Broadband Internet Access in Regional Australia

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This article was written to commemorate the Basser Computing Laboratory's early contributions to communications technology by examination of an underused modern technology. It commences with a brief tutorial on spread-spectrum communications, together with a summary of the salient characteristics of the technology. Outdoor and non-mobile uses of Wireless LAN NICs are then introduced with two case studies. In conclusion, the policy implications of spread-spectrum technology for broadband Internet access in regional Australia are examined, together with an analysis of some opportunities for Australian entrepreneurs.

Keywords: broadband services, regional Australia, spread spectrum, Internet access, case study, wireless ISP, national communications policy
CR Categories: C.2.1 – Network Architecture and Design

1. REGIONAL AUSTRALIA AND COMMUNICATIONS

It is little known that Professor John Bennett and the Basser Computing Laboratory were striving to bring computing access to regional Australia even in the late 60s and early 70s. Schools throughout NSW could send pencil-marked (mark-sense) Hollerith card decks in to the University of Sydney, and the programs would be conductively read and compiled. The user would be sent back the compiler listing and any run results. At a rough estimate, a 100-card deck amounted to say 10000 characters each way with a week turnaround, or 100 millibits/sec. This is 100 times smaller than the 10 b/s that was usually achieved as a staff member of Sydney University, but it was valuable.

This paper draws attention to a relatively recent development that is important to communications in regional Australia, and yet which does not seem to be as fully utilised as it might be.

2. SPREAD SPECTRUM WIRELESS NETWORKING

Domestic microwave ovens operate in a narrow band of radio frequencies just above 2.4 GHz. While their emissions are closely controlled through shielding, the sheer number of ovens constitutes a substantial noise source in this part of the radio spectrum. As a consequence, the band is not used by critical commercial services, and most spectrum authorities including the Australian Communications Authority (ACA, 2001) have made 2.400 to 2.484 GHz available for licence-free spread spectrum communications. Similar considerations apply in the band from 5.725 to 5.875

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GHz. The 2.4 GHz band was enthusiastically adopted by the IT industry for indoor LAN communications (WLANA, 2001). The 5.8 GHz band is just opening up, and only a few off-the-shelf products use it yet.

The free-space wavelength of electromagnetic waves at 2.4 GHz is 125 mm. This implies that a simple half-wave resonant antenna is slightly shorter than 62.5 mm long, and antennas can be quite easily accommodated in PCMCIA cards making this radio spectrum easily available to laptop and desktop computer users without any fuss. At 5.8 GHz these dimensions are halved, making simple antennas even smaller.

None of these communications options would be possible without spread spectrum (SS) technology. The principle of spread spectrum technology is to spread the information to be transmitted over a much wider bandwidth than is necessary, with a characteristic signature that enables it to be picked out from the noise. In most current systems direct-sequence modulation is used (DSSS) whereby each transmitted bit is modulated by a characteristic higher frequency binary sequence. The receiver uses the same sequence to separate this signal from competing signals and genuine noise. By appropriate choice of orthogonal sequences, many different communications can take place in the same channel.

3. WIRELESS LANS

The operation of most digital communications in this band is defined by the IEEE802.11 standard and its successors. The use that was first promoted and which is still the major use of network interface cards (NICs) to IEEE802.11 is local area networking. In fact the radiated power produced by commercial NICs is sized appropriately for this use, in the range 35-50 mW. This provides acceptable indoor range, negligible biohazard, and allows many networks to coexist in the same channel without undue interference.

The basic principle of the infrastructure mode (the most useful to examine) is for one NIC to be connected to a wired backbone LAN. This station is called the *access point*, and acts like a hub. All other stations logged on to the access point use the same channel and spreading sequence, and effectively communicate with the access point in a wireless LAN with total data capacity that may be up to 11 Mb/s. Data rates of 45 Mb/s have been announced.

The NICs are capable of changing their spreading algorithms if the radio channel is particularly noisy or the station signals are very weak, and gracefully degrade to data rates of 5.5, 2 and 1 Mb/s before giving up. The effective range of the LAN from the access point depends on

- the minimum tolerable data rate,
- local electrical noise including competitive WLANs, and
- absorption and reflection of the radio waves by the environment.

