Harris
Communications Consulting LLC

Expert report – Use of HFC to deliver broadband services

Prepared for Peter Waters & Associates

Michael G. Harris

12 December 2007

Michael G. Harris

Harris Communications Consulting LLC

16 Gorge Lane
Pound Ridge, NY 10576

Contents

1 Preliminary matters

Instructions

1.1 In relation to a regulatory filing to the Australian Competition and Consumer Commission, I have been asked to express my professional opinion on the following questions:

1 can a hybrid fibre coaxial (HFC) network be used to provide retail residential services which could otherwise be provided using unconditioned local loop (ULL)?

2 can an HFC network be used to provide retail business services which could otherwise be provided using ULL?

3 can an HFC network be used to provide wholesale residential services which could otherwise be provided using ULL?

4 can an HFC network be used to provide wholesale business services which could otherwise be provided using ULL?

5 what are the practical and operational implementation issues and costs associated with upgrading the headend systems of an HFC network which is at the current technology stage of the existing Optus HFC in Australia to be able to provide the services discussed in 1 to 4 above?

Author of Report

1.2 This report has been prepared by Michael G. Harris who is the principal of Harris Communications Consulting LLC.

1.3 I have significant practical experience in the cable television industry in the United States including being the Vice President of Engineering and the Chief Technical Officer for Century Communications (from 1973 to 1999). I also have significant experience in the telecommunications industry having worked as the Vice President of Engineering and the Chief Technical Officer for Citizens Communications from 1999 to 2004. Citizens is the incumbent wireline provider in a number of regions in the US. During the period 1989 to 1997 I was also the Senior Vice President of Engineering at Centennial Cellular, a wireless cellular operator.

1.4 My experience means that I have been in charge of engineering for each of the 3 technologies:

(a) cable;

(b) wireline telecommunications; and

(c) wireless telecommunications.

1.5 Since 2005, I have provided consulting services through my own business to a number of leading providers of cable services and vendors to the cable industry.

1.6 A copy of my resume is attached as Attachment A.

Federal Court Rules

1.7 Set out in Attachment B is the version of the "Guidelines for Expert Witnesses in Proceedings in the Federal Court of Australia" (**Guidelines**) that was provided to me before I commenced drafting this report and that I have reviewed before submitting the report.

1.8 I have drafted this report to comply with those Guidelines. In particular, I have no pre-existing relationship with Peter Waters & Associates and I have never been retained by or employed by Telstra.

Currency used in this report

1.9 All reference to monetary amounts in this report are expressed in United States Dollars.

Documents and materials provided

1.10 A set of consolidated facts and assumptions prepared by Peter Waters & Associates and set out in Attachment C.

1.11 Guidelines for Expert Witnesses in Proceedings in the Federal Court of Australia referred to above.

Additional materials relied upon for this report

1.12 I have reviewed a number of documents produced by vendors to the cable industry in the United States as well as standards issued by bodies including Cable Labs. I have also relied on the extensive body of literature regarding the cable industry that would be normally used by a practitioner in that industry. The specific documents to which I make reference in this report are set out below:

(a) Data-Over-Cable Service Interface Specifications: Business Services over DOCSIS®. TDM Emulation Interface Specification. CM-SP-TEI-I03-070803. Issued August 2007.

(b) Data-Over-Cable Service Interface Specifications: Business Services over DOCSIS®. Layer 2 Virtual Private Networks. CM-SP-L2VPN-I05-070803. Issued August 2007.

(c) ACIF C559:2006 ULLS Performance Requirements

2 Executive Summary

1 Can a hybrid fibre coaxial (HFC) network be used to provide retail residential services which could otherwise be provided using unconditioned local loop (ULL)?

An HFC network could be used to provide residential retail services that would otherwise be provided using ULL based products without modification. Data services provided on a "best effort" basis can be delivered using cable modem systems based on any version of the DOCSIS cable modem standard. Voice services over Internet Protocol can be delivered using the cable modem standard DOCSIS 1.1 and above. The DOCSIS 1.1 specifications define the quality of service parameters that are required to deliver voice services using Internet Protocols. That is, the existing Optus HFC network could provide all of the voice and data services that are currently provided to retail customers using ULL without modifying that existing cable network. Optus could offer these services to a greater number of potential customers if it were to engage in the usually fruitful task of both wiring existing multiple dwelling units and pre-wiring multiple dwelling units that are under construction.

2 Can an HFC network be used to provide retail business services which could otherwise be provided using ULL?

An HFC network can be used to provide retail business services that would otherwise be provided using ULL based products using the cable modem standard DOCSIS 2.0 and above. The DOCSIS 2.0 specifications define the quality of service parameters that are required to deliver business and voice services using Internet Protocols. These business services are voice, E1 and Layer 2 VPN. That is, the existing Optus HFC network could provide all of the services that are currently provided to business customers using ULL by modifying its existing cable core network. That is, modifications need only take place in the headend of the cable plant rather than any of the outside plant. Commercially available products to implement these services are available from major vendors such as Motorola and Vyyo.

3 Can an HFC network be used to provide wholesale residential services which could otherwise be provided using ULL?

There are no technical reasons that would prevent those residential retail services set out above from being provided on a wholesale basis by any cable operator, including Optus, to others.

4 Can an HFC network be used to provide wholesale business services which could otherwise be provided using ULL?

There are no technical reasons that would prevent those business retail services set out above from being provided on a wholesale basis by any cable operator, including Optus, to others. Extending the wholesale service to ensure that the access seeker maintains control of the quality of service is technically feasible, is defined in current Cable Labs standards but is not yet supported by equipment vendors. The current Cable Labs standards used and supported by equipment vendors permit QoS to be applied to telephony and business services by the HFC network operator. However, these specifications do not deal with the case where the wholesale customer seeks to control QoS.

5 What are the practical and operational implementation issues and costs associated with upgrading the headend systems of an HFC network which is at the current technology stage of the existing Optus HFC in Australia to be able to provide the services discussed in Error! Reference source not found. to 4 above?

Given that there is an abundance of capacity in both the upstream and downstream of the Optus HFC network, I would suggest that the implementation path could be:

(a) deliver residential and business voice services by using the existing DOCSIS 1.1 CMTS and interfacing the Ethernet output using Internet Protocols to the existing Optus core network (that currently deals with voice services in that form from its line-card equipped DSLAMs);

(b) reserve up to 2 upstream channels and one downstream channel for the delivery of E1 services. The cost per E1 (both hub end and customer premises end) is approximately $3,500; and

(c) reserve up to 2 upstream channels and one downstream channel for the delivery of Layer 2 VPN services. Based on list prices and making the assumptions set out in this report, then the cost per hub to run a spectrum shared DOCSIS 2.0 system to provide VPN services would be approximately $275,000 and the associated customer premises equipment would be approximately $90 and could be battery backed up for an additional $25.

That is, Optus would:

(a) use its existing CMTS to provide voice services over Internet Protocol and provide alternative customer premises equipment to customers acquiring voice services in addition to internet access services;

(b) acquire new equipment in the cable core network and deploy new customer premises equipment in order to offer E1 services; and

(c) acquire a new CMTS in order to provide business grade Layer 2 VPN services and voice services. These new services would also require new customer premises equipment.

Content of this report

This report sets out the reasoning behind my answers set out in this executive summary. The form of the report is as follows:

- in section 3, I first describe the architecture and technology of an HFC network, including upgrade pathways for cable networks;
- in section 4, I then discuss the services characteristics and requirements of voice and data services in an IP environment. This discussion is technically neutral between copper and cable networks since these networks will all be using some form of IP transport;
- in section 5, I consider how the services described in section 3 can be offered by competitors using unbundled access services on an incumbent's networks;
- in section 6, I then describe how cable networks can be used, including with upgrading described in section 2, to supply retail and wholesale services that are close substitutes for the use of incumbent's unbundled access services; and
- in section 7, I consider how a network similar to the current Optus HFC network could be upgraded to support best of breed technology, including the likely time and investment to complete the upgrade.

3 Description of an HFC network

Basic architecture

3.1 An HFC network consists of an optical fiber distribution network that feeds nodes and a coaxial cable network from the nodes to customer premises. Each node has up to 4 coaxial outputs and 4 is the most common configuration. Set out in Figure 1 is a diagram that I have prepared that sets out the elements that I will refer to in this report.

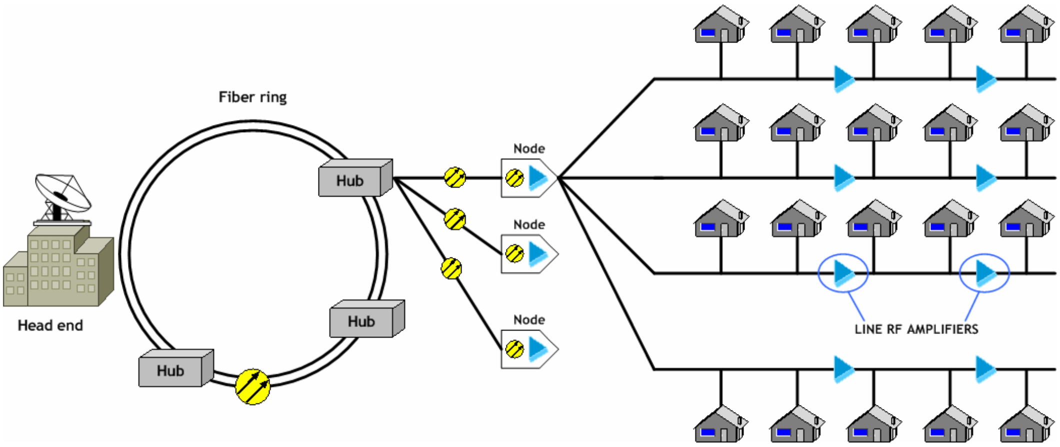


Figure 1 - Elements of an HFC network

3.2 The HFC network can be considered as spectrum that can be controlled by the cable operator within the constraints of relevant standards. That is, the frequency range available in the coaxial cable is available only to the cable operator and does not interfere with others and is not interfered with by others. In the United States, the organization of channels for both analog and digital television services is subject to specific standards that were developed by the Electrical Industry Association in conjunction with the National Cable Television Association. These channels are based on both the terrestrial channel plan and the needs of cable operators. I understand that there is no similar cable channelization standard in Australia. As a result, Australian operators could choose channel bandwidths that correspond to:

(a) 6 MHz which is the North American standard;

(b) 7 MHz which is the Australian standard and the European VHF standard; or

(c) 8 MHz which is the United Kingdom standard.

