A FRAMEWORK FOR AN AUSTRALIAN RESEARCH AND EDUCATION NETWORK

The Final Report of the Systemic Infrastructure Initiative
Higher Education Bandwidth Advisory Committee

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Executive Summary

The Higher Education Bandwidth Advisory Committee was established by the Minister for Education, Science and Training, the Hon Dr Brendan Nelson MP in August 2002 to advise him of the short to medium term bandwidth requirements of the higher education sector with a particular focus on research needs.

The Committee undertook a comprehensive process of consultation to collect quantitative data on the baseline situation and identify areas of deficiency with respect to network links to the major campuses of all universities and major research organisations, and commissioned a number of expert papers that assisted in its deliberations.

This approach was taken to ensure that the recommendations of the Committee are based on a knowledge of the current situation relating to network bandwidth, and that the Committee would be able to develop a realistic understanding of the demands that current and future research and education activities will place on network bandwidth.

This situation assessment indicated considerable disparity in the availability and affordability of bandwidth across the higher education sector, often greater than could be explained by differences in research intensity at the institutions. The major influence on this outcome – which is evident in both metropolitan and regional areas - has been changes in the nature of research activity, such as:

- increased collaboration nationally and internationally;
- the development of, and the need to access, extensive data bases arising from global research activities;
- the evolution of sophisticated and expensive 'instruments' as key research infrastructure, and the need to access them in order to be internationally relevant;
- the increasing need for advanced computing and storage capabilities.

These developments have all contributed to a rapid growth in the demand for (and dependence on) communications capacity – sustained growth rates in demand of 50% per annum have been evident for a number of years. An associated and significant factor in the growth in demand has been the growth in remote education, nationally and internationally.

There are a number of specific factors that have also contributed to the disparity evident in regional and remote areas. These include:

- the diffusion of higher education into more locations has resulted in many campuses being developed remote from main communications trunk routes;
- bandwidth capacity at many locations is available only from a single carrier;
- the business model used by carriers for charging the higher education sector is inappropriate in relation to the demands of the sector, leading to higher than appropriate costs.

In general, the impact of these factors has been to reshape and limit the research conducted, as a consequence of limited bandwidth. This has compromised the strategic research and education directions of the sector.

The present situation, while not in crisis, needs addressing as a matter of national priority. Technologically, demand for bandwidth at many locations now exceeds the capability of microwave-based systems to meet needs, and a transition to optical fibre-based systems is necessary. This step change in technology will require investment of significant funds.

It needs to be recognised that some of the disparity and deficiency is a consequence of applying competitive processes in the sector to what inherently needs to be a collaborative activity by the higher education sector as a whole. Such collaboration would allow the higher education sector to use the external competitive environment in telecommunications provision to achieve the best outcomes for higher education research.

Respondents to the Committee's inquiries were unanimous in stating the importance of bandwidth to the achievement of their strategic goals, and this would seem to provide a cohesive basis for collaboration by the higher education sector.

The Committee recommends that the higher education sector adopts a collaborative, strategic approach to the provision of bandwidth to campuses, and that the Commonwealth make a strategic intervention to establish this collaborative framework.

Specifically, the Committee recommends the establishment of the Australian Research and Education Network (AREN) as a collaborative venture between the Commonwealth, State and Territory Governments and the higher education sector, and collaboratively funded by those stakeholders.

AREN will evolve as a network of networks, with special purpose networks such as experimental and special research-focus networks built on a robust underpinning infrastructure. This underpinning infrastructure will comprise backbone infrastructure connecting major research centres, with connections to smaller research centres. Enhanced international connections will be provided to ensure that Australian researchers have opportunities to participate fully in international research collaborations and consortia, and have access to major international research facilities.

The strategic and management framework established for AREN is of major importance. This framework should facilitate participation in planning and use of the network, and encourage use of the network by the research community in particular, and by the higher education sector in general. Encouragement of use of the capacity of AREN is seen as vitally important to Australia's research outcomes - as network costs are a relatively small component of the total investment in research, the multiplier effect of adequate access to bandwidth capacity for university researchers is high.

It is proposed that an Advisory Committee, called ARENAC, representative of the sector and major stakeholders, be established to develop and review strategies and plans for AREN, and to monitor and review the implementation of the strategic evolution of AREN.

It is further proposed that the AREN be managed by an independent company owned by participants, called ARENMC in this report, and that this company would establish a regime of charges for services which would encourage use of AREN while providing sufficient funds for the company to be financially sustainable. It is recognised that ARENMC, in managing the 'network of networks' constituting AREN, may have peering relationships with other networks operated by State RENs in the execution of the plans.

The Committee has established notional targets for bandwidth capacity based on research intensity at campuses as follows:

Networked Computers	Research Staff and Students	Research Intensity	Minimum Target Capacity
<100		Low	Out of scope
100+	<200	Small	10+Mbps
500+	200+	Medium	100+Mbps
2000+	400+	Very high	1+Gbps

These targets have been used to establish a strategic plan for the structure of AREN, and to establish indicative costs of developing the network. The needs of different campuses and the feasibility of addressing those needs in the short-term and medium-term have been assessed to establish indicative priorities as a basis for future assessment and funds commitment. Further detailed investigation is required to assess the best options and opportunities in the development of AREN, and it is proposed that ARENAC be charged with this action.

An indicative estimate of the investment required over the next three years has been made, as an indication of the commitment required by the stakeholders. This estimate suggests that the achievement of the notional targets for bandwidth will require an investment by stakeholders of $50-60 million. To place this in context, this is considerably less than 0.5% of the expenditure on the higher education sector in that period.

Recommendations to Develop the AREN Framework

The Committee recommends:

An Australian Research and Education Network (AREN)

1. *That the Minister endorse the creation of the Australian Research and Education Network (AREN), as a next generation AARNet, to provide the bandwidth needs of researchers associated with the higher education sector (S6.2).*

2. *That AREN services and capacity be made available to the Australian higher education sector and the wider research community (S6.2).*

3. *That the Australian Research and Education Network Advisory Committee (ARENAC) be established to:*

   provide considered advice to investors (Commonwealth, State and Territory governments and research institutions) about the priorities for investment in the further development of the network domestically and internationally (S6.3.2); and

   provide strategic directions about the development of the network for the AREN managing company, based on the identified needs of researchers and the investors priorities, using the notional bandwidth targets for campuses and research facilities developed by the Committee as a guide (S6.3.2).

4. *That an AREN managing company (ARENMC) be established to manage the network within the broad strategic priorities identified by the ARENAC and that, subject to conditions to be negotiated, AARNet Pty Ltd be requested to undertake this role (S6.3.4).*

5. *That the Minister note that continuing investment in AREN by all stakeholders, including governments and research institutions using the network, will be necessary to maintain its capability to serve the national and international research infrastructure needs of the higher education sector and directs ARENAC and ARENMC to explore options to ensure the long term viability of the network (S6.3.3).*

6. *That the Australian Vice-Chancellors' Committee be asked to stress to its members the critical importance of linking the bandwidth needs of each campus to its research and teaching activities by ensuring that each institution's bandwidth requirements are specifically addressed in its strategic planning processes (S6.3.1).*

7. *That the Minister note that target bandwidth capacity levels related to campus characteristics of research staff and students and the presence of major research facilities and concentrations, have been set for 2005 as the basis for ongoing strategic investments (S5.4.1).*

8. *The Committee recommends that the Minister write to his Ministerial colleague Senator Alston and raise with him the need to explore opportunities to establish a formal relationship between the ANPs and the ARENAC to build on existing collaboration (S7.4.2)*

Initial priorities for addressing bandwidth needs

9. That the Minister agree that there is a high priority to address the provision of bandwidth as follows:

the establishment of a sustainable link between Tasmania and the mainland;

the upgrading of the capacity of the connection of Northern Territory University to AARNet;

the upgrading of the capacity of the links between the Brisbane AARNET PoP and Regional Queensland campuses;

the upgrading of the connections to Southern Cross University; and

that the Minister agree that ARENAC initiate as a matter of priority a process for resolving these issues which will involve discussions between stakeholders, including Commonwealth and State and Territory governments, institutions and AARNet or the ARENMC (S8.2).

10. That the Minister note that international broadband connections are a key element in Australian research capability, and that ARENAC be asked to evaluate options for enhancing this capability, and to recommend to the Minister the necessary actions to be taken (S8.3.3).

Securing access to bandwidth infrastructure

11. That the Minister note that addressing the issue of provision of bandwidth to remote campuses will require ARENMC to negotiate appropriate access to capacity on an unmanaged service basis (S8.2.2).

Future Development of AREN

12. That the Minister note the conceptual AREN framework and indicative program of works outlined in the report, and request ARENAC to bring forward detailed recommendations of priorities for funding in future years (S8.3).

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1. Introduction

The Higher Education Bandwidth Advisory Committee was established by the Minister for Education, Science and Training, the Hon Dr Brendan Nelson MP in August 2002 to advise him of the short to medium term bandwidth requirements of the higher education sector. The Committee is chaired by Dr Mike Sargent AM and comprises nominees from the Australian Vice-Chancellors' Committee (AVCC), the Australian Academic Research Network (AARNet), the Australian Partnership for Advanced Computing (APAC), the Council of the Australian Directors of Information Technology (CAUDIT), the Australian Research Council (ARC), the CSIRO, the Department of Education Science and Training (DEST), the Department of Communications, Information Technology and the Arts (DCITA) and the National Office for the Information Economy (NOIE). The membership of the Committee is provided at Attachment A.

The Terms of Reference for the Committee are provided at Attachment B. In particular, the Minister asked the Committee to provide him with an Interim Report by 31 October, 2002 on the short term needs of disadvantaged institutions or campuses and to recommend initiatives to be funded under the Systemic Infrastructure Initiative (SII) in 2002 and this Final Report, by 30 November 2002, to forecast what bandwidth Australian universities will need in the future to undertake high end research and to include a strategy by which current and future needs of universities can be assisted by the Government in a structured way. The initiatives recommended in the Interim Report submitted to the Minister on 31 October 2002 are included in this Final Report.

The Commonwealth will draw on the Committee's recommendations to provide a basis for policy development and to establish a strategic framework to inform the provision of SII funds in 2002 and subsequent years to address bandwidth issues necessary to support a robust and world-class research sector in Australia.

2. Background

The growing use of information and communications technologies in research is having a fundamental impact on the way research is being conducted and is leading to the concept of eScience or eResearch. Researchers now rely heavily on the Internet and World Wide Web to access research information and online journals and to communicate with their colleagues elsewhere in Australia and overseas. There is increasing use of modelling and data visualisation in research to better understand complex processes, especially in fields such as environmental sciences and biotechnology. Such research is dependent on the availability of high performance computing and advanced networks to facilitate the manipulation and exchange of very large datasets.

The concept of the *grid* has emerged from the availability of increased bandwidth and the grid infrastructure is being built on high capacity networks, computers, mass data storage systems, virtual reality and videoconferencing facilities and large-scale instruments.

Network technologies and services are now regarded as essential to support distributed research communities around the world. The development of these services however is in its infancy and the services will continue to evolve over the next 5 years.

Examples of grid technologies that are being developed include:

- Computing Grids providing access to distributed computers to allow applications to be executed across multiple computing systems;
- Cooperative Visualisation Environments connecting visualisation and virtual reality facilities (visualisation grids) to allow for example researchers at different locations to simultaneously examine a computer-generated model of an engineered product;
- Cooperative Working Environments connecting video-conferencing facilities to allow group-to-group communication and interaction, as for example in the Access Grid (which has over 100 sites internationally - see www.accessgrid.org);
- Data Grids allowing high-speed interactive access to large-scale distributed data sets (e.g. in astronomy, bio-informatics);
- Instrument Grids allowing access to large-scale instruments (eg electron microscopes) so that experiments can be conducted remotely.

There is also an increase in the use of information and communications technologies in teaching and learning. *Universities Online – A Survey of Online Education and Services in Australia*, published by DEST in March 2002, reported that 54 percent of the more than 90,000 units of study in Australian universities are now web supported. Furthermore, 95 per cent of universities provide access to their library catalogues via the Internet and 90 percent provide access to online journals and monographs.

High bandwidth links and associated communication services are a critical component of Australia's Information and Communications Technology (ICT) infrastructure. The infrastructure is essential to delivering access to data, computation, large instruments and cooperative working environments. Affordable bandwidth and network services to universities will lead to more effective investments in activities such as genomics, nano-technology, high-performance computing, advanced communications services and the nation's information infrastructure.

In summary, the machine to machine, person to machine and person to person interaction are increasingly dependent on the availability of affordable bandwidth to university researchers and educators. The vision outlined in this Report is to bring our best people together with each other and international peers intellectually as if they were located together physically.

Many of the larger universities have access to adequate bandwidth at present to support online education and research. However these institutions have limited opportunities to increase this bandwidth to support growth in demand due to the need to move to another technology level. The nature of university research and the universities' approach to research are being shaped by the available bandwidth and there is evidence that growth is being inhibited in part by the lack of affordable bandwidth.

Regional universities and the regional campuses of metropolitan universities are well behind the metropolitan campuses in terms of access to adequate bandwidth capacity, and the lack of affordable bandwidth has forced them to shape their research and education activities accordingly for some time. The Estens Regional Telecommunications Inquiry found that "higher bandwidth digital Internet services have a vital role to play in the future social and economic development of Australia, and concluded that there would be real benefits to the education sector if access for users to higher bandwidth services were included in any broad Government support program to improve access to higher bandwidth services in regional, rural and remote Australia" (chapter.5, p.146).

The Australian Academic Research Network (AARNet) provides a backbone network infrastructure that is accessible via eight Points of Presence (PoPs), located in each State and Territory. AARNet has made a very significant contribution towards the provision of access to affordable bandwidth for its members – the universities and CSIRO. However, metropolitan universities close to an AARNet PoP have a comparative advantage over regional universities and campuses, associated with the cost differential of securing access to the nearest PoP.

In recognition of this anomaly, the then Minister for Employment, Education, Training and Youth Affairs, the Hon Dr David Kemp approved funding of $3.2 million over 2001-2002 to assist a number of regional universities in the Northern Territory, Queensland and northern New South Wales to secure access to improved bandwidth. In the absence of competition from other telecommunications carriers, the universities' only option was to use these funds to subscribe to commercial services rather than to invest in longer-term access to telecommunications infrastructure.

The lack of longer term, sustainable solutions for regional universities, plus the increasing demand for higher bandwidth to support bandwidth intensive research in Australia is the focus of this Report.

The recommendations of this report will complement the proposals to develop the advanced computing and grid infrastructure from APAC and the information services recommendations from the Information Infrastructure Advisory Committee. These three initiatives will have a significant impact on the ICT infrastructure for the Australian research and education community.

3. The Approach

The Committee established a framework to ensure that university bandwidth issues would be addressed in a realistic and equitable way. The framework was based on the following points:

- Focus on the link between the university campus and the nearest AARNet or other appropriate point of presence. Note that the provision of links within a campus (or precinct when a campus is co-located with other entities) is not part of the framework;
- Aggregating demands as appropriate to define the most relevant network typology;
- Focus on addressing the bandwidth needs of existing universities rather than potential difficulties encountered in commercial decisions to establish new campuses or study centres;
- Collect information from both universities and State and Territory governments on their bandwidth strategies;
- Explore opportunities for synergies in the provision of bandwidth between neighbouring university presences, in particular in regional areas;
- Focus on establishing a strong driving link between the university research and teaching strategies and bandwidth strategy. This strong strategic link would be the basis for any further funding of the network to meet bandwidth requirements of universities;
- Confine considerations to addressing the capital needs to provide bandwidth to universities in order to assist in reducing their recurrent bandwidth costs, but not to address recurrent funding when adequate capacity has been made available;
- Take account of the need for access to overseas national research and education networks;
- Establish a framework for the implementation of the Committee's recommendations.

A three level approach was adopted as follows:

- Identify the baseline situation of university network links and report on immediate plans and identify current deficiencies (Members of CAUDIT and the AARNet Advisory Committee were asked to document the status of their inter-campus network links);
- Identify bandwidth requirements for existing and planned research activities. (A letter was sent from the Chair to each Vice-Chancellor and CEO of the CSIRO, AIMS and ANSTO with a request for this information. Also the strategic plans, research management plans and capital development plans of universities were scanned to identify bandwidth projects);
- Canvass research futures (Case studies were sought to identify discipline areas for services demanding high bandwidth connectivity, for activities such as accessing network-based research facilities, transferring large data sets, access grids and collaboration. Letters were sent and personal contact was made with sixty of the leading Australian researchers and a

paper was commissioned on The Future of High Bandwidth Grid Applications).

In developing the strategies to address the needs of the higher education sector, the Committee took cognisance of other Commonwealth Government initiatives such as the Broadband Advisory Group, the Regional Telecommunications enquiry, and the links to existing programs such as the Advanced Networks Program (ANP). The Committee also sought information as to State and Territory initiatives that might impact on the recommendations of the Committee.

The Committee met six times with four face to face meetings and two via videoconference over AARNet nationally and Internet2 internationally with members participating remotely from Seattle, Cairns, Townsville and Perth. An online discussion forum (Sharespace) was established by DEST and background information and working documents were made available to members and feedback was submitted using this online forum.

The Committee undertook a comprehensive process to collect quantitative data on the baseline situation and identify areas of deficiency with respect to network links to the major campuses of all universities and major research organisations. The Committee held discussions with the Broadband Advisory Group, the MCEETYA Bandwidth Task Force and the Pro/Deputy Vice-Chancellors (Research) Committee and commissioned a number of expert papers that assisted in its deliberations.

There are a number of parallel processes that will contribute to improved broadband policy outcomes. These include: the Regional Telecommunications Inquiry, the Broadband Advisory Group process, the House of Representatives Inquiry into Wireless Broadband Technologies, the Senate Inquiry into the Australian Telecommunications Network, the ICT Framework for the Future and current ACCC activities in relation to the development of a competitive broadband market in Australia. In providing its advice on bandwidth requirements for universities and research institutions, the HEBAC has, and will continue to, have regard to the outcomes of these policy processes.

This approach was taken to ensure that the recommendations of the Committee are based on a knowledge of the current situation relating to network bandwidth, and that the Committee would be able to develop a realistic understanding of the demands that current and future research activities will place on network bandwidth.

The data collection has been undertaken and the Committee is confident that it has sufficient data to make targeted strategic decisions for the 2002 funds to address short-term problems and to recommend strategic use of 2003 funds while addressing management and sustainability.

The form of discussions at the meetings and online in the Sharespace, and the contributions and responses from across the higher education sector and from many Commonwealth and State entities, are indications that the Committee has a broad level of support for its recommendations.

4. Analysis of the Current Situation

4.1. Introduction

The bandwidth available at university sites is influenced by a number of factors, such as:

- The institution's mix of research, teaching and administration at the site;
- The institution's proximity to established bandwidth infrastructure and the cost of accessing that infrastructure;
- The institution's allocation of priority and funding to the provision of bandwidth to the site, including both capital and recurrent costs;
- The institution's Internet traffic management policies;
- Bandwidth capacities within the campus.

Historical, geographic and demographic factors, as well as commercial decisions by universities, have shaped the capacity available and the means of provision of bandwidth at various campuses, with significant capacity and service differences evident across the sector. These differences manifest themselves as both access factors (availability of bandwidth at a location) and affordability (ability to meet the costs of usage).

Universities view the need for high bandwidth connections to other Australian universities, international universities and the commodity (public) Internet in different ways.

There are a small number of universities that simply want to acquire broadband services like any other service they purchase in the commercial marketplace (i.e. at the best possible price and with the minimum commitment of scarce IT management and technical staff time). The focus is on cost management and control of Internet traffic rather than capacity. These institutions are targets for commercial carriers offering contracts aggregating their full range of telecommunications needs such as fixed voice, mobile and commodity Internet services.

There are the majority of universities who regard broadband services as a critical component of their research infrastructure and in this context are prepared to invest significant funds and staff attention to ensure that they have the network connectivity and capacity to support high end researchers. This usually includes the capability to undertake research in networking on experimental networks and to support advanced network services and applications on a high capacity research network. This is in addition to the capability to support online learning and administration as a commodity Internet service like the first category.

Universities, if not constrained by geography and cost, will choose the extent of network infrastructure and communications services appropriate to their research and education needs. They will choose services to varying degrees from the commercially provided commodity Internet with a focus on traffic on one hand and the advanced research network with a focus on capacity on the other.

There is evidence in the responses from a number of Vice Chancellors and researchers that research is being constrained by the lack of bandwidth. In some instances, a particular research activity could not be initiated by the institution whilst in another case the research technique had to be modified introducing significant inefficiencies and the loss of data due to compression.

4.2. Providers of Bandwidth to Universities

4.2.1. The Nature of Bandwidth and Network Services required by Universities

The bandwidth and network services required by the university sector have characteristics that include:

- High growth;
- High complexity;
- Skilled and demanding end-users;
- Light-weight and flexible administration because the number of customers is small but sophisticated;
- Diverse and challenging requirements for leading edge (advanced) network services;
- Need to keep pace with services provided to collaborators in other countries.

The nature of the use and operation of the network serving the higher education sector rarely requires the 'full service' general market model of the commercial telecommunications companies, with its attendant costs. Rather the network usage demands flexible, innovative and advanced developments in service provisions and low management cost overheads. As a consequence the network supplying bandwidth to universities is aligned more to the 'private network' model, rather than the general purpose 'public network' model. Typically the private network model involves the acquisition of largely "raw" capacity such as fibre cables or wavelengths.

4.2.2. AARNET Pty Ltd (Attachment G)

The predominant supplier of bandwidth to universities is AARNET Pty Ltd, a not-for-profit company whose shares are held by thirty-seven universities and CSIRO.

AARNet has been very successful in offering services that are both generally cost competitive and more advanced than those of the commercial providers. AARNet's overheads have been kept to a minimum with a small staff (12 in total) and through leveraging the contribution of the technical staff from each Regional Network Organisation (RNO) as well as each university, The non-AARNet staff have contributed significantly to the success of AARNet especially in providing the regional connectivity.

AARNet has largely acted as a prudent broker for its members by acquiring capacity in the commercial carrier market by both aggregating and anticipating demand from members. The aggregation has been enhanced through AARNet's development of integrated services ahead of the commercial market (e.g. AARNet Mirror, Voice and Video over AARNet, advanced caching of web and news traffic).

The cost recovery model that underpins AARNet has limited the extent that it has been able to develop and deploy advanced network services, indeed, in many cases relying on members to drive initiatives for funds. AARNet provides a number of services with a common charging model to all universities regardless of their particular strategic approach.

AARNet's acquisition of a carrier licence has allowed it considerable additional scope in assisting its members achieve more cost-effective, and in some cases otherwise unachievable, outcomes for its members.

Examples of the value of the AARNet Pty Ltd carrier licence to universities include:

- Commissioning a contractor to lay fibre on behalf of ACT members, allowing members to put on their own active equipment and run low-cost gigabit Ethernet. Prior to this no one had openly sold dark fibre to a university, but following this initiative it has become more common, with consequent benefits to the sector;
- Acting as nominated carrier on behalf of members, allowing members to comply with the relevant sections of the telecommunications act without undue effort on their part;
- As power utilities can only sell capacity to a carrier (in the normal course of events) AARNet acts as the carrier in this regard on behalf of members (eg TransGrid and Powerlink);
- The carrier access regime allows AARNet access to other carrier's facilities and access to wholesale rates on products and offerings.

Whilst AARNet has been an outstanding success, it is restricted by its nature as a co-operative and its reliance on user pays, to making largely tactical decisions. The sector must address the bandwidth issues in a different and more strategic fashion if it is to meet the growth in demand that will require a technological change from leased commercial services and private microwave links to access to fibre. However AARNet is well placed to continue as the dominant supplier to the sector provided this role is fulfilled within a strategic context.

4.2.3. The Regional Network Organisations (RNOs)

AARNet supplies the international bandwidth and the national backbone that is terminated at a point of presence (AARNet PoP) in each capital city. The AARNet PoPs are typically collocated with one of the major universities in each location.

