THE TECHNOLOGY OF BROADBAND ACCESS

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INTRODUCTION

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WHAT IS BROADBAND?

“Broadband” seems a very flexible term, for example defined quite differently by engineers and marketers, as well varying with time. One technical definition covers data transmission where multiple streams of data share the one transmission medium, while the ITU-T (in recommendation I.113[1]) considers Broadband [ISDN] to be at rates greater than primary rate ISDN (1.54 Mbit/s in North America, 2.048 Mbit/s in Europe and Australia). Marketers, particularly in Australia, seem to think Broadband is data transmission at any rate over dial-up (56 kbit/s).

Broadband is a relative term, understood according to its context. (My personal definition is that broadband data is data transmission at a speed at least twice the speed I have at present!).

In this paper, I mainly consider broadband supporting data rates over 1 Mbit/s, and often up to 25 Mbit/s. “Broadband” has to support a wide range of services, up to and including high definition video. I believe that despite the media’s concerns about “broadband” and “broadband league tables” we must consider more than high speed Internet access, but also the end-to-end networks needed to support a full range of services – Next Generation Networks or NGN.

This article draws on a number of previous articles in the Telecommunications Journal of Australia to provide an overview of the technology needed to provide this form of Broadband – full service Broadband.[2]

BROADBAND SERVICE SUPPORT

Broadband access is only useful as part of an end-to-end network. Broadband networks have to work with current (legacy) networks, and support similar services as next-generation networks.

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[1] Part of the “Broadband ISDN” series developed in the 1990s by the ITU-T.

[2] These articles, all by Peter Darling, are:-

- “Future Network Standards”, TJA, Vol 53 No 1
- “The Marriage of Telephony and the Internet”, TJA, Vol 54 No 1
- ‘The 21st Century CAN”. TJA, Vol 55 No 2
- “Overview of Telstra Strategic Review”, TJA, Vol 56 No 1

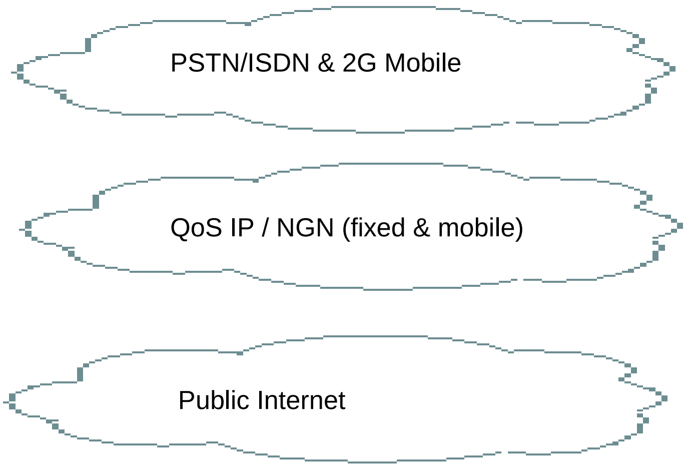

Figure 1 Future Networks

The **PSTN/ISDN** is based on 64 kbit/s digital connections, with a separate "common channel" signalling system. Network access may be analogue (telephony), 64 kbit/s digital (ISDN) or low speed digital (mobiles). The predominant service is voice (telephony), with low bit-rate text carried by 2G mobiles. Broadband networks will have to work with the PSTN, and should be able to support current PSTN services.

The current **Public Internet**. is a simple network able to support a wide range of services, based on the set of protocols defined by the Internet Engineering Task Force (IETF). The primary protocol is the Internet Protocol (IP), a simple connectionless packet protocol able to operate over a range of media. Other protocols work in association with the Internet protocol, for example, TCP to assist reliable end-to-end operation by acknowledging and/or requesting retransmission of packets. One of the main reasons for the success of the Internet has been the provision of open interfaces, encouraging rapid innovation (for example, the development of the World Wide Web).

The Internet is simple and robust, working to route each packet to the required destination. There is no guarantee of delivery of the packet, and unless an end-to-end protocol such as TCP is used, no knowledge of the delivery (or non-delivery) of a packet. The transmission and reception of each packet is a separate event, and each may be routed by a different path. At times of link congestion packets may be delayed or dropped, and may arrive at the destination in a different sequence from the transmission order. In summary, the Internet is a "best endeavours" network.

These characteristics cause problems for interactive services such as real-time two-way voice. At times of network congestion there may be unacceptable delay or jitter, and quality may not be adequate.

Applications using the Internet often use the associated Domain Name system to translate from (relatively) user friendly names to the underlying IP address for a required destination. Once an IP address is obtained, the sending customer equipment assembles information to be transmitted into a packet, places the IP address in the header fields and passes the packet to the network to be delivered.

The **Future Broadband Network** (full service Broadband) will need to support the services from these two main groups of networks, as well as providing the flexibility to support future services. There is a general consensus that this **Next Generation Network** will be based on Quality of Service enabled extensions to the Internet Protocols (IP).

ENABLING TECHNOLOGIES

Optical Fibre transmission technology is the major enabling technology for broadband. A single optical fibre pair can carry data at rates in the Terabit per second range, and a cable can contain multiple fibres, giving a multiple Tbit/s capacity.

The major part of the costs of an optical fibre systems often comes from the physical installation of the cable. The marginal cost to add extra capacity on an existing system is low, and for a cable carrying a large amount of traffic, the average cost per Mbit is low. For a low traffic load, the cost per Mbit is much higher.

