AARNet
The Australian Academic and Research Network

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Australian Vice-Chancellors' Committee
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International Academic and Research Networks:

A Brief Summary

August 1991

It is a challenging task to provide a clear, concise and up to date summary of the academic and research network facilities around the globe, and the manner of their interconnection.

While it is possible to assemble such summaries using on line resources such as maps, status reports and newsletters, international meetings (such as the INET'91 International Networking meeting in May 91, the Pacific PACCOM meetings, held annually since 1988, and comparable European and American meetings) provide an ideal opportunity to assemble a relatively accurate "snapshot" of currently accessible facilities.

The following notes are a summary of the material presented at these various meetings, and is intended to provide some insight as to how these networks are "glued together" at this moment. The notes will summarize the infrastructure within North America, Europe and the Pacific.

1 North America

1.1 The United States of America

Within the United States a number of Federal Government agencies actively support (and fund) research network facilities on a national scale. These facilities provide the major trunk routes across the nation. At a regional level these major data facilities are supported by regional networks which provide local infrastructural facilities.

The National Science Foundation supports the NSFNET network as a common trunk infrastructural facility directed not only to assist and provide services to programs in receipt of direct NSF funding, but also as a general academic and research facility. The Department of Energy, through the Office of Energy Research, supports the ESNET backbone network as a component of DoE funded research activities, and where DoE supports international collaborative research programs, the DoE provides the financial support for international network links. The National Aeronautics and Space Administration undertake a very active role with respect to US research programs and international collaborative programs, and operate the NASA Science Network (NSN) to support these programs. Additionally the United States Defense Advanced Research Projects Agency (DARPA) perform a similar role, with The Wide Band (TWB) as a domestic successor to the ARPANet, and also

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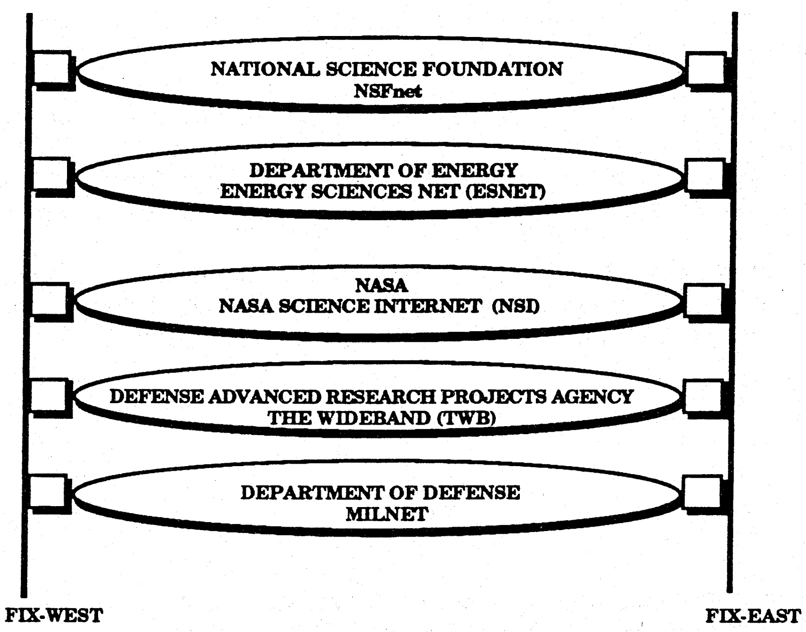
support a number of trans-Atlantic connections. Of course this is not the complete picture, as other academic and research networks (of which the CREN, incorporating the previous BITNET and CSNET networks, is a major example) also exist.

The effective result of these programs is that an institution may be an active participant in research programs funded by a number of agencies, and in theory (and in practice) such institutions could have a number of incoming network links from each agency's network.

To describe this somewhat complex situation it is necessary to provide an overview of the internal United States network structure in more detail.

1.1.1 US Backbone Networks

Each of the participating US Federal Agencies has effectively undertaken to support a backbone network across continental United States. The resultant collection of backbone networks can be conceptualized as shown below:



US Federal Interagency Network Structure

Thus while there are five distinct backbone networks, the two general interconnection points (known as "FIX" points) on each coast allow traffic to flow between the various networks, and also provide effective backup to each other by allowing certain traffic to fail over to another backbone in the event of connectivity failure within any of the backbones (failover conditions are not totally open as they are subject to a number of agency policy constraints).

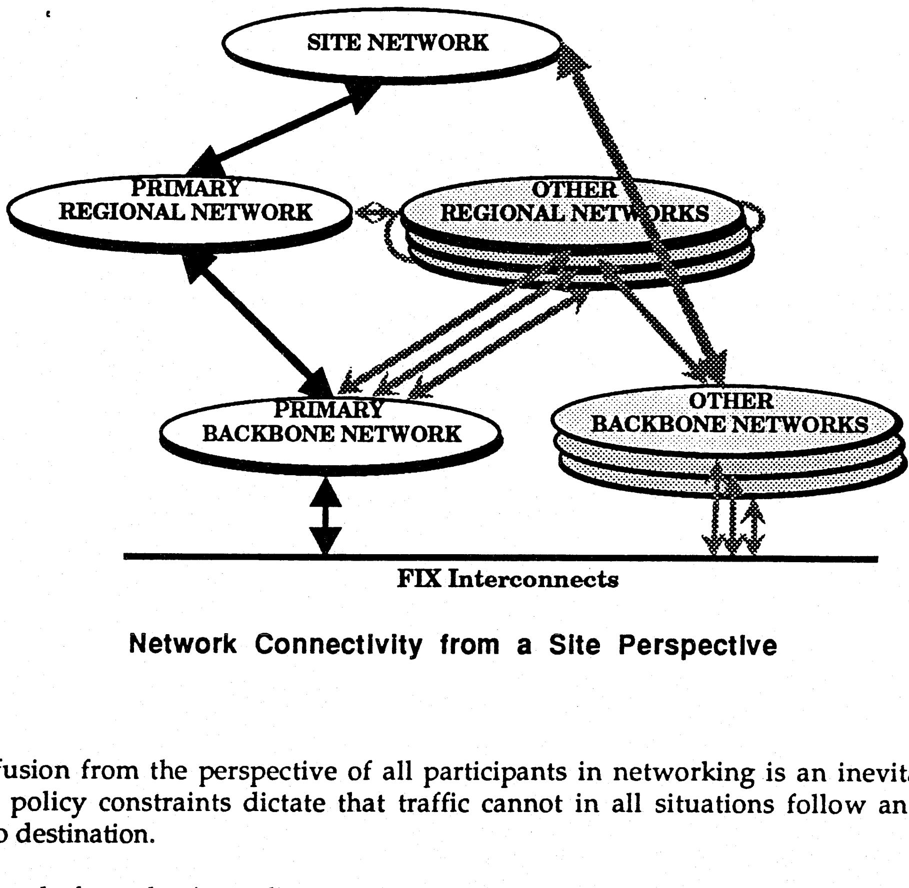
At this point these interconnections are supported by Ethernet. It is highly likely that this will be migrated to an FDDI backbone within the next few months.

