

○ WIRELESS BROADBAND TECHNOLOGIES FOR REGIONAL AND RURAL AUSTRALIA

A LAST-MILE PERSPECTIVE

AHM Razibul Islam, Department of Engineering, Macquarie University

Dr. Niloufer Selvadurai, Department of Business Law, Macquarie University

Professor Graham Town, Department of Engineering, Macquarie University

INTRODUCTION

The deployment of wireless broadband networks to deliver high-speed broadband services to regional and rural Australia is increasingly being examined as a viable alternative to the deployment of wired technology. Whilst last-mile connectivity (i.e. the connection which links the end-user to the network backbone) can be very expensive for carriage service providers deploying wired technology, the deployment of wireless technologies, typically characterised by lower capital and operational costs, can provide a more effective solution to the connectivity problems presently experienced by these remote demographics.

It is recognised that the provision of high speed broadband is critical to communities in regional and rural areas as it serves to expand economic capacity and stimulate commerce. However, accessibility and availability of broadband networks are generally lower in rural areas than the urban areas in both developed and developing countries due to low population density and poor economies of scale. Recent developments in wireless network technology however have the potential to provide access to broadband technology in regional and rural communities at reasonable cost. Hence, wireless technology has the potential to empower local communities and expand economic capacity and commerce in regional and rural areas.

The central purpose of this paper is to explore the alternatives presently available for the deployment of wireless broadband networks for regional and rural Australia. The alternative technologies will be analysed in terms of data rates and coverage distance in order to determine the best possible last-mile wireless connectivity solution for regional and rural Australia. The paper begins with an analysis of the broadband networks and services presently prevailing in Australia. This discussion is followed by an analysis of the motivation for the provision of wireless broadband networks in remote and rural areas in the country and the available technology options. Building upon these findings whilst allowing for geographical and radio propagation uncertainties at this stage in some regional and remote areas of Australia, the paper outlines certain recommendations as to suitable last-mile technologies to support connectivity for such areas. The proposals are based both on appropriate technology and identified economic drivers of broadband deployment.

THE CHALLENGE OF LOW POPULATION DENSITY

It is widely agreed that the provision of affordable access to effective broadband networks and services is critical to the development of e-commerce and the success of the national economy through enhanced global competition of local firms and industries. Technology, particularly Information and Communication Technology (ICT), has made a significant contribution to Aus-

tralia's strong productivity growth, accounting for some 40 to 70 per cent of the total productivity growth in manufacturing and service industries between 1984–85 and 2001–02 (Department of Communications, 2005). Additional to the increased productivity and economic benefits, areas such as education, health and community services greatly benefit through the deployment of broadband networks and services at an affordable price (Department of Communications, 2006a).

The definition of 'broadband' can have different meanings in different contexts. Generally, the term 'broadband' refers to a baseband signal with a minimum data rate equal to or greater than 64 kbps where usage is based on data volume (megabytes) rather than connect time. The Australian Communications Authority (ACA) notes that providing broadband wirelessly called as 'broadband wireless access' involves connection capabilities higher than 2 Mbps (House of Representatives Standing Committee on Communications Information Technology and the Arts [HRSCCITA], 2002, p. 2).

Australia covers an area of about 7.7 million square kilometres – a little less than that of the United States, about 50 per cent larger than Europe (excluding the former USSR) and 32 times larger than the United Kingdom (Australian Bureau of Statistics [ABS], 2000). In the 2006 Census (held on 8th August 2006), there were 19,855,288 persons usually resident in Australia and the resident population of Australia was projected to be 21 million approximately based on the estimated resident population at 30 September 2007 (ABS, 2008a).

Whilst Australia is not far behind in size, its population compared to Europe is 30 times smaller. Japan's population density is 336 persons per km² and the United Kingdom's is 244 persons per km², compared to Australia's 2.6 persons per km² (Geo Science Australia, 2005). Australia's population density varies greatly, ranging from very low population density in remote areas, to very high population density in the inner city areas. The ACT had the highest population density of the states and territories in June 2007 with 145 people per square kilometre, followed by Victoria with 23 and New South Wales with 9. The Northern Territory had a population density of only 0.2 people per square kilometre, the lowest of the states and territories (ABS, 2008a).

For infrastructure deployment requiring cabling, low population density is a significant disadvantage as the people living in rural and regional areas are dispersed over large areas. As of 30 June 2007, 68.5% of Australia's population resided in the major cities of Australia and only 2.3% of the population resided in remote or very remote Australia (ABS, 2008c). The density of population in the most populated urban cities in the country, Sydney and Melbourne, are respectively 2058/km² (ABS, 2008b) and 1566/km² (ABS, 2008e). Figure 1 represents statistical local area (SLA) population change in 2006–2007 and clearly demonstrates the increase or decline of population in the geographical units called SLAs.

A COMPARISON OF ALTERNATIVE BROADBAND TECHNOLOGIES

Broadband providers in Australia offer a range of technologies from fixed services Asymmetric Digital Subscriber Line (ADSL) to wireless and satellite broadband. At the end of December quarter 2007, there were 7.10 million subscribers to the Internet in Australia. This comprised 964,000 business and government subscribers and 6.14 million household subscribers.