High speed digital electronic technology enables switches/routers working at Gbit/s or even Tbit/s speeds, providing the basic network fabric.

The **Internet Protocols** support most current broadband network realisations.

Digital radio transmission, combined with **cellular techniques** and **smart antenna technology** enable broadband speeds over radio, particularly for access to mobile and nomadic[3] users.

Digital Subscriber Line technologies support broadband transmission over existing twisted-pair copper lines originally installed to provide analogue telephony.

BROADBAND NETWORKING

A Broadband network can be divided into two areas, with a clear distinction in the network arrangements (and appropriate technology) between each:-

- The **core or central network**, serving multiple users; and
- The **access network**, serving individual users.

The PSTN shows a similar division.

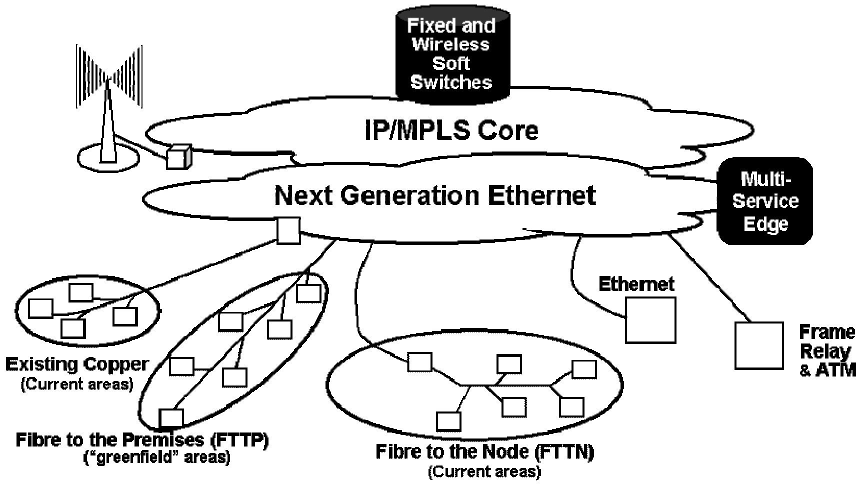

Figure 2 – Telstra's Proposed Network

Figure 2, based on information Telstra supplied in November 2005, shows their intention to provide a common Core Network, with varying Customer Access Network arrangements for different customers and different services.

THE CORE NETWORK

Traffic from a number of users is combined in this part of the network. This results in relatively large circuits interconnecting large routing/switching elements of the network.

As a consequence, these "thick routes" almost always use optical fibre as their underlying transmission medium. Pont to point transmission linked are derived using techniques such as SDH (synchronous digital hierarchy, known also as SONET in North America),

[3] A Nomadic user accesses a service at different locations, but is stationary for each access.

Much of the current Internet does not differentiate between different services. For full service Broadband networks, there is a need to provide different levels of assured quality for different services across the network.

Table 1, from ITU-T Recommendation Y.1451 shows proposed QoS classes required to be supported across future networks.

QoS Class	Applications (Examples)	Node Mechanisms	Network Techniques
0	Real-Time, Jitter sensitive, high interaction(VoIP, VTC)	Separate Queue with preferential servicing, Traffic grooming	Constrained Routing and Distance
1	Real-Time, Jitter sensitive, interactive (VoIP, VTC).		Less constrained Routing and Distances
2	Transaction Data, Highly Interactive, (Signaling)	Separate Queue, Drop priority	Constrained Routing and Distance
3	Transaction Data, Interactive		Less constrained Routing and Distances
4	Low Loss Only (Short Transactions, Bulk Data, Video Streaming)	Long Queue, Drop priority	Any route/path
5	Traditional Applications of Default IP Networks	Separate Queue (lowest priority)	Any route/path

Table 1

Network techniques, working at Layer 2, are used to provide the “constrained routing” needed for real-time, interactive services such as telephony (voice), supporting assured virtual paths to reduce the possibility of delay, jitter and wander in the data streams. Until recently this was achieved by the use of the ATM (Asynchronous Transport Multiplexing) protocols standardised by the ITU-T, but now the use of MPLS (Multiprotocol Labelling System) standardised by the IETF is becoming the preferred approach. These techniques change the connectionless public Internet (based on IP at Layer 3) into a connection-oriented network.

