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13 February 2009

Ms Patricia Scott
Secretary
Department of Broadband, Communications and the Digital Economy
PO Box 2154
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Dear ~~Ms Scott,~~ Patricia

Re: Questionnaire on broadband technologies

I refer to your letter of 4 February 2009 requesting the Australian Competition and Consumer Commission's (ACCC's) response to the Department of Broadband, Communications and the Digital Economy (DBCDE's) questionnaire on broadband technologies. Our response is enclosed for your consideration.

In ranking these technologies, it is important to note that many are capable of providing the same end user experience in terms of speed, reliability and upgradeability — from a technical perspective, they can therefore be very similar. Which technology is the most suitable for providing services of different speeds, in different regions and climates, and its upgradeability, is ultimately a question of the economics — that is, which technology can achieve the desired goal at the lowest cost.

In answering the questionnaire, the ACCC has drawn on the expertise of its senior telecommunications engineering advisor. A ranking has been provided based on technical capability where the differences between technologies are clear. In circumstances where the difference in technologies is not clear, the ACCC has also noted the relevant economic considerations. Furthermore, some of the economic considerations in relation to the deployment of alternative technologies have been the subject of previous ACCC advice to the DBCDE and public regulatory processes.

If you have any queries about the enclosed response, please contact Michael Cosgrave on (03) 9290 1914.

Yours sincerely

Graeme Samuel
Chairman

Encl.

Confidential

The following broadband access technologies are capable of providing *fixed* broadband services to end-users:

- **hybrid fibre coaxial (HFC);**
- **fibre-to-the-node (FTTN) with VDSL2;**
- **fibre to the premises (FTTP);**
- **terrestrial wireless;**
- **satellite; and**
- **any other technology not listed above.**

The ACCC interprets 'fixed broadband services' to be those for which the end user's receiving device is fixed. This is in contrast to 'nomadic' and 'mobile' broadband services, for which the end user's receiving device is portable to varying degrees. The ACCC also notes that 'terrestrial wireless' could potentially encompass several technologies — for example, WiMAX and 3G. In answering the questions below, the ACCC has included WiMAX and 3G in its assessment of terrestrial wireless technologies.

In ranking these technologies, it is important to note that many are capable of providing the same end user experience in terms of speed, reliability and upgradeability — from a technical perspective, they can therefore be very similar. Which technology is the most suitable for providing services of different speeds, in different regions and climates, and its upgradeability, is ultimately a question of the economics — that is, which technology can achieve the desired goal at the lowest cost. In answering the questions below, the ACCC has drawn on the expertise of its senior telecommunications engineering advisor. A ranking has been provided based on technical capability where the differences between technologies are clear. In circumstances where the difference is not clear, the ACCC has also noted the relevant economic considerations. Furthermore, some of the economic considerations in relation to the deployment of alternative technologies have been the subject of previous ACCC advice to the DBCDE and public regulatory processes.

1) Please rank from best to worst the listed broadband technologies in relation to dedicated speeds that are available to end-users. Please consider the impact of contention ratios on speeds in giving your answer. Please give the reasons for your ranking. Are you aware of any emerging technologies that would cause you to amend your rankings in relation to dedicated speeds that are available to individual end users only, within the foreseeable future, say 15 years? Where there is an emerging technology that is relevant, please indicate your understanding of the timing of its market availability?

Ranking

1. FTTP/H
2. HFC
3. VDSL via FTTN[1]

[1] DSL can also be provided over the legacy copper network. The ACCC has not included DSL provided over the copper network in its rankings.

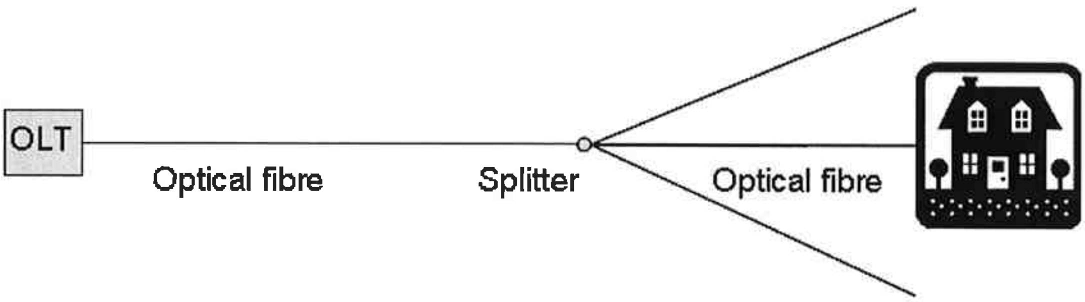
4. 3G
5. WiMAX
6. Satellite

With the exception of a dedicated point-to-point FTTP/H network, access services provided over all of these technologies would almost certainly involve a degree of sharing of network elements between end-users.[2] The contention ratio reflects the degree of sharing of transmission capacity, and is a key factor affecting the speeds experienced by end-users. Contention ratios of 1:10 to 1:100 are not unusual (with the lower ratio implying that fewer customers share a certain bandwidth). Ultimately, the choice of contention ratio for any of the technologies is an economic one — for a given number of end users, if each requires an increase in speed, less sharing of a given transmission capacity is required, which necessitates investment in more transmission capacity — and therefore higher costs.

