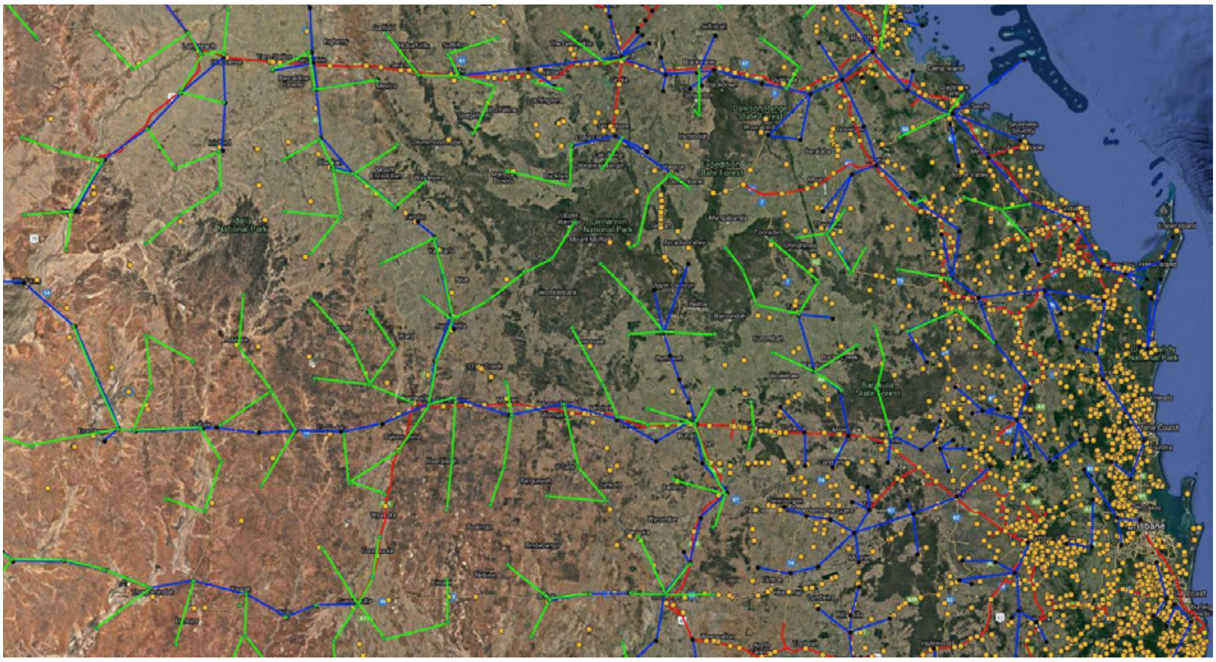
This privatisation farce would have failed but for a few technology advances that literally "saved the day" for the private sector – and the Governments / Ministers etc. are far too compromised to re-nationalise this infrastructure for the good of the Australian economy.

Competition Manifested Radio Black Spots

A recent "Radio Black Spots Report" (CE 2020) showed there are over 13,400 Regional locations primarily along major (and minor) roads where (3G) mobile phones apparently drop out because of low signal strength.



This is a map of Victoria and a bit of south NSW showing the reported Radio Black Spots as orange dots. The red lines show the paths of a high proportion of existing SMOF cables in the Regional areas, point-to-point radio hops are blue lines.



The above map is of South Queensland and it paints a similar picture to that of the Victorian map. The green lines are HCRC / DRCS point-to-point radio hops.

In almost all cases, the orange dots are on roads and are grouped and in many cases are very close / overlapping!

My educated guess (from working in Telecom/Telstra National Network Investigations for more than a decade) is that most of these reports are from a few people (maybe 200), most of the reports are on roads (i.e. in their cars) and these reports are geographically bounded for political advantage (i.e. Rorts / Grants for fostering election of candidates).

The other interesting observation is that many of the 3G "black spot" points are located very near existing HCRC / DRCS and other point-to-point radio masts! Intuitively, it seems that the thinking is that "where there is a mast (of any sort) there must be 3G mobile radio strength – so this is a Mobile Black Spot"!

It seems that nobody has actively inquired as to why there are so many "Radio Black Spots" – and why privatising the Australian Telecom Commission has not proactively addressed this issue. After all, it was the Federal Government(s) that privatised the highly efficient sub-Government Commission circa CE 1980 - 1990 – on the behest that the private sector – in competition against itself would be far more "efficient" in providing considerable better telecoms infrastructure and services at considerably lower prices (neither happened). "***The Davidson Inquiry and Report***"

Like many beforehand eras, transferring from a well-established transmission / switching technology to a more economic transmission / switching technology is not an overnight process, but takes several years. Fixed Access (analogue) telephone services (with ring down / loop disconnect signalling) had been around for over a century and were (and still are) heavily engrained in our living culture.

The take-up of mobile phone technology was extremely fast – but it took more than a decade of continual development before the GSM3 ("3G") mobile telephone technology (which incidentally uses VoIP technology) became generally accepted with a good-enough voice reception.

The fundamental massive economical advantage in converting to VoIP as per the GSM3 ("3G") mobile phone technology was that VoIP bridged the conceptual switching problem where the standard telephone call was essentially a Long-Held Call / Connection and Internet connectivity is a series of Short-Held Calls / Connections. VoIP is effectively a series of very short held connections using Internet Protocol (IP) over the physical bearer. "***Astounding Productivity of VoIP***"

Because of fierce rivalry between competing telecom service providers to provide 3G mobile device connectivity to a limited market it was obvious that the vast majority of the Australian population and 3G Radio Base Stations are centred in the Metropolitan Cities, with Regional Australia being a very poor second.

Consequently the competing Service Providers have multi-duplicated their (3G) Radio Base Stations at common locations in the metropolitan areas and have virtually nothing outside these metropolitan areas.

Apart from the massive extra cost of advertising / marketing / sponsoring to get / hold a physically limited market share – (which, economically, really drives up customer costs) – this multi-duplicated rollout of expensive 3G/4G etc. Radio Base Station equipment in engineering terms has to be the most inefficient scenario possible for Australia's economy.

There is a very high amount of (totally unnecessary) multi-duplicated equipment and network structures throughout the metropolitan areas and the severe lack of (3G/4G) Radio Base Stations outside the metropolitan areas. The only winners re those manufacturing and selling this equipment to competing service providers - and nothing beyond the tower structures is manufactured in Australia! "***Competition Disconnected Rural Australia***"

There are 124 exchange sites in Sydney (a metropolitan area) and 400 exchange sites in all Australia's metropolitan areas – and there are nominally three Radio Base Station locations per (metropolitan) Exchange site – so that comes out at about 1200 Radio Base Station sites for metropolitan Australia. Now include say three competing 3G Radio Base Station Service Providers at each of these sites. This is now 3,600 sets of Radio Base Station equipment sites, and each site would have nominally 6 directional antennae or about 21,600 sets in total of Radio Base Station equipment and associated antennae in the metropolitan areas.

Remove the totally unnecessary multi-duplication totally caused by highly inefficient competitive infrastructure and this leaves about 3600 * 2 = 7,200 totally redundant 3G/4G Radio Base Station antennae / equipment that end users are paying considerably extra for to facilitate competition – with compromised connectivity!

According to the Radio Blackspots programme there are about 13,400 non-metro locations of which about 50% may be real and the others are duplications – or about 6,700 locations that may need 3G Radio Base Stations for continuous connectivity.

If these superfluous 7,200 Radio Base Stations were relocated to non-metropolitan areas then the Radio Black Spots Program (Rorts) would be annihilated – except for Backhaul Network connectivity to connect these out-posted Radio Base Stations!

As a direct result of the intermittently failing 2 Mb/s Regenerators (caused by the Competitive business mindset), the rather extensive Regional "Transit and Trunk" network of pair and quad copper cable was totally replaced from about CE 1989 through to about CE 1993 at great expense by a very extensive network of buried SMOF cable (particularly in Victoria, lesser in NSW and rather thin in the other States), to interconnect regional cities, towns and villages. "***Competition Wrecked Australia's 2 Mb/s***"

At that time, the use of Fixed Access (network) telephones was plateauing, data use was rocketing but not "seen" by network planning engineers (who were still highly focussed only on telephone services) and there was immense commercial (Competitive Business mindset) pressure to minimise all Telstra's etc. overhead costs – and maximise shareholder dividends at the expense (opportunity cost) of radically improving Australia's telecoms infrastructure.