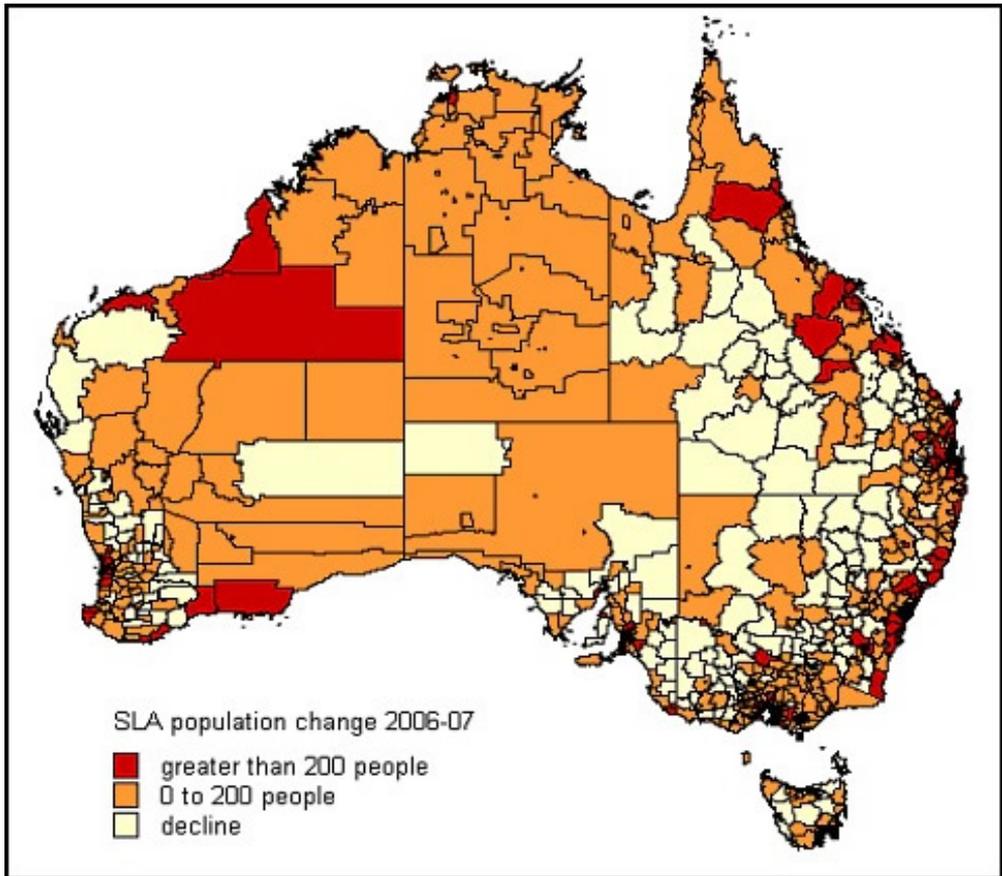


Figure 1 SLA Population Change, Australia, 2006–07

Source: Australian Bureau of Statistics (17 March 2008). 2006 Census Community Profile Series: Melbourne (Urban Centre/Locality).

Digital Subscriber Line (DSL) continues to be the dominant access technology used for non dial-up subscribers, with 3.81 million, or almost 73% of total non dial-up subscribers being connected using this means. Internet Service Providers (ISPs) operating in Australia as at 31 December 2007 are 421. Wireless technology continues to increase to over 481,000 subscribers at the end of the December quarter of 2007, compared with 186,000 subscribers at the end of the September quarter 2006. Satellite technology increased to over 58,000 subscribers at the end of the December quarter 2007. Internet connections with download speeds of 1.5 Mbps or greater increased to 2.51 million or 35% of subscribers in December 2007, compared to 1.13 million or 17% of subscribers at the end of September 2006.

Figure 2 presents the broadband technologies and their subscribers in the country at the end of December 2007. Most of the market is serviced by the 10 largest ISPs, including Telstra and Optus, which together provide services to 77 per cent of subscribers. Telstra is the largest provider of local and long distance telephone services, mobile services, dialup, wireless, DSL and cable Internet access in Australia. On the other hand, to provide services, Optus owns and operates

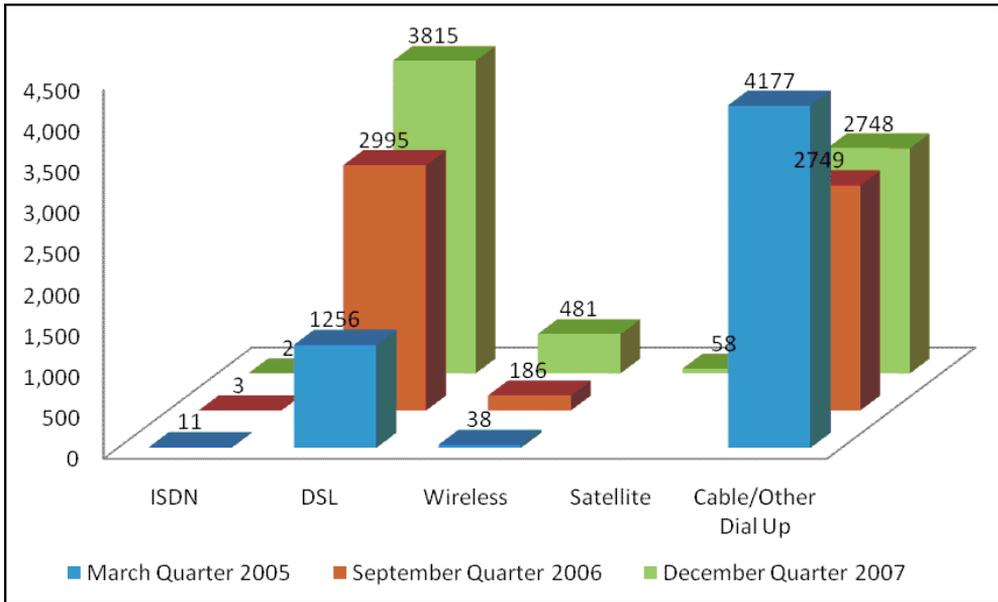


Figure 2 Broadband Subscribers vs. Access Technology
 Data Source: Internet activity Australia, Dec 2007, Australian Bureau of Statistics

its own network infrastructure, as well as using the services of other network service providers, most notably Telstra Wholesale to provide broadband, wireless and dial-up Internet services.