3.3 I also understand that both FOXTEL and Optus have used all 3 of these standards at different times for different services. For example, the current FOXTEL digital television service is based on 8 MHz channels, the previous FOXTEL analog television service was based on 7 MHz channels and the Telstra cable modem service is based on 6 MHz channels. My understanding is that the Optus HFC network also uses 6 MHz channels for its cable modem service. This understanding is based on the launch date of the Optus cable modem offering and because I understand that Optus uses the same cable modems for its service as those used by Telstra.

3.4 As a practical matter, the amount of spectrum that is available is limited by the equipment, equipment spacing and coaxial cable, that is used in the outdoor plant. In the US, the plant upper frequency limitation is typically determined by the need to carry both analog television services and digital television (both standard and high definition) services along with cable modem and telephony services. Different cable operators reserve the lower part of the upper band split for analog services and this ranges from a fixed lower frequency of 54 MHz to an upper frequency that could be 300 MHz, 400 MHz, 450 MHz or 550 MHz. There is no standard cut off for these analog services but major city cable systems will typically have an analog allocation of 450/550 MHz as determined by the cable operator. In practice, many US cable operators provide 80 analog channels each with a bandwidth of 6 MHz in this spectrum. In addition, other large operators are converting to digital only services in order to conserve the spectrum that is available. Some small operators in the US are still operating with upper frequency limits that are lower than 550 MHz.

3.5 Above the analog spectrum, the HFC network has an upper frequency that is typically used for the delivery of digital television services. Digital television services can be either standard definition television (**SDTV**) or high definition television (**HDTV**). The upper frequencies are also often used for cable modem carriers, other digital carriers (for example, for telephony), automatic level sensing control, leakage measurements and a variety of other test purposes. The size of this upper portion of the spectrum varies with cable operators across the United States. Some operators use an upper frequency limit of 750 MHz, others have an upper frequency level of 860 MHz and current outdoor plant equipment supplied by vendors will extend to 1 GHz. I am asked to assume for the purposes of this report, that the Australian upper frequency limit in both the Telstra and Optus HFC networks is 750 MHz.

3.6 This private spectrum is typically also divided into 2. One part, in Australia between 85 MHz and 750 MHz is used for “downstream services”. Downstream in this context means towards the customer premises. The other part, in Australia between 5 MHz and 65 MHz is used for “upstream services”. Upstream in this context means away from the customer premises. Such a split is shown in Figure 2 below.

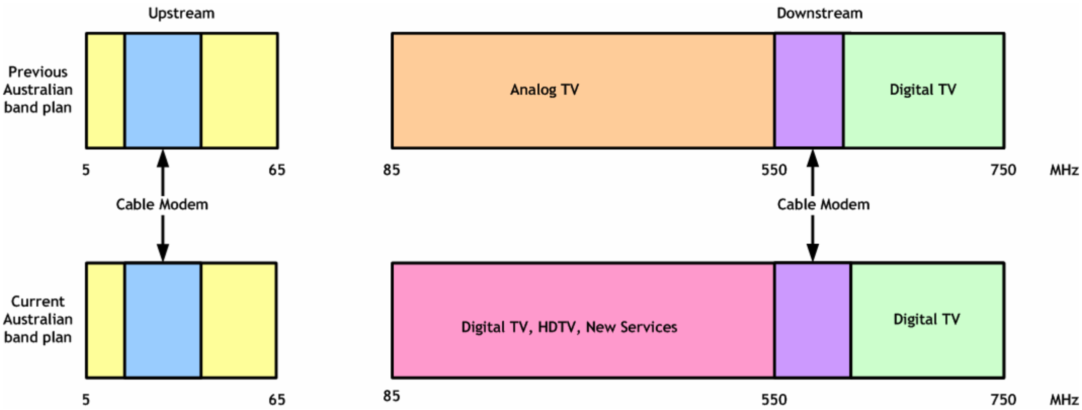


Figure 2 - Upstream and downstream use of spectrum

3.7 Although I refer to the Australian band plan in Figure 2 above, I would like to make reference to the existing spectrum usage/availability on the Optus HFC network. In practice, many of the services that are anticipated to be delivered in the downstream spectrum between 85 MHz and 550 MHz have not yet been deployed. As a result, the Optus HFC network spectrum use is likely to be similar to that shown in Figure 3 below.

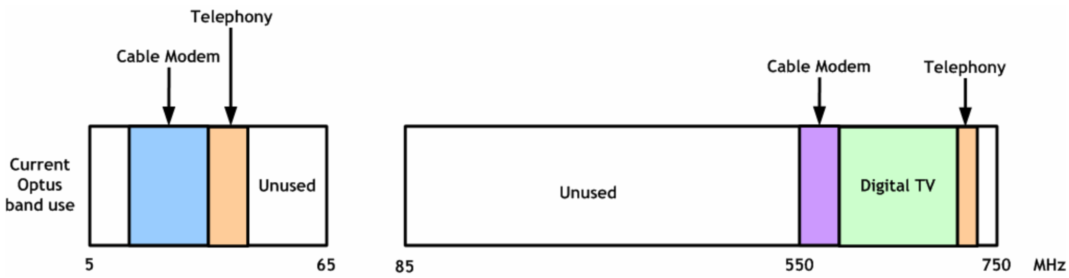


Figure 3 - Use of spectrum on Optus HFC network

3.8 As can be seen from Figure 3, there is a significant amount of spectrum that is unused in both the upstream and downstream sections of the spectrum. In creating this diagram, I have assumed that Optus uses a telephony technology known as constant bitrate (**CBR**) that I refer to in more detail below.

3.9 I mentioned above that the cable operators in the US use systems that have bandwidths of up to 1 GHz. Part of the reason for this is that many US cable systems carry analog television services. Typically, these television services are carried in the lower part of the downstream spectrum as I described in 3.4 above. In addition, cable operators carry a large number of digital SDTV channels as an enhanced product offering or because many of these SDTV channels were mined/reclaimed from the spectrum usually used for delivery of analog services because of capacity needs. Further, cable operators in both the US and in Australia are likely to need to be able to deliver HDTV services in addition to those HDTV services that are carried today.

3.10 Each HDTV service requires a digital data rate that is significantly higher than an SDTV service. For example, a high quality SDTV service that provides sport programming might have a bitrate of approximately 4 – 6 Mbit/s. If the same sports programming were to be delivered using HDTV, then the bitrate would need to be ***in*** the order of 12 – 15 Mbit/s. That is, HDTV channels require greater bitrate and therefore a higher bandwidth than SDTV channels. As a result, there is increasing pressure on cable operators to extend the downstream spectrum.

3.11 For example, DirecTV in the US announced in a press release issued on 8 January 2007 that it plans to have 100 HDTV channels by the end of 2007. DirecTV presently offers 75 HDTV services. This means that cable operators that compete with DirecTV for subscription television viewers will need to consider how to deliver a comparable package of channels. One option for the cable operator is to increase the available downstream bandwidth. This can be done by either increasing the bandwidth in the downstream spectrum or by a technique known as "analog mining." By analog mining/reclaiming, I mean a decision to use existing analog channels to deliver digital services. This is accomplished by converting the existing analog channels to digital (on the basis that digital requires significantly less spectrum per service than analog) and then putting multiple digital services in the old spectral position.

3.12 The decision to avoid the capital expenditure of a system rebuild to the extent possible is partly driven by the technological issue that increased bandwidth may not deliver appropriate returns. For example, if a cable network is already designed to run at a bandwidth of 860 MHz, then the number of channels that can be accommodated in an upgrade to 1 GHz may not justify the very large necessary capital investment. That is to say, analog mining/reclaiming is a much more cost effective way of delivering more spectrum space than a system rebuild.

3.13 In Australia, both Telstra and Optus carry only digital services. For this reason, the amount of spectrum available for new services in the part of the spectrum entitled "Digital TV, HDTV, New Services" in Figure 2 is significantly greater than the typically available spectrum in the United States. Indeed, my understanding is that Optus has significant unused capacity in its HFC network as I have set out in Figure 3.

3.14 Another approach that is taken to increase the number of two-way services that can be delivered per node is the technique of "node splitting**.**" When node splitting is performed, the number of premises that can be potentially served by a node is decreased. For example, a node that serves 2,000 homes could possibly be split into 4 nodes**,** each serving approximately 500 homes. Such splitting requires that additional fibers (or multiple wavelengths on the original fiber) be available at the node location. Many operators install additional fibers during initial construction. This is done because adding additional fibers during initial construction is able to be performed at a fraction of the cost of adding them later. A node typically has 4 outputs and is serviced by a single optical receiver. Node splitting is performed by installing separate nodes on each of these outputs (or 1 multiple service node) and feeding these new nodes with separate optical paths or wavelengths and optical sources. Node splitting decreases the number of premises that can be serviced from a node and increases the spectrum per premises for two-way services.

