Optical Fibre in the CAN

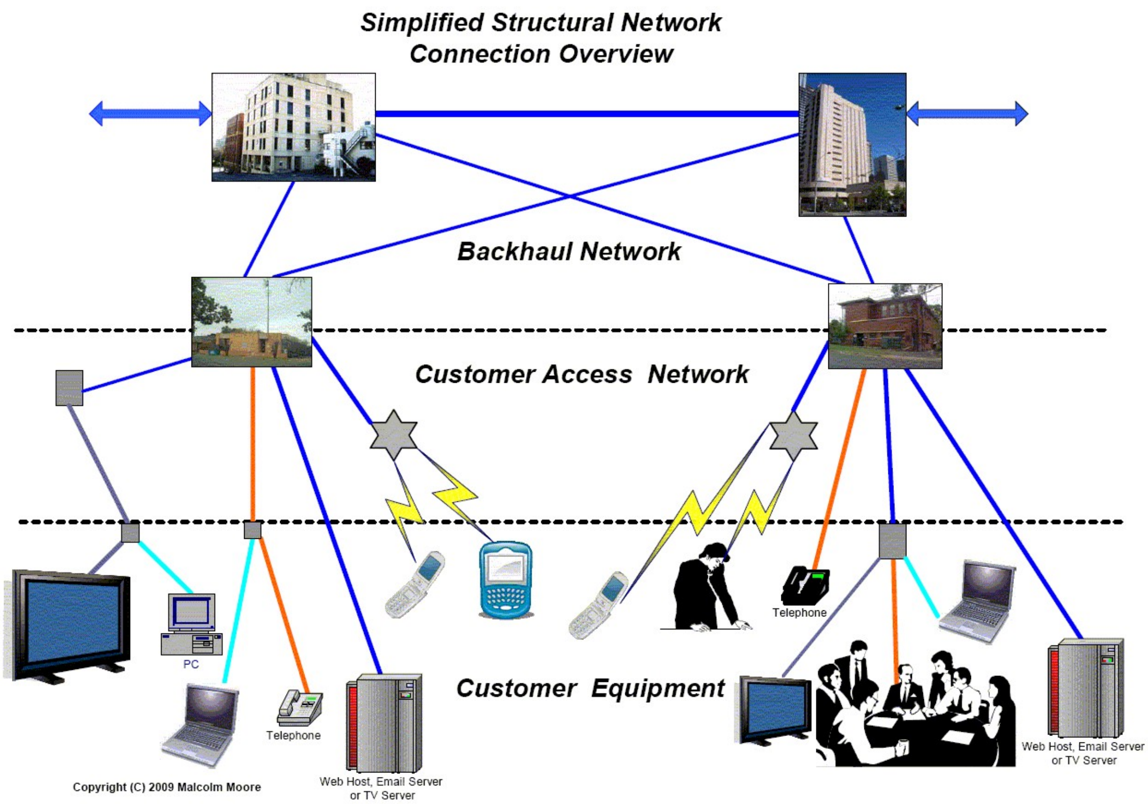
© Malcolm Moore
23-Mar-2003

(2003, 2005, August 2007)

Introduction

Optical Fibre to the Premises (FTTP)
This CAN infrastructure will be the CAN infrastructure of the future and it will replace all copper pair cable in the next few years - if successive Federal Governments can see their way to keep out of interfering with the progression of technology, and let one primary infrastructure business install and commission the full network - and the services can be resold at the competitive retail level.

Optical fibre technology will replace copper wire used in urban buried cable, aerial cable, radio using Satellite, ARCS/DRCS and HCRC, and CATV services using HFC. This is because FTTP is relatively inexpensive, is not nearly distance restricted as copper pair, and has a very wide bandwidth, making it suitable to carry CATV services, and Broadband Internet as well as telephony and it is high speed. FTTP can be structured to operate with bi-directional transmission on one fibre (with extra losses).