The Regional "Transit and Trunk" network rebuild process mainly involved the replacement of aged pair copper cable (CE 1950 – CE 1970) with SMOF cable technology that was ploughed (about 1200 mm) underground, to keep these cables very low maintenance. In most cases these SMOF cables had only 6 fibres and the main route cables had only 12 fibres. "***The Sudden Emergence of SMOF***"

The rollout and ploughing in of SMOF cable in Regional areas was completed by CE 1994 and it only took a couple of years before it started to become painfully obvious that the number of fibre strands was far too few to transport Telephony (and Radio Base Stations for Mobile devices), and the Service Control Network (SCN) and the fast growing Internet backhaul infrastructure. "***Competition Disconnected Regional Australia***"

(This mindset of only 6 fibres per cable was a very short term strategy – if any term at all. It is interesting to note that most Management people stuck in Recession mindset and people in "Commercial Engineering" (Sales and Marketing) have very short term goals and virtually no planning for future growth or new technologies.)

Looking at this economic problem another way; the extremely short-sighted and incredibly inept private sector competitive / recession mindset strategy of rolling out 6 fibre SMOF cable (instead of 36 or 72 fibre cable) in most of the Regional areas was a classic example of why the private sector (i.e. competition) should never be involved with infrastructure at any decision / operational / management level.

Further; it made absolutely no economic sense to have a minimum number of fibres when the SMOF fibre cost is small in comparison to the SMOF cable sheath cost, and the SMOF cable cost is very small in comparison to the ploughing process.

In bulk, a solid construction 6-fibre cable costs about $1.60 per metre, a 12 fibre cable costs about $1.80 per metre, a 24 fibre cable costs about $2.10 per metre, a 36 fibre cable costs about $2.40 per metre. Ploughing and associated costs sum up to about $20 to $30 per metre plus the cable cost: i.e. about $22 to $32 per metre!

In a lateral sense, having 6 fibres in a SMOF cable was possibly reasonable as two pairs could transport 30 + 30 Voiceband channels using 2 Mb/s PDH and there are two spare fibres. In connecting Regional cities using 140 Mb/s PDH over a pair of fibres could provide 1920 Voiceband (telephone) channels and still this left "plenty" of spare fibres! Internet connectivity was certainly not considered at all!

Until at least CE 1996, Forward Network Planning (engineering) was almost totally engrossed in "telephone circuits" and this planning area had no concept that data use was absolutely rocketing (even though it was typically about 4% of the total network usage in CE 1986). Like the Internet / Data; Mobile phones were also effectively seen as "another low use network" and the concept of the Service Control Network (SCN) – actually within Telecom / Telstra, was not even considered at all until about CE 1990 – and even then had a virtually zero profile until about CE 2000.

In line with non-metropolitan Telephony being an (internally accounted) commercially non-profitable line of business it made absolutely no competitive business sense to roll out ADSL2+ or Mobile Phone technology outside the metropolitan areas and the major Regional cities. There was however a strong moral sense (driven from numerous damning Regional Reports) to reluctantly roll out technology limited Radio Base Stations in Regional Cities and some Towns – and some highways.

The sunken costs of these infrastructures would far exceed the short term (< 2 years) expected Return on Investment (ROI) – so, commercially, these technologies would need some other "incentive" (like a Government Incentive/Grant) to make these infrastructures palatable to the shareholders!

As it was, the Davidson Report had already stipulated that the Federal Government in privatising Telecom Australia Commission would provide a very substantial (Universal Services Obligation – USO) funding of no less than $177M pa (indexed to the CPI) to the new "Telstra" (from CE 1989) to fund all Regional / Remote "telephony" (read as "telecommunications" in these days but literally taken for its documented word as "telephony"). So "telephony" somehow did not include "mobile telephones"! "***The Davidson Inquiry and Report***"

My understanding of the USO was that this "Rort" was to unofficially fund the rollout of the DRCS/HCRC Regional Remote telephone infrastructure (then costing about $471 M) and in the process make the new telecoms corporation "look" to be financially stable and therefore a good Superannuation investment. The USO should have terminated in 1985. "***HCRC Technology in Remote Australia***"

In keeping with the Federal Government continually feeding the private sector to make it "look efficient" – another "Gravy Train" was launched called the "Radio Black Spots Programme"! The ignorant intention was to ensure that people travelling on main roads would have (3G) Mobile Phone radio coverage – but in no time this was deliberately extended to cover any situation on any road – and aligned with politically sensitive votes for Parliament seats. In other words – "this is another massive Rort".

Even though most non-urban Regional tarred roads have SMOF cable alongside, the prime reasons for not having considerable 3G Radio Base Stations along these roads is that basically almost all of these SMOF cables have only six strands and there are no available SMOF strand pairs for 3G Radio Base Stations to be back connected into. "***The Sudden Emergence of SMOF***"

The basic engineering thinking was: two (or four) fibres are for connecting to an out-posted Telephone Exchange running 2 Mb/s for a Pair Gain System or switch (e.g. an AXE 104) and two spare fibres in case of growth of a fibre breakage. Since the inclusion of the Service Control Network (SCN) – that takes up two fibres (running 10 Mb/s IP) and/or is part of a Virtual Private Network; and/or that pair is running 10 /100 Mb/s IP on a backhaul connection to an ADSL2+ Modem/Router at that exchange site – there are no spare fibres! "***How the SCN Economised Maintenance***"

It is very unsurprising that the projected costs for installing remote Radio Base Stations under the Radio Black Spots (Gravy Train) Grants process has been substantially "bumped up" to (apparently) cover the cost of re-ploughing in more (thin) SMOF cable using 6-strand SMOF cable as the prime transmission medium.

With the general transfer of analogue telephone services circa CE 2002 to start using VoIP as the Voiceband transmission technology and Session Internet Protocol (SIP) to steer / control the call connection; this set an entirely different and highly economic strategy for providing 3G Radio Base Stations in remote locations and in the process minimise the amount of fibres needed to make network connectivity.
"***Re-Connecting Regional Australia***"

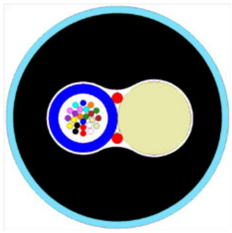
Competition Disconnected Regional Australia

With the weight of the Davidson Inquiry and Report (CE 1980-1982) kicking in, it quickly became obvious that the Federal Government(s) were on the path to privatise at least the Telecom Australia Commission - primarily to pay off massive Government debit - caused by businesses and corporations in Australia that had “legally minimised their tax obligations” – resulting in massively underfunded Consolidated Revenue. “***The Davidson Inquiry and Report***”

Circa 1980, Telecom had already introduced the then new digital technology of PDH transmission before the Davidson Inquiry, and Telecom was in the process of introducing AXE digital switching – both of which were highly synergetic and very low maintenance technologies. “***Highly Economic PDH Transmission***”

The serious lack of an inexpensive long-haul wide-bandwidth bound-transmission medium was the major problem. After a decade of solid research in this area TRL (in Melbourne) miraculously solved in in mid-April CE 1986 with the birth of Single Mode Optical Fibre (SMOF) technology! It was not well understood that the Syd-Mel SMOF PDH-based transmission link used the prototype 31 fibre cable technology, this SMOF cable (and PDH repeaters etc.) were rush-installed and fully operational by November CE 1987. “***The Sudden Emergence of SMOF***”

The cross section as shown on the right is what I believe to be very similar to the structure of the “prototype” SMOF cable used in the Syd-Mel SMOF cables PDH transmission network.



By CE 1989 the technology of SMOF cable engineering was well past “proof of concept” and well into “large scale manufacture”.

Worldwide standard manufacturing practice (i.e. large scale production) quickly became that of 12 fibres in a sub-tube and multiple (e.g. 6 or 8 or 12 sub-tubes in a cable – with plastic rods instead of sub-tubes if the cable was not manufactured to its full capability. The diagram on the right is a not-to scale depiction of this standard SMOF cable construction

This cross section above right depicts a SMOF cable that has three sub-tubes of 12 fibres – therefore 36 fibres where this SMOF cable would be capable of 72 fibres. A cable such as this is suitable for direct “zero tension” ploughing, has an outside diameter of 14.8 mm and a drum would usually contain 4,000 to 10,500 metres.

Most of the cost is in the strainer and sheathing (which is typically about $2.00 per metre). This cost is far greater than the SMOF strands that are typically less than $0.02 per metre (and less in bulk). Not only is SMOF cable technology at least an order of magnitude less costly as coaxial cable (with interstice quads), but the coaxial cable usually comes in 500 m drums – resulting in far more (expensive) joints than what is required with SMOF technology.

In the Regional areas there were three fundamental engineering problems that were considerably aggravated (i.e. made much worse) by the Competitive Business mindset.