3.15 In Australia, I have been instructed that Optus uses a system with 2,000 homes passed per node and Telstra uses 500 homes passed per node. In the US, most cable systems are presently operated with 512 homes passed per node with each node having the capability of being subdivided into 128 homes passed per node. Many new cable system designs are based on 256 homes passed per node with the capability of being subdivided into 64 homes passed per node. A number of vendors of node equipment have recognized the requirement to be able to subdivide nodes and produce devices that can be reconfigured from a single node design for either 512 or 128 premises passed per node to become 4 nodes each designed to pass either 128 or 64 premises. Where there is no need to change the node configuration they remain configured for the 512 or 128 premises passed as originally deployed.

3.16 There is only a need for node splitting when capacity for two-way services is limited. In the US, this limit is typically in the upstream. This partly arises from the fact that the US upstream bandwidth is fixed at 5 MHz to 42 MHz. This limitation is imposed by the need to be able to carry analog services from 54 MHz (as I set out above) and the degree to which the electronic systems can filter between the upstream and downstream channels.

3.17 In Australia, the upstream channels used are between 5 MHz and 65 MHz. That is, the upstream spectrum available is 60% greater than that in the US. As a practical matter, the spectrum between 5 MHz and about 12 MHz is subject to man-made interference and is not suitable for the delivery of services. This means that the practical upstream bandwidth in the US is about 30 MHz and is more than 50 MHz in Australia.

3.18 In my opinion, the amount of available upstream and downstream spectrum means that there is no immediate requirement to split all nodes in the Optus HFC network in Australia. Essentially, following the business model in the US, node splitting can occur on a node by node basis where demand is sufficient to require additional upstream capacity. This is unlikely to occur until there is a significantly higher loading on the Optus HFC network based on my understanding of the current topology of that network.

3.19 That is, the current outdoor plant and node arrangement (if operating correctly) would be sufficient to support a significant increase in the number and range of services that are offered that require an upstream component. As I set out below, the impact of my view is that the upgrades required to be able to offer voice and business grade data services become headend and core network investments rather than investments in outdoor plant.

3.20 The need for upstream services depends on the types of end user applications that are being provided. For example, the major application delivered using HFC networks is typically video. For normal television services, there is no requirement for an upstream channel as the services are delivered in a broadcast fashion towards the end user. In the US, there is typically a very small amount of upstream spectrum that is allocated for the purposes of ordering video on demand or pay-per-view services and for other purposes (for example, voting). I have been instructed that this is not the case in Australia.

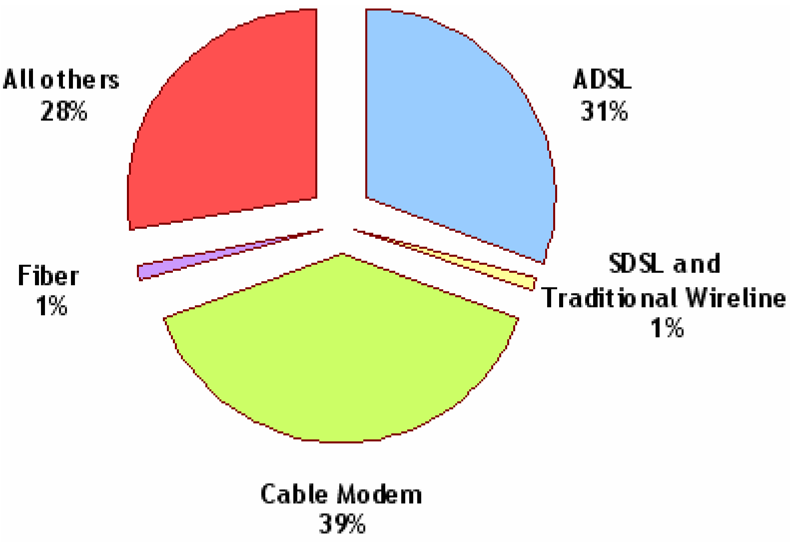
3.21 For applications that require two-way communications such as internet access and telephony, then upstream and downstream services are required. Ultimately, the quantity of two-way communications is constrained by the upstream bandwidth available to any group of customers. The ultimate limitation on delivery of applications that require upstream services is a function of the total upstream bandwidth available and the number of customers per node.

4 Operation of a cable modem system

4.1 The US cable television industry recognized in the early 90s that it would need to transform itself into a multiple product provider if it was to be able to compete with satellite delivered television services. As a result, the cable industry focused on the delivery of larger numbers of television channels (that could only be implemented by the introduction of digital cable television or significant bandwidth expansion) and by offering services that could not be offered by satellite television providers.

4.2 The major first offerings that the cable industry made other than digital cable television were broadband services using cable modems and telephony services. In the US, the early experiments in offering telephony services were not very successful. When I say this, I mean that there were a small number of telephony subscribers. One of the problems facing cable operators was that the technology available required the cable operator to invest in traditional circuit switches and product differentiation from ILECs and CLECs was problematic.

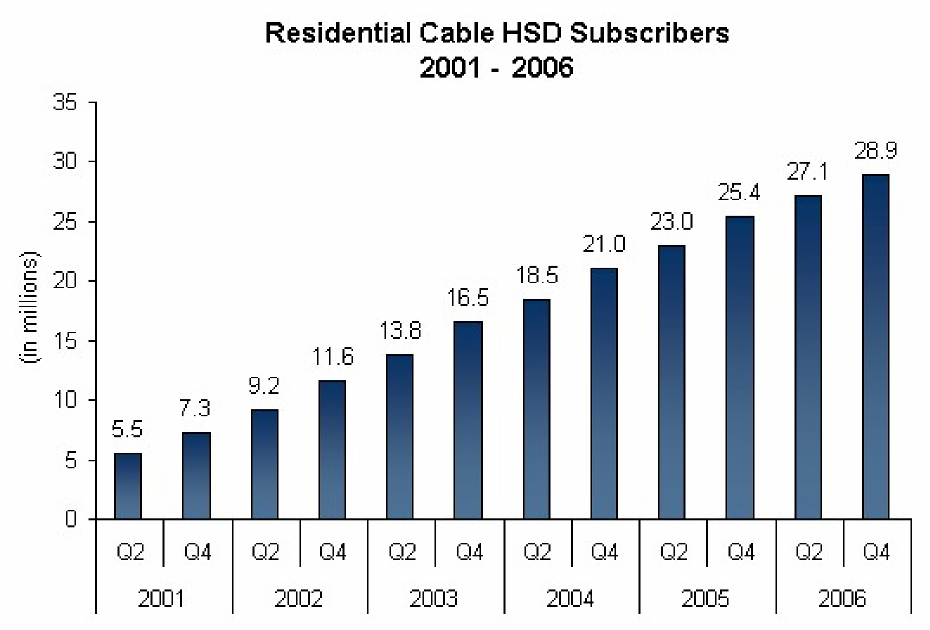
4.3 On the other hand, broadband services delivered by cable modem were introduced ahead of comparable services delivered using DSL technology by either ILECs or CLECs. As a result, cable operators in the US have a significant market share in the provision of broadband services and this is set out in Figure 4 below.



Source: FCC

Figure 4 - Delivery technologies for broadband services in the US

4.4 Part of the success of the delivery of cable modem services was the choice of the standards are known as Data Over Cable Service Interface Specifications or DOCSIS. The DOCSIS standard enabled customer premises equipment to be delivered at a relatively low cost. That is, the standardization process and particularly, the speed of standardization ensured that cable modems could be produced both quickly and efficiently by vendors and the scale of production assisted in reducing costs. From my experience in the deployment of the first cable modems, the price fell from approximately $300 per unit to less than $50 per DOCSIS modem over a short period. The growth of high-speed data (**HSD**) services delivered by cable is shown in Figure 5 below.



Source: NCTA

Figure 5 - Growth in broadband services delivered by cable

4.5 Cable operators are able to deliver broadband services that have cable modems as the customer premises equipment. In order to offer these services, the cable operator needs equipment in the headend of the cable system that is known as a cable modem termination system (**CMTS**). In addition, most cable operators use the broadband service to deliver internet services. That is, cable operators that offer broadband cable modem services typically act as internet service providers (**ISP**) or as a conduit to an ISP.

4.6 Set out in Figure 6 below is a diagram of a typical cable modem system that might be deployed by a cable operator.

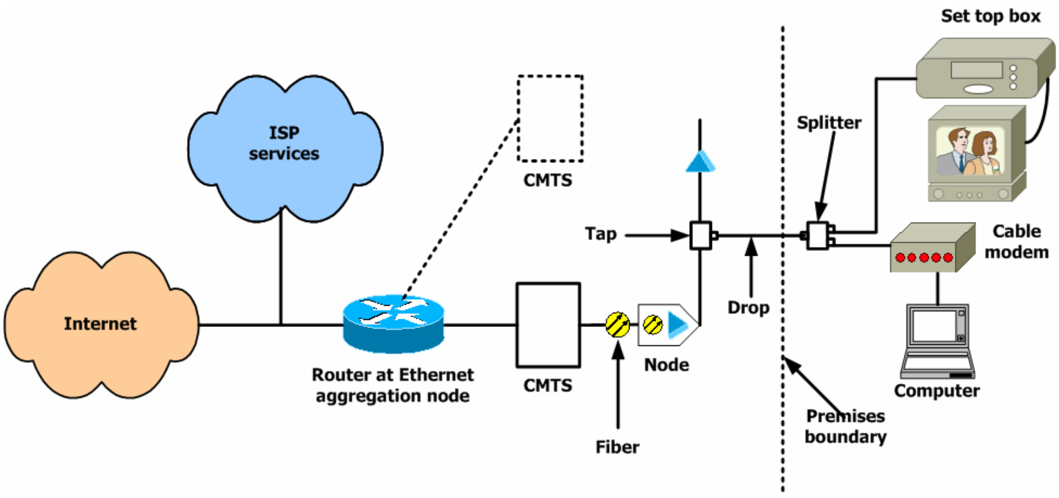


Figure 6 - Cable modem system

4.7 In order to act as an ISP, a cable system operator needs further equipment in addition to the CMTS. This equipment consists of an Ethernet Aggregation Node (**EAN**) and connectivity to the internet. The cable system operator will typically also install the normal equipment used by ISPs including a radius server for authentication, a mail server, a file server and often some operator specific content. I do not propose to describe the operation of an ISP further in the body of this report.

