# BROADBAND FACTS, FICTION AND URBAN MYTHS

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There has been a lively debate surrounding the Australian Governments plan to build a fibre-based National Broadband Network. Unfortunately, a variety of urban myths about the NBN have evolved and spread over the past 12 months. Some of these myths are based on misunderstandings of the capabilities and limitations of broadband technology and some are out of alignment with experience in countries where broadband access is more advanced than in Australia. The objective of this article is to correct some of these misconceptions, to debunk some of the more common urban myths and to provide some basic facts for the lay person on the capabilities and limitations of various broadband technologies.

## INTRODUCTION

The Australian Federal Government's plan to build a National Broadband Network (NBN) with fibre to the premises (FTTP) technologies delivering broadband to 90% of homes has generated heated debate about the role of government in providing funding for large infrastructure projects of this kind. An informed debate is highly desirable when significant expenditure of public funds is involved. However, it is unfortunate that the debate has included some uninformed commentary about the capabilities and limitations of different broadband technologies, and a variety of urban myths that have evolved and spread in recent months. The objective of this article is to correct some of these misconceptions, to debunk some of the more common urban myths, and to provide some basic facts for the lay person on the capabilities and limitations of a variety of broadband technologies

## DEBUNKING SOME URBAN MYTHS

### THE NATIONAL BROADBAND NETWORK IS A WHITE ELEPHANT WAITING TO HAPPEN

When I read the above comment by an economist in a recent newspaper article I was reminded of a famous comment made in 1876 by Sir William Preece, Chief Engineer of the British Post Office. In response to a report about the commercial deployment of the telephone in the USA, he said: 'The Americans have need of the telephone, but we do not. We have plenty of messenger boys.' It also reminded my of Thomas Watson's famous statement in 1943, as Chairman of IBM: 'I think there is a world market for maybe five computers.'

The 21$^{st}$ century, the century of the information age, has only just begun. Fast broadband is the foundation and driver of this new age. Many other countries are aware of the importance of broadband and already have much more fibre installed to the home than Australia. Figure 1 shows the fibre penetration, i.e. the fraction of homes connected by FTTP or fibre to the building (FTTB), by country for all countries that have more than 1% of homes connected by fibre (Reboul 2010).

Australia is not one of these countries. Leaders in the FTTP stakes are South Korea Japan, Hong Kong and Taiwan. Other countries such as Lithuania, Estonia, the USA, and Denmark are approaching 10% penetration or have already passed it. Australia has always lagged behind many other OECD countries in its uptake of broadband. The NBN will not be a white elephant. Instead, it will be a mechanism by which Australia returns to the ranks of the leaders in the introduction of the most important infrastructure for the 21st century.

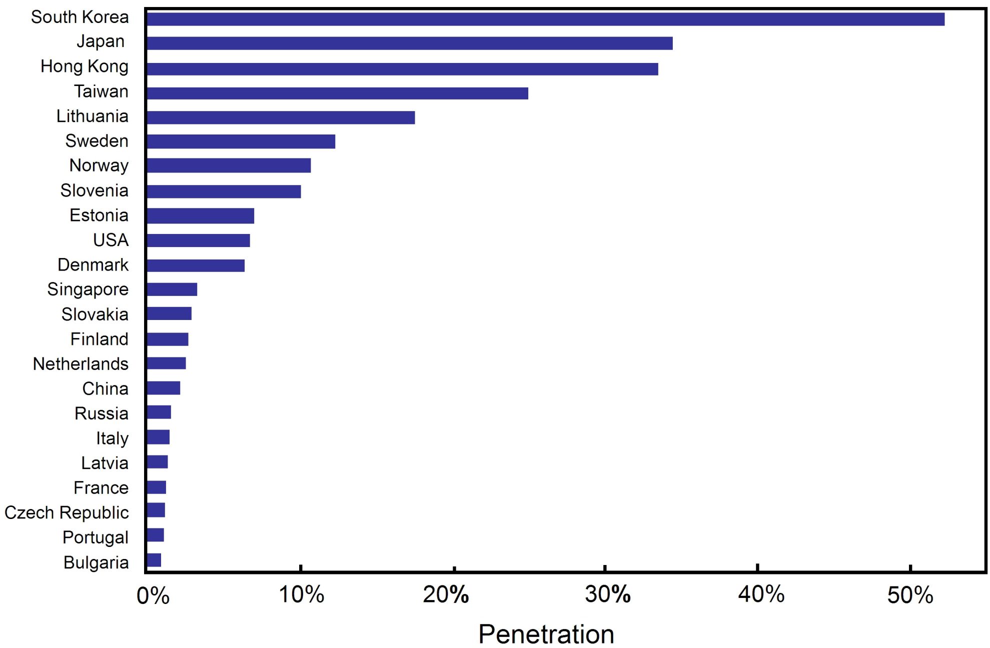


**Figure 1** Fraction of homes connected by FTTP and FTTB, by country, for countries with more than 1% of homes connected
Source: FTTH Council Asia Pacific 2010

Figure 2 shows the number of subscribers in Japan to FTTP, ADSL, and HFC broadband technologies over the period 2002 – 2009 (Sakuda 2010). (See Section 3 below for a brief description of these technologies). From 2002 to 2009, the penetration of HFC increased slightly while the penetration of ADSL increased rapidly. However, as a mature technology, ADSL penetration is now decreasing and it was overtaken by FTTP in 2008. This downward trend in ADSL usage is continuing, as an increasing number of customers in Japan churn from ADSL to FTTP.

