5 - Next Generation Telecommunications Networks

Recent advances in telecommunications technology has created a broad range of possible choices. The industry's future is fluid with carriers seeking competitive advantages. Vendors and carriers have been hesitant to provide information as to their likely future technologies. This chapter examines technologies that are able to be used but equipment purchases in the future by carriers will set the scene for the next generation of communications networks.

As will be demonstrated, the range of available options for provision of communication services is extensive and hybrid systems can provide cost effective solutions. Knowledge of these technologies and those that will follow are vital for telecommunication engineers who are planning for infrastructure development. The choice of equipment and protocols can have a great effect on product offerings for a considerable period.

It is for the reasons of commercial confidentiality that vendors and carriers may have been hesitant to provide information on future planning and equipment purchases. There are a number of consultants who are able to provide strategic advice regarding new telecommunications technologies but the reports available are very expensive and perhaps not targeted to the requirements of this report.

There are some good general reports on telecommunications protocols and technologies currently in use. The Australian Competition and Consumer Commission (ACCC) has a report on telecommunications infrastructure that provides a very good summary of the technologies available.[1] The newer technologies are examined in this chapter.

One lesson to be learned from the examination of these technologies is that this industry will need to be continually scanning for emerging technologies. The emergence of new technologies will require new skills to be learned in short training sessions and these skills will have limited opportunities in which they may be applied. The challenges faced by vendors and carriers to find skilled people to support their networks will continue. The technology is not becoming simpler.

Influence of Digital Telecommunications

Telecommunications networks were originally established as analogue networks. Repeaters were used to boost the signal as it travelled over the cable and boosted any noise that was also in the connection. The emergence of digital repeaters eliminated the noise while boosting a signal. Since that time in the late 1970s, telecommunications in Australia has become more focused on digital technology.

The telephone network has in the recent past relied upon a number of core technologies for the provision of voice services. One is the use of a circuit-switched telephony that provides a dedicated connection for the duration of the call and provides for highly reliable connections. However the connection ties up that bandwidth for the duration and therefore is expensive for interconnecting networks. This requires the networks to be over-engineered for the increasing volumes of data traffic that have surpassed voice traffic.

The telecommunications network has used packet-switched technology for nearly two decades. This technology transports the data into digital packets with address headers. These packets are sent across the network by any route available. This means that there is no dedicated link established for any of the packets. One common method of packeting the data is through Asynchronous Transfer Mode (ATM) that uses small fixed-size packets and provides for the high quality levels that voice communication requires. Another method is to use Frame Relay which is less sensitive to time delay but provides for greater flexibility such as variable packet lengths.

Internet Protocol (IP) networks

Internet Protocol (IP) is defined by a telecommunications vendor as “the combination of voice, data, video, wireless and multimedia applications into an integrated enterprise infrastructure based on packet-switched and Transmission Control Protocol over IP (TCP/IP) technologies and protocols. It is the next generation of networking technology that is capable of handling all types of traffic and delivers more services that were available with separate voice and data networks.”[2]

This type of network provides for greater utilisation of the network as the data packets are routed around traffic jams. It also allows carriers to consolidate their network into one common infrastructure. Additionally with some re-packaging of the packets, greater use of the network is able to be made. However there are some technical issues that need to be resolved.

The most important is the quality of a connection through a packet-switched network where packets of data (including voice) travel across the network but not necessarily through the same nodes. This is not a problem for data as the packets are compiled by the receiving device as well as being re-sent if the packets get lost. For voice communication it is very important for the packets to arrive on time and in the correct sequence otherwise the voice sounds broken or jittery. With a circuit-switched network this problem does not arise but an IP network is not circuit-switched. Therefore if a fully IP network is to be created, this issue of quality needs to be addressed.

Additionally, an IP network needs to be able to connect to any device on the network. Through the Public Switched Telephone Network (PTSN) this is easily accomplished as long as each device has a unique address in the form of a telephone number. With mobile and remote devices connecting and sending information, the issue of addressing becomes more important as a dedicated telephone line may be too expensive.

