Construction of Internet for Japanese Academic Communities

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ABSTRACT WIDE (Widely Integrated Distributed Environment) is a research project aimed at achieving a transparent distributed environment over heterogeneous distributed computing elements with the consideration of various types of connections for internetworking. The target environment of the research is computing environment in the academic and research communities especially in Japan.

The WIDE project started its research activities at the end of 1986. The initial purpose of the group was to design the future JUNET environment. In Japan JUNET has been the only network that provides connectivities among academic and research institutes in both private and public organizations. In order to provide better computer communication with the network, interconnection of networks based on open architecture is strongly required. As the result of various studies, the project started its actual design in late 1987 and has been establishing working environments by connecting several universities with various types of links.

Together with the actual state and the future plan of the WIDE project, this paper discusses the overview of technologies being employed for the achievement of project goals such as networking technologies, operating system architecture and name space. As the background status of the WIDE projects, this paper also reports an overview of existing academic and research computer networks in Japan, especially focusing on university environments where the sharing of the large scale computing resources are provided.

1 INTRODUCTION

Computer communications based on various technologies of computer networks and distributed processing provide general computing environment over distributed computing elements. By the rapid growth of computer technologies, each element tends to be varied in its software architecture and operating system. This heterogeneity of nodes is more obvious when we consider a wider domain of networks: a computing environment on interconnected networks.

As the integration of computing elements proceeds by the technologies on local area networks, strong demands begin to exist for the same sort of technologies for wide area networks. As the result, this has introduced to us the goal of providing a transparent computing environment for distributed and heterogeneous computing elements which are interconnected widely with heterogeneous communication links.

The **WIDE** (Widely Integrated Distributed Environment) project was started to provide answers to these requirements with a background of researches on JUNET. In other words, **WIDE** is a research project which establishes a transparent distributed environment over heterogeneous distributed computing elements with the consideration of intermittent interconnection links.

In the target environment of academic and research communities, there are several existing networks operated in Japan. Providing inter-connectivity among those networks is one of the primary concerns as the result of this work.

2 EXISTING COMPUTER NETWORKS IN JAPAN

There are several networking activities in Japan which provide academic and research purpose computer communications. The networks described in this chapter are operated with voluntary bases rather than with a single centralized formal organization. Each network has its own international connectivity. Furthermore,

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the networks have interconnected each other in terms of their message exchange services.

2.1 JUNET

JUNET[8] is an academic network in Japan which provides electronic message exchange services for e-mail and electronic news (including the USENET news). JUNET started its operation in October 1984 in order to provide a network testbed for network researches and to promote network activities for academic communities in Japan. The network started by connecting three universities; Tokyo Institute of Technology, Keio University and University of Tokyo with VAX using 300bps dial-up modems employing the UUCP protocol.

Currently JUNET connects more than 220 organizations and is used in several thousands of computers. The major protocol employed to transfer e-mail and news among organizations still is UUCP but the **WIDE** Internet is now playing a major role as the backbone of JUNET using X.25 and leased lines in order to process increasing traffic and to provide high reliability with short propagation delay.

JUNET is operated and administered in a totally volunteer basis in which neither registration fee nor annual fee is charged. Each participating organization is requested to support the links between its neighboring organizations. The only exception is the use of the international link; the cost to support international links is rather expensive, thus each of the users so far is charged and is registered at the gateways for accounting.

One of the major characteristics compared with other academic networks is the handling of Japanese characters (Kanji). A JUNET standard encoding of Japanese characters in the network which is based on JIS X0208 (Kanji code set) and JIS X0202 (corresponding to ISO 2022) was defined in October of 1985 and has been agreed and use since then. It is based on a 7-bit encoding scheme so that the user can make use of many software without a special Kanji support. Furthermore, Japanized version of many utilities including `rn`, `vn`, `less`, `xterm`, `gnuemacs` has been developed and distributed to handle Kanji messages. The traffic of JUNET has significantly been increased ever since the Japanese text in e-mail/news has been introduced. Presently, almost all of the domestic messages are represented in Kanji characters. One of the most busy gateways is handling about 1500 e-mails and 100 news articles (not including USENET news articles).

JUNET has been using the domain style addressing since May 1985 and the use of UUCP style bang addressing has been almost eliminated. The top domain of this was `.junet`. However, with the strong demand from the worldwide academic network community, ISO 3166 two-letters country code [3] has been selected to be used as the top domain. As the result, the program to change the representation from `.junet` to `.jp` has been taking place since January 1989 and presently this transition has been completed.