A recent report by the industry analysis group, Heavy Reading (Finnie 2010), has predicted that on current trends, Sweden, the Netherlands, and the USA will all reach a FTTP penetration of 20% or more by 2014 and that by 2016 China, and France will join Australia in achieving a 20% penetration rate. Canada and the entire European Union will reach 20% penetration of FTTP within two years of Australia achieving that penetration rate. This shows that Australia is not out on a limb in building the NBN. Instead, it will align Australia with other leading countries. It is worth noting that in counties such as the USA and Canada, this increase in the fibre penetration is driven primarily by market forces, not by government initiatives.

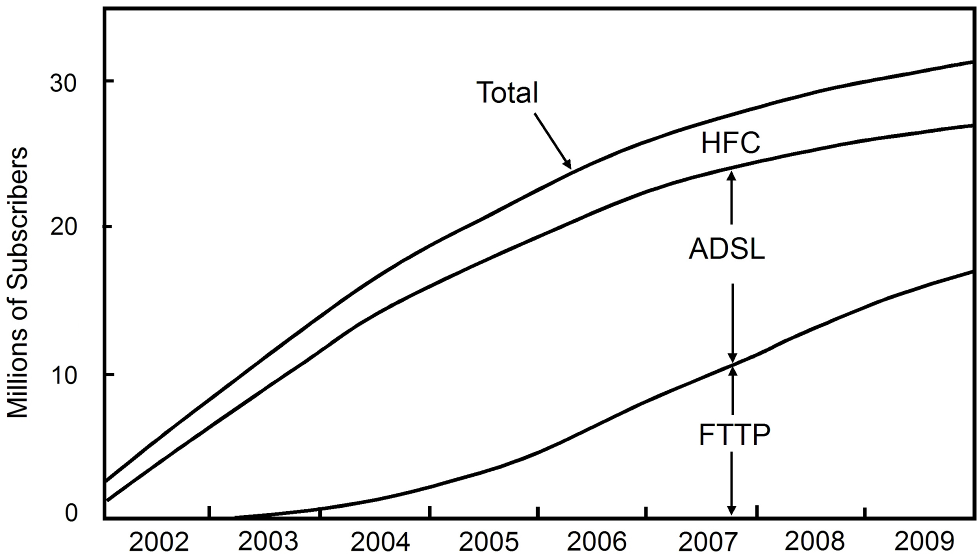


**Figure 2** Broadband subscriber numbers in Japan, 2002–2009
Source: Japan Ministry of Internal Affairs and Communication 2010

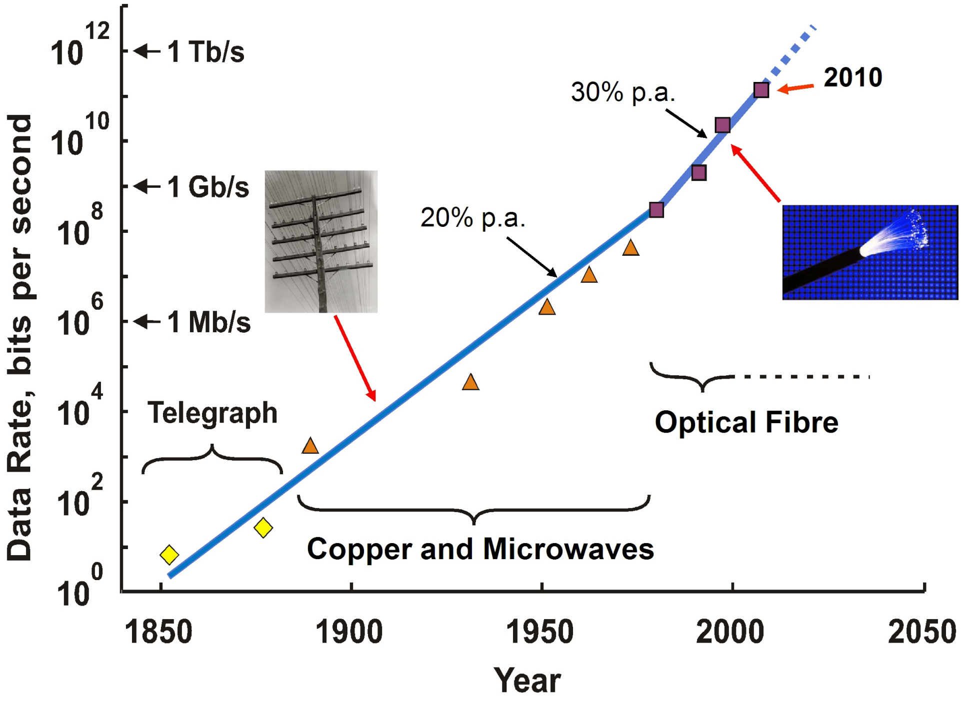


**Figure 3** Historical Evolution of backhaul capacity

It is interesting to look at the historical growth in data rate capacity of typical links in the Australian backhaul telecommunications network. This growth is shown in Figure 3, which gives the data rate as a function of time from 1850 to the present time. From the early days of the telegraph to the 1970's, the data rate grew at about 20% per annum. More recently, with the advent of the Internet and optical fibre, the data rate on backhaul links has been growing at 30% per annum.