The first problem was/is a severe lack of SMOF strands in the Inter-Exchange Network (IEN) / Backhaul cables that were ploughed into Australia's Regional areas circa CE 1990 – CE 1993 to replace coaxial cable, quad copper cable, point-to-point radio and pair copper cable – particularly where 2 Mb/s PDH regenerators (on pair copper cable) were causing intermittent 30 channel dropouts. "***Competition Wrecked Australia's 2 Mb/s***"

Circa CE 1990, all forward network planning was based on the incremental increase in telephone circuits and the growth of (fixed access) telephone services in the Regional areas had flattened out. Concurrently, virtually all data services were Voiceband (and therefore grouped with Voiceband telephone services) – and these data / fax services were then insignificant and lumped inside telephone services, and the number mobile phones (about 500,000 in Australia at that time) were rapidly expanding but fundamentally Metropolitan focussed and based, and really did not count in the Regional forward planning process. "***Competition Manifested Radio Black Spots***"

In the "background" Telecom/Telstra had been privatised with the clear focus on maximising shareholder dividends and executive renumeration – which directly translated to minimising and overhead / planned costs that did not have a short-term high return on investment (ROI). So the role of Forward Network (engineering) Planning was severely truncated to focus on projects in the near few years that would provide the highest ROIs – and most of these were in the Metropolitan areas, not the Regional areas! "***Short-Sighted Competitive Directions***"

SMOF transmission bearers showed tremendous productivity with 30 Voiceband channels per pair of fibres (in the Metropolitan Junction Network replacement process) and in most cases these 6-fibre and occasionally 12 fibre Junction cables could be rather quickly rodded and roped through existing under-footpath conduits. "***Massive Productivity of 2 Mb/s***"

The technologies of the SMOF cables used to replace the Metropolitan Junction Network were nominally 6-fibre and occasionally 12-fibre, and were also capable of being directly ploughed. So my educated guess is that the same technology cables (with nominally 6 fibres and occasionally 12 fibres) were extensively used as Regional Transit of 2 Mb/s transmission to replace existing pair copper cables; matching the 2 Mb/s backhaul circuits being used in these Regional areas – and do this as fast as possible to eradicate the problem of intermittently dropping out 2 Mb/s regenerators on pair copper cable. "***Competition Wrecked Australia's 2 Mb/s***"

As a direct consequence of the very short term planning (apart from maximising shareholder dividends and excessive renumeration for executives), the Regional SMOF infrastructure was/is critically short of fibres leaving virtually no "room" for other transmission systems and/or alternate network routing to minimise network congestion (between major metropolitan centres) and maximise network connectivity outside the metropolitan areas. "***Short-Sighted Competitive Directions***"

A reason may have been the possible shortage of SMOF strands at that time because all around the world there were SMOF cables being manufactured and rolled out as fast as possible to capitalise on this new technology. As I best understand it Australia had multiple SMOF cable manufacturers including Standard Telephone and Cables (STC), Prysmian, Alcatel and possibly Olympic, and as I understood it these cables were being manufactured from the ground up – not just assembled as they mostly are these days (using imported SMOF strands).

I find it very difficult to understand why most of these SMOF cables had only 6 fibres in them when they could have had at least 12 if not 36 or even 72 fibres for a very small increase in overall build cost (including ploughing – which is the big ticket item). With the introduction of remote monitoring and control of all telecoms equipment from a common location (circa CE 1996), this technology used a closed Internet structure and in this process used up spare fibres in these cables – particularly in Regional areas. So – in most situations the Regional areas had no spare SMOF strand pairs for future growth. "***How the SCN Economised Maintenance***"

In the late CE 1970s, along with the fast growing technology of Large Scale Integration (LSI) came the development of single chip microprocessor technologies that would by the mid CE 1980s shake the telecoms world like never before. These technologies took several years to develop, but as they did, they started the transformation towards the "paperless office" concept – where everything was saved in memory / databases and not on paper records/cards. "***Productivities of Electronic Databases***"

Other concurrent LSI developments in the early CE 1980s included the compact and inexpensive Dial-up modem (as a single LSI chip). By the mid CE 1980s it was becoming obvious that data transmission was becoming a major telecoms product (along with the emergence of mobile devices). Fax machines had become the total replacement for Telegraphs and Telex / TRESS, and Emails plus Bulletin Boards (the early versions of Websites) were starting to become quite common office tools. "***Telegraphs to Telex to Fax***"

Although Voiceband communications worked quite well, a tell-tale issue was that with Fax machines, where the maximum data speed was 56 kb/s (with a zero length Access Network line at each end). The expected data speeds very rarely exceeded 32 kb/s and in most cases the connection speeds were in the order of 14 kb/s. So – something was wrong and it was not blatantly obvious (even to the technical experts). If you were in a Homestead then the Fax data speed would be struggling to exceed 5.6 kb/s. "***Competition Wrecked Australia's Pair Copper***"

There was and still is a fundamental misunderstanding that most Homesteads are not "Consumers" but in reality are "Small/Medium Businesses" but this knowledge never got through the Davidson Inquiry, and certainly never got through to the Telecom Corp. senior executives – because this does not fit the high usage / high pay / high profit "business model" that is commonplace in metropolitan CBDs.

The Competitive Business consideration that Homesteads needed to have the same connectivity as metro CBDs was absolutely laughable. Homesteads were seen as (the ultimate) "cost centre" and the Davidson Report backed this up with the USO to ensure these fringe dwellers continued to have a minimum standard of (just) working telephones! Had the four engineers (who had no telecoms experience/expertise) chairing this mock Davidson Inquiry been honest, they would have put the priority on all Homesteads to have considerably better telecoms infrastructure connectivity than small businesses in the metro areas! "***Davidson Inquiry and Report***"

Hence the $177 M pa CPI indexed USO to finish off rolling out the DRCS/HCRC technology in the Regional Remote areas and in the future plough in new cable / point-to-point radio to transport digital backhaul transmission to back-connect the Regional Rural exchange sites. The USO was intended to (financially) be more than enough to make the soon to be privatised Telecom Commission look good when floated on the ASX – and temporarily get the Federal Governments somewhat out of their Consolidated Revenue debit situation. "***Davidson Inquiry and Report***"

The second problem was that almost all long-haul transmission is capital-city centric and this severe shortage of SMOF cables (and long-haul transmission) that cannot inter-Regionally connect outside / bypass metro State Capital cities is now a major National Security issue. "***Competition Wrecked Australia's SMOF Rollout***"

> *When working in the Telecom Commission in March CE 1986 as a Class 1 Engineer (with 19 years very wide experience as a Technical Officer) I was part of a group discussion about the NSW Regional network structure. We were standing around a rather large map of NSW on a mapping table and it was rather obvious to me that "all transmission systems led to Sydney"!*
>
> *So I posed the question that if Sydney had a major incident (e.g. earthquake / fire / bomb etc.) then how would inter-Regional connections stay working? The unexpected answer was that those calls would use another exchange site in the CBD (even the metro) and it wouldn't be a problem! Then I put my hand over "Sydney" and said "They can't – this is blocked – there is (hypothetically) no transmission through Sydney"!*
>
> *The ensuing discussion was anything but pleasant as I had clearly really upset the senior / supervisory engineering hierarchy who had probably never had a "junior" person ask the obvious heavy / real question.*
>
> *Seeing that this was getting rather uncomfortable I picked up a ruler and used it as a staff to indicate that it would be quite practical to run a transmission system from about Toowoomba (in Qld) to about Shepparton (in Vic) – through about Dubbo – Parkes; and use this to not only bypass Sydney but provide a loose mesh for direct inter-Regional connectivity.*
>
> *Everything went very quiet, some people walked away and I was led to an office where I was then tasked with designing the (then highly mythical) Mel-Syd Single Mode Optical Fibre (SMOF) network – and moved to an area away from most people!* "***The Sudden Emergence of SMOF***"

With the earlier long-haul technology of FDM it was highly effective to pick up Groups (12 channels) and Super Groups (60 channels) and in State Capital City CBD Exchange sites directly cross-connect these with Group Extension equipment – so that different Regions had direct Voiceband connectivity without Trunk Switching in the State Capital cities. This could not be done with PDH as there was no equivalent short-haul PDH interface equipment. The alternative was that many 2 Mb/s circuits were permanently locked up through AXE switches to provide the equivalent cross connections. "***Productivities of FDM Extensions***"

Fundamentally there are no physical (SMOF and/or point-to-point Radio) inter-Region cross connections that physically do not pass through the State Capital City backhaul network. With Internet connectivity – this technology heavily relies on alternate path routing. These inexpensive opportunities are left wanting.