About 100 m might be considered normal in built environments. Such WLANs are competitive with wired LANs where the data rates are adequate, at about $A1000 for an access point and $A300 for each connected station. They really shine where one or more of the following apply:

- *Difficult wiring*: retrofitting in heritage buildings, domestic dwellings;
- *Flexible environments*: university and school campuses, convention centres, exhibition centres, in temporary locations for quick set-up and re-use; and
- *Networking mobiles*: wherever laptops congregate, such as airport lounges, hotels, libraries, and increasingly in workplaces.

4. BROADBAND NETWORKING

But this article is not about short-range nor mobile applications, except to note that the volume of these uses has driven the price of the hardware and software down to low levels. Exactly the same NICs can be used for medium range communications up to 40 km, and it is these applications that are so important to regional Australia.

Point to Point

The simplest is the point to point link. This is a do-it-yourself version of the familiar microwave link. There are two NICs, one at each end. To achieve a substantial range three things need to be handled.

- The two points at either end of the path need to have a clear line of sight between them (see also Section 5). It is this clear path that eliminates almost all absorption and most of the reflections.
- The two NICs do not use their in-built antennas, but are connected to directional antennas that direct their power in a torch-like beam to each other, and similarly for reception.
- If extreme range is needed, a bi-directional amplifier may be fitted between the NIC and the antenna. In one direction this boosts the output power to the limits defined by the ACA, and in the other provides a more sensitive and lower noise receiver than the one in the NIC.

Point to point links can be of considerable use in regional Australia by providing broadband access to users located more than a few km from a country town, and in linking multiple access points to achieve coverage of a small country town. The cost of such a link may be of the order of $A2000-4000, and may deliver 11 Mb/s to 10 km, or 1 Mb/s to 40 km.

ISP coverage

Some Australian ISPs provide point-to-point access if requested for 24×7 online customers (for example Southern Internet, 2001). However, the really important application is that of providing wireless coverage over a substantial area at lowest cost. The scheme to be described can drop the per-user cost to around $A700. They are in use in the USA, but rarely as yet in Australia. The concept is to take a WLAN and modify it in some critical areas.

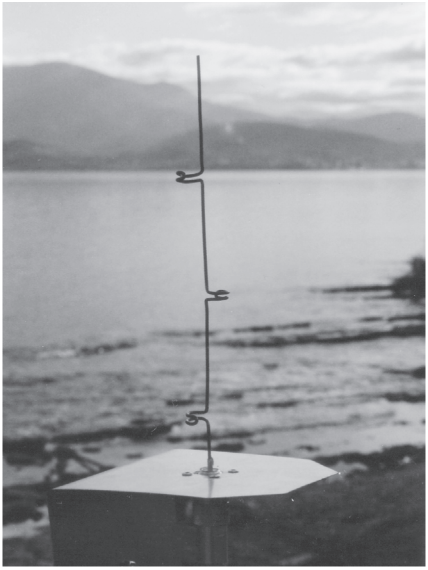
Assume that a high bandwidth Internet link is available in a country town, to which a wireless access point is connected. The access point signal is taken to a nearby high point or mast. An antenna is connected, designed to produce a substantially horizontal radiation pattern, tailored in azimuth to the population area it is designed to serve. A bi-directional amplifier is used, to reach the maximum allowable EIRP (Effective Isotropic Radiated Power).

Subscribers to the ISP service must have line of sight to the access point antenna, though community sharing is quite possible. Each subscriber has an NIC and a highly directional antenna pointing towards the access point antenna, again within the ACA limits.

This will achieve a possible 11 Mb/s service area of 5 km radius (assuming an antenna omnidirectional in azimuth), probably capable of supporting 50-70 broadband users with a reasonable fraction of this data rate at most times. Greater range is possible at lower rates, as shown in case study 2. These range extensions have been achieved over the indoor 100 m by eliminating problems in the radio path, providing highly directional antennas, and boosting the central power where highly directional antennas are not possible.