Figure 4 shows the access rate available in Australia from 1985 up to the present time (Quigley 2010). Figure 4 includes a data point at 100 Mb/s around 2016, when the NBN is near completion, and a data point for XGPON (1 Gb/s) in the early 2020's. Figure 3 and Figure 4 are included here to illustrate how data rates in the telecommunications network have been growing exponentially for many years. Given the unbridled growth of new and emerging applications that use the Internet, one would have to be very brave or naive to suggest that this growth will suddenly stop.

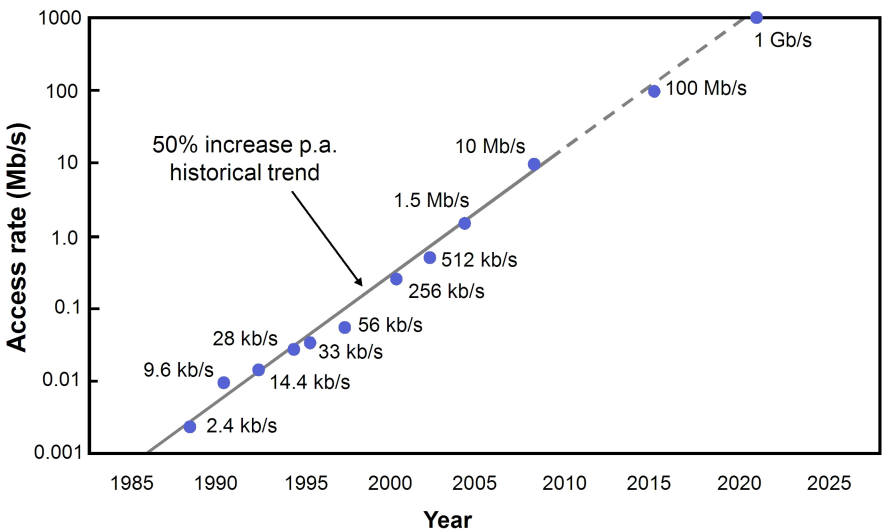


**Figure 4** Historical evolution of access capacity
Source: NBNCo

In summary, the NBN will be necessary infrastructure that will be required if the network in Australia is going to keep up with growing demand for increased bandwidth. Australia is currently behind many other countries in broadband access capabilities. Rather than becoming a white elephant, the NBN will help Australia to move into the company of the world leaders in broadband and to capitalise on the economic and social benefits that advance broadband technologies can bring to Australia.

## 100 MB/S TO THE HOME IS NOT NEEDED BECAUSE THE HUMAN BRAIN CAN'T PROCESS THAT MUCH INFORMATION

Human brains can, in fact, process huge amounts of data. A number of high-definition, and perhaps 3D, video signals in a single house, together with some on-line gaming and some telecommuting could easily make large inroads in a 100 Mb/s link. Add to this the data requirements of new on-line services such as on-line health monitoring, energy monitoring and home security and there will be pressure on the network to deliver even more than 100 Mb/s to the home. As shown in Figure 2, users in Japan are voting with their feet and choosing FTTP because they find a need for the extra bandwidth it provides.

Only a few years ago, many people were perfectly happy with dial-up modems. At that time, no one saw YouTube coming or the multitude of other services that have pushed many users in Australia to ADSL2+. Today, in 2010, we cannot tell what new applications will be driving broadband in 2012 or 2015.

### WIRELESS CAN PROVIDE 100 MB/S TO THE HOME

One often reads press articles claiming that wireless technologies are developing so rapidly that they could eventually overtake fibre. However, the capacity of wireless access is constrained by the very limited slice of the electromagnetic spectrum that can be used by wireless communications (see Section 3 below for an explanation of the limitations of wireless). In addition, the radio-frequency spectrum in a cellular network is shared by all users in that cell. Therefore, to achieve anything approaching 100 Mb/s to the home would require almost one base station tower for every user. Figure 5a shows an artist's impression of a FTTP network using underground fibre ducts and nano-cells in the home. A single mobile phone tower is visible in the background. Figure 5b shows an all-wireless network delivering a full 100 Mb/s to every home. This network would require a tower outside most houses and an underground fibre to every tower. The fibre infrastructure needed to support this network would be much the same as for the FTTP network in Figure 5a.