1.1.2 Regional Networks and Individual Sites

While the diagram above provides a reasonable picture of the trunk facilities, the picture of connectivity from the perspective of an individual site is more complex.

The NSFNET does not in general provide direct connectivity to individual sites. There are some 15 or so points of attachment to the NSFNET which provide an interface to the so called mid level or regional networks. These regional networks are self funding groups which provide interconnectivity within a geographic area to various academic and research related member organisations. Such mid level networks (BARRNet, NEARNet, CERFNet,...) were commonly established with the initial sponsorship of the NSF but with the transition into self funding the regional networks adopted a more open charter than just academic and research organisations, and the services offered by regional networks typically are including the provision of software and other services as well as Internet connectivity.

The resultant picture from a site perspective is indicated below:



Network Connectivity from a Site Perspective

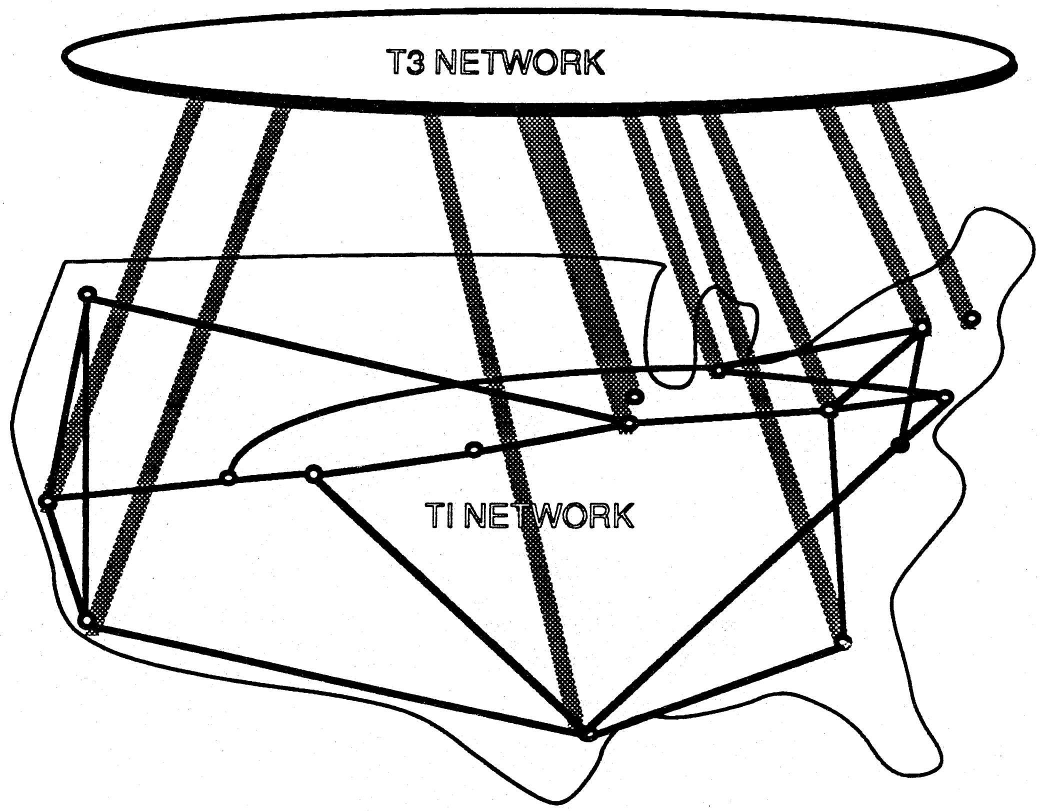
The resultant confusion from the perspective of all participants in networking is an inevitable consequence, particularly when policy constraints dictate that traffic cannot in all situations follow an optimal network path from source to destination.

To provide an example from the Australian perspective, Australian networks may use ESNET to access hosts which are connected to ESNET as their primary backbone, but may not use ESNET for general transit traffic. Hence when NSFNET connectivity fails on FIX-WEST (the preferred carrier for the Australian networks) the NASA NSI backbone performs the transit service. If both the NSFNET and NSI are unavailable at FIX-WEST, backbone routing will be performed via the MILNET for Australian networks.

1.1.3 The NSFNET

The NSFNET is the major backbone network service provider in the United States, with a broad charter to provide infrastructural services to the US Scientific and Research community.

The task of managing the NSFNET was awarded to MERIT (an 8 Michigan university consortium) under a 5 year contract, in 1987. This consortium is supported by the carrier MCI, (which supplies backbone carrier service) and IBM (which supplies routing equipment) for the purposes of fulfilling the NSF contract commitments. The resultant network of 1.5 Mbps DRS links was operational by July 1988, servicing the 13 attachment points, and full FIX backbone interconnection was operational in 1989. The TI links are interconnected in a mesh whereby most points are interconnected via 3 links.



NSFNET Network Topology

The steady growth of usage of the NSFNET facilities has necessitated an additional $8 million contract awarded to MERIT to augment this structure with an additional 2 1.5Mbps links to service the South-East of the continent and also to provide a 45Mbps high speed backbone interconnecting 8 major switching sites. The 45Mbps service will be provided again in conjunction with IBM and MCI (working within a not-for-profit organisational structure). It is anticipated that the services will come on line in late 1990.