In the above picture of the stylised three network structures that go together to make and end-to-end call, in the Customer Access Network (CAN) layer, the blue lines from the local exchanges to the Customer (Premises) Equipment border represents Fibre to the Premises (FTTP).

In business cases it is common to have the optical fibre connect all the way to the premises equipment like Network Routers that interface with Web Hosting Servers.

Some Basic Optical Engineering

In simple engineering terms the maximum attenuation (loss in power level) that can be tolerated over a customer link is about 20 dB, and this value in transmission terms is called a Power Budget.

Considering that typical Optical Fibre has an attenuation of about 0.31 dB/km +/- 0.03 dB at around 1300 nm, then a typical maximum length would be about 64 km before regeneration or re-amplification is necessary.

This simplistic approach does not take into account splicing (joining the fibres from one cable to another cable to form the full length), and this costs about 0.1 dB per splice.

Considering that these cables come in 5 km drums, then in 60 km there would be 11 splices plus two connectors at each end having nominally 0.1 dB loss; totalling 15 joins or splices; or 1.5 dB.

The Optical Fibre Power Margin would therefore be decreased to 18.5 dB instead of 20 dB, and the typical length that could be spanned is therefore about 18.5 dB / 0.31 dB/ km = 59.6 km which is about 60 km.

The actual Power Budget is highly dependent on the manufacture of the Small Profile Connector used as the interface in the equipment to connect from the printed circuit assembly to the fibre itself, and many of these interfaces are engineered for a much lower Power Budget (say 6 dB) - and these are much cheaper too.

Recently (2007) patents have been granted for grafting Optical Fibres directly onto Solid State chips and this new technology will significantly lower the cost of Optical Fibre interfacing from several $100 per interface down to about $5 to $20 per interface.

This new technology will open the doors for Optical Fibre cable to cost-effectively replace insulated twisted copper pair cable on a grand scale in the near future.

It should be obvious that with a power budget of only 6 dB, taking into account four connectors and two splices, this brings the nominal power budget back to 5.4 dB, and that works out at about 17.5 km, so it is rather easy to replace the current nominally 4 km limit of metropolitan 0.40 mm copper pair cable and have plenty of distance to spare.

Two immediate options surface and these are simple cost-effective business solutions: Remove about 70% of the existing Terminal / Local exchange sites and fully utilise the remaining 30% of Local / Terminal exchange sites as the launching points for Optical Fibre CANs with nominal 15 km radii.

Leave the sites as they are and introduce a 'Passive' Optical Fibre CAN that has a number of 'splits' in it feeding to the customers (this is called a PON for Passive Optical (Fibre) Network).

Both options are engineering compromises and telecommunications engineers will come up with the best business solutions that will most likely be a mix of both extremes and other innovations.

Early Business Applications

In the mid 1990s there was considerable work done to extend the IEN into the CAN with small SDH rings that traversed several buildings and each building had an SDH element in it.

By utilising an Add Drop Multiplexer on the SDH Network Element, it was possible to extract one or more 2 Mb/s links in the Business Premises and these links had a direct connection with the parent Node / District exchange site so that Broadband Retail business services such as ISDN, and MegaLinks could be directly connected by Optical Fibre and not copper pairs.

There have been several 'green field' installation tests to prove the technology of engineering FTTP and these have proven highly successful and each has raised questions and provided the opportunity for innovation to bring the installation costs down while improving reliability and decreasing maintenance requirements over the lifetime of the installations which are expected to exceed 40 years - and this is in line with pair copper cable.

CAN Demarcation Points for Optical Fibre

In all cases at the Local/Terminal exchange site, the optical head multiplexer is part of the CAN, and the demarcation point between the Inter-Exchange Network (IEN) and the CAN is at the 'Equipment' (Router / Server) side of the ODF/DDF.

At the Customer Premises, the Optical Fibre connector from the CAN is both the demarcation point and the Interconnect point between the CAN and the Customer Premises Network (CPN). This is a simple rule to follow and it is highly consistent with other technologies and their demarcation and interconnect points with the CAN.