**Figure 5a** Artist's impression of networks delivering 100 Mb/s to the home – FTTP network using underground fibre ducts and nano-cells in the home
Note that the details of the antennas and the size of the anttena towers may vary.

**Figure 5b** Artist's impression of all wireless network delivering a full 100 Mb/s to every home
Note that the details of the antennas and the size of the anttena towers may vary.

## FUTURE ADVANCES IN WIRELESS WILL MAKE FTTP OBSOLETE

This often-stated urban myth misses the key differentiating factors that separate fibre and wireless. As shown in Section 3, a single optical fibre can carry 10,000 times the information that can be carried on the entire radio frequency spectrum and that when a fibre is used, the information can be dedicated to a single user. On the other hand, wireless suffers from limited bandwidth because the radio-frequency spectrum is necessarily shared, not dedicated. Therefore, fibre provides the ultimate future-proof solution for broadband access to fixed locations such as homes. Within a home, mobility can be provided by femto-cells and other local wireless local area networks. Wireless broadband is ideally suited to mobile applications, where the connected device is outside a home or building. It is also well suited to sparsely populated areas where the cost of installing fibre could be prohibitive.

FTTP and wireless technologies are complementary, not competitive. FTTP can provide data rates well beyond what the laws of physics allow wireless to operate at. On the other hand, wireless provides a degree of mobility that FTTP cannot provide. Fortunately, the screen size of small mobile devices is quite small, and video on these devices does not require nearly as much bandwidth as fixed video screens. Wireless provides a convenient access to limited data. FTTP provides the full power and capacity of the Internet to a fixed location. Both technologies have their place. Neither technology will make the other obsolete.

## ADVANCED DSL WILL PROVIDE 100 MB/S TO THE HOME

DSL technologies are now mature and are close to achieving their maximum possible performance. Figure 6 shows a plot of the theoretical maximum download bit rate of DSL connections versus the distance from the node to the user.

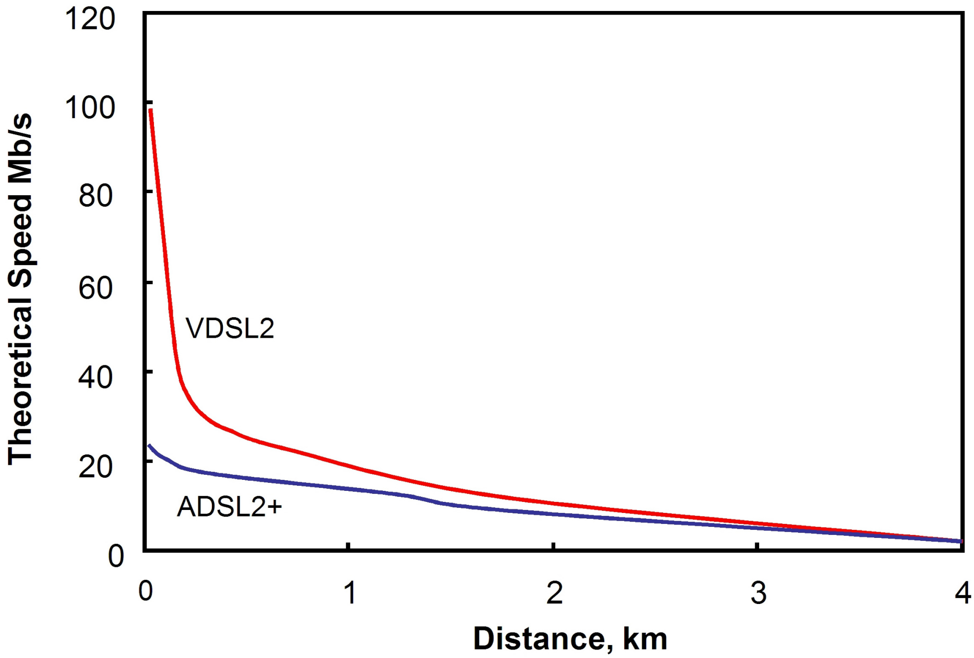


**Figure 6** Theoretical speed against distance for DSL

VDSL can theoretically deliver around 100 Mb/s to a user if there is a node just outside the home, but as the distance to the user increases, the theoretical bit rate drops off rapidly. ADSL2+ theoretically can deliver around 20 Mb/s to a house with a node just outside, and this drops to around 10 Mb/s at 2 km. In short, DSL will be able to provide 100 Mb/s to the home only if there is a node close to each house. Figure 7 shows an artists impression of a 100 Mb/s FTTN network employing VDSL. The blue boxes are nodes in the street containing DSLAMs.

**Figure 7** Artist's impression of a FTTN network delivering 100 Mb/s to the home

## IT WOULD MAKE SENSE TO KEEP THE EXISTING HYBRID FIBRE COAX (HFC) NETWORK IN PLACE AND ALLOW IT TO COMPETE WITH THE FTTP NETWORK.

