Backhaul Network Transmission Systems

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Introduction

Historically, the original purpose of Backhaul Network-based telecommunication transmission systems was to provide telephony / telegraphy connections between geographically separated local switchboards so that distance communications could happen well beyond one local switchboards' customer access network. The following paragraphs give a very brief overview of the technical advances that have continually brought down the costs over several decades.

Open Wire (like that seen in old country pictures along the railroad or main highways) got by with using much heavier gauge copper than that used in the CAN. For the Voiceband, the frequency response was basically flat, and the terminating impedance was characteristically 600 ohms.

These systems could go as far as 70 km before needing amplification (and remember the telecommunication system specifications were loose compared to today's standards)! These systems were phased out by the 1930s and replaced by "3 Channel" systems – taking 3 rack positions (3 * (600 mm * 300 mm)) for the terminating and/or repeating equipment.

In a concurrent move, twisted quad, and twisted pair cable technology came to the fore by the 1920's to replace Open Wire in metropolitan areas – simply because the space taken by Open Wire was unwieldy. Cable was highly successful but like Open Wire, it too was another engineering nightmare. It took a brilliant English mathematician Oliver Heaviside to identify that the cables lacked a sufficient inductive component, and he introduced 'Loading Coils' to mitigate this situation.

In Australia, 88 mH loading coils were inserted in all metropolitan junction cables 915 m from each metropolitan exchange and then at 1830 metre spacings to the distant metropolitan exchange. This was a brilliant engineering move; as tandem connecting any two or more junction cables would act like a continuation of a junction to the local exchange. The lumped inductances with the nominal spacings acted like a lossy low pass filter, cutting off at about 3.4 kHz, but the nominal impedance was 1200 ohms and not 600 ohms. (Note 3.4 kHz = 0.034 MHz)

It was not until the early 1950's when there was a massive technology development in ferrite magnetics, that these coils became very compact and highly consistent. Even so, these coils were highly susceptible to induced lightening damage, incorrect installation and almost non-existent commissioning processes that the metropolitan Backhaul Networks had highly inconsistent channel levels and the network was plagued with excessive network echo that was exceedingly difficult to isolate and maintain.

The 1950's saw the rise of coaxial cable based transmission systems with the bandwidth extending to over 4 MHz and giving rise to systems that had 960 Voiceband channels on one coaxial cable pair, using Frequency Division Multiplexing (FDM) based on banks of 4 kHz spaced channels, and each Voiceband channel having its own associated signalling channel in that 4 KHz but out of band.

This was an engineering feat in modern filter design using passive components, and even though these systems required repeater amplifiers every 5 km (to account for the attenuation in the coaxial cable), systems were installed that spanned Sydney – Melbourne etc. With technology advances these Backhaul Network based transmission systems extended their bandwidths to 12 MHz to handle almost 3000 both way voice circuits (using valve technology).

The 1960's saw the rise of point-to-point radio transmission systems that were capable of handling a 4 MHz wide (960 channel) bandwidth. Not only did the parabolic antenna dishes have a massive isotropic gain, as their beam was pencil-like, so repeaters could be spaced typically 45 km apart (limited more by the earth's curvature as this is line-of-sight communications). Although this technology was very expensive, it was much cheaper than the coaxial cable solution and therefore a very good business engineering solution at the time.

The picture on the left shows a typical radio repeater site with a number of parabolic reflector antennae on opposite sides of a common tower. The radio receiving and transmitting equipment is located in the building in the lower-left. Note near the base of the tower there is a satellite receiving dish!

This Radio Communications Tower on Black Mountain in Canberra is a landmark (and a very good sight-seeing venue too). This tower was completed in 1975 and carried the major Sydney-Melbourne telecommunications traffic until Optical Fibre replaced most of that function in 1987.

