

2-3 Trends on Network Testbeds in the World

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becoming to the infrastructure of any kinds of R&D. Internet2 in U.S. includes various strategic networks and projects. And in Europe there are collaboration among many network testbeds led by EU.

Regarding characteristics on network testbeds, we have three issues. One is an adoption of photonic technology. Two is a focus on middle ware technology. Three is an attention on application technology. In the future, each network testbeds will have an originality, and they have many collaboration each other over the border.

Keywords

JGNII, Internet, Network testbed, Next generation network, Photonic network

1 Introduction

The Japan Gigabit Network (JGN) began operations in 1999, and was hailed at the time as the fastest network testbed in the world. Its successor, the JGNII, has been in operation since 2004. Network testbeds are now operating in North America, Europe, Asia, and elsewhere, with the incorporation of photonic technology, middleware research and development, and the investigation of a range of applications. This paper provides an introduction to these current trends in R&D of network testbeds.

2 What are network testbeds?

Network testbeds are networks designed mainly for the development of network technology. (In this paper, the terms “testbed networks” and “network testbeds” are interchangeable.) The discussion in this paper assumes that network testbeds satisfy the following criteria.

- (1) R&D takes place on the network.
- (2) Multiple research institutions are linked to

the network.

- (3) New network technologies are implemented on the network.

However, the above three conditions are not necessarily absolute; a network may be regarded as a network testbed even if it fails to meet one of the conditions. It is widely known that the JGNII network is currently hosting a wide range of R&D, with numerous associated research institutes linked to this network. The network also incorporates the latest photonic technology.

Network testbeds are designed to provide structures simulating those we assume will be required for future networks. These assumptions naturally give rise to the above criteria stipulating the general conditions that must be satisfied by a testbed. As an additional requirement, to encourage R&D, the AUPs (Acceptable User Policies) for these testbeds must specify restrictions on commercial traffic and clarify that no SLA (Service Level Agreement) is provided with use.

3 General trends in network testbeds

Existing testbeds have often been designed with a focus on ultra-high-speed communication. However, given a worldwide trend toward lower communication costs, it is becoming increasingly evident that universities and research institutes are not prioritizing the provision of ultra-high-speed network testbeds. Thus, testbed design is presently facing a dramatic shift in strategy.

The characteristics of current network testbeds can be described through the following observations.

- (1) We are witnessing an emphasis not only on the network testbed itself, but also on the R&D projects that the testbed can support.
- (2) R&D projects normally involve multiple network testbeds, and so the relationship between network testbeds and R&D projects is becoming increasingly complex.
- (3) The spectrum of targets in R&D projects is extending to middleware as well as to fields in science and technology, with even further expansion in scope anticipated.
- (4) Energetic R&D is now underway for a variety of middleware (involving the use

of grid technology, for example).

The following sections will describe the major network testbeds in North America, Europe, and Asia, with the above observed trends in mind.

4 Network testbeds in north america

4.1 CA*net4^[1]

CA*net4 is Canada's coast-to-coast photonic network developed for research and education. It connects all regional networks of Canada and supports the use of advanced applications.

Expanding on the achievements of its predecessor, the CA*net3 project (involving the construction and technological evaluation of a photonic network optimized for IP communications), the CA*net4 project has as its main technological target the implementation of UCLP (User-Controlled Light Path). The UCLP is a user-controlled network architecture that allows end users to manage and control their assigned optic fibers and bandwidth at the GigaPoP nodes.

The CA*net4 network topology is shown below.