Multi Protocol Label Switching (MPLS)

One way of assigning priorities to data packets is to use Multi Protocol Label Switching (MPLS). This method allows a network manager to give control over the path that the data packet takes across the network. For voice or video communications, a higher priority is given to these packets so that their transmission is not impeded by less temporally-sensitive data packets. An end-to-end path is established and brings a connection-oriented (such as a circuit-switched network) property to a connectionless (packet-switched) network.[3]

One of the advantages of this method of switching is that data is coming in as IP packets anyway and by using an abbreviated label in the MPLS packet this facilitates the switching. Additionally, the routing table look-up is performed only at the beginning of the transmission and this simplifies the process. Within the complex networks that carriers operate, there may be some hesitation to implement this technology until traffic demands increase to a point where new investment in the fibre infrastructure is necessary.[4]

Voice over Internet Protocol (VoIP)

As the move from circuit-switching towards the IP networks occurs, voice communication will be able to be transmitted as IP packets rather than Asynchronous Transfer Mode or Frame Relay packets. The value to the consumer is that voice traffic will travel as data in a less expensive network and make long-distance and international calls very inexpensive. Telecommunications carriers are well aware that this move is a threat to revenue and are positioning themselves to protect against revenue loss.[5] Some countries have already introduced legislation to ensure that their wholly-owned carrier does not lose income and to retain control over voice traffic for national security issues.[6]

A distinction needs to be made between IP telephony and Internet telephony. The former delivers traditional voice traffic through a PABX to the carrier's IP network rather than circuit-switched network. The latter is where voice travels through the public Internet from and to PC-based equipment or other enabled devices.[7]

The most important part of VoIP is the issue of quality which is discussed below. Circuit-switched networks provide the benchmark for quality but VoIP also must deal with issues such as security, traffic management, call identification, and carrier network interoperability.[8] As this technology requires the transmigration of not only a single carrier's equipment but also multiple carriers' equipment, there will be some delay in moving to a fully IP oriented network. The full IP network is not expected to be realised within the next decade[9] but a migration to this technology is already under way.

Quality of Service

In a packet-switched network such as the Internet, congestion in the network can slow data transmission. The TCP/IP protocols provide for re-transmission and this is acceptable when dealing with data. Voice and video traffic in a packet-switched network suffer from faults that are not present in a circuit-switched network. The following points outline the main issues:[10]

> **End-to-end latency -** This is the total transit time for packets in a data stream to arrive at the remote endpoint. Some networks give smaller packets greater priority and this may cause some problems for larger video packets. This is evident when there is an increase in the number of routers in the connection and network congestion.
>
> **Inter-stream latency -** This refers to the relative latencies that can be encountered between the audio and video data streams. It is based on how the relative average transit time for the given streams vary from each other. A difference between the two streams is noticed at only 40 ms.
>
> **Jitter or variability of delay -** This refers to the variability of latencies for packets within a given data stream primarily caused by network congestion. Differences of 50 ms create noticeable difficulties for video and audio.
>
> **Packet loss -** This refers to the loss of data packets in a real-time audio or video data-stream. Losses of more than 1 percent produce jerky video and missed words in conversations.

There are a number of solutions to Quality of Service. One is to have larger "data pipes" and is an expensive and unsustainable solution. Another is to prioritise the data packets so that voice and video have a clear path to the receiver (See the section above on Multi Protocol Label Switching). A final approach is to reserve part of the network for this traffic through queuing or buffering.

The Internet Engineering Task Force (IETF) has developed an Architecture for Differentiated Services (DiffServ – RFC 2475) to differentiate IP traffic so that the traffic's relative priority could be determined on a per-hop basis. By using DiffServ, traffic is classified based on priority and allows traffic with similar service characteristics to be passed with similar traffic guarantees across multiple networks. DiffServ allows for five categories of service differentiation. They are:

Relative Priority Marking; Service Marking; Label Switching; Integrated Services / Resource Reservation Protocol; and Static per-hop Classification.

H.323

The International Telecommunications Union (ITU) has developed the standard H.323 to transmit and receive audio and video information over the Internet from a circuit-switched network.[11] This standard facilitates the implementation of a common set of services through various telecommunications carriers. This is a complex system with 17 messages required to initiate a call.

Session Initiation Protocol (SIP)

This protocol was initially developed by The Internet Engineering Task Force (IETF) to allow for multi-person conferencing. The developers chose to use a low-technology option and base connections on standard IP communication such as Hyper Text Transfer Protocol (HTTP), Simple Mail Transfer Protocol (SMTP), Universal Recognition Language (URL) and the Domain Name System (DNS).

