CSIRO Telecommunications & Industrial Physics

Response to the House of Representatives Inquiry on Broadband Wireless

Summary

1. Broadband wireless is here to stay. Improvements over the next few years will see greater mobility, reconfigurability, lower costs and access to customers. However, for Australia to keep up with the rest of the world, the benefit of broadband wireless has to be demonstrated to the general public.
2. We suggest that the value of broadband wireless should be encouraged through pilot studies. The business case for some technologies is not apparent because there have been few or no demonstrators.
3. Increasing use of broadband technologies will inevitably lead to increased carrier frequencies and spectrum should be kept available or freed up for the future.
4. Australia's use of spectrum should be compatible with other major countries (eg USA and Europe) to maximise technological and cost advantages for Australian consumers and also enable Australian companies to compete more easily in the global market place.
5. CSIRO can play a role in advising government of the advantages/disadvantages of emerging broadband wireless technologies. It has a wide range of skills relevant to such technologies and systems.

Context

This response is intended to provide an overview of CSIRO's perspective on wireless technologies as applicable in the Australian context. CSIRO has no special relationship with any particular technology, and is involved in research and development across most of the broadband wireless technologies that may be considered. As a consequence, this submission is not intended to review in detail any particular technology or provider of such technology, but is rather intended to put the technologies in perspective and propose some options. It is hoped that this information might also highlight areas of broadband wireless technology that CSIRO sees as having potential, particularly for next-generation systems and infrastructure.

1. Introductory Remarks

The title of this Inquiry prompts two initial questions, why wireless and what is meant by broadband?

Wireless has become increasingly important for communications because of at least four main advantages that it has over wired services. The first advantage is the mobility wireless systems provide - as evidenced by the uptake of mobile phones. The second advantage is system reconfigurability – the system can be changed without ripping up or changing cables. The third advantage is its relatively low cost when the density of subscribers is low. The fourth advantage is the capacity of wireless networks to accommodate point to multipoint data distribution, applicable to disaster management and warning systems. We note that the first two advantages are missing elements from the terms of reference of the Inquiry.

The term ‘broadband’ is used rather loosely defined and its actual definition is changing with time as new technologies and applications arise. To someone on the end of a conventional telephone line, broadband may be 200 kbps[1]. However, the future dream is that all systems will operate seamlessly as far as the user is concerned. Such convergence is expected to provide video information, unified messaging, freedom to communicate almost anywhere, information filtering and redirection, contextual information and, of course, ease of use. To provide high quality video, for instance, the minimum data rate is about 8 Mbps. With future developments in data compression this rate could be reduced by a factor of three to four. Therefore, a definition of broadband is a baseband signal with a minimum of 2 MHz bandwidth or a digital signal with data rate greater than 2 Mbps. There are other applications mentioned in the terms of reference that require bandwidths not as great as this, and these are identified at appropriate places in this submission.

The cost of long-haul telecommunications continues to fall with the result that broadband services could be provided very inexpensively if an economical way could be found to connect the users to the network. This ‘last-mile’ access is the roadblock and is the emphasis of what follows.

As a delivery mechanism of broadband services, wireless has limitations compared to optical fibre systems. The capacity of fibre systems is significantly higher than wireless systems, and issues of reliability and availability do not generally impact on the services provided. The primary difficulty with fibre delivery is connectivity, since fibre needs to be accessible to all users to be effective. For rural and remote access, connectivity is an issue. Wireless may offer last-mile services to overcome some of these difficulties. However, if one also includes the requirements of mobility and reconfigurability, then wireless has clear advantages. These comments are expanded later.

In this input to the Inquiry, we address the applications and technologies where wireless has advantages for delivery of broadband services in the Australian context.

It is widely recognised that the technology for broadband wireless exists in a variety of forms. CSIRO has historically contributed to wireless technologies through satellite systems, microwave and millimetre wave radio development and propagation studies for indoor wireless networks, and continues to evolve new technologies for wireless services. However, consumer demand for broadband networks has not yet reached a level where economies of scale and the consequential rollout of services drive the cost of wireless broadband to an acceptably low level. In many cases, even extant cable and fibre solutions are not in high demand, and the additional cost of wireless networks make them unattractive solutions.

A recent approach by CSIRO to tackle some of the issues of broadband wireless through a program with the overarching objective of ‘ICT providing solutions to the Tyranny of Distance’ is outlined in Appendix A.

Despite the excellence of Australian research and innovation, the main impediments to the deployment of broadband wireless in Australia are not technology related but

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[1] kbps – kilobits per second; Mbps – megabits per second; Gbps – gigabits per second

are limited by cost and undemonstrated value. We will discuss the background to these impediments and suggest ways of removing them.

Finally, we propose ways of increasing the deployment of broadband wireless in Australia.

2. Comments on the Terms of Reference

2.1 The current rollout of wireless broadband technologies in Australia and overseas including wireless LAN (using the 802.11 standard), 3G (eg UMTS, W-CDMA), bluetooth, LMDS, MMDS, wireless local loop (WLL) and satellite.

Broadband services are now delivered to homes and businesses using a variety of technologies including cable modems, DSL technology, broadband fixed wireless and broadband satellite services. Table 1 summarises our assessment of some of the available wireless technologies, potential applications, the current performance and expected performance of the technology and its improvements in five year’s time.