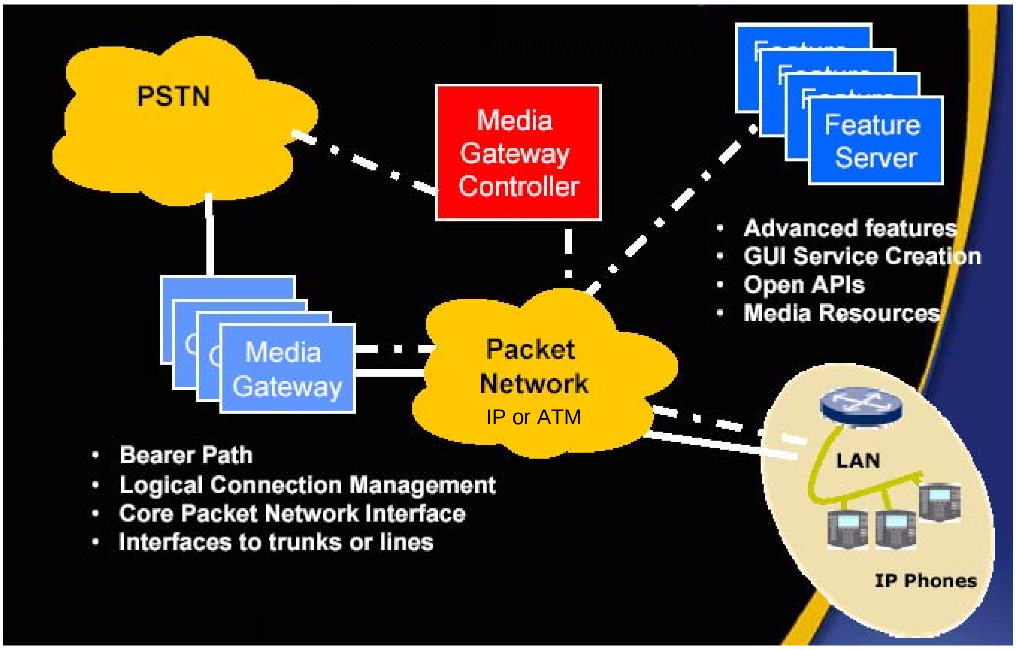

Figure 3 – SBC Network Architecture

Figure 3 was produced by the USA telco SBC four years ago, to show the architecture they were then planning to develop. This same style of architecture has been used, or is being planned, by many major network providers, with the major difference that there is now agreement that the core Packet Network will be based on the use of Internet Protocols rather than the ATM-based "Broadband ISDN" concept developed by the ITU.

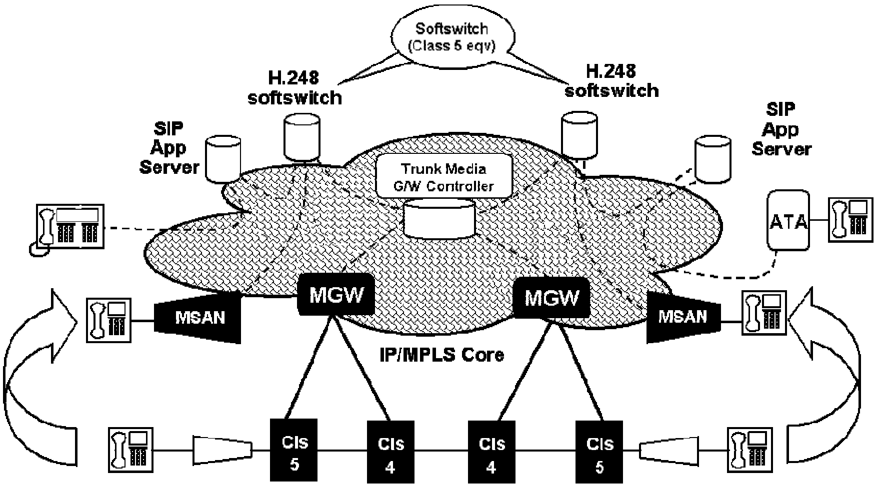

Figure 4 – Telstra Network Architecture

Figure 4, from Telstra's November 2005 presentations, shows their realisation of this approach for the provision of telephony service. The Core Network is used for both transport and control, with **Media Gateways** (MGW) performing telephony switching functions under the control of **Softswitches**. **Multi-Service Access Nodes** (MSAN) can provide telephony along with other services, and **Analogue Telephone Adapters** (ATA) provide direct IP to telephony access, using **SIP** (Session Initiation Protocol). Other realisations now being standardised use the **IP Multimedia Subsystem** or **IMS** developed initially for 3G mobile rather than Softswitches.

ACCESS NETWORKS

For most users, the level of traffic on an individual communications service is quite low. For much of the time their access link is idle, but it must be available to be used at any time for use. For example, In the fixed telephone network, facilities in the **Customer Access Network or CAN** are provided on a per customer basis, and must be in place even if only used for a very small part of the time. (For this reason, many people regard the CAN as having the characteristics of a natural monopoly.)

AN ACCESS NETWORK MODEL

The Broadband CAN has to provide reliable, high-speed access to and from each user. The appropriate technologies in each case will be determined by the balance between the service the user requires, the amount the user is prepared to pay, and the cost of installing and operating the access arrangements.

For users with a high level of traffic, it would probably be economic to provide optical fibre direct to the user's premises, possibly using techniques such as "SDH rings" to share the capacity of fibre between different users and provide better security in the event of a fault such as mechanical failure of the fibre.

For other users, the way to provide broadband access is less clear. High capacity transmission facilities need to be provided to each user, but the high cost of this provision limits what can be done.

The division between 'core network' and 'access network' applies for both existing and new technologies and services. High capacity access to and from the core network is provided up to a point of concentration serving a group of customers, generally in a limited geographic area – called an '**Access Unit**' in a previous article[4], and in the discussion below.

The Customer Access Network provides links to and from users to this Access Unit (and thus the core network) using technologies optimised for access, designed to be able to provide access to the core network at all times when required by the user.

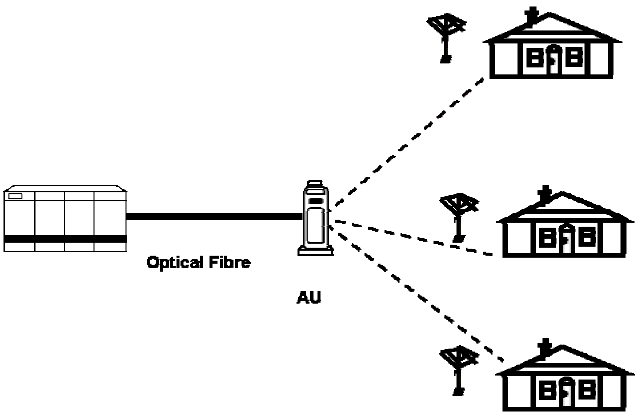

Figure 5 – Access Unit

The Access Unit may be located in public property (for example, at the side of a road) or in private property (for example, the basement or roof of a high-rise building).or in dedicated buildings (for example, current exchange telephone exchange buildings). The Access Unit might also be a Base Station for one of the growing number of radio-based technologies.