The RNOs are unincorporated joint ventures that are responsible for the planning and management of the links from the AARNet PoP to each member. The RNOs have made significant local investments in their regional links with assistance from time to time from the Commonwealth and other sources.

Some RNOs have transferred or are planning to transfer the management of the regional links to AARNet. The reasons include the difficulties with unincorporated joint ventures, the need for a carrier licence to undertake certain projects and activities and the demands being placed on their own technical staff.

It should be recognised that the RNOs and their member institutions have to date, by means of member contributions and other funds, provided infrastructure, staff and consultancies (see Section 4.2.3) to manage the wide area links that provide access back to the POPs. Each have their own peculiarities by virtue of individual enthusiasms, levels of cooperation, geography and the particular services they choose to provide but these individual state networks and services are in many cases quite extensive and require substantial management, maintenance and control.

Some, like NSW, are now fully managed by AARNet whereas others, like Queensland are still quite independent but in all cases they work in concert to make the national network the success it has been, and this cooperation is viewed as a strength by many of our overseas counterparts. The AREN would strengthen this by providing a stronger management model.

4.2.4. Advanced Network Programs – (Attachment H)

The Advanced Network Programs (ANP) (i.e. GrangeNet, CeNTIE and m.Net) were established to contribute to the development of advanced network infrastructure in Australia that will deliver long-term benefits to the Australian economy. The program has supported the establishment of a national advanced backbone network for specific research purposes.

GrangeNet has built a DWDM (Dense Wave Division Multiplexing) backbone to link Melbourne, Canberra and Sydney (at 10Gbps) and Brisbane (at 5Gbps), and is connected to the AARNet PoPs in those cities and to the AARNET international gateway in Sydney. Institutions that connect directly to GrangeNet currently pay only a small subscription charge monthly with no traffic charges applying within the GrangeNet network.

The GrangeNet capacity of 5Gbps between Brisbane and Sydney with tails of 1Gbps to sites in those cities compares broadly with the current AARNet Brisbane to Sydney capacity from Optus of 63Mbps (see Table 2).

CeNTIE is establishing a transcontinental fibre backbone research network consisting of broadband Metropolitan Area Networks (MANs) in Sydney and Perth linked by a combination of CeNTIE's DWDM-based Perth to Melbourne network and GrangeNet's Melbourne to Sydney network. The two metropolitan area networks (MANs) interconnect member sites with multiple 10Gbps connections.

The above capacities are specifically associated with approved ANP projects and are intended to carry research and pre-commercial traffic only, rather than the universities' broader research and education traffic. However it would be desirable to explore opportunities to establish a formal relationship between ARENAC, GrangeNet and CeNTIE in order to consolidate and extend the existing collaboration between the ANPs and AARNet.

m.Net is establishing state-of-the-art wireless Local Area Networks (WLANs) and leading edge pre-commercial third generation (3G) mobile networks, and will link them with optical fibre to provide services in and around Adelaide's North Terrace precinct. There is also a regional hub at Whyalla being used to explore the remote delivery of services and interoperability between separated networks.

4.2.5. Commercial Telecommunications Companies

Commercial telecommunications companies provide some broadband services to universities especially where the distances are such that microwave is not a viable option due to the lack of line of sight, the distances involved, difficulties in gaining access to towers or environmental issues.

Generally the costs of these services are much higher than those provided by AARNet or the Regional Network Organisations (RNOs), as they are provided as a fully managed service, covering all telecommunications services.

The significantly higher cost of acquiring a commercial managed service often results in the institution acquiring significantly less capacity than that which can be provided when a microwave or fibre solution is feasible.

The commercial broadband providers must appreciate that in the future the successful providers of broadband services to the Australian research community will be those that offer affordable bulk capacity such as fibre and wavelengths to entities like AARNet.

4.3. Bandwidth Demand and Growth

4.3.1. Introduction

The demand for and growth in bandwidth capacity in universities and the research institutions is consistently and rapidly increasing, with the growth of interactive collaboration, international linkages, digital libraries and sophisticated instrumentation. The analysis of past and current trends provided in this section indicates the scale of growth in demand, despite limitations in accessibility and affordability in the sector.

4.3.2. AARNET Traffic

AARNet is a very large network by Australian standards with an end-user base approaching 800,000, most of whom use connections at speeds of 10Mbps or greater. Unlike most networks in Australia, AARNet is a net content provider, for example in May 2002, AARNet and its members delivered 18.78 terabytes to the public Internet (or almost 19 million megabytes), but received only 12.85 terabytes from the Australian commodity (public) Internet. AARNet is also a significant international player. In May 2002, AARNet served 27 terabytes to the rest of the world and received 39 terabytes.

The 39 terabytes that AARNet provided to the rest of the world in one month is equivalent to 7800 full length digital movies.

Changes in the monitoring and management of traffic have not always provided consistent long-term measurements but Table 1 gives an indication of long-term growth.

Table 1: AARNet International Traffic Growth

Year	International traffic received by all AARNet clients Terabytes	Traffic volume increase pa
1995	12	
1996	27	125%
1997	52	92%
1998	95	83%
1999	142	49%
2000	207	46%
2001	302	46%
2002	393 est.	30%

The average growth in traffic has fallen from approximately 50% per annum to an expected 30% per annum in 2002. The decline in the growth of Internet usage by universities corresponds to the introduction of traffic management systems such as student and staff quotas and charge-back to end-users or academic departments by over 85% of institutions in the last few years in order to reduce communications costs.

It is anticipated that universities will continue to impose constraints on demand in order to meet budgetary constraints as most of the larger universities face annual expenditure of over $1,000,000 and growth in demand of 30-50% annually which has not until now been fully offset by the reduction in unit costs shown in Table 3 below.

AARNet has eight PoPs in Australia, one in each capital city. The capacities to the national and international commodity Internet as at 6 June 2002 are shown in Table 2.

Table 2: AARNet Capacity to Regional PoPs

Location (PoP)	Capacity to International Internet Mbps	Capacity to National Internet Mbps	Aggregate capacity to other PoPs Mbps	Total capacity Mbps
Sydney	392	36	123	551
Melbourne	126	36	108	270
Brisbane	77	22	63	162
Perth	43	11	75	129
Adelaide	32	10.5	75	117.5
Canberra	31	11	66	108
Hobart	5	2	12	19
Darwin	4	1.5	1.5	7
AARNet Mirror		30		30
Total	710	160	523.5	1393.5

The AARNet international capacity of 710Mbps shown in Table 2 consists of 310 Mbps of trans-Pacific capacity from Sydney principally to interconnect with the advanced research and education networks of North America and other countries and 400Mbps of commodity capacity to the international Internet.

AARNet has continued through a variety of mechanisms to significantly reduce the unit cost of Internet transport and services to members as shown in Table 3:

Table 3: AARNet Reduction in Unit Traffic Costs

Year	Total received traffic by members terabytes	Traffic volume increase pa	Average unit cost per gigabyte	Unit cost reduction pa
1998	125		$113.78	
1999	195	56%	$104.67	8.0%
2000	289	48%	$88.12	15.8%
2001	440	52%	$67.52	23.4%
2002(est)	580	31%	$52.00	23.0%

4.4. Current Bandwidth to University Campuses

The Committee undertook the collection of baseline data (see Attachment I) on the network connections from usually each institution's major campus to the nearest AARNet PoP and also the network connections between institution's campuses. Connections to small sites such as study centres were not included in the survey.

A total of over 400 network links were identified with commercial carriers providing 140 of these links and approximately 60 being private microwave links operating at speeds of 34Mbps to 155Mbps. An indicative estimate of the capital cost of this broadband private microwave network is $120 million.

This private network not only spans campuses in each capital city but also covers well over several thousand kilometres from Kalgoorlie to Cairns. Many aspects of this network are geographically large by world standards. For example, the CSU private microwave network (an example of the use of institutional funds supported by the Government and AARNet, NSW RNO and CSU staff effort to build an inter-campus network and link to the AARNet PoP microwave system) has links that run 120km (Albury - Wagga), 320km (Wagga - Bathurst), 200km (Bathurst to Dubbo) and 200km (Bathurst to Sydney) - in total around 850km - making it possibly the largest privately owned microwave system in the university sector anywhere in the world. The maintenance costs are around $350,000 per annum including site rentals. The high capital costs have prevented most of these microwave links from being designed as fully redundant systems.

The baseline data demonstrates that the university sector has been proactive in providing broadband capacity to support research and teaching. The Commonwealth government has also provided substantial funds through capital development grants and other infrastructure initiatives to assist universities fund these projects. This current evolutionary cycle is nearing its end having commenced in 1995 with the establishment of microwave based regional networks with the assistance of Commonwealth Research Data Network CRC funding.

These achievements have ensured that the university and research sector is not in a crisis situation with respect to bandwidth. However the substantial reliance on private microwave does not allow institutions to continue the evolution to fibre that is necessary to move to the next level of bandwidth provision without significant capital investment. Affordable access to fibre with a significant degree of control by the sector is the only way that this step change can be addressed.

All universities are facing this technological change in communications and this cannot be addressed by an incremental approach, or by the current processes for acquiring bandwidth capacity that have lead to a situation in which disparities in access and discontinuities in the network configuration occur widely. In addition, the opportunity cost of the staff time involved in developing proposals (see Section 4.2.3) for external funding and complex negotiations and largely unsuccessful tender processes indicates that a strategic approach must be taken to meet the next technological challenge.

This comprehensive baseline data (Attachment I) is a snapshot of the national AARNet backbone connecting the AARNet PoPs, the RNO links from each AARNet PoP to universities and research organisations and the institutional inter-campus links. The Committee believes that this data should be maintained to inform ongoing strategic and tactical planning. The Committee has sought the agreement of AARNet to publish this data on the AARNet web site. It is suggested that each RNO nominate an officer who will have the responsibility to maintain the data and be granted write access in order to undertake this responsibility.

4.5. Identified Deficiencies

4.5.1. Basis

The Committee examined the following factors in developing its position on bandwidth deficiencies:

- The current capacity from the main campus to the nearest AARNet PoP;
- The distance to the nearest AARNet PoP and the affordability of solutions;
- The capability of the network to deliver capacity to the PoPs;

- The presence of significant bandwidth intensive research such as high performance computing, grid applications and the management of large data-sets;
- The identification of bandwidth in strategic, research and capital development plans;
- The feedback from the institution and anecdotal evidence of the impact of the lack of bandwidth on current and planned research.

4.5.2. Metropolitan

Brisbane

South East Queensland is the fastest growing area in Australia. This affects both the area in general and Brisbane in particular in terms of meeting the growth in service demands. Many new campuses and research sites have sprung up in this area in the past 10 years to meet this growth. These include the Griffith campuses at Logan and Southbank, the UQ campus at Ipswich, the QUT campus at Caboolture, CQU and USQ sites in Brisbane and, of course, the University of the Sunshine Coast. Research sites include the CSIRO labs at Pinjarra Hills and the Queensland Manufacturing Institute. Between them UQ, GU and QUT are involved in 31 CRCs which shows a hub of research work. Local broadband reticulation is essential for researchers to apply the latest technology to their work.

Melbourne

Melbourne has a very high level of higher education and research activity, yet there are signs that the data network upon which much of this activity depends is under stress from traffic loads. This has arisen through the natural growth and adoption of new bandwidth intensive services.

Eight of the nine Victorian universities have campuses in metropolitan Melbourne (ACU, Deakin University, La Trobe University, The University of Melbourne, Monash University, RMIT, Swinburne University of Technology and Victoria University). In total there are 43 campuses within Melbourne, with 129,809 EFTSU (83% of the Victorian total of 155,764[1]), 14,849 FTE staff (85%), and 50,242 network-connected workstations (86%). CSIRO has 8 sites in Melbourne with 1,444 staff (69%).

There are 41 CRCs in Melbourne. Universities also have research and educational associations with a number of other organisations including 27 hospitals, medical and bio-technology research centres, 8 other research centres, and 11 cultural institutions, with whom there would be mutual benefit from improved network connections.

The Victorian universities and CSIRO formed a consortium that built the Victorian Regional Network (VRN) in 1996 to provide access to AARNet. The VRN provides a single broadband link to each university based on microwave technology. Each Victorian university has developed extensive wide area networks connecting their major campuses and smaller sites throughout metropolitan and regional Victoria. It is well designed and has been able to provide resilient economic bandwidth. The major campus links are either bandwidth limited dark fibre or purchased microwave, typically 155Mb/s or 34Mb/s. Other sites have capacities ranging from 34Mb/s to as low as 64Kbps.

[1] These are estimates based on reported figures and DEST 2001 staff and student tables and thus do not include TAFE components.

The current VRN is inadequate to serve the growing needs of the universities and CSIRO. Major drivers for higher capacity broadband links to all university campuses include:

- Annual growth rates of network traffic have now resulted in bandwidth deficiencies being evident between a number of the major campus links, interrupting normal use and hindering the introduction of new services;
    - Surveys undertaken by the Committee have shown that researchers from many disciplines need to engage in activities using resources, techniques and services that require high bandwidth network connectivity;
- Improved access is required to existing resources such as APAC National Facilities, CSIRO High Performance Computing and Communications Centre, supercomputing facilities at Swinburne University of Technology, The University of Melbourne and Monash University, and Virtual Reality facilities at RMIT;
- The DSTC at the Caulfield campus of Monash requires a high capacity link to GrangeNet for it to be fully effective as a GrangeNet partner;
- Researchers throughout Australia will require access to the Australian Synchrotron.

The Victorian Regional Network barely meets current needs and is not capable of meeting future needs of the universities and CSIRO, for these reasons:

- The dependence on microwave based technologies means that there is only very limited potential to increase bandwidth, but this is not considered to be a cost efficient investment;
- The capacity of the VRN severely limits the nature of involvement with advanced research networks such as GrangeNet and CeNTIE;
- The current network prevents the deployment of multiple network environments supporting differing needs of the research community, teaching and administrative functions of the universities;
- The design of the current network has resulted in each university being responsible for its own inter-campus links and opportunities for bandwidth aggregation and shared infrastructure are limited;
- Unlike the current VRN, an upgraded network design would facilitate bandwidth aggregation and connectivity with research institutions such as those located at hospitals and medical and bio-technology research centres.

An analysis of the numbers of academic staff and higher degree research students, the numbers of workstations located at each campus in metropolitan Melbourne, and the capacity of the current network links, supports the conclusion that the current VRN is inadequate in its design and bandwidth capacity to support the concentration of research intensive activities present in Melbourne metropolitan campuses and CSIRO.

Sydney

Sydney is a significant research and education centre, housing the main campuses of five universities (Macquarie University, Sydney University, UNSW, UTS and UWS), many smaller campuses of these five universities and those of five other universities (Australian Catholic University, University of New England, Wollongong University, Central Queensland University, Charles Sturt University). Overall there are around 23 campuses within metropolitan Sydney. There are also several CSIRO sites and other affiliated research organisations (e.g. ANSTO) and the key Australian Technology Park

(ATP) housing research, or research support organisations, such as ac3 and the Australian Photonics CRC. The majority of hospitals within Sydney have a teaching and/or research relationship with a university.

All Sydney based universities are connected via 34Mbps microwave from their “main” campus to the AARNet PoP at the University of Technology, Sydney (UTS). Connections from sub-campuses to main campuses are via a mixture of microwave or carrier provided services such as ISDN, Frame Relay or DSL. Other organisations and non-metropolitan university sub-campuses are generally connected to the PoP using a similar mixture of technologies. Bandwidths on links range from 64Kbps to 34Mbps. There is little, or no, redundancy in most connections.

Connections from the hospitals to their affiliated organisations range from direct fibre (where the hospital is in the immediate vicinity of a university) to microwave and carrier provided services. Lack of any, other than the expensive commercial Internet, connectivity to cultural institutions in Sydney (such as the State Library or Museums) inhibits any new network-based research and teaching collaborations.

The inadequacy of the current arrangements has long been recognised, with many of the links of insufficient capacity to support university research and teaching activities, either in the capacity provided to the AARNet PoP (one institution, UNSW, has already had to supplement its 34Mbps microwave with a 100Mbps carrier service), or between campuses.

To address a number of these bandwidth deficiencies, the five metropolitan universities have collaborated in the Sydney Basin Fibre Project (SBFP) to install dedicated fibre capacity between five main university campuses and the AARNet PoP. As key components, the project will also establish PoPs at the Australian Technology Park and Sydney CBD. The CBD PoP is seen as providing a basis for future connectivity to cultural organisations in the area. The network, to be completed around the end of 2002, will provide redundant routes. Sydney University and UNSW have also contributed additional funds to connect a number of metropolitan sub-campuses as part of the project. The dark-fibre capacity is on a ten-year lease. Although initial data rates will be 1Gbps, a key advantage of controlling dark fibre is the ability to increase that capacity significantly using wavelength division multiplexing (WDM). At least, two orders of magnitude speed increase should be possible over the same infrastructure during the ten-year lease. Comparable capacity managed carrier services are not financially viable.

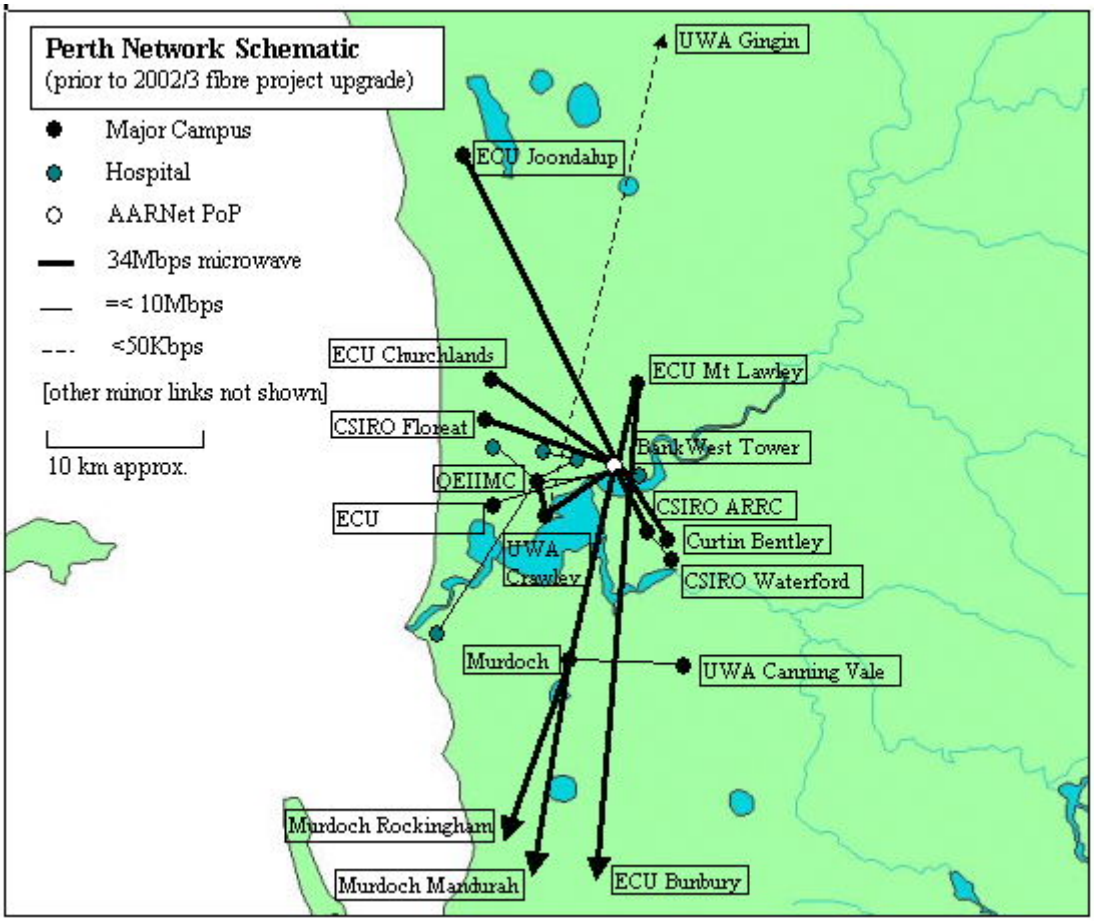
Figure 1: Sydney Basin Fibre Project (SBFP)

The SBFP was funded primarily by DEETYA (as it then was) with some help from the State Government, AARNet and the institutions concerned. A useful model for future research network development was the level of collaboration between the SBFP and CeNTIE. Neither project had adequate funds to build their minimum required Sydney fibre capacity, but by each project taking responsibility for different network segments and then instituting "fibre swaps", both projects could achieve their requirements. AARNet has agreed to provide management services for the completed network, integrating it with the management of AARNet facilities and the RNO. Again, this is seen as a successful model for education and research networks.

Perth

The main campuses of all 5 universities and principal CSIRO laboratories in Western Australia are located in the Perth metropolitan area. Some 10 years ago, WARNO was formed as an unincorporated joint venture between The University of Western Australia, Murdoch University, Curtin University of Technology, Edith Cowan University and CSIRO (i.e. excluding Notre Dame University, which has made its own arrangements for connecting to the Internet).

Figure 2: Perth Higher Education Locations



The WARNO arranged for one campus from each member to be connected to the single point where the AARNet PoP is located, creating Parnet (Perth Academic and Research Network). Parnet physically consists of an E3 ATM Microwave Radio Network linking those institutions at 34Mbps to the AARNet PoP located in the BankWest Tower in the central business district of Perth. This site is also the central

point for Edith Cowan University's own microwave network interconnecting its main Perth campuses (Churchlands, Claremont, Mt Lawley, Joondalup).

Further details of Parnet can be seen at http://www.ucs.uwa.edu.au/network/parnet.html with technical details at http://www.parnet.edu.au/, and full details of existing connections are set out in Attachment I.

Each member is responsible for connections between its various campuses, and various approaches have been employed, including the following:

- ECU is about to replace its internal microwave links with leased fibre;
- UWA has established its own fibre between its main campus at Crawley and its campuses at Nedlands and at the QEII Medical Centre, Hollywood;
- UWA has obtained access to some capacity on Health Department networks to achieve connections to its other medical centres located at the Royal Perth, Princess Margaret, King Edward Memorial, Graylands and Fremantle hospitals;
- CSIRO is in the process of acquiring leased fibre between its Shenton Park facility and its new premises in the Australian Resources Research Centre (ARRC) building near Curtin University;
- Curtin University has installed its own fibre to connect with the Bentley Technology Park and the ARRC;
- Various other links have been established to connect minor sites to the main campuses of each WARNO member.

A project is currently in progress to replace the existing Parnet network with fibre links, and to relocate the AARNet PoP to the CSIRO's premises in the ARRC. The WARNO members themselves are funding this project.

The current project will, however, be unable able to address (through insufficient funds) the following significant deficiencies in the metropolitan area connections:

a. Lack of resilience in network paths (it will still essentially be a "star" network);
b. Inability to improve connection for the various hospital sites;
c. Continued existence of other single points of failure;
d. Inability to upgrade the AARNet router to cope with projected increased traffic loads over the next 12-24 months.

In addition, the following important and serious longer-term deficiencies exist:

e. Lack of end-end connection to national/international gigabit networks for researchers in WA: though CeNTIE has a node in Perth, and IVEC has established a fibre network linking UWA, Curtin, CSIRO and Perth Central TAFE (with a connection to CeNTIE), there are various limitations on the use of these networks for general-purpose research activity by all universities in Perth;
f. Reliance on a single network path to the eastern states and overseas: even though the current AARNet supplier, Optus, is believed to be making arrangements for a separate physical route across the Nullarbor Plain, this may still not eradicate all single points of failure;
g. More efficient and speedy Internet access to various locations in SE Asia: this is required especially to address the need to support international education markets, but also to improve research collaborations in the region;

h. Cost of network traffic: the current charging regime for all uses of network capacity employs a per-byte formula with no provision for discount rates at unsociable hours, or for bulk traffic at lower priority, or for occasional very-high-demand usage, or similar provisions; this is proving to be a serious impediment to some research efforts – this includes both established research collaborations, and research of a more speculative nature.