2.2 BITNET-J

One of the academic networks familiar to researchers in mathematics and physics is BITNET. BITNET related activities have started since middle of 1985 in Japan and it now connects 43 Japanese organizations including 62 hosts. Most of these organizations are universities and national institutes. Their links are 9.6Kbps leased lines and run RSCS protocol. The backbone site of BITNET in Japan is located in Science University of Tokyo and it also has connections to The City University of New York.

BITNET and JUNET had no gateways and the traffic between these networks was forced to be routed via United States. However, in late 1988, three universities started to operate e-mail inter-exchange between these networks, and now the inter-exchange of email is supported by one of the domestic gateways in the above universities.

2.3 HEPNET-J

Another network also familiar to researchers in the field of physics is HEPNET. It utilizes leased lines, NACSIS private X.25 network, DDX-P which is a X.25 network serviced by NTT, operating over DECNET protocol. Japanese HEPNET is mainly organized by KEK (National Laboratory for High Energy Physics) and it works as area 40 portion of the international HEPNET (or DECNET, in terms of including SPAN). Presently connecting 27 universities, it provides remote login, remote file access, and remote job entry. E-mail service is also available and exchange with BITNET is operated at KEK.

2.4 International Connection

The International traffic of JUNET has been handled at two gateways; KDD laboratories and The University of Tokyo. KDD has handled USENET news and e-mails for company organizations connecting several gateways including the UUNET gateway. The University of Tokyo connects to SURAnet, which is one of regional networks of NSF Network's regional networks. This is used for university organization traffic with TCP/IP protocol over leased satellite link as a part of NACSIS X.25 private packet network. Thus, this link employs IP over X.25 (RFC877[6]) technology. A machine called `mtfuji.gw.u-tokyo.ac.jp` is placed in National Science Foundation, Washington D.C. to

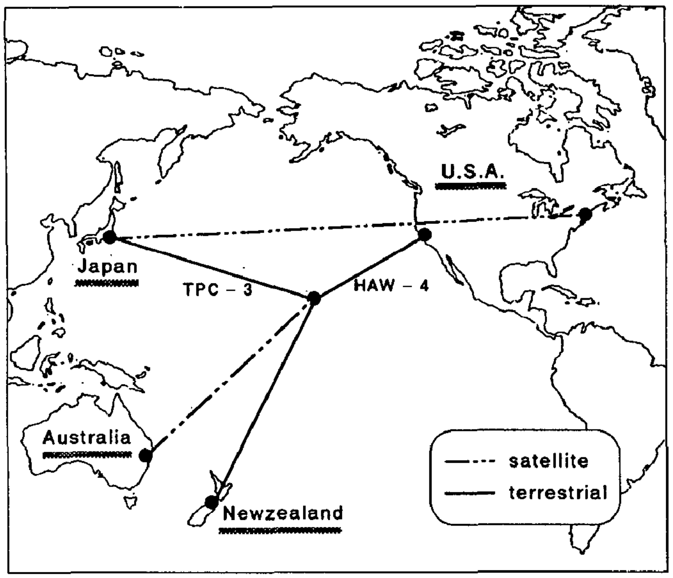

Figure 1: **WIDE International Connection**

operate the role of a email relay function for Japanese traffic.

A project called PACCOM [10] started in June 1988 by the University of Hawaii is an attempt at building a Pacific infrastructure. Several research groups in Japan such as high-energy communities and the **WIDE** project are involved in the project so that better international communications can be achieved. The initial participants are U.S., Australia, New Zealand and Japan. And Korea is planned to join in late 1989.

The link from University of Hawaii, which has 512Kbps optical fiber cable link to mainland U.S.A., to Australia was established in May 1989 using 56Kbps satellite link and is planned to convert to 64Kbps terrestrial link in September 1989. The link is connected to the Australian Academic Research Network (AARN) at Melbourne University. The link from Hawaii to New Zealand using 19.2Kbps terrestrial link was established in April 1989 by the joint efforts with the University of Waikato.

In August 1989, two terrestrial links of 64Kbps were established from Hawaii to Keio University and to the University of Tokyo. The **WIDE** project is responsible for the Keio University's link as well as the domestic connection between Keio University and the University of Tokyo. The University of Tokyo is sponsoring the link in order to provide international connectivities to Japanese astronomy and physics researchers. Figure 1 illustrates **WIDE** international connectivities using IP protocol.