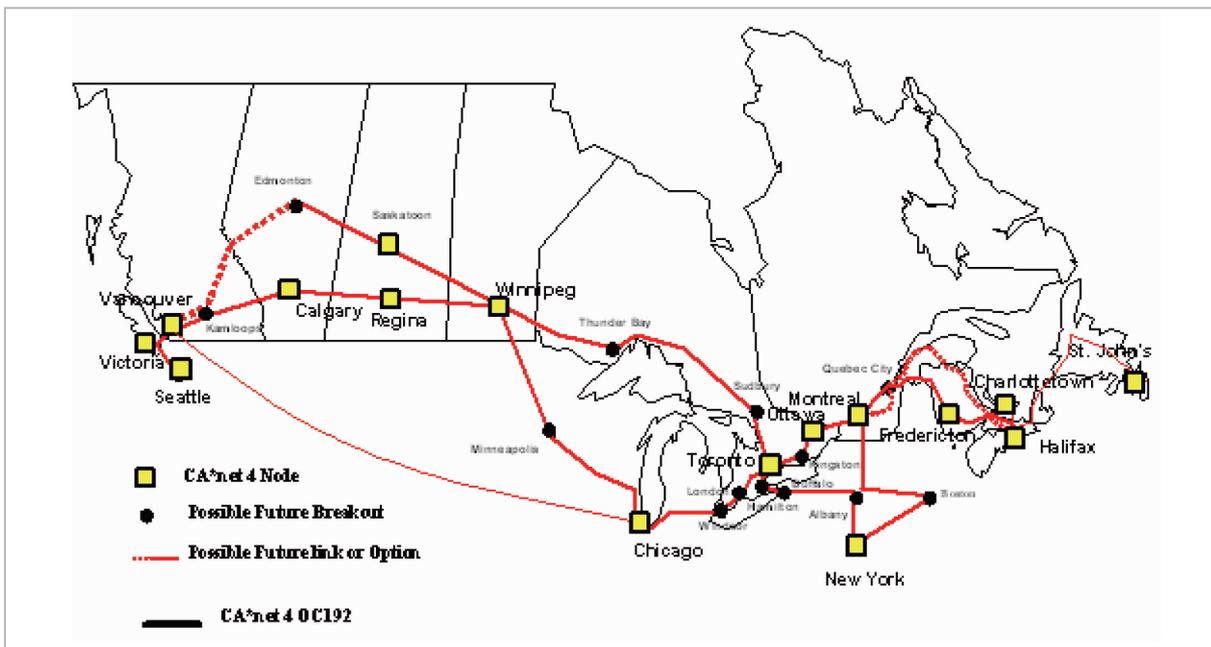


Fig. 1 CA*net4 network topology

(Excerpt from http://www.canarie.ca/canet4/library/c4design/large_file_transfer.ppt)

4.2 Abilene (Internet2)^[2]

Abilene is a research testbed network in the US dedicated to Internet2 projects, and is designed for the development of advanced network technologies, innovative Internet applications, and commercial Internet implementation. Abilene use is presently limited to education, e-learning, research, and clinical studies among institutions of higher education, and it is not open to commercial traffic. Access is limited to Internet2 members and these educational institutions.

Abilene is operated by the Internet2 Consortium, a group formed by the University Corporation for Advanced Internet Development (UCAID) and a number of corporate partners.

Since it is not directly associated with national governmental policies, Abilene receives no special funding from the federal government, and is solely supported by the Internet2 membership fees and connection charges collected from participating institutes. However, research using the network is in part funded by grants based on various governmental policies and initiatives such as the NGI.

The operational costs are covered by capital investment by universities, matching investments by businesses, and membership fees (totaling \$3.3 million/year). The connection charges for OC-192 POS/10GigE total \$490,000/year. University members of Internet2 contribute capital investment totaling \$80 million annually for the expansion of university facilities, network connection fees, and application development. Corporate members contribute in a variety of ways, from monetary support to the provision of network-related equipment, in addition to payment of the required membership fees.