The primary function of this tower is no longer for Backhaul Network routes using radio links, but as CAN distribution for Mobile Cellular Phones, and as a Radio / TV transmitting antenna

Technology Advances

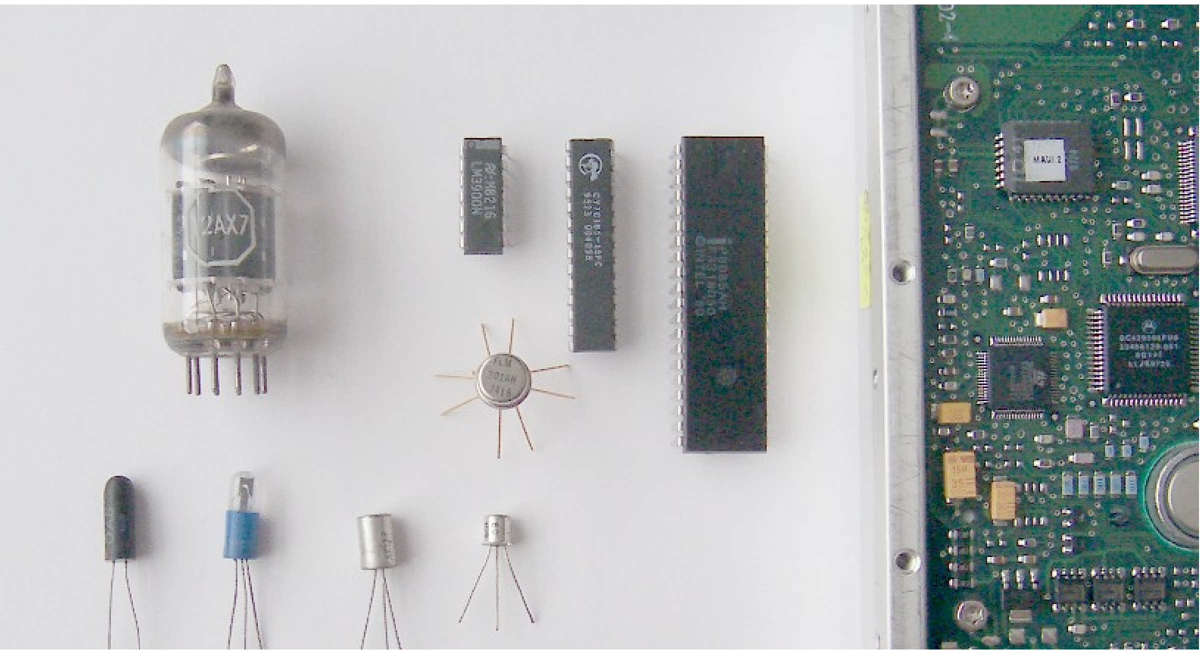
This topic might urk the grain of diehard economists, marketing and sales people; but the advances in technology is the prime reason why telecommunications has changes so much in the last 50 years - not competition as so many ill informed economists and business analysts would have everybody believe.

These advances were never competition driven by sales, but by engineering gurus making a series of small and relentless advances in technologies - mostly because they saw a better way to 'make a mousetrap', and revenue/sales is usually the furthest thing on these people's minds - I know - I have been in the technology development environment for several years. The hurting truth is that competition does absolutely nothing to drive down prices - competition actually forces overall costs way up.

With reference to the picture below: Point contact diodes line the black two-wired black (OA5) diode appeared commercially in the early 1950s, and it took until the late 1950's before transistors like the germanium OC72 (with the blue base and thee leads) became commercially available. Two of these transistors did what the double Triode (12AX7 valve - top left) did, but with about 10 mW each for the transistors compared to about 1500 mW for each half of the valve - so the power and size savings were enormous; and the purchase cost was about the same - heralding the 'use-by date' for valves by about 1960.

In the early 1960's silicon became a preferred substrate compared to germanium as it was considerable cheaper to fabricate, and metal housings like the adjacent AC132 transistor made these components far cheaper to manufacture so the germanium 'use-by date' happened about 1965 in round dates.