This technology uses a peer-to-peer model of the initiation of a session and can link instant message applications with services. This IP-ready protocol is well suited to utilise an IP network and requires 4 messages to initiate a voice call (compared to 17 for H.323). This protocol has been used by Microsoft's instant messaging application, MSN Messenger.[12]

Session Initiation Protocol appears to be more powerful as it matches H.323 and can be used to implement data applications with voice integration. In some applications this protocol can enable the mobile handset to be used as a data entry device. Other possible aspects include location features, credit card transaction confirmation and instant messaging and conferencing.[13]

Internet Protocol version 6 (IPv6)

The creation of addresses for the Internet currently uses a 32-bit address within the Internet Protocol version 4 (IPv4) addressing scheme. This provides for a theoretical maximum of 4.3 billion different addresses but due to inefficiencies, far fewer of the available number are used. Some inequalities exist with in the system such as the People's Republic of China having been allocated only 16 million numbers in the IPv4 scheme.[14]

In order to counter the inevitable exhaustion of these address as a result of the growth of connected devices, the Internet Engineering Task Force (IETF) has developed the IPv6 scheme (RFC 2372) that uses a 128-bit address that provides for a seemingly inexhaustible number of addresses (up to 8×10^{17} addresses). The move to increase the number of possible addresses stems partly from mobile service providers[15] as well as other engineering, consumer electronics and service providers seeking to connect devices to the Internet.

The move from IPv4 to IPv6 will require changes to both routers and software. The Internet Engineering Task Force requires IPv6 to be backward compatible and should be easy to use. However, demand will be the driver of change and investment in new equipment will require a firm business case. Regardless of this, Japan and South Korea are already experimenting with this addressing scheme.

ENUM (Electronic Number)

Telecommunications carriers use a single database that maintains the telephone numbers for all telecommunications devices on a country-by-country basis. The planning for this numbering system is through the International Telecommunications Union (ITU) and is known as E.164. This system specifies the format, structure and administrative hierarchy for telephone numbers.

ENUM protocol developed by the International Telecommunications Union (RFC 2916) provides an infrastructure by mapping connections between an E.164 telephone number and the Domain Name System (DNS) where telephone numbers are mapped to IP addresses.[16] This protocol would marry two of the most popular communications addressing schemes – the telephone and the Internet.

In other countries, telephone number portability is an issue that is able to be rectified through ENUM. This protocol is designed to be used on an IP network and will add to the utility of these new networks. An advantage to users is that this provides a more individualised method of being contacted with specific devices active at certain times of the day.

Another benefit is that Voice over Internet Protocol (VoIP) translates a telephone number (E.164) into an Internet address through the Domain Name System. As users would chose to “dial a number” rather than “enter” an Internet address using letter and symbols, the value of ENUM becomes clear.[17]

This protocol will face particular difficulties as the ENUM database will need to be centralised on a country-by-country basis.[18] Many governments would prefer not to have to regulate communications addressing (as evidenced by domain address bodies) and the ENUM approach would change this preference.[19] Internet address registrars would need to provide addresses to a centralised database and questions arise regarding reliability of this provision. Additionally as ENUM constitutes a global change in databases and protocols, a lengthy process is envisaged.

Broadband

The rate of adoption of broadband technology by private consumers and business is increasing with market adoption growing quickly. There are some barriers to subscriptions with one being the price for the service and another being incompatible infrastructure. The Federal Government who has control over the regulation of the telecommunications industry has a role to play in providing for competition as well as the public carrier, Telstra.

Broadband refers to the ability of a single access line or wireless link, connected to a telecommunications network. This connection provides for fast always-on access to digital content, applications and a range of services. This definition focuses on functionality rather than speed but is assumed to be 200 Kbps or higher.[20]

The value of broadband is that it provides greater data rates to be transmitted from device to device. This provides for greater amounts of data to be transferred in less time. As with the processing power in computing devices, users are seeking greater data rate transfer capabilities. This has led to advances in technology as has been demonstrated through Ethernet capacity from 10 Mbps through to 10 Gbps. While these data rates can be attained in a purpose-built network, there was difficulty in increasing the data rates available through the existing telecommunications infrastructure that was built for voice traffic.