Each of the listed technologies (although perhaps less so for satellite) is able to provide very high speeds for end-users. However, the actual speed available to a particular customer depends upon how many customers are using the various shared network elements that each technology includes (as well as the applications being used by each customer). In each case **the capacity available for a particular customer can be tailored and managed** by selecting the sharing of the shared elements. The choice between the technologies to provide a particular customer speed is therefore not a technology question, but is rather an economic question — that is, how much does it cost to share the shared network elements in the manner needed to provide the desired speeds?

The following diagrams show the shared network elements for several of these technologies, and how capacity is shared between customers. In each case the optical fibre backhaul is shared, and each uses similar technology for this backhaul. Typically this will be 1 Gbps Ethernet, several 1 Gbps Ethernet connections, or 10 Gbps Ethernet.

FTTH



Several standards are available for FTTH networks. While the EPON standard has been widely deployed in Japan and Korea, the standard generally preferred in the USA, Europe and Australia is the ITU-T GPON (Gigabit Passive Optical Network).

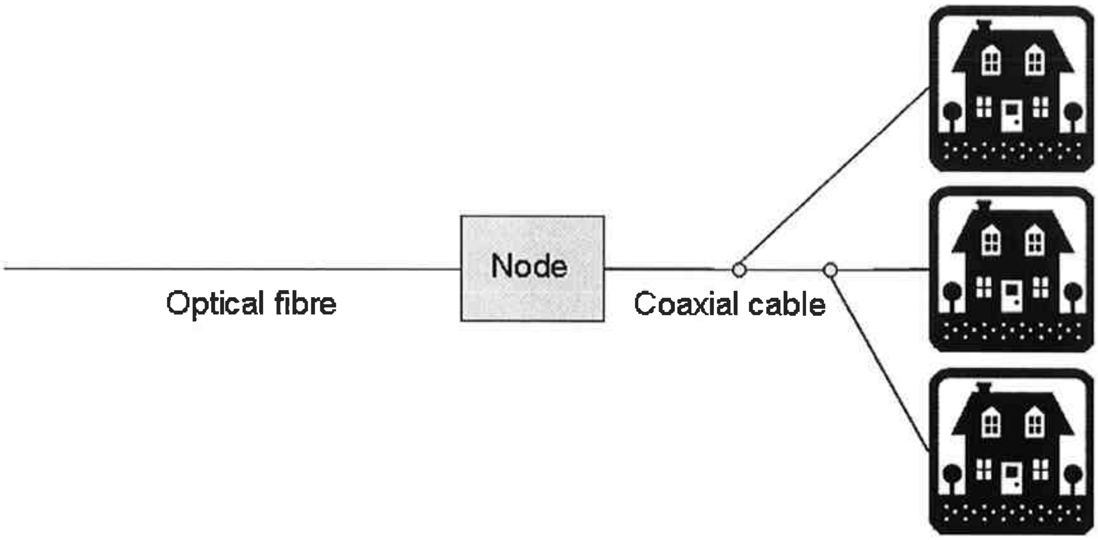
[2] Whether an access service provided via a point-to-point FTTP/H network involves such sharing of network elements will depend on whether the access seeker interconnects at the OLT or a point deeper in the network.

GPON (FTTH/P)[3] uses a single shared optical fibre to the point where the fibre splits. Optical signals for one customer pass along the shared fibre to the split and after the split along all the fibres, not just the one for the particular customer. The optical fibre from the splitter back to the Optical Line Terminal (OLT) uses 2.4 Gbps shared between all the customers connected to the particular OLT. The optical connection from the OLT back into the core network is also shared.

The capacity available to customers is managed by selecting the split ratio for the optical fibre. This is generally either 32 or 64 for a GPON, but fewer customers can be connected if desired to obtain a higher data rate per customer.

While point to point FTTP/H network architecture ensures dedicated capacity over that access fibre is available for each customer in the network, the ACCC is unaware of any wide scale deployment of a point to point FTTP/H network other than for major customers.

HFC



HFC uses one or more TV channels to provide data services, with each channel able to provide about 40 Mbps. HFC networks use a shared coaxial cable between the optical node and customers' premises. The backhaul optical fibre from the node is also shared.