5. THE RADIO PATH AND GROUND SYSTEMS

Outdoor communications require a clear line of sight between sender and receiver at 2.4 GHz and 5.8 GHz. However, this needs to be qualified. At these frequencies attenuation due to water vapour



and rain is negligible (the peak absorption occurs at higher frequencies), and penetration through a few metres of tree foliage may be acceptable. Being able to see the other end is thus not essential at all times. In addition, the e-m waves are also diffracted by large objects. To assure the maximum received signal it is therefore necessary to have a clear zone around the line joining sender and receiver. This includes buildings and the ground. Increasingly at long distances the curvature of the Earth and refraction (bending of the waves) by the atmosphere also play a part in determining received signal strength, and in turn the data rate and reliability of the path.

These bands lie in an awkward region of electronics technology where conventional lumped circuit technology is beginning to break down (a 60 mm wire does not behave like a wire), and microwave technology is still awkward (a copper waveguide with 60 mm side is big). Attenuation in coaxial cables is high, and short runs are essential. Mast-mounting of the radio transmitter and receiver is an advantage.

However, antennas are compact and relatively low cost. Simple omnidirectional antennas can be home-built or purchased, while high-gain antennas up to 24 dBi are based on small parabolic dishes at a cost of say $A200. Limited-gain directional antennas to about 14 dBi are within range of amateur construction at costs of about $A50 (Hecker, 2000). The photograph shows a simple 6 dBi homebuilt collinear antenna (220 mm high) for shore-to-boat communications.

Case Study 1

For the first case study, consider a point-to-point link from an ISP in the City of Hobart and a dwelling on the other side of the River Derwent, 8 km away with the path 90% over water (the photograph does double duty in showing the path). Assume 50 mW is produced by the NICs. Table 1 shows the parameters and design choices.

Terminals	Height	Identifying name	Distance A-B
Point A	13.0m	Howrah (suburb)	8km
Point B	50.0m	ISP connection	90% sea path
Frequency	2.425GHz		
Wavelength	123.6mm		
Desired fade margin	15.0dB	Choose to offset path imperfections	
LOS height at midpoint	31.5m	Check against Fresnel zone clearance	
60% Fresnel zone width	18.9m	Clear zone required around direct LOS	
Onset of d^4 law	> 21.0km	Power drops off faster with distance	

Item	Parameter	Power/Gain/Loss
Radiated power	50mW	**17.0dBm**
Antenna gain Point A		20.0dBi
Antenna gain Point B		20.0dBi
System gains		**40.0dBi**
Free space loss	8km	-118.1dB
Feeder loss Point A	*cable, length*	-2.0dB
Feeder loss Point B	*cable, length*	-2.0dB
Oxygen absorption	8km	-0.1dB
Water absorption	8km	-0.1dB
Allowance for near field tree	3m	**-0.9dB**
System losses		**-123.2dB**
Received power		**-66.2dBm**

Transmission rate	11	5.5	2	**1Mb/s**
Receiver sensitivity at BER = 10^{-5}	-82	-87	-91	-94dBm
Power margin	**15.8**	**20.8**	**24.8**	**27.8dB**

Note:

- The EIRP of each end is calculated by adding the power delivered to the antenna to the antenna gain, so 17-2+20=35 dBm which corresponds to 4 W, the ACA limit between 2.400-2.463 GHz.
- If the noise margin of 15 dB (received power = 30 × noise power) is adequate, communication will be possible at 11 Mb/s.
- On rare occasions the path may be interrupted or degraded for a few minutes by a large passing ship.

Table 1. Link Power Budget, Case Study 1

The conclusion is that most of the Eastern Shore (30% of the population of Greater Hobart) can be serviced with broadband communications *now*, not some time in the future. The number of links is limited so the solution does not scale well, and the installation cost per link is probably around $A2000. However, costs are almost purely incremental with subscribers.

Case Study 2

Consider a small country town on relatively flat terrain except for a single hill of 50 m just outside the limits. From this hill one can see almost all of the houses in the town, and a number of outlying farms. This time put a horizontally omnidirectional antenna on top of the hill on a 10 m mast, with 6 dBi gain enhancing horizontal radiation over vertical. A bi-directional amplifier (Teletronics, 2001) is also fitted, increasing the EIRP to the ACA limit. These steps are designed to give maximum coverage. If the hypothetical hill already has a mobile phone tower or TV tower, it may be possible to locate the ISP antenna on that tower, reducing costs.