As Figure 5 shows, the Access Unit is connected by Optical Fibre to the other elements of the Core Network. Customer access from the Access Unit may use a wide range of technologies, as discussed in later sections, including:-

- **Coaxial cable**:- For example, extending the use of a cable TV service.
- **Copper**:- Using the current copper access network, both for telephony and data using DSL (Digital Subscriber Line) technology;

[4] *The 21st Century Can*, TJA Issu??f

- **Terrestrial Radio**: - including the current narrow-band mobile services, and the next generation broadband systems;
- **Satellite and Tethered Stations**:- Radio access from geostationary satellites, position keeping platforms or by constellation of satellites in other orbits;
- **Distribution by Powerline**: - The final access may be over the mains power line, with high frequency signals superimposed over the 50 Hz (or 60 Hz) power distribution.
- **Optical Fibre**:- The final distribution may also be by optical fibre, using techniques such as Passive Optical Networks to reduce infrastructure cost.
- **Other Technologies**:- A range of other technologies for the last ten to a hundred metres have been proposed (for example distribution by unguided optical link or very high frequency radio links requiring line of site access).

WHY NOT OPTICAL FIBRE TO THE USER?

Optical fibre technology is able to carry data at very high rates, and a customer access network based on optical fibre would meet all likely business and consumer needs for broadband access for a considerable time. For some users (for example, those requiring mobile access or those requiring fixed access from multiple locations at different times) this would not be possible, but for many others this may be a long term goal.

Economic reality is the key . Do users really want services demanding hundreds of Mbit/s (or even Gbit/s), and how much are they willing to pay?

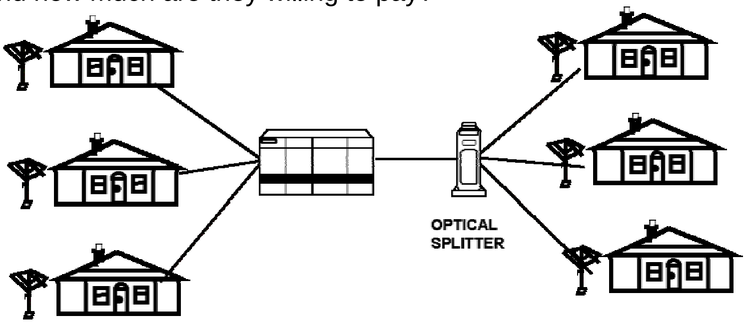

Figure 6 - Fibre to the User

Optical Fibre access is current technology – standards have been developed, equipment is available and is being deployed in some areas. In 2003, the three largest local telephone companies in the USA agreed on a joint technical approach to **FTTP** (*fibre to the premises*, also sometimes called *fibre to the home* or **FTTH**). They have all subsequently started commercial trials. **Verizon** has been the most optimistic about the technology, and is now rolling out their **FiOS**[5] service, providing a triple play of TV (SDTV and HDTV), voice and Internet, in competition with cable TV companies. A number of smaller companies in the USA and Europe have started FTTP services.

There are two main technologies now in use to provide fibre to the user:
A point-to-point access network, with individual fibres to each user (as shown at the left of Figure 6) similar to the telephony CAN structure. The main problem with such a network has been high cost, but according to some vendors the reducing cost of active optical equipment is overcoming this objection. Greenfield installations using equipment to the standard IEEE 802.3ah are now taking place in the USA. Installations are either direct from the exchange, or using an intermediate active optical unit. Similar networks are in place to meet the needs of large business users.

PON (Passive Optical Network: An alternative and (to date) less costly technology has been standardised and is now commercially available. This technology replaces active opto-electronics at a user's premises and in the field with more robust and less expensive passive devices, using optical splitters at the Access Unit to service a group of users, as show on the right of Figure 6. Current standards and equipment provide data speeds from 155 Mbit/s up to 2.4 Gbit/s to each user.

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[5] See http://newscenter.verizon.com/kit/fiber/

The cost of providing a FTTH installation is now close to that of providing a traditional copper telephony access. There are continuing trials of FTTH in Australia, but no concerted move to provide FTTH in new housing estates, based in part on commercial and regulatory concerns.

The Victorian Government has taken recent initiatives[6] to set a framework so that Fibre to the Home could become a standard approach in new housing estates. VicUrban, the developer of a new housing development in Melbourne's north, has undertaken to have fibre to the home (FTTH) rolled out across the estate.

MultiMedia Victoria has issued a tender for the provision of FTTH on the Estate, and will use the experience gained to provide public information about the viability of FTTH. The Aurora website indicates the Victorian Government is seeking to learn more about

- the costs involved in rolling out FTTH in a new estate;
- who would pay these costs;
- how risk would be allocated in joint FTTH projects;
- the kinds of services that make FTTH a selling feature;
- the economies of scale required to make a FTTH project work;
- whether government policies, Federal, State or local, impact on the success of FTTH rollout, and
- the information developers, local councils, investors, and State Government require when undertaking FTTH projects.