It is estimated that it would cost several hundred thousand dollars to address deficiencies (a)-(d), but (e)-(h) are entirely beyond the scope of individual institutions or of WARNO to address directly (there are political as well as technical and financial issues in addressing these deficiencies).

Nevertheless, it is clear that the state of the fibre market in Perth currently presents some unique opportunities to acquire long-term access to fibre-based connections at very attractive prices; these opportunities may not be available for much longer.

4.5.3. Regional

Queensland and Northern NSW Regional Campuses

The eleven universities in Queensland and The University of Southern Cross in Northern NSW operate 40 campuses and teaching/research sites. Thirty-seven of these sites are in a 2000km coastal corridor from Cairns to Lismore and west from Brisbane to Toowoomba. In addition JCU has a site at Mt Isa, CQU a site at Emerald and SCU a site at Coffs Harbour. The area has approximately 45,000 network-connected computers servicing some 16,700 university staff (EFT) and 120,000 students (EFTSU).

Of these 37 sites, 23 are regional (i.e. outside of the Greater Brisbane metropolitan area). These regional sites host 50% of the computers and approximately 40% of the region's staff and students. This is consistent with the population distribution in this area.

Network services are provided to some 2660 academic/research staff and 1880 research students at these regional university sites. In addition, numerous other research organisations (e.g. CSIRO in Brisbane, Rockhampton, Toowoomba & Townsville; AIMS in Townsville; SRI in Mackay; QIMR and MRI in Brisbane) connect to the QRNO for collaborative work.

While lack of funds severely limits the development of broadband capacity and services between universities as well as between universities and other research organisations, the growth in demand continues unabated. This was recognised by the Commonwealth's funding for the Breaking the Bandwidth Bottleneck Project that subsidised regional universities in Queensland for 2001/2.

Major drivers for broadband links include:

- High Performance Computers (HPCs) located at GU (Gold Coast), UQ (Brisbane), QUT (Brisbane) and JCU (Townsville) providing visualisation service to all universities and participating in collaborative research. CQU, USQ and JCU (Cairns) have smaller computing facilities to participate in these developments;
- The Queensland Parallel Supercomputing Foundation Ltd (QPSF) is a partnership of GU, QUT, UQ, CQU, USQ, SCU and JCU and a partner in APAC. USC is an affiliate member. MetaCentre (Grid) technologies were pioneered between Griffith and QUT and are now being extended to other QPSF members. Computing and visualisation services are available to all QPSF members and very high speed access to this resource is needed by

researchers at all universities in addition to it underpinning emerging grid developments;

- Access to GrangeNet (hub at QUT in Brisbane) is required by researchers at all universities both to interact with other researchers and to access the research services and data sets available via GrangeNet;
- By the end of this year there will be eleven access grid video walls installed within the QRNO, largely used for improved collaboration between university researchers. Six of the eleven video walls will be in regional sites;
- The need for remote access to large, shared research facilities such as synchrotron, electron microscopes, telescopes etc.;
- Need for access to larger distributed data sets for research with access grid techniques;
- CRC's need collaboration among partner universities. Regional universities are currently involved in thirteen CRCs but their involvement can be constrained by lack of access to broadband communications.

Figure 3: QRNO Regional Research Personnel and Infrastructure.

The map in Figure 3 shows the distribution of research capacity in regional Queensland together with that in the Brisbane metropolitan area. The people numbers at each location include academic staff, dedicated research staff (e.g. post doctoral research fellows) and research students. While involvement in CRCs is shown at each site, this reflects only part of the research activity.

Based on the level of bandwidth intensive research activity and the number of research staff and students located outside Brisbane, the Committee has assessed that ideally bandwidth of 1Gbps is needed at the campuses in Townsville, Rockhampton, Toowoomba and Lismore and 10 to 100Mbps at other sites such as Cairns, Mackay, and Sunshine Coast.

The actual bandwidth available at present is well below this (e.g. 16Mbps to Cairns (JCU), 22Mbps to Townsville (JCU), 4Mbps to Sunshine Coast (USC), 16Mbps to Toowoomba (USQ) and 4Mbps to Lismore (SCU)).

The regional university campuses have suffered some protracted outages due to the lack of redundancy and diversity.

Regional New South Wales

Within regional NSW are the main campuses and most sub-campuses of five Universities (Newcastle, Wollongong, Southern Cross University, Charles Sturt University, University of New England), but many metropolitan universities have regional campuses or interests, including hospitals. Overall there are around 24 campuses spread across the state. Network connectivity in most cases is required back to a main campus or the Sydney AARNet PoP. The exception is Southern Cross that has been unable to obtain cost effective services to the AARNet PoP in Sydney, or the closer Brisbane PoP. Both distance, and the implicit lack of reasonably priced managed carrier services mean that the bandwidth to these campuses varies from just adequate but expensive (e.g. the 34Mbps microwave infrastructure from Wollongong, Newcastle or Charles Sturt) to the totally inadequate (such as the 4Mbps capacity from Southern Cross to the commercial Internet).

In many cases (for example Newcastle and Wollongong) there is adequate existing fibre in the area, some of it government owned, but access is limited to carrier provided limited bandwidth managed services with high recurrent costs.

Examples of known impacts of these bandwidth, or access, constraints include:

- Newcastle University is a partner in ac3 at the Australian Technology Park (ATP), but makes minimal use of the facilities because of the limited bandwidth available. Their microwave connection to Sydney is already 80% used for day-to-day network access, without bandwidth intensive research traffic;
- Many regional universities have identified video conferencing as a key strategy to deal with distance between campuses. Many, not just regional, universities have also identified video conferencing as a way of interacting with regional hospitals for teaching and research. Network (IP) based video conferencing costs a fraction of the traditional ISDN technologies but often cannot be deployed due to bandwidth limitations;
- Southern Cross University currently does not connect to AARNet as the cost of setting up a dedicated link to the nearest PoP is prohibitive. The cost of carrier services is such that SCU is limited to miniscule bandwidth to the Internet and between campuses in comparison with any other NSW University. The total bandwidth for all connections is only 16Mbps. They have a wide range of projects involving collaborations with other organisations that are dependent on

this bandwidth. Modern technologies such as video conferencing are not feasible due to the limited bandwidth;

- The University of Sydney's Plant Breeding Institute at Cobitty and Narrabri is connected via 2Mbps and 64Kbps ISDN respectively. In both cases this severely limits the transmission of large data files and images used regularly in cooperative projects. The Mongolo Radio Observatory is connected back to the University of Sydney by a simple, unreliable telephone line which is not adequate for a facility which generates large, and potentially real-time, data sets for analysis elsewhere;
- Charles Sturt University, with its widely distributed campuses, has invested heavily in a large microwave network over the years, identifying substantial savings over carrier services, but still high costs. However, the limits of capacity back to the Sydney AARNet PoP and between campuses is already constraining research such as cooperative research with CSIRO in the area of complex systems;
- Wollongong, in a situation very similar to Newcastle, has funded microwave connections to Sydney that are reaching 60% capacity. Frame relay connections between campuses at 265Kbit CIR are typically 75-80% loaded. The result has been that funded research projects such as participation in the Smart Internet CRC, or high performance computing using ac3 have been curtailed, transferred or abandoned. There are many additional examples. In the teaching area it has been necessary to set strict, fixed limits on the student access to the internet and streaming technologies, such as video conferencing, are banned.

Many of the constraints on access to AARNet, and hence the national and international research community, are caused by the limited number of PoPs AARNet can operate and the building of "radial" connections back to (in the case of NSW) Sydney. The provision of a research and education network which is distributed in a similar way to those of the major carriers in regional areas would allow institutions to connect at a realistic tail cost to one of numerous local PoPs. Whether this is achieved by the use of existing carrier capacity, managed in a way that supports national research and educational requirements rather than commercial constraints or via parallel dedicated capacity, such as separate fibres or wavelengths is a matter for further consideration. However, without such an infrastructure in place new initiatives will be inhibited by both network costs and the time taken to provision new high-bandwidth connections.

Regional Victoria

Higher education and research institutions are located throughout Victoria. The geographic spread of sites is significant, covering the length and breadth of the state, from Mildura in the north-west to Lakes Entrance in the east.

All Victorian universities have at least one campus outside Melbourne. There are 30 campuses in regional Victoria, with 25,957 EFTSU[2] (17% of the total), 2,815 FTE staff (15%), and approximately 7,931 network-connected workstations (14%). CSIRO has six regional sites with 665 staff (31% of Victorian staff). There are 70 rural health sites associated with Latrobe University, Monash University, RMIT, The University of Melbourne and Victoria University. Monash University and The University of Melbourne have 460 medical and dental students placed in rural centres.

There are seven CRCs in regional Victoria, located at Albury/Wodonga (1), Creswick(1), Geelong(1), Hamilton(1), Horsham(1) and Mildura (2) addressing a wide

[2] These are estimates based on reported figures and DEST 2001 staff and student tables and thus do not include TAFE components.

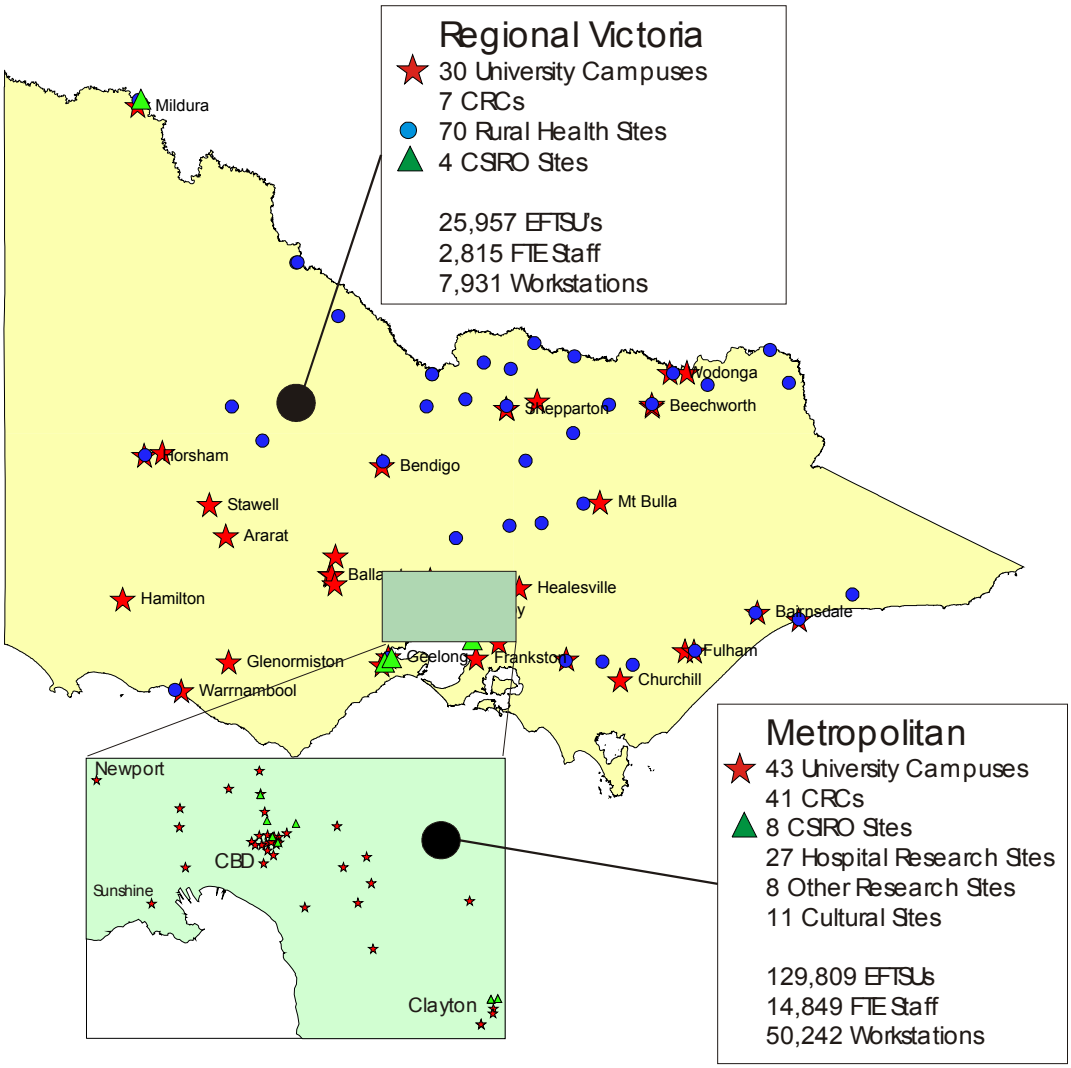
range of disciplines with a regional focus. RMIT's research into environmental issues affecting the Gippsland Lakes in the east (in association with TAFE), and Latrobe University's partnerships in Mildura with TAFE, CSIRO and the Riverlink Postgraduate Research Network are examples of innovative, collaborative, regionally focused research programmes. The University of Melbourne's Institute and Food Land Resources is located in nine sites throughout Victoria.

An innovative example of a broad community initiative is the Education Precinct being developed in Gippsland where local TAFE colleges, schools, the Churchill campus of Monash University and local research and community centres are working in partnership to promote regional development. All of these initiatives report that their activities are constrained by lack of bandwidth.

Students and researchers at these sites require access to similar network based resources as do their colleagues in metropolitan areas, but insufficient bandwidth exacerbates the barriers of distance. Data networks are a critical element in large-scale operations relating to the high performance computing, accessing and manipulating large data sets, simulations and visualisations. Networks also enable access to electronic libraries of information and resources essential to research and teaching. They also offer communication methods supporting collaboration across geographic areas, yet the size and remoteness of each campus have been barriers to the provision of cost effective bandwidth.

A review of wide area networks developed by Victoria's universities shows that many universities have made very significant investments from their own resources to develop the skills to build and manage functional network links to their regional campuses. Microwave technologies have been the most cost-effective by far. Recurrent costs have been manageable, after an initial large capital investment. Where physical characteristics have made microwave deployments too expensive, bandwidth has been purchased from carriers, with the continuing burden of high recurrent costs limiting the provision of sufficient bandwidth. These are the campuses that are experiencing the most serious restrictions to research and teaching activities.

Figure 4: Higher Education and Research Locations in Victoria



An analysis of academic staff and student numbers together with the number of workstations at each campus has identified the following limitations of the capacity of the current network links:

- A number of sites require high capacity broadband connections to cater for the volume of their traffic and diversity of their use. The Waurn Ponds campus of Deakin University, Bendigo campus of La Trobe University, Churchill campus of Monash University and the Mt Helen campus of the University of Ballarat are all very significant campuses whose future operations are limited without upgrades to their network capacity;
- The University of Melbourne, Victoria University and CSIRO each have significant research functions located at Werribee. There is an opportunity to establish a research precinct with shared high capacity network services to meet the needs of researchers;
- ACU's Ballarat campus is of sufficient size and diversity to require an upgrade to their 2Mbps link to cater for traffic associated with teaching, research and student support activities;
- There are many smaller campuses throughout regional Victoria that are served with low bandwidth communications links (2 Mbps, 128Kbps to as low as

64Kbps), including sites in Merbein (CSIRO); Mildura and Mt Bulla (Latrobe University); Bonegilla, Fulham, Lakes Entrance, Sale (RMIT); Warragul, Glenormiston and Creswick (The University of Melbourne); and Healesville (Swinburne University). Reports from many of these sites indicate that activities are impeded by the absence of sufficient affordable bandwidth, particularly where CRCs are co-located;

- University staff and students are assigned to 70 rural health sites throughout Victoria. The relatively low bandwidth connections, typically 64Kbps, do not adequately support their research, teaching and learning functions, without considering the potential application of network resources to support the delivery of health services to rural communities.

Regional Western Australia

There are no universities in WA whose main campuses are located outside the Perth metropolitan area. However, each of the 5 universities has at least one regional campus, some being quite significant. There are (or are planned to be) some 24 sites in 16 towns spread right across WA, from Esperance and Kalgoorlie in the South and East, to Derby in the far North; the largest concentration is in the South-West corner of the State, an area equal in size itself to the whole of Victoria.

Western Australia has the longest distances and most remote centres of population of any state in Australia. Nevertheless, apart from a few locations (see below), the amount of activity (teaching, let alone research) at these sites is very small, and it is accepted that these are beyond the scope of the proposed AREN.

Recognising the special problems facing the networking of most of these remote sites, the 5 WA universities have been proactive in collaborating with the WA State Government in its successful bid for NetworkWA to the National Communications Fund. Even so, this grant may not be sufficient to bring access to adequate bandwidth within reach for many of these centres. Details of this scheme can be seen at http://www.uwa.edu.au/it/network/ncf

The most significant concentrations of university activity outside Perth are as follows (with road distances from Perth):

- Edith Cowan University: Bunbury (184 km) – shortly to be connected via a 34Mbps microwave link;
- Murdoch University: Rockingham (50 km) – connected via a 34Mbps microwave link;
- Murdoch University: Mandurah (75 km) – connected via a 34Mbps microwave link;
- Curtin University: Muresk (near Northam, 110 km) – connected via a 348Kbps Frame Relay link;
- Curtin University: Kalgoorlie (603 km) – connected via a 640Kbps Frame Relay link;
- UWA: Gingin (70 km) – currently connected via dial-up at an effective speed of ~4Kbps.

In all cases, there is some research activity at these locations (eg the Australian International Gravitational Research Centre (AIGO) is located at Gingin). In addition, UWA is a partner in two small research centres located in Albany (409 km).

Networking arrangements that have already been put in place to serve the needs of these sites are considered to be adequate for the time being in most cases (a significant exception being the link to Gingin). However, these will need to be kept under constant review, both because regional activity is expected to increase (in

keeping with various State and Commonwealth imperatives), and because existing provisions are not expected to scale well. It is also of some concern that there seem to be no affordable options for connecting really remote sites to Perth; for instance, the siting of Rural Clinical Schools in locations such as Derby (2,391 km), Broome (2,232 km), Port Hedland (1,635 km), Karratha (1,535 km), and Esperance (725 km) will inevitably lead to bandwidth demand that cannot be met. And the link to Gingin is becoming a matter of some urgency. It would appear that a microwave link may be the best option, possibly redeploying the units to be decommissioned when the Parnet Fibre Project is implemented. The funding required cannot be determined until such a study is undertaken, though it is likely to be in the order of $100,000 to obtain adequate bandwidth at affordable recurrent prices.

4.5.4. Remote

This section deals with university locations that are at substantial distances from other sites and are poorly served by network infrastructure but where significant research is undertaken.

Tasmania

At present there is only one undersea connection between Tasmania and the mainland and a commercial carrier owns this connection. The 'full-service' offers made for this service by the carrier imposes costs on Tasmanian institutions that are proportionally much higher than for many other universities on the mainland. While several potential projects to provide additional bandwidth to Tasmania are on the drawing board, at present there is no alternative to the carrier owned cable. AARNet currently subsidises the connection between Melbourne and the University of Tasmania to enable the university to maintain an AARNet PoP, however the premium price on accessing this connection means that the affordable level of bandwidth is less than optimal.

Northern Territory

Access to bandwidth for research institutions in the Northern Territory is problematical, because of similar reasons to that which apply for Tasmanian institutions and that is that a single carrier has the only available infrastructure. The Northern Territory University (NTU) can only gain access to a carrier managed service, rather than acquire long term access to dedicated fibre. Both AARNet and the Commonwealth, through the previous funding approvals, effectively subsidise NTU's access to limited bandwidth connections (6 Mbps).

The Committee acknowledges that the speed and affordability of the network link from the AARNet PoP in Sydney to NTU is an issue that is not satisfactory, but accepts that at the present time, there is no clear sustainable and affordable resolution.

The Committee acknowledges that while this may involve a continuation of the current arrangements (including the Commonwealth subsidy), the Committee's preference is for the negotiation of right of access, rather than to subsidise recurrent expenditure on access to services.

The development of an affordable solution for NTU will require the NT Government engaging with the Commonwealth on this issue in order to find a solution that aggregates traffic and encourages competition on the back-haul links from Darwin to other capital cities. The joint submission to the Committee from the Batchelor Institute of Indigenous Tertiary Education, the Menzies School of Health Research and the Northern Territory University provides a sound basis for the further consideration of possible options.

The Committee notes that there is an underlying issue in acquiring access to fibre or wavelengths where there is only one carrier who will only offer managed services. The

Committee views this as a competition issue and where there is no competing carrier, it believes that access to fibre or wavelengths should be provided on terms consistent with competitive markets and service levels required by the customer.

The Committee believes that when governments are providing supporting funds to major infrastructure developments (e.g. railways, power interconnect, pipelines) or major projects are submitted for government approval, governments should ensure that potential improvements in national telecommunications infrastructure and potential enhancement of the competitive environment are adequately considered in the project proposal.

4.5.5. International Capacity

Most fields of research are reliant on networks for collaboration and it has been estimated that approximately 70% of research now relies on networks involving global collaborations. However, Australia is falling behind in terms of intercontinental capacity compared to that between North America and Europe.

High capacity international links are necessary for Australian researchers to collaborate internationally and to effectively access expensive and/or unique research facilities located in other countries. In many cases, it would not be feasible or affordable to establish such facilities or instruments in Australia and without adequate affordable international capacity, Australia will not be globally competitive in critical fields of research.

European researchers benefit from the intense competition in the trans-Atlantic undersea cable market that results in very low prices for that capacity. A similar situation exists between the US mainland and Japan, where prices can be an order of magnitude cheaper than for Australia to the US.

The government funding agencies in Japan, Korea, Taiwan and Singapore have recognised the strategic benefits of international collaboration in research and are supporting high-capacity international links to improve their global competitiveness.

AARNet has been particularly successful over recent years in negotiating access to increased bandwidth via the trans-Pacific cables. Australian universities have 400Mbps of capacity to the international commodity Internet and an additional 310Mbps of capacity on the trans-Pacific Southern Cross Cable Network to connect Australian researchers to the advanced research and education networks of North America and other countries.

Despite the availability of this capacity, and considerable reductions in the unit cost of international traffic by 68% over the last 4 years, AARNet has not been able to keep pace with the international connectivity being provided to researchers in North America and Europe where connections are typically of the order of 10Gbps and funded largely by national or regional funding agencies.

Furthermore, Australian researchers must pay the full bi-directional cost for international traffic with North America whereas researchers in the US and Canada do not pay for international capacity. This anomaly is a legacy of the Internet having been invented in the US and, consequently, international connections do not even rate as an issue in North America. Australia is working through international forums to make international Internet charges fairer and more truly competitive.

This traffic charge impacts the way research can be conducted by Australian research organisations and has a detrimental impact on the location of large international databases and major international research facilities in Australia. For example, an Australian researcher pays approximately $50/Gbyte (2002) for AARNet traffic

compared with $2/Gbyte to ship a CD or no charge for a US researcher. Timeliness and responsiveness now dictate that sending a CD is no longer an alternative.

The AARNet connections to the rest of the world are through Sydney (Figure 5). There is a need for an alternative international connection to address both national and international resilience and latency especially for the Western Australian universities who have suffered outages of several hours.

There is also a need for international research and education bandwidth into South East Asia, both to serve the growing needs to communicate with the region and to deliver online education (see Section 5.1 on Growth Parameters), and to afford alternative routes to Europe and across Australia for resilience.

European researchers are as keen as Australian researchers to develop direct links between Australia, the Asia-Pacific region and Europe in an order to promote research collaboration and to reduce the US-centricity of the Internet.

