WBT Inquiry
Submission No. 1

BushLAN–development of novel VHF wireless Internet technology for rural Australia

Submission to Parliamentary Inquiry into Wireless Broadband Technologies

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Summary
Recent Australian research suggests that low-power (< 100 W), very high frequency (VHF) radio waves with frequencies of 45-70 MHz could be used for the wireless transmission of Internet data over non-line of sight distances of 3-100 km in regional Australia at speeds >100 kbps. Such alternative "last mile" links could provide a low density population of rural users with Internet access speeds like those available to modem users in urban regions. While the data rates would be lower than those of satellite and line of sight microwave links, the infrastructure costs would be much lower.

Co-operation of data communications with presently operating analog TV transmission on channels 0, 1, and 2 can be achieved by locating the data services on locally unused channels (typically, only one channel is occupied in a given region) and by using spread-spectrum techniques to reduce interference to negligible levels.

We are developing an experimental network (BushLAN) to test this novel technology in the Australian Capital Territory. Three nodes will be installed at two locations in the Australian National University and one location at the University of Canberra. An additional node will be located a further distance away (> 50 kms) in the ACT. If successful, the technology could then be trialed by a rural Internet service provider and commercialised.

This project also catalyses university research and training efforts in wireless communication technology, digital signal processing, and computer networking.

1. Background

Rural industries contribute substantially to Australia's national income and exports. Because Australian businesses have to compete in global markets from the very beginning, they all need access to modern digital telecommunications. And, increasingly, private individuals need and want Internet access in their daily lives. Unfortunately, the low population density of rural Australia often makes the provision of high-speed telecommunications technology infrastructure originally developed for high population density areas uneconomic.

The most commonly considered case is those users who have no access to telephone services. These are often located in geographically flat and dry regions in central Australia. There are many more, however, living 5–100 kms from regional town centres in places like south eastern NSW. In these regions, the terrain is often hilly, and the weather wet enough to support agriculture, a big export industry for Australia. Telephone services there are for the most part out of date and inadequate for dialup Internet because of line noise levels, dropouts, etc.

This geographic digital divide has social and political as well as economic impacts, and presents serious practical problems for governments. Moreover, the issue of rural communications service provision is the principal obstacle to full privatisation of Telstra.

Nearly all the land-line infrastructure in regional Australia is owned and controlled by Telstra. A large-scale upgrade of this infrastructure to use fibre optic, ADSL, cable and other conventional broadband land-line solutions is not likely because of the huge (tens of billions of dollars) capital cost, which would probably not yield sufficient return on investment.

Digital wireless systems are attractive for Internet links in rural areas. The principal technology in use at present uses microwaves ($f > 1$ GHz) to establish line of sight communications between relay towers. Such systems are very effective as high speed data trunklines, and can be part of the solution to connect major regional centres to the digital backbone in most of the country. Here microwave links would follow major roads into head-ends located in regional centres along the way. However, in the hillier, wetter environment in parts of New South Wales, Victoria, or Queensland, where the largest rural population lives and works, the use of microwave wireless links requires frequent repeater towers, which are expensive to install and maintain. In cases where a tower already exists the cost can be reduced. But for that important "last mile" (in fact, up to 50 miles) of a link to individual subscribers, individual towers are prohibitively expensive and impractical.

Another solution is to use a two-way satellite link. The main drawback here is the difficulty in obtaining adequate returns on the high capital cost of the satellite(s) and ground equipment from a small population, which may necessitate eternal subsidies for set-up and subscription costs. There are also some technical difficulties—long latency times because of the earth-satellite round trip, and the sensitive nature of the microwave satellite link to weather conditions.

Low frequency waves in the VHF range potentially provide an elegant solution that is not burdened with the line-of-sight problems of microwave or the infrastructure costs of satellite. Of particular interest is the analog television band I (distributed over 45-70 MHz), which has an effective range (depending on local topography) of up to ~100 km or even larger. This band will be vacated at the completion of the simulcast tests with the changeover to digital TV, and so far there are no clear proposals for their deployment. Digital TV is not planned for bands 0 and 1. In some regions such as the ACT, channels 0 and 1 are not in use, so that we are currently able to perform field tests without interfering with other services. In those regions where they are, or if indeed analog TV continues indefinitely, it would still be possible to use parts of the band for low-power digital wireless, especially if spread-spectrum techniques are used. A similar practice is already employed in simulcast where the digital TV signal is made to look like white noise on an analog TV. Our initial channel studies (section 2) show that VHF wireless data connections are indeed feasible over significant distances at very low powers (40 km at 20 W). Base station and tower requirements would be modest compared to other transmission modes, and a reasonable target price for the "computer top box" comprising a VHF digital transceiver and computer interface is $A600.