For the purpose of the analysis, it is useful to consider in detail the nature and characteristics of each of the broadband technologies presently being offered in Australia, which are as follows:

ADSL

ADSL is a form of DSL, a data communications technology that enables faster data transmission over copper telephone lines than a conventional voice band modem can provide. Data transmission speed to the subscriber is higher than data transmission from the subscriber and hence the qualifier 'asymmetric' is used. The maximum transmission speed is from 2 to 8 Mbps and the maximum range is up to 2 kilometres (for 0.4 mm cable). Currently about 90 per cent of households can access ADSL broadband, providing maximum speeds of between 2 Mbps and 8 Mbps from a choice of 19 Internet service providers depending on the distance between the premises and the exchange. At 31 January 2007, there were 2,432 exchanges providing ADSL service coverage to 91 per cent of the Australian population (Telstra, 2006). But in some metropolitan and regional areas, network components are primarily installed to facilitate low data rate voice service rather than other broadband services.

Figure 3 shows the number of ADSL and ADSL2+ enabled exchanges in Australia.

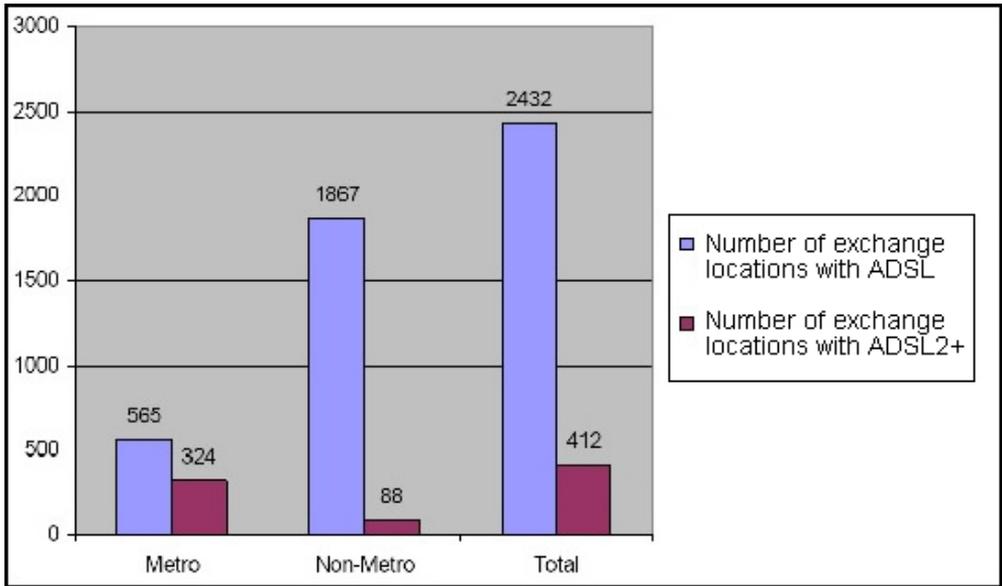


Figure 3 Number of ADSL and ADSL2+ enabled exchanges in Australia. Service provider websites and ACMA data request to targeted ISPs Metropolitan and non-metropolitan breakdown based on Telstra Wholesale *ADSL Enabled Exchanges* report available at www.telstrawholesale.com/products/access_broadband_reports.htm.

ADSL2+

ADSL2+ services are provided outside the regulated broadband requirement of the national provider Telstra and as such are primarily enabled in areas where there is high interest. Fifteen service providers with 400 exchanges in metropolitan areas and regional centres have allowed for the provision of ADSL2+ services in the country. The delivering speed can be up to a maximum of 20 Mbps depending on the distance between premises and exchanges because of noise, interference and crosstalk generated in the system. Again, for the last mile connectivity in regional and rural Australia, ADSL 2+ can not provide connections and hence, a wireless technology solution is required.

HYBRID FIBRE CO-AXIAL (HFC) CABLE

HFC combines fibre network with co-axial cable for broadband network services. By using frequency division multiplexing, an HFC network may carry a variety of services, including analog TV, digital TV (standard definition and high definition TV), video on demand, telephony, and high-speed data. Services on these systems are carried on Radio Frequency (RF) signals in the 5 MHz to 1000 MHz frequency band. In this type of network, optical fibre is used in main paths (from head-ends to optical nodes) while coaxial cables distribute signals from optical nodes to subscribers. The maximum transfer rate is 30 Mbps to the subscriber and 10 Mbps from the subscriber.

The existing HFC networks in Australia offer a maximum data rate of 17 Mbps to 2.7 million premises in the major capital cities (Department of Communications 2006b). Optus and Telstra run the major HFC cable networks in Australia. Telstra's network passes 2.5 million homes in

Adelaide, Brisbane, the Gold Coast, Melbourne, Perth and Sydney. Optus' network is capable of servicing 1.4 million homes in Brisbane, Melbourne and Sydney. There is a considerable degree of overlap between these networks, resulting in an estimated combined coverage to 2.6 million homes. Telstra uses its HFC network for television and broadband services, as does Optus, which also uses HFC for voice telephony services.

While the HFC cable passes 2.25 million homes in urban Australia, only 1.4 million are 'serviceable'. Telstra's Foxtel HFC network treats only seven per cent of the 2.5 million homes passed by its network as unserviceable (Bartholomeusz, 2008). There are a variety of reasons for this including network design, the practical difficulties of dealing with body corporate premises, and the bulkiness of the necessary equipment that has to be installed in each apartment. In regional Victoria, Neighbourhood Cable uses its HFC network to provide broadband, pay TV and voice telephony services, high-speed data services and virtual private networks in Ballarat, Geelong and Mildura.