Optical Fibre CAN Structures

There are three fundamentally different Optical Fibre structures that have been created for use in the CAN. The first version is a direct connection from the Local / Terminal exchange site to the premises, and the second version is a passive optical network (PON) which also connects from the Local / Terminal exchange site and then goes some of the way before passive splitters break the fibre into a further eight fibres, and then each of these fibres is broken into a further four fibres - so there is a total of 32 Premises that are commonly connected from one source at the Local / Terminal exchange site. The third version is an active system that connects several businesses to a common feed (but that is fast becoming outdated).

The present copper-based insulated twisted pair cable CAN was engineered for telephony, and served its purpose very well, but the engineering specification requirements of Broadband Internet, far exceed that available with twisted pair insulated copper, and ADSL technology has really pushed the physical limits, and the cables are physically old and becoming brittle. It is high time that the incumbent insulated twisted copper pair cable CAN was totally replaced and Optical Fibre is the very strong candidate.

Passive Optical Network (PON)

The basic structure extends a limited number (say 50) fibres in a cable from the optical heads in the Local/Terminal exchange site, and the cable extends towards the customers.

In the first service pit, optical splitters are included to split each optical fibre up to about 6 times providing up to about 64 premises connections per fibre leaving the pit. As this is new technology there is some deliberation on including the optical fibre splitters in the Local/Terminal exchange site and extending full cables to the customers.

With each split the power level is halved (3.01 dB) and there is an intrinsic splice joint loss of 0.1 dB, so for five splits to make 32 customer feeds form one optical head, there would be nominally 5 * (3.01 + 0.1) dB = 15.55 dB in the splitter.

Take off 0.4 dB for the four connectors (two in the head and two at the customer premises) and the total attenuation loss is about 15.95 dB. If there was a nominal 20 dB Power Budget this leaves a 4.05 dB Power Margin.

Assuming 0.31 dB /km will give 13 km of length to the 1600 customers off the original 50 optical heads.

If there were six splits, to make 64 customer feeds from one optical head, then there would be nominally 18.66 dB lost in the splitters, leaving a Power Margin of 0.94 dB, giving a total length of about 3 km for 3200 customers from 50 optical heads. This could be very commercially viable for a Pay TV OF CAN but it is right on the physical limits and would prove to be very unreliable over time.

The advantage of the PON is that the optical interfaces are not cheap and that having one optical head is much cheaper than 32 heads, but it could be necessary to have a reverse path for bi-directional communications and variations on this theme could bring the reliable structure down to say 16 or eight customers per terminal optical head.

As mentioned earlier more recent innovations to provide much cheaper solid state to optical fibre interfacing may totally change the structure to make PON a poor choice and direct wiring far more cost effective.

The problem with bi-directional transmission is that the reflections caused by splicing and jointing appear like noise in the reverse path (just like looking through a window and seeing a reflection of yourself - or glare from the sun spraying over the vision through a window). This increased noise level appreciable affects (decreases) the power margin, and it is necessary to have a splitter at each end, which also drops the effective power margin by 6.22 dB. With these factors in mind, it seems that the PON has probably had its use-by date.

Direct Optical Fibre - Technologies

Although the cost of Optical Fibre cable is so small that the main cost is digging the hole to trench it in (and not the cable itself), running a single optical fibre with bi-directional transmission may well be the way to go.

The engineering problem is to provide multimedia services over the one cable and that comes down to the optical head, where it is not cost-effective to multiple splice cables, but it is highly cost effective have a single splice in each ens of a single fibre.

This approach drops the nominal Power Margin by 6.22 dB. If the total Power Budget was say 10 dB then this would leave 3.78 dB for attenuation which works out at about 12 km and that could be a very cost effective Optical Fibre CAN

Another engineering approach is to utilise Coarse Wave Division Multiplexing (CWDM) so that more than one light wavelength can travel down the same fibre from the one optical head. With this approach, the optical head uses a multi-wavelength laser assembly and this can transmit Pay TV on one wavelength and Broadband Internet on another wavelength. Currently the technology of multiple wavelength lasers are expensive making this not yet viable.