4.8 In order to minimize both equipment costs and operational costs, cable operators in the US choose to use cable modem systems that comply with industry agreed standards. In 1988, the cable industry in the US formed Cable Labs. Cable Labs develops standards with the cable industry in the US and vendors to the cable industry for a variety of digital services. There have been various forms of the DOCSIS standard that have a range of features. The current DOCSIS standard is 3.0 that allows for the high-speed delivery of Internet Protocol based services. Cable Labs has produced a chart that compares the various versions of the DOCSIS standard and I reproduce this in Table 1 below. The cable modems designed for each higher version are "backward compatible" to earlier version. That is, a cable operator using DOCSIS 1.1 today could install DOCSIS 3.0 modems and those modems would work on the existing version of DOCSIS deployed.

DOCSIS Version	**1.0**	**1.1**	**2.0**	**3.0**
Services				
Broadband Internet	X	X	X	X
Tiered Services		X	X	X
VoIP		X	X	X
Video Conferencing			X	X
Business Services			X	X
T1/E1 Voice and Data Services			X	X
Private Networks for Business (L2VPN)			X	X
Entertainment (Switched Digital Video)				X
Downstream Channel Bonding				X
Source Specific Multicast				X
QoS for IPTV Multicast				X
Consumer Devices				

DOCSIS Version	1.0	1.1	2.0	3.0
Cable Modem	X	X	X	X
VoIP Phone (MTA)		X	X	X
Residential Gateway		X	X	X
Video Phone			X	X
Mobile Devices				X
IP Set-top Box				X
Service Level Assurance				
Per Subscriber	X	X	X	X
Per Application		X	X	X
For IP Multicast				X

Table 1 - Varieties of DOCSIS standards

4.9 There is no "right" version of DOCSIS that should be used universally. Instead, each cable operator chooses which version of DOCSIS best meets its business needs. Each version of DOCSIS is "backwards compatible" with previous versions. This means that a cable modem that meets the DOCSIS 2.0 standard will also support services that are delivered using DOCSIS 1.1. As a result, a cable network operator can deploy cable modems before delivering new services. The cable operator also has an option to deliver some DOCSIS 2.0 services in part of its network and DOCSIS 1.1 in other parts and have a common set of cable modems.

4.10 Each version of DOCSIS represents a variation that allows a broader range of services. The original DOCSIS 1.1 standard was designed simply to provide internet based services. In effect, the DOCSIS 1.1 modem was a replacement for a dial-up modem and provided significantly greater bandwidth. Once the cable industry had realized the potential for cable modem services, the DOCSIS standard was developed further to be able to support Voice over Internet Protocol. In order to be able to support voice services, DOCSIS 1.1 introduced QoS on a per application basis. This means that the DOCSIS 1.1 device can act as a residential gateway and give priority to voice services over data services.

4.11 The next version of DOCSIS after DOCSIS 1.1 was DOCSIS 2.0. DOCSIS 2.0 is designed primarily to deliver business services over HFC networks. The standard permits the delivery of T1/E1 voice and data services as well as supporting private business networks. From a consumer perspective, DOCSIS 2.0 also permits the use of video phone/video conference services where the QoS is set by the video application. There are a large number of vendors that have had their equipment certified as compliant to DOCSIS 2.0. DOCSIS 2.0 also permits higher upstream bitrates than those available from DOCSIS 1.1.

4.12 The most recent version of the standard is DOCSIS 3.0. The major driving force behind DOCSIS 3.0 was the need for the delivery of Internet Protocol television (**IPTV**) services using multicast. That is, DOCSIS 3.0 supports QoS standards for upstream and downstream delivery using dedicated virtual local area network elements. DOCSIS 3.0 can be considered as an access network for next generation networks as the access network QoS is determined by the application on a session by session basis. DOCSIS 3.0 is a relatively recent release and there are a limited number of vendors that have been certified as meeting the standard.

4.13 One of the additional features of DOCSIS 3.0 is that it permits "bonding" of radio frequency channels. The specification calls for a capability to bond a minimum of 4 upstream and 4 downstream channels.

4.14 I am instructed that each of Telstra and Optus currently use DOCSIS 1.1. New cable modems that are being deployed by Telstra (and I would assume also by Optus), are most likely DOCSIS 2.0 compatible. The fact that both Telstra and Optus have chosen to use the DOCSIS 1.1 variant reflects the fact that they are not addressing the business market or IPTV using their respective HFC networks.

4.15 There are a variety of bitrates that comply with DOCSIS 1.1 depending on the modulation technique used to deliver data from the CMTS to and from the cable modem. In the direction from the CMTS to the cable modem, the cable operator has the choice of using 256 QAM or 64 QAM. QAM is an acronym for quadrature amplitude modulation and the higher the number before the expression "QAM" the higher the bitrate that can be sent for a given bandwidth.

4.16 Although the bitrate rises with the order of QAM, the rise is not linear. For example, 16 QAM allows for a capacity of 3.5 bit/s per Hertz. However, 64 QAM permits a capacity of 5 bit/s per Hertz. As a result, 64 QAM can carry up to about 17 Mbit/s in a standard 6 MHz wide DOCSIS channel whereas 256 QAM can carry up to 30 Mbit/s in a standard 6 MHz wide DOCSIS channel. Similarly, in the direction from the cable modem to the CMTS the choice of modulation is either QPSK or 16 QAM. QPSK is an acronym for quadrature phase shift keying. QPSK is similar to the equivalent of 4 QAM. If a cable operator deploys 16 QAM between the cable modem and the CMTS then the bitrate will be approximately 1 Mbit/s whereas QPSK delivers 512 kbit/s.

4.17 I mentioned above that DOCSIS 3.0 permits bonding of up to 4 channels. The maximum bitrate that can be delivered per channel depends on the modulation used. For example, if each channel uses 64 QAM then the maximum bitrate per channel is 17 Mbit/s and the maximum bitrate of 4 bonded channels would be 68 Mbit/s. In practice, a cable operator that wishes to maximize downstream bitrate would choose to use 256 QAM in order to achieve a maximum bitrate of 120 Mbit/s.

4.18 In the US, different cable systems offer different maximum bitrates depending on the modulation system being used in that cable system. Similarly, I understand that Telstra has deployed 256 QAM in Sydney and Melbourne and therefore offers 30 Mbit/s services from the CMTS to the cable modem in those cities. However, other than in Sydney and Melbourne, I am instructed that the maximum data rate to the cable modem is limited to either 17 Mbit/s (Telstra) or 9.9 Mbit/s (Optus).

Delivering data to residential and business customers

4.19 Residential and business customers have some common needs and some requirements that are distinct. In general, residential use of data services is for access to internet services. There are a variety of internet applications including the web, email, instant messaging, chat and file sharing. All of these applications have varying sensitivity to the quality of the internet connection provided. In general, there are 4 parameters that are commonly used to determine the quality of service of an Internet Protocol link including residential internet access. These parameters are:

(a) availability: this is normally expressed as a percentage and calculated as the duration of time that the service can be used divided by the duration of time that the service was required;

(b) latency: this is the delay in the delivery of information between the information's source and the information's destination;

(c) jitter: this is the rate of change of latency; and

(d) packet loss: this is expressed as a percentage and is an indicator of how much of the information that was intended to be delivered was not delivered first time.

4.20 There is a concept in internet access of a "best efforts" service. A best efforts service is a service where no service level parameters are provided and the service is delivered on an "as is" (best efforts) basis. Historically, best efforts delivery has been acceptable for residential and business internet services where none of the key parameters set out in 4.19 above have been specified. However, newer services that are delivered using Internet Protocols, whether or not they use the internet, have QoS requirements that are more demanding than best efforts.

4.21 It is possible to use voice services such as Skype that are entirely internet based and that do not have associated QoS standards. However, when the use of these services is extended (for example, to use Skype to connect to the public switched telephone network that is referred to as Skype Out), then the absence of QoS parameters becomes more apparent. Voice services are particularly susceptible to problems that arise from both jitter and packet loss. Voice is also adversely affected when latency is very high as high latency makes voice conversations difficult to conduct.

4.22 Set out in Table 2 below is a brief analysis of the effects on various applications of some of the QoS parameters that I have described.

	Bandwidth	**Latency**	**Jitter**	**Loss**
Multimedia/VoIP	Medium	**Important**	**Important**	Moderate
Interactive	Low	**Important**	Moderate	**Important**
Data Transfer	**High**	Unimportant	Unimportant	Moderate
Web browsing	**High**	Unimportant	Unimportant	Moderate

Table 2 - QoS impact on various applications

4.23 In addition to internet access services, business users may also need specific data services for the delivery of information. For example, a shop that is part of a franchise chain may need to report sales, inventory and other information to a head office function on a daily or more frequent basis. It is essential that this data is transferred on a timely manner and with a high level of data integrity. If the retail outlet is a bank or a medical center, then the importance of the data integrity is likely to be even higher. As a result, such businesses typically acquire services from telecommunications operators that have QoS service levels provided by the operator that give the business some certainty as to the service.