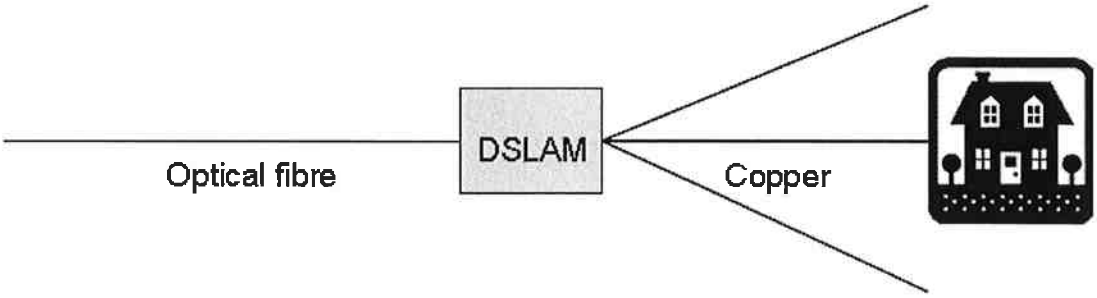
For HFC the capacity available per customer is managed by selecting the number of customers to be served off a particular coaxial cable segment. If needed, the coaxial cable can be segmented to serve fewer customers with the same capacity.

Which DOCSIS version is used affects the speed capabilities of HFC. DOCSIS 1.1 was the original standard for simply providing internet standards and is used by both Telstra and Optus. DOCSIS 2.0 was developed in response to a need to supply business services and in particular allows greater uplink speeds. DOCSIS 3.0 is a relatively new technology and uses the combined data rate from several channels to

3 FTTH is frequently implemented using a GPON. A GPON has an optical line terminal (OLT) in an exchange and connects to customers using optical fibre. There is an ONT (optical network terminal) in the customer's premises. The optical fibre splits near the customer premises in order to serve a number of customers from the one OLT. The OLT is connected to the core network using an optical fibre.

obtain the customer data rate, and is discussed below under the 'emerging technologies section'. The DOCSIS 3 standard requires that the data rate from at least four channels can be aggregated and that hence at least a data rate of well over 100 Mbps is available. Greater numbers of channels can also be aggregated if desired.

VDSL with FTTN



VDSL with FTTN has dedicated copper pairs for each customer. However, the optical backhaul link from the DSLAM is shared between all the customers served by that DSLAM (and potentially by other DSLAMs if the DSLAMs are daisy chained – which could be used, for example, where there are several DSLAM at a particular location sharing a single backhaul link, or several DSLAM closely located with each serving a small number of customers).

The shared element is the backhaul, and the capacity per customer is managed by selecting the number of customers to be served by the DSLAM. Often the DSLAM serves 384 customers and has a 1 Gbps Ethernet connection. If greater capacity is required per customer then either additional backhaul capacity can be added or the number of customers served reduced.

VDSL via FTTN data rates are dictated by a number of additional factors, for example the number of services using copper pairs within a cable, external interference sources, the configuration of the copper pairs, the wiring in the customer's premises, and especially by the length of the copper pair. With copper pairs of less than 0.8 km, 50 Mbps downstream should generally be possible across the copper pair dedicated to the particular customer.

In summary, the choice between these technologies to provide a particular customer speed is not a technology question (as they can all do it). It is rather an economic question – how much does it cost to share the shared network elements in the manner needed to provide the desired speeds per customer. Ranking these three technologies on the basis of speed and contention ratios without considering the economics is therefore not possible, as it will depend on the particular contention ratio that is chosen.

Wireless technologies

Wireless access technologies require significantly increased network capacity as the number of users and the amount of traffic they generate grows.

3G mobile is a shared network. 3G HSPA can now provide 14 Mbps downlink per antenna segment. With 3G HSPA evolved this can be expected to increase to 42 Mbps, and with 3G LTE to well over 160 Mbps. The capacity per customer depends upon the number of active customers in the antenna sector and the distance. That is, all active customers within the particular antenna sector share the available capacity. The capacity available for a particular antenna sector depends upon:

- the bandwidth and frequency of spectrum allocated
- the carrier power
- the number of carrier channels used for signals from the antenna

The end-user's experience will also depend on the distance between the user and the base station and the nature of the wireless path (for example, is it line of sight, and are there reflections).

WiMAX uses similar technology to 3G LTE, but usually the transmission frequencies are significantly higher, resulting in it being more suited to metropolitan rather than rural applications.

Satellite technologies are generally able to provide more limited data capacity than VDSL via FTTN, FTTP/H, HFC and 3G.

'Very Small Aperture Terminal' (VSAT) technology provides distributed data from a central point to multiple receive-only terminals, and can reach downlink speeds of up to 38 Mbps. Two-way satellite systems provide the user with much more capable downlinks than uplinks. The most recent service being developed is 'Ka-band' which can provide uplinks of 2 Mbps and download rates between 10 Mbps and 100 Mbps, shared between all active customers in the antenna coverage area.