With consideration that there are several Regional localities that are either on the State Border – or adjacent and/or within say 50 km of each other – it makes absolutely zero common sense that these localities are not cross connected to provide alternate path routing. "***Digital Connectivity Converged into Internet***"

The third problem is that a very high percentage of Main and Intermediate cables in the Regional (city, town village) Customer Access Network (CAN) have had water ingress for many decades and the paper insulation that was standard technology when these cables were buried / installed in the CE 1930s – CE 1960s has to a large degree rotted. While this situation only mildly affected Voiceband telephone use, it had a major negative effect on Fax and data transfer speeds and was the critical problem when it came to using this very aged network infrastructure for ADSL connectivity and the ADSL downstream speeds in particular were severely crippled. "***Competition Wrecked Australia's ADSL***"

The concept of ADSL started in the early CE 1990s but like all technologies it took over a decade for ADSL2+ technology to mature and start to become a widespread Broadband technology. By the early CE 2000s, ADSL2+ was capable of providing a nominal maximum downstream speed of 24 Mb/s on 0.40 mm pair copper less than about 900 metres and this would have been a perfect Internet technology connection stepping stone for all Towns and Villages. "***Basics of ADSL and HFC Broadband***"

Circa CE 2017, the Dept. Comms (temporarily) put on their Website a composite Excel workbook detailing the downstream speeds of a virtually all ADSL services in Australia. I wrote a Visual Basic front end and analysed this data and displayed a vast amount of information that showed where and in what grouped situations (but not why or how) Australia's ADSL performance was so pitiful.

It was surprising to see from these records that in many of the Regional localities with ADSL2+ Digital Service Line Multiplexers (DSLAMs) installed in these small towns / villages where all the premises are within 900 metres and should have had 24 Mb/s downstream; the maximum downstream speeds were typically 20 Mb/s to 22 Mb/s or 13 Mb/s to 15 Mb/s (and a lot slower). "***Competition Wrecked Australia's ADSL***"

There was no way that ADSL2+ could ever provide reasonably good data / Internet connectivity (i.e. data speeds exceeding 12 Mb/s to Homesteads with pair copper because the distances well-exceeded 4 km – and physically bonding pair copper would have involved field expertise that had been then recently discarded.

As already outlined there is overwhelming evidence that the Main and Intermediate cables leading out from the Local Exchanges in most cases are wrecked because of water ingress – so ADSL2+ is not viable. It is now rather clear why Telstra deliberately came up with a non-complying Broadband Tender – so they would not have to re-build the Main and Intermediate cables they had deliberately let fall into an unrepairable state of maintenance. This should have been the fuse for Telstra (and all the other competing telecoms businesses in Australia) – to be mass nationalised.

In my professional opinion, the aged and rotting pair copper Access Network should have been totally replaced by SMOF technology from about CE 1995 onwards. The underlying problem was-is that Telstra as a private sector competitive business has problem

The causes of all these problems came down to the privatising of Telecom Australia Commission and the consequences of putting a Competitive Business mindset into an Infrastructure Business. "***Infrastructure Business - Competitive Business***"

With serious consideration that Regional Remote areas (Localities / Homesteads / Villages / Towns / Cities) now desperately need (and would use) fast and reliable Broadband (Internet) connectivity, Australia's economy was again in the crucible of

Competitive Business where Infrastructure Business was the correct mindset. The technology of Satellite connectivity in Regional Remote had been around since the CE 1980s with Australia being “coerced” with then AUSSAT P/L into purchasing a Hughes Satellite (including the enormous launching and control costs) from the USA but this was strictly analogue and extremely expensive. With more recent advances in satellite and digital technologies it became an economical possibility for satellites to provide Broadband (Internet) connectivity (providing there were thousands of remote earth stations to cover the continuous expensive operational costs. “***Satellites Prove to be Highly Uneconomical***”

By CE 2005 with the then solid emergence of SIP/VoIP network connectivity (primarily as in GSM3 mobile phone technology) it was very fast becoming obvious that the network efficiency of VoIP far exceeded that of long held calls that was standard technology for over a century (via the Inter-Exchange (Backhaul) Network). “***Astounding Productivity of VoIP***”

Way back in the late CE 1970s, the then Federal Government engaged with the then Telecom Australia Commission to initiate an economic technology to provide about 13,000 terrestrial telephony services to people in the remote parts of Australia. The brilliant outcome by TRL (circa CE 1978 – CE 1985) was the development and manufacturing of the High Capacity Radio Concentrator (HCRC) with over 900 radio masts and very extensive 1.5 GHz point-to-point radio network with multiple (22) * 2 Mb/s streams to interconnect and connect with NEC telephone line concentrators to provide telephony. “***HCRC Technology in Regional Australia***”

Even though Telstra has been paid the (Davidson Report) USO “gravy train” of $177 M pa (indexed – now worth about $233 M pa) absolutely nothing has been done (in all these years) to re-engineer this extensive infrastructure (which I have recently been very reliably informed the masts are in excellent physical condition) to very inexpensively transport IP (say at 1 Gb/s) and provide the back-connectivity for 3GSM, VDSL, Fixed Wireless. Instead, in some Remote locations ADSL had been reluctantly provided at 6 Mb/s (3 * 2 Mb/s PDH) maximum!

What this chart (above right) clearly did not take into account was that the pre-existing (and very reliably reported to still be in excellent mechanical condition DRCS/HCRC towers and associated huts etc.) can be very inexpensively re-engineered to replace the 1.5 GHz point-to-point radio equipment (transporting nominally 22 +* 2 Mb/s PDH) with 1.5 GHz point-to-point radio equipment transporting nominally 350 Mb/s to 2,000 Mb/s IP thus providing an extremely inexpensive backhaul connectivity throughout the Regional Remote areas of Australia. In the above chart, this line would sit (well) under the purple straight line!

This 1.5 GHz based vast inland IP infrastructure could then be very inexpensively back-connected by “Edge Routers” at several Regional City points to provide inexpensive / fast / reliable Backhaul Internet connectivity for Fixed Wireless / 3G / 4G / 5G Mobile and FTTP / FTTN connectivity to well in excess of 13,000 Regional Remote Homesteads and Urban premises (at nominally 100 Mb/s bi-directional).

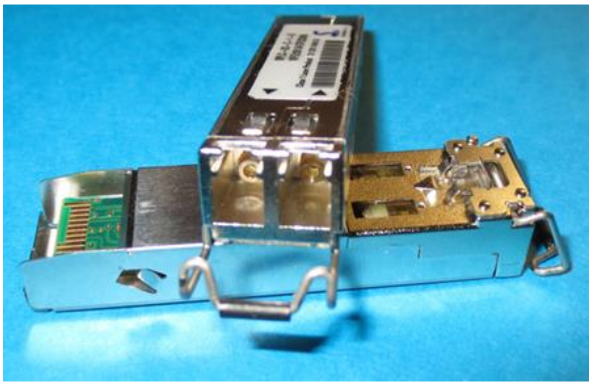
There were plenty of IP Edge Routers in the Metropolitan areas - thanks to the rebuild of the Cable Internet infrastructure (CE 2005) to have geographically diverse routes to the then two IP Switch / Router Centres in each State Capital City. “***Competition Wrecked Australia’s Cable Internet***”

Because GSM3 mobile phones use Internet connectivity, the GSM3 Radio Base Stations needed to be back-connected to an (IP) Edge Router – and Edge Routers need to be solidly back-connected into the (IP) Core Network. This 1.5 GHz backhaul network would very inexpensively solve the problem of a high percentage of Radio Black Spots in Regional Remote Australia. "***Competition Manifested Radio Black Spots***"

The Regional Australia Core Network connectivity problem is that every State has two geographic IP centres that are (both) in the State Capital City. So there are literally no geographically diverse routes because both the IP centres are both in the one State Capital City. From virtually all Regional areas the Core Network is (still) a **tiered star** structure where the Hub is the State Capital City!

Regional Australia desperately needs several regionally located Main Switch Routers (in all the larger Country cities) that are mesh interconnected by high capacity (many multiple 10 Gb/s IP on SMOF with typical regenerator spans of 50 to 100 km).

From about 2005, the concept of a Small Form Profile (SFP) Optical Fibre interface component has revolutionised the connection of IP with SMOF cable being able to be virtually directly connected with a printed circuit board assembly.



This picture shows a couple of SFP modules – top and bottom. These very inexpensive and highly reliable.

The SFPs include their own electronics to interface with optical fibre – which simply plugs in the front!

An SFP module simply plugs into a SFP socket that is mounted on the main printed circuit board.