Network growth is a continuing aspect of the NSFNET. September 1990 statistics indicate some 1,800 networks and 4 Giga packets transmitted. The application packet profile indicates a breakdown as shown in the following table:

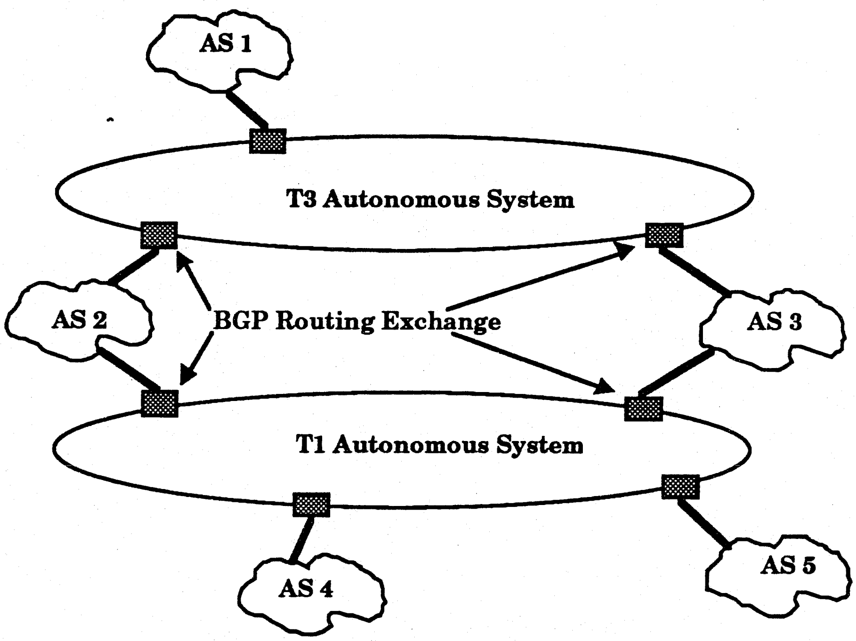
Application type	% of total data packets	% of total data bytes
Electronic mail/news	23%	27%
Interactive Access	19%	8%
File Transfer	28%	50%
Name Services	11%	10%
other	19%	5%

Link utilisation is averaged at 40% for the month over all links, with individual cases as high as 60% (considered unacceptably high from an engineering viewpoint as this implies a high degree of saturation during working hours).

Technical Notes:

The network is an IP protocol network, using SPF routing technology. Support for OSI CLNS services are anticipated to be available over the NSFNET by the end of this year. At this stage there is no significant demand for the CLNS routing services from the US user community.

The implementation of the T3 45Mbps backbone will be using the structure of a distinct autonomous system, sitting beside the existing set of T1 links as indicated overleaf. Treating the two trunk systems as distinct Autonomous Systems implies that, where feasible, traffic will route within a single link set. This, in the diagram, traffic between AS1 and AS3 will remain within the T3 Autonomous System. It also should be noted that in the first instance the interface to the 45Mbps trunks will be 10Mbps Ethernet interfaces!. A program of upgrade to 100Mbps FDDI interfaces is underway.



NSFNET T1 / T3 Configuration

In terms of international links attached to the NSFNET, Canada (CA*net) is directly attached to the NSFNET in three locations: Seattle-Vancouver, Ithica -Toronto and Princeton - Montreal. Additionally there are links to Mexico from Boulder and Houston. Additionally the mid level networks on the east coast include the sites at Princeton (JVNC) which runs links to NORDUNET, JANET and INRIA), and an IBM EASINet TI connection to CERN (Switzerland). It is a logical assumption that these links will come under the direct purview of the NSFNET in the near future, considering that JVNC has lost NSF funding as an NSF Supercomputer Centre.

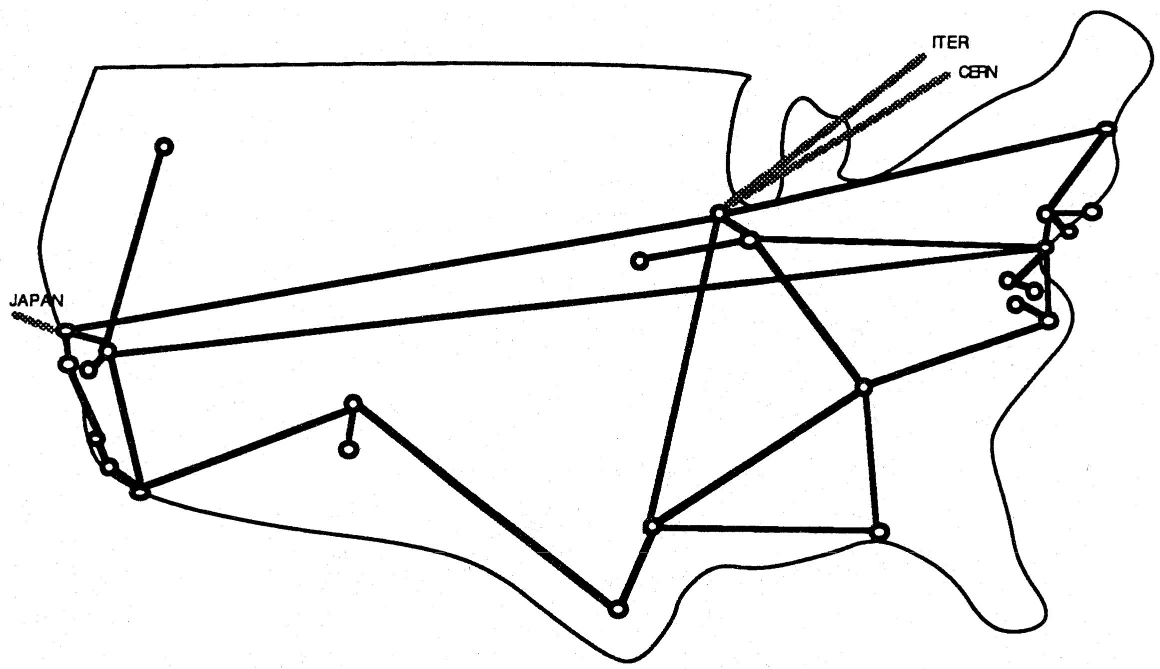
1.1.4 NASA Science Network (NSN)

NASA also operates a backbone network using T1 (1.5Mbps leased circuits) within the US. This backbone network is currently being migrated from a Proteon router TCP/IP single protocol network to a multi-protocol TCP/IP and DECnet network over the next 12 months, with an associated program of phasing out Digital DECnet routing equipment from the operational network, and phasing out all dedicated (single protocol) DECnet links as well.