Recent upgrades to Telstra's HFC network have pushed peak download data rates to around 100 Mb/s and at least one commentator has suggested that this network be allowed to compete with the FTTP network in the areas that it covers. However this would be a waste of infrastructure because some of the fibre currently used in the HFC network could be used in the FTTP network. In addition, as shown in Section 3 below, HFC cannot grow in bandwidth capability like FTTP and it consumes more power, thereby producing more greenhouse gases than FTTP.

In one of the darkest periods of Australia's telecommunications history, the Telstra and Optus companies spent many billions of dollars in the mid 1990's installing duplicate HFC networks. This unnecessary and wasteful duplication was driven by attempt to gain market dominance rather than a desire to provide the public with the most cost-effective and advanced technology. This kind of facilities-based competition has been successful in large North-American markets, but makes little or no sense in Australia. In contrast, the NBN model allows services-based competition over a so-called wholesale bit-stream, and recognises the economies of scale in building a single advanced network rather than multiple networks. The commentators who propose that the HFC network should be retained seem to have misunderstood these fundamental facts.

## FTTH IS ENVIRONMENTALLY UNFRIENDLY

A recent report commissioned by the City of Seattle (CTC 2009) found that if a FTTP or FTTN network was to be installed in Seattle, the resulting gains in energy efficiency in industry and the reduction in usage of private and public transport would result in a greenhouse emissions reduction of 600,000 tonnes of $CO_2$ per annum in the Seattle area. These gains would come from improved teleconferencing, increased telecommuting and the attendant reduction in traffic congestion. Scaling this result from the population of the greater Seattle area to the population of Australia, suggests that a greenhouse reduction in Australia of up to 10 million tones of $CO_2$ per year could be achieved. The Seattle study does not include an allowance for reduced inter-city air travel enabled by enhanced telepresence. We have calculated the greenhouse gas reductions that could be achieved if 50% of business air travel on the Melbourne to Sydney route were to be replaced by teleconferencing. This calculation shows that this reduction in business travel would save Australia an additional 2 million tonnes of $CO_2$ per year.

The Seattle study does not include an allowance for the energy consumed by the FTTP network and the greenhouse gasses associated with that energy consumption. Figure 8 shows the power consumption per user of the Internet with different access technologies (Baliga et al. 2008), as a function of the access rate.

For almost all bit rates, a FTTP network consumes around 7 watts per user. The alternative technologies all consume more power, with wireless access networks consuming between 20 and 30 watts per user, depending on the access rate. For an access rate of 10 Mb/s, wireless network would consume approximately four times more energy than a FTTP network. If we consider a national network with 5 million users, the 10-Mb/s wireless network would consume approximately 100 megawatts more than a 100-Mb/s FTTP network. Depending on what kind of power station is built to provide the extra power needed to run the wireless network, it would result in a greenhouse impact of up to 2 million tonnes of $CO_2$.

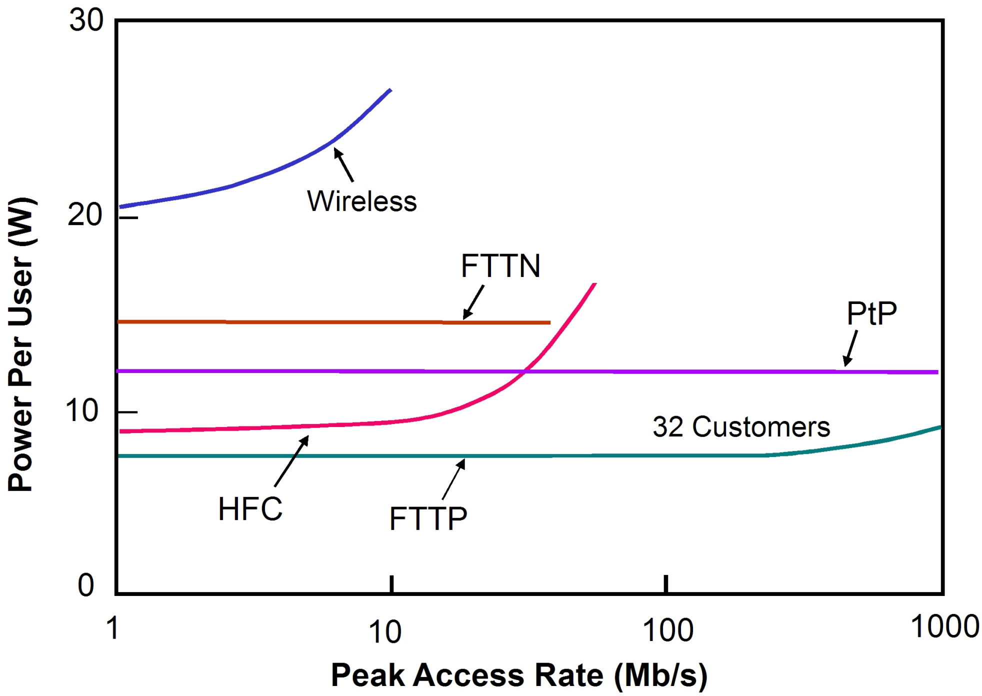


**Figure 8** Power per user for different access technologies against peak access rate

## THE NBN CANNOT BE JUSTIFIED ON ECONOMIC GROUNDS

In the Seattle study mentioned earlier in this article, it is estimated that the economic impact of a FTTP network on healthcare through lowered transportation costs, improved medical efficiencies, and direct medical cost savings would amount to more that US$600 million per annum in the Greater Seattle area. Adding the economic benefit of the environmental improvements mentioned earlier, the total economic benefit amounts to around US$1 billion per annum in the Greater Seattle area.