There is an old saying "a stich in time saves nine (stiches)"! When we look at the cost of the NBN and the cost to the Australian economy in not having excellent Broadband connectivity for almost 20 years – that financial chest to push into privatisation was (and remains) extremely expensive to the Australian economy. Externally costed, this Competitive Business mindset was crippling to Australia's emerging Broadband / Internet economy relating with Regional Australia; costing many $$Billions (far more than the total cost of the NBN). "***Competition Cost Far More than the NBN***"

Satellites Prove to be Highly Uneconomical

The concept of flying over an area to get a much clearer picture of the geography has long been our jealousy of watching birds fly. The use of the then new technology of aeroplanes in WW1 (CE 1914-1918) to do reconnaissance on a foreign territory / army etc. positions was in its “baby steps” and was well-developed by WW2 (CE 1939-1945) where it was standard practice in WW2 to have aerial photography of foreign territory using bomber and spy aeroplanes.

Engineering advances in the CE 1930s-1940s with far higher frequency transmission technologies were another world away from the then standard AM radio receivers and mainly Voiceband equipment used in telecoms. At these far higher frequencies, resonating electromagnetic fields behave much like a skipping rope and a bouncing ball – which introduced a whole new line of electronics radio technologies (including at least the travelling wave tube (TWT), klystron, waveguide, Yagi / log-periodic / parabolic (reflector) antennae, cyclotron, Smith Chart etc.) that made very high and super high frequency transmission possible and practicable.

At super high frequencies (over say 1,000 MHz) the electromagnetic field can be “beamed” – introducing point-to-point radio and (Doppler) radar and the radio-telescope – all of which are highly technologically related.

During WW2 there was the research had development of large unmanned rockets carrying explosives in the head for the purposes of bombing another geographic area / country over a rather long distance. The Germans were using this technology at the end of WW2 (circa CE 1945) to deliberately target London (England) over a distance of about 80 to 200 km away.

These rockets went towards the stratosphere before returning to earth. It was not so obvious that a two or three stage / section rocket (with very large disposed rocket engines and fuel tanks) could use the small remaining stage as a prime (extremely expensive) espionage tool if this could continue travelling / orbiting around the world (at a relatively low altitude) and relay television pictures of (mainly) foreign lands and intercept / relay radio transmissions for “security” and communications purposes!

The technology of satellites as an international espionage / spy tools was almost untouchable and in the CE 1950’s “Cold War” both the USA and the USSR put an immense amount of their financial and labour resources into rockets / satellites and long distance point-to-point radio, television and optical lens technologies.

Because of this totally unnecessary intense competition (particularly in the USA to stave off “utilities” (infrastructures) being owned by their Federal Government), the overhead costs were (and still are) enormous. These costs spiralled well out of control with both countries needlessly wasting far more than their financial “reserves” and now almost 70 years later the USA is in a far worse financial position owing untold $$trillions to the private sector “Federal Reserve”! This has left a few incredibly wealthy families that literally control both sides of the USA Government (at all levels) and all the pollies dance in step like little puppets – praising “competition”!

With the availability of inexpensive colour photography by the CE 1960s, many Australian farmers had aerial shots of their properties to far better understand how the land could be best managed. Similarly, the use of (high) altitude very high definition photography was a prime international espionage tool.

It also became possible to in the CE 1960s use an incredibly expensive three stage rocket and position a geostationary satellite about 35,768 km above the equator as a radio relay station that could “see” almost half the world. The prime purpose of satellites is for telecoms connectivity and the (political) cover use is for international espionage – by intercepting and monitoring transmission.

The “Space Race” that the USA took up against the USSR in the CE 1960s onwards was in reality an extremely desperate attempt at the tail of the Cold War by Industrialists / Bankers in the USA who were/are fanatically showing the rest of the “western (European)” world that their (anti-communist) economy in the USA was the one and only way to efficiently run an economy – by exclusive private enterprise!

As Australia had signed the ANZUS Treaty (CE 1953) and so Australia was then politically and industrially subordinate to the USA and literally had to “follow orders” – including privatising the Telecom Australia Commission infrastructure - which by the mid CE 1970s was considered to be one of the best - if not the best telecom infrastructure in the world (including the USA) – and ironically – the Australian telecoms infrastructure (“utility” in USA language) was a 100% Federal Government owned Infrastructure)! “***External Control from the USA***”

Under the ANZUS Treaty, the USA military set up a substantial Satellite tracking station in Pine Gap (NT), midway between Uluru (Ayres Rock) and Alice Springs. This Satellite tracking (controlling) station is purely military (for the USA) and with its associated orbiting surveillance satellites has a close watch on Asia.

For several years Australia was coerced (pushed) by the USA to invest in satellite technology. It is “interesting” that the AUSSAT / Satellite Division was deliberately split out of OTC as AUSSAT P/L in 1981; who “ordered” a satellite in CE 1982 - which was a Hughes brand (from the USA of course) - that went into service in CE 1985 to provide military, and civilian communications including TV and Voiceband for Regional Remote communities.

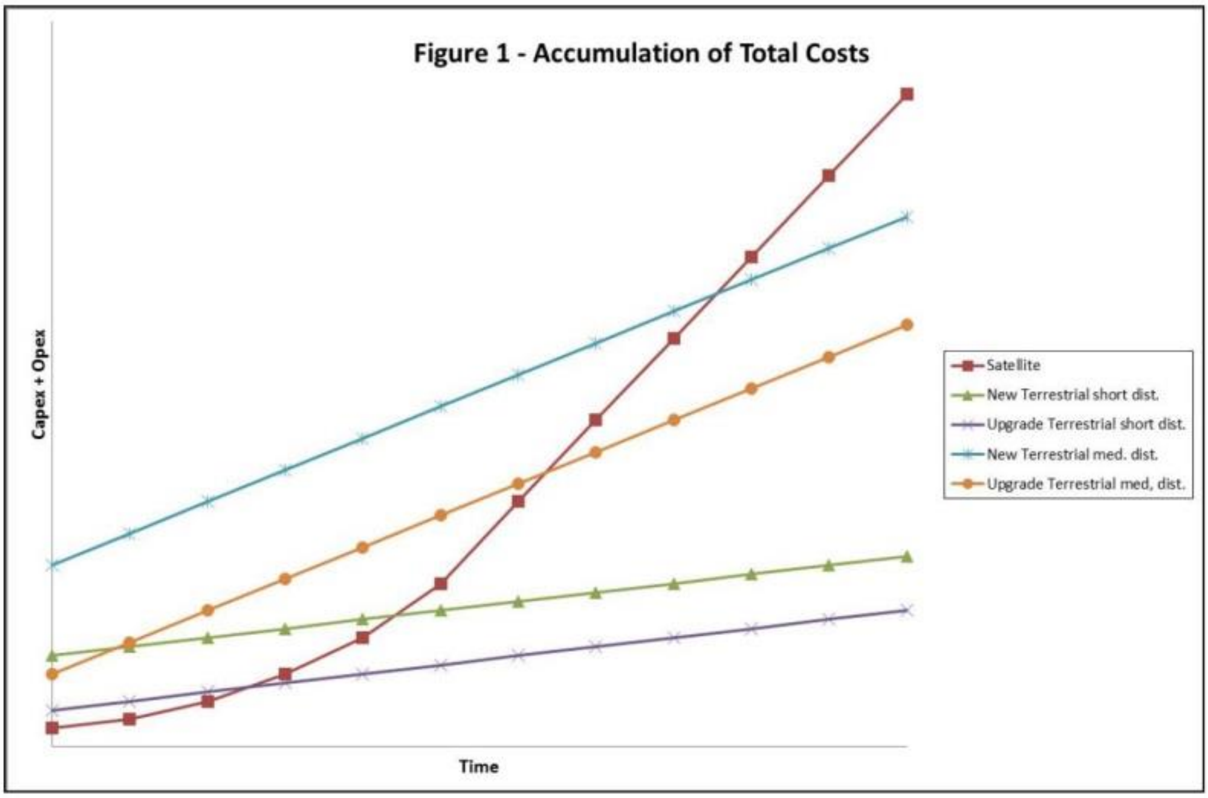
This satellite had a main Earth Station in Scorsby (Melbourne) and other Satellite tracking stations in Ceduna (SA), and Belrose/Oxford Falls (Sydney) – even though there was a substantial FDM network and the HCRC technology that Telecom Australia TRL had just completed (circa CE 1978 - 1985) to connect most of the Regional Remote with telephone services. “***HCRC in Remote Australia***”

Unsurprisingly because of the immense overheads of operating this AUSSAT satellite, this ran at an operating loss and the Satellite licence was sold to Optus Communications which at that time was a consortium consisting of: Mayne Nickless (24.99%), Cable & Wireless (24.5%), BellSouth (24.5%), AIDS (10.0%), AMP (10.0%) and National Mutual (10.0%).