3 COMPUTER CENTERS IN JAPANESE ACADEMIC INSTITUTES

Japanese Universities have organized a network structure for accessing main frame and supercomputer resources. Presently, this is separated from the networks described in chapter 2 and provide almost no connectivity for international access, but obviously strong demands to provide interconnection between this mainframe network and the general purpose networks are existing. Local area network functions in mainframes or supercomputers and the general purpose interconnection of campus networks, both of which are rapidly being developed, are opening a new dimension of the connectivities to the large scale computers.

3.1 Seven Major Computer Centers

By the traditional strategies of the Japanese government concerning education, there were seven national universities distributed throughout the country. These universities still tend to be considered "major" in terms of a large academic project by the government. The computer centers in the seven universities started in 1965 following the recommendation of the Science Council of Japan to the Japanese government in 1963. They are defined as shared resources for researchers in public, national, and private universities as well as junior colleges and technical colleges engaged in scientific research, while each of the other Japanese computer centers is private to where it belongs. In order to organize this sharing, Japan is geographically divided into seven regions and each of the seven centers mainly serves one region. Thus, sharing of supercomputer resources is achieved by placing a supercomputer at each of the seven centers. From north to south, these seven universities are Hokkaido University, Tohoku University, The University of Tokyo, Nagoya University, Kyoto University, Osaka University and Kyushu University. Although each of them has its own characteristics in terms of services and equipment, they are all operated and controlled by a single principle. Table 1 shows mainframe and supercomputer equipments at these seven centers. Note that each of the center operates several mainframes and a supercomputer as a single cluster system which is providing almost transparent a single virtual system environment. Furthermore, all of the elements in a cluster are from the same vendors and running the same kind of operating systems. In this type of environment, supercomputers are treated as a backend processor or as a part of the mainframe cluster, making the user environment and the network environment exactly identical with those of mainframes. The geographical map of the seven computer centers is illustrated in Figure 2.

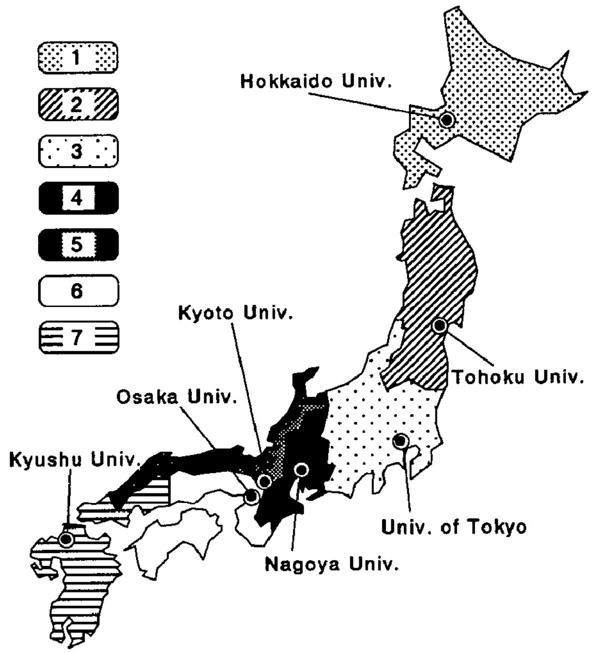

Figure 2: **The Seven Computer Centers**

Table 1: **The Seven Computer Centers and Their Computers**

university	mainframe	supercomputer
Hokkaido	HITAC M-682H	S-820/80
Tohoku	ACOS 2020	SX-2N
Tokyo	HITAC M-680H,M-682H	S-820/80
Nagoya	FACOM M-780/20	VP-200
Kyoto	FACOM M-780/30	VP-200,VP-400E
Osaka	ACOS 2020	SX-2N
Kyushu	FACOM M780/20	VP200

3.2 Mainframe Network

The N-1 Network is a computer network for mainframes at universities funded by the Ministry of Education. The development of the network was first started in 1973 by The University of Tokyo, Kyoto University, Tohoku University, Hitachi Corporation, Fujitsu Corporation, NEC and NTT. The network started its operation in 1980 employing N-1 special protocol over X.25 packet switching network. The services provided by the network are remote TSS terminal access, remote batch processing and file transfer. Since the primary purpose of the network was the sharing of computing resources, not much attention has been paid to provide services of information exchange such as electronic mails. In 1989, e-mail exchange service among mainframes was started however interconnection with other networks is not yet provided. A user has been charged for network communication by a 128 bytes packet as well as other resources such as CPU time, disk usage and session time. By the use of the NACSIS communication links which is free for universities, charging for the communication have been discontinued.