The standard telephone service operates in the frequency spectrum between 0 and 4 kHz. Initially Internet connections were through an analogue modem with a maximum data rate of 56 Kbps. Faster data rates can be achieved if different frequencies are used within the access network.

In the deregulated telecommunications market, voice traffic remains the most profitable market for carriers. Data traffic has grown significantly in the past decade with data using the same lines as voice but carriers are now able to differentiate this traffic and provide variable rates to maximise use and profitability. As this technology becomes better accepted by the general community, prices are likely to reflect market demand and reduce in price.

Digital Subscriber Line (DSL)

A Digital Subscriber Line (DSL) uses the standard twisted pair of copper wire in a cable that exists within the local loop or "last mile" telephone network. Digital Subscriber Line is a generic term for a technology that provides for faster data transmission on cables designed to carry traditional voice traffic and is sometimes known as *x*DSL.

A recent review of the available Digital Subscriber Line technologies shows 5 possible types (See Table 5.1 – Digital Subscriber Line Technologies Used In Australia).[21] Each provides for differing data rates and limits on the distances the signal is able to travel. The value of the Digital Subscriber Line to telecommunications carriers is that the carrier is able to offer high-speed Internet connections without laying new cable. By altering equipment at the exchange and the customer's premises, the life-span of the cable is able to be lengthened. The choice of technology is dependent upon the carrier.

However, there are some difficulties with some connections. There are a few telecommunications connections that utilise a "pair gain" technology that allows for two telephone lines to be established with only one cable. While this technology was perfectly suited for a telephone and facsimile line, it is not suited for the broadband connections. Telstra, who is the owner and manager for much of the "last mile" where pair gain technology is used is working on resolving these issues.[22]

Table 5.1 – Digital Subscriber Line Technologies Used In Australia [23]

Acronym	Full Name	Theoretical Maximum Data Rate (Mpbs)	Theoretical Maximum Distance (kms)
ADSL	Asynchronous Digital Subscriber Line	8	5.4
ADSL2	G.992.1	8.2	5.6
SHDSL	Symmetric High-bit rate DSL	2.3	6
HDSL	High-bit-rate DSL	2	3.6
VDSL	Very-High-Speed DSL	22	1

BOX 5.1 – THEORETICAL MAXIMUM AND ACTUAL DATA RATES

Theoretical maximums are often stated by vendors but the use of the word "theoretical" is often dropped. For example, the common broadband connection, Asynchronous Digital Subscriber Line (ADSL) is theoretically able to provide 8 Mbps from the carrier to the user and 800 Kbps from the user to the carrier and is therefore asynchronous. However, the actual data rate from the Internet Service Provider (ISP) to the user is much less. This data rate is usually advertised as 1.5 Mbps from the provider to the user. However, when a connection made by a user to the server that is hosting the web site, the numerous connections between the two points has the potential to slow the transmission as does high activity form the server. The result is a data rate that is perhaps one-tenth of the advertised connection.

The following paragraphs examine a number of the seemingly more popular *x*DSL technologies.

Asynchronous Digital Subscriber Line (ADSL) – This is the most popular DSL technology and operates in the 25 kHz to 1.1 mHz frequencies leaving open the under-4 kHz frequencies for voice traffic. Using discrete multitone modulation, the line is divided into 256 "sub-carriers" for downstream traffic and 32 for upstream thus being "Asynchronous". If there is interference, only one or two of these channels are affected and with TCP/IP, data packets can be resent. This technology allows for voice traffic and Internet access on the same telephone line with an "always-on" Internet connection. This technology is highly suited to residential and small business applications.

High-rate DSL (HDSL) – An evolution of Integrated Services Digital Network (ISDN) and uses echo cancelling and digital-signal processing as does ISDN. This technology uses two pairs of wires with an inverse-multiplex stream up to the receiver where it is multiplexed. This provides for higher data rates and eliminates the need for repeaters. The market for this technology is the commercial user as this allows for a range of telecommunications equipment to be used on the network. Additionally the error rates are very low and compare favourably to fibre optics.[24]

Very-high-rate DSL (VDSL) – This technology is suited to high-density premises such as apartment buildings or planned suburbs. By using a fibre optic network to deliver communications services to a localised point, VDSL provides the last part of the network with a high speed connection. VDSL transmissions are limited to less than 1 km but can provide for data speeds of up to 22 Mbps. While able to use standard telecommunications protocols (such as Asynchronous Transfer Mode-ATM) VDSL is also able to use Ethernet to achieve these speeds. There is some debate regarding the applicability of this broadband technology for applications such as video-on-demand within Australia.