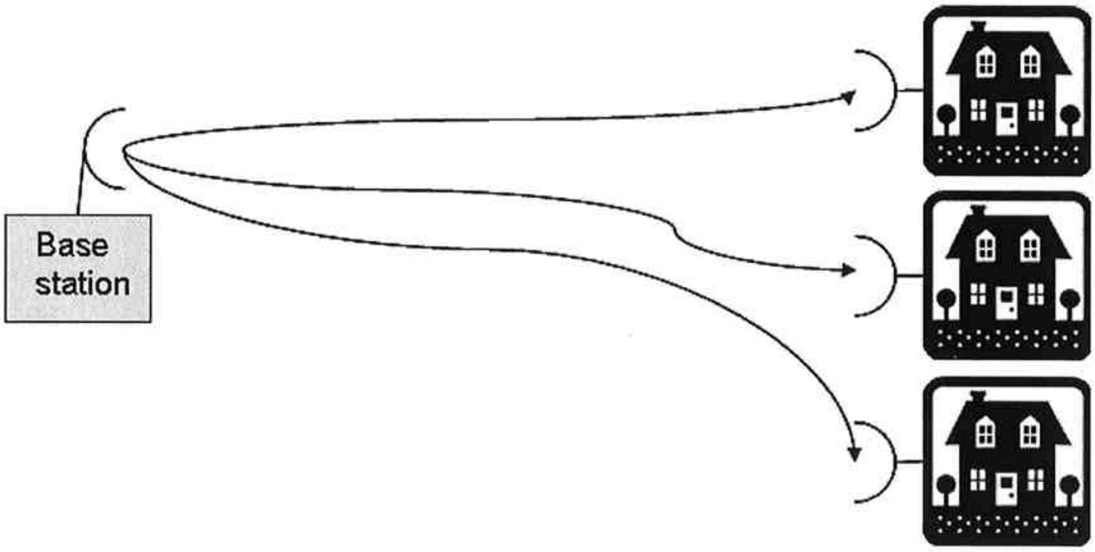
<u>Emerging technologies that may influence the ranking</u>

For VDSL via FTTN, future use of DSM3 (Dynamic Spectrum Management version 3) could push data rates to 100 Mbps, for pairs of less than 1 km, by dynamically managing the crosstalk between copper pairs. DSM3 is now working in the laboratory, is being standardised by the ITU-T, and is generally expected to be available commercially within 1-2 years. Note that for DSM3 to be effective it is necessary for all copper pairs within a cable bundle to be served by the one DSLAM.

The capacity of HFC networks can be upgraded at a relatively low cost (compared to the cost of fibre rollouts) through the use of technologies such as DOCSIS 3.0. For HFC, use of DOCSIS 3.0 allows a number of the TV channels to be bonded together to provide higher data rates than currently experienced on Telstra and Optus' HFC networks. Equipment to bond four channels to give around 160 Mbps is now available, and it is expected that eight channels and 320 Mbps will be available soon. This data rate is then shared between the active customers on the particular coaxial cable segment.

Upgrades of 3G HSPA and 3G HSPA evolved to 3G LTE are expected to increase downlink speed per antenna segment to 160 Mbps (which has been demonstrated) and perhaps then to 320 Mbps. 3G LTE using 20 MHz spectrum and MIMO (Multiple Input, Multiple Output antennas) has been demonstrated at 170 Mbps and equipment is now available from vendors. 3G LTE networks use shared radio spectrum to connect to all the customers in the area covered by the antenna segment. The diagram below shows the likely network structure of a 3G LTE network.

3G LTE



The backhaul from the base station might be an optical fibre or a microwave radio system, and is shared between all the customers connected through the base station (which possibly includes a number of antenna segments). For 3G LTE, the capacity available per customer is managed by selecting the cell size. If greater capacity per customer is required the cells can be made smaller (and in the end with one cell per customer provided by a femptocell – for example, to cover one house or building). Again, the choice of how many customers per cell are used is essentially a question of cost.

3G LTE has some similarity to HFC with DOCSIS 3.0 in terms of capacity and sharing. With a DOCSIS 3.0 network the average throughput available to a customer is managed by managing the segmentation of the coaxial cable part of the HFC network. The traffic engineering of the shared radio sector for 3G LTE is similar to this.

LTE is a 4G wireless broadband technology. It represents the next step in a progression from GSM (a 2G standard) to UMTS (3G technologies based upon GSM). Each of these technologies is standardised by ETSI's 3GPP program. A distinct market advantage of these technologies is that they are backward compatible and have a very large established customer base and hence economies of scale. LTE works in an all-IP network similar to the new fixed communication networks.

2) Please rank from best to worst the listed broadband technologies in relation to the proven track record of the technology in Australia and/or overseas, for example, in terms of established supply arrangements and long term and large scale deployments. Please give the reasons for your ranking.

In ranking the various technologies, the following criteria have been used:

- Are the relevant international standards in place and stable?
- Are major international vendors already delivering the necessary network and customer equipment internationally and within Australia?

- Is there sufficient technical expertise to plan, build, operate and support a major roll-out?
- What data rates are able to be provided?
- Are required local agreements such as spectrum usage in place?