The NSN also operate (or are the principle funding agency of) a number of international links, including links to Australia, New Zealand, Canada (Nova Scotia), the UK and Chile. Within the UK the link is part of the so called "UK fat pipe" which serves the DARPA / UK requirements as well as NSN requirements within a single physical link. On the UK side this link is accessed by the use of DECnet and IP over the JANET X.25 facilities.

1.1.5 Energy Sciences Network (ESNET)

The Office of Energy Research of the Department of Energy operate a third backbone network in the US, again using T1 links in a trans-continental configuration. The network is a cisco-based dual protocol TCP/IP and DECnet (HEPNET) network currently, and X.25 and OSI CLNS services are under evaluation. Also ESNET is examining the requirement for video transmission within this infrastructure.



ESNET - T-1 Network Topology

The network uses some 26 routers and carries some 0.5 gigapackets per month (some 10% of the NSFNET volume).

Technical Notes:

ESNET have just completed a full upgrade of their cisco AGS-1 units with the recently announced CSC/3 processor cards. This upgrade provides additional throughput capabilities to the routers, but equally importantly offers additionally memory in the units. Because of the advantages in configuration offered by additional memory, this approach may well be a viable course of action for AARNet sometime in the coming 12 months.

ESNET also operates (or funds) a number of international links, including 2 64Kbps links from the US to CERN supporting DECnet, a 384Kbps multi-protocol link US - CERN, 56Kbps DECnet US - Japan, 9.6Kbps DECnet US - Brazil (IP support late this year), and ESNET are also a partner in the multi-agency "fat pipe" from the US to Germany.

1.1.6 Other US Backbone Networks

There are two further US Federal agency networks to build the total picture here. The MILNET carries unclassified military traffic, and is interconnected with the US research networks to support various programs. Also the Defense Advanced Research Projects Agency (DARPA) supports a dedicated network (The WideBand, or TWB) which includes video conferencing facilities as well as data switching functionality.

The coordination of the agencies' efforts is undertaken at both an engineering and planning levels and broader policy levels through inter-agency coordinating bodies (the FNC, FEPG, IAB and the IETF are the major bodies, but numerous other bodies are also involved in various roles). The intent of these bodies is to ensure that the network services provided by each agency is a consistent component of the broader Federal network infrastructure.

1.1.7 Regional Networks - FARNET

FARNET is the association of the 24 US domestic regional, state or metropolitan networks, These networks operate at the level between the trunk backbone networks and individual sites. In general these networks are US domestic facilities, but a small number of international links are supported (e.g. NYSERNET IP link to Israel). FARNET member networks are not in general funded through general programs, and operate on a cost recovery basis. This implies that at the regional level member organisations include academic, regional / state government, industrial (research) and commercial organisations. The latter two categories are generally research-oriented, or service the research community, but are also a necessary component of the regional network structure in order to provide the necessary economies of scale to make the structure self-funding.

The technologies supported by the regional networks include multi-protocol data switching and a limited use of voice and video services in some cases. While high speed links are deployed in some cases, there is a very large set of low speed links to support a growing number of member organisations.

If a trend is evident at this level, it is one of the commercialisation of this technology. Already there are two fully commercial regional networks (PSI and Alternet). As well as this regional level commercialisation, the partnership of IBM and MCI in a not-for-profit organisation to support the T3 NSFNET backbone requirements indicates the same trend at the national level.

1.1.8 US Future Activities

In terms of future activities, the major area of activity at present is concerned with the High Performance Computing Initiative (HPCI) which is currently being considered by the US Congress. This bill proposes an expansion of the research communications infrastructure into the area of very high speed, high capacity network facilities on a national scale (there ar already five so called "gigabit testbeds" under construction to prove the viability of the technology). This program is intended to address the steady growth in usage of the existing facilities as well as addressing new technologies such as switched video and similar applications.

Additional activities include the development of OSI technology, including the work undertaken within the US Industry Science and Technology Council. This work will evidently include the deployment of a national T1 network as a test bed for OSI technologies.

1.2 Canada

The Canadian National Academic and Research network, CA*net was commissioned on the 25th October 1990. This network is funded through the National Research Council of Canada. CA*net uses the same model of a nationally funded backbone network and self-funded regional networks as is employed in the US. The national network uses a set of 56Kbps as internal trunk lines. At this stage the program is still forming a stable base within the complex structure of multiple regional networks and a national network which is overshadowed by the US network (high traffic levels from Vancouver to Montreal would travel more efficiently via the US NSFNET than via the CA*net facilities).

Current activity is concerned with the engineering of T1 backbone links, and in partnership with the Canadian govenrment, CA*net is embarking ona three year program to install a T3 backbone national network.

1.3 Other American Nations

The infrastructural in other nations is more piecemeal, due to the high cost of technology in the Central and South American nations. Direct links exist to Chile, Mexico and Brazil in support of specific research programs, and intermittent links also exist to other nations including Argentina, Costa Rica, Venezuela and others.

The United Nationsl Development program has been active in assisting a number of South American countries to develop their network infrastructure, including ARNET in Argentine and Brazil.

2. The Pacific

In terms of international connectivity in the Pacific region, the major effort of the United States effort is focused through the University of Hawaii. The various United States Federal Government agencies who support national and international networking programs have, in general, contracted a section within the University of Hawaii to provide engineering and operational management services for such links. Within the arrangement the National Science Foundation, the National Aeronautics and Space Administration and the Department of Energy all have contracts with the University of Hawaii to provide services to various Pacific nations in support of the agencies' specific research programs. The University of Hawaii itself also supports this program. These agencies work within a United Stated inter-agency informal structure which is directed towards ensuring that wherever possible such links are "open" links, allowing not only those bodies involved in the specific research programs to have access to the link, but also including the general provision that the academic and research community in the nation involved may also have open access to the link.