An alternate solution is to employ 1 Gb/s Ethernet bi-directionally on Optical Fibre (not using CWDM) and integrate the Internet and Pay TV with an intelligent Headend. This approach would provide the possibility of Pay TV over 1 Gb /s Internet, with Internet, and VoIP.

When the costs of Small Form Profile optical interfaces come down it may be possible to utilise two fibres instead of one and then have a range of up to 60 km, and this might be a viable rural and remote solution where 3G Radio is not desirable.

Optical Fibre Business Solutions

With Optical Fibre CAN this is a relatively new access network technology that is maturing since its introduction about 1996, when its structure was strictly an extended SDH ring running 155 Mb/s with 2 Mb/s spurs hanging off it at Business Premises.

With the development of Internet, bandwidth requirements for Business has increased considerably and Optical Fibre CAN with data rates of 2 Mb/s are really the low end of the data rate market for corporate businesses.

In these terms 2 Mb/s pipes are often simply far too thin and will usually be the main cause for network congestion, and the business standard is steadily pushing towards the STM-1 level (155 Mb/s clock rate) as the new base transmission industry standard.

For Business Purposes, an STM-1 is the logical bandwidth to consider as this is 155 Mb/s and this can carry a variety of payloads in a number of forms including SDH (Synchronous Digital Hierarchy), ATM (Asynchronous Transfer Mode), 100BaseT / 100BaseF (Ethernet), and this is fitting comfortably with the new optical standard lowest denominator.

The engineering problem is that where CANs formed the telephone answering service interface with the Inter-Exchange Network (IEN) for telephony, CAN structures connecting to corporate businesses are now more likely to be part of the corporate Information Technology (IT) network, and are therefore may be part of the Local Area Network (LAN) in some cases, but more likely be a major connection component of the Wide Area Network (WAN), or Metropolitan Area Network (MAN) as it was sometimes known.

Where To From Here

As it has been pointed out in earlier associated subjects about the network converging technologies, there are many ‘legacy’ technologies here that will be phased out, and this is not nearly as simple as switching off a light. This phasing out of legacy technologies takes about five years per technology. It costs a lot of money to close technologies, and it costs a customer base - if the technology is not a transparent internal move.

Telstra already has a massive amount of assets invested in copper pair technology (and the associated pair gain systems including first and second generation

DSLAMs), and it simply is not in a position to switch it off and let everybody use Wideband CDMA (3G) for telephony and Internet purposes.

The failed competitive experiment called Optus also has a huge amount of legacy equipment invested in the HFC CAN that it too would love to lose (or seriously upgrade), and most other much smaller telcos have the same problem - or will have the same problem in a few years. All these competing infrastructure businesses have advanced their infrastructure front lines but have a substantial legacy of older equipment in service - no making that much money - but still holding customers.

You do not find this topic of the cost of closing down technologies being covered in Economics, and if it is covered then only the good side is shown; when in fact closing down technologies is an enormous stress on management resources and this is a prime reason why economies of scale make these changes cost-effective - but it is simply not cost effective in a competitive infrastructure environment - which we have in Australia.

Conversely the coverage of Wideband CDMA is still geographically far too thin to let all users immediately move off copper pair and switch onto W-CDMA. Anyone who is suggesting in 2005/6 that Telstra should just drop the copper pair Access network and ‘simply’ move to radio (W-CDMA) must have either a total lack of knowledge of the telecommunications industry, or has a poorly hidden financial agenda – or both.
In an attempt to extend the life of the copper pair technology that exists to virtually every premises; Telstra has gone along the line of introducing ADSL to provide the functionality of Broadband Internet to all metropolitan residences within 3.5 km of the local telephone exchange buildings.