In areas where a copper access network is already in place, and in the absence of a major "killer application", there is very little likelihood of a successful business case to provide widespread FTTH based solely on commercial returns. In the absence of commercial investment, the introduction of a widespread Optical Fibre CAN may only proceed with agreement at the political level.

In Australia, a paper[7] by the Page Research Centre, associated with the National Party, developed as part of the recent discussion on the privatisation of Telstra, described an option for a government-provided optical fibre CAN, replacing the existing copper CAN, to all but 6000 remote users in rural Australia.

It quoted an estimate prepared by the construction company Baulderstone Hornibrook that that this would take $7 Billion over five years, but noted that Telstra's costing was closer to $30 Billion over 20 years.

TAKING OPTICAL FIBRE CLOSER TO THE USER.

DSL - Extending the Use of the Copper CAN

The copper telephony access network in place in Australia is able to pass much higher frequencies than the original 4 kHz for which it was designed. This fact was used for ISDN customer transmission systems developed in the 1980s, and has been extended using Digital Subscriber Line (DSL) technology.

As Figure 7 shows, the available spectrum on the copper pair is split to cover the two directions of data carriage over the single pair. As the diagram shows, the most common approach results in asymmetrical transfer with a higher rate of data from the network to the customer, with voice continuing to be carried as a 4 kHz analogue band below the DSL signals.

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[6] http://www.mmv.vic.gov.au/broadband/Aurorafordevelopers

[7] *Future Proofing Telecommunications in Non-Metropolitan Australia,* Page Research Centre Ltd, March 2005. www.page.org.au

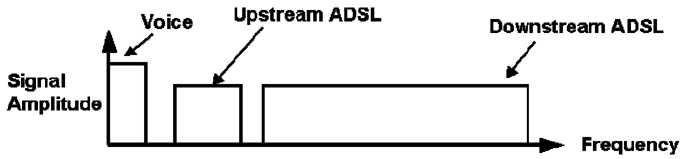

Figure 7 – ADSL Spectrum Allocation

This **'ADSL'** or **Asymmetric Digital Subscriber Line** is now the most common way of providing broadband access in Australia. If a copper access line is in good condition (which is certainly not assured) speeds of up to 2 Mbit/s from the network to the user can be achieved using the initial ADSL standards at average distances in a suburban exchange area, and up to 256 kbit/s in the reverse direction. This may be adequate for one SD TV programme, but not for the full range of 'triple play' services.

The speeds available in a real-life network are limited by interference, reflections and attenuation. Initial Australian operational standards[8] allow for the use of ADSL to approximately 4 km from the exchange at typical speeds up to 1 Mbit/s 'down' and 256 kbit/s 'up', with systems able to operate at reduced speed under more difficult conditions. The industry body ACIF has also agreed on network and operational standards for the next generation of DSL, **ADSL2** and **ADSL2+**, providing speeds of up to 10 Mbit/s[9] at distances of 1 to 1.5 km from the exchange. .

There has been a range of differing DSL system standards agreed internationally, both asymmetrical (with a greater speed from the network to the user) and symmetrical (equal speeds in each direction). Newer technologies that have recently been standardised have the promise of increasing the achievable speed, but care needs to be taken because systems using different standards (or even multiple systems using the same standard) within the same physical cable cause interference.

If the termination point of the copper can be close to the end-user, the loss is less and higher frequencies can be used[10] than with a system at the exchange. Korea Telecom is now providing regular DSL services at speeds greater than 20 Mbit/s, and speeds as high as 100 Mbit/s are being planned with new VDSL standards.

Technology now being introduced enables the copper access network to support:

- Telephony, either by analogue access or IP telephony;
- Data, generally broadband Internet access; and
- Video on demand, using IP-based TV technologies, if bit rates of 5 Mbit/s and above are available.

Future DSL technologies (e.g. VDSL and VDSL2) could enable higher speed access and support of other services such as High Definition TV over short distances of copper.

DSL Access Units – Fibre to the Node

A **DSLAM** (DSL Access Multiplexer) provides the Access Unit Function for DSL, connecting to the copper pairs on the user side, and to a data network (generally IP based) via optical fibre on the network side. The first generation DSLAMs were relatively large, and were generally located at the exchange building. Current generation DSLAMs are more flexible, and in addition to provision at the exchange site can be located closer to a group of customers. DSLAMs may be stand-alone, or combined with the Access Units for the telephone network.

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[8] These have been developed as a set of ACIF network and Operational Codes, agreed by the industry and registered by the ACA. Details are at www.acif.org.au/publications/Suites/ull_dsl

[9] Some of the suggestions of higher speeds reported in the media do not seem to take into account the reduction in speed as the number of ADSL services in a single cable increases.

[10] TransACT in Canberra offer speeds up to 20 Mbit/s over their own short copper access lines using VDSL, a high speed DSL variant.

The first ADSL standards (ADSL1) were sufficient to provide ADSL service at download speeds below 1 Mbit/s for users within 4 km, and at lower speeds for users further from the exchange. For the first generation of DSL-based broadband, Telstra capped this technology at 256 kbit/s download, presumably to ensure that virtually all customers connected to metropolitan exchanges could receive the service.

Later international standards for ADSL (ADSL 2 and ADSL 2+), supported download speeds up to and beyond 10 Mbit/s for users located close to an exchange, but for customers further from the exchange the available speed dropped off rapidly.