2.1 Australia

It is not intended to cover the Australian situation and AARNet in any detail within the scope of this report.

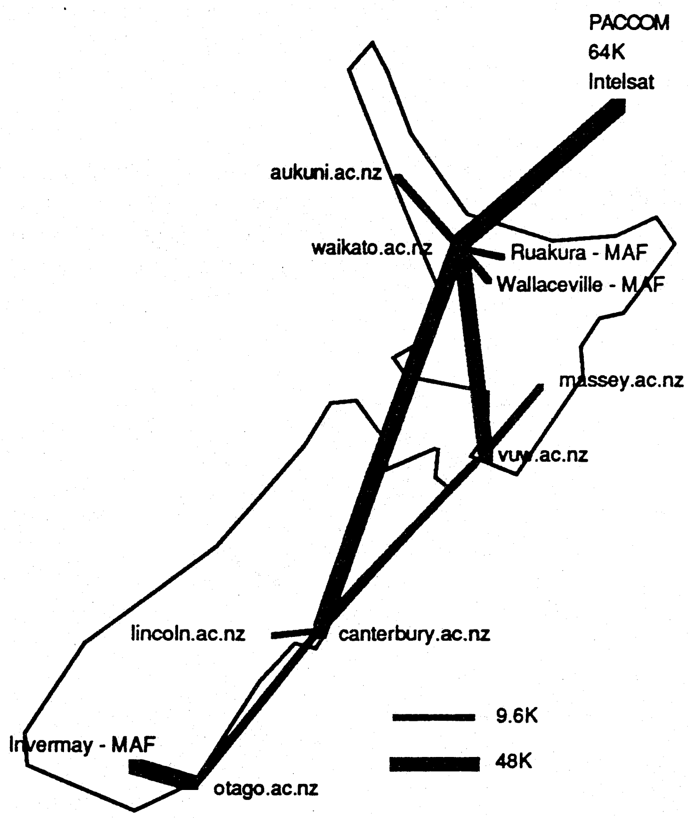
2.2 New Zealand

Over the previous three years there have been significant levels of progress within New Zealand in terms of the construction of a cohesive internal national network together with a consistent approach to the provision of the network services[1].

Within the New Zealand university community the Kawaihiko network provides a backbone network service to the university member sites. The approach adopted by Kawaihiko is similar to that of AARNet, using cisco gateway servers and leased lines to provide a national multi-protocol network. The seven university members of Kawaihiko have adopted a cost sharing model where each university member has purchased a local gateway server, a leased internal digital circuit and also purchased a volume-based share in the common international link to FIX-West

1 The material presented here is summarized from presentations given at PACCOM 90, and the paper "New Zealand's Academic Networks", John C. Houlker, University of Waikato (j.houlker@waikato.ac.nz), July 1991.

At this stage all internal link capacities are 9.6K with the exception of the circuits from Canterbury and Victoria to Waikato, which are 48K circuits (leased line circuit tariffs are generally high in New Zealand), and the internal topology uses a central triangle configuration with four tail links, as indicated below. This structure gives the network a degree of redundancy in the core of the network[2].



Kawaihiko / TUIA - Link Topology

It is anticipated that the major north/south island link will be upgraded to 48Kbps bandwidth in the near future.

The international link to FIX-West uses an Intelsat circuit, at 64Kbps. The link is half circuit funded between New Zealand and the United States through PACCOM.

Kawaihiko is a component of a larger national academic and research network, TUIA. TUIA also includes the government research body DSIR (and the DSIRnet private X.25 network) as well as the Ministry of Agriculture and Fisheries (MAFnet, another X,25 private network, supporting DECNET and PRIMEnet). The general direction of TUIA at this stage is a trend of development from a private X.25 switched network (supporting primarily DECNET and the UK JNT Coloured Book Protocols) to a coherent multi-protocol backbone service. At this stage there is a concerted effort to include the infrastructural communications services of TUIA into a National Research Computer Network under the auspices of the NZ Ministry of Science and Technology, although there is no evidence that this will entail any financial commitment from the government in so doing. A Working Party of the Crown Research Institutes, the universities, NZ Telecom the National Library and the

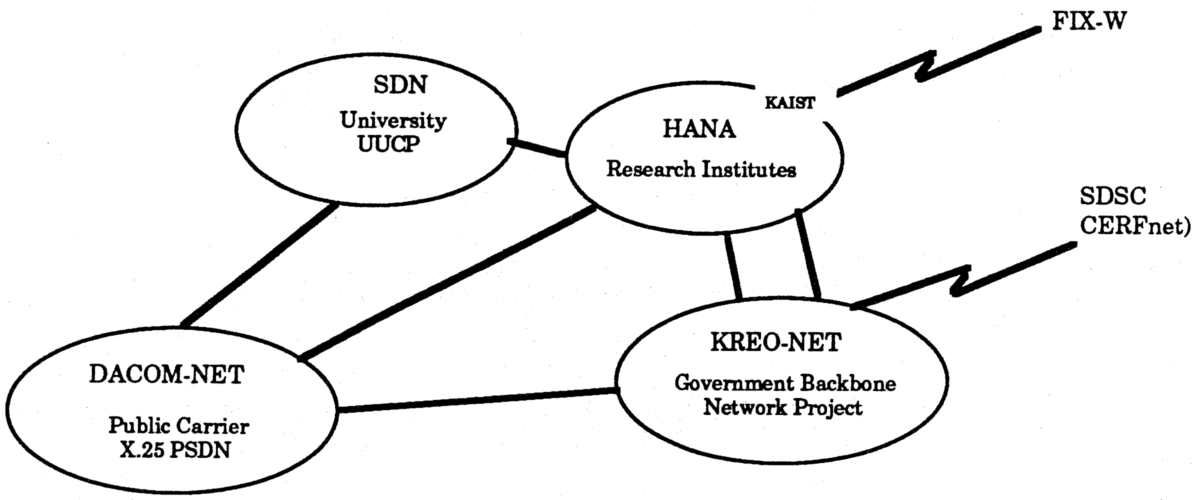
2 Although unless the North/South Island links are on physically distinct cable structures (which is unlikely) there is not as great a level of physical cable failover capacity as the diagram would indicate., leading to the observation that engineering of redundancy is more complex than initial impressions may tend to suggest. The imbalance of line capacities in the central triangle would also not allow effective loadsharing within the three links.