Regarding the current rollout of wireless broadband technologies in Australia, CSIRO is most familiar with wireless local area network (WLAN) based on the 802.11a and 802.11b standards, cellular mobile (including 3G), local multi-point distribution systems (LMDS) and satellite. Each of these technologies has had a chequered history in Australia so far. The use of the 802.11a systems is currently limited by the available allocated spectrum and regulated power levels for this purpose (compared with the USA). The introduction of 3G has been slower than expected, as it has been in other parts of the world, and the cost has stimulated interest in other technologies. For example, 802.11b WLAN systems have been successfully used for broadband nomadic data access at public ‘hot spots’. LMDS is now being successfully used in parts of Australia but the high cost has limited its wider acceptance. Satellite is now a mature technology and is widely used in Europe and the USA. In Australia, its wider use has been limited until recent years because of decisions of government departments (eg BMAC receiver) and Telstra (eg terrestrial-based solutions in rural regions).

<u>The WLAN solution</u>

CSIRO has had a long involvement in WLANs having developed and patented the technology underpinning the 802.11a high-speed WLAN standard (see Appendix A). Currently the lower-speed 802.11b technology is being rolled-out and, due to the large volumes being manufactured, costs have reduced to the point that many new uses are being explored. An example is the use of 802.11b for broadband fixed customer access. It can provide true broadband access for a radius of many km in favourable terrain. However it has limitations. The spectrum is a shared, unplanned, licence-free band and this means that expanding usage by nearby in-building users can cause serious congestion and delay to access services. Due to the lower density of users, this is less of a problem in suburban and rural areas and CSIRO is exploring its use there with a trial system.

Table 1: Comparison of wireless technologies.

Technology	Application	Mobility	Carrier frequency	Current performance	Expected future performance	Comments
Wireless LAN 802.11a, h	Indoor and outdoor short range	Fixed & pedestrian	5 GHz	54 Mbps	>50 Mbps	802.11a market increasing rapidly
Wireless 802.11b, g	Short range outdoor~ 5km	Fixed & pedestrian	2.4 GHz	11 Mbps max.	>20 Mbps	802.11b systems are widely available
3G (UMTS, IMT-2000)	Cellular up to 5km	Pedestrian & vehicle	2 GHz	155 kbps	2 Mbps	Becoming widely available
4G mobile	Cellular up to 5km	Pedestrian & vehicle	3 – 20 GHz		20 Mbps	Concepts only
Bluetooth	Very short range	Pedestrian	2.4 GHz	< 1 Mbps	5 Mbps	Becoming widely available
Wireless local loop (WLL)	Medium range	Fixed	3.4 GHz	< 1 Mbps	2 Mbps	Several vendors using WLL
Intelligent transport systems	Short range	Vehicle	5 & 20 GHz		100 Mbps	Experimental development
LMDS	Short range	Fixed	28 GHz	50 Mbps	100 Mbps	Limited take-up in Australia
MMDS	Short range	Fixed	40 GHz	50 Mbps	100 Mbps	Available in Europe
High altitude platform station	Medium to long range	Pedestrian & vehicle	Up to 60 GHz		> 150 Mbps	Experimental development
Gigabit wireless	Outdoor short range ~ 1km	Fixed	60 to 105 GHz	155 Mbps	>1 Gbps	First commercial systems appearing
High-speed WLAN	Indoor & short range	Pedestrian & vehicle	60 GHz	100 Mbps	500 Mbps	Experimental systems available
Fibre-wireless	Outdoor medium range	Fixed	40 to 90 GHz		1 Gbps	Not available on the market
Satellite Ku-band	long range, point to point	Fixed	12/14 GHz	2 Mbps downlink 55 kbps up-link	5 Mbps downlink 100 kbps uplink	Existing transponder capacity, geostationary satellites
Satellite Ka-band	long range, point to point & mobile	Pedestrian & vehicle	20/30 GHz	5 Mbps downlink 500 kbps up-link	16 Mbps downlink 2 Mbps uplink	Proposed transponder capacity both geostationary & low earth orbit satellites

Note: Many numbers are indicative only.