With a radical change in focus after SMOF technology suddenly appeared in CE 1986, Optus now radically changed its business focus to roll out SMOF in Metro CBD areas (where the big money is) and also the highly expensive HFC competitive rollout against Telstra in CE 1992. “***Competition Wrecked Australia’s HFC***”

Since then, Cable and Wireless bought out Bell South stake in Optus in CE 1997 and the name changed to Cable and Wireless Optus P/L and the Federal Government relaxed business ownership restrictions – so C&W increased their holding to 52.5% By CE 1998 Optus started to become profitable and was floated in the ASX in 1998!

During CE 2001 Singapore Telecoms (part of the Singapore Government) made a successful takeover bid (with idiots in the Australian Federal Government approving this foreign takeover). Optus/Singtel came off the ASX as a wholly owned part of the Singapore Government. Go figure!



The chart above (from another publication) clearly shows that Satellite (Broadband) connections are the cheapest to install – but very quickly become by far the most expensive to maintain. The later I certainly concur with.

From my personal professional experience I very seriously doubt that the Capex costs for Satellite establishing a satellite are nearly as low as is shown here (crimson line and square markers) and I would place it above the cyan line as a starter – as most satellites are used for discreet espionage / interception of through traffic – so the capex costs would be deliberately downplayed.

As for maintenance costs of SMOF technology transmission and switch / routing equipment – the costs are virtually zero apart from power consumption – which is quite low! So the cyan line with cross hairs should be virtually flat. "***The Phenomenal Productivity of SMOF***"

(I think the engineer that made this chart came from the FDM era where maintenance overheads were low but continuous!) If anything the "upgrade" (from FDM to PDH / IP) should have been an almost flat line too! "***Immense Productivity of SDH***"

The Privatisation Wheels Fell Off

The Davidson Report had been out since CE 1982 and there had been considerably growing political pressure (particularly from the USA, the ASX and Superannuation fund management corporation executives) that Australia privatise the Telecom Australia Commission.

Basically, Australia Telecom Senior Executives knew that privatisation was imminent in the mid-CE 1980s and the earlier co-incidental rapid (and extremely economic) introduction of digital switching, transmission, database etc. technologies really facilitated their strategies to make several structural changes to the Business Units to make the Commission "slide into" becoming a Corporation. This was still going to be awkward because Telecom Australia was still very much an "Infrastructure Business". "***Infrastructure Business - Competitive Business***"

Inside the Commission there had been a few large scale Business Unit restructures (circa 1987) that had prepared for the privatisation push, and set themselves up a virtual "sub-corporations" (with their own marketing).

The Business and Government / Enterprise customers (the ones that paid big money) had their own Business Units that were Capital City based, with National management! My understanding was that these Business Units were virtually autonomous and operated as "highly efficient" sub-Businesses (but apparently lacked the imperative numbers of engineering and technical expertise).

This left the Consumers (i.e. the vast majority of the population) and most of the overall network in a difficult situation as this grouping ran at a loss and was largely subsidised by the Business and Government / Enterprise customers. With new and inexpensive, highly reliable switching and transmission technologies being introduced through the CE 1980s plus the then recent introduction of mobile devices; the consumer area was now looking to also have a very positive cash-flow by the early CE 1990s, and end-user prices were certain to come down even further.

Some of the Business Unit restructuring included the Internal Plant (exchange) Maintenance staff being pulled into new State-based (Inter-Exchange) "Networks" Business Units, with the District-based External Plant staff involved with the external plant (i.e. cables / service pits etc.) Customer Access Network left assigned to District management. Districts were re-assigned to Regions – within State boundaries, and I understood that the Union had a large hand in "shaping" this mess.

By CE 1988 Telecom was now in the second phase of rush introducing SMOF to replace metro pair copper Junctions Cables running 2 Mb/s PDH between exchange sites were intermittently failing. "***Competition Wrecked Australia's 2 Mb/s***"

Because it was highly imminent that Telecom was about to be privatised – long term (infrastructure business mindset) planning (10, 25 years etc.) was discarded and long term (competitive business mindset) planning (1, 2 years) was the new focus - and no "real" forward planning.

Most of these metropolitan SMOF Junction Cables should have had 36 to 72 fibres in them – but because of the competitive business mindset to minimise expenditure on capital items most of these SMOF cables had and had only 6 or 12 fibres in them even though these cables could have had 24 or 48, even 72 fibres (with the same sized and cost cable sheath) – and the overall project cost would have been 1 or 2% more with massive future savings. "***Short-Sighted Competitive Directions***"

By CE 1991 Telecom (as Telstra) was replacing Transit pair copper cables in Regional Rural areas. Most of these cables also had only 6 fibres (to apparently minimise rollout costs). From my perspective it was astoundingly short-sighted planning and direction to plough-in any type of cable and not consider the long-term use of new applications and technologies requiring far more strands.

Like their metropolitan sisters, the Transit and Main SMOF cables that were ploughed in Regional Rural (and come Remote) areas were mostly 6 fibres where the cable sheath is far more expensive than the fibres and the ploughing is far more expensive than the SMOF cable – it simply did not make infrastructure business economic sense – but it certainly did make competitive business economic sense! "***Infrastructure Business – Competitive Business***"

In hindsight I am very highly suspicious that ploughing in 6-strand SMOF cable was deliberate to ensure that the USO "Gravy Train" kept rolling. This also was extremely short-sighted planning – characteristic of the Competitive Business mindset hell-bent on minimising build / maintenance costs (and maximising shareholder dividends). "***Competition Disconnected Regional Australia***"

Following the Telstra Network Engineering restructure circa 1990, the original number of Districts were significantly reduced (particularly in metro areas) so there was basically "Metro" as State Capital City Regions and the "CountryWide" Regional areas with a re-distribution of Districts under these new (non-metro) Regions that in some cases crossed State Borders to better suit the geography.

To me - this restructure made no sense because all the Internal Plant staff were now under the Networks ("almost" State-based) structures, and External Plant staff were all under Regional management in a different Business Unit – so these (common) technical areas were deliberately drawn apart from working together – which they certainly did before (but I seriously doubt the senior executives had any knowledge these two technical groups – particularly in country areas worked closely together!

Following the Davidson Report (CE 1982) it was now (CE 1988) clear that Telecom was to be privatised and consequently a minimum amount was to be spent on anything that does not have a high and fast return on investment. So the replacement of very old Main and Intermediate cables (that were "everywhere") was put on "permanent hold". "***Competition Wrecked Australia's Pair Copper***"

After "Corporatising" in CE 1989; the notion of Telecom Corp Headquarters became the corporate centre and not as State managed organisations. The State-based Business Units went through another reshuffle / restructure to be Nationally-based and no longer State-based. This should have happened in CE 1975!

With privatisation, the roles of engineers traditionally taking the reigns of executive management had abruptly stopped and a different breed of executive management based on advertising and marketing took over most of the high paid positions. Most of these people had a very "limited" expertise about telecoms engineering / practices / equipment / network structures – and were "short-term" focussed.

Telecom Corp was well on the way to making low priced "essential" services (based on the equipment having been rolled out at that time) to be seen as "discretionary" services, and consequently the prices were discreetly raised to cover the new (totally unnecessary) costs of Advertising, Marketing and Sponsoring – far higher renumeration for Senior Executives and Shareholder Dividends!

Telstra (its new name) was essentially rudderless in the telecoms industry fending off the financial market that was desperately stripping rivers of gold out of Telstra as shares and dividends. So the funding for infrastructure re-investment was severely curtailed. TLS shares started (way overpriced) at about $7.40 and stayed on a downward trend for some years (as people in desperation gradually sold out) ending up at about $2.00 (and stayed there for several years).

As it turned out, the technology of SDH arrived in the early CE 1990s, partially hiding this extremely short-sighted competitive business-minded fiasco for inter-State and inter-Region connectivity, but by CE 1997 there was far more Regional IEN connectivity that was urgently needed. "***Immense Productivity of SDH***"

There were several executive management changes in the next few years (where most of the upper executives were now "competitive business-focussed" Advertising / Sales and Marketing people).

On the world scene the Overseas Telecom Corporation (OTC) was a relatively small player – with the vast majority of international under-sea communications being between the USA and Europe the USA and Asia. OTC had positioned itself as the alternate (southern hemisphere) necessary carrier – passing through / by Australia and had competitively marketed itself to be rather profitable. From a competitive business mindset the executives (at least) looked to be ideal people to run the Australian Telecom Corporation (ATC) – which was a far larger infrastructure.