4.24 In the US, data services such as those described in 4.23 above, are often delivered at a symmetrical bitrate of about 1.5 Mbit/s and this service is known as T1. In Australia and European countries, the equivalent service operates at a bitrate of 2.048 Mbit/s and is known as E1.

4.25 These business requirements have the characteristics of symmetry and specified QoS parameters. Residential customers are likely to need specified QoS parameters for services such as voice but are unlikely to require the same degree of symmetry as business services.

4.26 Another mechanism by which businesses can connect with offices is the technique known as “virtual private network” (**VPN**). In a VPN, the business has a connection available to it that appears to the business to be dedicated capacity for that business but that uses infrastructure that is shared between end users. Telecommunications operators offer VPN services extensively and they form a key element of the portfolio of business services that a telecommunications operator would normally expect to provide.

4.27 Although I have outlined the requirement for data symmetry, there is not normally a need for high speed symmetrical services in respect of small or medium enterprises (**SME**). One of the techniques used by SME to reduce bandwidth requirement is the practice of outsourcing web hosting. That is, SME tend to use other businesses to host their web presence as these businesses specialize in the high bandwidth application of web hosting.

4.28 In order to deliver residential services that are best efforts, any of the existing versions of DOCSIS is appropriate. In order to apply QoS parameters to voice applications, then at least DOCSIS 1.1 is required in order to ensure that the voice service is treated as a higher priority than other services that can be delivered using best efforts. If a cable operator wanted to provide business services such as E1 or VPN, then the operator would need to use DOCSIS 2.0 in order to support these services. None of the services set out in this section would require DOCSIS 3.0. However, as DOCSIS 3.0 cable modems are compatible with earlier versions of DOCSIS, such cable modems could be deployed.

4.29 I would note that DOCSIS 3.0 is a relatively new standard and there are only a few CMTS vendors that offer DOCSIS 3.0 equipment. More vendors offer DOCSIS 3.0 compatible cable modems.

5 Services provided using incumbent wholesale access services

5.1 In both Australia and the United States, incumbent wire line telecommunications providers are obliged to provide access to unbundled network elements. Access seekers, referred to as competitive local exchange carriers (**CLEC**) in the US, use these unbundled network elements to provide services.

5.2 My analysis concentrates on 2 specific types of service that are used by CLECs. These are:

(a) access to unbundled local loops (that I understand to be referred to as unconditioned local loop or ULL in Australia); and

(b) access to the higher frequencies on a line where the base band frequencies are used by the incumbent to provide voice services and the upper frequencies are used to provide digital subscriber line (**DSL**) services. I understand that these services are referred to as line sharing services or LSS in Australia.

5.3 Access to a line sharing service enables a CLEC to provide broadband services to residential premises by installing a DSL access multiplexer (**DSLAM**) in the local central office building. The local central office building is referred to as a local exchange building in Australia. The CLEC can then choose whether to offer the DSL broadband service independently of the switched voice service offered by the incumbent local exchange carrier (**ILEC**). Alternatively, the CLEC could acquire a wholesale line rental service from the ILEC and then use access services such as local call resale and public switched telephone network (**PSTN**) terminating and originating services in order to provide both resold local and facilities based national and international voice services as well as the DSL broadband service.

5.4 There are a number of variants of DSL services. A commonly used variant that is deployed in both Australia and the United States is known as ADSL2+. ADSL2+ complies with an internationally agreed standard and is capable of delivering broadband at line rates of up to 24 Mbit/s downstream and 1 Mbit/s upstream.

5.5 It is possible to "rate shape" the ADSL2+ service to be able to offer line rates that are lower than the maximum rates set out in the standard. In this fashion, a telecommunications provider can create a range of products that use a common DSLAM in the local exchange building.

5.6 There are limitations created by the way that the upper frequencies in a line sharing service interact with the base band services used for voice. This restriction is codified in Australia by Communications Alliance in the code entitled ACIF C559:2006 which I have reviewed as part of my preparation of this report. As a result of these limitations, the line sharing service is well suited for asymmetric DSL services (the family of DSL services known as ADSL) but not well suited for symmetrical services. As a result, my opinion is that it is most likely that line sharing services would be used for the delivery of asymmetric broadband DSL services and not for symmetric broadband services.

5.7 In contrast, access to a ULL could be used for a range of asymmetric and symmetric services. Assuming that the CLEC deploys a DSLAM in the local exchange building, then the DSLAM could be used for both ADSL and symmetric DSL services. In the United States, a DSL technology known as symmetric high-speed digital subscriber line (**SHDSL**) is used for the delivery of T1 services at 1.5 Mbit/s. SHDSL can also be used for the delivery of E1 services at 2.048 Mbit/s that is the primary rate in the digital hierarchy used in Australia. A CLEC that has acquired access to ULL could offer a range of services to both business and residential users.

5.8 As set out above, symmetric services are used by businesses for telecommunications applications. Businesses also need asymmetric services for internet based applications. Residential customers generally use asymmetric services. As I previously explained, businesses are more likely to require assurances with respect to QoS. This means that the range of services that can be offered can be summarized in the form that I set out in Table 3.

Access service	Business symmetric	Business asymmetric with QoS	Residential asymmetric without QoS
LSS	✗	✓	✓
ULL	✓	✓	✓

Table 3 - Business and residential services

5.9 The line rates that are available are set out in Table 4

DSL variant	Upstream maximum	Downstream maximum	Symmetric?
ADLS2+	1 Mbit/s	24 Mbit/s	✗
SHDSL	2.048 Mbit/s	2.048 Mbit/s	✓

Table 4 - Line rates

5.10 It is feasible to use DSL services to provide higher line rates than those that I have set out in this section. However, individual telecommunications companies whether CLECs or ILECs, typically choose to set a cut-off limit for symmetric services above which fiber is the preferred access network technology rather than copper. I understand that Telstra takes the view that symmetric services above 4 Mbit/s will typically be delivered using fiber. Part of the issue here is that the distance from the local exchange building limits the use of DSL technology to supply symmetric services. Even SHDSL at 2 Mbit/s is limited to approximately 1.7 kilometers.

5.11 A CLEC is not constrained to providing only retail services whether to businesses or to residential premises. If a CLEC installs a DSLAM in a local exchange building, it is in a position to offer other CLECs a wholesale DSL service. Such a wholesale service might allow an internet service provider (**ISP**) to migrate from a dial-up only service to a broadband service in areas where it might not be economic for the ISP to deploy a DSLAM.

5.12 DSLAMs are not limited to the delivery of DSL based services. Many modern DSLAMs are also able to act as line cards for base band spectrum. That is, the DSLAM can convert an analog voice telephone line service into a digital form. The DSLAMs can provide the necessary ringing voltage and line currents to allow conventional analog handsets to be connected and to function in precisely the same way as if they were connected to the local switch operated by the ILEC in the local exchange building where the DSLAM is housed. This means that an CLEC that acquires ULL and has deployed a voice line card equipped DSLAM could offer voice services that it would carry as an IP stream to its core network.

5.13 A spectrum sharing service would not allow the base band spectrum to be made available to the CLEC and so a CLEC could not offer a voice service based on a DSLAM if it only acquired LSS rather than ULL. Set out below in Table 5 is the ability for CLECs to deliver voice services to their customers.

DSLAM deployed	LSS	ULL
DSLAM no line card	Voice services delivered using local call resale and PSTN terminating and originating (typically with wholesale line rental)	Voice services delivered using local call resale and PSTN terminating and originating (typically with wholesale line rental)
DSLAM with line card	Not normally deployed but could deliver voice services using local call resale and PSTN terminating and originating (typically with wholesale line rental)	Voice delivered to core network from DSLAM over IP

Table 5 - Voice services

6 Services that can be provided using cable

6.1 It has been possible for cable operators to offer telephony services for at least the last 10 years. The initial cable telephony technology was known as "constant bitrate" (**CBR**) technology. From the early part of this century there has been an alternative technology available based on the delivery of voice of Internet Protocol (**VoIP**). VoIP technology is significantly cheaper for cable operators than CBR technology and, as a result, has led to cable operators in North America offering voice services and achieving significant penetration based on their published customer numbers. CBR technology is inefficient compared to DOCSIS in terms of the upstream capacity used. Each upstream channel is approximately 2.25 MHz wide and it is likely that Optus uses 4 such channels.

6.2 As I have shown in section 4 above, cable systems can be used to supply high speed data services at up to 30 Mbit/s downstream and 1 Mbit/s upstream using the existing DOCSIS 1.1 system that is deployed in Australia by both Telstra and Optus. The DOCSIS 1.1 standard supports the delivery of voice services and will establish an appropriate QoS path when voice is the application. DOCSIS 1.1 was designed for the delivery of VoIP services rather than older technologies such as CBR.

6.3 Cable operators in both the US and Canada currently deliver competitive voice services to the voice services provided by both ILECs and CLECs. Most of these services are delivered (or have, in the past, been delivered) using DOCSIS 1.1. I say that some were delivered in the past using DOCSIS 1.1 because a number of these cable networks have upgraded to DOCSIS 2.0 but still use the backwards compatibility for some voice services.

6.4 Many cable operators in North America offer voice services and have successfully achieved significant penetration of voice compared to either their reach or the number of cable television subscribers. Set out in Table 6 below is some data from Q4 2006 illustrating this point.

Cable Operator	Telephony subscribers
Time Warner	1,860,000
Comcast	1,855,000
Cablevision	1,209,000
Cox	600,000
Charter	445,800
Videotron	398,000
Rogers	366,000
Shaw	250,904
Mediacom	105,000
Cogeco	78,931
Insight	16,200
CableOne	2,925
Other	180,000
Total	**7,374,835**

Source: Cable Digital News Estimates, Company Reports

Table 6 - North American cable telephony

6.5 The US cable industry has identified that one of its next growth opportunities lies in the delivery of services to businesses. Most customers of cable systems in the US are residential end users and the potential to deliver business grade services to SME has been identified as a significant potential. As a result, there has been significant activity in establishing standards for the delivery of business grade services using cable networks. These standards have been developed by Cable Labs and include standards for delivery of T1/E1 services and VPN. However, the first of these standards will only work on systems that have deployed DOCSIS 2.0 or higher.