This has both bought time (about five years) to provide a basic form of Broadband – with a very limited upload speed, and this has also given Telstra a chance to alter the Core/Inter-Exchange Network in metropolitan areas to be able to Internet and this has virtually replaced some levels of switching in the IEN for telephony with IP based switching

By about 2007, twin insulated copper pairs for Customer Access Networks will have past their 'use-by date' and this infrastructure will need to be entirely replaced by a Broadband capable Customer Access Network in all metropolitan areas, and 3G radio in areas that cannot be connected by Broadband fixed access services. The only alternative is to replace the entire DSLAM structure with third generation ADSL 2+ technology (including the modems at the residences), and even this is a temporary fix before FTTH.

Third Gen ADSL 2+ has a much wider Upstream bandwidth extending up past 200 kHz and this could provide a sufficient bandwidth for Upstream data rates exceeding 400kb/s (but the IEN infrastructure will need to be considerably hardened/ thickened for this to work and currently this is virtually impossible in all areas other than major capital cities).

Hybrid Fibre Coax (HFC) CAN is a technology that simply will not go away - and it has early ageing problems because it was originally engineered using the cheapest available materials (another total failing that is a direct product of competition, and not a product of infrastructure-based business).

Currently the Pay TV and Internet is structured on Data On Cable System (DOCSYS) 2 and this has a major failing of having a very small back channel allocation, making upstream speeds extremely slow. Currently DOCSYS 2 uses 500 to 600 MHz for Downstream and 30 to 50 MHz for Upstream, and that is a prime reason why Cable Internet has such a slow upstream data rate.

In mid 2007, Foxtel removed all its analogue channels from HFC in both the Telstra and Optus competitive infrastructures, opening the way for the spectrum below 500 MHz to be used for Internet. DOCSYS 3 has the capability to use this bandwidth below 500 MHz and is seriously being considered to radically increase the upstream data rate, and downstream bandwidth.

In non-metropolitan areas, the situation is already desperate as the Core network is far too thin to carry Broadband Internet at volume, and the residences are typically 2 km to 15 km from telephone exchanges, and this means that in most cases some form of PGS is already included and therefore ADSL is not an option. Optical Fibre is one solution and 3G is the other solution.

As far as I am aware (August 2007), Telstra has put in a considerably large mesh of Optical Fibre in non-metropolitan areas to carry 3G Internet / Mobile phones from base stations that have been planned and are going into country areas (and will continue to be going into country areas for some years as is customary with large infrastructure projects).

Much of the remainder of this optical fibre will have been programmed in for future Broadband Internet in non-metropolitan areas as this network structure also needs to be thick like its city cousin (but the distances are 10 to 100 times longer between centres - so the transmission technologies will be different). This dark fibre in Telstra's IEN will be the base for high speed broadband in rural and remote areas to connect with 3G and FTTH CAN technologies.
For some reason that I do not understand (September 2007), Senator Coonan appears to have struck a competitive infrastructure deal with Optus/Elders to provide Broadband in Regional and Remote areas - where Telstra already has infrastructure and is developing this infrastructure alongside the 3G project in the Rural and Remote areas - which I believe is due for completion in 2009.

In my extensive professional opinion, this deal seems to be an incredible waste of valuable resources and will probably result in a very similar mistake to that made in 1992 with the incredibly stupid competitive rush to provide HFC in major capital cities, costing about 300% more than necessary and with an approximate 80% overlap.

In today's (2007) terms, the 1992 competitive infrastructure HFC CAN cost about $10 Bn, where it would have cost less than $3.3 Bn if it was not competitive infrastructure. Senator Coonan has, I believe, put up about $1Bn in competition to the existing and developing Telstra Rural and Remote infrastructure, and I believe that this is totally CAN - without consideration for very considerable IEN infrastructure. (I believe that the costing was based on the PSTN connectivity model, and that is why I believe that these competitive policies and project costings are both wrong and inappropriate).

Comments and Corrections are welcome