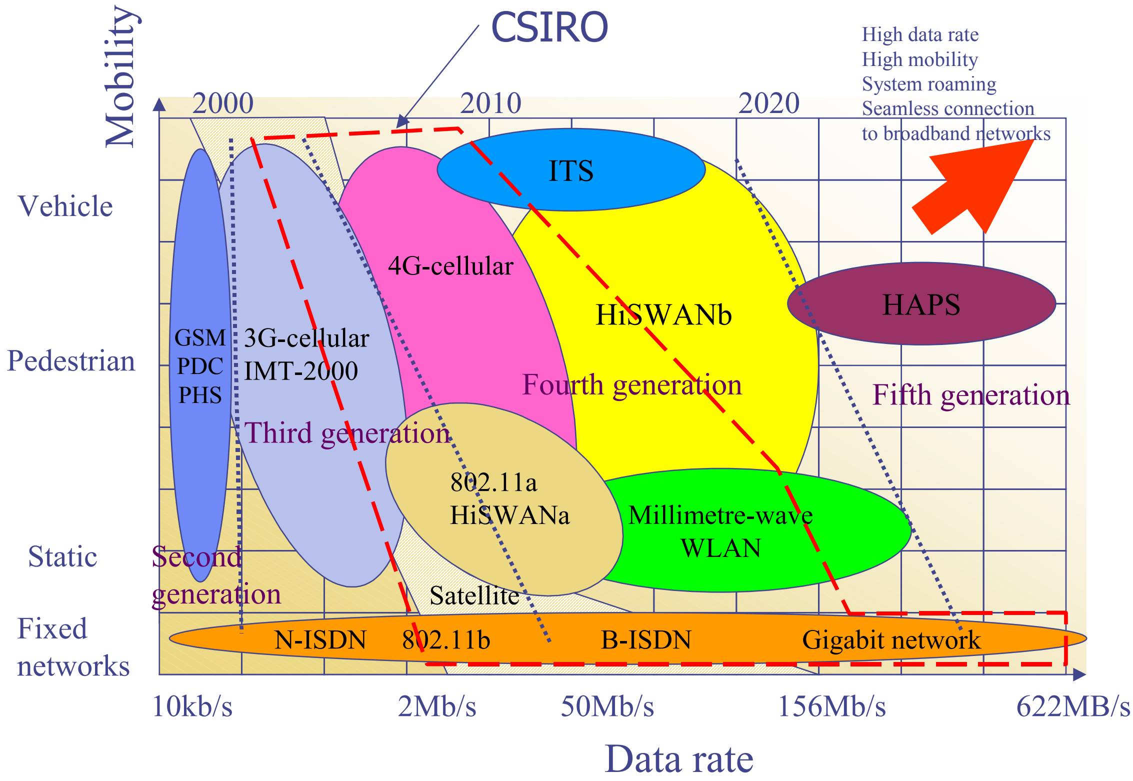

Figure 1: Inter-relationship of some wireless technologies.

<u>The fixed wireless access solution</u>

There have been many wireless access systems developed over the last 25 years. However these have generally been for voice services or low bandwidth data. The only major broadband wireless fixed-access system taken to market recently is based on LMDS or MMDS technology. CSIRO has worked on LMDS with a major carrier and once explored a start-up in this area. Two years ago predictions suggested large-scale use of these systems but costs did not reduce quickly enough to drive demand, resulting in a restricted market mostly in high-density business areas. The WLAN solution above is the only existing technology that can achieve this fixed broadband access at low cost.

<u>The satellite solution</u>

Satellite services are perceived as expensive options, reliant on ownership of space and ground assets and fraught with risk. Recent failures of broadband satellite services have highlighted the difficulties associated with the provision of broadband satellite services. However, the primary cause of these failures lies fundamentally in flawed business models and an over emphasis on new technology. Broadband satellite solutions currently exist, and satellite service providers are reassessing how broadband access can be provided to customers. There is a significant drive in the satellite services market towards end-user direct-to-satellite access models, and the cost structure is shifting steadily towards these models. As a result, satellite operators and service providers are now offering affordable global and regional broadband access to small business customers. Direct access personal users are becoming a reality through smaller and more affordable bidirectional ground terminals. Satellite services provide ubiquitous solutions compatible with the needs of rural and regional Australia. Three factors:

- increasing numbers of satellite service providers in the Asia Pacific region;
- reducing costs of ground infrastructure; and
- operating models that account for the direct-to-satellite broadband market

suggest a renewed applicability of satellite technology in the broadband wireless area in niche markets. One of these is Internet Service Providers (ISP) who currently find wired services provide limited access to content.

2.2 The inter-relationship between the various types of wireless broadband technologies.

The inter-relationship of the many of the available and proposed wireless technologies is shown in Table 1 and also in Figure 1.

Underlying these technologies is a common set of skills. These platform technologies are:

- Antennas
- Radio wave propagation
- Radio systems engineering
- Digital systems and signal processing
- Modem technology
- Telecommunications systems
- Networks and traffic engineering
- Software

All of the skill set listed above is active at CSIRO as outlined in the article given in Appendix A. Figure 1 shows (dashed line) the range of wireless technologies CSIRO is currently researching.

Fundamental to all wireless system design is an understanding of radio-wave propagation. CSIRO has funded activities in this important area over many years both for research and also participation in international studies and organizations such as the International Telecommunications Union (ITU). Currently the Chairman of Working Party 3M of the Radiocommunications sector of the ITU-R is Ms Carol Wilson of CSIRO.

2.3 The benefits and limitations on the use of wireless broadband technologies compared with cable and copper based broadband delivery platforms.

As mentioned in the Introduction, wireless has become increasingly important because of advantages of mobility, reconfigurability, cost and multiple access to customers. We note that the first two advantages are missing elements from the terms of reference of the Inquiry.

Wireless technologies have generally been favoured for providing services in a mobile or portable environment, where the benefits are perceived in terms of accessibility and convenience. Factors such as quality of service and reliability of connection are often secondary considerations. Limited data access has been provided through extensions to existing mobile phone technology, and the new 3G and 4G networks promise further access, but the fundamental role of these services is still to provide seamless mobility for voice and data users.

Wireless systems of various forms are important for mission critical services, such as search and rescue, firefighting and environmental monitoring. Many of these systems do not currently use broadband but in the future with increasing use of computer technology they will. For these services, some form of redundancy is needed.

A limitation on wireless broadband technologies, as compared with cable and copper based delivery platforms is the limited bandwidth due to limited spectrum availability. Mobile cellular and WLAN systems have shown how this can be overcome by re-using the frequency in other ‘cells’. Whilst most radio systems can make use of this technique to fit more broadband users into a limited spectrum, this greatly increases cost.