Figure 5: AARNet International Links

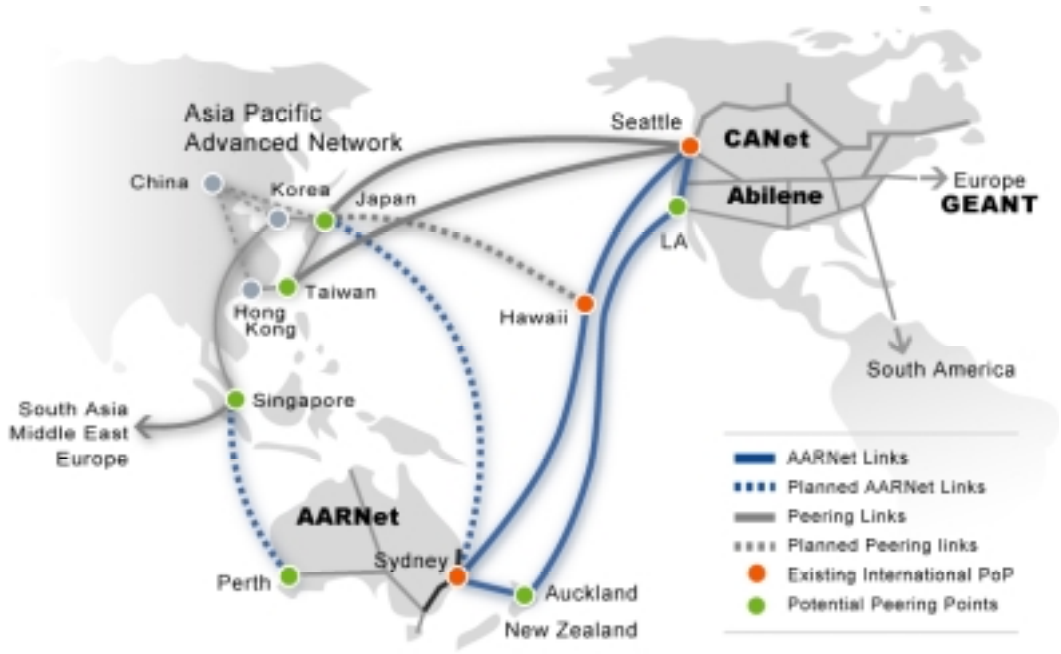


Table 4: Comparison of International Research and Education Bandwidth Capacities

Links	June 2002	Likely within 18 months
Between European countries	2.5-10Gbps	10Gbps
Europe - North America	2 x 2.5Gbps	2 x 10Gbps
North America - Japan	1.2Gbps	10Gbps
Japan - Korea	90Mbps	10Gbps
Korea - China	planned	10Gbps
China - Hong Kong	4Mbps	10Gbps
Hong Kong - Taiwan	Taiwan-Japan – 90Mbps	10Gbps
Korea - Singapore	2Mbps	10Gbps
Australia – North America	2 x 155Mbps	2 x 622Mbps
Australia - Japan	nil	155Mbps
Australia - Singapore	nil	155Mbps

Table 4 indicates the existing and planned research and education capacity on international links and contrasts this with the capacity on the Australian international links. Note the comparison of 155Mbps to 622Mbps for the Australia researcher compared with 10Gbps for many international colleagues and competitors. Australian governments and the research and education sector must see this as a serious issue to be addressed in order to keep pace with the leading research nations.

4.6. Network Development Issues

Many respondents have noted that the development of the networks providing bandwidth to the higher education sector has been fragmented and sub-optimal, as a consequence of the competitive process required of individual institutions to acquire funds for network expansion. While AARNET has provided some coordination, there are numerous cases where network enhancements have been undertaken outside the context of an integrated framework.

This clearly indicates that forcing users (the customers of the network services) into a competitive environment to acquire bandwidth capacity is unlikely to achieve the desired outcomes. The better way forward is to ensure that the users have a coordinated and collaborative approach to the market so that they can get maximum benefit from a competitive environment for telecommunications capacity and services.

While the networks were based on point to point microwave links, the competitive approach was workable however the move to fibre backbone loops interconnecting campuses independently of ownership now requires an integrated and collaborative approach. This sharing of capacity will also require a greater degree of standard with respect to network protocols.

5. Bandwidth Requirements for Research 2003-2005

5.1. Growth Parameters

The growth in demand for bandwidth is driven by a number of factors:

- Organic growth with ongoing education and research demands – historically a growth of about 50% per annum;
- The evolving collaborative research frameworks engendered by research funding processes; and
- The rapid globalisation of both research and development activities;
- The emergence of ICT infrastructure as a catalyst for new research methodologies and practices, referred to as eScience or eResearch.

Based on the first factor alone, it is expected that the demand for bandwidth will increase by an order of magnitude in the next five years. Even if the 50% pa growth figure is contested on the grounds that some of this may have come from increasing take-up of Internet use, which could now plateau, it is more than compensated by the increasing size of the typical data elements (eg text -> graphics -> audio -> video), and by totally new applications (such as Video-over-IP, Access Grids and Grid Computing).

In addition to the research drivers for increased bandwidth nationally and internationally, the support of a significant higher education 'export' sector in education places increased urgency on the development of international links of higher capacity, particularly to Asia. The recent projections for international students (on-shore and, increasingly, off-shore) made by IDP Education are as follows:

1987: 7,200
2001: 188,000
2025: 996,000

These projections support ongoing growth of 50% or more in demand. (See http://www.idp.com/aboutidp/mediacentre/november2002/article874.asp and http://www.abc.net.au/rn/science/ss/stories/s715503.htm - Anthony Bohm, Head of Planning and Research at IDP Education on Radio National, 2-Nov-02).

5.2. Feedback from Universities and Leading Researchers

All Vice-Chancellors were asked to canvass research futures and identify where a lack of bandwidth may be impeding research and, if appropriate, identify critical areas of research that will not proceed if appropriate bandwidth cannot be secured.

Thirty responses were received, many of which were very comprehensive. It was clear that some respondents had some difficulty in responding specifically to the questions asked given the limited timeframe and difficulties in identifying lost research opportunities or modified research practices that reduce efficiency and effectiveness. One respondent wrote "Our concern is that current and planned research is tempered by the availability of bandwidth" whilst the consolidated response from the Northern Territory research institutions reported that "researchers spend significant time to find ways to reduce dataset sizes so that they can be handled on existing network links. Information is lost in the non reversible data reduction process".

A number of universities identified regional research projects that could not proceed or were severely hampered due to the lack of broadband access in regional areas. The areas identified included tropical, desert and rural health research and education; marine and tropical environmental research; GIS and remote sensing; metrology, e-

astronomy; e-Australia connected communities; gravitational and seismic data sharing and agribusiness.

The metropolitan universities with good (by commercial standards) connectivity to AARNet identified the need for national and international gigabit connectivity to the advanced network infrastructure such as offered to participants in GrangeNet and CeNTIE.

Adelaide University identified the applications that are driving this demand to be research into computing and data grids, HPC grids, grid computing for environmental research, bio-informatics and bio-grids, high energy physics, GIS and satellite imagery, geology, geophysics, virtual astronomy observations and molecular modelling.

Monash University canvassed their research community through their Committee of Associate Deans (Research) to identify current or planned research activities that are being hindered by the absence of sufficient communications bandwidth between Monash University sites, within Victoria, nationally and internationally.

While most respondents were based on the major Monash campuses, the limited network connectivity available to both metropolitan and regional centres was also strongly noted.

The most common deficiencies identified related to:

- Accessing, updating, exchanging large data sets;
- Access to high performance computing;
- Visualisation and imaging services;
- Teleconferencing services supporting collaboration and real time data exchanges;
- Access to remote instruments;
- Access to online scientific journals;
- Research into grid services;
- Reliable data services to regional centres; and
- Simulations.

It is evident that high capacity bandwidth is a critical element to many important areas of research at universities such as Monash, including:

- Chemistry: quantum chemistry, molecular astrophysics, drug discovery, molecular biology, spectroscopy;
- Bioinformatics, biotechnology and biochemistry;
- Education: high definition multimedia;
- Electrical Engineering: tele-robotics, telecommunications;
- Fluid mechanics and fluid dynamics;
- Health informatics;
- Information technology: grid services;
- Mathematics and geoscience: simulation science;
- Medical informatics: remote diagnosis, robotic surgery;
- Physics: computational physics and computational materials science; and

- Rural health: telehealth, e-health.

The detailed responses, subject to the approval of the respective institutions, will be available on the DEST web site at www.dest.gov.au/

5.3. Emerging Applications Requiring High Bandwidth

A report was commissioned by the Committee to analyse the impact of such high-bandwidth interconnections on research outcomes across a range of disciplines, by taking current cutting-edge research projects in Australia and overseas, analysing their grid needs, and then forecasting these needs forward (see Attachment D).

The report also attempted to directly estimate the economic and scientific impact of high-bandwidth connections upon Australian universities and research institutes.

The focus of the report was *grid* applications. The benefits of high bandwidth networks were classified by both scientific area (e.g. biology, chemistry) and by grid type (e.g. data grid, grid computing, cooperating working environments and telepresence).

The study identified that the key discipline-specific use of high-speed grids will be for data grids and grid computing in the following disciplines:

- Astronomy and Physics;
- Biochemistry and Bioinformatics;
- Earth and Environmental Sciences; and
- Engineering.

The report concluded that:

- The need for grid computing as an enabling technology across all branches of science and engineering is clear;
- The need for growth in grid bandwidth is driven by the growth in very large data sets, and the need to combine large data sets from multiple sources or generate large local data sets (such as visualisation data) from those grid data sources;
- That waiting until an application appears that can “pay up front” for the bandwidth will mean many missed opportunities. The analogy with roads and highways is insightful. Building a highway will invariably generate more traffic and economic growth. But conversely, waiting until someone at a remote location is willing to pay for a highway to them will invariably lead to lost business and economic opportunities.

The Committee also approached 60 leading researchers and sought feedback on emerging research problems and collaborations that they will not be able to pursue due to limitations on bandwidth and communications services.

The issues identified (see Attachment D) included:

- Collaboration with overseas colleagues (especially US and Europe);
- Current limitations lead to inefficient practices such as:
  - Storing the same data sets at multiple locations;
  - Transferring data sets by mail;
  - Not much use of videoconferencing;
  - Tendency to acquire and use local computing systems (when others may be more efficient);

- The reliability, speed and security of communications services;
- A need for improved latency with the move to interactive and collaborative visualisation and shared virtual work environments;
- The dislocation and out time required for travelling where alternate communication and collaborative environments could be used, be it not for availability and cost.

The leading researchers identified the following trends in bandwidth use by international colleagues and competitors:

- Access to larger supercomputers, mass storage systems, and tera-grid facilities;
- Overseas centres will be generating large multi-gigabit files. Access to this data is difficult or prohibitive – need 100Mbps bandwidth;
- New approaches and tools being developed for interactive 3-D visualisation of remote data sets;
- Remote visualisation is becoming more important for access to large data sets;
- The size of bioinformatics data sets for example is doubling every year.

Some of the researchers were concerned that the uptake of these tools in Australia may be limited by communication costs.

5.4. Notional Bandwidth Targets for Strategic Planning

The Committee, informed by the above growth, current developments, identified deficiencies, future research requirements and international trends, has defined notional bandwidth targets, based on campus characteristics, for the next five years to assist in the development of a strategic framework to address university and research bandwidth requirements.

The targets are built upwards from the campus targets to targets for the national backbone and then international capacity.

These targets are for national strategic planning purposes only and the actual bandwidth deployed to individual campuses will be influenced by institutional decisions and the bandwidth provided will depend on a variety of factors.

5.4.1. Notional Campus Targets (2003-2005)

The notional targets per campus characteristics are as shown in Table 5 taking account of the qualifications above. The capacities in this table are being used as an indicator of communication services; in other words higher capacities will allow the use of more of the advanced communication services that are needed by the research communities.

These targets were tested against a sample of institutions in Queensland, NSW and Victoria, including metropolitan only, regional only and both metropolitan and regional institutions and do provide a rational basis for network planning.

Table 5: Notional Bandwidth Targets based on Campus Characteristics

Networked Computers	Research Staff and Students	Research Intensity	Minimum Target Capacity
<100		Low	Out of scope
100+	<200	Small	10+Mbps
500+	200+	Medium	100+Mbps
2000+	400+	Very high	1+Gbps

Institutions seeking capacity beyond these levels will need to define their needs as part of their research and teaching profile for a campus.

There will also be situations where it is appropriate to consider the capacity required by a precinct or a cluster rather than individual institutions. This type of situation would warrant aggregating the individual attributes.

The targets in Table 5 will need continuous assessment and revision, because of the rate of change in networking and the take-up of new bandwidth intensive research projects and approaches to research including collaboration.

The Committee recommends that the Minister note that target bandwidth capacity levels related to campus characteristics of research staff and students and the presence of major research facilities and concentrations, have been set for 2005 as the basis for ongoing strategic investments (Recd #7).

5.4.2. National Backbone Targets

The national AREN backbone must be dimensioned to support the load imposed by the actual capacity utilised by each campus. The actual backbone capacity will be determined by the concentration of research and education activities in each region and the traffic volumes across each segment of the backbone and the number of network overlays supported (see Figure 6). The actual dimensioning will be informed by monitoring usage however local and overseas experience suggests that the national backbone will need to evolve from 300Mb to 10Gbps during the next three years.

5.4.3. International Targets

The AREN must keep pace and be a component of the Global Terabit Research Network (GTRN) to ensure that Australian researchers have affordable international capacity comparable with international colleagues and competitors. Based on overseas experience and the strategies of the international research network in North America, Europe and SE Asia, the AREN will need to provide international links to our main research and education targets that will be in the order of multiple 10Gbps connections.

6. The Proposition - An Australian Research and Education Network (AREN)

6.1. A Strategic Approach

Broadband communications is the key infrastructure of the 21st century, just as rail was in the 19th century and electricity and roads in the 20th century. In the immature stages of the development of key infrastructure networks, when the demand is uncertain and a competitive market has not emerged, government investment plays a key role in establishing the embryonic networks.

In this context the significant points to be drawn from the history of the development of the Internet in Australia are:

- The commercial Internet emerged from the research and education sector and will continue to be fuelled by the requirements of this sector (e.g. security, quality of service, transaction processing);
- Innovative and advanced services tend to be incubated on the national research and education networks prior to delivery on the commodity Internet;
- Universities are intense breeding grounds for business, industry, government and community consumers of bandwidth as their students graduate as network-literate and bandwidth demanding;
- The sector is a significant provider of services to the commodity Internet, which is growing in importance.

Universities acting alone cannot meet the current and future requirements for bandwidth to address the current deficiencies and future demands from high-end research nor can the sector wide requirements be met by an ad-hoc or competitive approach.

The current and future needs for broadband capacity to support research and education must be addressed within an overarching strategic framework instead of through competitive grants programs typically used for research infrastructure. The process for addressing these needs must be consistent with national competition principles. This can be achieved within the proposed strategic approach.

The strategic approach results from the need to integrate the needs of many institutions, and the data exchanges between the institutions, to create an effective and efficiently funded network. The development of this strategic framework will require a stable and ongoing partnership between universities, and between the higher education sector and the Commonwealth and State governments.

This framework is referred to as the **Australian Research and Education Network (AREN)** framework.

AREN will be developed as a “private network” serving the research and education communities associated with the higher education sector.

The AREN in the future will be part of a national and a global innovation infrastructure (i.e. the Global Terabit Research Network) that will facilitate Australian researchers, regardless of how remote their location or employment in universities, research organisations and industry, to be full participants in collaborative research as well as the development and use of innovative applications and services.

The AREN is a critical component of a broader strategy for broadband communications in Australia. There are considerable national benefits that are to be derived from a globally interconnected AREN but this is unlikely to be achieved in the long term without substantial provision of funding by the Commonwealth government as a key component of research funding in the higher education sector.

While much of the discussion of this report is related to research, the nexus between teaching and research in the higher education sector will result in AREN serving both needs.

6.2. Key Objectives and Principles of the AREN

The Committee has developed a set of objectives to be met by the AREN organisation and a set of principles to underpin the development of strategy, priority setting, operation and management (see more detail in Appendix F: The Role of the Australian Research and Education Network).

The objectives and priorities of the AREN will be developed with reference to complementary frameworks, including any similar initiatives in the health and education sectors, to maximise the alignment of strategic outcomes.

The objectives of the AREN organisation are:

- Provide leadership and expertise in the national advanced network agenda supporting Australian innovation, social transformations and productivity improvements;
- Provide a platform for the development and use of advanced network services by the research and education community in Australia;
- Enable Australian researchers to participate in collaborative research projects on the international stage and access global cyber-infrastructure including supporting access to advanced computing and *grid* services;
- Provide the infrastructure to support the development, sharing and delivery of innovative online education content and applications nationally and internationally and the development of learning and research communities across Australia;
- Facilitate access to national and international information resources to optimise the efforts of researchers to create, manage, discover and disseminate knowledge;
- Represent Australia's interests in the global advanced network forums and play a lead role in the development of Asia Pacific advanced networks.

The operating principles within which the AREN organisation will achieve its objectives are:

- A strategic and a coordinated approach will underpin the deployment of new advanced network infrastructure;
- Affordable access should be available to all members of the research and education community regardless of location;
- Innovative broadband infrastructure, technologies, applications, content and services deployed on the AREN network should be diffused where appropriate into the Australian commodity Internet;
- The advanced research and education network will contribute to the competitive data communications environment within and from/to Australia.

The Committee recommends that the Minister endorse the creation of the Australian Research and Education Network (AREN), as a next generation AARNet, to provide the bandwidth needs of researchers associated with the higher education sector (Recd. #1).

The Committee recommends that AREN services and capacity be made available to the Australian higher education sector and the wider research community (Recd. #2)

6.3. Building an Australian Education and Research Network

6.3.1. A Collaborative Approach Needed

AREN is effectively a network of networks, in which networks at international, national, regional and precinct level are integrated into a consistent and cohesive framework to underpin research and education in Australia.

The critical nature of the infrastructure foundation of AREN, coupled with the distributed nature of the research capabilities and the geographic distances involved, clearly demands that the investments in the network infrastructure be made in accord with a consistent strategic plan and in accord with priorities established in that plan.

Clearly this can occur only with strong and sustained collaboration between stakeholders in AREN, and with a consistent and robust process for developing, reviewing and revising the plan. In this respect it is important that the provision of bandwidth to researchers and educators in the higher education sector is seen as a key and priority infrastructure by universities. To ensure that appropriate recognition of this occurs and that adequate data is available to review and develop AREN, it is critically important that the bandwidth needs of each campus are linked to the teaching and research strategies and activities contained in the universities strategic plans.

The Committee recommends that the Australian Vice-Chancellors' Committee be asked to stress to its members the critical importance of linking the bandwidth needs of each campus to its research and teaching activities by ensuring that each institution's bandwidth requirements are specifically addressed in its strategic planning processes (Recd. #6).

6.3.2. Developing the Strategic Plan – The Role of ARENAC

Given the diverse stakeholders in AREN – researchers and educators, universities, Commonwealth Government, State and Territory Governments – and the potential interactions between AREN and other sector and regional networks, it is essential that a formal process and structure for strategic planning of network evolution, in which stakeholders are involved and consulted, is established.

It is proposed that a broadly based advisory body which can provide investors (e.g. Australian governments, institutions) with up to date, realistic and timely advice on how to establish, maintain and upgrade our national research and education network capability, be established.

Such a body would have the role of continually monitoring and advising on:

- The networking needs of the sector;
- Opportunities for cost-effective investment in capacity;
- The opportunities provided by developments in technology;
- Evolving the concept and the vision of the AREN; and

- Key initiatives being taken by comparable overseas countries and their implications for Australia.

This Australian Research and Education Network Advisory Committee (ARENAC) would consist of an independent chair and representatives of the Australian Vice Chancellors Committee, the Australian Research Council, NHMRC, CSIRO, CAUDIT, DCITA, DEST, and the company that will manage the AREN (see section 6.3.4).

This committee would need in its considerations to consult widely with relevant State and Territory Governments and their instrumentalities and departments, and with research and educator user groups, such as APAC, CRC Association, etc.

As noted in Section 6.3.1, to ensure that adequate data is available to review and develop AREN, it is critically important that the bandwidth needs of each campus are linked to the teaching and research strategies and activities contained in the universities strategic plans.

The committee would report to stakeholders on the current, future and evolving needs for developing AREN. It would also provide recommendations to funding bodies on the extent and priorities for investment in the development of AREN to ensure its capacity to service the needs of researchers and educators is sustained.

ARENAC would need a small permanent secretariat, probably consisting of one project officer, to enable it to carry out its functions.

The Committee recommends that the Australian Research and Education Network Advisory Committee (ARENAC) be established to:

provide considered advice to investors (Commonwealth, State and Territory governments and research institutions) about the priorities for investment in the further development of the network domestically and internationally; and

provide strategic directions about the development of the network for the AREN managing company, based on the identified needs of researchers and the investors priorities, using the notional bandwidth targets for campuses and research facilities developed by the Committee as a guide *(Recd. #3).*

6.3.3. Investing in AREN

The effective and efficient evolution of AREN will depend on strong collaboration between the stakeholders – the Commonwealth, State and Territory Governments and universities. The Commonwealth has a key role in providing funds to ensure that appropriate strategic decisions are encouraged. However investment by other governments and universities will be necessary to leverage Commonwealth funds to achieve optimal outcomes for AREN.

In addition, while Commonwealth Government investment will be crucial to ensure that AREN evolves in a strategic framework, it is recognised that individual States may seek to maximise the return to State communities by making additional investment to extend the capability of infrastructure to serve wider community needs, beyond that of the higher education sector. Similarly individual universities may wish to make individual investments to increase capacity or to extend the network to serve their particular strategic needs. Such investment should be encouraged.

However, benefits accruing to the higher education sector from investments in AREN will be maximised if *all* investments, be they by Commonwealth, State or Territory Governments, or by research institutions, are made in a coordinated manner using ARENAC as a collaborative mechanism to ensure strategic imperatives are satisfied. It is important that all proposed investments in AREN are consistent with the advice provided by ARENAC. In this respect it is important that all Commonwealth

investments in provision of bandwidth to the higher education sector be consistent with the strategic plan formulated by ARENAC.

The Committee recommends that the Minister note that continuing investment in AREN by all stakeholders, including governments and research institutions using the network, will be necessary to maintain its capability to serve the national and international research infrastructure needs of the higher education sector and directs ARENAC and ARENMC to explore options to ensure the long term viability of the network (Recd #5).

6.3.4. Managing the AREN –The Role of ARENMC

To ensure that AREN is managed in a consistent, responsive and flexible manner, it is proposed that a not for profit company owned by the sector would be established which would have the role of managing the AREN on an ongoing basis. The overall mission of the company would be to provide the highest possible quality networking services to the Australian higher education and research sector. Its specific roles would include:

- To establish standards of service and protocol standards;
- To manage core facilities;
- To undertake facilities management on behalf of participants;
- To ensure interoperability with other networks;
- To acquire facilities required by the Strategic Plan;
- To maintain currency of facilities – upgrades etc.;
- To identify opportunities for enhancement of network.

This company is similar conceptually to AARNet. However, contractual arrangements with the funding organisations, and the formal interactions with ARENAC would need to be agreed for AARNet to undertake the role of ARENMC. The company would be expected to operate within the telecommunications regulatory framework, and, as with AARNet, it is likely to require a telecommunications carrier licence.

It is envisaged that any decisions for major capital investment would occur only with the concurrence of ARENAC to ensure that these decisions are aligned with the strategic plan. It is also envisaged that ARENMC would be responsible for decisions to make those investments from its own funds that are necessary to ensure currency of technology and achievement of service requirements.

However, there is a need to ensure that the network can evolve in a flexible and agile manner in response to opportunities provided by other investment decisions and in response to evolving needs of user communities and campuses. ARENMC would have the responsibility to inform ARENAC of the evolving opportunities to achieve the strategic outcomes.

The Committee recommends that an AREN managing company (ARENMC) be established to manage the network within the broad strategic priorities identified by the ARENAC and that, subject to conditions to be negotiated, AARNet Pty Ltd be requested to undertake this role (Recd #4).

6.3.5. The Role of Regional Educational Networks

The AREN as a network of networks includes the regional networks and as such the ARENAC and ARENMC must be supported by active and effective state Research and Education Network organisations (RENs). The RENs must be seen as an integral part of the environment.

The assets (e.g. cables, ducts, active equipment, space, towers) that make up the AREN network irrespective of the source of funds used to acquire the assets will be normally held by ARENMC. For instance assets that make up the AREN may be held by ARENMC “in trust” for the RENs or alternatively held “in trust” by a REN member university or research organisation.