4.3 Range of network testbeds in the US

Abilene (Internet2) is the best-known network testbed in the US, but there are a multitude of additional network testbeds and associated projects, mainly established by the NSF

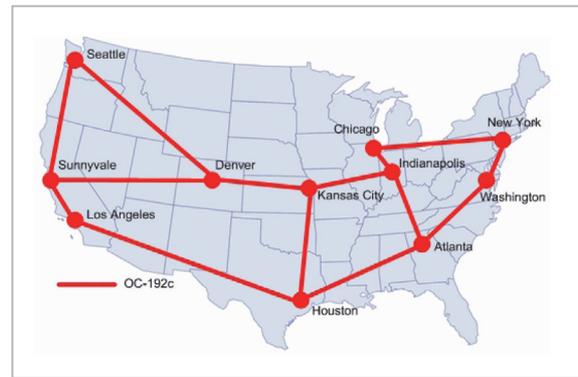


Fig.2 Abilene network topology

(Excerpt from <http://abilene.internet2.edu/images/abilene-current.gif>)

(National Science Foundation).

Figure 3 shows a summary of the major network testbeds and associated projects established primarily by the NSF.

Table 1 provides details of the network testbeds and the related projects shown in Fig. 3.

HOPI is an Internet2 project to implement a hybrid shared-IP-packet and switched-optical-wavelength network, with the deployment of testbed facilities planned for 2006. The HOPI testbed is being constructed using the Abilene, RON, and NLR networks.

The Regional Optical Networks form a photonic network testbed operated by Fiber Co. founded by the Internet2 to support regional photonic fiber network initiatives aimed at research and educational institutions.

The MAN LAN is a high-performance exchange point located in New York City designed to facilitate interconnection among US and international research and education networks. It was built through a collaborative effort between the Internet2, NYSERNet, and Indiana University. Connection charges are collected on a monthly basis.

The NLR is an ultra-high-speed network owned and operated by researchers. The Internet2 provided a total of \$10 million in funds to cover a five-year period, and has access rights to the 10-Gbps circuit. The Internet2 organization is using the NLR along with Abilene as foundations for the development of a hybrid