Symmetric High-data-rate DSL (SHDSL) – This technology was developed by the International Telecommunications Union as provided through the standard G.992.1. This technology doubles the distance and speed that the Asynchronous Digital Subscriber Line (ADSL) technology provides. This technology may be used in conjunction with ADSL as a hybrid system to provide for greater distances from the switch.[25]

What should be kept in mind with broadband technology is that carriers will introduce more powerful data-rate technologies as the market is able to accept them. If the example of computers and processing power is considered to be applicable to broadband connections, then it is possible that we will see a range of broadband technologies providing for larger data transmissions. Further research will incorporate new technologies and innovative ways of providing this service. Chapter 8 – Wireless Broadband outlines the options for delivering wireless broadband connectivity.

Optical Networks

Optical fibre provides for higher reliability, increased performance, reduced maintenance and greater flexibility than copper cabling. However, the current cost of fibre networks is still above that of the copper networks between exchanges and users. As new infrastructure is established, network designers have a range of options available to increase the data traffic available.

New technologies that employ optic-based microprocessors could radically reduce the cost of installing fibre optics to the desk[26] and provide greater performance. Currently signals on fibre optics must be converted from electrical to optical and back again. Repeaters currently use an electronic converter and this slows down the signal. The new repeaters will use phontonics to transfer the signal and will provide for faster data transmission.

This next section examines some of the applications using optical fibre reaching more closely to the user and in the inter-exchange networks.

Wave Division Multiplexing (WDM)

This technology is able to provide for a greater number of transmissions through existing fibre optics. As copper wires allow for the use of different frequencies to increase capacity, fibre optics use different parts of the spectrum to send a signal. This is known as Wave Division Multiplexing (WDM).

Dense Wave Division Multiplexing (DWDM)

Dense Wave Division Multiplexing (DWDM) is able to separate light transmissions into more segments within the same spectrum range therefore gaining the term “dense”. A 16-channel system is able to use a 2.4 Gbps fibre connection and provide for 40 Gbps transmissions. This increase in volume is able to provide additional bandwidth from the existing cable. The channel spacings for this technology is between 0.4 nm and 1.6 nm and the distance the signal is able to travel makes it suitable for long distance transmissions.

However as the precision of the equipment increases there is a greater chance for errors in the installation to become critical failures. Additionally the equipment generates heat and needs to be cooled. Some communication routers include DWDM and avoid the need for international multipexing hierarchies (See the next section on SDH / SONET). By employing these routers, Internet Service Providers (ISPs) can utilise higher data rate connections less expensively.

Coarse Wavelength Division Multiplexing (CWDM)

As the name implies, Coarse Wavelength Division Multiplexing uses channel spacing that are between 12 and 50 times greater than Dense Wavelength at around 20 nm. The CWDM lasers generate heat but not as much as other lasers and are able to be air cooled and are less costly to use. However, CWDM lasers are used in metropolitan areas as the distance the signal is able to travel is around 50 kms.

Synchronous Digital Hierarchy / Synchronous Optical Network (SDH / SONET)

As digital telecommunications transmissions for multiplexed fibre optics have been largely developed on a country-by-country basis. within the panoply of technologies there was a need to standardise the transmission hierarchies to allow for multi-vendor interoperability. The International Telecommunications Union has developed a number of standards that define a number of aspects such as data rates, payload maps, formats, optical interfaces and ring architecture. There are seven of these standards and are known as the Synchronous Digital Hierarchy (SDH).

The US, through the American National Standards Institute (ANSI), has developed a comparable version of the Synchronous Digital Hierarchy and is known as the Synchronous Optical Network (SONET). Fortunately the two classifications are able to co-exist with matching line rates, but the Synchronous Optical Network has two additional levels not catered for by the European Synchronous Digital Hierarchy.[27]

New Synchronous Optical Network switches are being developed to include a number of protocols including multiple traffic types that allow for greater responsiveness. These switches are likely to be priced below current offerings and will be smaller and use less power. These switches will do this by mapping unjoined SONET payloads in to single entities. This provides for a more efficient use of bandwidth, thereby increasing the total line use.