By Federal Government decree circa 1995 the Overseas Telecom Corporation (OTC) was usurped into the Australian Telecom Corporation (ATC) forming the Australian and Overseas Telecom Corporation (AOTC).

As a "compromise" and because the OTC was famed for being internationally competitive, most of the OTC senior executives / staff were instilled at higher level positions into the new AOTC to change the executive culture. Telstra did not quite collapse into oblivion but Telstra lost its longer term planning expertise and a lot of its industry memory as AOTC set on a reverse course to be a competitive business.

Without any real "infrastructure-focussed" long term engineering prowess on the Executive / Board the problem of lack of inter-exchange fibre (particularly in Regional areas was largely put on the back-burner (forgotten) as the ROI would be many years (if ever)! "***Competition Wrecked Australia's SMOF Rollout***"

Circa CE 1993 ND&C were pivotal in the fierce competition against Optus of the Telecom Pay TV Cable Network in the metro areas and by the late CE 1980s ND&C was proving to be a champion business unit. The problem was that the HFC infrastructure was literally wrecked in installation and could not be properly commissioned. "***Competition Wrecked Australia's HFC***"

What had also become obvious in the late CE 1980s was that remote monitoring and control of telecoms equipment into a common management area had incidentally produced massive operational savings. It was now CE 1997 practical and highly economic to have a nationally centralised Network Operations Control Centre and nationally a skeleton maintenance staff of less than 150 – where before this had several thousand highly trained staff. "***How the SCN Economised Maintenance***"

CE 1997 as the Service Control Network (SCN) was changed from terminating in Sydney (for NSW / Qld / NT) and Melbourne (for Vic / Tas / SA / WA) to terminating into was Melbourne (Clayton TRL offices). With this remote alarm / control structural change it was recognised that the Cable Gas Pressure equipment that CE 1980 had a really background (very low maintenance) priority in CE 1990 was now seen as one of the high maintenance pieces of equipment (in virtually every exchange site).

It was not that the Gas Pressure Equipment became high maintenance. It was that the new (digital) equipment installed from CE 1980s onward, had a virtually zero maintenance requirement – and the older Crossbar switching and FDM transmission equipment had been removed, so that this situation pushed the relative maintenance needs of the Cable Gas Pressure Equipment to then be the "most needy"! I also very seriously doubt that any of the staff in the new "Global Operating Centres" had a clue that this was vitally important (maintenance) equipment, or knew what it did!

Again, this was incredibly short term (Competitive Business mindset) thinking because Broadband Internet as ADSL was emerging circa CE 1998 – and would need to use the pair copper Access Network infrastructure in perfect operating condition. As Telecom was split up and privatised, Australia ended up with one of the worst Broadband Networks in the developed world (using ADSL2+ over internally wet Main and Intermediate cables). "***Competition Wrecked Australia's ADSL***"

Even so – the use of SMOF as a direct replacement was flatly refuted circa CE 1991 "That money is for Shareholder Dividends"! – as this would have set up Australia as having one of the best Broadband Networks in the developed world.
"***Privatisation Cost a Lot More than the NBN***"

With much the same short term "Competitive Business" high revenue mindset; in the CE 1990s and CE 2000s the metro areas had been flooded with multiple competing mobile service providers on common / nearby Radio Base towers – the non-metropolitan (Regional) areas had been left literally high and dry with very little mobile connectivity. "***Competition Manifested Radio Black Spots***"

In CE 1999 because of the massive discontent in primarily Regional areas that (primarily) did not have mobile phone connectivity; the (Labor) Federal Government raised the "***Networking the Nation***" program (costing about $300 M).

The problem was that it came back to the town and city locals to band together to write hundreds of requests in the form of business case / engineering scope documents to justify the spending of this "grant" – to prop up the inconspicuously failed privatisation of Telecom. This is/was the standard work of most telecom engineers that had been widely been (forcibly) "let go" – primarily because much of the engineering work could now be done with large databases (set up by engineers).
"***Productivities of Electronic Databases***"

Note the USO (of about $177 M pa) apparently played no part in providing this infrastructure as it was strictly tied to "fixed telephones" in Regional areas! It was obvious that the Federal Government Ministers (all sides) were too compromised to re-focus this funding and address obvious telecoms problems in Regional Australia.

Literally none of these (Networking the Nation) requests to the Federal Gov. had any comprehension of the Telecom engineering knowledge that was mandatory Radio Base Station network back-connection requirements to provide reliable connectivity.

Virtually all of these requests were denied because Telstra did not have Regional backhaul connectivity (remember Telstra had only 6 fibres in most of these SMOC cables in the Regional areas and these were already fully occupied)! "***Competition Wrecked Australia's SMOF Rollout***"

From what I recall of the grant allocations – most went back into Telstra to build a few towers (that they were probably going to build anyway) and the rest was wasted on ancillary items. I distinctly remember Toowoomba receiving money for a large TV to go into a community hall – and that had literally nothing to do with telecoms!

From about CE 2000 to now (CE 2020) there have been at least 20 Inquiries (Select Senate, ACCC, Productivity Commission Regional Telecoms) that (in my professional opinion) have each cost Australia at least $5 Bn each in in lost Australian productivity – that is worth about $100 Bn lost from Australia's economy.

As I was fundamentally "semi-retired" by CE 2000, I had the option and attended and was a "witness" in several of these Hearings and it was "interesting" for all the wrong reasons!

> *From my expert knowledge in this area it was very clear to me that all these Inquiries have proven to be a total waste of resources because those Chairing (and sitting in – and the Staffers involved with) these Inquiries had/have an extremely limited knowledge of the history and structure of the Australian telecoms network, how it connects, the direct relationship to consumer complaints, and how to fix these problems.*
>
> *In talking with some of the Staffers during one of the Select Senate Inquiries (between "witnesses" giving "evidence"), it became very clear to me that the Staffers had obviously received many submissions but almost all were letters of complaints and they had cherry-picked the "witnesses" where possible to make up the "witness" numbers.*
>
> *In an earlier life – these ministerial complaint letters would have ended up with me in NNI and the problems would have been resolved – but that area was closed down because it had (then in CE 1996) literally zeroed (for a year) what were thousands of ministerial complaints – and the Business Unit was considerably downsized (almost eliminated).*
>
> *At this particular Inquiry they said they had literally run out of suitable "witnesses" and had called on some equipment manufacturers / resellers to describe their products to these rank amateurs (oops Senators).*

It is really no wonder that these Reports read like an evidence finding inquiry. The Recommendations are pitiful as anybody could have written these blatantly obvious paragraphs of "waffle".

If the Panels in these Hearings included people that had people with relevant telecoms expertise, then the Reports would have included detailed practical and financially realisable proactive guidelines that would have launched the complete recovery of Australia's telecoms fiasco into a highly economic infrastructure specification of the correct type of telecoms equipment technologies - and with realistic timetables – including close realistic estimations of the required workforce count, and the cost outlay (and the expected return of investment (ROI) for Australia's economy).

Here is a typically classical example as a Select Senate Inquiry:

> *CE 2009 I presented a submission the Select Senate Committee on the NBN and subsequently was a Witness (in Canberra). Realising time restraints I very briefly introduced myself and then asked were there any questions about my Submission – and the Panel was silent. Nobody had even opened my 13 page Submission!*
>
> *So I started to describe the structure of the Regional Remote Backhaul network – essential for Broadband connectivity and it was clear they were all clueless about this. They needed a picture – or something!*
>
> *Fortunately, I had a separate PowerPoint presentation indicatively showing the (missing) essential Regional Backhaul Network infrastructure to necessary to connect Broadband in Regional Remote areas.*
>
> *Later in this hearing Senator Ian McDonald (Qld) asked how Broadband could be connected to Birdsville. This question was intentionally rhetoric but I quickly gathered my thoughts using a map of Australia to show that Birdsville is connected by a long-haul Radio system that starts in Roma, passes through Charleville and Quilpie and this is about 1000 km long.*
>
> *This Backhaul radio system is most probably fully occupied by inter-exchange Voiceband telephone connections along this route. So there had to be a different strategy – to much better utilise this long haul radio bearer to provide a significant Backhaul connectivity to Birdsville. I then pointed out the Longreach is north of this radio link – and if this radio link was intersected with SMOF – this would be a game changer.*
>
> *Although the distance is about 280 km, there happens to be a SMOF cable about 150 km long heads towards a repeater station in the radio link. Adding another nominal 150 km of SMOF cable would provide a multiple 1,000 Mb/s backhaul connections and this would dramatically open the whole SW of Queensland including Birdsville (– to Quilpie) for Broadband using ADSL2+ DSAMs – and cost about $5 M as my initial guess. And Yes – nothing of my answers was in the Select Senate Report!*

The above example is one of many responses from several of these Inquiries and it beggars belief that the Government would be so stupid to hold any Inquiry with panels of people that have no expertise / experience in the topic at hand.