Based on this, an appropriate ranking is:

1. HFC
2. 3G
3. FTTP/H
4. VDSL via FTTN
5. Satellite
6. WiMAX

HFC

In Australia, Telstra's HFC network passes 2.5 million premises, of which around 2.3 million are classified as serviceable by Telstra. Optus' HFC network passes 2.2 million homes, 1.4 million of which are classified as serviceable by Optus. In the USA, cable networks are relatively ubiquitous. The networks have been in place in the United States for a significantly longer period than in Australia but this has largely been for the purpose of delivering pay TV. The use of these networks for broadband and particularly voice is relatively new but growing very rapidly indeed. In Canada the cable networks pass 94% of homes. Regarding the DOCSIS standard of HFC networks, as noted above, DOCSIS 1.0 is currently used in Australian, but there are a number of deployments of DOCSIS 3.0 or various forms of pre-DOCSIS 3.0 technology overseas, particularly in the USA. Nonetheless, few details exist at present regarding DOCSIS 3.0 upgrades, though Virgin UK, Comcast and Time Warner Cable have upgraded to DOCSIS 3.0 and have stated that capital expenditure has remained within guidance.[4] These implementations are typically using four bonded channels to provide well over 100 Mbps.

Optus is using its HFC network for voice services.

These networks have been in large-scale operation in Australia in excess of 10 years, there is sufficient local expertise, and high data rates are already being used by customers. Hence, the technical capability is well-proven.

3G

In Australia, Telstra's NextG network (3G HSPA+) covers 99% of the population; Optus' 3G network (launched in 2005) currently reaches 80% of the population; and Vodafone's 3G network covers Canberra, Sydney, Melbourne, Perth and Brisbane. Both Optus and Vodafone have announced plans to extend the coverage of their 3G networks to reach 98% and 95% of the population respectively.

The international standards are firmly in place, and build on the sequence of standards from the ETSI 3GPP (GSM-GPRS-EDGE-HSPA-LTE). A key success factor for these networks is the very wide worldwide deployment and hence the availability of

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4 UBS, 'UBS Investment Research — TLS: Assessing Plan B', 20 January 2009.

both network equipment, customer equipment and technical expertise. Telstra was able to build a world-scale network very quickly indeed drawing extensively upon local technical expertise. The Telstra network is already providing data rates of world best practice. There have been few technical issues that would have been visible to customers. Spectrum has been available, although further spectrum would be of value in enabling the highest data rates.

Hence, the technical capability is well proven.

FTTP/H

In terms of FTTP/H networks, TransACT currently deploy FTTP/H in one suburb in the ACT.[5] FTTP/H has also been deployed in new estates Australia wide over the past few years. Companies such as BES (Western Australia), GeoMedia (Western Australia), Bright (Western Australia) and Pivit (Queensland) all have commercial deployments, although in small numbers (about 3,000 subscribers in total). Telstra has also recently signed exclusive agreements with a number of developments across the country in new estates.

Internationally, FTTP networks have been deployed in several Asian and European countries, and Canada and the United States. In particular, the EPON standard has been very extensively used in Japan and Korea. However, the preferred standard is now GPON, and is seeing more widespread deployment in Europe (especially) and the USA. GPON is generally accepted by carriers as being the preferred standard for Australia. In particular, GPON is seen as a necessary technology by a number of carriers in order to compete with the HFC networks, especially in Europe and the USA. This has resulted in aggressive capability developments, especially by the HFC operators and vendors. The ACCC notes that in relation to FTTP/H networks the choice between PON and point to point network architecture has considerable implications for the nature of access services which can be offered to access seekers. That said the ACCC is unaware of any wide scale deployment of a FTTP/H point to point network other than for major customers.

While there has been only a little deployment within Australia, the vendors are well placed to deliver equipment and there is sufficient local expertise.

VDSL via FTTN

In terms of VDSL via FTTN networks, TransACT have been deploying VDSL via FTTN networks in the ACT since 2001. Currently, around half the suburbs serviced by TransACT in the ACT are served by VDSL via FTTN.[6]

Aside from the TransACT network, VDSL2 is not able to be deployed in Australia prior to industry agreement on the deployment code. This code is necessary because of the crosstalk between services operating over copper wire pairs within the same

5 TransACT, 'Frequently Asked Questions', http://www.transact.com.au/knowledge/servicesAvailability.aspx#faq24, accessed on 10 February 2009.

6 TransACT, 'Service Availability', at http://www.transact.com.au/servicesearch/ServiceAvailability.pdf, accessed on 10 February 2009.

cable (which is also a requirement for ADSL2+, but there the industry code is in place and working).