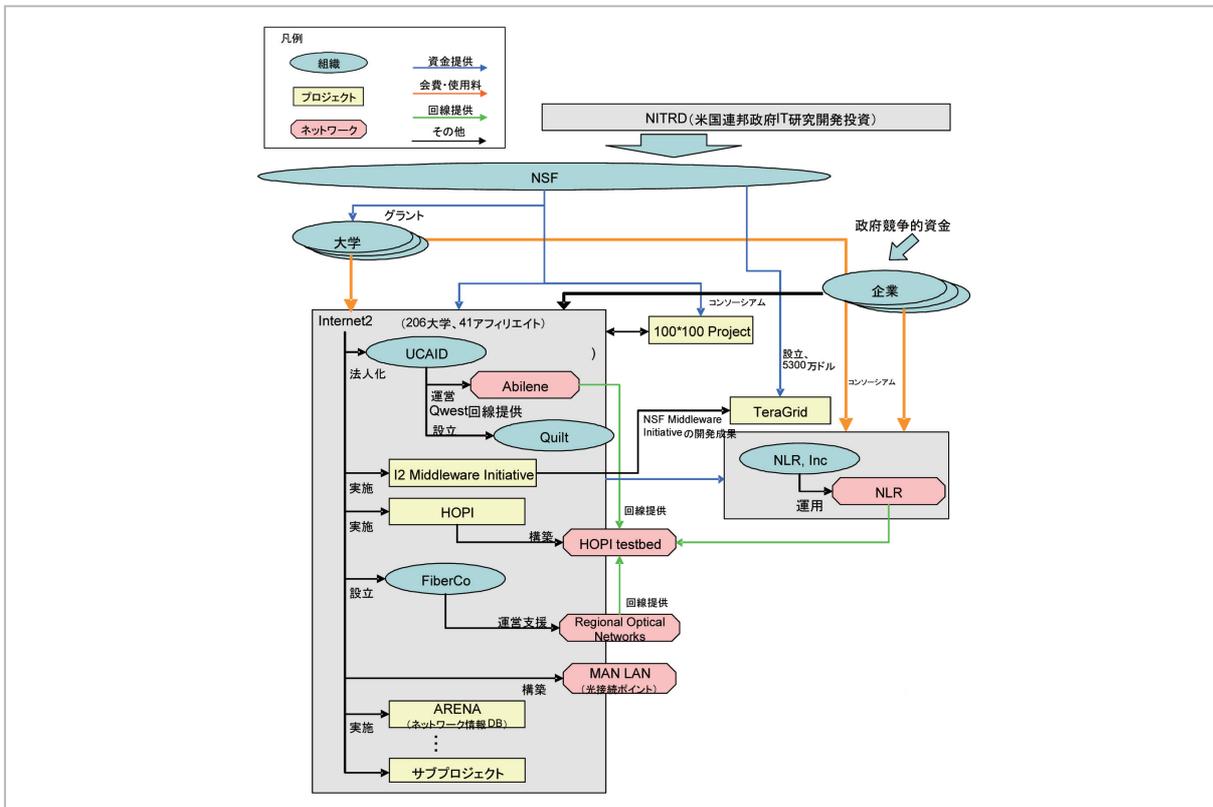


Fig.3 Major network testbeds and associated projects mainly established by the NSF
 (Drawn from references provided by Mitsubishi Research Institute, Inc.)

Table 1 Major network testbeds and associated projects by the NSF

Name	Summary
HOPi testbed	HOPi is an Internet2 project to implement a hybrid shared-IP packet and switched-optical-wavelength network, with the deployment of testbed facilities planned for 2006. The HOPi testbed is being constructed using the Abilene, RON, and NLR networks.
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MAN LAN	The MAN LAN is a high-performance exchange point located in New York City designed to facilitate interconnection among US and international research and education networks. It was built through a collaborative effort between the Internet2, NYSERNet, and Indiana University. Connection charges are collected on a monthly basis.
NLR	The NLR is an ultra-high-speed network owned and operated by researchers. The Internet2 provided a total of \$10 million in funds to cover a five-year period, and has access rights to the 10-Gbps circuit. The Internet2 organization is using the NLR along with Abilene as foundations for the development of a hybrid optical packet environment.
TeraGrid	The Teragrid offers 20 teraflops in computing capacity using computer resources distributed among five sites. The NSF provided \$53 million in funding for four of these sites in 2001. The NSF Middleware Initiative effort now involves research and development involving the Internet2, EDUCAUSE, and SURA.
I2 Middleware Initiative	The "I2 Middleware Initiative" is a project to provide core middleware services to Internet2 member universities.
ARENA (Advanced Research and Education Network Atlas)	The ARENA project involves the creation of a database of information on advanced research and education networks around the world.
100*100 Project (100 Megabits to 100 Million Homes)	This is a joint project between researchers from universities and elsewhere to rebuild existing Internet architecture to provide 100-Mbps access rates to homes and small businesses. This project has been awarded a five-year grant from the NSF Information Technology Research (ITR) Project. The Internet2 organization provides technical support and two principal researchers for this project.
PacificWave	The Pacific Wave project is part of joint efforts between CENIC and PNWGP, and has as its goal the construction of a network connection facility covering the entire US Pacific coast. This will promote efficiency in IP traffic by relaying such traffic from other networks, as well as through greater overall efficiency in network transmission.
PlanetLab	PlanetLab is an open, decentralized platform for developing, deploying, and accessing worldwide network services. The Abilene observatory (a project to support the collection and distribution of Abilene network data) provides the eight core router nodes for PlanetLab.
GLIF(Global Lambda Integrated Facility)	The GLIF is a worldwide Lambda-based research facility for the development of applications and middleware on the LambdaGrid. This facility was founded by researchers at SURFnet, the University of Amsterdam, and NORDUnet at the 2003 Annual Global LambdaGrid Workshop. The Internet2 organization is participating in this project in the context of an optical wavelength experiment conducted with MAN LAN.

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The “I2 Middleware Initiative” is a project to provide core middleware services to Internet2 member universities.

The ARENA project involves the creation of a database of information on advanced research and education networks around the world.

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The Pacific Wave project is part of joint efforts between CENIC and PNWGP, and has as its goal the construction of a network connection facility covering the entire US Pacific coast. This will promote efficiency in IP traffic by relaying such traffic from other networks, as well as through greater overall efficiency in network transmission.