SATELLITE

For rural and remote Australia, the satellite network has the attraction of offering additional bandwidth to connect these regions to international destinations. Satellite broadband services provide 100 per cent coverage of Australia's land area. In April 2007, there were around 41 satellite broadband service providers operating in Australia, with most of these service providers being regional ISPs that resell satellite broadband to regional, rural and remote customers (Market Clarity Database, 2007). Satellite coverage of the Australian continent is provided by Orbcomm, Iridium, New ICO, Globalstar, Inmarsat, Intelsat (which acquired PanAmSat in mid 2006), SES Global, NewSat, Optus and iPStar. Satellite phones are used in remote Australia using local carriers Telstra and Vodafone and satellite operators including GlobalStar, New ICO and Inmarsat. However, the high costs and low speeds of satellite technologies have relegated them to be truly a last-option broadband technology. It is clear that without Australian Government subsidies, prices for satellite services would be significantly higher than those for other broadband technology platforms. Hence, it is unlikely that affordable broadband services can be provided in the regional and rural Australia with satellite coverage.

OPTICAL FIBRE

Australia's main line telephony network relies primarily on optical fibre networks, with copper lines connecting households to local exchanges. The country's inter-capital and metropolitan fibre optic transmission network traverse 44,645 km and 135,556 km respectively, equivalent to circling the Earth 4.5 times (Australian Competition and Consumer Commission, 42). The fibre 'backbone' is supported by a comprehensive carrier-operated microwave network consisting of 25,289 transmitters and base stations (Australian Competition and Consumer Commission, 45). Fibre to the node/kerb (FTTN/FTTK) and Fibre to the Premises/home (FTTP/FTTH) are the two main fibre-optic technologies being considered in Australia. In FTTN, fibre optic cable connects the telephone exchange to the cabinet on the street. Customers connect to this cabinet using traditional coaxial cable or twisted pair wiring. FTTK is similar technology and consists of fibre-optic cables which run to a platform that serves several customers. Each of these customers has a connection to the central platform via coaxial cable or twisted pair. FTTP/FTTH extends optical fibre directly onto the customers' premises or business.

In Canberra, TransACT Communications offers an FTTH network in which optical fibre is taken to within 300 metres of the connection to the home, from which very high speed DSL (VDSL) is used to carry voice and data transmissions over copper to around 45 to 65 customer premises. In May 2007, TransACT announced the rollout of a FTTH development in the community of Forde, which will provide download speeds up to 30 Mbit/s and 10 Mbit/s for uploads. FTTH services will be provided to more than 1,000 homes in the community by 2013 (TransACT, 2007). The Queensland Government has initiated Project Vista, which plans to bring a 100 Mbit/s broadband service to Brisbane through a deployment of FTTH technology. The project is estimated to cost \$550 million and is scheduled for rollout in 2008. The Victorian Government has developed the Aurora project, which aims to deliver FTTH broadband services to approximately 8,000 residents in the Aurora estate in Melbourne's northern suburbs. Residents will be offered voice telephony, data and video services over the network, including pay TV, free-to-air television and the emerging video-on-demand (VOD) services (Australian Government, 2008). The Tasmanian Government is pursuing the TasCOLT project, which is a pilot project with aerial fibre cabling using new-generation passive optical networking technology.

However despite the above, per-household deployment costs for these technologies are presently too high to attract investment by broadband providers. Therefore, regional and rural areas in Australia require a combination of technologies to provide affordable broadband services rather than the complete deployment of fibre itself.

WIRELESS

There are approximately 204 companies providing wireless services in Australia, with more than half of these companies providing services to regional areas of Australia (Market Clarity Database, 2007). At present, 60 wireless broadband providers are working in the country. Future proposals suggest that up to 12 Mbps or more are expected to be available using wireless technology for broadband services.

Wireless broadband can provide last-mile connectivity to customer premises using a number of technologies in different spectrum bands. Broadband wireless access (BWA), Fixed wireless access (FWA) and Wireless access services (WAS) are types of services to provide wireless Internet connections in Australia. Telecommunication carriers, ISPs and other carriers using a radio connection from end-user to core network can deliver wireless broadband services. A variety of different technologies can be used for BWA, FWA and WAS services, and these will be detailed in the sections to follow.

MOTIVATION FOR WIRELESS BROADBAND CONNECTIVITY

As detailed above, the existing broadband technologies being offered in Australia primarily focus on main cities and areas closer to main cities. A study by the Bureau of Rural Sciences, titled '2008 Country Matters: Social Atlas of Rural and Regional Australia', has found that only 24 per cent of remote communities have access to broadband, compared to 46 per cent of homes in major cities.

Hence, to serve the 835,000 premises of regional and rural Australia, last-mile connectivity becomes a crucial challenge. A relatively small population spread over vast Australian regions

(especially in the remote and rural areas) makes it difficult to use wired-based technologies particularly in the last-mile connections to customer premises.

Currently, ADSL exchanges cannot access most of the remote and rural parts of Australia and broadband services are not being delivered in these regions with this technology. The high capital and operational costs associated with such expansion has to date deterred investment.

In comparison, as wireless technology involves lower capital costs and operational costs, it is a more effective means of linking these demographics. On the basis of the present state of technology, coverage distance and data rates are sufficient to support broadband connectivity using wireless technology.

Additionally, the current dilapidated state of wire-line infrastructure in regional Australia strengthens the need for wireless connectivity option for last-mile connectivity. Therefore, it is high time to consider possible candidate wireless broadband technologies to provide sufficient broadband connectivity from the backhaul network to the end-user premises in these parts of Australia.

To further analyse the possible wireless broadband technology options in the last-leg of the network in regional and rural Australia, a number of possible options will be canvassed below. The basic objective of this analysis would be to find out pros and cons of technology issues of candidate wireless broadband technologies considered for this research. Later, we will narrow down our technology options based on this analysis. Based on the selected technology alternatives, some proposals would be made to find out a compromise for the last-mile connectivity in rural and regional Australia.

A COMPARISON OF ALTERNATIVE LAST-MILE TECHNOLOGIES

Building on the consideration of the alternative technologies available to support the provision of broadband services, it is necessary to consider the alternative wireless last-mile technologies. These include:

1. Wireless Local Area Network (WLAN)
2. 3G Mobile
3. Satellite
4. Fixed Wireless Access (FWA) and Wireless Local Loop (WLL)
5. Worldwide Interoperability for Microwave Access (WiMax) and Long Term Evolution (LTE).