Ministry are to report on the proposed framework of such a network by December 1991, and the Ministry expects implementation and funding mechanisms to be recommended by June 1992. It remains to be seen whether such a broad group can achieve the required focus within the nominated timeframe.

Additional international activity by New Zealand includes the installation of a VAX PMDF-based mail gateway to the University of The South Pacific (using international phone facilities as the transport for the mail relay). Also planned is a link from Canterbury to the McMurdo Sound Antarctic bases.

2.3 Korea

Korea came on line to PACCOM (and the Internet) in June 1989 with the establishment of a 56Kbps satellite link from Hawaii to HANA, the domestic research network. This link is the successor to earlier UUCP links to the Netherlands (EUNET at Amsterdam) and the United States and Internet X.25 links to CSNET in the United States. This facility complements an existing 9.6Kbps BITNET connection to the United States, and the UUCP links to Amsterdam are also still in place.



Components of the Korean Networking Structure

At this point the Internet component of the overall domestic infrastructure is not overly widespread: IP access appears to be concentrated to a small number of research institutions, while universities are interconnected using UUCP facilities. Government initiatives are underway to improve facilities, and a high speed TI backbone with multi-protocol support as a likely direction . The internal connectivity within Korea is indicated below. Research institutions generally use 56Kbps internal connection, while the universities generally use lower bandwidths.

The international 56Kbps satellite link between KAIST and Hawaii is fully funded by KAIST.

2.4 Japan

A number of academic and research networks exist within Japan, and there are a number of locations where inadequate domestic communications facilities create an anomalous situation where domestic traffic must be passed via Hawaii and mainland United States.

WIDE is a research network within Japan, examining a number of internet-related research topics, including X.25 integration, ISDN facilities, integration of voice servers and mobile internet connectivity services. The

WIDE network is connected by a 64Kbps cable link to Hawaii. WIDE interconnects 32 research sites in Japan using both X.25 services (provided to universities by a Government communications infrastructure program, NACSIS (Gajuko-net)) and leased capacity. The overall objective of the WIDE program is that of research relating to communications technology.

TISN (Todai International Science Network) is an infrastructural network for the support of science research programs TISN is a multiprotocol network, supporting both DECNet and the Internet Protocols. The research domains supported by TISN include higher energy physics, space aeronautics, genuine technology, stellar and terrestrial environments, seismology and biochemistry. TISN uses a 64Kbps cable link from Japan to Hawaii, and a direct 56Kbps DECNet link also interconnects the higher energy physics laboratory, KEK to the United States Higher Energy Physics DECNet (HEPNet) (a component of the United States Department of Energy funded Energy Sciences Network, ESNET) via Lawrence Berkley Laboratories on the United States West coast.

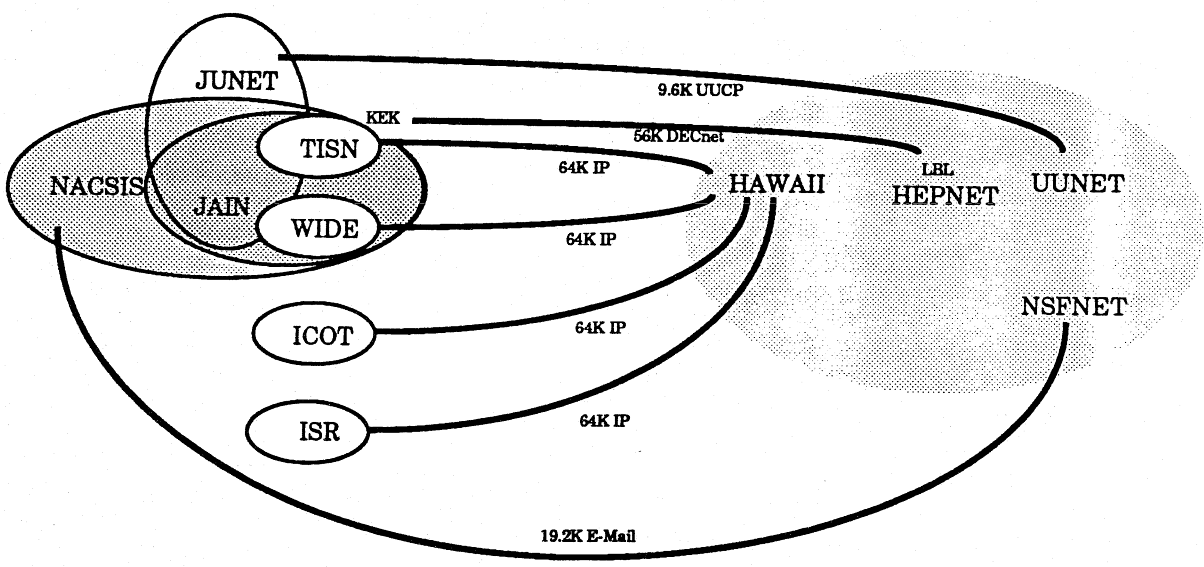
Both WIDE and TISN are members of a domestic Internet, JAIN. Within a larger project of the Japanese Ministry of Education (which has entailed significant investment by the Ministry into domestic communications infrastructure for network facilities for universities) NACSIS, the JAIN project provides Internet connectivity to some 13 universities.

ICOT is the Japanese fifth generation computer project, which is undertaking computing technology research in collaboration with a number of research bodies in the United States. A third 64Kbps cable link connects ICOT to Hawaii and the Internet. Within Japan there is no domestic connection between ICOT and peer sites or domestic networks.

The ISR (Institute for Supercomputer Research) is a non-profit organisation of Japan. A fourth 64Kbps cable link across the Pacific interconnects ISR and Hawaii, fully funded by ISR.

Additional links include an older 9.6Kbps UUCP connection to the UUNet host in the United States (which was the international connection of JUNet, which itself has now folded into JAIN) and it is understood that a TI (1.5Mbps) connection is underway, between NACSIS and the United States National Science Foundation (NSF) in Washington DC, but details of this connector are unclear at present.