NACSIS (National Academic Center for Science Information System) is an organization of the Ministry of Education in order to provide scientific information as well as access methods for it. In order to achieve this mission, NACSIS has established a private packet switching network throughout the country. The packet switching network is used for library information exchange, the N-1 network, and various experimental projects including TCP/IP experiments for universities over X.25 packet switching network. The organization is 100% funded by the Japanese government and the packet switching network can be used by universities at no charge. Currently, it connects 50 universities including 26 libralies and the NACSIS itself. The universities connected to the NACSIS network other than the seven major universities are such as Hirosaki University, Tokyo Institute of Technology, Okayama University and Hiroshima University.

3.3 Simple Analysis of Usage

The overall concept of sharing large computing resources is regional independency. That is, a university should be served by one of the computer centers in the region to where it belongs. Although a user is free to access any of resources at one of the seven computer centers via N-1 Network, the inter-region traffic is extremely low. Table 2 shows inter and intra region access for each of the centers in terms of actual cpu time and ratio of usage respectively.

The statistic information in the table introduce the following simple analytic ideas concerning usage of mainframes and supercomputers in Japanese University environment:

i) Almost all of the usage is localized within a region. A user is using computers in the same region.

ii) Tokyo and Kyoto machines are very heavily used. Users in these regions are mutually using each other.

iii) Other than ii), Tokyo users use Hokkaido machines and Kyoto users use Nagoya machines.

i) is obvious because there is almost no reason for users to use machines in regions other than their own. Communication among regions are supported but charged. All are using a single user management system but a user has to do some paper work to use others. Exceptions are when machines in a region is over loaded like in ii). The users in such a region need

Table 2: **Regional Comparison in CPU Time[h:m](Mainframes/Supercomputers)(1987)**

User's Region	Computer Centers							
	Hokkaido	Tohoku	Tokyo	Nagoya	Kyoto	Osaka	Kyushu	Total
Hokkaido	1669:44	0:04	0:41	0:00	0:15	0:01	0:08	1670:53
	3295:35	0:00	2:13	0:05	12:23	0:00	0:00	3310:16
Tohoku	0:46	1512:08	0:32	11:13	1:27	0:01	0:00	1526:07
	0:01	3503:51	0:04	0:00	0:02	6:23	0:00	3510:21
Tokyo	17:27	11:01	8515:18	25:09	4:07	0:37	0:16	8573:55
	177:19	78:06	6523:47	2:29	348:33	10:33	0:00	7140:47
Nagoya	6:46	0:14	7:06	2914:29	10:31	0:01	0:03	2939:10
	0:01	0:01	11:40	2101:55	46:40	1:31	0:00	2161:48
Kyoto	0:02	0:02	36:46	7:23	5491:37	8:57	0:01	5544:48
	0:00	0:00	66:12	42:20	5949:13	10:13	0:01	6067:59
Osaka	0:15	0:00	71:19	58:55	796:40	1253:46	49:11	2230:06
	0:00	0:00	5:24	1:10	521:48	2885:01	396:08	3809:31
Kyushu	0:31	0:03	48:15	1:23	59:23	1:26	1387:13	1498:14
	0:05	0:00	0:31	0:00	248:04	0:05	1761:10	2009:55
Total	1695:31	1523:32	8679:57	3018:32	6364:00	1264:49	1436:52	23983:13
	3473:01	3581:58	6609:51	2147:59	7126:43	2913:46	2157:19	28010:37

secondary centers as in iii). Note that compatibilities are not assured among those machines in terms of operating system environment such as libraries, services and operations. Especially when vendors of machines are different, there are almost no chance to migrate a job from one to another. Thus, their reason for iii) is trivial.

3.4 Campus Networking

There started a new promotion on campus network constructions by the Ministry of Education since 1987. Tohoku University and Kyoto University received the first year grant and was funded for construction of the campus networks. The campus networks provide connectivities both to small computers in a campus and large computers in the computer center using TCP/IP and other (de-fact) standard protocols. This introduced the new possibility of sharing large computers nationwide by the interconnection of campus networks. The interconnection of campus networks has been experimented using IP connectivity over NACSIS's X.25 packet switching network.