Another limitation of wireless broadband technologies, as compared with cable and copper based delivery platforms, is the apparent inability of service providers to arrive at a suitable cost model for the provision of services that encourages the roll out of broadband wireless networks. Again it may be emphasised that technologies exist for wireless broadband networks. Sound business cases for implementing wireless solutions, however, need to demonstrate significant added value to the customer and are prone to failure where demand does not warrant the infrastructure expenditure. In the case of short-range indoor wireless networks, such cases may be made. It is questionable whether such cases can be made at present for most access technologies.

As shown in Table 1, wireless can provide very broadband communications, although except for satellite this is achieved only over short ranges. The microwave and millimetre-wave frequency bands have several characteristics namely absorption and scattering by water in the atmosphere (eg water vapour, fog and rain) and mainly line of sight propagation. Recent research is investigating ways around these limitations including ad hoc networks that convey information by several hops to a local base station, smart antennas and better technologies for increased power transmission (eg gallium nitride semiconductors). However, more research is needed to achieve the bandwidths that will be required in the future in a cost effective manner.

2.4 The potential for wireless broadband technologies to provide a 'last mile' broadband solution, particularly in rural and regional areas, and to encourage the development and use of broadband content applications.

The business case for some of the technology areas have been ill formed and market hype has led to a mismatch of expectations in the long run, eg. Iridium and LMDS. Therefore, services and business case need to go hand in hand.

LMDS (and MMDS) appears to an ideal technology for a solution to the last mile problem. However, people could not obtain the equipment when they needed it and it is still very expensive compared with other options. Some of the technical issues have not been fully ironed out, for example the effect of vegetation on the signals. However, with technological improvements and costs continuing to fall with greater integration, we expect to see more point-to-multipoint LMDS systems in the next five years. Such systems will be needed in parts of Australia shortly because, for example, in some suburbs of Sydney no provision has been made for broadband cable connections. Therefore, wireless technologies will have an impact not just in rural and regional areas, but in any area in which either cable or ADSL cannot or will not be provided, so that they are likely to apply in total to more people in urban and semi-urban than in remote areas.

It appears likely that many technologies will compete to provide the last mile broadband solution. For instance, it is possible technologies developed originally for indoor communications, such as 802.11a, will be adapted for this problem. Trials are already underway and verbal reports indicate good results.

WLAN technology can provide ‘last mile’ broadband access as mentioned earlier and this is especially so in rural areas where user density is lower and pressure on the spectrum is less. However, in rural and regional areas it is often more than the last ‘mile’ but rather ranges in excess of 10km are needed. With no hills and few trees this is possible with WLAN, but more likely a combination with fibre or microwave links or the use of WLAN as point to point (wireless bridges) will be needed.

CSIRO is currently investigating the use of WLAN (IEEE 802.11b) as a fixed wireless access technology. A trial consisting of a wireless access point providing 11Mbps broadband access to multiple wireless clients located in residences within a 5km radius is in progress. Initially, the trial was aimed at rural access, but the results also apply to suburban access. The practical experience gained from such a trial is providing valuable insights into how wireless technology can be implemented to provide “the last mile”.

2.5 The effect of the telecommunications regulatory regime, including spectrum regulation, on the development and use of wireless broadband technologies, in particular the Radiocommunications Act (1992) the Telecommunications Act (1997), and Parts XIB and XIC of the Trade Practices Act.

Australia’s use of spectrum should be compatible with other major countries (eg USA and Europe) to maximise technological and cost advantages for Australian consumers. Having a more compatible regulatory regime should also enable Australian companies to compete more easily in the global market place as products can be trialled with confidence here or overseas and then be introduced into the market without costly redesigns. For example, spectrum utilization at 5 GHz in Australia is different from the US, e.g. in part of the band, in point-to-multipoint, US allows higher power transmission than here. This could limit the use of available WLAN technology in Australia.

2.6 Whether Government should make any changes to the telecommunications regulatory regime to ensure that Australia extracts the maximum economic and social benefits from the use of wireless broadband technologies.

Ten years ago, the original narrowband Internet access proliferated into the public arena very quickly with the advent of large numbers of small “garage” ISPs who could provide access with a bank of low-cost modems and a few 128 kbps ISDN lines for backhaul.

Today, associated with any broadband WLAN access technology are substantial backhaul and connection fees to enable connection to an Internet point of presence (POP). Case studies have shown that these fees often cripple any business case for providing broadband data to residential users at acceptable costs. This applies to all ‘third tier’ broadband ISPs (not only Wireless ISPs).

Also, the ACA regulates that a wireless ISP must be a carrier (if its customer’s pay for the service) and there is a high entry cost for small companies (starting at $10,000 per year).

To summarise, high backhaul and connection fees and high carrier fees tend to reduce the participation of small ISPs in proliferating broadband access. This may be a contributing cause to the low penetration of broadband in Australia at the moment. A change in the regulatory regime may ameliorate this situation.

2.7 Likely future national and international trends in the development and use of wireless broadband technologies.

In the short term, the demand for bandwidth is going to continue to be a significant driving force, as is equity of services in city, rural and remote regions. At the same time, we expect there to be a need to demonstrate the value of ICT services delivered by broadband. Trials will be needed to demonstrate that applications with high-perceived value (eg. health and education) can be delivered to user communities at a significantly reduced cost than is currently provided by other means.

In the technology area, some of the future trends (next five years) are summarised in Table 1. Whatever happens, we anticipate that the demand for wider and wider bandwidth will lead inevitably to higher operating frequencies. It is important, therefore, that available spectrum at higher frequencies should be kept free.