6.6 Cable Labs has produced specifications for the delivery of T1/E1 services over cable systems that relies on an underlying DOCSIS delivery system. This specification is "Data-Over-Cable Service Interface Specifications: Business Services over DOCSIS®. This Emulation Interface Specification. CM-SP-TEI-I03-070803" and was issued in August 2007. One of the vendors of equipment that complies to these specifications is Vyyo. For the purposes of this report, I contacted Jeff Gardiner of Vyyo to determine the extent to which T1 services complying with the specification are being trialed or deployed in the US. Based on the information provided, most of the major cable operators in the US are trialing the deployment of T1 services. Vyyo reports the statistics set out in Table 7, in respect of the 4 largest cable operators in the US (Time Warner, Cox, Comcast and Charter.

Parameter	Value
Businesses passed by cable	1,864,500
T1s in that footprint	2,984,697

Table 7 - Potential T1 market in US for largest 4 cable operators

6.7 Cable Labs has also issued a specification for the delivery of Layer 2 VPN services over DOCSIS based cable. This is "Data-Over-Cable Service Interface Specifications: Business Services over DOCSIS®. Layer 2 Virtual Private Networks. CM-SP-L2VPN-I05-070803" and was issued August 2007. The intention behind this specification is to enable cable operators to be able to offer a service that competes with telecommunications operators' VPN services. The current state of this specification is "issued". This means that vendors are in a position to design to meet the specification and for those designs to be verified against the Cable Labs specification.

6.8 Cisco Systems offers a suite of products that would allow a cable operator to offer Layer 2 VPN services. I am aware that these are also being trialed in the US currently. My understanding is that these trials are technically successful and the next stage is to move to commercial deployment of Layer 2 VPN services.

7 Upgrading an HFC network to deliver business and residential voice and data services

Introduction

7.1 There are 3 distinct issues that I would address if I were in the position of considering upgrading an HFC network similar to the Optus HFC network in order to deliver services within the footprint of the existing network:

(a) delivery of services to multiple dwelling units;

(b) delivery of telephony using VoIP technology; and

(c) delivery of business services.

7.2 I am asked to assume that Optus' HFC network passes 2.25 million homes of which 1.4 million are serviceable. I am further instructed that many of the homes which are not serviced by Optus are MDU. In addition to these MDU, there will be some premises that are not able to be serviced by cable at all. Provided that the business rules that are applied in the installation of cable systems are reasonably commercial, this will be a small percentage of premises passed.

Multiple dwelling units

7.3 Multiple Dwelling Units (**MDU**) provide an opportunity to have a low per unit cost of installation of cable service provided that the number of units taking a service is a reasonable fraction of the total number of units in the building. For the purposes of this report, I have assessed the average cost per unit of installing a cable service on the basis that the block of units did not have any existing cabling. I also chose to consider the costs in Southern California on the basis that the labor costs in this area are amongst the highest in the cable industry in the US. The results that I obtained are set out in Table 8 below.

Units per MDU	Southern California
4	$835
8	$1,335
16	$2,335

Table 8 - Post construction cable installation costs for 4/8/16 unit MDU

7.4 I have also reviewed the costs of wiring 4/8/16 unit MDU in Nevada in order to be sure that the costs that I have set out in Table 8 are reasonable. The result of this review was that pricing in Nevada is comparable to that in Southern California.

7.5 The costs set out in Table 8 represent the cost of installing wiring in the MDU block and lateral cables to each of the units. As a practical matter, in a new MDU the builder of the units normally installs a cable system that meets the technical requirements of one of the local cable operators. If riser wiring has been installed but there is no lateral cable in place, then the typical cost of running a lateral cable from a lock box on the relevant floor of the MDU to the unit is $125 in Southern California. If there is a need to install an amplifier, then the additional cost is $200 for the amplifier and $125 for the cost of installation and various other required materials.

7.6 In the US, there is a near ubiquitous deployment of cable. In addition, a significant proportion of premises passed by cable acquire cable services. That is, there is a high penetration of cable services in the US. The National Cable Television Association reports that substantially more than 95% of all homes passed by cable are capable of being served by cable modem services. MDU are considered to be some of the most attractive premises for cable deployment because the relative cost of installing an apartment in an MDU is lower than the cost of installing a single dwelling unit. Clearly, the attraction of any particular MDU will depend on the willingness of the owner to permit installation of cable, the physical complexity of cable installation and the likely take up of cable services within the MDU.

7.7 One indication of the attractiveness of MDU is the extent to which specialized "overbuilders" target MDU. Overbuilders are companies that install HFC systems in areas where there are existing HFC systems. Examples of overbuilders include RCN Communications, WOW Communications and Knology. Each of these businesses has overbuilt in their target areas. Set out in Table 9 below are the subscriber numbers for these companies.

Company	Subscribers
RCN Communications	361,400
WOW Communications	355,000
Knology	221,800

Table 9 - Overbuilders' subscriber numbers

7.8 RCN Communications specializes in relatively densely populated cities. In July 2007 it provided a description to an investor briefing that shows the extent to which the company targets MDU. I reproduce this element of the investor briefing in Figure 7 below.

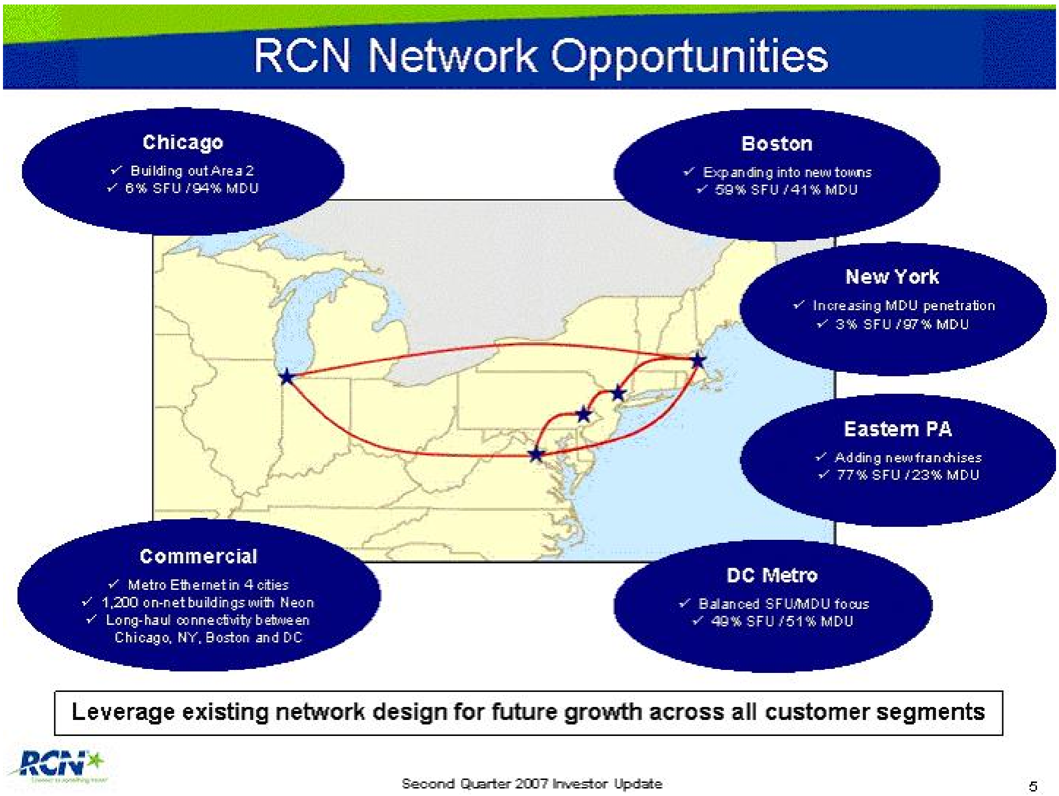


Figure 7 - RCN Communications MDU build

Telephony using VoIP technology

7.9 Given that Optus already has DOCSIS 1.1 deployed in its network, it would be logical for Optus to deliver voice services using VoIP and taking the benefit of the QoS capability of the version of DOCSIS that it has deployed. Further, I am instructed that Optus has already deployed power in its HFC network to ensure that its existing CBR based voice service remains available when mains power to premises has been lost (for example, during a black out).

7.10 I also understand that Optus has a core network that is designed to be able to interface with an Internet Protocol stream from its DSLAMs. That is, my understanding is that Optus acquires ULL and uses the ULL for the delivery of both voice and data services. As a result, the Optus core network is capable of dealing with voice services from devices that have functionality similar to that of a DSLAM.

7.11 A DOCSIS 1.1 CMTS interfaces to an Ethernet aggregation point in a similar fashion to the manner in which the outputs from a number of DSLAMs will interface to an Ethernet aggregation point. On this basis, my view is that the incremental cost of providing VoIP voice services rather than CBR voice services will be low and will relate to the establishment of links from existing CMTS.

7.12 I am also of the view that the existing outdoor plant of the Optus HFC network is unlikely to require an upgrade in the short term. There is sufficient upstream and downstream capacity in the Optus HFC provided that the system is performing properly. As a result, there is no upstream limitation on the deployment of new services. Node splitting may be required in the future if there is a significant uptake on the new services that could be offered that make use of upstream capacity.