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5 Network testbeds in Europe

In Europe, the EU (European Union) is taking the initiative in establishing the so-called “e-Infrastructure”. This infrastructure will promote the coordinated use of research and information resources scattered around Europe (involving GRID calculation, high-speed networks, storage, etc.) to create a framework for the development of e-science. The European network testbed—such as GEANT, EGEE (a GRID research project), and DEISA—all hope to benefit from the synergy arising from the e-Infrastructure.

5.1 GEANT and GEANT2^[3]

GEANT is a network testbed promoted by DANTE (Delivery of Advanced Network Technology to Europe), with interconnection among the NRENs (National Research & Education Network) of different European countries. The purpose of the testbed is to provide a data-communication environment beyond the gigabit level. GEANT was in operation from Nov. 2000 to Oct. 2004, and GEANT2 began operations in Sept. 2004. The number of target NRENs for interconnection is assumed to be 30 (See Fig. 1). The bandwidths of the GEANT and GEANT2 backbone circuits are 10 Gbps and 40 Gbps (10 Gbps × 4), respectively; there appearing to be strong demand for the establishment of faster, ultra-high-speed backbones.

5.2 SURFNET^[4]

SURFNET is a national research network in Holland that links research and educational institutions such as universities in the country through high-speed networks. It was developed as a network platform for the GigaPort Project (involving the Dutch government, private businesses, and educational and research institutions), and is now being applied to R&D of applications relating to electronic collaboration, e-business, and more. As of 2005, the

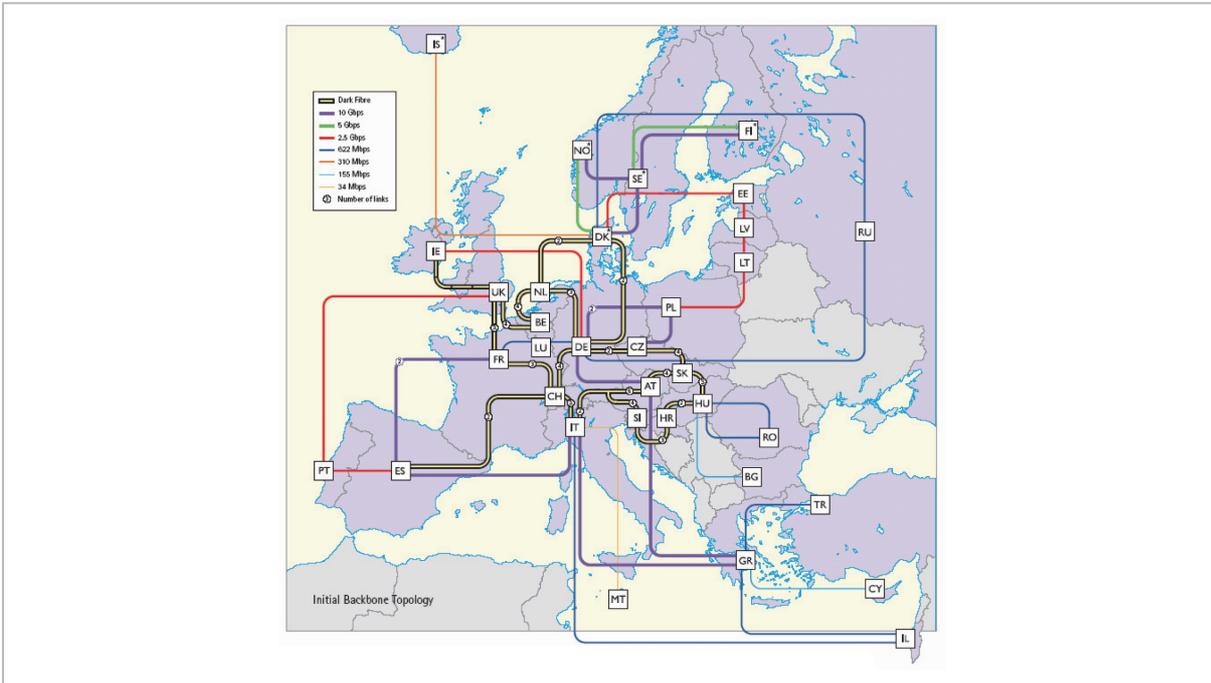


Fig.4 GEANT2 network topology

(Excerpt from http://www.geant2.net/upload/pdf/GEANT2_brochure_2nd_edition_final.pdf)

