20030323 Digital CAN

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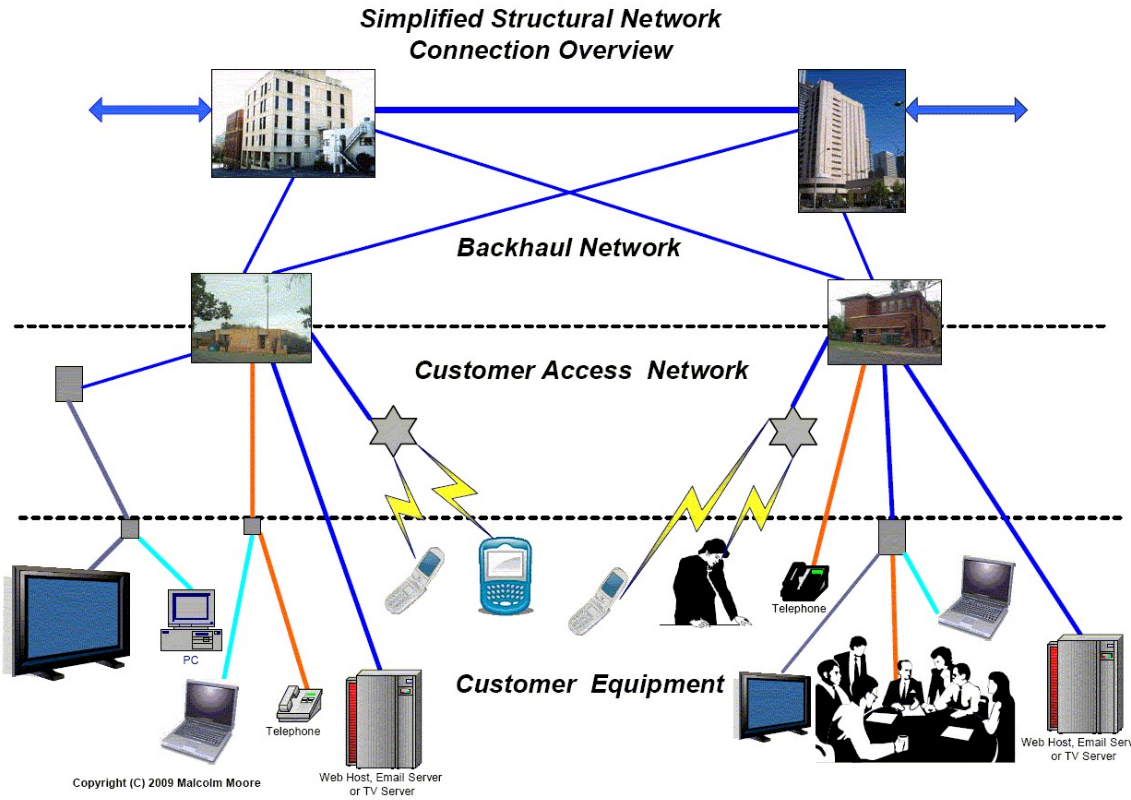
Positioning ADSL (Asymmetric Digital Subscribers Line)

In the picture below of the stylised network infrastructures as physical layers, ADSL is represented here as operating over the orange (copper pair) line running down from the left hand local exchange to the grey box at the border of the Customer Premises Equipment.



Here, the grey box represents the ADSL/Telephone filter interface and ADSL modem. The voice circuit continues to the telephone and the Internet circuit, which is represented as a cyan line is part of the Local Area Network (LAN) in the premises, forming part of the Local Premises Network.

ADSL (Asymmetric Digital Subscribers Line)

Line conditioning for Asymmetric (directional data speeds in a) Digital Subscribers Line (ADSL) utilises bandwidth well above the telephony/dial-up Voiceband (which up to 4 kHz).

Most customer access cable has a usable frequency response capability of about 1000 kHz, but this is very length and construction dependent, and the longer the line; the lower the frequency response capability.

With urban (0.40 mm cable), the useful range is limited to about 3500 metres for ADSL. (In practice if the total distance in the CAN exceeds about 1200 m then the download speed is very compromised - no matter what the advertising says. The longer the ADSL CAN line - the slower the maximum download speed.

Remember that ADSL technology is pushing very hard on the physical limits of copper CAN: Maximum allowable Transmit Powers, Cable Attenuation, Attenuation / Frequency Distortion, Near End Crosstalk, Far End Crosstalk and Noise Floor limitations - so if anything can compromise the performance - it will!