With advances in Quality manufacture, planar etching became possible and multiple chips could then be bulk manufactured on one silicon slice and cracked up later (like a chocolate block) really plunging the cost of transistors to well under $1 per unit, and much smaller packaging too, like the BC109 bottom-centre.



A direct follow on from planar etching was the development of integrated circuits with many transistors on one substrate, and the mid late 1960's saw the introduction of analogue Integrated Circuits, and here is an LM301 Operational Amplifier hermetically sealed with 8 leads (centre) and about 50 transistors in it, and compared to valves and earlier transistors this was highly predictable and extremely reliable.

In the early 1970's there were huge productivity production gains by using Printed Circuit Boards like the one shown on the right hand side, and the preferred IC packaging moved to Dual-In-Line (DIL) to support robotically assembled circuits.

Digital ICs became very predominant in the late 1960's and the packaging grew to accommodate larger Application Specific Integrated Circuits (ASICs). These technology developments greatly reduced the need for local maintenance crews because the equipment reliability and stability was dramatically improved.

By the early 1970s analogue integrated circuits (ICs) had improved new equipment reliability by another order of magnitude and digital ICs were making their presence felt with the first microprocessor – and digital transmission was the new technology front. The large DIL chip shown here is an 8085, which has a clock rate of about 5 MHz, has about 6200 Metal Oxide Silicon transistors in it and that was fast for 1976.

Compare that to the processor chip in the underside of the disk drive shown on the right - which has a clock rate of about 800 MHz and the chips hold several hundred thousand transistors and that was about 2002.

Note that the chips on the disk drive are surface mount, and the spacing is minute in comparison to the earlier DIL chips - and the reliability is so high and that the manufacturing costs are so low that complete disk drive assemblies are now 'throw away' items - where 30 years ago the contents of this disk drive would have taken a building and a team of around-the-clock maintenance crews to maintain it. ***This is an example of a 'better mousetrap' build by technologists, but not by competitive sales and marketing teams!***

Understand that all these components in their prime had a comparatively equal purchase cost, and this should clearly show that while electronic component technology was advancing at a rapid rate over the past 40 years, the overhead costs had dramatically fallen as reliability rocketed and maintenance needs plummeted.

The prime reason that telephony calls did not dramatically fall in line with these advances was that competitive infrastructures were introduced and this huge business mistake literally wasted the savings made by introducing advanced technologies.

Technology Advances in Digital Transmission

In the 1980s, the first phase of digital transmission reached maturity with a range of digital transmission encoding standards being recommended by the International Telecommunication Union - Telephony (ITU-T) and internationally agreed on. Recommendations G.710 - G.719 became the international standard for plesiosynchronous transmission standards based on a 2.048 Mb/s clock rate carrying 30 channels of 64 kb/s data streams.

Recommendations G.703 & G.704 became the international standard for voice encoding based on an 8 kHz clock rate, limiting the Nyquist frequency to a maximum of 4 kHz and with 8-bit encoding following the companding logarithmic A-Law, this appeared like a 13 bit digital converter with a greatly enhanced signal to quantisation noise performance over about 24 dB.

Optical Fibre was in its infancy in 1985 and reached maturity by 2000, and in that time it proved to be such a successful Backhaul Network transmission bearer technology that it replaced unloaded quad cables and coax cables by 1990, and then almost replaced all radio bearer systems by 1992 (except where the terrain was too stony) and replaced loaded cable junctions in all metropolitan areas by about 1994.

By the mid 1990s plesiosynchronous digital hierarchy (PDH) transmission systems were really struggling to have the necessary bandwidth capacity, and maintenance overheads of these systems was comparatively labour intensive (but was about 1% of what the equivalent analogue system maintenance required only 20 years earlier),

With rapid improvements in digital processing and clocking techniques, it was possible to introduce Synchronous Digital Hierarchy (SDH) which had a 'payload' and 'network management' transmission structure – meaning that the SDH systems were to all intents and purposes – self-managing and auto reporting, and this brought the reliability up by at least 10 times, and reduced the need for human intervention by another order of magnitude - such that most telecommunication sites could operate without any maintenance presence.