2. Methodology and innovation

Over the past two years, the Plasma Research Laboratory at the Australian National University has been applying its expertise in radio-frequency (rf) technology to develop a concept for a moderate speed (~100 kbps) Bush Local Area Network (BushLAN) operating at VHF frequencies. This effort is developing the building blocks for such a system in a series of engineering student research projects (see the BushLAN website listed above for details):

Our next step is to extend the BushLAN concept to a fully operational wireless network. This would take the form of a distributed test bed in which all of the BushLAN transceiver hardware components would be located at each of the sites. BushLAN embodies a whole range of Internet and radiofrequency techniques and is consequently directly in line with the research goals of the institutions involved in both teaching and research.

Over the next three years, we propose to develop a working BushLAN prototype network operating at low power (~ 20 W) among university laboratories located within the ACT. The distances and topography of this arrangement are quite similar to those encountered by rural Internet service providers in New South Wales, and were chosen to model the situation of Allstate Computers in Cowra. The three initial network nodes would be:

Base:	ANU Research School of Phys. Sciences & Engineering (RSPhysSE)
Remote 1:	ANU Fac. of Engineering & Information Technology (FEIT) (~ 1 km)
Remote 2:	University of Canberra, School of Electronics and Telecommunications Engineering (~5 km) (UC)

After a trial period, we will add a fourth station further away (e.g., Tharwa).

Each node will be equipped with a prototype BushLAN transceiver, as well as a full suite of wireless test equipment (spectrum analysers, etc) that can be used for round the clock experiments in channel characterisation and the development of data communications technology specifically for VHF channel operating conditions—error correction, encoding and link protocols.

The experimental network will also provide abundant opportunities for research and education in digital wireless technology for students and staff in the following areas,

- Channel characterisation and data communications;
- rf data transceiver design and implementation;
- Link-layer software protocol development for rf applications.

The wireless technology research program at RSPhysSE has attracted about twenty 4th year engineering thesis students since 1999; about half of these have contributed to the development of the basic BushLAN concept. We also now have 2 PhD students and one post-doc working on wireless technology. We are thus confident that the BushLAN experimental network will attract greater student participation in communications engineering projects at RSPhysSE, FEIT, and UC.

We now describe our ongoing work and how it will evolve under the collaboration to address the critical issues in the implementation of the BushLAN network.

(i) Field Tests
Field experiments were performed on channel 1 at 59.5 MHz (under an ABA experimental emission license) in the Australian Capital Territory. Figure 1 shows the path loss as a function of distance in the ACT. The transmitting antenna was located atop Mount Ainslie and the received signal was measured in various places as far south as Naas (40 kms). The straight line is the theoretically-predicted path loss for line-of-sight. The terrain is hilly with several mountains like Mt Taylor of relative altitude 250 m which might have, but obviously did not, block the signal. The base line is the ambient noise level.

Accoding to Shannon'sTheorem, with 20 W of power, the channel propagation and noise characteristics permit transmission at > 250 kbps with a channel width of 250 kHz over distances of 40 km. Separate sliding correlator experiments indicated that multipath does not induce Inter-symbol interference (ISI) to 5 Mbps over non line of sight conditions at 15 kms. This may be surprising from the digital comms point of view, but in fact could be expected, based on experience with analog TV.