Cables that Will Never Work Properly

The copper pair cable that is being utilised for ADSL was never engineered for ADSL - it was engineered for voice (with a bandwidth up to 3.4 kHz), and the cable was originally tested up to about 30 kHz - so that it could be used for Radio program transmission up to 15 kHz (+/- 0.2 dB) for the AM Bands - and that worked very well.

This ADSL technology uses an upstream frequency range between 25 kHz and 138 kHz and a Downstream (towards the customer) frequency range between 138 kHz and 1107 kHz, employing Coded Orthogonal Frequency Division Multiplexing (COFDM) based on frequency spacings of 4.3125 kHz.

This much wider downstream bandwidth allows a much faster download data rate than the upload data rate - hence the term Asymmetric in ADSL. The newer versions ADSL 2, 2+ have a wider bandwidth and can therefore download at a potentially faster data rate. In practice this is true if the CAN is generally less than about 700 m and that would suit small business nearer CBDs/local exchanges.

Voice Frequency Customer Access cable was never engineered for ADSL technology and the attenuation incurred in the cable is quite high at these frequencies and consequently the transmit levels from both ends is very loud to clear the noise floor at the receiving end.

The Crosstalk Problem

The big problem is Crosstalk, where the balance between pairs to ground and other pairs is not perfect, and with voice grade cables the pairs / quads have not been capacitance balanced with the 5-way balancing technique. So, even if the intrinsic capacity balance is quite good from manufacture, it simply is not good enough for cables at these high frequencies without balancing after installation and maintenance activities.

To compound matters much further, the field staff these days simply do not have the expertise that was lost in the 1980s as Optical Fibre replaced Pair and Quad cables used for analogue carrier installations. Executive Management, in haste to make the quick income, have opted for speed over Quality now have a very second rate physical CAN that is incapable of carrying high speeds ADSL because the field techniques do not look to minimise crosstalk through proper pair balancing.

To prevent intermodulation (distortion and noise) into other systems a splitting filter is included at the local exchange site and at the customer premises to isolate as far as possible the ADSL frequency band from the Voiceband.

Further with ADSL2 there is a transmit level control that turns the up transmit level even higher when the modem is actively transmitting data, and this compromises the adjacent pair crosstalk isolation - further raising the noise floor and can cause adjacent ADSL systems to drop out because their received signals will fall under the raised interference noise level.

At the local, or district exchange site the Backhaul Internet (IP) is present at the pair of Edge Router / Switches, called so as they are on the outer edge of the Backhaul or Core Network and interface between the High Capacity Backhaul Network and the Digital Services Loop Access Multiplexers (DSLAM) for ADSL, Universal Broadband Routers (uBR) for Internet over HFC, and Optical Line Termination Units (OTLs) for Fibre to the Premises (FTTP), and for Fibre to the Node (FTTN)

The Edge Router connects to the DSLAM through a pair of Optical Patch cords, or in some cases through Cat6 cables.

The Optical Patch Cords usually connect through an Optical Distribution Frame (ODF) like the one shown here.

The Optical Patch Cords then connect into the Internet side of the DSLAM equipment shown here.

The DSLAM consists of two main parts, the Data Modems and the Line Filters.

The Line Filters are a High Pass / Low Pass type that passes the Voiceband and Direct Current for line signalling through the lower half, and in the upper half connects the Data Modems such that the modems signals are prevented from going back into the telephone exchange switching equipment.

If the copper pairs have phone lines associated with them then the copper pairs come from the telephone switch to the Equipment side of the MDF, where they are then cross connected back to a cable on the Line side of the MDF that connects to the DSLAM filter Equipment side.

From the Line side of the DSLAM, another cable then connects back to the Equipment side of the MDF where the pairs are then cross connected to the Line side of the MDF, where the customers physical appearance is as a cable leading into the street.

The picture above depicts a typical Digital Services Line Access Multiplexer (DSLAM) installation in a local exchange, where in the top left picture, the Internet streams come through a Digital Distribution Frame (DDF) from the Terminal or Node Router/Switch. The line side of the DDF connections go to the DSLAM and connect to the banks of local exchange end ADSL Modems behind two rows of the blue panels in the centre picture. (Some DSLAM equipment uses 1000BaseT or 1 Gb/s Optical Fibre, STM-1 (155 Mb/s) Optical fibre.)