4 ISSUES IN WIDE

The **WIDE** environment extends over the general academic organizations, thus resulting in a target of a *very* large-scale distributed environment for universities and research institutes. Technologies to achieve this goal therefore can be studied by developing an environment to cover universities in this country. In such an environment, a simple network structure as a collection of identical technologies can never be assumed; it would be both impractical and inefficient. The highest efficiency on such an environment can only be achieved with; 1) flexible technologies to employ various heterogeneous primitive technologies on communication and operating systems, and 2) integrated functions to provide transparent environment based on technologies describe in 1). Problems and issues arising as a result, which must be solved, are divided into the following separate issues.

4.1 Communication Technologies

In order to develop a communication architecture for a practical wide area distributed environment, characteristics of low-level communication technologies have to be well studied and evaluated of them. One of the primary focus of the research, thus is to establish technologies which provides the best and most efficient usage of existing and available heterogeneous types of links. The heterogeneity is classified by several criteria such as bandwidth, dynamic throughput change, dynamic delay time change, overhead for connection establishment, and charging system (i.e. monetary cost).

The actual considerations are made toward various communication technologies such as dial-ups, voice grade leased line, digital leased line, public packet switching network, private packet switching network, ISDN and issues like satellite versus terrestrial. The goal here, therefore, is to employ these links properly yet at the same time providing transparency for upper level protocols.

Issues on comparison of intermittent links and permanent links are also one of the strong interests of the project. The inclusion of both types of links introduces advantages on performance,reliability and economics of the network as a whole.

Especially in the Japanese academic environment, DDX of NTT, Venus-P of KDD and INSnet 64 (ISDN) of NTT are available as packet switching networks. NACSIS which is an agency of The Ministry of Education, provides an nation-wide private packet switching network and provides it at no charge to universities. Therefore X.25 technologies are studied carefully in **WIDE** as [1].

Intermittent links build-in to operating system architecture is another interest of the project due to the ISDN availability and cost effectiveness of voice-grade dialup links. This solves not only cost problems but also reliability and robustness of the network in terms of its usage as back-up channels.

New technologies have to be developed in order to maintain such an intermittent connection. Issues here involve how and when the connection is established, how it should be disconnected, and how routing information should be controlled over the intermittent links. This technology is studied and reported in [5].

ISDN service (called INSnet 64) was first introduced in Japan in early 1989. Efficient usage of this technology has to be carefully studied in terms of existing operating system's communication technologies. ISDN is a integration of charged packet switching network and dial-up links. Dynamic establishment of these channels has to be achieved so that both economics and traffic efficiency are simultaneously satisfied.

Table 3 shows the variety of links used for the **WIDE** Internet construction.

Table 3: **Links in WIDE Internet**

	Intermittent		Permanent	
grade	name	speed	name	speed
data	NACSIS X.25	9.6-48K	Digital	64K (-6M [1])
	ISDN X.25	- 64K		
	ISDN dial up	-64K		
voice	dial up	-19.2K	3.4KHz	19.2K
	ISDN dial up	-19.2K		

4.2 Robustness of the Entire Network

Since the target environment of **WIDE** is large and widely extended, a serious network partitioning problem caused from the failure of the intermediate nodes and the links connecting them, stem out which need solving. Providing redundant paths is one solution for the problem but more advantage can be achieved by employing the communication technology strategies described above. The use of the intermittent links especially for this purpose is reasonable and practical so that rapid detection of failures in the network, propagation of this information, efficient establishment of dynamic backup connections, dynamic adaptation of routing for the backup links, and the final post motum processing can simultaneously be achieved. These processes are also studied and combined into a system called *survival strategy* which is reported in [7].

[1]available, not yet used for WIDE

4.3 Gateway Technologies

The concept of internetworking has been introduced in [14] as a basis of current network interconnection technologies. Here, gateway nodes plays a big role in both control and information inter-exchange. For the **WIDE** environment, a very large-scale network interconnection as well as a very complicated topology are assumed and considered. Routing control function is one of the first to be designed and developed. Experimental studies in order to solve handling of very large number of addresses at the gateways is done using existing internet addresses by introducing a mapping function between internal addresses and external advertised addresses to an autonomous system. The routing adaptation to the backup connections using the intermittent links are also being studied using the testbed.

As interface definitions, the **WIDE** gateways also provide functions to select proper datalink entities depending on the type of upper services as interface definitions. Actual autonomous networks need to employ gateways to handle various networking policies such as access permissions for gateways and datalinks. Functions to answer to these requirements are also designed as the gateway functions.