backbone speed of SURFNET5 is 30 Gbps, but there are plans to increase this to 80 Gbps.

Figure 5 shows the network topology of SURFNET5.

5.3 EGEE [5]

EGEE is a collaborative effort among 27 countries in Europe to develop grid technology and grid-based services, and is based on the GEANT network. The goal of this initiative is to provide an environment in which researchers may access computer resources regardless of physical location.

The main objectives of this initiative are as follows.

- (1) To construct a stable grid network and increase access to computer resources
- (2) Development and maintenance of middle-ware for more reliable service
- (3) To attract researchers from industry and academia and to provide opportunities for advanced support and training

Below are some examples of actual EGEE applications.

- Large Hadron Collider Computing Grid (LCG)



Fig.5 SURFNET5 network topology

(Excerpt from <http://www.surfnet.nl/en/organisation/network/flasheng/map.html>)

Uses the grid foundation to store and analyze petabyte-level data obtained through actual experiments and simulations of the high-energy physics experiments performed at

CERN

- Biomedical

Data mining of petabyte-level data within the genome database, indexing of medical databases, and on-demand computing of heterogeneous data

6 Network testbeds in Asia

6.1 CERNET2 [6]

In China, efforts to create a next-generation Internet on a national scale began officially in Aug. 2003, with the following three goals.

- Creation of an advanced network to support future research
- Creation of a test environment for new technology and new business applications
- Cultivation of an industry of IPv6-compatible products

CNGI consists of three layers—(1) a layer that establishes connection with the international NGI; (2) multiple backbone networks, metro networks, and the GigaPoP system that connects them; and (3) a multitude of campus networks. The CERNET2 network is different from CERNET, and it is intended to serve as the largest backbone network for China's next-generation Internet, the CNGI. The network was planned as part of a national NGI in 2001; trial operations began in 2003. It has provided IPv6 services since April of 2004. The network topology of CERNET2 is presented below.

6.2 KOREN [7]

KOREN is a non-profit research network provided to universities, research institutions, and industry research organizations. It offers a research environment for the development of high-speed communication devices and application services, and is positioned to support R&D of basic technology and associated applications, and more broadly, Korea's IT vision of an Information Superhighway.

Between 1995 and 1997, KOREN mainly supported the development of network technology and associated devices, but since 1998

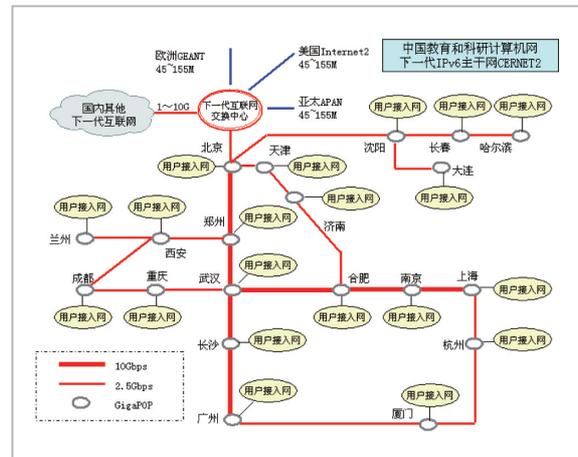


Fig.6 CERNET2 network topology

(Excerpt from <http://www.ampath.fiu.edu/CANS2004/nov%2003/Jianping%20Wu-%20nov30.ppt>)

the network has shifted to providing an advanced research environment for next-generation technologies based on QoS, Multicast, IPv6, and MPLS.