WLAN

WLAN is a type of network that is established by the linking of two or more devices or computers using IEEE 802.11 standard and its successors. Network Interface Cards (NICs) are inserted in the devices or computers that need to be connected wirelessly using WLAN. WLAN needs to be operated in Ad-Hoc wireless mode for wider outdoor coverage in the regional, rural and remote Australia. In this mode, NICs between two computers or devices connect wirelessly forming a network directly. To get a better coverage distance, NICs can be connected to directional antennas rather than their own in-built antennas. A bi-directional amplifier between the NIC and the dir-

ectional antenna can increase the coverage distance adding up some costs. This kind of point-to-point WLANs can provide 11 Mbps to 10 km or 1 Mbps to 40 km distance in regional Australia.

ISPs can provide this kind of wireless coverage over substantial regional or rural areas. In this process, a high bandwidth backbone network connection can be connected using an access point of WLAN. The access point signal can then be directed by using omni-directional antennas with suitable radiation pattern to serve the population of that area. In this process, each subscriber should have a NIC connected to his/her device connected with directional antenna to access the signal in a point-to-point fashion. A speed of 11 Mbps is achieved using this kind of technique in an area with radius 5 km. Extended coverage distance is possible with lower data rates. In Australia, 802.11 can be deployed on the following bands (HRSCCITA, 2002, 18):

- 2400 – 2463 MHz at 4W Effective Isotropic Radiated Power (EIRP)
- 2463 – 2483.5 MHz at 200mW EIRP
- 5150 – 5350 MHz at 200mW EIRP
- 5725 – 5875 MHz at 1W EIRP
- 5795 – 5815 MHz at 2W EIRP.

3G MOBILE

Third generation mobile services can provide both voice and broadband data access. In this process, data can be supplied in both fixed and mobile devices. 3G mobile technologies include Code Division Multiple Access (CDMA) 2000, Wideband CDMA (W-CDMA), Universal Mobile Telecommunications System (UMTS). General Packet Radio Services (GPRS) and Enhanced Data Rates for GSM Evolution (EDGE) are falling under 2.5 G technologies in between the transition from 2G to 3G technologies and hence will not be discussed.

With CDMA-2000, a data rate of 144 kbps per customer is possible using 1x EV variant. Nortel proposes developing a progressively modified 800 MHz CDMA system (a 3G technology) based on existing CDMA infrastructure, and expects it to be able to provide both mobile and fixed wireless data access for 97% of the Australian population (Nortel Networks 2002, 13–20). Nortel believes that its CDMA2000 product could solve much of Australia's regional Internet problem (King, 2002).

W-CDMA systems work on a RF bandwidth of 5 MHz, much wider than the CDMA2000 carrier size of 1.25 MHz. This wider carrier size helps the receiver to better separate different incoming signals and to enhance performance. 144 kbps per customer data rate is also experienced in this standard.

Hutchison was the first to offer a service using 3G technology in Australia. In March 2007, the network was upgraded to the High Speed Downlink Packet Access (HSDPA) protocol, allowing typical download speeds ranging from 600 kbps to 1.5 Mbps, with a theoretical maximum of 3.6 Mbps (Zdnet, 2007). HSDPA is a family standard under UMTS.

Optus has planned use of 3G in the 900 MHz frequency range to address smaller regional centres as well as rural and remote locations. The new network is reported to initially provide speeds of up to 3.6 Mbps using the HSDPA protocol, with an eventual upgrade to 14.4 Mbps planned (Optus, 2007).

Telstra started its own 3G network in 2006 called 'Next G' using 800 MHz 3G UMTS technology. Telstra claims that coverage now reaches 98.8 per cent of the population, covering

1.9 million square kilometres (Telstra, 2007). In April 2007, Telstra claimed that its Next G network was capable of providing network speeds of up to 14.4 Mbps in the downlink and 1.9 Mbps in the uplink, yet user side hardware is only capable of a maximum 7.2 Mbps. Telstra recently announced that they have the largest mobile phone subscribers in Australia (9.7 million) (Cellular-news, 2007).

In October 2006, Vodafone announced that it had switched on HSDPA on the network, increasing download speeds to Vodafone customers up to 1.8 Mbps (up from 384 kbps) (Australian Communications and Media Authority [ACMA], 2007, 22).

Figure 4 shows the increase of 3G mobile phone subscribers along with the fall of fixed line subscribers between 30th June 2006 and 30th June 2007 (ACMA, 2008). It is evident from the figure that 3G mobile services and mobile services in general will play a very important role in regional, rural and remote parts of Australia.

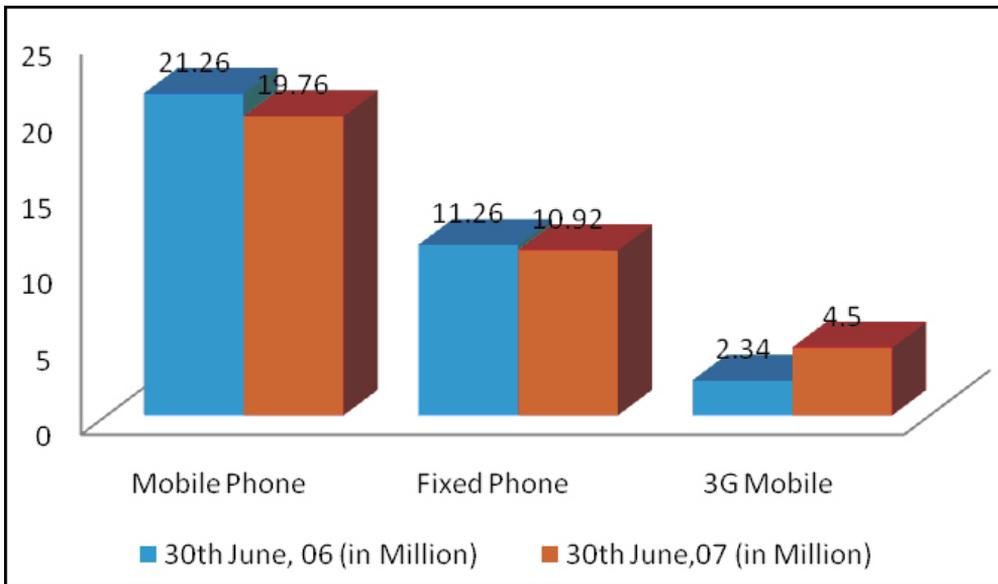


Figure 4 Trends of Mobile Phone Subscribers in Australia
 Source: ACMA Media Release, Number of mobile phones now exceeds Australia's population, 28 April 2008.