Some additional trends are: the likelihood that within two years, every new PC will come equipped with a combined 802.11a and b unit on the mother board; the mobile phone may well be able to tap into a hi-speed WLAN when within cells, and revert to a lower data rate PCS network when out of WLAN range; price reductions will mean that niche wireless local loops (WLL) will become more common, but not mainstream.

Until now, broadband access has mainly referred to desktop or laptop computers connecting to high-speed core networks via wired LANs or, more recently, via WLANs in office spaces. This paradigm is already changing in two ways. Firstly, wireless access technologies such as 3G mobile (W-CDMA or UMTS, CDMA2000) and WLAN are allowing wireless broadband access in public areas. Secondly, the terminal devices are evolving. The most prominent change is the advent of the PCA (Personal Communications Assistant), which is essentially a small handheld PDA (Personal Digital Assistant) with a communications capability (often with both 3G and WLAN). A recent conference in the USA demonstrated web browsing with a PCA to a local CDMA2000 3G network at 150kbps. It is possible that such a capability could be a ‘killer application’ which could see a proliferation of broadband wireless services (especially amongst the younger generation) as has been seen in the mobile telephone industry over the last 10 years.

With the widespread availability of broadband wireless data networks, it is also possible that we will see much more machine-to-machine communication (such as motor vehicles reporting maintenance information to manufacturers) and mobile information services (such as vehicle guidance, mapping on demand, and traffic congestion reporting).

Some thoughts on technology trends in the more distant future are given in the article in Appendix A.

3. Impediments to Broadband Wireless

Our contention is that the main impediments to the deployment of broadband wireless in Australia are not technology related but are limited by cost and undemonstrated value. We will discuss the background to these impediments and suggest ways of removing them.

Cost is a major issue in broadband wireless and some evolving technologies, such as WLAN, are changing the equation. In the USA, residential broadband penetration has been significantly higher than in Australia. There, residential broadband is priced at approximately US$50 per month with no download restrictions. In Australia, the price ranges from A$55 per month for a 300Mbyte download limit to A$340 per month for a

10Gbyte download limit. It may be that there is a price threshold above which subscribers will not participate no matter how good the service is. It is also possible that the existence of a download limit is a psychological barrier against participation. There may be business reasons for broadband ISPs having these cost structures (see the previous discussion on backhaul and connection fees); however, such cost structures may be inhibiting the proliferation of broadband services. This situation will perhaps be ameliorated if broadband data access can be bundled with telephone services such as voice over IP (VoIP). Currently, the quality of service (QoS) of IP-based packet networks is not sufficiently high to reliably allow this but industry groups such as the IEEE802.11 WLAN group is working on this as a very high priority.

Rural users do not see sufficient value in the Internet - either wired or broadband wireless - to justify the asking price. There is a need to have a demonstrator for lead applications to show the value of such services.

The biggest barriers to ready availability of broadband are commercial applications that have a high enough perceived value to drive demand.

4. Proposal for Demonstration of Broadband Wireless Applications

Australia is lagging behind other developed countries in the uptake of broadband services. The relatively poor nation-wide infrastructure and the lack of access to high speed Internet services are just two symptoms of this lag. One of the reasons for this situation is that the advantages and potential use of broadband has not been demonstrated widely to government and the general public.

The lag is especially acute in rural and remote areas. Large towns quite near major capital cities do not have access to the broadband infrastructure and even some parts of Sydney will not have access to broadband cable in the near future. Some of this broadband infrastructure can be provided by wireless when cable is difficult and/or expensive to install.

We suggest that the uptake of broadband services could be encouraged through pilot studies, e.g. solutions to the last mile problem or broadband connection of services within a rural or regional-size town. The business case for some technologies is not apparent because there have been few or no demonstrators.

Demonstrators of the type funded by DCITA ‘Building on IT Strengths’ (BITS) and the National Communications Fund (NCF) should be encouraged for broadband wireless applications. There is also value trialling emerging technologies in similar demonstrators but on a smaller scale than either BITS or NCF.

5. Role for CSIRO

Up until the early 1990s, Australian government departments were able to receive advice from Telstra/OTC on telecommunications technologies and wireless in particular. Since then, commercial imperatives have meant this role cannot continue. In respect to broadband wireless technologies, CSIRO has most skills and experience to provide independent advice to government. In recent years, CSIRO has advised DCITA and NOIE on several issues, but it is in a position to do more if given the opportunity.

6. Conclusions

An overview of has been given of CSIRO's current perspective on wireless technologies as applicable in the Australian context. Our main conclusions are:
1. Broadband wireless is here to stay. Improvements over the next few years will see greater mobility, reconfigurability, lower costs and access to customers. However, for Australia to keep up with the rest of the world, the benefit of broadband wireless has to be demonstrated to the general public.
2. We suggest that the value of broadband wireless should be encouraged through pilot studies. The business case for some technologies is not apparent because there have been few or no demonstrators.
3. Increasing use of broadband technologies will inevitably lead to increased carrier frequencies and spectrum should be kept available or freed up for the future.
4. Australia's use of spectrum should be compatible with other major countries (eg USA and Europe) to maximise technological and cost advantages for Australian consumers and also enable Australian companies to compete more easily in the global market place.
5. CSIRO can play a role in advising government of the advantages/disadvantages of emerging broadband wireless technologies. It has a wide range of skills relevant to such technologies and systems.