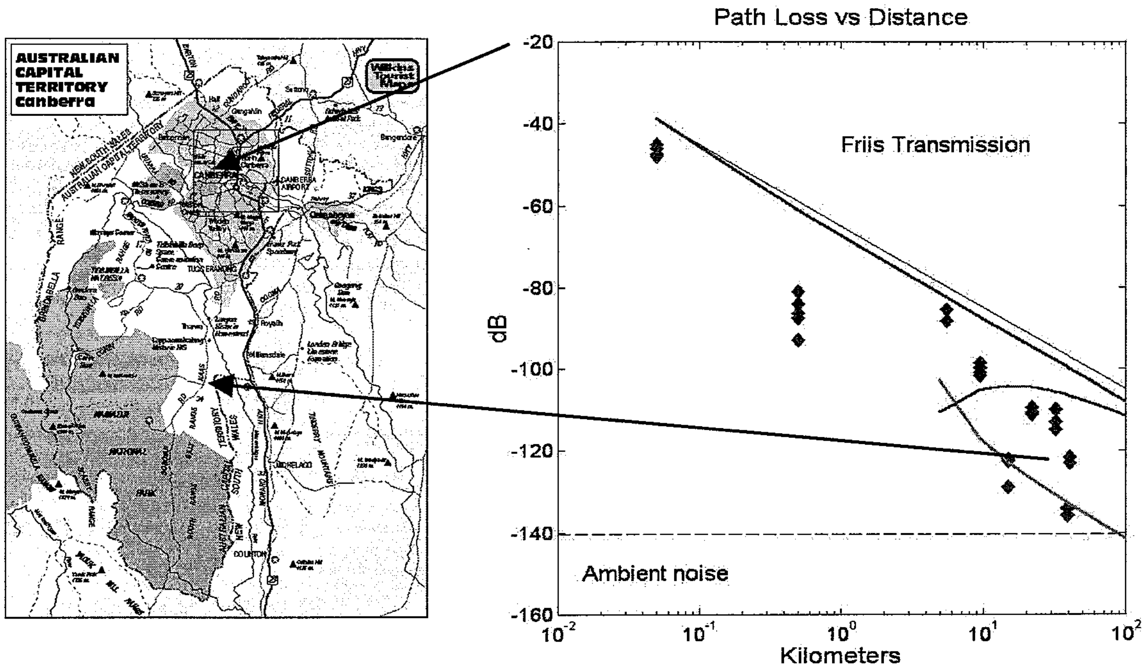

Fig. 1. Results of VHF channel test in the Australian Capital Territory. The transmitter was located atop Mt. Ainslie in North Canberra and operated with a power = 20 W, frequency = 59.5 MHz. The graph shows the measured signal levels compared with those predicted by the Friis transmission relation (conservation of power with finite receiver acceptance angle). The curve labelled "mid" shows the signal levels predicted for a case in which a 200 m high, 1 km diameter hill is located midway in the transmission path, and the curve labelled "source" shows the levels predicted for a case in which the hill is 3 km from the transmitter.

These are promising results; however, we really need to extend these to larger distances (~ 100 kms) and more diverse weather conditions where multipath induced ISI, impulse noise and atmospheric effects are more important. After initial development of the BushLAN network connecting the university lab sites, we will move a station to a more remote location (e.g, Tharwa) to assess performance under more challenging conditions.

(ii) Hardware design concept

The main intellectual property in BushLAN will be the Link Layer Protocol. The significant innovation in wireless comms in general is more and more the tight link between the LLP and the channel propagation characteristics. The results above already indicate that the BushLAN LLP will be unique.

A digital transceiver concept has been developed and tested in the Plasma Research Laboratory, and compact rf amplifier designs (~100 W) are under development. The following figure shows the design. Like all modems, the same system is used at the client as at the base.

Most of the hardware components are inexpensive and readily available. We are aiming at a price of $600 per unit. We take full advantage of recent advances in embedded systems and employ a Rabbit Semiconductor RMC2100 processor with an

Ethernet interface, 512 kB each of flash ROM and SDRAM, C-compiler and a TCP/IP stack (source code available). This allows a fairly complex LLP to be implemented (at least as powerful as some commercial systems). The Ethernet interface connects to the client/server PC and allows IP connectivity independent of PC platform.

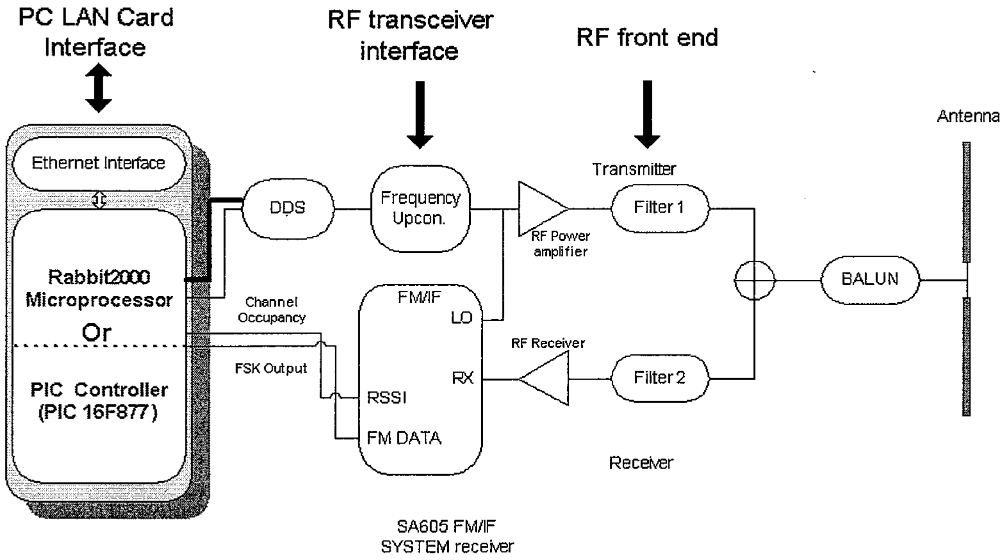

Figure 2. BushLAN transceiver schematic

(iii) National Interest Survey
Preliminary indications are that Australia has a strong demand for a project like BushLAN. No similar system is being investigated at this level of affordability anywhere else in the world, let alone Australia.