If exchange-based ADSL 2+ is to be used to provide high speed broadband access, then only those users near the exchange will benefit from exchange-based service. Higher speed access to a larger number of users can be obtained by placing DSL Access Units remote from the exchange, nearer the user.
Based on figures provided by Telstra at its November 2005 Briefings, then for a target download speed of 12 Mbit/s:-

- For the approximately one third of users that are located within 1.5 km from an (urban) exchange, service could come from ADSL2+ DSLAMs at existing exchange sites (on the left hand side of Figure 8);
- For the other two thirds who are more than 1.5 km from their current exchange, Telstra proposed establishing 'nodes' within 1.5 km of each user using equipment remote from the existing exchange (in cabinets at locations close to the user, e.g. road-side locations), as shown on the right hand side of Figure 8.

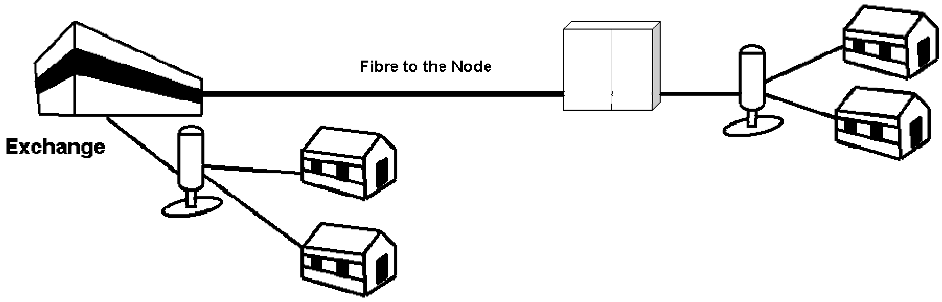

Figure 8 – DSL Access Arrangements

This approach has been called **Fibre to the Node** or **FTTN,** and has been used by network operators in North Asia, North America and Europe. A consortium of other Australian communications network providers, the G9[11], has proposed a technically similar approach to the provision of broadband access.

REGULATION, COMPETITION AND INVESTMENT

Technologies such as FTTN and FTTP that involve substantial work upgrading the telephony access network produce access networks with natural monopoly characteristics, with one infrastructure provider the direct result.

A similar situation applied for the telephony CAN, but it was largely developed before competition in telecommunications. Regulation was put in place to allow other network operators to use the CAN without having to pay monopoly rents to the incumbent.

The political challenge of the new technologies is to give a good enough return for an organisation to invest in the provision of infrastructure, while continuing to support service competition.

At the time of writing, commercial and regulatory concerns have resulted in Telstra withdrawing its FTTN proposal, and the similar G9 FTTN initiatives seem to be a long way from realisation.

[11] http://www.allenconsult.com.au/publications/view.php?id=305

RADIO-BASED ACCESS

Customer access systems can use radio to provide the link from a serving point (Access Unit) to and from the end-user. This point can:

- Be situated close to the user, for example at a WiFi 'hot spot', which is connected to a fixed broadband access arrangement;
- Cover a small to medium area, for example from a radio base-station in a cellular system; or
- Be located remotely from the user, as in a traditional wide-area coverage system such as TV transmission, in a high altitude platform or a satellite system.

For mobility, radio access is essential. The high value placed on mobile services by the market has been reflected in prices set for spectrum access, in many cases increasing the total cost of radio-based systems.

Cellular Mobile services provide voice plus data. The latest releases of 3G systems use an all-IP architecture to deliver a full range of services, from low-rate text through voice to medium-speed video. These systems are optimised for mobility, and do not seem to be candidates to replaced the wired CAN except in limited cases, such as in rural and remote areas. Telstra has indicated that it believes the 850MHz UMTS 3G network it is installing, as described in a previous Telecommunications Journal article[12], will provide broadband access after it has been enhanced by the introduction of HSPDA .

Local Area services (including IEEE 802.11a at 5.8 GHz, and IEEE 802.11 b & g at 2.4 GHz) can provide extensions of the public Internet within a dwelling or business, or in a commercial location ('WiFi hot spot'). These services may provide IP telephony services in the same way as any other broadband access, but they are subject to interference and, in public locations, possible high network loads. A number of groups are investigating the use of these systems for broadband access in rural areas, using high gain antennas and radiated powers higher than normally permitted. If there is limited interference in such a location, the low cost of consumer equipment should make these a viable alternative for Internet access, though less so for telephony use.

Wide Area Services provide for customer access over wider areas. In metropolitan areas, these systems may use small or medium size cells. In rural areas the service area may be only limited by radio propagation limitations. These systems include those based on standards such as WiMax (based on the IEEE 802.16 series of standards now being finalised).

For systems which have been standardised and achieved a mass market, the cost of customer equipment can be very reasonable. This has already happened with WiFi equipment, where user equipment is now being incorporated as standard in laptop computers by Intel and others. The WiMax Forum was established in April 2003 to achieve the same goal with the IEEE 802.16 suite of standards.

Proprietary versions of these services are now being commercially offered, including:-

- **Personal Broadband Australia** is using proprietary iBurst technology from Arraycom to offer a broadband access service, designed for both nomadic users and mobile users. The company provides coverage in the major cities in NSW, Queensland, the ACT and Victoria, with extension to capital cities in other states planned. The service is being sold by a number of service providers, with an advertised speed of 1 Mbit/s / 345 kbit/s, and a market positioning as 'mobile broadband'.
- **Unwired Australia** is using a pre-standardisation version of IEEE 802.16 equipment to provide broadband Internet access to nomadic[11] users, initially in the major capital cities. They now offer broadband Internet access at stated speeds from 256/64 kbit/s to 1024/256 kbit/s to nomadic users, and will upgrade the network to comply with WiMax standards.