6.4. The Architecture of the AREN

The AREN consists of a robust physical infrastructure supporting a number of logical networks that in turn support a range of advanced network services. These advanced services provide researchers with the tools to conduct research in new and exciting ways (e.g. eScience) and allow educators to develop online content and access the information infrastructure.

The robust physical infrastructure integrates a variety of physical networks that may be defined by different technologies on one hand or are geographically defined on the other (e.g. regional networks).

The components that together comprise the robust physical infrastructure must have the following attributes: cohesive, interconnected, flexible and evolving.

The design of the robust physical infrastructure must be as fundamental as possible to ensure that very few limitations are imposed on the development of logical network overlays including experimental networks. Furthermore, the capacity of the robust physical infrastructure must significantly exceed the actual capacity needed so that the flexibility to build and modify the logical networks is not inhibited.

The interconnected nature of the AREN both horizontally in terms of physical technologies and low level protocols or geographic scope and vertically in terms of the logical networks and advanced services demand a strategic approach as a poor decision at the physical level can impact on the overall utility of the AREN.

Simply, the AREN is not a single network but a network of networks (see Figure 6) with the ability for permanent and dynamic logical networks to be added or removed without a need to intervene at the physical layer.

The focus of this report is the design, funding, construction, management and evolution of this robust national network infrastructure with parallel international connections.

Figure 6 – Multiple Independent Networks Operating over Common Infrastructure

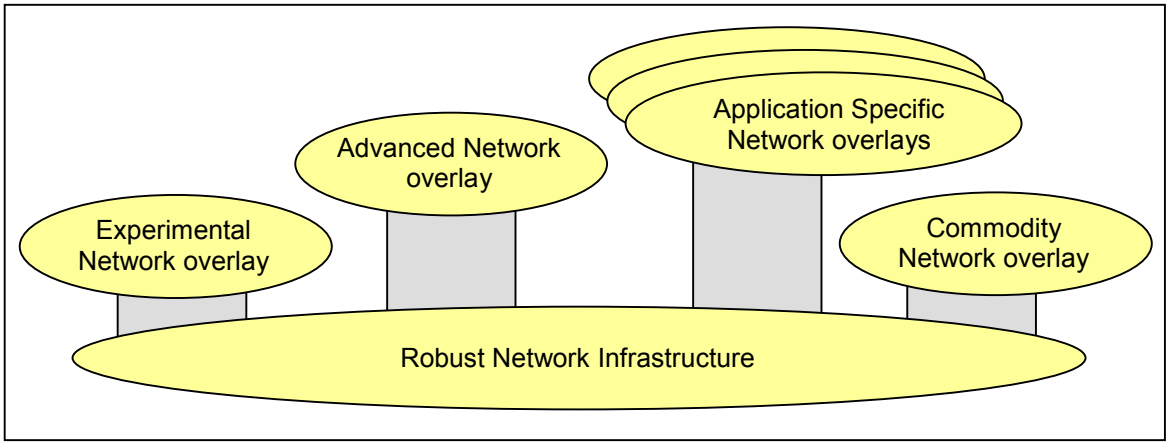


Figure 6 illustrates four network environments that are required as part of the AREN:

- Experimental networks;
- Advanced networks;
- Application specific networks; and the
- Commodity Internet.

The requirements of these environments are summarised in Table 6.

Table 6 – Overview of the AREN Service Attributes by Service Category

Services Attribute	The Experimental Network	Advanced Services	Application Specific Services	(AREN) "Commodity" Internet Service
	Experimental	← ← ←	→ → →	Production
Performance levels	High but unpredictable	High and predictable	Above Medium and predictable	Medium and unpredictable
Performance level guarantees	None	Clearly defined and achieved targets	Clearly defined and achieved	Often assumed high, but actually no guarantees
System vulnerability to individual user action	Aim for low	Required low	High	High
Capacity	100Gbps+	10Gbps+	1Gbps+	100+Mbps

The "Network Infrastructure" (depending on geography, availability, need and cost) can be any of (or a mixture of) dark fibre or wavelengths together with capacity from one or more commercial suppliers.

"Robust" in this context means that the "Infrastructure" has attributes such as quality of service management; mesh management and support for multiple independent network environments.

Fortunately, the needs of experimentation and advanced production services can be met by running multiple independent network operations overlaid on a common network infrastructure as shown in Figure 6.

Figure 6 also demonstrates how several autonomous networks can co-exist on common infrastructure such as separate but integrated networks for each university or a separate health network or an application specific network for say grid computing or networked radio-telescopes.

This powerful concept will allow each network environment if necessary to be operated autonomously largely by separate people; using different technologies and systems; and to different performance targets.

6.5. The AREN Conceptual Backbone

The approach to building the national research and education backbone has to date been tactical rather than strategic because funds for single projects only were available through usually competitive processes. This has limited the sector to solving problems on an institution or campus basis as opportunities arise.

While this approach has enabled significant progress to be achieved, the Committee believes that the opportunity now exists to approach the provision of bandwidth on a *network* basis as opposed to individual connections.

The *network* approach seeks to identify the optimal approach to connecting all university campuses and where practicable providing network resilience. Note that whilst deficiencies were predominately identified at the campus level, the optimal solution is a network problem so that cost is minimised and resilience is maximised.

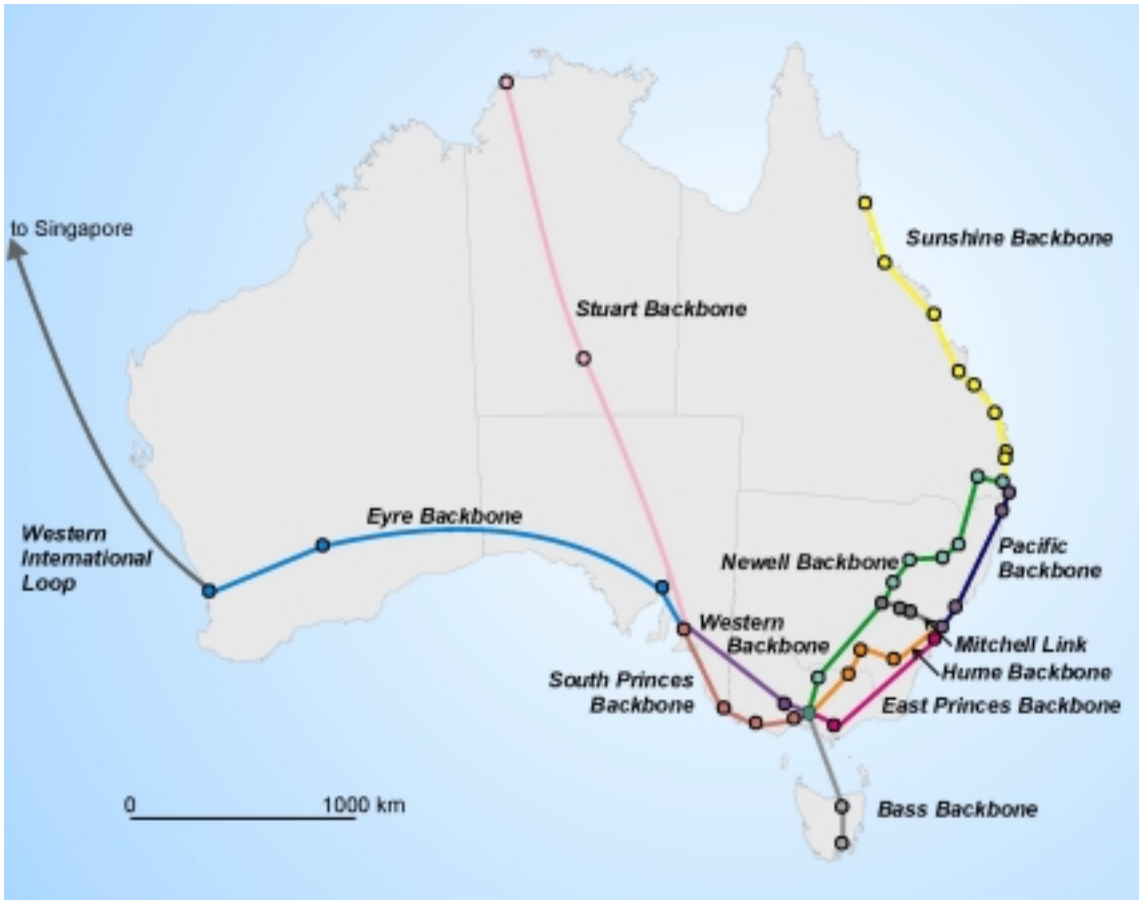
A conceptual approach is proposed as follows:

1. Establish a *Sunshine Backbone* from Brisbane to Cairns connecting Cairns (JCU), Townsville (JCU), Mackay (CQU), Rockhampton (CQU), Gladstone (CQU), Bundaberg (CQU), Wide Bay (USQ) and Sunshine Coast (USC);
2. Establish a *Pacific Backbone* from Brisbane to Sydney connecting Gold Coast (Griffith University and Bond University), Tweed Heads (SCU), Lismore (SCU), Newcastle (Newcastle University at Callaghan) and Ourimbah (Newcastle University) with the possibility of connecting Coffs Harbour (SCU), Port Macquarie (SCU) and Taree (UNE);
3. Establish a *Newell Backbone* from Brisbane to Melbourne through USQ (Toowoomba), Armidale (UNE), Tamworth (UNE), Coonabarabran (Radio Telescopes), Dubbo (CSU and Sydney University Rural Health), Parkes (Telescope) and Shepparton (La Trobe University);
4. Establish a *Mitchell Link* from Sydney through Bathurst (CSU) and Orange to connect with the Newell backbone at Parkes;
5. Establish a *Hume Backbone* from Sydney to Melbourne connecting Canberra (ANU, University of Canberra), Moss Vale (Wollongong University), Goulburn (CSU), Wagga (CSU) and Albury/Wodonga (CSU, La Trobe);
6. Establish an *East Princes Backbone* from Sydney to Melbourne through Wollongong (Wollongong University) and Gippsland (Monash at Churchill) with the possibility of connecting the Wollongong University campuses at Shoalhaven, Batemans Bay and Bega;
7. Establish a *South Princes Backbone* from Melbourne to Adelaide through Geelong (Deakin), Warrnambool (Deakin) and Mount Gambier (Flinders University);
8. Establish a *Western Backbone* from Melbourne to Adelaide through Ballarat (University of Ballarat);
9. Establish an *Eyre Backbone* from Adelaide to Perth through Whyalla (University of SA), and Kalgoorlie (Curtin University);
10. Establish a *Bass Backbone* from Melbourne to Hobart through Launceston (University of Tasmania);
11. Establish a *Stuart Backbone* from Adelaide to Darwin through Alice Springs (NTU and Flinders) to Darwin (NTU, Batchelor College);
12. Establish a *Western International Link* from Perth through Singapore to SE Asia and Europe.

This approach has been tested to demonstrate that the major campuses are in reasonable proximity to the backbones and therefore should be capable of being connected economically. There are numerous smaller campuses that appear to be in reasonable proximity but not all smaller campuses have been matched against the conceptual backbone.

It should be noted that the routes are indicative and when final routes are determined at the project implementation stage the feasibility of directly connecting smaller campuses will be assessed to determine whether additional campus specific extensions are required.

Figure 7: Conceptual AREN Backbone



These major backbone conceptual routes would need to be further defined in the context of available infrastructure and evolving opportunities to ensure that campuses with significant research and education activity are connected economically to AREN.

7. The Operation of the AREN

7.1. National Infrastructure

The national AREN infrastructure (see Figure 7) must be developed in a coordinated manner within the strategic framework developed and managed by ARENAC who would keep the strategy under review in respect of typology, capacity and technology.

Commonwealth investments would be in the main targeted at addressing the access issue in order to reduce the cost of providing access (capacity provision) by acquiring rights to network elements, with recurrent costs in general being met by the members in the form of traffic charges.

7.2. People

The construction of the AREN must be accompanied by the necessary skilled staff to develop, deploy and operate the networks and advanced communication services. It should be noted (see Section 4.2.3) that many of these people are available in the existing RNOs that will evolve into new state research and education networks (RENs).

The movement along the AREN continuum from the experimental networks to the advanced and commodity networks will require not only a robust network infrastructure but the skilled people to develop and support the logical networks and the advanced communication services.

Substantial and ongoing research and development must be undertaken to improve the current network services and develop the next generation of network services. There is substantial effort required to ensure that data networks are reliable let alone deliver the new services that will be required.

Examples of technologies and services that need development are:

- Quality of Service (QoS) Capability;
- Next Generation Internet Protocol Service (e.g. IPv6);
- Traffic Engineering;
- End-End Performance;
- Multicast;
- Security;
- Access, Authorisation, and Accounting;
- Measurement and Monitoring;
- Caching and Content Distribution.

Funds will continue to be required, in addition to financial support to establish and evolve the AREN infrastructure, to ensure that the advanced services and higher-level technologies are available to enable researchers to take full advantage of the AREN. Funds will be available as required to the State RENs and their member institutions to provide the support; focus and feedback required to properly address ongoing research requirements and needs.

The development of this skills base is of national importance outside the higher education sector, as the skilled personnel developed in AREN will be critical to the achievement of broadband agendas by other sectors.

7.3. Implementation Issues

7.3.1. Charging for Capacity and Usage

It is envisaged that the AREN charging policy would encourage productive usage through mechanisms such as introducing a fixed capacity charge that reflects the minor capital works and the capital employed to enable the network to sustain itself apart from the major enhancements.

Traffic charges would loosely match operating costs so the gigabit traffic costs are kept as low as possible to encourage researchers to use the AREN.

The policy must encourage responsible usage and mechanisms will need to be considered to make very low cost capacity available to researchers with for example large-scale datasets at times of low utilisation.

7.3.2. Connection of Small Sites

The focus of the AREN is the major campuses of all Australian universities and publicly funded research organisations not small satellite campuses or study centres of universities or research organisations.

The reason is because it is not possible at this stage to address, at a national level, the advanced network connectivity to all university sites – institutions must prioritise (financial realism). The notional targets in Table 5 as revised over time will assist with this issue.

However opportunities to provide advanced connectivity to these sites will be taken up where it is rational to do so to optimise opportunities (eg. an inland route Sydney to Brisbane passing nearby to smaller regional activities). This capability is a strength of the proposed AREN advisory and management structure.

Other sources of funds will be required where it is desirable to go beyond the major campus policy.

7.3.3. Membership of the AREN

Membership rules and acceptable use policies will be developed from the current AARNet policies to ensure users of the AREN are research institutions or researchers and education communities associated with the higher education sector (see AARNet Access Policies at http://www.aarnet.edu.au/about/accesspolicy/index.html).

Institutions in the higher education sector should be offered the opportunity to participate in AREN from its inception. Members who wish to benefit from the AREN broadband connection will be required to enter into a long-term contract with AREN for provision of capacity to minimise the potential for stranded investments. A subscription to join may be required for any members who are not ‘foundation’ members.

7.3.4. Regional Aggregation

AREN policies such as charging and acceptable use must encourage aggregation within the sector at the regional level.

However the approach to aggregation must be consistent with the strategic framework and recognise that demand aggregation in the broadband context is about creating the business case for investment, not simply about attempting to bring together the dollar expenditure of multiple organisations or sectors on a common set of products or services in order to drive the cost/unit down. Once the investment is made, it is

necessary and important that the aggregated demands are dissected into cohesive 'product' sets or sectors, with appropriate charging regimes for each 'product' or sector.

7.4. Collaboration

7.4.1. Collaboration with State Research and Education Network Organisations (RENs)

The RENs are extremely important in the development and on-going evolution of the AREN. They must be nurtured and developed further to both plan and support local tail connections to the AREN backbone as well as providing regional knowledge and plans into the AREN framework. Many universities already pay permanent staff to manage their AARNet connectivity and this forms part of the contribution that universities can make towards AREN operations (see section 7.2).

However it is not envisaged that the RENs would necessarily own assets themselves or need to be incorporated.

7.4.2. ANP Collaboration

The GrangeNet and CeNTIE projects are similar to the experimental and advanced networks in the AREN conceptualisation. They are building network components that are comparable to the AREN robust network infrastructure concept, however the approach is different in that these components are intended to carry research or pre-commercial traffic only, and not all institutions will have direct access. The precise nature and extent of collaboration between the ANP projects and the AREN will be subject to further discussion between the key participants.

The Committee would anticipate that, in future cycles of advanced networking initiatives, the AREN would be well placed to deliver the robust network infrastructure needed to support such research projects and test-beds.

This approach will ensure that the AREN evolves in a manner that is informed by and consistent with the outcomes of future advanced networking initiatives and that these initiatives contribute directly to the development and evolution of the AREN. For example, the network overlays in Figure 6 evolve from the experimental network overlays on the left of the diagram to the advanced and commodity overlays to the middle and far right respectively.

Whilst these research initiatives should be part of the overall AREN strategy, they may be managed in a different way to the AREN itself but will recognise the overall context.

The Committee recommends that the Minister write to his Ministerial colleague Senator Alston and raise with him the need to explore opportunities to establish a formal relationship between the ANPs and the ARENAC to build on existing collaboration (Recd. #8)

7.4.3. Collaboration with other Education Sectors

The Committee recognises the need for the AREN to assist other education sectors such as VET and schools, and the ARENMC would develop relationships and engage in active consultation with state and territory governments to monitor and explore synergies, and identify opportunities to assist other participants within the education sector, where there is a net benefit to AREN members without compromising the principles and objectives of the AREN.

However, it is considered that the conceptual model of AREN is widely applicable to cohesive sectors, such as the VET sector.

7.4.4. Collaborative Research with Industry

The AREN core infrastructure has the potential to be used more widely but the strategic objectives may become more difficult to achieve if the clientele is too broad. This issue will need to be managed within acceptable use policies.

7.5. Interactions

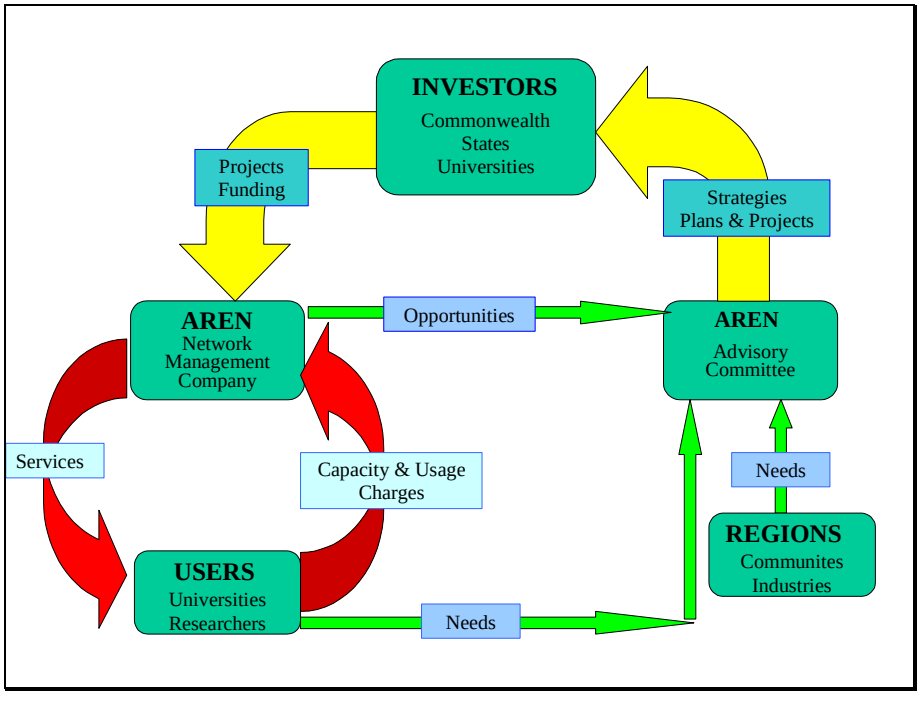
The interaction of ARENAC, in its role as a strategic advisor to the investors in AREN, and of ARENMC, in its role as mangers of AREN, with the investing stakeholders, with users of AREN, and with a broader suite of organisations and communities of interest who are potential collaborators with AREN, is shown in Figure 8.

It is envisaged that the processes of ARENAC will be informed by a broad-ranging interaction with the higher education sector, with potential collaborators, and with the various Australian Governments, so that the strategic propositions and plans presented to the stakeholders are broadly based. Of particular importance is the identification for ARENAC of opportunities arising through the on-going interaction between ARENMC and its clients and suppliers.

It is expected that following receipt from ARENAC of strategic positioning proposals and plans, including recommendations of priorities, the investing stakeholders would make decisions as to the investments to be made, and would contract with and fund ARENMC to undertake the necessary actions to achieve the outcomes desired. The recommendations of ARENAC would in general be outcomes focussed, rather than involve prescriptive detail of projects, to allow ARENMC to seek the most cost-effective solutions.

As noted previously it is essential that ARENMC has in place an appropriate charging regime for services and capacity provided, so that the organisation can sustain and keep technologically current the investments made in AREN. The funds invested after consideration of the ARENAC recommendations should be aimed predominantly at major capability and capacity improvement.

Figure 8: AREN Interactions



8. The AREN Program of Works

8.1. Establishment of Priorities

The program of works will be developed in the context of the Conceptual AREN Backbone (see Section 6.5). However, the scope, timing and improved costing of the consequent projects to be implemented will be determined by strategic priorities and the opportunity to leverage existing and planned fibre deployments by the commercial carriers and utility companies.

The Committee agreed on the immediate priorities, these are in section 8.2 with more detail in section 8.2.1. Other elements of the AREN requiring funding have been assigned indicative priorities only and these are described in section 8.3.

The Committee has also identified a number of requirements that will need to be addressed within the recommended AREN framework. It has provided indicative estimates of the timeframe in which these requirements should be addressed. However this list of requirements is not complete and is not to be interpreted as assigning specific priorities to the projects listed. The ARENAC will need to undertake a comprehensive information gathering and analysis process as part of prioritising and costing these and other requirements that could not be investigated within the timeframe of this report.

8.2. Priorities for Immediate Funding 2002

The Committee has identified a number of immediate deficiencies and has recommended a solution where it was aware of an opportunity to resolve the deficiency in a sustainable and strategic manner or alternatively the Committee has recommended a process to advance the identification of a solution to the deficiency.

The Committee agreed after the analysis of the deficiencies (see Section 4.5 Identified Deficiencies) that the main areas needing priority attention are:

1. Regional Queensland back to AARNet PoP in Brisbane (The Sunshine Backbone);
2. Hobart to AARNet PoP in Melbourne (the Bass Backbone);
3. Northern Territory to AARNet PoP in Sydney (the Stuart Backbone);
4. Northern NSW (the specific issues relating to SCU deficiencies).

The Committee recommends that the Minister agree that there is a high priority to address the provision of bandwidth as follows:

the establishment of a sustainable link between Tasmania and the mainland;

the upgrading of the capacity of the connection of Northern Territory University to AARNet;

the upgrading of the capacity of the links between the Brisbane AARNET PoP and Regional Queensland campuses;

the upgrading of the connections to Southern Cross University; and

that the Minister agree that ARENAC initiate as a matter of priority a process for resolving these issues which will involve discussions between stakeholders, including Commonwealth and State and Territory governments, institutions and AARNet or the ARENMC (Recd. #9).

8.2.1. Statement of Works

The whole scope of works for these areas of immediate priority is set out in this section for clarity. However in a number of cases significant further work needs to be undertaken before a firm and final recommendation is made. The specific recommendations below therefore relate to actions to be taken immediately rather than to the full implementation of the particular segments of the AREN network.

The Sunshine Backbone

AARNet and the QRNO are working with the major Queensland energy company to develop a sustainable bandwidth solution for the coastal university campuses from Cairns to Brisbane.

This initiative will provide a 2.5Gbps trunk from Brisbane to Cairns connecting Central Queensland University (Rockhampton) immediately, James Cook University (Townsville) by the end of 2003 and the University of Southern Queensland (Toowoomba) by the end of 2004. The connection of the James Cook University (Cairns campus) is subject to further discussions as it may not be available until 2006.

The only viable and sustainable option for the connection of the University of Sunshine Coast (Sippy Downs) and University of Southern Queensland (Hervey Bay) to the AARNet Brisbane PoP (at this stage) is microwave at a capital cost of $180,000 and $364,000 respectively and this and other options will be explored in detail.