4.4 Inter-Object Communication

The experimental programming environment for the **WIDE** is currently achieved by providing an interprocess communication interface among distributed resources using the resource control mechanism described below. This introduces entry points of services, names for them, control parameters to select the optimal channel in terms of type of services, data representation, authentication and security control of the objects as general interface for C programs.

4.5 Resource Access Mechanisms

A resource is defined as an entity to provide service in the **WIDE** and each of the entities is named after hierarchical name spaces. Compatibility with the existing name services [4] is provided and access control is also achieved using the concept of ownership which is also defined in the same name space. Detailed experiment is described in [2].

4.6 Applications

WIDE applications are developed using the resource access mechanisms and inter object communication functions described above. Currently, the existing internet functions and interactive phone system is developed on the environment.

4.7 Network Management

As a result of a 5 year operation experience with JUNET, the establishment of a network management system is strongly being demanded. Technologies to organize security control, access control, policy control, network maintenance, and strategies for network failures are studied and then put into a single guideline and a system for network management.

4.8 Security

In the WIDE internetworking environment, many kinds of organizations will be interconnected providing various network services such as file servers, databases, mail service and printers, users may access them through network. The **WIDE** environment, with hosts and users not under organizational control, is vulnerable to eavesdropping and interference from unauthorized intruders. Furthermore, under such environment, the growing quantity and the value of information sharing, exchanging, and storing make attacking networks more attractive to intruders. To prevent such attacks, security mechanisms for network protocols and services are required.

To treat security issues arising in the **WIDE** environment [16], the "association model" given by Voydock and Kent [15] shown in Figure 3 can be presented.

In this model, an entity in the $n+1$ layer makes an association, which is an end-to-end path through the network, using functions provided by the n layer. The entity in the $n+1$ layer communicates with other entities by exchanging PDU (Protocol Data Unit) which is an individual unit of transmission at a given network layer. It will assume that these entities are in a secure area. An intruder is considered as a computer under hostile control situated in the path of an association, and all PDUs transmitted on the association must pass through the intruder.

According to the model, Voydoc classifies security attacks, which can be mounted by an intruder, into passive attacks and active attacks. In a passive attack, the intruder merely observes PDUs passing on an association. They are (1)release of message contents, and (2)traffic analysis. On the other hand, in active attacks, the intruder performs processing on PDUs

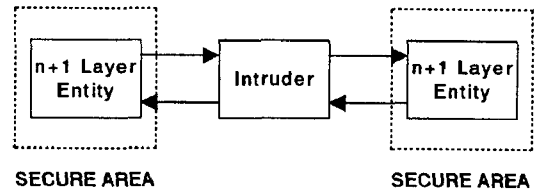

Figure 3: **The Association Model**

passing on the association. They are subdivided into three categories, namely (3)message-stream modification, (4)denial of message services, and (5)spurious association initiation.

In order to provide several functions to prevent passive attacks and to detect active attacks within the **WIDE** environment, the following approaches are made:

1. Since not all network services provided in the **WIDE** environment need security mechanisms, only certain functions used in the presentation layer or the application layer of specific applications are needed.

2. Data encryption techniques is developed to prevent the release of message contents and to detect message stream modifications. For any critical applications, certain functions can be provided in order to encrypt contents of PDUs and control information such as PDU headers.

3. **WIDE** being an academic research network environment, the traffic analysis is considered an insignificant threat thus making a preventive function unnecessary.

4. An authentication system is developed suited for **WIDE** environment to detect and to prevent the spurious association initiation.

5. To detect denial of message service, time stamp and acknowledgment techniques for each PDUs are used.

4.9 Authentication

There are several discussions in the public literature about protocols and mechanism of the user authentication. A report by Needham[9] gives authentication schemes for large scale computer networks based on conventional encryption algorithms such as Data Encryption Standard (DES) and on public-key encryption algorithms[12]. However, there is less material available describing how to construct and manage a complete authentication system.

Kerberos[13] produced by MIT Athena project is a trusted third-party authentications service for open networks. The system was developed based on DES algorithms and authentication schemes by Voydoc[15]. Currently, Kerberos is applied for many network services such as NFS, rlogin, and other applications provided by Athena project. However, it is hard to manage a large scale computer network using Kerberos, due to the fact that Kerberos has to manage many keys for interrealm service access. If there are n realms, Kerberos manages and share n^2 keys with other Kerberos systems. In the case that Kerberos is applied to a large scale computer network, shared keys for interrealm access have to be maintained and updated correctly.