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[12] "Overview of Telstra Strategic Review, TJA, Vol 56 No 1

- **Austar** is using the same technology as Unwired to provide IEEE 802.16 based broadband service, initially in major rural centres. Austar and Unwired will support inter-system roaming, and with Soul Communications are bidding for Government funding to extend the network into other rural areas.

These services are able to provide medium to high speed broadband Internet, and via that access, IP telephony, but do not have sufficient bandwidth for standard definition TV.

There are considerable differences of opinion on the ability of wireless techniques to provide a viable alternative to other techniques for Broadband access. A report by the British Consultants *Analysys* for the ACCC[13] suggested that either 3G or WiMax could provide a cost-effective means of providing broadband access in rural and remote areas. The NZ-based firm *Network Strategies* disputed the Analysys report[14], pointing to the limited availability of spectrum and claimed errors in modelling coverage and available capacity characteristics.

These arguments are about non-urban areas. In urban areas, radio-based techniques are not likely to be able to provide the density of coverage needed to serve as the major service provider, except perhaps as an alternate technology to provide the final link between an Access Unit situated close to a user and the user's premises.

CABLE TV NETWORKS

In many countries users have access to cable TV provided over a separate customer access network. These entertainment delivery networks ('Pay TV' or 'Cable TV') use optical fibre links to an Access Unit that serves a geographic area, and then coaxial cable to customer's premises, hence their description as 'HFC' or hybrid fibre/cable networks. The first generation of these systems used a range of frequencies in the VHF and UHF bands to send analogue TV signals, encoded for security. Current systems have been upgraded to carry digital signals in addition to, or in place of, analogue signals, generally with a return capability from the user to the network.

Not all the available spectrum in the cable is in use for broadcast TV and radio. In general, some spectrum has been reserved for other purposes, and is matched with a return capability from the user to the 'access unit'. This spectrum may also be used for

- Circuit-switched telephony, as in the Optus cable;
- Broadband Internet access, using cable modems, generally operating to the DOCSIS standards[15];
- IP telephony over the broadband access; and
- Digital TV for 'video on demand' services

If the cable infrastructure is already in place, this technology provides a relatively easy means for the provision of an alternative telephone service. Many network operators in North Asia, Europe and North America are introducing the 'triple play' of entertainment, broadband Internet and telephony using their current cable TV networks.

The situation in Australia is different, with the cable TV network infrastructure provided by current telephone companies (Telstra and Optus) rather than specialist cable TV operators. These networks are providing data (Internet) access, and Optus's telephony service. Particularly under current ownership, the Foxtel Network seems unlikely to provide an alternative CAN for all the 'triple play services', and Optus has given no indication of any intention to extend its investment.

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[13] *Analysys - Comparative costing of wireless access technologies in Australia* (5 May 06); available from ACCC website www.accc.gov.au .

[14] *Network strategies—accurate assessment of costs of wireless access tech in Aust* (Jul 06); available from the ACCC website www.accc.gov.au

[15] Data over Cable Service Interface Specification, developed by CableLabs and standardised as ITU-T Recommendation J.112 (DOCSIS 1.1) and ITU-T Recommendation J.122 (DOCSIS 2.0)

Powerline Communications

The AC power distribution network (or CAN) rivals the copper telephone access network in size. In a similar way to the telephone CAN, the electricity access network is able to carry higher frequencies than the 50 Hz power distribution for which it was designed.

Two potential uses have been identified:-

- Within a dwelling, for distribution over the internal power wiring (In-house); and
- For access to a dwelling, to provide delivery of broadband Internet and other services (Access).

Figure 9, from a report prepared for Australia's Department of Communications, Information Technology and the Arts (DCITA)[16] shows possible points where the high frequency information may be injected and recovered. Most applications use the low voltage transformer point, serving 15 to 30 dwellings in urban areas.

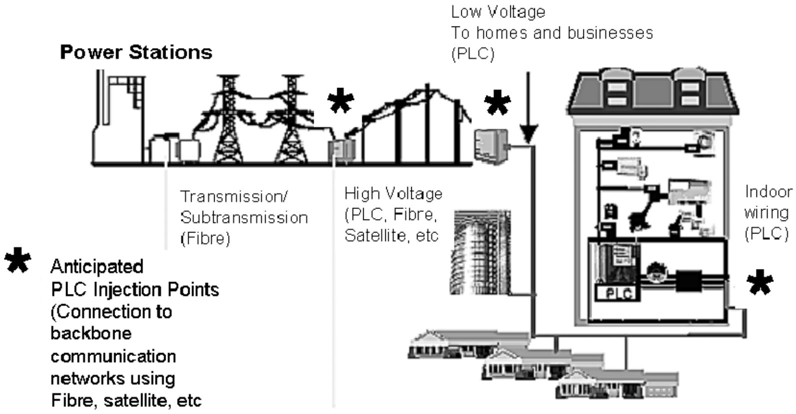

Figure 9 – Powerline Communications

Several different standards have been developed internationally to provide high speed broadband access via powerlines, primarily Internet but also IP telephony

Powerline communications are able to deliver broadband access. The current technology is claimed to deliver up to 45 Mbit/s, which would be shared by the users connected to the distribution point, but this may not be realistic in an operational environment, taking into account possible interference, as the majority of the Australian power distribution network is pole mounted and is likely to radiate the high frequency signals added for broadband communication.