SATELLITE

Satellite broadband technologies are offered both in backbone transmission networks and last-mile connectivity (i.e. local area access networks). Satellite can be a backbone transmission networks for remote or rural areas where fibre or copper networks are not available. Many satellites (mostly US based) have some coverage over Australia, but C&W Optus and PanAmSat have satellites (GEO) with Australian dedicated footprints (Technology Applications Group, 2001).

Bigpond, a subsidiary Internet service provider of Telstra, provides satellite Internet connections for regional customers who live too far away from ADSL or cable exchanges. Both One-way satellite and 2-way satellite were used by Bigpond. Recently, from 30 November 2008,

BigPond will no longer provide one-way Satellite (BigPond Satellite Info, 2008). Speeds on BigPond Satellite range from 256 kbps down/64 kbps up to 800 kbps down/128 kbps up.

The first domestic player in the Satellite market, Optus, has fleet of satellites – Optus A1, A2, A3, B1, B2 and B3, C1, D1 and D2 – which cover Australia, Papua New Guinea and the Southwest Pacific islands. The satellites are used along with the international satellites such as Intelsat, PanAmSat and Asiasat to provide broadcast services, VSAT (very small aperture terminal) services and other satellite services. SatWeb and Satdata are two forms of satellite services offered by Optus. SatWeb offers one-way or two-way high-speed access to the Internet with data speeds up to 200 kbps in one way and 400 kbps in two-way connections. SatData (Internet protocol-based broadband via satellite) offers two-way point-to-point connections to wirelessly connect remote sites forming a WLAN using IEEE 802.11 standard. Data rates from 8 Mbps to 36 Mbps are possible through this process.

The Australian Broadband Guarantee Project started in 2007, aimed at ensuring that all Australians living in regional areas have access to metro-comparable broadband and provided subsidies for the rural customers using satellite broadband connections. But still, as a last-mile connectivity approach, satellite broadband connectivity proved to be a higher cost alternative than other broadband wireless technologies.

FWA AND WLL

WLL connects the end-user to the core network. The core network could be the public switched telephone network (PSTN), an integrated services digital network (ISDN), the Internet or a Local/Wide area network. When the end-user or a customer connects to the core network by means of equipments installed in a fixed location, it is termed FWA. WLL can also be implemented using wireless access with extended roaming capabilities termed as BWA. Therefore, in general, WLL can be implemented using a number of different wireless and radio technologies whether it is FWA or BWA. In our analysis in sections to follow, we will segment the description of FWA access based WLL and BWA based WLL (such as WiMAX) to better differentiate the feasibility status of their respective deployment in remote, rural and regional parts of Australia.

FWA solutions can be either terrestrial-based or space-based. Terrestrial-based systems are classified as Local Multipoint Distribution Systems (LMDS) and Multichannel Multipoint Distribution Systems (MMDS). A space-based system is suitable for remote areas where cable-based systems or terrestrial based systems such as 3.4 GHz wireless broadband systems are not economic.

LMDS generally works in the microwave range across the 26 GHz and 31 GHz. It is a particularly suitable point-to-multipoint technology for outer urban and rural areas where line-of-sight communication is possible within a range of 15 to 25 km. Minimal installation costs are required for deployment of LMDS as it only requires the network interface unit and antenna to be set up on the customer's roof top. The communication is established between the Base Transceiver Station (BTS) and customer through line-of-sight.

MMDS works below the 10 GHz range. It can support 3.2 Mbps per base station and a maximum coverage of 20 to 40 km, which is generally more than LMDS. Like LMDS, it can provide point-to-multipoint voice and data services. It is more commonly used for pay-TV applications in remote or sparsely populated areas. Table 1 below represents the frequency spectra used for LMDS and MMDS applications in Australia. AAPT and Optus have LMDS network. On the other hand, AUSTAR and Akal have MMDS coverage in Australia. AAPT's LMDS offers

2 Mbps data rate throughout various regions of regional Victoria for data, Internet and voice applications. It has been noted by m.NET that in the case of LMDS, a lack of equipment availability and a high cost structure has seen limited deployment in Australia (HRSCCITA, 2002, 43). Also, overseas experience suggests that strict line-of-sight requirements and sensitivities toward the proliferation of base station towers need to be addressed before LMDS is a viable alternative to the fixed line platforms.

Service	Band	Frequency range	ACA Licensing
MMDS	2.3 GHz	2302–2400 MHz	spectrum licensed
LMDS	27 GHz	26.5–27.5 GHz	spectrum licensed
LMDS	28 GHz	27.5–28.35 GHz	spectrum licensed
LMDS	31 GHz	31.0–31.3 GHz	spectrum licensed

Table 1 Frequency spectrums for LMDS and MMDS applications in Australia

These systems have a range of approximately 5 km and provide high data rates with approximately 100 watt of power (HRSCCITA, 2002, 43).