7.13 Optus will need to consider how it implements the customer premises equipment associated with the delivery of voice services using VoIP. A number of cable modem manufacturers such as Motorola and Cisco produce cable modems with ports into which standard telephones can be plugged. That is, the cable modem contains an analog telephone adaptor (**ATA**). As I discuss below, vendors offer integrated cable modems with a battery pack for emergency power at a wholesale cost of $25.00 more than one without battery back up.

7.14 A second advantage of the integrated cable modem is that the voice application receives its QoS priority without the need for any external software. Such a device has a wholesale price of approximately $90.00. It may be possible to recover this amount from the end user of the cable system. Even if it is not possible to recover the capital cost of the customer premises equipment from the end user, it is likely that there will be a monthly recurring charge associated with the voice service from which the customer premises equipment capital cost can be recovered.

7.15 Until the voice services using VoIP become established, there would be no need to remove the older CBR system currently deployed by Optus. Eventually, I would expect that this system would be removed and replaced as the replacement system is cheaper to install and maintain and would provide interoperability with the existing Optus core network. Ultimately, the removal of the CBR system will release 9 MHz of upstream capacity that would contribute to the 9.6 MHz required for 3 DOCSIS services. The 9.6 MHz is calculated as 3 sets of 3.2 MHz bandwidths.

Business services

7.16 There are two forms of business service that could be offered on an HFC network either as an alternative to the acquisition of ULL or to expand the customer base served by the HFC network. These services are:

(a) the delivery of E1 on a point to point basis with at least one of the points being on the HFC network; and

(b) Layer 2 VPN services.

E1 business services

7.17 The delivery of E1 services could be implemented using equipment from a number of vendors. For the purpose of describing the implementation of the service, I shall assume that the technology sold in the US by Vyyo as “T1 in a box” (**Vyyo System**) will be deployed.

7.18 The Vyyo System needs one 6 MHz downstream channel to provide up to 22 E1 services in the downstream direction. However, the system limitation is in the upstream where a 3.2 MHz channel supports 4 E1 services. For nodes with a high business use, I would propose to use two 3.2 MHz upstream channels to achieve up to eight E1 services per node.

7.19 The customer premises equipment is an E1 cable modem that also has an Ethernet port. I am aware from my experience in the telecommunications industry that there is a trend to deliver business data services as Ethernet rather than the telecommunications centric E1. The modem can be used for either so there is a potential upgrade path for the customer.

7.20 Making the assumptions that I have set out in this section, the cost per E1 (both hub/headend and customer premises end) is approximately $3,500 based on a fully loaded chassis of Vyyo equipment. In the US, a reasonable cost for a T1 is approximately $400 per month. However, this cost varies widely and ranges between $200 and $1,200 per month. If prices are similar in Australia, then the payback period for the E1 system (assuming that the cost of the cable system is sunk) is about one year.

Layer 2 VPN business services

7.21 In order to provide Layer 2 VPN services, it is necessary to install a CMTS system that supports this standard. If the system is only required in order to support business services, then it is possible to take advantage of the higher upstream bit rates offered by DOCSIS 2.0 and choose to deploy 1 upstream channel initially for Layer 2 VPN services. Once the CBR voice system is replaced, then an additional channel could be added.

7.22 The Layer 2 VPN services could be implemented using the Motorola BSR 64000 CMTS system. To provide business grade VPN services, along with 2 voice ports, the cable modem could be the Motorola SBV 5200. This cable modem can be provided with a battery back up that is integrated into the device.

7.23 I have reviewed the Motorola list prices for CMTS equipment both at the cable plant end and the customer end. If I make the following assumptions, then I can develop a proposed approach that could be adopted by Optus:

(a) the Motorola CMTS would be fully loaded with twelve 2x8 cards. These are configured as 2 downstream services and 8 upstream services per card. This equates to 24 downstream DOCSIS carriers (that would support 24 single receiver nodes) and 96 upstream carriers;

(b) the initial upstream deployment will be 1 channel per node but this could be scaled as the CBR upstream channels are released;

(c) the DOCSIS 2.0 business customers would likely want both voice and VPN services; and

(d) 6 MHz downstream channels are available as I have previously indicated.

7.24 Based on the assumptions set out above, then the cost per headend to run a spectrum shared DOCSIS 2.0 system to provide business Layer 2 VPN services and voice services would be $275,000. The customer premises equipment would be either an SBV 5200 cable modem (that includes router and voice ports) at a cost of $90 or a variant on this router that includes battery backup for an additional cost of $25.

Attachment A — Resume of Michael Harris

Michael G. Harris

Harris Communications Consulting LLC

16 Gorge Lane
Pound Ridge, NY 10576

PROFESSIONAL EXPERIENCE

06/07-Present Member of CommScope Broadband Technical Advisory Board

Primary Responsibility:

- Evaluate new and existing products.
- Develop new products.
- Evaluate possible acquisitions.
- Provide training for in-house personnel.

03/06-05/07 Consulting to Allied Capital/Longview Cable for Cable TV Operations

Primary Responsibility:

- Evaluated equipment for system rebuilds.
- Reviewed rebuild specifications and construction practices.
- Evaluated various systems for possible purchase.
- Reviewed Proof of Performance reports.
- Reviewed CLI reports.

(note: Allied Capital decided earlier this year to sell all their existing operations)

03/05-Present Consulting Services to Diamond Castle Holdings, LLC. for Cable TV, Cellular and other acquisitions

Primary Responsibility:

- Evaluated various systems for possible purchase.
- Reviewed construction practices.
- Reviewed Proof of Performance reports.
- Reviewed new construction certification reports.
- On site inspection of new under grounding activities relating to system rebuild.

- Reviewed CLI reports.
- Projected on-going extraordinary capital expenditure requirements.

10/99 –12/04 Senior VP Engineering and CTO Citizens Communications

<u>Responsibilities Included:</u>

- Evaluated new technologies for use in Citizen's network with over 2.4M subscribers.
- Evaluated video over DSL equipment and suppliers.
- Lead on multi-company consortium for deployment of video services.
- Total responsibility for Citizens Cable TV systems which included the following:
  - All FCC matters including Proof of Performance, CLI and public file.
  - All rebuild, new build and upgrade specifications for electronics and physical construction.
  - All Headend specifications, equipment selection and construction.
- Responsible for Capital Expenditure Tracking and Control for entire company.
- Lead on our Capital Review Committee meetings for project approval.
- Developed and Maintained Capital Approval Matrix and policies.
- Capital budget review and approval responsibility.

1973 – 1999 Senior VP Engineering/CTO Century Communications

<u>Responsibilities Included:</u>

- All engineering activities for Century's 1.7 Million Cable TV subscribers which included:
  - FCC proof of performance format, testing, documentation and final review.
  - CLI reporting and documentation and certification for both aerial and ground based tests.
  - General construction practices.
  - System design for both new build and rebuilds.
  - Capital reporting and tracking to budget.
  - Evaluation of new technologies.
  - Developed electronics lab for the manufacturing of amplifier replacement modules. (1973 through 1985)
  - Member of Century's Board of Directors.

*Century had approx 72 Cable Systems across the US and Puerto Rico. We were the largest Cable Operator in the Los Angeles/Orange County area. We were also the largest Cable Operator in Puerto Rico.

1989-1997 Senior VP Engineering/CTO Centennial Cellular.

- Total responsibility for Centennial's initial entry into Cellular Telephone Business.
- Initial deployments included:
  - Lincoln, NE
  - Yuma, AZ
  - El Centro, CA
  - South Bend, Huntington & Ft. Wayne, Indiana.
  - Kalamazoo, Battle Creek & Benton Harbor, Michigan.
  - Greater San Juan, Puerto Rico. We were one of the first companies to select and deploy CDMA Cellular Technology.
  - At the time of sale the company had approximately 10M POPS.

*Centennial Cellular was a division of Century Communications.

1971-1973 Northwest Regional Engineer for Teleprompter Corporation

- Total engineering responsibility for Cable TV systems located in the NW Region.
- Developed the first FCC Proof of Performance reporting documents for Teleprompter.
- Responsibility for all System and Headend Construction and Certification.

*Teleprompter, at that time, was the largest Cable Television Operator in the US with 1.1 Million subscribers.

1967-1970 US Army (35H20) RA50203023

- Boot camp at Fort Lewis, Washington.
- Mathematics and Electronics Teacher at Aberdeen Proving Grounds, Maryland.
- Mathematics and Electronics Teacher at Corpus Christi NAS, Texas
- Director of the Army Calibration Lab on the USNS Corpus Christi Bay located in Vung Tau, Vietnam.
- Awarded the Bronze Star in 1970.

1966-1967 RCA Service Company/White Alice Project-Anchorage, Alaska.

- Maintained a Forward Propagation Tropospheric Scatter Transmitter, and related Telephone and Teletype equipment, at Cape Newingham, Alaska. This was pre-satellite technology and phase out was started in the early 1970's.

EDUCATION

Columbia Basin College – AAS Electronics Technology	1964-1966
US Army Electronics and Calibration Technology School (35H20)	1967/1968

MEMBERSHIP IN PROFESSIONAL GROUPS AND ORGANIZATIONS

Society of Cable Television Engineers	1981-Present
Society of Cable Television Pioneers	1996-Present
American Radio Relay League	1972-Present
Ham Radio Operator (Extra Class Call W1MH)	1961-Present
Loyal Order of the 704 Society	1997-Present

Attachment B — Federal Court Guidelines

Guidelines for Expert Witnesses in Proceedings in the Federal Court of Australia

This replaces the Practice Direction on Guidelines for Expert Witnesses in Proceedings in the Federal Court of Australia issued on 11 April 2007.