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Appendix A: ICT at CSIRO Telecommunications & Industrial Physics - "Providing Solutions to the 'Tyranny of Distance'"

(Article prepared for a future issue of 'ICT Solutions')

1. Introduction

The provision of broadband telecommunication services to all Australians, regardless of location, poses unique challenges due to our country's immense size and widely dispersed, highly mobile population. This extends to residents in large cities and smaller towns, to the sparsely populated outback and to the delivery of goods and services overseas.

The challenge for ICT is to deliver universal access to the wide range of electronic services becoming available, from telehealth and distance education to entertainment, information media, commerce and financial services. Having access to these services is vital for not only people living in remote areas but also, for example in the case of telehealth, to elderly and housebound people living in cities and towns. It is vital for industrial competitiveness as well.

Pressure has been building from many quarters to make broadband telecommunications services available for vital industries such as health, mining, the environment, defence and transportation as well as consumers. However, it is not simply a matter of rolling out existing technological solutions. Research is needed to deliver, for example, reliable mobile services seamlessly, high quality education and health care services to people in rural and remote regions without the need to travel large distances, and Internet services with no waiting. Further, ICT should deliver these services in a functional and affordable way.

In response to these and other challenges, CSIRO Telecommunications & Industrial Physics has refocused its activities to have greater impact than before in ICT. A new strategy centred on "ICT providing solutions to the 'Tyranny of Distance'" was commenced in September 2001. Unashamedly we adopted the Geoffrey Blainey book title of "Tyranny of Distance" in this aim because in its widest sense this phrase is as relevant today as ever before. Blainey says, "My book is essentially about people and commodities, and for them the cost of distance has usually been high" (Geoffrey Blainey, 'The Tyranny of Distance', Revised Edition, 1982). This cost of distance is not limited to the Australian environment but recurs in other parts of the world, from rural America to the regional cities of India. Therefore, the solutions delivered should be for a global market.

The key element of the CSIRO's strategy in ICT is to carry out research on telecommunications systems, infrastructure, protocols and services, which provide the user with seamless, "always connected" access to broadband services regardless of location or class of user equipment. Before outlining some of the ICT research solutions we are pursuing, it is noted that CSIRO has an enviable record for telecommunications innovation in the past. Three major contributions have been to satellite earth stations, wireless local area networks (WLAN) and local development of advanced microwave semiconductors and these are outlined below.

2. Past Achievements

<u>Satellite Communications</u>
Since 1985 CSIRO has been involved in building or upgrading over 40 earth-station antennas for satellite communications. These antennas vary in size from 4m up to 26m.

Of these earth stations, over 20 were built for Telstra (formerly, OTC/OTCI) and 12 for the Department of Defence. About half have been installed in overseas locations, including two in Vietnam.

The then overseas carrier business OTC (now Telstra) negotiated business cooperation contracts with Vietnam's Posts and Telegraph Department and a contract for the first earth station was signed in 1988. Ultimately in 1990 and 1993 US$66million and US$200 million business cooperation and revenue sharing partnership contracts were signed where these earth stations and associated equipment played a major role.

Over a dozen Australian companies benefited directly through the manufacture of the antennas or of feed-horns or systems, and tracking systems. In most cases, their participation in earth station projects has considerably enhanced their overall expertise because of the specialised nature of the work. Some of the companies benefiting include AWADI, Auspace, Clough Engineering, Sydney Engineering Sales, Tunra, Codan (Qld), Connell Wagner, Evans Deakin and Johns Perry.

The benefits are dominated by the revenue derived from Telstra's contracts in the Indo-China region. Telstra's success in gaining contracts to provide telecommunication services in Vietnam, Laos and Cambodia is attributable in part to having access to CSIRO's expertise in design of earth station antennas, and the capacity of CSIRO to work with Australian engineering firms in this area.

WLANs and Radiata

Another major achievement for CSIRO was the development of the underlying technology for Radiata, a start-up company that was purchased by Cisco in November 2000 for about US$300 million. This technology resulted from an ambitious CSIRO project that commenced in 1990 to demonstrate an indoor wireless local area network (WLAN) with data rate greater than 100 Mbps. A carrier frequency near 60 GHz was selected initially because of the availability of spectrum and this project would build on CSIRO's expertise in radio systems that came originally from radio astronomy and microwave landing systems. By 1995, an orthogonal frequency division multiplexed (OFDM) system was shown to overcome the severe multipath environment indoors and 100 Mbps had been demonstrated. Of importance for the future was the submission of a provisional patent application for "A Wireless LAN", which ultimately became foundation intellectual property for Radiata. Researchers from Macquarie University led by Professor David Skellern were involved in developing parts of the system through CSIRO funded research grants. At about this time, the US Vice President, Al Gore, promised that all US schools would be connected by high speed internet and frequency spectrum would be made available for doing this. A band of frequencies above 5 GHz was allocated and a study group developed a standard for indoor WLANs. CSIRO's patent was proposed as the basis for what became the 802.11a standard. The CSIRO WLAN patent, which is now accepted in over 20 countries, closely matches the standard and CSIRO has agreed to licence the technology to all comers. In 1997, David Skellern and his colleague Professor Neil Weste founded a company called Radiata Communications Pty Ltd (a contraction of Radio Data), and a substantial initial investment was secured to develop a 5 GHz WLAN. Within 3 years, a chip set implementing the 802.11a standard was developed and a prototype was demonstrated at a major exhibition in the US in September 2000. Two months later Cisco purchased Radiata. Today the technology is close to being rolled out in Cisco's 5 GHz WLAN.