In the **WIDE** project, a decision to develop a new authentication system suitable for present environment has been agreed upon. This system, based on public-key encryption algorithm, applies the authentication scheme by Needham to a system. Since it is hard to manage an overall network by only one authentication server, the subdivision of networks into domains according to network management policies is being done, and each domain is managed by one authentication server. To provide inter-domain access, the domain concept is used in a hierarchical manner. An authentication server for an upper domain authorizes and controls inter-domain accesses between subdomains.

The overview of the entire concept of **WIDE** environment is shown in Figure 4.

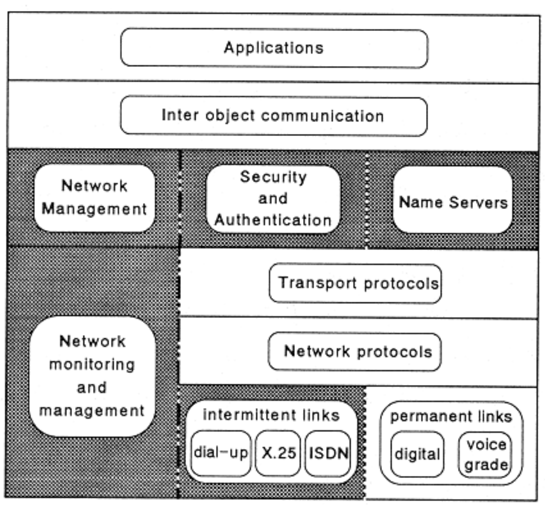

Figure 4: WIDE Structure Overview

5 The WIDE INTERNET

The **WIDE** Internet is designed in order to provide a testing environment for large-scale distributed systems technologies. Thus, the **WIDE** Internet is constructed by interconnecting local area network environments by various types of links. Practical works for the studies are being done using the **WIDE** Internet toward approaching the goal of the **WIDE** environment. The following technical strategies are made for the initial **WIDE** Internet.

5.1 Detalinks

Instead of using an identical link for a datalink, the Internet is designed to employ as many different links as possible as far as the link is available to the Japanese academic communities. This introduced problems concerning routing, datalink selections, interface definitions in terms of efficiencies and availabilities. These problems are issues for the researchers to solve. Datalinks used to construct the initial **WIDE** Internet are so far as follows:

Dial-up Voice Grade Line Most of the organizations are equipped with a dial-up line using a high-speed modem for asynchronous serial line communication with up to 19.2Kbps because the necessary equipment for this is cheap in cost and used in the existing JUNET connections. This is employed as one of the *intermittent* connections for general high-level protocol(i.e. IP).

3.4KHz Voice Grade Leased Line Like the dial-up line, the 3.4KHz voice grade leased line is used with high-speed modems to provide 19.2Kbps point-to-point connections in the internet.

64Kbps Digital Leased Line Digital leased line is available up to 6Mbps in Japan, but currently only 64Kbps channels are used in the **WIDE** Internet. Xerox's synchronous point-to-point protocol is used so far and the Point-to-Point Protocol (PPP) [11] is being developed with a joint efforts with the PACCOM project.

Packet Switching Network NACSIS is providing a private packet switching network for universities with from 9.6Kbps to 48Kbps X.25 connections. This is also used by the general high-level protocol as a datalink entity.

ISDN Several INSnet 64 are installed in the **WIDE** environment to develop a software for the ISDN. INSnet 64 is 2B+D (two 64Kbps channels plus one 16Kbps data and control channel) and INSnet 1500 (up to 1.5Mbps) became available in July 1989.

5.2 Technologies Employed

As for the initial protocol suite, TCP/IP protocol suite was selected as the basic protocols for the **WIDE** Internet for its availability advantages . OSI protocols are studied over the constructed Internet. All the software has been developed on operating systems which are UNIX 4.3 BSD or its equivalent. The reason for this is, again, the availability advantages.

Each of the organizations connected to the **WIDE** Internet has a single Ethernet segment with at least two "gateway" nodes. One is a router connected to the primary link of one or more high-speed digital channels and another is a workstation which is equipped with an ISDN channel. The ISDN is used when the primary permanent connection is failed or when the router failure is detected. This is invoked by a special protocol to exchange information to decide invocation of a intermittent link. The handling of the protocol and other network management functions are responsibilities of the workstation node. This structure using a combination of a permanent link and ISDN enables high reliable backbone structure of the **WIDE** Internet.