Nevertheless, within Australia there is extensive experience with ADSL2+ and VDSL2 is a very similar technology (it simply adds higher frequencies for the signals sent over the copper wires). As the frequencies become higher degradations such as crosstalk become ever more severe, as do the requirements of the copper wires. Nevertheless, there has been expensive work in this area in Australia (particularly by Telstra and NEC) and it is well understood. A number of major international vendors within Australia deliver ADSL2+ equipment and would readily be able to do so for VDSL2 (and indeed it would be the exact same equipment). It can be confidently expected that a large scale deployment could be undertaken. Note that typical vendor equipment is now able to provide which ever version of DSL is required, be that ADSL2+ or VDSL2.

VDSL2 has been deployed internationally by a number of major carriers, and most notably by Deutsche Telekom in street-side nodes.

Table 1 summarises the status of VDSL via FTTN and FTTH in Europe and Asia, and shows that FTTx deployment is relatively widespread in Korea and Japan.

Table 1 Status of FTTx deployment in Europe and Asia

Country	Broadband household coverage ratio	Broadband penetration (household)	FTTx share of broadband
France	96%	61%	0.09%
Germany	90%	41%	0.16%
Netherlands	99%	73%	2.33%
Sweden	92%	55%	14.5%
UK	95%	56%	0.01%
Japan	94% 80% (FTTH)	55%	33%*
Korea	78%	89%	28%

Note: * FTTH/B

Source: Ovum, *A comparison of broadband policy in Europe and Asia*, 2007.

Satellite

Optus currently owns and operates four satellites. Their footprints cover Australia, New Zealand, Asia, Hawaii, Norfolk Island, Papua New Guinea, Lord Howe Island, Cocos Island, Christmas Island and Murdoch Sound. This network constitutes a series of wireless access networks to regional and rural subscribers for delivering television, Internet, telephony and data communication services.

Setting aside Foxtel/Telstra and Optus, the other main satellite TV player in Australia is Austar. Austar serves regional areas and has a geographic agreement with Foxtel/Telstra that Austar will serve regional areas and Foxtel/Telstra will serve the main metropolitan areas. SelecTV is another smaller satellite player.

While satellites have generally had limited data rate capabilities, this is changing markedly, with several of the new systems becoming quite technologically competitive with terrestrial technologies such as the slower versions of ADSL.

There is sufficient technical expertise in Australia to deploy and support these new technology satellite systems.

WiMAX

WiMAX was first deployed in Australia several years ago. Current Australian WiMAX deployments include Allegro Networks in (South East Queensland); Unwired in several major cities, Austar (Wagga Wagga); Digital River Networks (areas of Queensland, New South Wales and Victoria); Emerge Technologies (Kalgoorlie & Kambalda in Western Australia); and Internode Systems (Yorke Peninsula in South Australia). These deployments either cover small numbers of remote customers, or (for example for Unwired, using a pre-WiMAX standard) potentially larger numbers of customers in cities such as Sydney.

Internationally, 3G has vastly greater scale than WiMAX. This is likely to be because, whereas 3G networks are able to leverage off existing mobile network infrastructure, spectrum availability and customer device availability, WiMAX has not had this leverage.

WiMAX has often been deployed where there is no existing copper infrastructure (for example, in parts of Asia). Usually the frequencies that have been assigned have been quite high, which limits its geographic range. However, ideally, high frequencies are usually preferred where capacity is of priority (such as in high population areas) and low frequencies where coverage is of priority (such as in rural areas). Consequently, 3G networks have a very distinct (and probably insurmountable) technical advantage in rural areas, such as would be the case in Australia. With the current frequency assignments it is highly likely that 3G networks will be able to provide a superior and more cost-effective service. Note that, aside from the challenges of frequency assignments within a particular country, should a country use frequencies differing from those used in the major parts of the world such as Europe and the USA it is then almost inevitable that network and customer equipment would either be unavailable or delayed, as well as expensive.

3) Please rank from best to worst the listed broadband technologies in relation to upgradeability of broadband services, defined as the ability of the technology to provide increasing speeds, functionality and quality of service to end users over time. Please give the reasons for your ranking. Are you aware of any emerging technologies that would cause you to amend your rankings in relation to upgradeability of broadband services, within the foreseeable future, and if so, please indicate your understanding of their market availability? Please note which technologies, if any, you consider as future proof.

Concerning the upgradeability of the various technologies, several factors need to be considered:

- What, if any, of the old infrastructure is retained?
- Are civil engineering works required?
- Is the customer still able to use equipment from previous generations?
- While an upgrade might be technically possible, is it likely to be economically viable?

Note also, that in making any changes to the network infrastructure, some legacy services may no longer be able to be supported. This needs to be carefully considered in relation to the customer benefit.

Based upon these, the ranking is:

1. FTTP/H
2. HFC
3. 3G
4. VDSL via FTTN
5. Satellite
6. WiMAX

While they have been numerically ranked, FTTP/H, HFC and 3G are in reality perhaps better ranked more nearly equal and each is technically capable of providing very high data rates indeed. VDSL and satellite are more limited and WiMAX is limited by the allocated frequencies and its competitive lagging of 3G.