When it came to the Regional Telecom Inquiries these were no better as they had “prominent people” on these Boards – and most of the “witnesses” were people with long standing lack of connectivity issues – and all these “prominent people” were absolutely clueless as what action to take to address/resolve these problems!

At one stage the Federal (Liberal) Government brought out a few “initiatives” to make Broadband more affordable. One of these schemes included the “aggregation” of potential Broadband users (by sales consultants) to act as middle-men to make this all happen! Seriously, this is what Forward Network Planning engineers do very quietly in the background some years before a product is rolled out - and in the process ensure that the backhaul / core network infrastructure is capable of transporting this increased / changed traffic density.

The competitive rollout of ADSL2+ technology to provide Broadband connectivity to most of Australia was nothing sort of a total shambles with several Inquiries that in reality found nothing – not even that the pair copper cable was internally wet in virtually every instance there was complaint! Had any ADSL2+ modems been properly installed and commissioned (to specification) there would have been zero complaints. Typical very dishonest advertising and marketing together with no proper install and commissioning processes laid the foundation for a totally ruined rollout of ADSL2+ Broadband. "***Competition Wrecked Australia's ADSL***"

Compounding this ADSL2+ rollout fiasco a very high percentage of Regional areas – particularly the Villages – totally missed out on ADSL – and apart from not being considered to be a high profit area (because it is not metro), I think that the prime reason came down to not having any spare SMOF strands – or available point-to-point bandwidth space in the backhaul to provide ADSL facilities. "***Competition Disconnected Regional Australia***"

Realising that ADSL technology (in the hands of the Private Sector) was a total disaster - the Federal (Liberal) Government then decided to put the pressure on Telstra in CE 2004 to come up with the (Broadband) goods or face Nationalisation. Telstra went into a blind panic and over CE 2005-6 invested about $2.5 Bn to totally restructure the entire Cable Internet Router / Backhaul infrastructure to utilise the pre-existing Cable Internet access network technology to provide Cable Internet. "***Competition Wrecked Australia's Cable Broadband***"

Although Telstra's Cable Backhaul network was totally rebuilt in the metro areas and all the Broadband Routers relocated to all the Local exchange sites (nationally 400 of them) this was yet another competition caused infrastructure disaster because the fiercely competitive rollout of the Cable TV Access Network was unable to connect to over only 1 M premises, when the minimum Broadband connection requirement was 6 M metro premises. "***Competition Wrecked Australia's HFC***"

With a change in Federal Government mood swings – the pressure to provide Broadband was abating – so the Federal Government quietly and quickly shelved this pressure to nationalise Telstra.

With a change in Federal Government to Labor, they saw the utter mess that was the telecoms infrastructure, and it seems they had read some reports visioning FTTP as the obvious future strategy – so instead of engaging Telstra (which now had Sol Trujillo as their new CEO – who was naturally abrasive against Governments) the Federal Government set up a new Commission the National Broadband Network (NBN) to fight against Telstra and put in Broadband.

By now the wheels of Telstra (and all the other competing telcos in Australia) were well and truly off and the ACCC and the ACMA and the TIO were also rudderless as were several other mini/micro organisations such as ACCAN, BIRRR and several other "support" franchises that frankly should have never been necessary.

In a recent Productivity Commission hearing in Sydney (CE 2020) – where the Commissioners had absolutely zero telecoms infrastructure knowledge or expertise, I got into a heated discussion where the presiding Commissioner flatly refused to accept that privatisation of the telecoms infrastructure had anything to do with to lowering of service standards etc. His background was that he was a long-standing Professor of Economics and I seriously doubted he had ever worked outside the realms / cradle of the public service let alone in the telecoms arena at any level at all.

Privatisation Cost Far More than the NBN

Privatising Telecom Australia Commission had the prime effect of changing the business mindset from being an "Infrastructure Business" – providing the best telecoms technologies available to all the community and businesses at the lowest prices possible (so they can maximise their business profitability) and maximise community communications; to being a "Competitive Business" where the best telecoms technologies are provided to the few those who are in the metro areas and will pay the most and the rest – i.e. the Regional areas that make Australia's exports have minimum service standards. "***Infrastructure Business – Competitive Business***"

The rather obvious indication when the wheels have fallen off a sub-Government responsibility is when the Federal Government initiates a substantial financial package with the intention to correct the direction of an infrastructure that it has privatised. The "Networking the Nation" initiative CE 1999 was an absolute disaster, and the Federal Government continued with many useless Inquires / Reviews very ill-conceived "initiatives" – but not nationalise the immensely expensive infrastructure that was self-destructing. "***The Privatisation Wheels Fell Off***"

It eventually became clear to the Liberal Federal Government that the farmers and graziers businesses in most of Regional areas were really haemorrhaging because their telecoms infrastructure was way below the minimum standard – and this is where Federal Government stupidity started to reign.

Instead of making a common sense stance and nationalising the Regional telecoms infrastructure – including the Backhaul infrastructure – which is paramount for Australia's national security and defence; these Federal Government morons decided to put out a tender for a limited (radio-based) Broadband telecoms infrastructure in a Regional area – and try and keep this quiet!

So the Liberals of course lost the next election and the Labor clowns decided to put in a FTTP network (nationally) – and scrap the regional half-baked tender. Meanwhile ADSL is being rolled out in Metro areas – and not showing the obvious failings in the Access Network being in an extremely run-down state – all thanks to privatisation. "***Competition Wrecked Australia's ADSL***"

Meanwhile the need for Broadband connectivity is considerably increasing - and those in the Regional areas that make Australia's economy profitable get nothing!

Telstra Corp. had the Network Design and Construction (ND&C) Business Unit that could have rolled out FTTP with about a 6 month focus and direction, and then really made it happen – but Telstra Corp. had actively disbanded this Business Unit.

The re-structure of the metropolitan Cable Internet (a $2.4 Bn national project) in CE 2005 was not done by ND&C but by Silcar (now Thiess Services) and took about 12 months – where this could have been done in about 2 months and about a quarter of the project cost (i.e. about $0.6 Bn) by ND&C; but they were already disbanded no thanks to privatisation and competition. "***Competition Wrecked Australia's Cable Internet***"

Transfer that concept from the farcical NBN Corp. to the well-drilled and highly experienced ND&C BU (operating as a sub-government Commission) and this national rollout would have been done in about a fifth of the time (i.e. nationally about

18 months) and for about a quarter the cost and no useless / expensive marketing through Advertising and Sponsoring.

The Telecommunications Ombudsman had in excess of 120,000 NBN originated complaints per year. It seems the TIO took my advice last year and in the past year there has been a process transfer where all these complaints now go straight to the NBN Corp. (Note: the NBN was packaged ready for privatisation as a Corp. not as a Commission as it should be).

The NBN Corp. has an intrinsic problem where the vast majority of the workforce are private subcontractors (all of which work to a time constraint - not a Quality standard – so everything is "just working")! All this could be very quickly eliminated by simply transferring the NBN Corp to NBN Commission and have all staff on terminate-able contracts (no sub-contractors and yes staff can be fire and/or terminated).

With this subtle structural change, the NBN Commission field staff would then be heading in the correct framework be properly trained and properly install every piece of telecoms equipment to the satisfaction of the end users and the complaints to the TIO / ACCC / ACMA / BIRRR / ACCAN / Local Ministers / Senators / Papers / TV Stations / Facebook / Twitter etc. would be zero!

The massive economic costs of privatising and splitting up Australia's telecoms infrastructure through the CE 1980s was incredibly well-concealed by a string of continuing mainly digitally-based (and SMOF) technologies that absolutely caveated operational costs through the CE 1990s and like the decades before then, the end user costs kept continuing to fall through the CE 1990s as it did in the CE 1980s and CE 1970s and CE 1960s etc.

Even though there were massive reductions in operational costs and bandwidth availabilities in the CE 2000s, the immense inefficiencies of competition and privatisation of Australia's telecoms infrastructure has cause a no-ending raft of complaints that are not internally managed by the competing telco businesses and the end user prices are quietly rocketing.

Mobile phones service rental used to cost $5.00 per month plus call costs circa CE 2000 now are at least $40 CE 2020 (as a contract with bundled calls and Internet usage) whether it is wanted or not.

Malcolm Moore JP BE(Elect.)
[redacted]