Unwired Australia Pty Ltd has announced plans to develop a national fixed wireless broadband network, operating in the 3.4 GHz band. In 2005, Australian Pay TV operator Austar, which owned licenses for 100 MHz of the 2.3 GHz spectrum Australia-wide, made a deal with Unwired Australia to swap spectrum for wireless broadband services across the country. In 2006, Austar United and Unwired together with Soul Company formed AUSalliance for the purposes of obtaining funding from the Australian Government's Broadband Connect Infrastructure Program and rolling out a regional broadband network (Austar United, 2006). In 2008, Austar sold its 2.5 & 3.5 GHz spectrum licenses (previously used for MMDS applications) to the OPEL (Optus & Elders) consortium for AU\$65 million which has been later cancelled by the current Federal Labor Government (Austar United, 2008).

WORLDWIDE INTEROPERABILITY FOR MICROWAVE ACCESS (WIMAX) AND LONG TERM EVOLUTION (LTE)

WiMax is an IEEE 802.16 standard-based technology enabling the delivery of last-mile wireless broadband access as an alternative to cable and DSL. To accommodate non line-of-sight access over lower frequencies, IEEE 802.16a includes support for mesh architecture. 802.16a operates in the licensed and unlicensed frequencies between 2GHz and 11GHz. IEEE 802.16 can provide wireless access using both point to point links and mobile cellular access. These connections would be ideal for connecting a single location in a village or town via a high-speed wireless link back to the nearest fibre point of presence.

In particular, IEEE 802.16d is termed 'fixed WiMax' since it does not provide mobility. IEEE 802.16e is called 'mobile WiMax' and this version is one of the five major wireless standards referred to as '3.9 G'. WiMax technology is particularly suitable for areas with low population and flat terrain. For countries that have skipped wired infrastructure as a result of prohibitive costs and unsympathetic geography, WiMAX can enhance wireless infrastructure in an inexpensive, decentralised, deployment-friendly and effective manner (Wikipedia, 2008a).

IEEE 802.16d uses frequency in the range of 2 GHz to 11 GHz. Currently, there is no global licensed spectrum for WiMax. The WiMAX Forum has published three licensed spectrum profiles: 2.3 GHz, 2.5 GHz and 3.5 GHz, in an effort to decrease cost. Economies of scale dictate that the more WiMAX embedded devices (such as mobile phones and WiMAX-embedded laptops) are produced, the lower the unit cost (Wikipedia, 2008a). In general, the higher the frequency, the shorter the range WiMax signal can cover in an urban environment.

5.8 and 3.4 GHz were the planned frequencies to use for WiMax deployment in the recently terminated OPEL consortium (The 7:30 Report, 2008). In practice, with mobile WiMax technology, a maximum speed of 10 Mbps over 10 km can be provided with a line-of-sight environment, especially in the remote/rural areas. Fixed WiMAX is also seen as a potential standard for backhaul of wireless base stations such as cellular, Wi-Fi or even Mobile WiMAX (Wikipedia, 2008a).

Under the third generation partnership project (3GPP), LTE is the project name of a new air interface for wireless access. Increased capacity (100 Mbps download and 50 Mbps upload rate) and higher spectrum efficiency are possible with this technology. Using multiple antenna configurations, a maximum download data rate of 326.4 Mbps and upload rate of 86.4 Mbps can be expected. Most carriers supporting GSM or high speed packet access (HSPA) networks can be expected to upgrade their networks to LTE at some stage and is expected to be commercially available in around 2010.

COMPARISON OF DATA RATES, COST EFFECTIVENESS AND ACCESS

Based on the above analysis, it is clear that Australia has a number of wireless broadband technologies available for use by customers. In this paper, the main concern for the regional, rural and remote wireless connectivity solutions for last-mile connectivity in Australia has been to address the following three objectives:

- a. Wireless broadband solution with reasonable data rate
- b. Cost-effective and affordable technology deployment and
- c. Create business opportunities through Internet access among rural people or people living in remote areas.

As discussed, generally the choice of wire-line or wireless technologies depends on the market and the services offered, on the basis of performance, price, quality of service, geographical coverage, user friendliness, customer service and customer satisfaction. Considering these factors, a wireless broadband solution for last-mile users has been a popular solution in Europe using WiMAX. On the other hand, the same WiMAX technology did not get full acceptance in the United States because the cost of deployment does not allow the desired return on investment (Wikipedia, 2008b). Wireless broadband connectivity can offer cheaper and faster deployment in specific circumstances where wire-line solution is expensive or difficult to reach. Hence, regional, rural and remote Australian territories can be provided with wireless broadband last-mile connectivity using a combination of wireless technologies. Again, the data rate and the cost of the wireless connectivity solutions to create business opportunities would be the drivers to determine which technology would be the best for a particular region in Australia.

Deploying wireless broadband technology can be a very cheap solution using the free licence spectrum of Instrumental, Scientific and Medicine bands at 2.4 GHz WLAN or WiFi. For example, Airnet in Adelaide and community groups such as Melbourne Wireless both use the free-access 802.11b WiFi band to establish broadband data connections (HRSCCITA, 2002, 43). Wire-line backbone networks can be connected with the end-users through WiFi in rural areas of Australia where regional town centres have fibre backbone networks. But in order to provide sustainability, licensed spectrum would be the best solution for infrastructure development in those regions planning future upgrade to higher bit rate services. With unlicensed spectrum a wireless broadband service could be offered to consumers in a certain location, but at any time unacceptable service interruption may arise if additional transmitters are deployed or sources of interference discovered within the service area (Nortel Networks, 2002).

From the service provider's point of view, a service provider needs to achieve an acceptable return on investment for installed infrastructure and ongoing operational costs. Therefore viable business cases are required for the service providers as well as selection of appropriate technology for last-mile connectivity in Australian regional, remote and rural areas. On the other hand, users need to get the services at an affordable rate. It would be necessary to reduce the spectrum licensing costs from the Australian government as far as regional, remote and rural Australian territories are concerned. The Northern Territory government submitted that 'the cost of spectrum must be kept low or offered at no cost where delivery is into remote communities' (HRSCCITA, 2002, 74).