From the local telephone switching equipment, cables run to the equipment side of the Main Distribution Frame (MDF), shown in the bottom left picture. From the line side of the MDF, another cable runs to the DSLAM filter bank - behind the other two rows of blue panels shown in the centre picture. Another cable then goes from the Customer/Subscriber side of the DSLAM where the splitting filters are common to both the ADSL and telephony and this cable goes to the equipment side of the MDF as shown in the right picture.

The customer cables on the street side of the MDF are then connected by jumper leads from the DSLAM (equipment side) of the MDF - as shown on the right hand picture and this finally goes out to the customer.

DSLAM equipment that provides ADSL services on voice-band grade copper pair telephony wires is a very ugly fit that is made practical because switched telephony circuits do not use the bandwidth above 4 kHz. Because excessive levels from ADSL creates sideband demodulation that interferes with telephony equipment, a guard band up to about 12 kHz and 60 dB is necessary and this is implemented with High Pass / Low Pass filters to isolate noise created from transmitters in DSLAM equipment, and customer premises-based ADSL modems.

ADSL technology has three major technology drawbacks. The first is that the physical line limits the downstream (exchange to customer) data rate in accordance with the line length and this limit cuts in at about 500 m, resulting in the longest practical distance being about 3500 m with about 25% of full downstream bandwidth capability. The upstream data rate is normally limited to about 64 kb/s - and this is never mentioned in advertising as it is the Achilles' heel for video conferencing. CAN cables are voice grade and their crosstalk between pairs is 'average' for bandwidths beyond 30 kHz.

As the bandwidth for ADSL exceeds 1 MHz (1000 kHz) inter-channel noise will cause channel dropout issues - specially with ADSL 2 which runs normal (loud) levels in standby and then considerably raises its transmit levels to get over the quiescent background noise level (caused by other ADSL services). The obvious consequence is that other ADSL channels will experience even higher background levels and drop out. A close analogy is the acoustic noise levels in a Bar as more people come in, talk, drink, then shout to each other to be heard.

Optical Fibre to the Node (FTTN)

This is a variant on xDSL, based on providing copper pair to the customer and usually utilising ADSL, and not Optical Fibre to the Customer. The advantage of this CAN configuration is that almost every household already had copper pairs installed and if the physical line was short enough (that is - less than a couple of km), then xSDL can transmit and receive at rather high speeds.

Internet Protocol feeds from the Edge Core Network (that is part of the Inter-Exchange Network - sometimes called the "Backhaul") through a Local/District Router/Switch - (usually termed a Node in the Backhaul) through an Optical Fibre cable that is extended beyond the Local Exchange site to a the Digital Services Line Access Multiplexer (DSLAM) which is located at a Kerbside Cabinet - **and this location is called the Node**. ***The CAN-based Node can be several km from the local exchange.*** From this Node, the same old copper pairs are then extended to the Customer Premises, running ADSL protocol for Internet facilities.

Even in cases where the DSLAM is located in a road-side Cabinet (which is called the 'Node'), the major CAN component is still copper pair cable to the Premises running the ADSL protocol. The total number of fibres in the cable feeding from the

Backhaul Node to the CAN Node are quite small and would never be nearly enough for a stepped translation into FTTH / FTTP - unless an Optical Line Multiplexer /Concentrator was to replace the DSLAM, and all the customers premises in that area had the copper pairs replaced by Optical Fibres.

In my opinion, FTTN is a short-sighted engineering approach, that appears much cheaper than Fibre from the Backhaul to the Premises or Home (FTTH/ FTTH), but FTTN is fraught with ageing problems associated with the existing copper pairs (which are on average about 40 years old and not getting any younger) and functionality problems, because the bandwidth is very low compared to FTTH. This bandwidth issue is a major concern because FTTH will be used for a variety of services including Pay TV and Free To Air TV, Digital Radio, and Datacasting over FTTH, and FTTN cannot do this.

Because the Nodes are located externally there are a number of operational issues that make it very unattractive including remote power management, physical security problems, damage by vehicles & vandals, travel to do connections/disconnections, dust and water invasion and damage, air conditioning and reduced life expectancy of equipment. These add up to ***"Don't do it!"***

Radio ADSL

In Regional and Remote areas, ADSL over copper pair cable is simply not possible as the insertion loss is already too great by a few km (outer town outer limits) An alternative of utilising point to point radio can be commercially viable, because the radio bandwidth is about 5 MHz wide (which will comfortably carry the ADSL and the voice channel), and the distance can be as far as 30 km (which is limited by the curvature of the earth and line of sight). The point to point radio system would be part of the CAN along with the DSLAM and the demarcation points would follow the DSLAM at the exchange end and radio at the customer end as described in Telecommunications 101[1].