The overall known international connectivity for Japan to the US is (roughly) as indicated in the following figure (overleaf).



Japan Connectivity to the US

Of interest is the recent formation of the Japan Council of Research Networks (JCRN) which held its inaugural meeting in October 1990. The major role of this group is evidently to coordinate the internal infrastructure of Japan's research networks to provide a more coherent service to the research community.

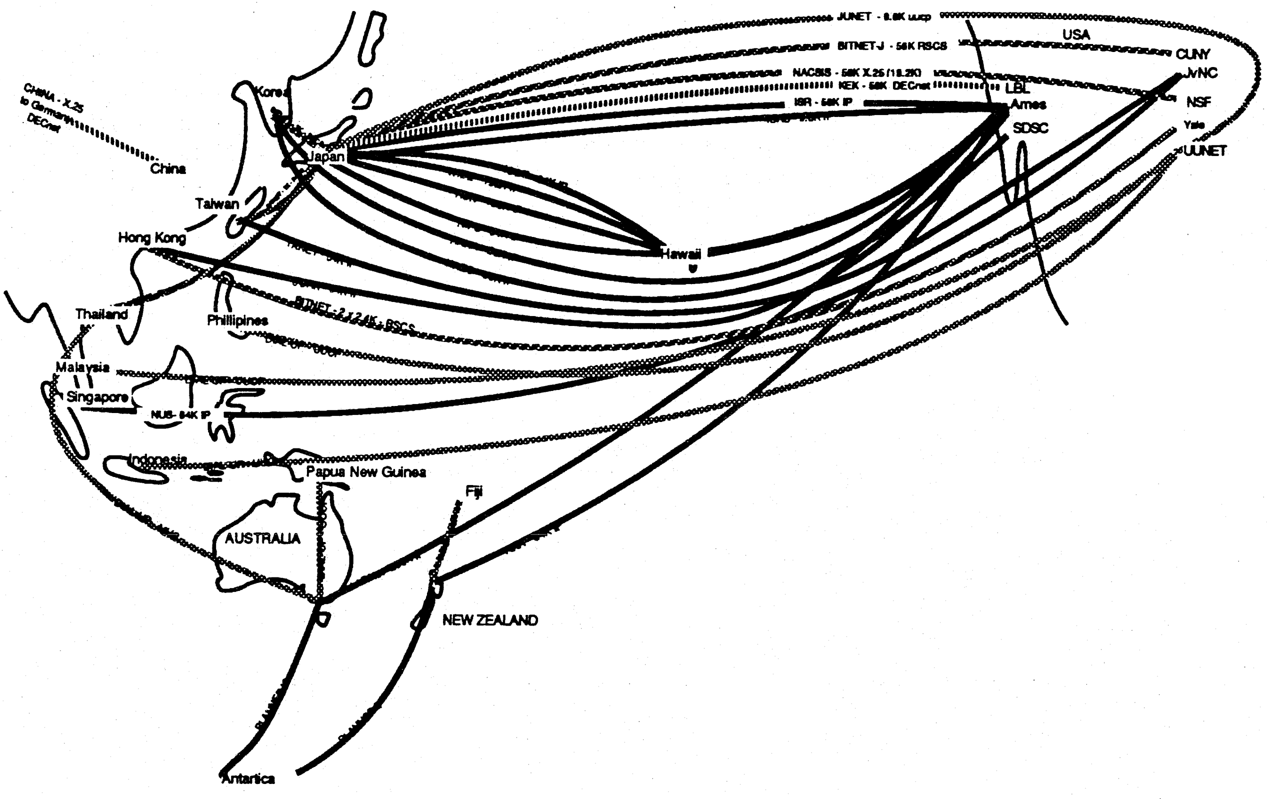
2.5 Malaysia

Within Malaysia the JARING (Joint Advanced Research Integrated Networking) project is undertaking the establishment of a national infrastructural research network in Malaysia. Currently the country uses international X.25 to uunet to transfer mail via the uucp protocols. Within Malaysia a number of sites are similarly linked using uucp over the domestic X.25 service[3].

The current plans include the installation of low to medium speed dedicated domestic links at the nodal points to support TCP/IP traffic, and the installation of a dedicated TCP/IP international link. No precise timetable for these plans has been determined to date.

2.6 Pacific Connectivity

The resultant (known!) network connectivity in the Pacific region is indicated in the next figure.



Pacific Connectivity - August 1991

3 JARING Project: An Introduction, Mohamed b. Awang-Lah, Malaysian Institute of Microelectronic Systems (MIMOS) *mal@rangkom.my*

3. Europe

With the multiplicity of networking efforts within Europe over the past few years, the resultant rather complex network structure is difficult present in a background document of this type.

Because of these complexities it is more appropriate to present a short background to the technology development in Europe, and relate this effort to the resultant organisational and network structure that exists today.