Like healthcare and the environment, there are many other economic and social benefits from the NBN that are not captured by simplistic business model calculations of the economic return of the NBN based on the fees generated by broadband subscriptions and the cost of the infrastructure. The commentator Paul Budde made the point very well in a recent e-mail newsletter:

> 'Australia is among the leading countries whose government is actively investigating the social and economic benefits that can be achieved through the deployment of a mainly fibre-based telecoms infrastructure. Services that depend on high quality broadband infrastructure include tele-health, e-education, e-business, digital media, e-government, smart meters etc. In countries where the national telco is lagging behind we see that local governments have no choice

> other than to take a leadership role, as they have done with similar infrastructure over the last 100 years.'

A recent report from the OECD, entitled 'Network development in support of innovation and user needs' (OECD 2009) makes the case for government investment in broadband infrastructure, citing the multiplier effects of these investments:

> 'High-speed broadband networks are a platform supporting innovation throughout the economy today in much the same way electricity and transportation networks spurred innovation in the past. New innovations such as smart electrical grids, tele-medicine, intelligent transportation networks, interactive learning and cloud computing will require fast communication networks to operate efficiently.'

## ACCESS TECHNOLOGIES – A PRIMER

This Section provides a brief overview of the key characteristics of some of technologies that compete for a role in delivering broadband to the residential user. Figure 9 summarises some of the main features of broadband delivery using fibre-to-the-home (FTTH), digital subscriber line (DSL), hybrid fibre coax (HFC) and wireless. The dotted box on the left of Figure 9 represents the telephone exchange or switching centre. This is the hub from which broadband data is distributed to the customer. A number of items of switching equipment are located in the telephone exchange, together with equipment that connects the telephone exchange to the access network.

### FIBRE TO THE PREMISES (FTTP)

The majority of customers of the NBN will be connected to the network using gigabit passive optical network (GPON) technology. This is illustrated at the top of Figure 9. A fibre from the telephone exchange feeds a splitting device (a 'splitter') that typically connects to 32 homes via 32 fibres (only two are shown in Figure 9). The fibre is connected to a user modem in each home, and the modem is connected to the home network, typically using a WiFi or Ethernet network (not shown in Figure 9). The FTTP technology planned for the NBN is called GPON. This GPON technology typically provides 100 Mb/s to the home.

The potential data capacity of fibre to the premises technology is virtually unlimited. This future-proof feature of FTTP makes it the natural choice for the NBN. As the need arises for even greater data rates, it will be a straightforward matter to upgrade the user modem to a higher data rate by simply changing the user modem. The telecommunications industry has already standardised the next generation of GPON (to be called XGPON). This technology will provide up to I000 Mb/s to the home. FTTP networks are well-suited to the provision of pay TV services.

Figure 9 shows a femto-cell wireless base station connected to one of the user modems. Femtocell technology provides a very low power wireless signal inside a home that enables conventional 3G and 4G wireless handsets to connect seamlessly to a wireless provider's network. It is anticipated that this technology will become widespread in the next few years, and will form a foundation for continued growth of broadband services to handheld wireless handsets.