Each subscriber to the ISP service (or group of subscribers; there is nothing to stop a group of people in a block of units or a shopping mall pooling a radio link with some bandwidth competition) will install a directional antenna pointing directly at the hill, and use a standard NIC. A more conservative fade margin of 20 dB (100 × noise power) will be used to recognize the more cluttered environment.

Either direction may be the critical one. At each point the maximum EIRP is radiated towards the other point, so the differences lie in the receiving antenna gains and receiver sensitivities. Table 2 shows the maximum distance at which 2 Mb/s service is possible (15 km), for approximate comparison with a top-level Telstra ADSL service (up to 1.5 Mb/s download and up to 256 kb/s upload).

Terminals	**Height**	**Identifying name**	**Distance A-B**
Point A	60.0 m	Lookout Hill	15 km
Point B	5.0 m	Subscriber	
Frequency	2.425 GHz		
Wavelength	123.6 mm		
Desired fade margin	20.0 dB	Choose to offset path imperfections	
LOS height at midpoint	32.5 m	Check against Fresnel zone clearance	
60% Fresnel zone width	25.8 m	Clear zone required around direct LOS	
Onset of d^4 law	> 9.7 km	Power drops off faster with distance	

	Parameter	**Power/Gain/Loss**	**Power/Gain/Loss**
Radiated power Point A	1000mW	**30.0 dBm**	
Radiated power Point B	50mW		**17.0dBm**
Antenna gain Point A		6.0dBi	as at left
Antenna gain Point B		20.0dBi	as at left
System gains		**26.0dBi**	**26.0dBi**
Free space loss	15km	-123.5dB	as at left
Feeder loss Point A	*cable, length*	-1.0dB	as at left
Feeder loss Point B	*cable, length*	-2.0dB	as at left
Oxygen absorption	15km	-0.1dB	as at left
Water absorption	15km	-0.2dB	as at left
System losses		**-126.8dB**	**-126.8dBi**
Received power		**-70.8dBm**	**-83.8dBm**

Transmission rate A->B	11	5.5	2	**1Mb/s**
Receiver sensitivity at BER = 10-5	-82	-87	-91	-94dBm
Power margin	11.2	16.2	**20.2**	**23.2dB**
Transmission rate B->A	11	5.5	2	**1Mb/s**
Receiver sensitivity at BER = 10-5	-96	-101	-105	-108dBm
Power margin	12.2	17.2	**21.2**	**24.2dB**

Table 2. Link Power Budget, Case Study 2

This analysis must be modified if the surrounding terrain is hilly so the coverage is worse, or if the town has a ribbon configuration so that parts of it are out of range (such as along the Mornington Peninsula). A totally flat terrain can also cause problems in getting the station antenna high enough. However, multi-station configurations are easily possible, and indeed would be essential to fully service a regional city of say 20000 people. It is estimated that the wireless links of a single station should cope with the broadband access needs of say 50-70 domestic and small business subscribers, and central station costs would be split amongst them. Stations can also be co-located in dense usage areas with sectoral coverage.

Price comparison

It is difficult to provide directly comparable rates, but rough analyses suggest that wireless ISPs should be able to provide broadband access to the Internet in towns and cities in regional Australia for significantly less than the price of ADSL links as published by Telstra (Xnet, 2000).

Urban environment

Outdoor use of the 2.4 GHz spectrum in densely populated urban areas such as Sydney and Melbourne is less important, because of limited scalability, interference, multi-path cancellation due to reflection from buildings and vehicles, and a higher electrical noise environment. Wired solutions, whether copper-based or optical fibres, will continue to be more important. There are some applications however for point to point links between buildings.

6. SECURITY

Wireless communications are intrinsically subject to eavesdropping; security and unauthorised access are serious concerns. Suitable deployment techniques have to be used to ensure security is maintained. There is insufficient room in this paper to present an in-depth analysis of the issues, but the most important features are:

- IEEE802.11 communications use Wireless Equivalent Privacy (WEP), which is based on the RC4 encryption algorithm and its huge state space. RC4 is considered a secure algorithm.
- Encryption is optional and some installers do not turn it on.
- Brute force cracking of the WEP 40-bit keys is feasible in months with PC arrays or supercomputers; however many systems use 128-bit keys.
- Recently, Fluhrer, Mantin and Shamir (2001); Stubblefield, Ioannidis and Rubin (2001); Loeb (2001) demonstrated that a particular weakness in TCP/IP traffic could be exploited in some situations to crack WEP keys in minutes to hours on a PC. The time is only weakly dependent on key length.
- In many broadcast systems all users have the same key, which presents insecurity through human leaks.