The Ministry of Information and Communication (MIC) of Korea presents the policies and the project goals of KOREN based on overall public policy, and formulates the corresponding basic plans.

The National Computerization Agency (NCA) of Korea is in charge of the operation of the network, organization and management of development meetings and user forums, and support for international research collaboration. The KT Corporation is in charge of the construction and modification of the network, operation and maintenance, and support and management of member institutions.

The KOREN network topology is illustrated below.

6.3 SingAREN [8]

SingAREN is a research and education network in Singapore, with a main focus on joint international research and broadband application development. The network was created as a national project to reinforce the activities of the research and education community in Singapore and to promote international cooperation, and began operations in 2001. Universities and research institutions

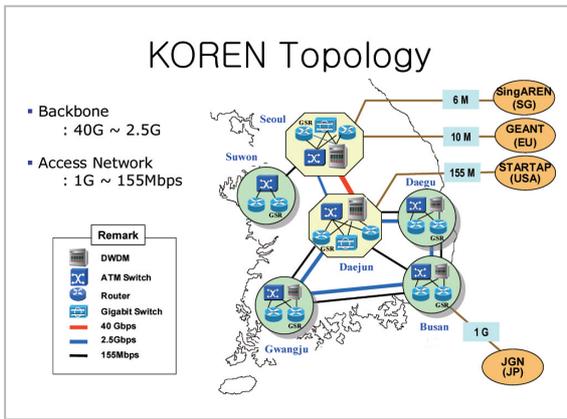


Fig.7 KOREN network topology

(Excerpt from <http://www.ccirn.org/general/AP%20Networks%20at%20CCIRN.ppt>)

are participating in R&D of grid computing, photonic networking, and broadband applications such as those involving IPv6.

A total of five national universities and research institutions are involved in the operation and maintenance of SingAREN. Among these entities, the National University of Singapore (NUS) plays the central management role and performs duties outside of normal operations, such as management of the executive office.

In Oct. 2003, SingAREN was transformed into a non-profit organization and currently receives no funding from the Singapore government.

The network topology of SingAREN is shown below.

6.4 ThaiSarn [9]

ThaiSarn is a network for research and higher education, connecting researchers in Thailand with their counterparts throughout the world. The major nodes within Thailand are linked by 155–620 Mbps ATM circuits. The current goals of network operations include research on application technologies in remote education, remote medicine, TV conferences, VOD (video on demand), and the practical implementation of these technologies.

ThaiSarn operations began in 1992 with the aim of promoting Internet use, especially

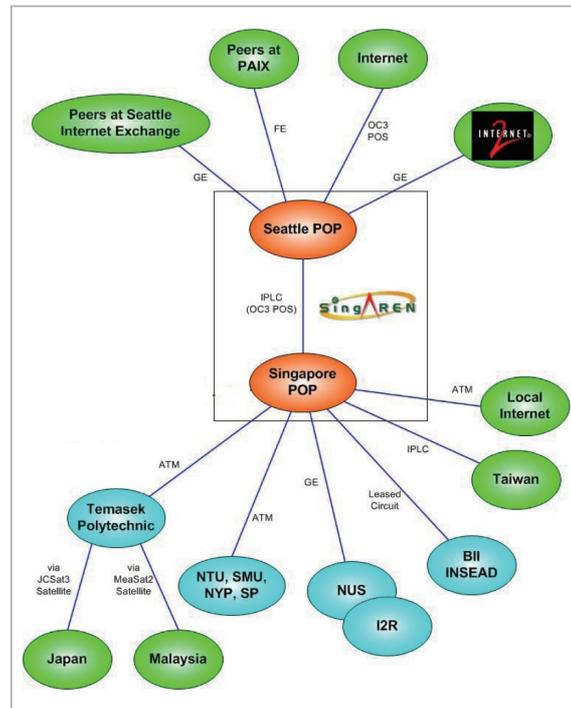


Fig.8 SingAREN network topology

(Excerpt from <http://www.singaren.net.sg/connect/netmap.shtml>)

among university researchers. Today's ThaiSarn3 represents the third generation of this network, and was constructed based on the Thai government's IT2000 Plan (originally scheduled for implementation from 1996–2000, but the start date was delayed until 2002 due to the country's economic crisis).