Passive Optical Networks (PON)

A Passive Optical Network utilises the speed of transfer and reliability of fibre through a distributed network that provides end users with lower cost connection than with fibre-to-the-home (FTTH). This type of architecture has been standardised by the International Telecommunications Union (Standard G.983).

Data transfer speeds are 155 Mpbs synchronous (both directions have equal transmission rates) or asynchronous with 622 Mpbs downstream and 155 Mbps upstream. This technology uses Time Division Multiple Access (TDMA) and allows for 32 users. The total bandwidth of 622 Mbps would be divided by the number of users (for example, 32 users would have access to around 19 Mbps of data).[28]

Another type of Passive Optical Network from the exchange is divided at an optical splitter and the entire set of wavelengths is sent to the user's terminal. The device that divides the signal differentiates which wavelength is for which user and uses a Wave Division Multiplex (WDM) technology. The optical splitter gains the name “passive” as there is no active separation as there would be with an electronic switch. Going upstream from the user, the signal is converted into a specific wavelength at the user’s terminal and sent through the splitter that then joins all upstream wavelengths for transmission to the exchange.

Summary

This industry has the most complex, hybridised systems than any other industry examined in this project. The relationships with building construction, electrical, electronics and information technology industries are significant.

The Australian Communications Industry Forum forecasts[29] that the make-up of the next generation network will comprise:

For customer access

- High speed digital access over copper (VDSL, ADSL2, and other versions of *x*DSL)
- High speed digital access over optical fibre (active or passive optical networks, Ethernet over fibre and other proposals such as direct IP over fibre)
- High speed digital access over radio to/from non-mobile terminals (including LMDS, Bluetooth and the different flavours of IEEE 802.6)
- High speed digital access to/from mobile terminals (including the different flavours of 3G mobile and 2.5G mobile)

For carrier networks

- Core networks, based on packet technology, able to provide support for a wide range of services supporting network services meeting differing end-user needs for quality of service and bandwidth.
- Direct optical switching and transmission, including optical switching with DWDM (wavelength switching)

One vendor has highlighted that IP and ATM will coexist in a multiprotocol core with MPLS providing the unifying technology.[30]

Implications for the Shared Technology industries

Automotive

No implications predicted for these technologies in this industry.

Building and Construction

Telecommunications is as ubiquitous an essential service as electricity but more technologically up-gradable, members of this industry will need to consider issues such as access to conduit and communications risers as well as refurbishment of existing infrastructure. While electricity cabling provides a single resource, telecommunications will provide many more services and in terms of the utility of the building. Members of this industry will need to provide for greater access to these technologies.

Engineering

Benefits to this industry will come in the form of greater access to remote and network connected devices. Individual devices will have Internet addresses to allow for greater communication and interoperability.

Electrical

Members of this industry will need to decide where their competencies begin and finish. Infrastructure construction is well suited to this industry but managing communications networks requires skills more related to information technology than cabling. An awareness of issues relating to data speeds, interference and testing within and between cabling types and connections will be fundamental to the integrity of the network.

Electronics

This industry will play a dominant role in the commissioning and maintenance of telecommunications systems. The nature of the next generation networks will see analogue voice playing less of a role and packetised data becoming the predominant technology. In this aspect electronics plays an increasingly important role. The introduction of photonics and microelectromechanical systems (See Chapter 16) into telecommunications requires this industry to further expand the definition of their boundaries.

Information Technology

This industry will provide a dominant role in the management of the familiar Internet Protocol (IP) based communications systems with the decreasingly voice-focused and circuit-switched telecommunications network. The move to IP will have profound changes that will continue to require members of this industry to re-skill. Fortunately, network management protocols will be familiar with the new protocols to be introduced and will find the transition easier than those familiar with traditional circuit-switched telecommunications.

Telecommunications

Obviously this industry will need to plan for skill development. Operatives in this area will need to have a good grounding in telecommunications infrastructure, network management and an understanding of quality of service issues. There will be a greater reliance on information technology rather than "traditional telecommunications". The merging of Internet Protocol (IP) with voice communications will lead to single entity of information and communications technology (ICT).

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