HFC

As noted in question 1, the capacity of HFC networks can be upgraded at a relatively low cost (compared to the cost of fibre rollouts) through the use of technologies such as DOCSIS 3.0. Table 2 shows the increase in the range of services (speeds, functionality and quality of service) that can be offered with incremental DOCSIS upgrades.

Table 2 Different capabilities of different DOCSIS standards

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				
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

Source: Harris, Cablelabs

The data rates available to customers are ultimately dictated by the number of channels combined by DOCSIS 3 and the number of customers sharing the coaxial cable segment. In both of these areas HFC is quite flexible and able to be readily extended. Both can be undertaken now where necessary. As noted, the development of these technologies is being pushed very strongly, especially in the USA, in order to compete head-to-head with FTTH, and rapid progress is being made both technically and in deployment. Aside from migrating to more capable customer equipment, the network changes should be transparent to the customer.

3G

As noted in question 1, 3G networks are upgradeable to 3G LTE . The increases in speed that can be expected and the expected timeframes for the deployment of these technologies are outlined in question 1. Ultimately, the customer data rates can be pushed as far as desired by allocating sufficient spectrum and making the cells sufficiently small (and ultimately to a femptocell per person if needed). Aside from migrating to more capable customer equipment, the network changes should be transparent to the customer.

FTTH

FTTH networks are able to be upgraded by several means. The various proposals include a higher line rate on the optical fibre (perhaps to 10 Gbps instead of the 2.4 Gbps used by GPON), the use of multiple wavelengths, or changing to a single fibre per customer rather than a shared fibre (i.e. point to point). Of these, the generally expected direction is to use multiple wavelengths over the shared fibre, as that is seen to give very high data rates in the most economical manner.

Multiple wavelengths could be used by the addition of wavelength-selective filters on each of the customer-specific fibres of the passive optical network. While this would require a field trip, it would not require civil works and would likely be economically viable than changing to a dedicated fibre per customer.

VDSL

As noted in question 1, VDSL via FTTN networks can be upgraded with the use of DSM3. As noted earlier, this would only be possible if a single DSLAM is used for all of the copper pairs in a particular cable bundle. In any case, it is expected that increasing data rates past about 100 Mbps will not be viable, and in that respect VDSL would ultimately fall behind HFC, 3G and FTTH. Aside from migrating to more capable customer equipment, the network changes should be transparent to the customer. It should be noted that VDSL via FTTN is not likely to be a 'stepping stone' to FTTH, due to the large proportion of costs that are associated with deploying nodes for VDSL via FTTN; nodes which are subsequently stranded with FTTH deployment.

Satellite

Satellite services are ultimately constrained by the equipment on the satellite, the power available to run it, and by the size of antenna used by the customer. While substantial steps have been made and the new systems are quite capable, satellites can be expected to not keep up with HFC, 3G or FTTH where terrestrial systems are geographically cost-effective.

WiMAX

WiMAX uses similar technology to 3G LTE and would theoretically then be seen to have the same potential development path. However, as noted, WiMAX is significantly weakened by its market position versus 3G and by the frequency allocations.

<u>Emerging technologies that may influence the ranking</u>

This has been covered in the notes above.

4) Please rank from best to worst the listed broadband technologies in relation to the reliability of the technology, including in different geographies and climates where appropriate. Please give reasons for your ranking. Are you aware of any emerging technologies that would cause you to amend your rankings in relation to reliability, within the foreseeable future, and if so, indicate your understanding of the timing of its market availability?

Criteria that need to be considered include:

- Outside factors influencing the signals being sent in the system. For example, is the system influenced by the weather or by interference from other systems?
- How easy and quickly can a system be restored should it be disrupted?

Ranking

1. FTTP/H
2. HFC
3. 3G
4. WiMAX
5. VDSL via FTTN
6. Satellite

It is difficult to rank FTTP/H, VDSL via FTTN and HFC technologies in terms of reliability. If all are deployed below ground, FTTP/H technology may be more reliable as it is not subject to damage to nodes (e.g. due to car accidents). Further, as there is no copper element, FTTH/P may be more reliable because fibre is less subject to water damage than copper (be that copper pair or coax). On the other hand, *aerial* FTTH/P deployment may be less reliable than VDSL via FTTN and HFC, because it is subject to wear and tear from the weather. Similarly, Optus' HFC network may be less reliable (than VDSL via FTTN and Telstra's HFC) in variable climates, as it is an above-ground deployment. A particular concern for copper pair cable, particularly for older cables is water ingress, although concrete steps are taken to minimise this.

One issue with VDSL via FTTN technologies that does not arise with FTTH or HFC is that of 'cross-talk' or 'mid point injection interference'. Cross-talk occurs when one xDSL service interferes with other xDSL services transmitted over copper pairs, which are in close proximity to each other (i.e. within the same binder cable). Cross-talk increases the further the copper pairs run in parallel, the closer they are together, and the larger (more powerful) the interfering signals. Cross-talk also increases with the frequency of the transmitted signals: VDSL2 is affected to a greater extent than ADSL2+. As well as crosstalk from other VDSL services, it is also prone to interference from a range of electrical equipment. VDSL services are also critically dependent upon the configuration of the wiring within the customer's premises.