Microwave Semiconductors

In 1983 the then Chief of Division, Dr Bob Frater, recognised that gallium arsenide (GaAs) semiconductor devices would be important for radio systems and CSIRO would need such devices in the future. As a result, a new research program was established under the leadership of Dr John Archer, who returned to Australia after seven years in the US at the National Radio Astronomy Observatory. Over the next 4 years a new facility was developed for the fabrication of GaAs high-electron mobility transistors (HEMT) and Schottky barrier diodes. The first working transistors were demonstrated in 1987. Soon after, devices with 0.3 mm gate lengths were produced which allowed operation up to 50 GHz. Because of the technical success of this work, there was significant commercial interest in developing a major GaAs fabrication facility in Australia based on the CSIRO process. A business plan was produced and attempts made to raise the necessary capital in October 1987. At a crucial time in the fund raising, the stock market collapsed. Although efforts to raise funds continued for about two years afterwards, there was little enthusiasm for the venture and the plan was shelved. Thereafter, the CSIRO GaAs facility was redirected to provide a monolithic microwave integrated circuit (MMIC) prototyping facility using 2-inch GaAs wafers. Over the next 12 years, the capabilities were improved considerably with the assistance of the Department of Defence. By 1998 devices with 0.15 mm gate lengths could be produced. The development of MMICs commenced in 1990 and by 1997 circuits operating up to 110 GHz were demonstrated. The cost of maintaining this facility as well as improved access to commercial services for fabrication of circuits in other facilities, with other types of materials, ultimately lead CSIRO to decide to close the fabrication facility in 2001 whilst continuing to work at the forefront of MMIC technology by using an external foundry. For instance, CSIRO demonstrated the first MMIC amplifier to work at higher than 200 GHz using the new indium phosphide semiconductor technology developed by TRW Inc.

3. Current ICT Research and Development

The research program on ICT providing solutions to the 'Tyranny of Distance' is currently focused in four main areas:

- Space and satellite communications
- Broadband wireless communications
- Mobile communications, and the
- Centre for Networking Technology for the Information Economy (or CeNTIE).

An outline of this research is given below.

<u>Space & Satellite</u>

Cheap and flexible satellite communications, particularly affordable customer premises terminal equipment (CPE), form a key element of any strategy to provide broadband telecommunication services in remote and rural areas. Also, the demand for broadband services is driving satellite operators to use higher frequencies than in the past, to Ka-band (20/30 GHz) and beyond. Low earth orbit satellites offer another way of providing small terminals and higher bandwidth than geostationary satellite solutions but achieving this at low cost is proving to be a challenge. Earth station technology is also becoming more sophisticated. For gateway services to large population centres via geostationary satellites and for some low earth orbit systems, multibeam antennas offer a unique solution to the future needs. Some of the research in space and satellite communications that CSIRO is undertaking is outlined below.

Bidirectional Customer Terminals. Highly integrated, low-cost systems capable of transmit and receive operation, initially in Ka-band but in the longer term extending upwards to other bands, will be a focus of research, incorporating electromagnetic design of the feed system, packaging and integration of electronic up-converters and down-converters and end-to-end system simulation. Civilian and defence satellite applications are envisaged as high data rate satellite telecommunications systems migrate to these higher bands.

Emphasis is on increased bandwidth through direct coupling between the feed system and MMIC based receiver and transmitter systems.

Multibeam Antenna Systems: Simultaneous access to a large number of satellites by means of a single system is a desirable feature for many earth station operators. A new multibeam earth station has been developed by CSIRO and four have been supplied to customers in Europe. This antenna can receive and transmit signals from/to up to 19 satellites simultaneously. We are actively pursuing the commercial production of this antenna.

Microsatellite Systems. As a member of the CRC for Satellite Systems, CSIRO is contributing to the FedSat microsatellite, which is due for launch at the end of this year. In particular, CSIRO supplied the Ka-band transponder for the communications payload. The principal areas of research are advanced integrated systems for lightweight, compact and low-power consumption transponders suitable for applications on small satellite platforms, and new switched beam antenna systems with improved efficiency to optimise space usage on small satellites.

Broadband Wireless

Millimetre-wave operation is of growing importance to the distribution of broadband telecommunication services in cities and in remote areas. Through millimetre-wave systems research we are focusing on new applications aimed at providing flexible, high-data-rate connectivity to mobile users. Development of in-building applications are predicted for 60 GHz WLAN systems, because current solutions do not provide adequate bandwidth for future applications and services. In the outdoor domain, millimetre-wave systems are also increasingly being used in intelligent transport systems, for example in intelligent cruise control and, more importantly, to provide high-speed connectivity for in-vehicle computer communications. Line-of-sight applications also continue to provide new and exciting market opportunities. For example, the 59-64 GHz ISM band has recently opened up for provision of short-range, wideband services to consumers. The high atmospheric attenuation in this band allows frequency re-use so that radios can operate on the same wavelength in close proximity without concern for interference. Frequency bands between 71-76 GHz and 81-86 GHz, which have lower attenuation, are also being investigated for possible wireless backhaul systems with multi-Gbps capability.