Users of the radio spectrum have expressed concern about the radiation that would be produced in the HF and low VHF radio bands by the technology. There is also some concern about the susceptibility of the technology to interference created by electro-mechanical and electronic devices using the power system. The Australian Communications Authority has recently released a Discussion Paper[13] looking at the implications of introducing broadband powerline communications.

The report to DCITA cites commercial service in Europe (primarily Germany to date) and trials in many other countries. Powerline communications technology over underground power distribution and within a building does not create the same level of interference problems (which may explain the reasons the technology has been more successful in European urban areas, where much power distribution is underground).

[16] PB Associates, 'Technology Review of Powerline Communications (PLC) Technologies and their use in Australia' 25 June 2004. A report to the Department of Communications and the Arts, available at www.dcita.gov.au/Article/0,,0_1-2_3-4_119354,00.html .

The Australian communications regulator, the ACMA, issued a Discussion Paper in mid 2005, receiving more than 270 submissions, many of which were from radio users concerned with unwanted emissions.

The ACMA has issued guidelines[17] that must be followed for trials in Australia. At September 2006 trials had been notified by Aurora Energy in Tasmania, in the Newcastle Region of NSW and at Queanbeyan in NSW. These trials are being monitored to measure the actual radiated energy, and the frequencies at which it occurs.

It is likely that broadband powerline communications could be successful in the high-density residential market, but until interference concerns can be addressed (if this proves possible) broader commercial use seems unlikely.

NON-TERRESTRIAL WIRELESS

Radio access from elevated platforms has a long history, but the platforms are generally attached to the ground (transmitting towers). Short-term access from a moving plane has been used for emergency purposes, or wide area broadcasting. Longer term, options giving effective use of the radio spectrum include:

- Platforms at a fixed position relative to the user, enabling tightly focussed radio beams to be used; or
- Platforms moving relative to the user, with antenna arrangements at the user's premises tracking the platform or multiple platforms.

Systems of this type include:

- Tethered platforms (blimps), acting in effect as a high tower;
- Non-tethered platforms that are designed to maintain a constant location, above the troposphere (and above the very variable weather);
- Low earth-orbit satellites, with many satellites in a system so that service can be provided continuously; and
- Satellites in geo-synchronous orbit that stay at the same position relative to the user.

Non-terrestrial wireless potentially could be used to provide a full range of broadband and narrow-band services. High altitude platforms can use super-high radio frequencies that require line-of-sight access, as there is usually an unobstructed path from platform to user. At these frequencies, there is significant capacity available for broadband carriage, using frequencies generally unable to be used with terrestrial systems (except for line-of-sight links).

Geosynchronous satellites orbit at a distance of approximately 35,790 km above the earth, which results in a round-trip propagation delay of approximately one quarter of a second for signals travelling to and returning from the satellite. This delay does not present a problem with non-interactive systems such as television broadcasts, but reduces the performance of common network protocols such as TCP/IP and adds considerable delay to IP telephony services.

This may be acceptable for use on direct links, but poses considerable problems for services over an end-to-end network connection when the delay from other links and routers must also be taken into account. More than one such satellite in a connection would prevent the use of the link for voice. Such an access is only likely to be used for IP telephony as a last resort (e.g. in island or very remote locations without viable alternative access arrangements).

Tethered platforms have two main problems – keeping a constant position with varying weather, and the tether itself which is a major problem for air traffic.

Platforms above the troposphere can overcome some of these problems, as long as they are able to keep a constant position and orientation on a long-term basis. Maintenance and fuel

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[17] See the ACMA website at www.acma.gov.au/ACMAINTER:STANDARD::pc=PC_2845

requirements may also limit service availability, or require a second platform on standby to cover outages.

There are at present no tethered platforms in operation in Australia, and to the best of the writer's knowledge none are currently planned.

Low earth-orbit satellites have not delivered their promise. Many systems were planned, and several launched during the 1990s. Following the commercial failure of these systems, it is very unlikely that any further will be implemented in the short to medium term.

Geosynchronous satellites are currently being used to provide internet, video as well as telephony access. International systems such as Inmarsat, and domestic systems using satellites such as those owned by Singtel-Optus and IPStar are an effective means of providing service in remote areas, and for temporary installations, as well as providing direct links in a business network. These systems have the advantage of flexibility and coverage, but except in remote areas are less likely to be competitive in cost with terrestrial alternatives, after account is taken of the disadvantages discussed above.

CONCLUSION

Broadband in the Core Network can be provided economically, and networks are now being installed to provide full service Broadband, by development of existing Internet networks and/or by the upgrading of existing telecommunications networks.

Broadband Access technology is available, but the economics of the use of the technology is much less certain.

To date, we in Australia have benefited from technological developments which have resulted in a continuing increase in the data access speeds:-

- From 300 bit/s to 56 kbit/s over the telephone network using modem technology;
- Data access at Mbit/s speeds over existing Pay TV networks;
- DSL over the existing copper wires provided for the telephone network at Mbit/s speeds; and
- Growing data access speeds over 2.5G and 3G mobile networks.

We have almost reached the end of the “low hanging fruit”. For access speeds over 10 Mbit/s, users who are not lucky enough to have access to a Pay TV HFC cable, or be close to an exchange, are out of luck.
The solution is to move the Access Unit (the Optical Fibre termination point) closer to the end-user. This could be done by a FTTN network, or by a full Optical Fibre access network.

These solutions require significant investment, and at this stage it is not at all clear that the Business Cases for these investments make commercial sense, without Government support, which is not at present likely in Australia.

The technologies exist – what is the priority for their implementation?