Broadly, wireless technologies (3G, WiMAX and satellite) perform better in less densely populated areas than in densely populated areas. This is because, as the density of customers increases and/or the intensity with which they use the broadband service increases, the smaller the cells need to be to ensure that each customer can obtain a satisfactory data throughput. That is, in high density population areas with many customers the cell sizes will need to be quite small. Hence, for example, as 3G cell sizes are reduced to provide an increased capacity for customers it can be expected that the base stations will move closer to the customers (the optical backhaul network for the base stations will therefore move ever further into the network).

For any wireless network there are two objectives: capacity and coverage. In densely populated areas capacity is required. In sparsely populated areas coverage is required. For covering short distances and capacity, high frequencies are desirable; for achieving coverage/for long distances, low frequencies are desirable. If using high frequencies over long distances, directional antennas are required. In addition, low frequency signals pass through buildings and other obstacles more easily than high frequency signals. WiMAX is currently using 4 to 7 times the frequency of 3G.

All wireless systems are affected by climatic considerations (e.g. rain or clouds can disrupt the signals, and this is of particular concern for the north of Australia). Delivery of services via satellite technology also involves an element of unavoidable delay, as the signal travels a great distance from the ground station to the satellite and back to the user — it takes around 0.3 seconds to travel from the ground station to the satellite and back to the user. As a result, satellites generally provide access seekers with a more limited scope of product offerings. It can also be difficult to predict the launch and in-orbit failures in the satellite system. Further, if the access seeker or the end-user has responsibility for the air sector, this may present risks to the integrity, quality and cost of services received by the end-user. Nonetheless, satellite is an ideal wide-area point-to-multipoint delivery mechanism. It is currently one of the main providers of telecommunications services to remote settlements in Australia, because it can see as much as 42 per cent of the earth's surface, and therefore has the potential to reach end users that are widely dispersed.

It should also be considered that the ranking of the different technologies may be considered differently (in terms of reliability) by different customer segments. In many cases, most small business and residential consumers will be satisfied with 'best efforts' service provision — that is, they are unlikely (in the immediate future) to require highly reliable data services. In terms of reliability, wireless and fixed voice and data services are therefore likely to be substitutable to some extent for these customers. In contrast, medium to large business customers are likely to require greater quality of service. For these customers, wireless and fixed data and voice services are more likely to be complements, with wireless used to achieve mobility where needed.

Emerging technologies that may influence the ranking

As noted, LTE is an emerging technology that upgrades the current 3G technology. 3G LTE is well suited for coverage where distances are too great for DSL. Hence, it is likely to offer greater reliability in more geographically dispersed areas. With upgrades to 3G LTE, in densely populated areas the network structure for VDSL via FTTN, HFC and 3G is optical backhaul and then either VDSL2 (for copper/ VDSL via FTTN), DOCSIS3 (for HFC) or 3G LTE (for radio) as the 'last mile'. Each of these solutions is very similar, and the preferred solution will be a matter of the economics. It is likely that where a copper access network already exists the VDSL via FTTN with VDSL2 solution will be the cheapest. In less densely populated areas the greater reach of 3G LTE can be expected to provide a more cost effective solution than a solution requiring extensive optical fibre deployment. Hence, it can be expected that 3G LTE will provide very effective solutions for the edges of the network. For the more densely populated areas it will be more aimed at sub-sections of the customer base, and particularly those requiring mobility.

As noted in previous questions, and shown in table 2, deployment of DOCSIS 3.0 on HFC networks is likely to improve the capability of HFC networks.

5) Please give any views on the technical suitability of the listed technologies for urban, rural or remote Australia.

Any of the technologies could be used in any of the areas; however the economics are likely to differ markedly.

As noted in question 4, wireless technologies (WiMAX, 3G and satellite) are particularly well suited to less densely populated areas. In the cities the need to have small cell sizes to ensure high data rates per customer mitigates against them economically, although technically it is viable. Hence, these technologies are likely to be more technically suitable for rural and remote areas than metropolitan areas, so long as low frequencies can be used in the rural areas.

As noted in the response to question 4, of WiMAX and 3G, a low frequency 3G technology is likely to be more suitable than WiMAX in rural areas and in city areas can be expected to provide much superior in-building coverage. Again as noted in question 4, satellite is likely to be particularly suitable for remote Australia, because it can 'see' a large proportion of the earth's surface.

On the other hand, and as noted in the response to question 4, VDSL via FTTN, FTTH/P and HFC are likely to be more suitable than wireless technologies for urban Australia, where the population is more dense, and the distance over which a signal must travel is less of a concern.