Based on current commercial offerings, satellite broadband is almost twice the price of terrestrial services. This places those remote communities that need these services the most, but are too distant from an exchange to access terrestrial broadband, at a distinct disadvantage (HRSCCITA, 2002, 81). Particularly, in remote Australia, satellite may be the only option still now for a 'last-mile' distance of more than 50 km. But suitable fibre optic backbone development can provide a better solution by connecting the rest partly wirelessly using CDMA 2000 or HSDPA based 3G mobile technologies as currently used by different service providers in the country. Another way to bring satellite costs down for end users is to use 'neighborhood networks' to connect users to a shared satellite base station. Conxteel already offers such a product, which uses 802.11b Wi-Fi links to make the user connections (HRSCCITA, 2002, 81). Effective high-gain antennas or directional antennas can also be used to increase the range of WiFi devices.

For financial viability, reduced wholesale prices for wireline or satellite broadband capacity must be available to wireless access providers. All restrictions with regards to reselling, redistributing or third-party sharing that are currently manifested in the terms and conditions of many of these companies must be abolished (HRSCCITA, 2002, 68).

Nationwide fibre optic backbone development would lead to a sustainable development for the provision of high-speed last-mile wireless connectivity in rural or remote demographics. Complete deployment of fibre itself in the rural or remote areas may be commercially less viable from service provider perspectives as return on investment is critical in those regions.

Among the existing backbone networks, microwave, satellite and optical fibres can play important roles to provide long haul access up to the regional resource servers (RRS) located in any regional town centre or rural town centre. Last-mile networks can then be connected from the RRSs to the end-users in remote or rural regions using suitable wireless technologies as in Figure 5.

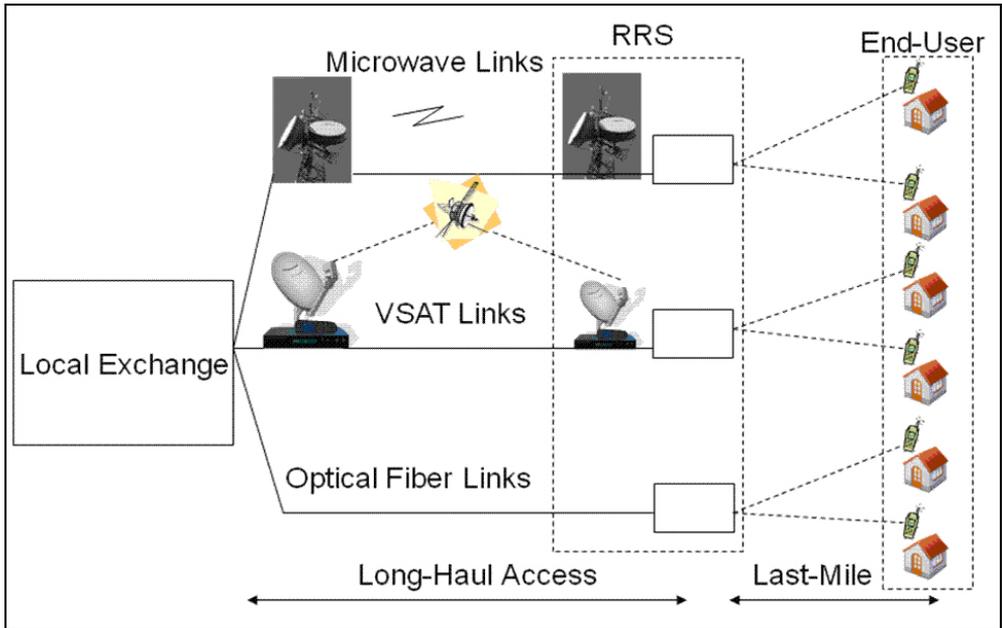


Figure 5 Backbone Connectivity Alternatives for Last-mile Networks
 Source: ACMA Media Release, Number of mobile phones now exceeds Australia's population, 28 April 2008.

For fixed wireless connectivity in rural areas like wireless local loop (WLL), CDMA 450 or 700 MHz technology can be leveraged for the last mile approach other than CDMA 2000. Zapp networks in Romania were able to establish connectivity by CDMA450 standard for non-mobile endpoints at a distance of 50 km with data connectivity of 1.3 Mb/s (uplink was 110 kbps) (Harris, 2004).

Finally, both fixed and mobile WiMAX can be deployed for rural and remote areas mainly using the existing frequency bands in 2.3, 2.5 and 3.5 GHz. Fibre backbone located in the regional town centres (RRS) can be utilised to provide WiMAX connectivity for customers within 10 km of ranges. Telstra's 800 MHz UMTS technology 'Next G' can be extensively utilised in this regard to provide connectivity along with WiMAX deployment in these regions. 'Next G' and mobile WiMAX could be very successful in creating business opportunities with their inherent high-speed data connectivity.

CONCLUSION

Wireline technologies are well-established to meet the maximum data speeds envisaged for 2020 and beyond (Dominic Quai, 2007). In Australia's regional, rural and remote areas, this can be best provided with fibre backbone connectivity throughout the regional or rural town centres of the country. However, as discussed, wire line technologies have a variety of limitations. Accordingly, for the last-mile connectivity, a combination of wired and wireless broadband technologies offers the most affordable and best reasonable data rates with an inherent advantage to quick deployment of the connectivity in these demographics.

Such a policy would facilitate business opportunities in these regions by combining data speed and cost compromise with the mobility advantage of wireless broadband solution in the last-mile. Further economic analysis on wireless broadband deployment in the last-leg of the network in regional and rural demographics will need to be conducted to determine the best wireless technology; see also (Mishra et al., 2005), (Camp et al., 2006) and (Smura, 2004). As discussed, it will also be necessary to identify the appropriate technology drivers, which will vary depending on several factors outlined in section V. These factors need to be assessed and weighed in the context of the needs of regional and rural communities to determine the best compromise for customers, service providers and Australian government.

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