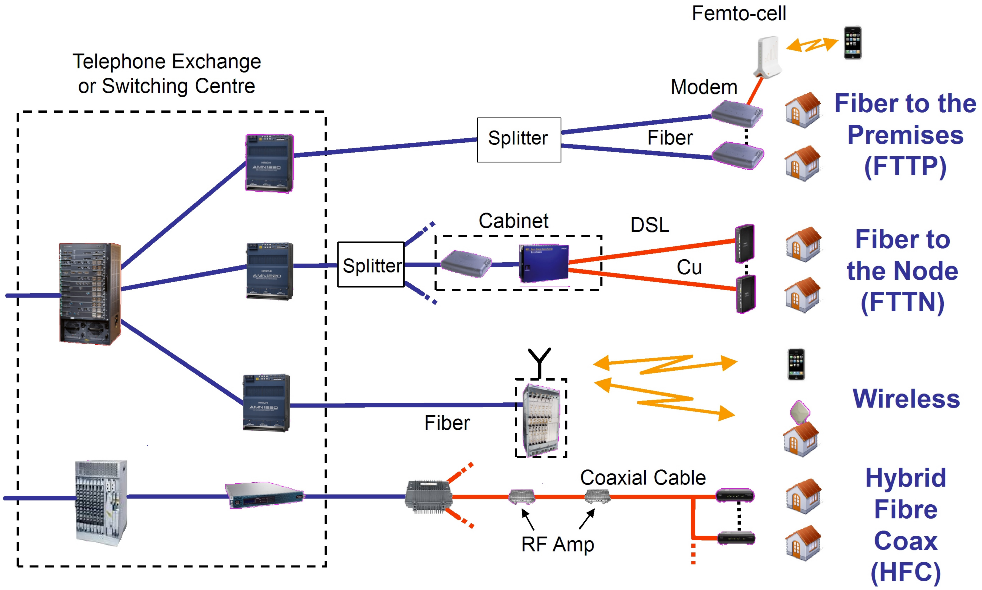


**Figure 9** Schematic diagram showing key component of a number of access technologies

## DSL

Many homes in Australia are currently connected to the network via asynchronous DSL (ADSL). These connections typically use ADSL or the more recent ADSL2+. ADSL uses the existing copper wires that have been used for many years to provide basic telephone connections between the home and the local telephone exchange. The beauty of DSL technology is that it is able to squeeze much more bandwidth out of a pair of copper wires than was ever envisaged when the original telephone network was installed. A piece of equipment called a DSLAM in the telephone exchange enables this increased bandwidth.

Despite its remarkable features, DSL has a disadvantage in that the achievable data rate decreases the further the home is located from the telephone exchange. Typical data rates for ADSL2+ are around 10 Mb/s. However, many homes are limited to much lower data rates than this because the distance to the nearest exchange.

One way to improve the data rate achievable on DSL networks is to locate the DSLAMs closer to the user. In Fibre to the node (FTTN) networks, DSLAMs are located in cabinet in the street and these cabinets are fed by fibre from the telephone exchange (see Figure 9). FTTN networks can theoretically provide 100 Mb/s to the user, but this is a theoretical upper limit. Typically, 50 Mb/s is a more realistic limit.

## WIRELESS

Figure 9 shows how a wireless network can connect either to a mobile device or to a fixed location such as a home. A more detailed schematic of a cellular wireless network is shown in Figure 10.

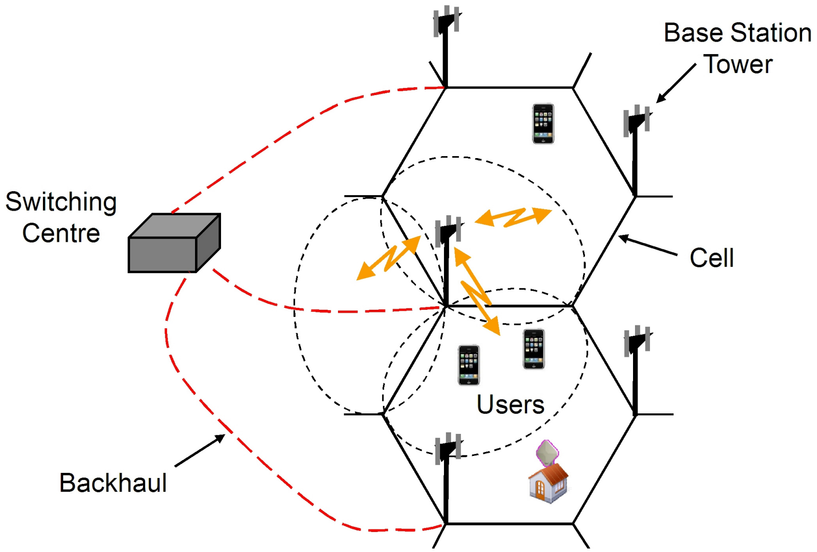


**Figure 10** Cellular wireless network

The network comprises an array of base stations with antenna towers arranged around an array of so-called cells. The cells are represented as hexagons in Figure 10, but in practice, their shape is irregular. The antennas beam their signals into the cells and the users in a cell share the bandwidth (i.e. the data) provided by the base stations. Figure 11 is a photograph of a base station tower. In recent years, these towers have begun to clutter the skyline and are a common sight. From the point of view of aesthetics, some might say too common!

**Figure 11** Base station tower

## HYBRID FIBRE COAX (HFC)

Approximately 2 million homes in Melbourne and Sydney are passed by HFC networks owned by Telstra and Optus. Some parts of these networks are currently being upgraded to higher bit rate, but they are highly asymmetric and their upload capability is severely limited, particularly if all users try to download data at the same time. Broadband access over these HFC networks will be decommissioned as the NBN comes on stream. As shown in Figure 9, HFC networks are fed by fibre. Close to the customer, the data is carried on copper coaxial cable and amplified by electronic radio frequency (RF) amplifiers. HFC networks also carry cable television.

## FEMTO CELLS

Femto cells are very small wireless cells that are installed in the home or office. Figure 9 shows how a femto cell can be attached to a user modem in a FTTP network. Femto cells potentially offer users lower cost mobile data when at home or in the office. It is expected that the NBN will drive a proliferation of femto cells and assist in facilitating the concept of 'fixed/mobile convergence'.