Integrated Services Digital Network / Mega Link / Frame Relay

With the Integrated Services Digital Network (ISDN) / Mega Links / Frame Relay using copper pair cable, the technology for these Access Networks is virtually identical - but with slight changes in the channel and signalling usages. For Primary Rate ISDN, this CAN technology uses 2 Mb/s with 32 x 64 kbit/s digital paths feed off the Node or District Exchange/Switch through an ISDN Multiplexer to the DDF, where it then passes through a Business Access Unit (BAU) in the CAN then onto two copper pairs (in a cable) to the Customer Premises, where it then connects to a Customer Wideband Modem and is converted back to two 2 Mb/s streams (send and receive) and this connects with the Customer Premises Equipment (for example a PABX Indial, an Email Server, a Web Server, a business File Server, Video conferencing).

A **Business Access Unit (BAU)** is in reality a Symmetrical High Speed Digital Service Line (SHDSL) Modem, located at the Node/District or Local Exchange and it connects with two copper pairs in the analogue CAN to the Customer Business Premises. Because it has two pairs, this BAU / CAN has separate go and return (send and receive) paths, unlike ADSL which has bi-directional transmission on a single pair.

[1] http://www.moore.org.au/comms/01/20051102%20Telecommunications%20101.pdf

Although ADSL has a fast download data rate the ADSL upload rate is comparatively slow, making ADSL not suitable for business network structures, and this is where a BAU shines. The standard transmission protocol remains as 30B + D (30 Bearer channels and one common Data channel for LAP-D signalling), but commercially the connection can be constructed with a number of channels blocked - at a cheaper usage rate - using the same equipment to provide say 10, 20 or 30 Bearer channels on the same copper pairs.

For MegaLinks and Frame Relay this technology is virtually identical to PRI ISDN except that the connection is dedicated (by a software switched connection) and the connection protocol is usually ITU recommendation X.21

All these Digital CAN technologies have the same demarcation points as described in Telecommunication 101 and pictorially, they are shown below connecting from a DDF interface to copper pair connecting to the MDF through to a cable feeding through towards a customer termination point, where there is Customer Premises Wideband Terminating Equipment that then connects to the customer equipment.

Because of insertion loss in the pair copper cable, the usual maximum distance for this type of CAN is about 2000 m before regenerators are required or another bearer technology is used instead of pair copper cable. Common alternative bearers include point to point radio and optical fibre.

At the customers premises, the CAN connects to the Customer Premises through the Customer MDF as a pair cable then connects and then the ISDN Multiplexer / PABX, Computer/Server etc.

The demarcation point between the CAN and the IDN is at the equipment side of the Intermediate Distribution Frame (IDF) where this pair connects back to the ISDN Multiplexer - which is connected to the Node (District) Exchange / Switch (in the IEN), where it is switched through to the distant end CAN.

The demarcation point between the CAN and the CPN is the first connection to the customers MDF from the CAN side, after the Line Multiplexer/Modem.

Basic Rate ISDN (BRI) never really happened in Australia, and the common practice is to run a 2 Mb/slink - but use 10 or 20 of the total 30 available channels - at a proportionately decreased price..

Frame Relay / Mega Link CAN

Frame Relay / Mega Links / WANs etc also fits into this CAN structure in a very similar manner as these all have a Digital CAN - via a Digital Multiplexer in both the Customer Premises and the IDN/Core Network interfacing to the physical CAN (which can be Twisted Copper Pair(s), Optical Fibre(s) and/or Radio).

Within the IDN / Core Network; the Frame Relay / WAN path connects from the CAN Line Multiplexer via Routers to create Wide Area Network (WANs) through District, Regional, and interconnect/Gateway switches - which are usually connected by long distance Optical Fibre transmission systems between these building sites.

In this case, the demarcation point between the CAN and the IDN / Core Network is the Equipment side of the IDF or Optical Distribution Frame (ODF) in the Node Switch, connecting to the CAN (and including the Line Multiplexer). The demarcation point between the CAN and the CPN is the first connection to the customers MDF from the CAN side, after the Line Multiplexer/Modem.

Comments and Corrections are welcome