IEEE80-2.11 communications *must* be secured at the network level, for example by techniques like the Secure Socket Layer (SSL). The wireless access points should communicate with the wired Internet through a firewall, as a virtual private network. Appropriate authentication is also needed.

7. POLICY

At present, Australia is allocating substantial funds to make Internet access available to regional Australia, with broadband access being a target. The policies are mainly driving along two paths:

satellite access and ADSL. Satellite access can be discounted as an option for all but the most difficult and remote users, for the following reasons.

A ground station to link to a geostationary satellite is a high initial cost, increasingly so in southern Australia as large dishes are required to view the satellite at low elevations. For example, in southern Tasmania satellite broadband must be considered to be only just feasible for domestic consumers.

The service is asymmetrical: the high speed is from the Internet to the user via the satellite, with upload being through a modem. This does not help when the user is engaged in an electronic information exchange with another user, such as sending large attachments (pictures, designs, documents, software) with email. Delivery of on-line services or mounting a web-server is difficult. Even uploading web site changes to an urban ISP is a chore. Webcams and online control via video are impossible. All this limits the development of IT industries and usage in regional Australia.

ADSL provides a feasibly costed service, though the less marked asymmetry is still a problem. The key problems are the cost compared to wireless, the limited speed, and the painfully slow rollout of ADSL to regional Australia. For the highest per capita income suburb in Tasmania (Howrah/Tranmere) potential subscribers are told 'We have no current plans to provide ADSL to your area' (Telstra, 2001). However, ADSL services are good for Telco shareholders, because they enhance the value of the monopoly on copper wire 'last-mile' connections.

In short, satellite and ADSL are desirable services, but they are mostly relevant to really remote users and dense urban environments respectively. Country towns and regional cites can be provided with broadband services at lower cost almost immediately, through the use of spread spectrum technology. Why has this not happened? Probably four related reasons are important:

- 'Big-picture' solutions (satellite, ADSL) fit better with the thinking of politicians and Telcos.
- Spread spectrum is a grass-roots technology; any small ISP can set up a wireless broadband service. Indeed so can amateur groups. This discourages Telcos.
- ADSL is to Telstra's advantage in maintaining market dominance and preselection through leverage of the infrastructure monopoly.
- Spread spectrum technology has an image of 'short-range WLAN' in Australia.

Take-up of ADSL in a *Networking the Nation* trial in Launceston (northern Tasmania) resulted in only 180 subscribers (target of 2500 by mid 2002). The Commonwealth Government recently announced a subsidy to waive the $A189 connection fee and reduce the monthly fee to $A50.50 from $A89 (*Mercury*, 11-07-2001). It would be interesting to see the effect of an equivalent subsidy ($A1.1M over two years) applied to wireless broadband in a similar city without broadband services.

It may also be noted that mobile phones are being adopted in developing nations rather than upgrading the poor wired infrastructure. In many countries the number of mobile phones exceeds fixed phones. The situation with the Internet in regional Australia has many parallels with this scenario.

In the USA, high speed access to 2 Mb/s via CDMA phone technology (also spread spectrum) has been developed (Qualcomm, 2001). However, this technology appears to be more suited to occasional high download bandwidth for mobile users, rather than the 24×7 and high-speed upload access required for web-servers and e-commerce (Bender, Black, Grob, Padovani, Sindushayana and Viterbi, 2000).

8. OPPORTUNITIES AUSTRALIA MAY BE MISSING

There are entrepreneurial opportunities for several groups from spread spectrum technology.