The estimated cost of the Sunshine Backbone is $7.5M.

Stuart Backbone

The Committee concludes that there is little that can be achieved in the short to medium term and continued use of carrier services is possibly the only solution to connecting the AARNet PoP in Darwin to the AARNet PoP in Sydney in the immediate future. AARNet is seeking improved carrier pricing but the possibility of a sustainable solution offering an immediate significant capacity upgrade to NTU is unlikely.

Integration of the needs for bandwidth in the Northern Territory of the higher education sector, the Territory Government, and the Commonwealth Government (including Defence, CSIRO, remote community health and other needs) may provide a catalyst for change, and should be investigated. Integration of these needs with the requirements of major infrastructure projects, such as rail, port and gas developments, may offer additional advantages.

Bass Backbone

The Tasmanian AARNet PoP in Hobart is connected to the AARNet POP in Melbourne via carrier capacity. The cost of this link makes it financially impossible to provide bandwidth to research organisations in Tasmania that is comparable to their sister organisations in mainland capitals.

Discussions are being held with a consortium considering the business case for a microwave solution across Bass Strait and also with the Basslink project sponsors. However the assessment is that a substantial increase in bandwidth in the near future at affordable prices is unlikely.

The only option at present is to subsidise limited carrier capacity.

Southern Cross University Issues

Southern Cross University (SCU) have an immediate problem as they currently use carrier services to connect each campus (Lismore, Coffs Harbour, Tweed Heads) to each other and to the commodity Internet. The cost of these connections was subsidised by the Commonwealth for two years under the same initiative as the Queensland regional universities and the NTU link.

One possible solution to the SCU issues is the construction of the Brisbane to Lismore segment of the Pacific Backbone. The Committee wishes to encourage a detailed investigation of the options and the development of a specific project proposal.

Table 7: AREN Statement of Initial Works

Project (see Model S6.5)	**Activity**	**2003**	**2004**	**2005**
1. **Sunshine Backbone Detailed Plan**	Progress Sunshine Backbone Project	X		
2. **Stuart Backbone Investigations**	Continue DEST subsidy Initiate Commonwealth and NT Government Investigation of Options	X X	X	
3. **Bass Backbone Investigation**	Initiate Commonwealth and Tasmanian Government Investigation of Options	X		

8.2.2. Services Acquired from Commercial Telecommunications Carriers

The particular cases of providing bandwidth access for Tasmanian and Northern Territory higher education institutions, as outlined in the previous section, are examples of a general problem faced in providing bandwidth to remote campuses, generally in the situation where there is only one supplier of services and competitive pressures do not exist. This results typically in offers of a 'fully managed service' more relevant to general telecommunications traffic, rather than the specific traffic needs of the higher education sector research. These sector needs are generally for an 'unmanaged service' or for capacity under an indefeasible right to use (IRU), which can then managed by ARENMC on behalf of the sector. Historically this has provided a lower cost to the sector, as unnecessary commercial management services are not charged to the sector.

Addressing the remote campus issue will require ARENMC to negotiate a position and contract with the commercial carrier for unmanaged services or an IRU.

The Committee recommends that the Minister note that addressing the remote campus issue will require ARENMC to negotiate appropriate access to capacity on an unmanaged service basis (Recd. #11).

8.3. Program of Works 2003-2004

An indicative program of works is set out in this section

The Committee recommends that the Minister note the conceptual AREN framework and indicative program of works outlined in the report, and request ARENAC to bring forward detailed recommendations of priorities for funding in future years (Recd. #12).

8.3.1. Non-Metropolitan Program

Pacific Backbone

The University of Newcastle needs gigabit capacity to replace the heavily loaded microwave link that has the dual role of an internal inter-campus link as well as the link to the Sydney AARNet PoP.

The construction of the northern most component of this backbone would address the immediate deficiencies faced by SCU whilst the southern most component would connect Newcastle to Sydney.

The construction of the complete Pacific Backbone at an early stage would also provide a major component of the national AREN backbone. The indicative cost is estimated for planning purposes at $3.5M to $4M.

Newell Backbone

The connection of UNE in Armidale to the AARNet PoP in Sydney is now being addressed as a result of DEST capital development funding that has facilitated the development of a consortium comprising UNE, Transgrid, Country Energy and AARNet. This initiative is seen as an exemplar for addressing regional bandwidth problems. However the deployment of the AREN Newell Backbone could add resilience to the UNE to Sydney link that is under construction.

Mitchell Link

While the overall backbone network in NSW addresses many locations, there is an East-West axis from Sydney to Parkes that takes in Bathurst (CSU) and Orange, where there are significant population centres and campuses. A link along this path connects these campuses and also provides a coupling between the coastal and central backbone runs, providing routing alternatives for reliability.

East Princes Backbone

The backbone will possibly be built from either end namely from:

- Wollongong (Wollongong University) and a future extension to Batemans Bay (Wollongong University) to the AARNet PoP in Sydney;
- Churchill (Churchill campus of Monash University) with future extensions to university sites at Hamilton, Fulham, Sale, Bairnsdale and Lakes Entrance to the AARNet PoP in Melbourne.

The completion of the link in the future will provide additional resilience on the Sydney to Melbourne segment of the AREN backbone.

Hume Backbone

The Hume Backbone provides the main AREN backbone from Sydney to Melbourne via Canberra and connects campuses of ANU, University of Canberra, CSIRO (Canberra), Wollongong University (Moss Vale), Goulburn (CSU), Wagga (CSU), and Albury/Wodonga (CSU and LaTrobe).

South Princes Backbone

This backbone will be built initially from Melbourne to Geelong to provide a 1Gbps network connection to Waurn Ponds campus of Deakin University and the 2 CSIRO sites in Geelong.

At some future stage depending on the requirements, the segment from Adelaide to Mt Gambier will be built with ultimately the full backbone deployed to provide resilience to Adelaide and Perth should the Western backbone fail.

Table 8: AREN Backbone Program

Project (see Model S6.5)	Activity	2003	2004	2005
1. **Sunshine Backbone** (Brisbane to Cairns)	Install 2.5Gbps Backbone from Rockhampton to Brisbane	X		
	Extend Backbone to Townsville	X		
	Extend Backbone to Toowoomba		X	
	Extend Backbone to Cairns at 100Mbps+			X
2. **Pacific Backbone**	Investigate options and a specific proposal	X		
	Establish backbone from Brisbane to Lismore link	X		
	Establish Sydney to Newcastle link	X		
	Complete backbone			X?
3. **Newell Backbone**	Establish backbone from Brisbane to Melbourne via Armidale, Tamworth, Coonabarabran, Dubbo, Parkes and Albury		X	X
4. **Hume Backbone**	Establish backbone from Sydney to Canberra, Wagga and Albury/ Wodonga	X		
	Complete backbone			X
5. **Mitchell Link**	Establish link from Sydney to Bathurst	X		
	Complete link		X	
6. **East Princes Backbone**	Establish backbone segment from Sydney to Wollongong	X		
	Establish backbone segment from Melbourne to Gippsland (Churchill)	X		
	Complete backbone			X?
7. **South Princes Backbone**	Establish backbone segment from Melbourne to Geelong (2 Deakin campuses plus 2 CSIRO sites)		X	
	Establish backbone segment from Geelong to Adelaide via Mt Gambier			X
8. **Western Backbone**	Establish backbone segment from Melbourne to Ballarat connecting ACU and Creswick campuses)		X	
	Add link to Bendigo			X
	Establish backbone segment from Ballarat to Adelaide			X
9. **Eyre Backbone**	Establish backbone segment from Adelaide to Perth via Whyalla and Kalgoorlie			X

Western Backbone

The Western Backbone is a critical component in the national AREN backbone from Cairns to Perth and also provides connections to Ballarat (University of Ballarat and ACU) and other major rural towns. The option of a tail link to the Bendigo campus of La Trobe University will also need to be investigated.

Eyre Backbone

The Eyre backbone will address three key issues namely as follows:

- The provision of affordable gigabit capacity from and to WA universities and research organisations;
- The opportunity to address the issues of resilience across the Nullabor;
- The provision of sufficient trans-continental capacity to offer multiple connections the rest of the world.

8.3.2. Metropolitan Program

The Committee identified a significant number of requirements beyond those specifically relating to regional campuses with immediate needs and the development of the national backbone.

These additional requirements relate to the development of metropolitan networks in areas of major research and education intensity.

Information on a number of these requirements is presented with indicative priorities however this process needs to be expanded under the guidance of the proposed AREN Advisory Committee (ARENAC) to ensure that all such requirements have been identified, evaluated and assessed before specific priorities can be assigned.

These identified but incomplete requirements are described below using the conceptual AREN framework.

Brisbane

A priority is linking the QREN2 node and the GrangeNet node at George St to the QREN1 node at St Lucia.

Sydney

The Sydney Basin Fibre Project has solved many but by no means resolved all metropolitan Sydney networking issues.

Those still outstanding are:

- Many sub-campuses are still connected via low bandwidth carrier managed services. They fall into the unfortunate range of bandwidth requirements that does not justify the capital cost of a fibre connection, but it is too expensive to obtain via a managed service. Laying of new fibre in metropolitan Sydney is expensive and the Sydney Basin Fibre Project has mainly relied on existing surplus carrier capacity;
- Similar cost constraints prevent the provision of high-bandwidth connections to hospital and cultural organisations, even though they may only need a short tail connection to a SBFP PoP. Thus significant opportunities for collaboration are not capable of realisation.

Sub-campuses of the University of western Sydney are widely spread over the rapidly growing western Sydney region. The rate of growth of western Sydney, in both population and geographical area, has tended to exceed the growth of infrastructure resulting in many UWS campuses being essentially regional in services available. UWS is addressing inter-campus fibre capacity via CDP funding, although full funding has not yet been assured.

Canberra

The campuses of ANU, University of Canberra and CSU together with the CSIRO Divisions in Canberra along with a number of cultural organisations have been connected by private fibre to the AARNet ACT PoP. This has built on an inter-government department fibre network named ICON. AARNet manages the network on behalf of the participants.

Melbourne

A new network design known as VERN (Victorian Educational Research Network) has been proposed by the Victorian universities and CSIRO which will address the limitations of the current network (the Victorian Regional Network or VRN), and has the flexibility to accommodate bandwidth upgrades which will meet the needs of the sector for the next decade. Its initial configuration consists of 1 to 2.5 Gbps connections between the major metropolitan campuses of ACU, Deakin University, La Trobe University, Monash University, RMIT, Swinburne University of Technology, The University of Melbourne and Victoria University and also CSIRO sites at Melbourne Central, Parkville, Werribee and Clayton.

VERN will be designed to extend the benefits of broadband services beyond its major campuses, by bandwidth aggregation, potentially providing cost-effective connectivity to research precincts including hospitals, research centres and university staff located on these premises.

The Werribee based research activities of CSIRO, The University of Melbourne and Victoria University are a candidate for the establishment of a network precinct that would provide services and generate opportunities for researchers not economically feasible otherwise. The Werribee precinct has been included in the initial plans for the deployment of VERN. Other potential precincts may be formed collaboratively with third parties at a later stage including the localities of Clayton, Prahran, Carlton and Parkville.

All nine Victorian universities and CSIRO have committed to contribute $1.7M towards the development of the first stage of the VERN project. An RFP for fibre infrastructure has been issued and its evaluation is underway to determine the most appropriate staging strategies. Its deployment is contingent upon further funds being sourced, however submissions to State and Federal funding initiatives have been unsuccessful to date.

The establishment of VERN to metropolitan campuses, including the Werribee research precinct, will provide substantial benefits to all universities and CSIRO. The presence of VERN is also expected to attract other research centres and organisations to connect to the broadband network facilitating cross-sectoral collaborative research. Existing microwave infrastructure whose function is replaced by fibre connections will be re-deployed to service regional and smaller metropolitan campuses.

Hobart

The University operates a number of metropolitan campuses located within the central business district of Hobart. These campuses are co-located with other bodies, such as the Royal Hobart Hospital, which allow for collaborative research activities to occur between University researchers and those from external organisations.

The Hobart city sites are of enormous importance to the higher education environment in Tasmania, as these sites are the primary location for medical research activities through the Royal Hobart Hospital and University Clinical School, together with the Menzies Institute for Population Research. The University's Hobart campus also hosts a High Performance Computing facility available to researchers within the University and associated bodies. This HPC operates through the Tasmanian Partnership for Advanced Computing (TPAC), and is aligned with the Australian Partnership for Advanced Computing (APAC), based in Canberra.

Currently these sites are connected to the main University campus, in the Hobart suburb of Sandy Bay, via a series of microwave radio systems providing limited communications capacity. These systems are approximately 8 years of age, and do not meet the bandwidth needs of these sites.

The University is seeking to improve communications bandwidth within the Hobart central business district linking research and teaching sites to the University's main campus in Sandy Bay, which also houses joint University/CSIRO Forestry and Antarctic Commonwealth Research Centres, and is the Tasmania point of presence to the Australian Academic Research Network (AARNet).

The technology solution to improve bandwidth would ideally be the installation of an optical fibre cable or alternatively an upgrade to existing microwave links from 8Mbps to 155Mbps. The bandwidth improvement will provide an excellent opportunity for further collaboration between researchers in Tasmania, and their national and international counterparts through the AARNet point of presence.

Existing telecommunication services to the Hobart CBD sites are microwave based, and have reached saturation point, which is now inhibiting further research and academic collaboration between these sites and others within and outside Tasmania.

Initial cost estimates for the upgrade of microwave based infrastructure is approximately $400,000, whilst fibre optic cable estimates are in the order of $1million.

Adelaide

The major campuses of the three SA universities are all in the metropolitan area. All campuses have at least 34Mbps microwave links. The Bedford Park campus of Flinders University and the Mawson Lakes campus of the University of South Australia were recently upgraded to fibre leased from ETSA Utilities with the assistance of funding of $500K from the 2002 SII round and capital development funds allocated to the University of SA.

The University of Adelaide hosts the AARNet POP and has a gigabit connection to the PoP and the University of SA (City East) also has a gigabit connection to the AARNet PoP using private fibre under North Terrace.

The University of Adelaide is currently installing its own ducts and fibre from the North Terrace campus to the Waite campus. This fibre link will also support the CSIRO Divisions at Waite, South Australian Government Agricultural Research and Development organisation (SARDI) and the Australian Wine Research Unit. The link will also connect the MCEETYA owned company education.au limited to AARNet providing a substantial improvement over its current ISDN link.

However the South Australian Centre for Parallel Computing (SACPC) requires a 10Gbps connection to the CeNTIE network. This will require access to fibre from North Terrace to Gawler. The SACPC is working with the State Government on this issue.

Perth

In the metropolitan area, projected growth in data traffic, the need to accommodate emerging national and international e-science collaborations, the need for greater resilience in network design, and the escalating costs of locating the AARNet PoP in the CBD, all together require that Parnet's existing microwave-based network be replaced by fibre to which long-term rights are obtained. WARNO is able to fund some of this work from its own resources (and has commenced a Project to do so), but requires an injection of the order of $500,000 to complete the work.

Darwin

The broadband metropolitan connections in Darwin to the AARNet PoP are NTU (100Mbps), CSIRO (512Kb), Arafura-Timor Research Facility (ATRF) (100Mbps) and Menzies School for Health Research (MSHR) (100Mbps). There is a requirement to upgrade the NTU and ATRF connections to 1Gbps during the planning period.

The Batchelor College of Indigenous Tertiary Education (BIITE) currently has no direct connection to the AARNet PoP. They can only access AARNet over slow links via one or more regional centres that are part of the Northern Territory Government network that in turn connects to the NTU Chan Building at 384Kbps.

Table 9: Metropolitan Programs

Indicative Project (see Model S9.1)	Activity	2003	2004	2005
Brisbane	Connect QREN2 node and GrangeNet PoP in the city to QREN1 node at St Lucia		X	
Sydney	Investigate UWS inter-campus requirements for fibre links	X		
Melbourne	All major campuses, including Werribee Precinct	X	X	
Hobart	Upgrade microwave or install fibre		X	
Adelaide	Build a fibre link from North Terrace to Gawler		X	
Perth	Replace microwave link with fibre		X	
Darwin	Upgrade NTU and ATRF connections to the AARNet PoP to fibre		X	

8.3.3. International Program

The provision of international bandwidth capacity has been identified as an important aspect of sustaining Australia's research standing and capability. The market for international capacity is volatile, and opportunities to address the need will almost certainly occur. It is important that these opportunities be adequately assessed against the strategic framework.

It is proposed that ARENAC will undertake a comprehensive investigation in 2003 of the strategic requirement for international connectivity and the option available taking into to account the need for improved links to SE Asia and Europe, a western loop to SE Asia and Europe and additional capacity to North America.

Table 10: Indicative International Projects

Indicative Project (see Model S9.1)	Indicative Cost	Activity	2003	2004	2005
International Loop – Pacific	$ being sought for 15year IRU	Canvass Options Upgrade from 155Mbps to 622Mbps	X X		
International Loop – Indian	$ being sought	Canvass Options Implement possibly a 155Mbps		X X	

The Committee recommends that the Minister note that international broadband connections are a key element in Australian research capability, and that ARENAC be asked to evaluate options for enhancing this capability, and to recommend to the Minister the necessary actions to be taken (Recd. #10).

8.4. Indicative Investment Scope

The indicative program of works outlined suggests that the overall investment required to establish the next generation of a research and education network serving the higher education sector is of the order of $50-60million.

Historically State and Territory Governments and universities have invested significant funds in provision of broadband capacity for research and education. As noted previously, it is important that all potential investments in bandwidth to service the higher education sector be made in the context of the ARENAC strategic plan, and that the Commonwealth investment be used as a catalyst for leveraged investment.

To achieve this, it is suggested that the Commonwealth should seek collaborative investments from State and Territory Governments and from higher education institutions over the next three years to achieve the outcomes proposed in this report over the next three years, and that the Commonwealth investment in this period would be of the order of $35-$40 million.

9. Summary of the Anticipated Outcomes

The Committee recommends that the higher education sector adopts a collaborative, strategic approach to the provision of bandwidth to campuses, and that the Commonwealth make a strategic intervention to establish this collaborative framework.

Specifically, the Committee recommends the establishment of the Australian Research and Education Network (AREN) as a collaborative venture between the Commonwealth, State and Territory Governments, and the higher education sector, and collaboratively funded by those stakeholders.

AREN will evolve as a network of networks, with special purpose networks such as experimental and special research focus networks built on a robust underpinning infrastructure. This underpinning infrastructure will comprise backbone infrastructure connecting major research centres, with connections to smaller research centres. Enhanced international connections will be provided to ensure that Australian researchers have opportunities to participate fully in international research collaborations and consortia, and have access to major international research facilities.

The strategic and management framework established for AREN is of major importance. This framework should facilitate participation in planning and use of the network, and encourage use of the network by the research community in particular and by the higher education sector in general. Encouragement of use of the capacity of AREN is seen as vitally important to Australia's research outcomes - as network costs are a relatively small component of the total investment in research, the multiplier effect of adequate access to bandwidth capacity for university researchers is high.

It is proposed that an Advisory Committee, representative of the sector and major stakeholders, be established to monitor and review the implementation of the strategic evolution of AREN.

It is further proposed that AREN be managed by an independent company owned by participants, and that this company would establish a regime of charges for services which would encourage use of AREN while providing sufficient funds for the company to be financially sustainable.

The Committee has established notional targets for bandwidth capacity based on research intensity at campuses as follows:

Networked Computers	Research Staff and Students	Research Intensity	Minimum Target Capacity
<100		Low	Out of scope
100+	<200	Small	10+Mbps
500+	200+	Medium	100+Mbps
2000+	400+	Very high	1+Gbps

These targets have been used to establish a strategic plan for the structure of AREN, and to establish indicative costs of developing the network. The needs of different campuses and the feasibility of addressing those needs in the short-term and medium-term have been assessed to establish indicative priorities as a basis for future assessment and funds commitment.

As an indication of the investment required, the achievement of the notional targets for bandwidth will require an investment by stakeholders of $50-60 million. (To place this in context, this is less than 0.5% of the expenditure on the higher education sector).

Attachment A
Membership of the Higher Education Bandwidth Advisory Committee

Chair: **Mike Sargent AM (Dr)**	MA Sargent & Associates Pty Ltd
Evan Arthur (Dr) **DEST**	Branch Manager, Innovation Branch, Higher Education Division, Department of Education, Science and Training
Jonathan Potter (Mr) **CSIRO**	Chief Information Technology Strategy Advisor, CSIRO
Alan McMeekin (Mr) **AVCC**	Executive Director, ITS, Monash University
Alex Reid (Professor) **AVCC**	University IT Policy Executive Officer, and Professorial Fellow School of Computer Science & Software Engineering The University of Western Australia
Deane Terrell (Professor) **AARNet**	Chair, AARNet Pty Ltd
John O'Callaghan (Professor) **APAC**	Executive Director, Australian Partnership for Advanced Computing (APAC)
Lawrence Cram (Professor) **ARC**	Executive Director (Physics, Chemistry and Geoscience) Australian Research Council
Chris Cheah (Mr) **DCITA**	Chief General Manager, Telecommunications, Department of Communications, Information Technology and the Arts
Patrick Callioni (Mr) **NOIE**	Chief General Manager Strategy and Programs The National Office for the Information Economy
Kent Adams (Mr) **CAUDIT**	Director, Information Technology & Resources James Cook University, Townsville

Ron MacDonald (Professor) **AVCC** Added to strengthen linkages with the AVCC and the Deputy/Pro Vice Chancellors (Research) Committee	Deputy Vice Chancellor (Research) University of Newcastle

ALTERNATES

Philip Allnutt (Mr) **DCITA**	General Manager Industry Development Department of Communications, Information Technology and the Arts
Don Scavone (Mr) **DCITA**	Manager Broadband Networks Department of Communications, Information Technology and the Arts
Richard Windeyer (Mr) **DCITA**	Manager Broadband and Convergence The National Office for the Information Economy
Anne-Marie Lansdown (Ms) **NOIE**	General Manager Access Branch The National Office for the Information Economy
Duncan McIntyre (Mr) **NOIE**	Manager Connectivity Policy The National Office for the Information Economy
Ian Petersen (Professor) **ARC**	Executive Director (Mathematics, Information and Communication Sciences) Australian Research Council
Ian Atkinson (Dr) **CAUDIT and AVCC**	High Performance Computing James Cook University, Townsville

SPECIALIST SUPPORT STAFF

George McLaughlin (Mr) **AARNet – Technical Advisor**	Executive Director/Company Secretary, AARNet
Peter Nissen (Mr) **CAUDIT**	Executive Officer (Projects) Council of Australian University Directors of Information Technology (CAUDIT)
Peter Nicholson (Mr) **DEST**	Director Educational Innovation and Technology Policy DEST

Attachment B
Terms of Reference of the Higher Education Bandwidth Advisory Committee

Background

The use of information and communications technologies in higher education is pervasive. A recent DEST survey indicates that about 54 per cent of the more than 90,000 units of study available at Australian universities are web-supported. Only four years ago, very few of these subjects would have had an online component.

The growing use of information and communications technologies in research is having a fundamental impact on the way research is being conducted. Researchers now rely heavily on the Internet and World Wide Web to access research information, online journals and to communicate with their colleagues elsewhere in Australia or overseas. There is increasing use of modelling and data visualisation in research to better understand complex processes, especially in fields such as environmental sciences and biotechnology. Such research is dependent on the availability of high performance computing and advanced networks to facilitate the manipulation and exchange of very large datasets.

While many of the larger universities generally have access to adequate bandwidth at present to support the growth in online education and research, not all universities are so well placed, particularly a number of those with campuses in regional areas.

There is capacity under the Systemic Infrastructure Initiative (SII), established under *Backing Australia's Ability,* to support improvements in infrastructure, including information and communications technology (ICT) infrastructure. However, the first round of competitive applications for funds, held in 2001, failed with one exception to address the bandwidth issue in a strategic way.