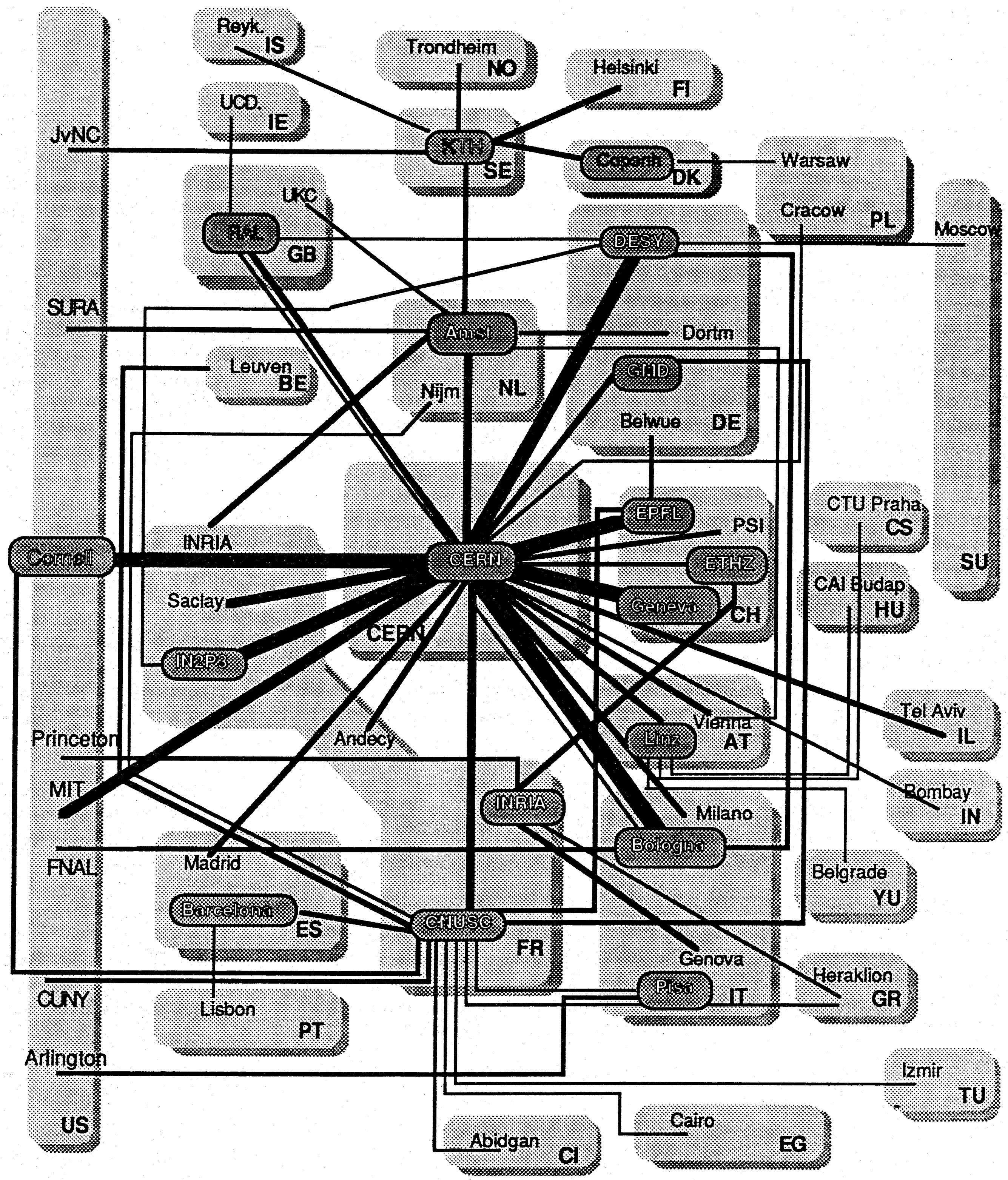
European nations in general did not follow the same technical development path as the US over the previous decade or so. Whereas in the US the effort has been directed towards protocol engineering for internetwork connectivity, the European effort was split between the deployment of available vendor-specific technologies (principally DECNET) and the participation in the development of telecommunications carrier (CCITT) sponsored technologies (X.25 and OSI). With the rapid maturation of the US effort into a commonly available network technology (TCP/IP) Europe is now faced with a complex issues of resolving a large investment into developing technology which has still to produce real solutions in a broad level of user adoption (in OSI), the ready availability of cheap effective technology (in TCP/IP) and a somewhat uncoordinated existing physical infrastructure of network links within the continent.

With the increasing requirement in Europe for interoperability with US facilities, Europe has recognised the overwhelming requirement for coordination of effort leading to an internal infrastructure with the attributes of coherency and interoperability. This task is being undertaken through the EURO-CCIRN - a body whose major agenda is the coordination of a backbone infrastructure in Europe, RARE and RIPE.

The efforts within Europe are currently being undertaken in a number of areas. TCP/IP networking infrastructure is being addressed through RIPE. RIPE has published an IP inventory of European connections which is attached to this report. It should also be noted that this group is now working with the European HEP/SPAN Coordinating Committee with a likely outcome of a coordinated multi-protocol infrastructure which could effectively serve both user sectors.

Other programs include IXI, a program of industry collaboration directed toward international X.25-based services for the European research community, and COSINE, an EEC funded activity directed at this stage toward the further development of the OSI protocol stack. Neither of these programs are at this stage offering a stable basis for supporting current requirements in Europe, and their futures are not entirely clear at this stage.

One of the most significant recent developments is the engineering of a high bandwidth European backbone network, scheduled to be operational by mid 1991. The type of structure envisaged uses a major high speed North-South axis running from NORDUNET (Nordic countries), through SURFNET (The Netherlands and possibly offering connection services to UK, Belgium and surrounds), CERN (France, Germany and Switzerland) and Italy. It is envisaged that this internal structure is to be supported with a set of trans-Atlantic links, basically with a link from each of the European backbone hub points.



European Major Leased Lines - Academic and Research Network Facilities

Acronyms and Abbreviations

AARNet	Australian Academic and Research NETwork
CCIRN	Coordinating Committee for International Research Networks
DARPA	U.S. Defence Advanced Research Projects Association
DoE	U.S. Department of Energy
DSIR	New Zealand Department of Scientific and Industrial Research
EUCIRN	European Committee for International Research Networking
FEPG	The U.S. Federal Internet Engineering Planning Group
FIX (East and West)	Federal Internet Exchange centres
FNC	U.S. Federal Network Council
HPCI	The U.S. High Performance Computing Initiative
IAB	The Internet Activities Board
ICOT	The Japanese Fifth Generation Computer project
IP	Internet Protocol
ISR	The Japanese Institute for Supercomputer Research
JAIN	Japanese Academic Inter-University Network
JUnet	Japanese University Network
KAO	The NASA Kuiper Airborne Observatory
Kawaihiko	New Zealand University Network
KREONet	Korea Research Environment Open Network
MAF	New Zealand Ministry of Agriculture and Fisheries
NACIRN	North American Committee for International Research Networking
NACSIS	The Japanese National Department of Education sponsored X25 network
NASA	U.S. National Aeronautics and Space Administration
NOC	Network Operations Centre
NREN	The U.S. National Education and Research Network
NSF	U.S. National Science Foundation
PACCOM	Pacific Community Network
PEPG	Pacific Internet Engineering Planning Group
RIPE	European IP Research Networks
TISN	The Japanese Tokoyo based International Science Network
TUIA	New Zealand Academic and Research Network
WIDE	simply the Japanese wide area internet --- a research network