- *Antenna design*. This niche is probably filled by Pacific Satellite (2001), but with aggressive increase of Australian expertise in SS, the demand for expertise in antennas and connection equipment could grow substantially, internally as well as for export in the Australasian region.
- *Migration to 5.8 GHz*. Spread spectrum NICs operating in this band are few, though there is an upconverter that translates 2.4 GHz signals to 5.8 GHz and vice versa, at extra cost. Integration of antennas and systems is still some way off. There may be scope for engineering development in Australia focused both on 5.8 GHz and ruggedized outdoor SS systems, provided concepts are rapidly turned into product and export markets are aggressively sought.
- *Consulting*. SS links are low cost and grass roots solutions. At present, most systems are set up in conjunction with supplier advice. A common experience is that this tends to be conservative and more expensive than necessary. There may be room for consultancy services specialising in SS.
- *ISPs*. Adding a wireless 'last mile' strategy may benefit many ISPs and improve competition in the provision of broadband services, to the consumers' benefit.
- *Education*. Graduates intending to work in the network side of the IT industry must have the basic rudiments of radio and SS technology, for the outlined reasons and for mobile communications generally. The value of engineering and computing degrees to international students could be enhanced, with export consequences.
- *Roll-out*. The policies of the Commonwealth and of the political parties should provide incentives (parallel to the ADSL and other initiatives) for the establishment of wireless ISPs in regional Australia, as soon as possible. Community access centres should also be capable of managing such funds and services.

REFERENCES

AUSTRALIAN COMMUNICATIONS AUTHORITY (2001): *Radiocommunications class licence (Spread Spectrum Devices)*. Available at http://www.aca.gov.au/publications/info/spreadsp.htm.

BENDER, B., BLACK, P., GROB, M., PADOVANI, R., SINDUSHAYANA, N. and VITERBI, A. (2000): *CDMA/HDR: A bandwidth efficient high speed data service for Nomadic users*. Available at http://www.qualcomm.com/hdr/pdfs/CDMA_HDR_IEEE.pdf.

FLUHRER, S., MANTIN, I. and SHAMIR, A. (2001): *Weaknesses in the key scheduling algorithm of RC4, J.Cryptology*. Available at http://www.simovits.com/archive/rc4_ksaproc.pdf.

HECKER, J. (2000): *How to make a simple 2.425GHz helical aerial for wireless ISM band devices*. Available at http://users.bigpond.net.au/jhecker/.

LOEB, L. (2001): *What's up with WEP?* Available at http://www-106.ibm.com/developerworks/library/s-wep/?dwzone=wireless.

McLARNON, B. (2001): *Wireless LAN/MAN product directory*. Available at http://hydra.carleton.ca/info/.

PACIFIC SATELLITE (2001): *Home page, antenna systems*. Available at http://www.pacsat.com.au/.

QUALCOMM (2001): *HDR Home page*. Available at http://www.qualcomm.com/hdr/.

SOUTHERN INTERNET (2001): *Permanent high speed services*. Available at http://www.southcom.com.au/services/24x7fast.html.

STUBBLEFIELD, A., IOANNIDIS, J. and RUBIN, A. (2001): *Using the Fluhrer, Mantin, and Shamir attack to break WEP*. Available at http://www.cs.rice.edu/~astubble/wep/.

TELETRONICS (2001): *Bi-directional amplifiers and 5.8 GHz upconverter*. Available at http://www.teletronics.com/.

WLANA (2000): *WLAN Association*. Available at http://www.wlana.org/

XNET (2001): *Mornington Peninsula wireless network*. Available at http://www.x.net.au/mornington_server.html and http://www.x.net.au/wireless_peninsula.jpg.

ZDNET (2001): *Summary of features*. Available at http://www.zdnet.com/products/stories/reviews/0,4161,2684722,00.html.

BIOGRAPHICAL NOTES

Arthur Sale FACS FIEAust gained his PhD in Binary Arithmetic Algorithms. He worked at Philips NV (Netherlands) and the University of Natal (South Africa) before joining the Basser Computing Laboratory in 1969. After active involvement in five years of change, he left Sydney to take up a Chair at the University of Tasmania to establish its computer science department. He helped establish the Tasmanian Branch of the ACS, chaired its Branch Executive and served as National Vice-President of the ACS. He was Chair of the University's Professorial Board, and later Pro Vice-Chancellor (Information Services) with two Australian awards for client service quality to his Division's credit. In 1999 he left the University and now undertakes consultancies in mobile and ubiquitous computing, teaches a few graduate students for fun, and makes glass art some of which can be seen on his website http://arthur.sale.tripod.com/.