The Minister has set aside $2.5 million in 2002 from the SII fund to address bandwidth issues, particularly for those universities at most disadvantage in terms of access to affordable bandwidth. These funds need to be allocated within the context of an overarching strategy to address bandwidth issues more generally in subsequent years under the SII.

The Committee

The Minister has decided to establish an expert committee to advise him of the short to medium term bandwidth requirements of the higher education sector and report back to him:

- by 31 October, 2002 on the short term needs of disadvantaged institutions or campuses and recommend initiatives to be funded under the SII in 2002; and
- by 30 November, 2002 on what bandwidth Australian universities will need in the future to undertake high end research; including a strategy by which current and future needs of universities, over the next five years, can be assisted by the Government in a structured way.

The Committee's recommendations will be used by the Commonwealth as a basis for a strategic framework to inform the provision of SII funds in 2002 and subsequent years, as necessary, to address bandwidth issues.

The Committee's first priority will be to develop options for addressing the need for affordable bandwidth for those universities or campuses at most disadvantage,

particularly those in regional areas. These options should include recommendations for the allocation of $2.5 million in 2002 from the SII to address high priority needs.

The second priority for the Committee will be to forecast the longer term need for bandwidth to support high-end research in Australia. While access to systemic infrastructure funds is only available to universities, the strategic framework will need to take into account the forecast needs of other members of the research community, which fall under the Education, Science and Training portfolio, such as the CSIRO, the Australian Institute of Marine Sciences and the Australian Nuclear Science and Technology Organisation. This work will underpin a strategy to assist the development of bandwidth infrastructure necessary to support emerging research needs.

The Committee will have access to research, commissioned by DEST, on the availability of bandwidth for universities in order to identify gaps in university access to affordable bandwidth and to provide a basis for the development of a strategy to improve the equity of access to bandwidth for universities. The Committee's deliberations will need to take account of implications for universities of funding provided to successful proposals under DCITA's National Communications Fund or other Commonwealth government programmes. The Committee will also need to be cognisant of the deliberations of the Government's Broadband Advisory Group, which has been established by Senator the Hon Richard Alston, Minister for Communications, Information Technology and the Arts, to provide strategic advice on the development of the broadband market in Australia, including factors affecting the broadband take-up in key user sectors such as education. There will be some cross-membership between the Broadband Advisory Group and this Committee to ensure a coordinated approach.

The Committee's recommendations should seek to encourage collaboration between universities and other industry or State and Territory government partners. The focus of the Committee's advice to Government will be on achievable outcomes, within the limited budget, and may draw upon work already undertaken by various groups. The aim should be to try to ensure that an institution or campus has access to bandwidth that is appropriate to support its teaching and research activities.

Composition of the Committee

The Committee will act as an expert group rather than a representative group and will consist of:
A Chair, and nominees from the following groups:

- Australian Vice-Chancellors' Committee (AVCC) – two nominees;
- AARNet (Australian Academic and Research Network);
- Australian Partnership for Advanced Computing (APAC);
- Council of the Australian University Directors of Information Technology (CAUDIT);
- Australian Research Council (ARC);
- CSIRO;
- Department of Education, Science and Training (DEST);
- Department of Communications, Information Technology and the Arts (DCITA)/National Office for the Information Economy (NOIE) – two nominees.

In the case of the AVCC, two nominees will be sought to ensure a balance between the needs of metropolitan and regional areas. Members will be invited by the Minister for Education, Science and Training to participate on the Committee for the duration of the Committee's tenure. The Committee will provide an interim report by 31 October 2002 recommending initiatives to be funded in 2002 from the Systemic Infrastructure Initiative. The Committee will conclude with its final report to the Minister setting out a strategic framework to inform the provision of SII funds in 2003 and beyond by 30 November 2002.

Attachment C
List of Vice-Chancellors and Heads of Research Organisations Who Provided Responses

Organisation	Title	Last_Name	Job_Title
Australian Maritime College	Dr	Otway	Principal
Adelaide University	Professor	McWha	Vice-Chancellor
AIMS	Professor	Hall	Director
ANSTO	Professor	Garnett	Chief Executive Officer
Charles Sturt University	Professor	Goulter	Vice-Chancellor
CSIRO	Dr	Garrett	Chief Executive
Deakin University	Professor	Wilson	Vice-Chancellor & President
Griffith University	Professor	Davis	Vice-Chancellor
James Cook University	Professor	Moulden	Vice-Chancellor & President
La Trobe University	Professor	Osborne	Vice-Chancellor & President
Macquarie University	Professor	Yerbury	Vice-Chancellor
Monash University	Professor	Darvall	Vice-Chancellor & President
Northern Territory University	Professor	McKay	Vice-Chancellor
Queensland University of Technology	Professor	Gibson	Vice-Chancellor
RMIT University	Professor	Dunkin	Vice-Chancellor & President
Southern Cross University	Professor	Rickard	Vice-Chancellor
The Flinders University of South Australia	Professor	Edwards	Vice-Chancellor

Organisation	Title	Last_Name	Job_Title
The University of Melbourne	Professor	Gilbert	Vice-Chancellor
The University of New South Wales	Professor	Hume	Vice-Chancellor & President
The University of Newcastle	Professor	Holmes	Vice-Chancellor & President
The University of Queensland	Professor	Hay	Vice-Chancellor & President
The University of Sydney	Professor	Brown	Vice-Chancellor & Principal
The University of Western Australia	Professor	Schreuder	Vice-Chancellor & President
University of Ballarat	Professor	Cox	Vice-Chancellor
University of Canberra	Professor	Dean	Vice-Chancellor & President
University of South Australia	Professor	Bradley	Vice-Chancellor & President
University of Tasmania	Professor	McNicol	Vice-Chancellor
University of the Sunshine Coast	Professor	Thomas	Vice-Chancellor
University of Western Sydney	Professor	Reid	Vice-Chancellor & University President
University of Wollongong	Professor	Sutton	Vice-Chancellor & Principal

Attachment D
Report on Bandwidth Requirements of Major Research Groups

The request for information on the need for bandwidth and communications services was sent to 60 researchers associated with Key Centres of Teaching and Research, ARC Special Research Centres, Major National Research Facilities, Foundation Fellows and major users of the APAC National Facility.

Responses were received from:

- National Networked TeleTesting Facility for Integrated Systems, Perth
- Mechanical Engineering, Monash University, Melbourne
- Victorian Partnership for Advanced Computing, Melbourne
- Institute for Molecular Bioscience, Brisbane
- Special Research Centre for the Subatomic Structure of Matter, Adelaide
- Australian Maritime College, Launceston
- Australian Computational Earth Systems Simulator, Brisbane
- Cooperative Education Network for Nanotechnology, Adelaide (proposed)

In addition another response indicated no special need for advanced communications services.

Although there have been only 8 responses with advanced communications needs, they appear to be representative of the needs of major research groups and different applications around Australia. The 8 responses are summarised below against the four questions that were asked.

1. What are the current limitations to an increased use of bandwidth and communications services?

- Lack of bandwidth at the national level (WA and Tasmania)
- Lack of international bandwidth
- Lack of reliable, high quality videoconferencing systems (WA)
- Costs at all levels (local, regional, national, international) were emphasised in all responses. IMB noted the increased overheads to manage traffic, monitor the network, control access as well as managing data and websites.

2. Are there emerging research problems and collaborations that you will not be able to pursue due to limitations on present bandwidth and communications services?

- Collaboration with overseas colleagues (especially US and Europe) is being constrained in most of the application areas.
- Current limitations lead to inefficient practices such as:
  - *Storing the same data sets at multiple locations*
  - *Transfering data sets by mail*
  - *Not much use of videoconferencing*
  - *Tendency to acquire and use local computing systems (when others may be more efficient)*
- Reliability, speed and security of communications services.
- Seamless access between networks (not sure if this is a current limitation).
- Latency is a major issue with the move to interactive computing (ie, interactive web interfaces to application software on remote computers). This will also impact collaborative visualisation and shared virtual work environments (ie video- and animation-based services).

3. What are the trends in bandwidth use by your colleagues and competitors overseas? Do you foresee that increased use of bandwidth by overseas groups will make it harder for you to maintain your international research profile?

- Overseas colleagues have access to larger supercomputers, mass storage systems, and tera-grid facilities.
- Overseas centres will be generating large multi-gigabit files. Access to this data is difficult or prohibitive – need 100Mbps bandwidth.
- New approaches and tools are being developed for interactive 3-D visualisation of remote data sets. Remote visualisation is becoming more important for access to large data sets – the size of bioinformatics data sets for example is doubling every year. The uptake of these tools in Australia may be limited by communication costs.

4. What will be your need for advanced communications services in the next 3-5 years?

- Distributed computing, large-scale data access and videoconferencing services: 7 out of 8
- Collaborative visualisation and shared work environments: 5 out of 8
- On-line instrumentation: 3-4 out of 8

There was little difference in the demand for these services nationally and internationally.

Comments on Costs:

The issue of costs was mentioned in all 8 responses. This may reflect a lack of real or perceived benefits for the costs, or it may reflect increasing costs in a tight budget (and therefore to be expected in surveys of this kind). Nevertheless the responses express a concern that use of increased bandwidth and additional services may not be possible with some research budgets.

Comments on other Services:

The 8 responses indicate an increasing demand for services that advanced communications enable such as computation, information access, shared virtual environments. It was also noted that software for some of the services (eg shared environments, simulation models, collaborative visualisation, grid computing) had not yet matured and still need to be developed.

The comments indicate that communications has to be kept in balance with other elements of the ICT infrastructure and that expertise needs to be available to support the infrastructure.

Comments on Research Practices:

One response noted that advanced communications was being driven by the desire to increase the efficiency of research practices – ie, to decrease the time for computation, to access data sets and to cooperate with colleagues internationally.

Improvements in research efficiency can be made through

- Interactive access to remote supercomputers (most still operate in batch mode)
- Collaboration through shared working environments
- Use of cooperative working tools
- Cooperative (simultaneous) visualisation of data sets

This of course is one of the aims of eResearch

John O'Callaghan
Lawrence Cram
25 October 2002

Attachment E
The Future of High Bandwidth Grid Applications

Summary

Connecting together all Australian Universities and research institutions with high bandwidth interconnections, such as gigabit fibre, is desirable but expensive. This report analyses the impact of such high-bandwidth interconnections on research outcomes across a range of disciplines, by taking current cutting-edge research projects in Australia and overseas, analysing their grid needs, and then forecasting these needs forward.

Introduction

Connecting computers over a wide area into a network creates a ***grid***, which enables application to utilize and access the networked computers and their resources. Grid computing is now a mainstay of everyday life – the Internet and world-wide web are grid applications. Unarguably, higher bandwidth connections are "better", as they enable more data to be transferred in less time, or more users to be supported over the same network. However, high-bandwidth connections are costly, especially over a continent as thinly settled as Australia. So the case for high-bandwidth connections hinges on what the economic and scientific value of such high-bandwidth connections are. This report tries to directly estimate the economic and scientific impact of high-bandwidth connections upon Australian Universities and Research Institutes. At the outset, we should point out that there are several difficulties associated with accurately quantifying the value of high-bandwidth connections.

- It is always difficult to estimate the usage of a facility before it is constructed
- Software and applications for advanced computing is a rapidly moving target. We are concerned not so much with whether current applications will benefit from high-bandwidth connections, but rather how will new applications and research in the next decade make use of such a high-bandwidth grid.

So the approach we have taken to quantify the benefit is to create several scenarios, and extrapolate current trends forward.

Grid applications can be classified in one of two ways:

- Scientific area (e.g., medicine, biology, geology, etc.)
- Application of the grid

The application of the grid can be broken into

A. *Data grids* – access to grid databases (such as genetic databases)
B. *Grid computing* – access to grid computing or remote instruments
C. *Cooperating working environments* – teleconferencing and remote visualisation
D. *Telepresence* – an individual acting as if he or she is present at a remote location, usually by controlling a remote device in real-time

Cooperative working environments and teleconferencing apply to all branches of science and engineering. In the USA, one of the most widespread uses of high-bandwidth grid cooperative working environments are *Access Grid* nodes (http://www-fp.mcs.anl.gov/fl/accessgrid/), which now connect many of the major US academic and research institutes and many others world-wide (well over 100 as of 9/2002). Access grid nodes allow large scale video-conferencing, using standardized hardware and software, and can connect dozens of sites together.

GrangeNet will facilitate the introduction of Access grid nodes in a handful of locations in Australia. That will enable those sites to engage in collaborative international and

national teleconferences at little or low costs to participants. Clearly this will potentially create a division between those institutions and cities that have, or do not have, access to Access grid nodes.

Telepresence has some interesting applications, such as remote surgery or remote control of instruments (e.g., in disaster recovery). However, the majority of the current uses of telepresence are highly experimental, in a few disciplines, and not bandwidth intensive (although they may have very stringent response time requirements, that will be facilitated by high-bandwidth connections and the next generation of internet protocols).

Thus the key discipline-specific use of high-speed grids will be for *data grids* and *grid computing*. For each discipline, we can construct likely scenarios of how high-performance computing will be applied. Often the line between these is blurred, as with any computing application, either the data can be moved to the user (*data grids*) or the user's application can be moved to where the data is (*grid computing*). The decision as to which approach to take depends on network bandwidth, reuse of data, portability of the application, and so on.

Astronomy and Physics

1. Real-time Access to Astronomical Observatories and Physics Laboratories (**A, B**)

Astronomers already make use of observatories around the world via the Internet. This often involves high-bandwidth connections to display diagnostic and access to the raw data to ensure that the integrity of the observations is not being compromised. Many telescopes record over a Terabyte of data per night, and fast retrieval of these data is only possible via the network. The alternative is slow and tedious transportation of large quantities of data on magnetic tapes and CDs. A similar situation applies to international Experimental Physics Colliders, such as the Large Hadron Collider (LHC) under construction at CERN. Processing this data will involve a massive grid project, in which Australian scientists, at Melbourne and other locations wish to participate in (see http://info.web.cern.ch/info/Press/PressReleases/Releases2001/).

"As from 2006, the four giant detectors observing trillions of elementary particle collisions at the LHC will accumulate over ten million Gigabytes of data, equivalent to the contents of about 20 million CD-ROMs, each year of its operation. A thousand times more computing power will be needed than is available to CERN today.

Nearly ten thousand scientists at hundreds of universities around the world will group in virtual communities to comb the data, searching for new physics. The strategy CERN has adopted to analyse and store this unprecedented amount of data is the coordinated deployment of grid technologies at hundreds of institutes which will be able to search out and analyse information from an interconnected worldwide grid of tens of thousands of computers and storage devices"

Researchers in Australia are already working on prototype grid tools to analyse data from the BELLE collector at the Japanese KEKB facility. The total raw data generated to date at BELLE is about 4 Terabytes. The data is being analysed in Australia, and currently being carried to Australia on magnetic tapes as it is generated. A key reason why such an inefficient data transport scheme is being used is because the current cost of international Internet traffic on AARNET is AU$50/gigabyte (or AU$200,000 to transmit the entire database). The cost of international Internet traffic is not currently competitive with the cost of, say DVD media (AU$2/gigabyte). Unless and until the cost drops to about AU$1 per gigabyte, Australia risks being cut off entirely from online grid participation in large-scale experimental physics research.

2. Virtual Observatories (http://www.us-vo.org/) (**A**)

Archives of past observations at different wavelengths are increasingly important in astrophysics research. As a result "virtual observatories" are being set up around the world to give astronomers access to both the raw, and processed datasets currently residing on tapes. These virtual observatories will give access to Petabytes of data so that astronomers can download the raw data and reprocess it in conjunction with others. These virtual observatories will also contain the latest theoretical models, to run simulations with which to compare with observations. Unfortunately, Australia does not, at present, have the network bandwidth or sufficient online storage to be a player in this emerging branch of astronomy.

3. Real-time Distributed Observatories – eVLBI (http://fibers.org/articles/news/4/7/15/1) and LIGO (http://www.ligo.caltech.edu/) (**B**)

One can greatly improve the signal to noise ratio and resolution of radio telescope data by combining the data from different telescopes via high speed networks. This is known as electronic Very Long Baseline Interferometry, or eVLBI. At present in Australia data need to be combined by recording it onto tape and transporting it to a central location for correlation. With high-speed networking, the tape recorders can be dispensed with, and new science attempted with high bandwidth interconnects. An example of this is eMERLIN, a new initiative by the University of Manchester in the UK. Another example is LIGO, in the United States. Australia is also wishing to tender on a still larger project to build a grid radio telescope whose resolution will be far beyond that of any current system.

Biochemistry and Bioinformatics

Grid computing already is an anchor and essential tool for bioinformatics – most genetic research is dependent upon online access to worldwide genetic databases. The size and complexity of these databases is growing, and other areas such as computational biochemistry and medical informatics will see increasing use of grid computing.

1. Bioinformatics Databases (**A**)

The growth in bioinformatics databases is immense. The major genetic database, Genbank, has about 22 billion bases and 18 million sequence records as of August 2002, and the number of entries is doubling every 12 to 18 months. Similar growth is occurring in other major databases such as Swiss-Prot, EMBL, PIR, KEGG/GENES, PDB. None of these major databases are being hosted in Australia, and there is only limited public mirroring of such databases (by ANGIS in Sydney). ANGIS is limited in resources and disc space (it recently added an extra terabyte of storage), and has had reliability problems due to resource shortages. The obvious questions are:

- Does Australia need to host/mirror major biological databases?
- What is the cost in grid services?

There are many reasons why Australia needs to host/mirror major biological databases are numerous, and include: security control; the ability to develop custom tools and searches on raw data; speed of access for frequent, repetitive searches; development of national expertise; and the ability to host/support Australian specific technology. Support of very large mirrored bioinformatics databases assumes the ability to create/update about a terabyte of data a year from international sources (about a gigabyte per day). A bioinformatics database need not be centralized in one location, assuming that an Australian grid exists to support it. For example, in the USA, the North Carolina Bioinformatics Grid (http://www.ncbiogrid.org/) has recently been set up to act as a state-wide grid supporting bioinformatics, with local nodes hosting or mirroring site specific databases, connected into a grid by common software.

Without a national data grid, or a national bioinformatics database of international reputation, Australia risks being a very regional player in biotechnology.

2. Computational Chemistry (**B, A**)

Computational chemistry covers a wide range of techniques: molecular dynamics (movement of molecules undergoing reactions), molecular docking (does one molecule fit another – critical to drug design, as most drugs work by blocking a protein from doing its job by docking with a site that is active), Quantum Mechanics calculations (electron distribution), solving X-ray crystal structures, etc. Several of these techniques can generate large datasets. In general most of the methods are highly CPU intensive, but generally do not rely on access to large databases.

Instead, each major run in a molecular dynamics simulation of a large molecule embedded in a solvent liquid or membrane generates a very large data set. The dataset can be reduced to the positions of a few tens of thousands of atoms, calculated over millions of time-steps (roughly of the order of hundreds of megabytes of raw data). Such data can be held locally on the machine on the grid that calculated the data. However, scientists at remote locations need to create 3D visualisations of this data, to understand properties such as the dynamic behaviour of docking sites (for drug discovery) or protein/protein or protein/membrane interaction (e.g., for transcription, infection, and metabolic pathways). To create these visualisations requires shipping the raw data to a local machine for visualisation. Shipping the raw data in a reasonable time (minutes rather than hours) requires a high-speed grid.

3. Clinical and Medical Databases (**A**)

Grid use of medical and clinical databases is presently severely constrained by privacy and ethical issues. Nevertheless, the move to collecting and correlating larger and larger medical and clinical databases is increasing, and will gain momentum as privacy and security issues are addressed by technology, regulation, and changing attitudes in society. The ability to confidentially, accurately, and speedily access a patient's lifetime medical records would significantly increase the efficiency and efficacy of medical treatment. Online data mining of very large data sets would enable far more rapid and effective determination of drug side effects. In this report, we leave aside the ethical issues, and instead address the grid computational and data needs of large-scale integration of clinical and medical databases. If Australia were to be a player, the grid infrastructure needs to be there soon as major vendors are rolling out pilot projects (e.g., IBM at the mayo clinic).

In specialized areas, such as neuroscience, such efforts are already well underway. Other emerging areas are data mining of epidemiological data and automation of clinical trials data.

Medical and clinical databases are increasingly coming on-line, with increasing volumes of data. Large data sets include radiological images and MRI scans, which are coming at ever higher resolution. MRI scans in raw form are at about the 1mm resolution, leading to about 1Mbyte of 3D data; radiological images are at far higher 2D resolution. Increasing use of these and other technologies will lead to huge databases of medical information. It is only a matter of time before these become more grid connected – to support portable medical records, and support in large scale data mining and epidemiological research.

If Australia is to be at the forefront of interconnecting clinical and medical data, then there needs to be an investment in infrastructure to support rapid and secure exchange of data.

Earth and Environmental Sciences

Presently, there are a number of international databases of earth and environmental data, including:

- The USGS/CalTech online historical repository of seismic data

- The NCAR data sets of atmospheric and oceanographic data (http://www.scd.ucar.edu/)

There are numerous repositories of satellite images and data. Australia federal and state agencies do maintain data repositories in these areas, but certainly not on the scale or level of online accessibility of the US sites. Online accessibility at low cost is going to be increasing crucial for advances in earth and environmental science, such as real-time satellite images for analysis of crop conditions on farms (a project already underway in pilot phase).

1. Geological and Seismic databases (**A, B**)

Large geological and seismic databases are maintained both publicly and privately (by mining companies). At present, there has been relatively little need to link these databases or provide very high-bandwidth access to these databases from Australia. However, this situation is likely to change fairly soon, especially with the federal funding of the ACcESS MNRF (http://www.quakes.uq.edu.au/ACESS/). There are several large-scale earth simulation projects underway internationally, that promise to be able to model the evolution of the earth – from the formation and motion of the continents to the formation of mineral deposits and evolution of mountains and plains. Such projects will generate huge data sets, which will need to be archived and accessible to researchers worldwide, for comparison with other models and detailed exploratory data. Clearly, if the ACcESS MNRF is going to have major international impact, one of its outcomes would be a grid repository of models and data on a scale similar to that of present US efforts in related domains. ACcESS itself is reliant on the GrangeNet backbone, to couple models and datasets at UQ and in Melbourne. Participation by CSIRO in Western Australia is limited by bandwidth to WA. Once again, the lack of bandwidth limits participation at the “entry point”, and entry into a group or proposal requires that the bandwidth exist at entry point, not at some unspecified point in the future.

2. Atmospheric, Oceanographic, and Satellite Data (**A**)

Satellite data is now an established part of daily life in the meteorological community. What is not realized is the extent to which increased satellite resolution, bandwidth coverage, and frequency of observations is creating a data avalanche that is largely being unexploited. The biggest use of these images will come in land management, and dealing with issues such as crop health and yields, salinity mapping, conditions of wetlands, and emergency management and forecasting (bushfire mapping, storm damage, etc.). Clearly, it is necessary to have access to large-scale historical databases, over decades, to determine progress in salinity management, the effects of global warming on native vegetation, regrowth after bushfires and other natural disasters. Satellite images are down to a resolution of a few metres, and are available on dozens of bandwidths. These high-resolution, multi-bandwidth images are crucial – high-resolution enables detection of small crop and vegetation features, multi-bandwidth enables automatic prediction of crop and vegetation condition and type, soil type, etc. A high-resolution image on multiple bandwidths, of just Victoria, would occupy about a Terabyte of storage. Compression technology can reduce this, but it is clear that large-scale historical satellite records will occupy Petabytes of storage. It is highly unlikely that all this will be located in one central place in Australia – instead data sets at various locations will need to be merged and combined, as happens now with genetic databases.

Engineering

Overall, engineering has seen far less use of grid computing than most other scientific disciplines. The principle reason has been the relative lack of large-scale international databases of engineering data or international collaboration on projects that generate very large datasets. Part of the reason for this is the relatively slow acceptance of

Computational Engineering in the engineering product lifecycle – beyond rather exotic engineering projects such as nuclear and space engineering.