Millimetre-wave transceivers based on MMICs are a key component of these wideband systems. To gain widespread acceptance in consumer applications, the relatively high costs must be reduced and this is a major challenge for systems designers. In particular, constraints on packaging of critical front-end components and efficiently marrying them with antenna structures and IF/baseband systems have made it difficult to achieve affordable solutions. For the technology to be commercially attractive in the consumer marketplace, a new approach to millimetre-wave system design and implementation is required where each element in the system is designed with regard to its ultimate integration in a larger system.

Research is focusing on developing new millimetre-wave systems architectures with an emphasis on enhanced mobility for high-data-rate communications.

In the near term, we are developing fully functional, limited-capability radio systems in the frequencies between 60 and 106 GHz, depending upon the application. Key areas of research include investigation of new systems and network concepts involving a high level of integration. The larger available bandwidths, new integrated circuit-based receivers and very compact antenna structures may lead to cost and performance advantages.

Mobile

The provision of data services, rather than voice traffic, will drive the evolution of the next generation of cellular-mobile systems. This creates opportunities for research aimed at utilising 3G/4G mobile technology to deliver data services to Australians, particularly in rural areas. As these new mobile services evolve, there is an increasing likelihood that an environment where information is delivered over the Internet to the desktop computer user will be transformed into a flexible cellular mobile-based network serving portable computer users. For application developers, wireless devices have significant constraints, such as relatively low bandwidth, poor connection reliability, limited CPU power and memory size, limited battery life and user-interface limitations, that must be addressed before successful systems can be widely deployed.

Research in CSIRO is investigating the seamless interfacing of advanced cellular networks to provide clients in remote regions with mobile access to data services. In regional and remote mobile applications, access to data sources may involve lengthy delays, which can impose significant problems in database systems and transaction - based applications. Research is focusing on providing consistent and accurate delivery of data with high information content over low bandwidth, high latency networks that have unpredictable availability and stability.

In many mobile applications, tracking the location of the user is an important requirement. Research in position location based on cellular mobile technology is developing applications for precision tracking of people, animals and goods in indoor and outdoor locations, initially with particular application to the sports industry and extending to automated goods handling.

An understanding of radio-wave propagation is fundamental to radio system design. Applications as diverse as mobile-cellular, indoor WLAN, satellite communications links and millimetre-wave wireless require consideration of propagation data to achieve the optimum performance. Studies to date include investigation of in-building and rural-cellular propagation. Further research is developing techniques and models for propagation into and within buildings from external cell-sites, and in the reverse direction, for WLAN applications and to assess in-building repeater leakage.

CeNTIE

CSIRO is the prime participant in the “Centre for Networking Technologies for the Information Economy” (CeNTIE) funded from the DCITA “Building on IT Strengths” (BITS) network test-bed initiative. This CSIRO-University-Industry consortium is establishing a new 'super' Internet - hundreds of times faster than the current one – with very significant ramifications for provision of a new class of information services, such as tele-health, media systems, information brokering, tele-collaboration and distance education. Through this involvement CSIRO is driving the early adoption of the Information Economy in Australia. Recently, CSIRO in association with Nortel Networks demonstrated the first 10 Gbps ethernet system in Australia.

Within the CeNTIE framework, CSIRO research is targeting the development of advanced software architectures for complex distributed systems, and mobile agents, which will traverse the network to allow network status to be constantly monitored. New architectures are being developed for programmable networks which are self-configuring and self-healing, which will underpin future virtual private networks (VPNs). This is aimed at enhancing the reliability of networks required for the Information Economy. Research is underway into new mathematical techniques for the analysis and design of networks as complex dynamical systems. We expect this will result in tools that allow the analysis of larger and more complex networks than is possible using traditional techniques.

4. The Future

Someone once said that in predicting the future, what is almost certain is your predictions will be wrong! This is a truism of ICT and especially in the current climate when the telecommunications market is so uncertain. However, in a discussion of the future there is possibly greater chance of predicting particular technological trends than future commercial products. We need to remember too that, as a rule of thumb, a product takes about 12 years from conception in the research laboratory to its appearance in the market place. The Radiata 802.11a WLAN and the CSIRO MultiBeam antenna fit this rule almost exactly. What appears almost certain is that ICT products in the future will allow greater mobility, portability and functionality than in the past. These products will also be more sophisticated and more human friendly. There is also convergence of technologies which will have a great impact on future ICT.

In the short term, the demand for bandwidth is going to continue to be a significant driving force, as is equity of services in city, rural and remote regions. At the same time, we expect there to be a need to demonstrate the value of ICT services delivered by broadband. Several trials in progress, including CeNTIE, should demonstrate how ICT services could be delivered to user communities (eg health) at a significantly reduced cost than is currently provided by other means. Therefore, in the short term we expect to see a range of initiatives and new technology that will temper the impact of ‘tyranny of distance’.

In the more distant future, the convergence of semiconductors, communications, networks, computing technology and materials could change the way users of ICT interact in particular communities. For example, this convergence has resulted in the possible development of small, intelligent devices that could be embedded in buildings, factories, farmsteads and vehicles. This raises the potential of networking these devices together in a ‘Smart Space’. Such a convergence of technologies may well become ubiquitous in the future. These complex networks of embedded devices will cooperate to achieve certain goals and tasks, take into account human preferences, will be aware of the environment, and will self-reflect, self-reconfigure and self-repair to operate in the most efficient and robust manner. Researchers from across CSIRO are investigating many of the concepts and technologies behind such Smart Spaces to make them a reality.