Our existing collaboration with one regional ISP (Allstate Computers, Cowra, NSW) has revealed a striking need for a wireless network in regional Cowra, which does have voice telephone service. About 20% of Allstates customers use redirection facilities for dialup Internet and have very poor service mainly as a result of poor quality telephone lines. Similar difficulties could be limiting regional businesses elsewhere in Australia.

This market interest has to be quantified for the specific characteristics of BushLAN in order to develop a business case. A market study of rural Internet usage patterns has been designed, and questionnaires will soon (May, 2002) be distributed to rural Internet service providers and customers.

(iv) Network modelling.
BushLAN has to be operated as a cellular network. One can imagine a base located in each regional centre with clients distributed up to 100 kms in hilly areas. The TV spectrum would have to be divided to service the clients without co-channel interference. Through a student project we have just begun to simulate the network load in BushLAN. Given parameters such as the backbone data rate, channelisation scheme, assumptions on usage patterns and the LLP chosen, the model aims to predict quality of service.

3. Funding of experimental network project

The equipment required to set up the four sites with BushLAN transceivers and high-end communications measurement instruments costs approximately $130,000. In addition, the services of a technical officer for one year are needed, and will cost approximately $60,000. Of the $190,000 total for the project, we are requesting $120,000 from the ARC Linkage Infrastructure and Equipment program, with $70,000 to come from the participating universities.

The universities will contribute substantial academic research staff time (1-2 FTE per year) to the project. In addition, we anticipate that the project will support the research of 4 graduate students and 10-15 honours students over the next three years.

4. Expected outcomes

We already know that moderate-speed long distance data communication at VHF frequencies is technically feasible. With the proposed experimental network infrastructure, we expect to develop a working long distance network that could service a small number (10 – 20) of users per cell. A logical follow-on project would be to build a larger network that could be tested by a rural ISP such as Allstate Computers in Cowra (200 out-of-town rural users). Significant further work beyond that, will be required, of course, to turn this into a commercially viable and licensable communications system.

The research program will also result in successful student projects—the students will become accomplished at digital wireless R and D and be well qualified to join industrial and government telecommunications organisations.

Demonstrated technical success of the BushLAN prototype would present several possibilities for commercial exploitation:

- As originally intended, as an alternative last-mile solution for rural Internet service providers.
- As a means for non-line-of-sight military data communication in an "electronic battlefield" situation.
- As an element in ad-hoc networks for data communications in remote monitoring (eg, mining) applications.

Licensing arrangements for use of IP developed during project research would be negotiated via ANUTECH Pty Ltd, the ANU's commercial arm.

We are presently exploring prospects for new funding to support BushLAN and related research into digital wireless. *Intel* has expressed interest in submitting a Linkage Project proposal in the November, 2002 ARC Linkage round, and *Tenix* and *DSTO* have also expressed interest in developing further wireless research. The Department of Communications, Information Technology, and the Arts have produced a list of contacts in the telecommunications industry who are potentially interested in the BushLAN concept. ANUTECH Pty Ltd is developing a proposal to the AusIndustry COMET program for funding of business-plan development for BushLAN and other rf technology research resulting from this work.

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Egan, Brendhan (REPS)

From: Jeffrey Harris [jeffrey.harris@anu.edu.au]
Sent: Thursday, 23 May 2002 1:22 AM
To: Egan, Brendhan (REPS)
Subject: RE: Submission to Inquiry on Wireless Telecommunications

Brendhan

1. At the time I sent the doc to you, URL s

http://rsphysse.anu.edu.au/BushLAN

and

http://wwwrsphysse.anu.edu.au/BushLAN

But now the links are broken. Something is wrong, I have e-mailed the webmaster, will let you know when it works again.

2. The file to use is named
bushlan_inquiry_5.doc

and the title is

"**BushLAN–development of novel VHF wireless Internet technology for rural Australia**"

This has some refinements compared to the earlier version our director (Erich Weigold) passed to Chris Pyne. Better summary, more complete authorship.

3. My postal coordinates etc are given in the signature of this message. Would you like to me to send you a modified file with these included?

Sorry for all the back and forth.

Thanks for your interest.

Best regards

JHH