All this is likely to change over the next few decades, with the emergence of "virtual and collaborative engineering" – the construction and validation of complete and accurate numerical models for entire structures, ranging from cars and buildings to dams, prior to construction. The need for such models comes from two sources: the competitive need to reduce design, testing, and manufacturing costs, and the need to increase product reliability and efficacy, and reduce operating costs. While not common, product recalls can be very costly and, indeed, damage a companies operating record (e.g., Firestone tires). Current engineering practice is generally to "over-engineer" a component (e.g., by making it stronger, or able to handle larger loads or worse conditions than in expected to be ever seen in practice), coupled with exhaustive testing. Unfortunately, over-engineering and testing are limited in what they can accomplish, and do not work well in forecasting coupled systems failures. It is notable that the greatest use of large scale computational engineering is, at present, in exactly those projects where over-engineering and exhaustive testing are not viable (e.g., Formula I racing, aerospace engineering, and the America's cup racing).

1. Computational Engineering (**A, B**)

Large scale computational engineering generates huge datasets. The two mainstays of Computational Engineering are Finite Element Analysis (FEA) and Computational Fluid Dynamics (CFD). A typical large-scale grid, using present technology, for CFD or FEA analysis, contains about a million points (nodes). The material properties at each grid point must be tracked over thousands of timesteps (e.g., as the car crumples in an FEA analysis, or in an engine combustion cycle, in CFD analysis). This data can be compressed in various ways, but a typical data set for several runs of a large CFD or FEA dataset might be tens of Gigabytes. At present, much of this data is used just once, to optimise or test one component, and not shared. However, the need to share and archive this data will increase as:

- Raw data from simulations of various subsystems needs to be combined
- Manufacturers and parts suppliers exchange data and simulations
- Corporations retain data to compare against field tests, as a defence against recalls, etc.

High-speed grids will facilitate this sharing of Virtual Engineering data both within Australia and internationally. Once again, if Australia is to be at the forefront of increasing export of highly manufactured goods, it will need to invest in supporting grids and Virtual Engineering.

A further need for grid computing in Engineering will be remote and distributed visualisation, and collaborative visualisation, where Engineers in one location can share virtual engineering data (visualisation) with another location, possible internationally. For example, Holden engineers in Melbourne recently viewed an HSV design with design engineers at Tom Walkinshaw Racing (TWR) in the UK, collaboratively, in real-time. While limited to 3-D images previously downloaded, it showed the clear benefits of Visualisation and Virtual Engineering.

Conclusion

The need for grid computing as an enabling technology across all branches of science and engineering is clear. The primary driver of grid computing will probably be “data”, and information generated from distributed data grids, rather than cycle-trading or distributed applications. The need for growth in grid bandwidth is driven by the growth in very large data sets, and the need to combine large data sets from multiple sources or generate large local data sets (such as visualisation data) from those grid data sources. It is also clear that waiting until an application appears that can “pay up front” for the bandwidth will mean many missed opportunities. The analogy with roads and highways is insightful. Building a highway will invariably generate more traffic and economic growth. But conversely, waiting until someone at a remote location is willing to pay for a highway to them will invariably lead to lost business and economic opportunities.

Acknowledgement

This document was created with informal personal input from experts across all the above disciplines. Citations are available on request.

Bill Appelbe

Victorian Partnership for Advanced Computing

Attachment F
The Role of the Australian Research and Education Network

The Internet has developed very rapidly from its genesis in Australia within the higher education and research sector in 1989 to becoming a strategic part of the nation's infrastructure and will continue to be key in the ongoing development and delivery of future technology for health and community services, industry incubation and economic growth, as well as being strategic to the educational and research activities in the 21st century. It is imperative that education and the research community have access to state of the art communications infrastructure that allows them to compete in the international arena in all of their endeavors.

Almost all developed countries and most developing countries have what is called a National Research and Education Network. AARNet is (currently) Australia's NREN (see the Advanced Research and Education Network Atlas (ARENA) http://arena.internet2.edu) which is connected to the NRENs of more than 40 other countries. An NREN provides an essential combination of expertise, leadership, innovation, infrastructure and services necessary to maximise economic outcomes of the nation's research and development in a wide range of fields beyond information and communications technology. It is essential that Australia continue to develop and evolve its NREN in a coordinated manner to ensure the nation remains competitive in the global arena.

The role of the AREN in meeting the needs of the education, research and broader community includes:

1. Leadership, Expertise and the National Agenda

- Providing the leadership, expertise and ideas to drive the national research, education and advanced network agenda.
- Participation with government agencies, other sectors and industry to drive the "broadband" agenda in Australia.
- To champion new ideas and approaches within the industry.
- Being a trusted, credible source of unbiased advice and expertise.
- Providing training and learning opportunities to energise the educational, research and commercial opportunities of the broadband infrastructure.
- To encourage and assist innovative solutions that provide affordable, sustainable infrastructure especially for regional areas.
- Encouraging a vibrant and competitive telecommunications infrastructure and content service industry.

2. Research and Higher Education Agenda

- Providing leading edge, location-independent, cost-effective Internet-enabled services that meet the needs and expectations of the higher education and research sector.
- Leveraging the research and development outcomes of existing large-scale investments in research infrastructure made by governments at all levels (for example, the Synchrotron and high performance computing facilities) by connecting these into the national and global cyber-infrastructure and making them available to researchers everywhere.
- To facilitate and support the evolution of virtual communities and eScience by deploying computational, data mining and access GRIDS.

3. Collaboration with the education sector, other sectors and with Industry

- Fostering Internet-enabled, distance-independent collaborations in research, teaching and learning with other relevant parts of the education sector.
- To encourage the leverage of the synergies between the higher education, research and health sectors, in the deployment of cost-effective, patient focussed delivery of health, social and other community services.
- Developing collaborative programs with cultural organisations for learning and research.
- Working with industry to develop and assist in the commercialisation of new products and services, through joint programs, technology transfer, and the provision of test-bed and incubator facilities.

4. The Regional Agenda

- Working with the research and education sector, relevant government agencies, local organisations and other stakeholders to address the issue of affordable, sustainable and location-independent Internet access from within Australia.
- Developing a focus and strategy for regional universities and campuses to act as an aggregation point for Internet-enabled services in those locations.
- Providing a focus with the Federal and State Governments in optimising the national utility infrastructure such as power, gas, water and railways, to develop innovative and sustainable solutions to providing affordable Internet access.

5. The Global Agenda

- To represent Australia's interests at international NREN forums.
- Playing a lead role in the development of the Asia-Pacific Advanced Network Consortium.
- Contributing to the deployment of the Global Terabit Research Network within the Asia-Pacific region to effect links East to the US West-Coast and West to Europe.
- Ensuring that Australia has Internet-enabled access to unique global resources that it could not afford to provide itself.
- Ensuring that unique Australian facilities become part of the global cyber-infrastructure.

6. Network Provision

- To develop, manage and continually evolve a cost effective, resilient and professionally managed set of infrastructure, network applications and services designed to enable the research and education community in Australia to meet their aspirations.
- Ensuring that the network architecture is future-tolerant, cost-effective, flexible, scalable, resilient, reliable and secure.
- Providing benchmarking of the network and service performance characteristics against those of our international collaborators (for example, Internet2, Canarie and GEANT).
- Ensuring that network capacity and performance meets or exceeds the needs of the applications and services it provides, underpinned by ongoing monitoring of end-to-end service at design performance levels.

7. Provision of Services

- Enabling Australian researchers to participate in global research and e-science projects by ready access to the global cyber-infrastructure (the combination of globally distributed computing, storage, analytical and visualisation facilities; and unique or expensive remote scientific facilities and instruments (eg radio-telescopes, particle-physics generators, synchrotrons).
- Enabling Internet-enabled teaching and learning through on-line authoring, development and sharing of learning objects, improved interaction between learners and teachers, remote audio-visual interaction, improved resource discovery, and access to digital libraries
- Providing low-cost collaboration enabling tools, facilities and services such as video-conferencing-over-IP and shared whiteboards.
- Developing and deploying innovative, first-to-market services and applications that will have wider applicability.
- Facilitating access to available services to all members of the NREN community, regardless of location (home, campus, regional or interstate locations, while travelling, nationally or internationally).

8. Access Issues

- Providing access to the research and education networks both nationally and internationally.
- Providing access to the commodity (public) Internet both nationally and internationally. (The research and education sector is a net exporter of information to the commodity Internet in Australia and this will grow with the development of the national broadband network).
- Encouraging the development of infrastructure and technologies that provide external access to the research and education community by their clients (for example, students and research partners) and staff (telecommuting) over the commodity Internet. This is a requirement both domestically and internationally.

Attachment G
AARNET Pty Ltd

The Australian Academic and Research Network (AARNet) was born out of a report commissioned by the AVCC in 1987 that proposed that the AVCC establish a network to provide data, voice and fax services. The AVCC secured Australian Research Council funding for AARNet in 1990 and a network was rolled out to the "front door" of every Australian university and CSIRO in April/May 1990. The AVCC transferred all AARNet's commercial customers, assets and the management of interstate and international links to Telstra in 1995 in exchange for initially favourable tariffs.

The AVCC obtained funds from the Research Data Network initiative (RDN) in 1996 and these funds were used to deploy regional microwave links under the umbrella of Regional Network organisations (RNOs). These links were funded approximately 50:50 from the RDN CRC allocation and member contributions.

AARNet2 was deployed following a tender issued in April 1996 as a national asynchronous transfer mode (ATM) backbone connecting RNOs and able to support the carriage of voice, video and data. Optus was selected for national backbone and international connectivity and a five-year contract was signed in early 1997. This agreement encompassed a high availability private backbone with an aggregate of 225Mbps for a fixed price. AARNet subsequently acquired long term (15 year) rights to use dual 1555Mbps links to North America and interconnected this capacity with the major Internet2, CANARIE, US Government research networks and the Asia Pacific Advanced Network Consortium. This allowed Australian researchers and educators direct access to the global research and teaching resources and facilities.

AARNet operated under the AVCC as a Board of Management until its incorporation in early 2000 as a not-for-profit company limited by shares. The shareholders are the 37 Australian universities and CSIRO.

Attachment H
Advanced Network Program

GrangeNet (http://www.grangenet.net)

GrangeNet ~ Australia's first Grid and Next Generation Network ~ was launched by the Minister for Communications, Information Technology and the Arts, Senator the Hon Richard Alston, on October 16th in Canberra.

The launch coincided with the completion of the IPv6, multicast enabled DWDM backbone network connecting Melbourne, Canberra and Sydney at 10 Gbps and Sydney to Brisbane at 5 Gbps.

The network provides the enabling technology in the development and deployment of grid and advanced communication services; services that will deliver the edge to Australian endeavours in science, education, cultural enrichment and assist our start-ups and SMEs.

It is a test bed for optimising the delivery of e-Learning objects, for the advancement of the new generation of tele-science, for the development of computing grids, for collaborative working and the establishment and manipulation of huge distributed data sets. And it is the quintessence of Australia's engagement in the creation of the next generation of the Internet.

The GrangeNet initiative will initially serve the academic and research communities in Melbourne, Canberra, Sydney and Brisbane. The GrangeNet points-of-presence (PoPs) in each of these cities are interconnected to the AARNet POPs such that all eligible AARNet members have access to GrangeNet. The metropolitan fibre network initiatives such as the Sydney Basin Project, the Icon Fibre Network in ACT and the proposed VERN will provide eligible organisations with gigabit access to GrangeNet. Additionally, GrangeNet has gigabit tails to participants at QUT, UQ, ac3, ANU, RMIT and CSIRO/Bureau of Metrology.

GrangeNet will carry all R&E (Research and Education) traffic between GrangeNet members but not commodity traffic – this will continue to be carried by AARNet and other carriers. Effectively, any research group who is prepared to agree to the GrangeNet Acceptable Use Policy and who has a legitimate need to use a high performance network can connect to GrangeNet.

CeNTIE (http://www.centie.net/)

CeNTIE - Centre for Networking Technologies for the Information Economy will develop a Foundation network that will link key Australian sites with the most advanced network possible using today's technology. The aim is to apply the new features the network enables to the needs of advanced industrial and research users

The Foundation Network's interstate capacity between Melbourne, Adelaide and Perth of 10 Gbps will be provided by consortium member, AMCOM Telecommunications. East Coast capacity will be provided by arrangement with another ANP, GrangeNet, and CeNTIE will also collaborate with the other successful bidder, mNet.

CeNTIE will use Nortel Networks' Optera DWDM (dense wavelength division multiplex) optical switches to connect interstate links with dedicated fibres laid in capital cities. Wavelength routing will be used to achieve connectivity in 10 Gbps increments between major nodes and at lower rates to secondary nodes. High-performance Nortel

routing switches will provide scalable bandwidth, and support various terminal interfaces at participating enterprises.

The business systems will run on their own individual virtual networks. A unique feature of the CeNTIE network will be the deployment of Nortel Network's programmable networking technology. This new technology allows the routers and switches which comprise a network to be reconfigured dynamically to create new services such as virtual private Internets and applications specific services. The development of this technology is an extension of existing collaborative research between CSIRO and Nortel Networks.

CeNTIE is establishing a transcontinental fibre backbone research network consisting of broadband Metropolitan Area Networks (MANs) in Sydney and Perth linked by a combination of CeNTIE's DWDM-based Perth to Melbourne network and GrangeNet's Melbourne to Sydney network. The two metropolitan area networks (MANs) interconnect member sites with multiple 10GBps connections.

MNet (http://www.mnetcorporation.com/)

m.Net Corporation aims to give Australia a global lead in the exciting new world of the wireless Internet and mobile commerce. m. Net - a consortium of multinationals, Australian IT and telecommunication companies, government and research organisations - has been established to create new opportunities for companies seeking to profit from the emergence of the mobile Internet.

Centred around Adelaide's "North Terrace Precinct" - a unique microcosm of business, education and cultural activity - the **m.Net** network will deliver an exciting platform for developing the future of the wireless Internet and mobile commerce. m.Net is establishing state-of-the-art wireless Local Area Networks (WLANs) and leading edge pre-commercial third generation (3G) mobile networks, and will link them with optical fibre to provide services in and around Adelaide's North Terrace precinct. There is also a regional hub at Whyalla being used to explore the remote delivery of services and interoperability between separated networks.

The networks will support a range of mobile terminals supporting advanced and experimental Internet applications, including voice-over-IP with the new IP standard Ipv6, as well as research and development on a large number of network and application related areas.

Prominent Australian and international companies and research institutions have already joined the **m.Net** consortium. They are keen to be part of a unique program that will generate economic opportunities flowing from the application of new wireless technologies.

The emphasis is on collaboration. **m.Net** combines international expertise and resources with Australian development capability, to stimulate new ideas and advance the development of the future global economy.

Attachment I
University Wide Area Network Links – Baseline Data Collection

The Committee has sought the agreement of AARNet to publish the baseline data on the AARNet web site rather than include it as an attachment to this report. This is because the baseline data is simply a snapshot of the situation and it needs to be updated continuously.

It has been suggested that each RNO nominate an officer who will be responsible for the maintenance of the data and will be granted write access to their RNO's data on the AARNet web site in order to undertake this responsibility.

The baseline data will be available on the web at www.aarnet.edu.au

The data as at October 2002 consists of:

Qld RNO	Qld links.xls
NSW RNO	NSW links.xls
ACT RNO	ACT links.xls
Tasmania RNO	TAS links.xls
SA RNO	SA links.xls
WA RNO	WA links.xls
NT RNO	NT links.xls
AARnet2 Regional Requirements	AARNet regional requirements.xls

Attachment J
Glossary of Terms

AARNet Australian Academic and Research Network
a licensed carrier that provides high-capacity Internet services between eight state and territory based regional Points of Presence for 37 universities plus research institutions.

AARNet Mirror
A major database operated by AARNet that "mirrors" overseas data bases so that they can be accessed more quickly and inexpensively as the data is only transferred across the international link once.

Access grid
the ensemble of resources that can be used to support human interaction across the grid. It consists of multimedia display, presentation and interactions environments, interfaces to grid middleware, interfaces to visualization environments. The Access Grid will support large-scale distributed meetings, collaborative work sessions, seminars, lectures, tutorials and training.

ACU Australian Catholic University.

ACCC Australian Competition and Consumer Commission

AIMS Australian Institute of Marine Science
Commonwealth Statutory Authority that generates the knowledge needed for the sustainable use and protection of the marine environment through scientific and technological research.

ANP Advanced Network Programs (see attachment H for further information)
established to identify Australia's future requirements for communications technologies and communication services.

ANSTO Australian Nuclear Science and Technology Organisation

Australia's national nuclear research and development organisation and the centre of Australian nuclear expertise.

APAC Australian Partnership for Advanced Computing
partnerships of universities which oversights and manages the development of and use of Australia's largest supercomputing facility

ARC Australian Research Council
a body that makes recommendations to the Minister for Education, Science and Training for the funding of research proposals and administers approved proposals. It also provides advice to the Minister on research matters.

AREN Australian Research and Education Network
proposed framework for Australia's bandwidth needs for education and research

ARENAC Australian Research and Education Network Advisory Committee

Proposed advisory body arising from the AREN

ARENMC Australian Research and Education Network Management Company

Proposed management body for the AREN

ATP Australian Technology Park Sydney

AVCC Australian Vice-Chancellors' Committee
a committee of the Vice-Chancellors of 38 Australian universities. It acts as a consultative and advisory body for all university sector affairs.

BAG Broadband Advisory Group
the federal government's advisory body on broadband development in Australia

Bandwidth
In a digital system, a measure of the data though put capacity of an optical fibre or network. It is measured in bits per second (bps).

Bit
A binary unit of information or data

bps bits per second
a measure of data speed for transmission carriers. High data speeds use larger units of measurement, such as kbps (kilobits per second – 1,000 bps), Mbps (megabits per second – 1,000,000 bps), Gbps (gigabits per second – 1,000,000,000 bps), Tbps (terabits per second – 1,000,000,000,000 bps)

Byte
a unit of information, usually eight bits, stored by a computer.

Caching
to put data into cache memory or mass storage. This increases the speed of transmissions.

CANARIE Canadian Network for the Advancement of Research, Industry and Education
A not-for-profit corporation supported by its members, project partners and the Canadian government. Its mission is to accelerate Canada's advanced Internet development. (http://www.canarie.ca)

CAUDIT Council of the Australian University Directors of Information Technology

CeNTIE Centre for Networking Technologies for the Information Economy

CDP Capital Development Pool

A Commonwealth programme providing grants to universities for specific capital projects. It is administered by DEST.

CeNTIE Centre for Networking Technologies for the Information Economy

CIR
The committed information rate

CRC Co-operative Research Centre
Centres that bring together researchers from universities, CSIRO and other government laboratories, and private industry or public sector agencies, in long-term collaborative arrangements which support research and development and education activities that achieve real outcomes of national economic and social significance.

CSIRO Commonwealth Scientific and Industrial Research Organisation
An independent statutory authority undertaking a wide range of research activities

CSU Charles Sturt University

CQU Central Queensland University

Dark fibre
optical fibre that is in place but has not yet been used by the owner and is available to a customer to use as raw data capacity in any way the customer wishes.

DCITA Department of Communication, Information Technology and the Arts

DEST Department of Education, Science and Training
formerly the Department of Education, Training and Youth Affairs (DETYA)

DWDM Dense Wave Division Multiplexing

DSL Digital Subscriber Line
a technology that enables the copper telephone network to carry data-streams of up to 6 Mbps.

EFTSU Equivalent Full-time Student Unit

A standard for measuring university students where all student attendance time is equated to a notional time for a full-time student in each course

e-Science

Fibre
see optical fibre

Frame Relay

FTE full-time equivalent
A measure of staff numbers

Gbps
see bps

GEANT The European Research Backbone Network
running at 10Gbps

GIS
geographical information systems

Global Terabit Research Network (GTRN)
an international partnership to establish a true world-wide next generation Internet to interconnect national and multinational high speed research and education networks.

GrangeNet Grid and Next Generation Network
(see attachment H for further information)

Grid – grid technologies
technologies which allow the coupling of geographically distributed resources and which offer consistent and inexpensive access to resources irrespective of their physical location or access point. It enables sharing, selection, and aggregation of a wide variety of geographically distributed computational resources (such as supercomputers, compute clusters, storage systems, data sources, instruments, people), thus allowing them to be used a single, unified resource for solving large-scale computer and data intensive computing applications (e.g., molecular modelling for drug design).

GU Griffith University

High Performance Computing
use of the fastest type of computers, particularly for carrying out complex mathematical calculations very quickly. They are used for specialised applications such as meteorological research.

HEBAC Higher Education Bandwidth Advisory Committee
see attachments A and B.

HPC high performance computing

Hub
a group of circuits connected at one point on a network. Hubs enable traffic concentration and economies of scale. Hubs are located in larger cities throughout a network for concentration and routing of traffic from cities with lower traffic demands.

ICT
Information and Communication Technologies

Internet2
the next generation Internet in the United States

IP, IPv6
one of the Internet protocols of which IPv6 is a new version being deployed on some research and national networks which supports a much larger of unique network devices

ISDN Integrated Services Digital Network
A digital access technique for voice and data transmission. It is a digital alternative to an analogue public switched telephone service.

IVEC Interactive Virtual Environments Centre
located in Perth and part of the CeNTIE initiative

JCU James Cook University

Latency
the time between transmitting data from one point and receiving it at another due to delays introduced largely by the network equipment in the intermediate path but also by the speed of electromagnetic transmission or the speed of light

Mbps – see bits per second

MAN
metropolitan area network

MCEETYA Ministerial Council for Employment, Education, Training and Youth Affairs
membership of the Council comprises State, Territory, Commonwealth and New Zealand Ministers with responsibility for the portfolios of education, employment, training and youth affairs, with Papua New Guinea and Norfolk Island offered observer status

Microwave
Electromagnetic waves in the radio-frequency range of 890 MHz to approximately 30 GHz that are used for line-of-sight transmission of voice, video, and data.

mNet Corporation
(see attachment H for further information)

MRI (Brisbane)

Multicast
the sending of data packets to multiple destinations simultaneously (i.e. broadcasting) rather than point to point transmission.

NHMRC National Health and Medical Research Council

Administers funding for health and medical research in Australia

NOIE National Office for the Information Economy

Commonwealth agency for information economy issues

NREN National Research and Education Network

NTU Northern Territory University

Optical fibre
a very thin glass fibre used to carry data in the form of light impulses

PoP Point of Presence
a geographic location where a Carriage Service Provider (CSP) can be accessed by a customer. The proximity of the customer to the PoP is related to the cost of accessing the service.

QIMR Queensland Institute of Medical Research

QoS Quality of Service

QPSF Queensland Parallel Supercomputing Foundation

QRNO Queensland Regional Network Organisation
see RNO

QUT Queensland University of Technology

Redundancy
the duplication of equipment or cable link with the automatic cutover if one of the duplicated items fail

REN Regional Network Organisation see RNO
the proposed state or regionally based organisations that are part of the proposed AREN.

Resilience
the design of the network so that a failure does not impact more than a single site (e.g. a fibre loop that breaks at one point still leaves a path in the other direction or a mesh design providing many to many connections).

RNO Regional Network Organisation
unincorporated joint ventures responsible for the planning and management of the links from the AARNet PoP to each member

SACPC South Australian Centre for Parallel Computing

SBFP Sydney Basin Fibre Project
A collaboration between the five Sydney metropolitan universities to address a number of bandwidth deficiencies

SCU Southern Cross University

SRI (in Mackay)

Terabytes
One million million bytes (10^{12})

UNSW University of New South Wales

UQ University of Queensland

USC University of Sunshine Coast

USQ University of Southern Queensland

UTSQ University of Technology, Sydney

UWA University of Western Australia

UWS University of Western Sydney

VERN Victorian Educational Research Network
the Victorian RNO

VRN Victorian Research Network
the proposed Victorian REN

Video-over-IP
The transmission of video over the Internet as data packets

Voice over AARNET
The transmission of voice over AARNet as data packets

VPAC Victorian Partnership for Advanced Computing

WDM wave division multiplexing colours of light

WAN Wide Area Network
see also LAN

WLAN Wireless Local Area Network
see also LAN