## THE ELECTROMAGNETIC SPECTRUM

All telecommunications technologies use signals that are transmitted over a distance with the data or information encapsulated in some way in the electromagnetic spectrum. To understand the key capabilities and limitations of different access technologies, it is important to understand a few facts about the electromagnetic spectrum. Figure 12 is a schematic of the electromagnetic spectrum. It includes a frequency axis (units of Hertz) and a wavelength axis. Note that these axes are logarithmic. The axes include expanded sections of the spectrum used by signals in wireless (1 MHz - ~5 GHz), coaxial cable (0 – 1 GHz), pairs of copper wires (0 - ~20 MHz), optical fibre (150 THz – 250 THz), and visible light. A key message from Figure 4 is that the width of the spectrum that can be passed through an optical fibre is 100 THz, or 100,000 GHz. This means that the information-carrying capacity of an optical fibre is about 20,000 times larger than the information-carrying capacity of the entire radio frequency spectrum.

The slice of the electromagnetic spectrum that is used by a particular communications technology is shared by all users that share the medium. This means that the data rate available to any one user is limited by the available bandwidth of the electromagnetic spectrum used by that particular access technology and by the number of users sharing that same slice of the electromagnetic spectrum.

As explained earlier, in FTTP access networks, the optical fibre is typically shared by 32 users. This means that if all users are accessing data at the same time, the theoretical maximum bandwidth available to a given user is one 32$^{nd}$ of the total bandwidth of an optical fibre, or about 3,000 GHz. This corresponds to about 1000 times more than the entire spectrum available to wireless communications.

In wireless networks, the slice of the electromagnetic spectrum available to wireless systems is shared among all users in a particular cell. If there is only one user in a cell, that user has access to a data rate that can be achieved using the entire available spectrum in the cell. This is what is sometimes referred to as the peak access rate in a wireless network. It is important to recognise that the peak access rate can be achieved only if there is one user in a cell. The only way to ensure that there is one user in a cell is to match the cell density to the population density. In urban areas, this means that large number of very small cells is required.

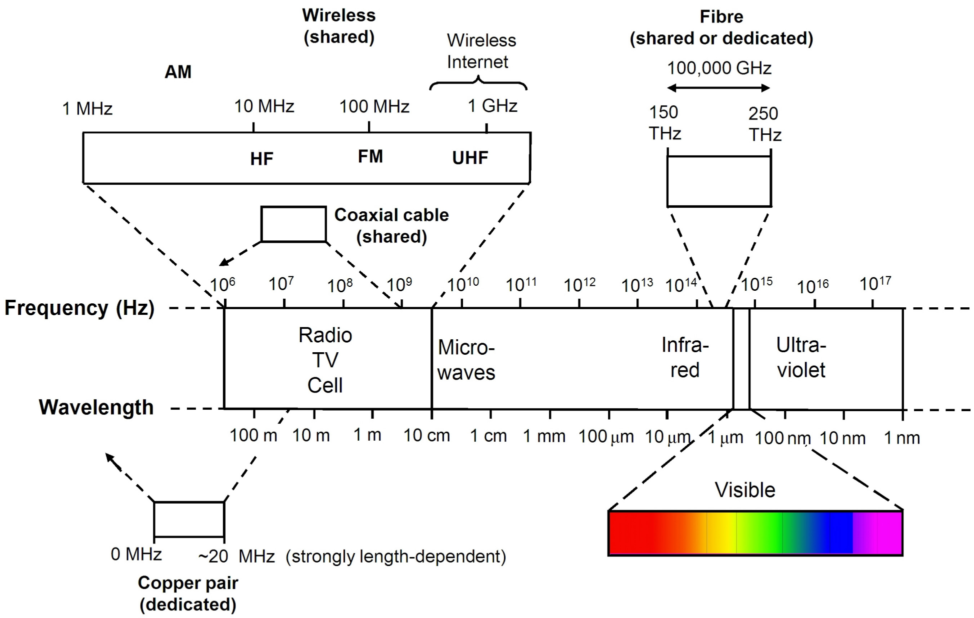


**Figure 12** The electromagnetic spectrum

# CONCLUSIONS

A National Broadband Network based on FTTP technology will provide the best possible platform for Australia to use as a basis for its move into the knowledge economy. The NBN will provide Australia with a future-proof broadband infrastructure and provide support for future generations of applications and services that will underpin all sectors of the Australian economy. The NBN infrastructure will provide necessary backhaul support for complementary wireless services and will encourage competition at the services level, thereby eliminating wasteful duplication of infrastructure in the access network. Importantly, the FTTP infrastructure in the NBN will be readily upgradeable to 1 Gb/s and even 10 Gb/s to the home as new applications and services continue to drive demand for more bandwidth.

Unfortunately, the public debate about the NBN has been peppered by ill-informed negative commentary from a number of sectors. This commentary has led to number of myths that have emerged in recent months. Hopefully, this article will help to debunk some of these myths and to provide some facts that can assist in keeping the debate on track.

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Cite this article as: Tucker, Rodney S. 2010. 'Broadband facts, fiction and urban myths'. *Telecommunications Journal of Australia*. 60 (3): pp. 43.1 to 43.15. DOI: 10.2104/tja10043.