The topology of the ThaiSarn network is illustrated below.

7 Future trends in network testbeds

Network testbeds are no longer limited to network technology research; specifically, we are entering a period during which R&D will expand into new fields—from grid and IPv6 middleware to general applications in science and technology. In the future, the unique features of the individual network testbeds will no doubt come into play when the international testbeds are connected both physically and through joint research. At the same time, the construction and operation of network testbeds throughout the world will most likely continue

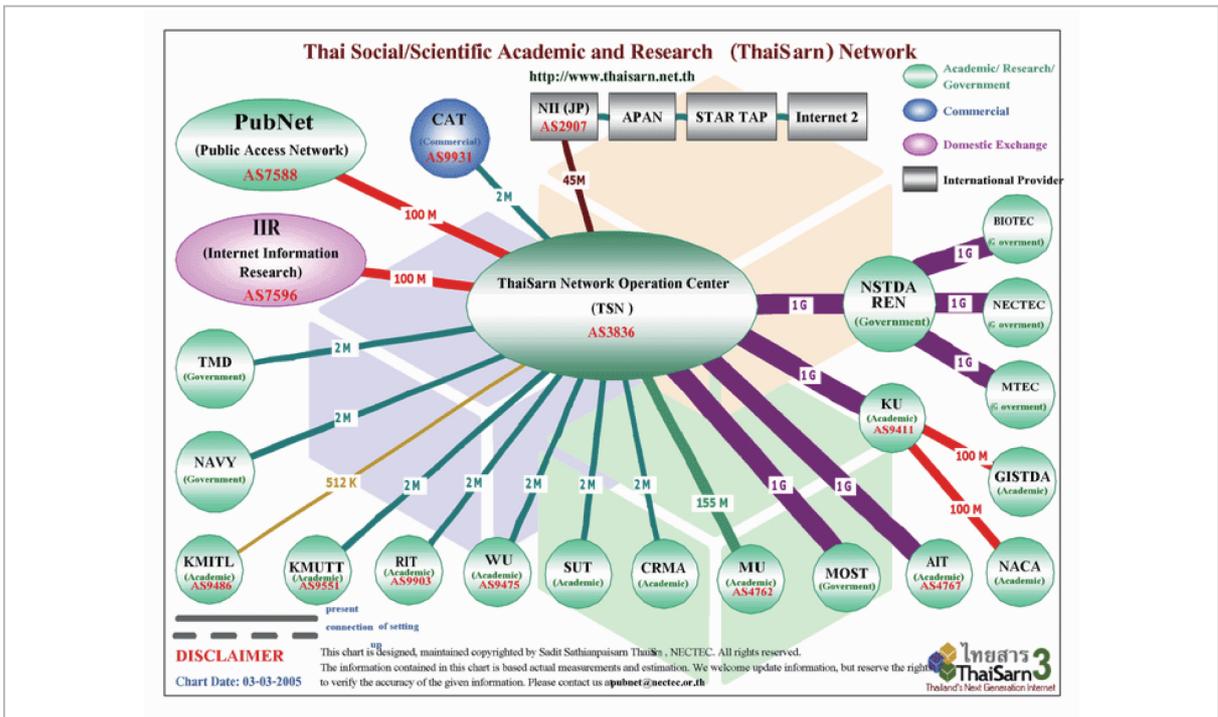


Fig.9 ThaiSarn network topology

(Excerpt from <http://thaisarn.nectec.or.th/htmlweb/image/ThaiSarn-Map-030320052.gif>)

to proceed hand-in-hand with individual national ICT strategies.

In Japan, as well, the key to future network testbed design will lie in our vision of a future information society.

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