Where PDH was struggling at 140 Mb/s, SDH could envelope this at 155 Mb/s, (the STM-1 level) and manage Optical Containers up to and beyond 1000 Mb/s (1 Gb/s) in the one pair of optical fibres, and have regenerators spaced at least 70 km apart, and be self-healing! SDH could also handle STM-1 transporting Asynchronous Transmission Mode (ATM), and SDH lent itself to Dense Wave Division Multiplexing

(DWDM) so that Optical Fibre bearers could transport 10 Gb/s and later 40 Gb/s per pair of optical fibres.

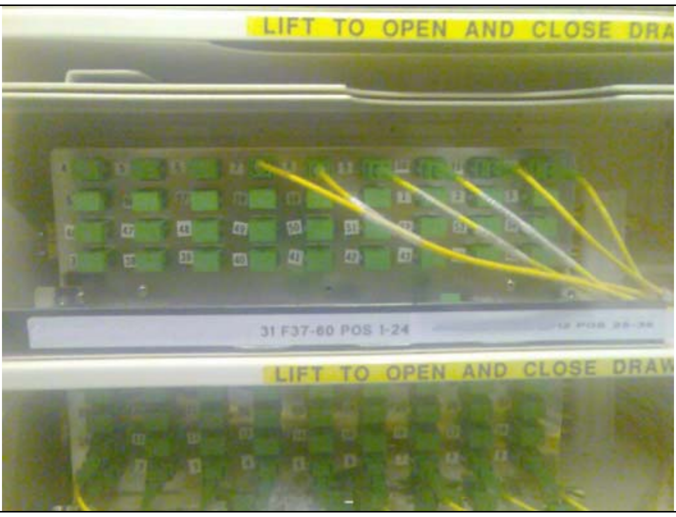
By 2005, the Optical Fibre (OF) cable manufacturing processes had improved so much that Backhaul Network engineered OF cable has typically 120, 240 or 312 fibres per sheath – with the latter being far more common. When Single Mode OF (SMOF) cable was introduced in 1986, large cables had 32 fibres in them.

Because of the high cost of laying cables, most are 320 strand SMOF and a low proportion of the cables are being actively used in rural and remote areas. The unused OF pairs are termed ‘dark fibre’ because they do not yet have Backhaul Network transmission systems attached to them, but with the rise and rise of Internet bandwidth requirements, this situation will not be the case for long.

Here is a suite of racks containing Optical Fibre trays and Terminating Patch Panels, where Optical Fibre (OF) cables fibres are terminated to the patch panels. Most OF cables used for Backhaul Network purposes carry 120, 240 or 312 fibres per cable.

Because OF Patch Cords are always slightly longer then required, there is an excess of up to a metre that needs to be placed in a flat tray in a flat 'figure 8' or oval form, do the delicate patch cable is not damaged.

Dark Fibre is optical fibre that is laid in a trench but does not have any transmission equipment attached to it (and any switching / routing equipment also attached in tandem to the transmission equipment). Just because it is 'Dark', this does not mean that it is deliberately unused. The associated transmission and routing equipment is also very expensive and in most cases it simply is not a commercial engineering proposition. Very naive Economists euphemistically see Dark Fibre as high speed connection potential for customers, when in fact the fibre cable is committed as part of the Backhaul Network and has no part in the CAN.

	This is a close-up of a typical OF Patch Panel shelf showing the individual (Green) connectors for each fibre in a cable. The (Yellow) Patch Cable is quite thick (about 2 to 3 mm in diameter) to protect the 'hair thickness' fibre strand.

Although this Panel looks to be virtually unused, almost all of the fibres would be allocated to network usage within a few months, and in general there is little optical fibre that is laid in the ground and not fully utilised.

A Fibre Cable that has been installed, but has no equipment attached to is called 'Dark Fibre' (even though the light that passes through a typical fibre system is not usually in the visible spectrum.

Comments and Corrections are welcome