6 INITIAL CONNECTIONS

The **WIDE** Internet is presently connecting Keio University, Tokyo Institute of Technology, University of Tokyo, Osaka University, Aoyama Gakuin University, Electorotechnical Laboratory and KDD Laboratory. The actual links used for the initial connections are shown in Table 4.

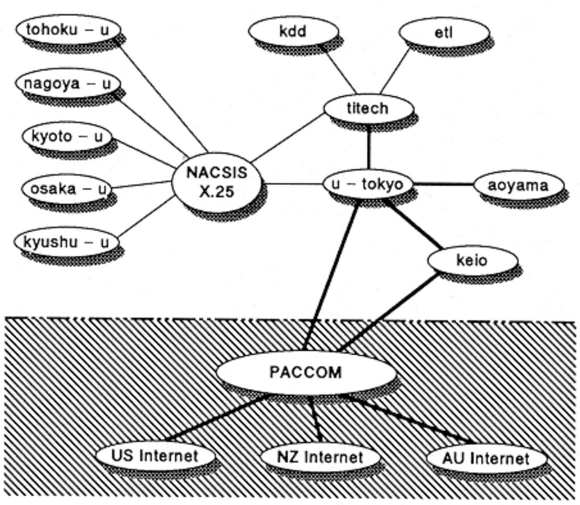

Figure 5: **WIDE** Connections

The PACCOM (Pacific Area Computer Communication testbed) has been connected in July 1989 to the **WIDE** Internet in order to achieve the interconnection with national Internet of U.S., New Zealand and Australia. This employs the TPC-3 (Trans Pacific Cable-3) optical fiber cable with 64Kbps leased line. This is shared by DECNET protocol for high energy and astronomy communities and TCP/IP for computer science communities.

The overall topology related to the **WIDE** Internet is shown in Figure 5.

7 CONCLUSION

In the Japanese academic and research communities, the existing computer networks can be divided into two groups. One is networking efforts by the seven universities and the NACSIS including services to share large scale computing resources among universities. General purpose computer networks such as JUNET, BITNET and HEPNET are operated by voluntary efforts and have international connectivities. Recent promotion by the Ministry of Education for construction of campus computer networking has started to establish interconnectivities between large scale computers and local area networks. Internetworking of campus networks thus can provide new means of accessing resources and sharing or exchange information in Japanese academic and research environment.

With the above background, the **WIDE** project researches the construction of the large-scale distributed environment for Japanese academic and research computing environment. The actual work for the construction started from setting up an internetworking environment called **WIDE** Internet using TCP/IP protocol suite over various heterogeneous datalinks.

The primary technical concern is focused in gateway technologies such as routing control, name and address issues as well as the efficient selections of various datalinks and paths.

The Internet is in operation since July 1988 and is currently connecting 5 organizations using dial-up line, voice-grade leased line, digital leased line, packet switched network, and ISDN. International connections will be set up with the United States, Australia and New Zealand in cooperation with the PACCOM project.

The first phase (Phase I), which is the initial two year plan of the project will last until March 1990. This phase is dedicated to the construction of the infrastructure and the design of the environment, including the prototype testing. The actual constructions of the environment itself and researches on OSI is planned as Phase II which will take another two years after the current phase.

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Table 4: **WIDE Initial Connections and Types of Links**

Name			Link	Bandwidth	Dialup Equipped
Keio Univ.	↔	U. of Tokyo	Digital Leased	64K	Equipped
U. of Tokyo	↔	Tokyo I. of Tech.	Digial Leased	64K	Equipped
U. of Tokyo	↔	Aoyama	Digital Leased	64K	Equipped
U. of Tokyo	↔	Osaka U.	NACSIS(X.25)	9.6K	Equipped
U. of Tokyo	↔	Kyushu U.	NACSIS(X.25)	9.6K	Equipped
Tokyo I. of Tech.	↔	KDD Lab.	3.4KHz Voice Grade	9.6K	Equipped
Tokyo I. of Tech.	↔	ETL	3.4KHz Voice Grade	9.6K	Equipped
U. of Tokyo	↔	NSFNET/CSNET	NACSIS(X.25)	9.6K	Equipped

†ISDNs are installed in several organizations.

discussions and suggestions.

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