Practitioners should give a copy of the following guidelines to any witness they propose to retain for the purpose of preparing a report or giving evidence in a proceeding as to an opinion held by the witness that is wholly or substantially based on the specialised knowledge of the witness (see **- Part 3.3 - Opinion** of the *Evidence Act 1995* (Cth)).

M.E.J. BLACK
Chief Justice
6 June 2007

Explanatory Memorandum

The guidelines are not intended to address all aspects of an expert witness's duties, but are intended to facilitate the admission of opinion evidence (footnote #1), and to assist experts to understand in general terms what the Court expects of them. Additionally, it is hoped that the guidelines will assist individual expert witnesses to avoid the criticism that is sometimes made (whether rightly or wrongly) that expert witnesses lack objectivity, or have coloured their evidence in favour of the party calling them.

Ways by which an expert witness giving opinion evidence may avoid criticism of partiality include ensuring that the report, or other statement of evidence:

(a) is clearly expressed and not argumentative in tone;

(b) is centrally concerned to express an opinion, upon a clearly defined question or questions, based on the expert's specialised knowledge;

(c) identifies with precision the factual premises upon which the opinion is based;

(d) explains the process of reasoning by which the expert reached the opinion expressed in the report;

(e) is confined to the area or areas of the expert's specialised knowledge; and

(f) identifies any pre-existing relationship (such as that of treating medical practitioner or a firm's accountant) between the author of the report, or his or her firm, company etc, and a party to the litigation.

An expert is not disqualified from giving evidence by reason only of a pre-existing relationship with the party that proffers the expert as a witness, but the nature of the pre-existing relationship should be disclosed. Where an expert has such a relationship the expert may need to pay particular attention to the identification of the factual premises upon which the expert's opinion is based. The expert should make it clear whether, and to what extent, the opinion is based on the personal knowledge of the expert (the factual basis for which might be required to be established by admissible evidence of the expert or another witness) derived from the ongoing relationship rather than on factual premises or assumptions provided to the expert by way of instructions.

All experts need to be aware that if they participate to a significant degree in the process of formulating and preparing the case of a party, they may find it difficult to maintain objectivity.

An expert witness does not compromise objectivity by defending, forcefully if necessary, an opinion based on the expert's specialised knowledge which is genuinely held but may do so if the expert is, for example, unwilling to give consideration to alternative factual premises or is unwilling, where appropriate, to acknowledge recognised differences of opinion or approach between experts in the relevant discipline.

Some expert evidence is necessarily evaluative in character and, to an extent, argumentative. Some evidence by economists about the definition of the relevant market in competition law cases and evidence by anthropologists about the identification of a traditional society for the purposes of native title applications may be of such a character. The Court has a discretion to treat essentially argumentative evidence as submission, see Order 10 paragraph 1(2)(j).

The guidelines are, as their title indicates, no more than guidelines. Attempts to apply them literally in every case may prove unhelpful. In some areas of specialised knowledge and in some circumstances (eg some aspects of economic "evidence" in competition law cases) their literal interpretation may prove unworkable. The Court expects legal practitioners and experts to work together to ensure that the guidelines are implemented in a practically sensible way which ensures that they achieve their intended purpose.

Guidelines

1. General Duty to the Court (footnote #2)

1.1 An expert witness has an overriding duty to assist the Court on matters relevant to the expert's area of expertise.

1.2 An expert witness is not an advocate for a party even when giving testimony that is necessarily evaluative rather than inferential (footnote #3).

1.3 An expert witness's paramount duty is to the Court and not to the person retaining the expert.

2. The Form of the Expert Evidence (footnote #4)

2.1 An expert's written report must give details of the expert's qualifications and of the literature or other material used in making the report.

2.2 All assumptions of fact made by the expert should be clearly and fully stated.

2.3 The report should identify and state the qualifications of each person who carried out any tests or experiments upon which the expert relied in compiling the report.

2.4 Where several opinions are provided in the report, the expert should summarise them.

2.5 The expert should give the reasons for each opinion.

2.6 At the end of the report the expert should declare that "[the expert] has *made all the inquiries that* [the expert] *believes are desirable and appropriate and that no matters of significance that* [the expert] *regards as relevant have, to* [the expert's] *knowledge, been withheld from the Court*."

2.7 There should be included in or attached to the report; (i) a statement of the questions or issues that the expert was asked to address; (ii) the factual premises upon which the report proceeds; and (iii) the documents and other materials that the expert has been instructed to consider.

2.8 If, after exchange of reports or at any other stage, an expert witness changes a material opinion, having read another expert's report or for any other reason, the change should be communicated in a timely manner (through legal representatives) to each party to whom the expert witness's report has been provided and, when appropriate, to the Court (footnote #5).

2.9 If an expert's opinion is not fully researched because the expert considers that insufficient data are available, or for any other reason, this must be stated with an indication that the opinion is no more than a provisional one. Where an expert witness who has prepared a report believes that it may be incomplete or inaccurate without some qualification, that qualification must be stated in the report (footnote #5).

2.10 The expert should make it clear when a particular question or issue falls outside the relevant field of expertise.

2.11 Where an expert's report refers to photographs, plans, calculations, analyses, measurements, survey reports or other extrinsic matter, these must be provided to the opposite party at the same time as the exchange of reports (footnote #6).

3. Experts' Conference

3.1 If experts retained by the parties meet at the direction of the Court, it would be improper for an expert to be given, or to accept, instructions not to reach agreement. If, at a meeting directed by the Court, the experts cannot reach agreement about matters of expert opinion, they should specify their reasons for being unable to do so.

footnote #1
As to the distinction between expert opinion evidence and expert assistance see *Evans Deakin Pty Ltd v Sebel Furniture Ltd* [2003] FCA 171 per Allsop J at [676].

footnote #2
See rule 35.3 Civil Procedure Rules (UK); see also Lord Woolf "Medics, Lawyers and the Courts" [1997] 16 CJQ 302 at 313.

footnote #3
See *Sampi v State of Western Australia* [2005] FCA 777 at [792]-[793], and *ACCC v Liquorland and Woolworths* [2006] FCA 826 at [836]-[842]

footnote #4
See rule 35.10 Civil Procedure Rules (UK) and Practice Direction 35 – Experts and Assessors (UK); *HG v the Queen* (1999) 197 CLR 414 per Gleeson CJ at [39]-[43]; *Ocean Marine Mutual Insurance Association (Europe) OV v Jetopay Pty Ltd* [2000] FCA 1463 (FC) at [17]-[23]

footnote #5
The *"Ikarian Reefer"* [1993] 20 FSR 563 at 565

footnote #6
The *"Ikarian Reefer"* [1993] 20 FSR 563 at 565-566. See also Ormrod *"Scientific Evidence in Court"* [1968] Crim LR 240.

Attachment C — Facts provided by Peter Waters & Associates

Hybrid Fibre Coaxial rollout in Australia - Facts and assumptions

Both Telstra and Optus have deployed HFC networks which consist of two-way, 750 MHz plant. The Telstra network is predominantly underground and the Optus one is virtually all aerial.

The Optus network is deployed in Sydney, Melbourne and Brisbane and consists of about 21,000 km (13,000 miles) coax cable (0.625" coaxial) and 5,500 km (3,400 miles) fibre cable (single mode optical fibre from 24 to 144 fibres per sheath) in suburban residential areas. The Optus network delivers power to the customer access units of telephony customers on its HFC network.

The Telstra HFC network covers suburban areas in Melbourne Sydney Gold Coast Brisbane Adelaide Perth and consists of about 40,000 km (25,000 miles) coax cable (0.625" coaxial).

The Optus HFC network was designed for voice as well as video so the headends are exchange buildings (central offices). The network is designed with:

(a) Sydney metropolitan area – 3 exchanges;

(b) Melbourne metropolitan area – 2 exchanges;

(c) Brisbane metropolitan area – 1 exchange.

The Optus HFC network has 2,000 homes passed per node and passes 2.25 million households. However, Optus does not provide services to multiple dwelling units (**MDU**) and claims to have 1.4 million serviceable homes passed.

The Telstra HFC passes 2.5 million homes and serves 70% of the households in the MDU that it passes. It has 279 nodes and 4172 hubs.

Both networks have the following band split: 5-65 MHz (up link) 85-750 MHz (down link). Currently, both networks are using approximately 128 MHz downstream for digital video and there is no analog video. The video channel spacing is 8 MHz on HFC (although the terrestrial channel spacing is 7 MHz).

Both Optus and Telstra offer cable modem services based on DOCSIS 1.1. The downstream bandwidth is 6 MHz and the upstream bandwidth is either 3.2 MHz or 1.6 MHz. There are up to 8 upstream carriers per hub/headend. The downstream modulation used by Telstra in Sydney and Melbourne is 256 QAM and 64 QAM elsewhere. Telstra delivers a maximum bitrate of 30 Mbit/s in Sydney and Melbourne and up to 17 Mbit/s in other cities in which it has an HFC network. Optus delivers cable modem services at up to 9.9 Mbit/s on its HFC network.

Both Optus and Telstra offer services based on SHDSL technology. Telstra has a distance limitation of 1.7 km for 2.048 Mbit/s symmetrical services.

Both Optus and Telstra use the public switched telephone network as the return path from digital set top units. That is, digital set top units do not use upstream spectrum for services such as video on demand.

The Australian Government estimate provided to the OECD is that there are 700,000 cable modem services in Australia (at June 2007). These are split across the 2 HFC networks with Optus claiming (Annual Report 2007) 365,000 cable modem subscribers at June 2007. Telstra reported (Annual Report 2007) 336,000 cable modem subscribers at June 2007

At June 2007, the Australian Film Commission reported that pay TV subscribers were:

Operator	Subscribers
FOXTEL (Telstra HFC and satellite)	1,292,000
Optus (HFC)	151,000
Austar (Satellite)	639,128