2 Trends on Network Testbeds

2-1 JGNⅡ Advanced Network Testbed for R&D

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As a part of "e-Japan Strategy", it was proposed that advanced research and development would be promoted on a newly constructed testbed network (JGNⅡ), focusing on the following themes, (Ⅰ) resilient core network technology, (Ⅱ) access network technology, (Ⅲ) site-collaboration resource sharing technology, (Ⅳ) plat-home middleware application technology. To meet these requirements, NICT has newly located seven JGNⅡ research centers, in which R&D for those four themes are extensively conducted by more than 80 researchers, in collaboration with industries and universities and international cooperation. In this report, an overview of JGNⅡ project and the research activities will be briefly reported.

Keywords
JGNⅡ, Collaborative research, IPv6

1 Overview of JGNⅡ research and development project

If we are to continue with innovation in modern information technology, we will need to see greater sophistication in basic network-related technology and the implementation of a wider range of applications. Constructing and applying a new next-generation R&D network to meet these demands will help lead us rapidly toward a more prosperous information technology society. The so-called “e-Japan Strategy II”, established by the IT Strategy Headquarters in July 2003, specifically set forth a goal of constructing a network testbed for research and development. Based on this strategy, the JGNⅡ has been built as a next-generation network for research and development.

In response, the Commission Report on Next-Generation R&D Network for a Ubiquitous Networking Society compiled in July 2003 by MIC, proposes construction of a next-generation network for research and development and addresses the need for leading research and development focusing on the four high-priority issues listed below. The JGNⅡ project pursues research and development targeting these topics based on the Commission’s proposals.

Ⅰ Research and development of resilient core network technology
Ⅱ Research and development of access network technology
Ⅲ Research and development of site-collaboration resource sharing technology
Ⅳ Research and development of platform middleware application technology

These four technologies must be combined to form a foundation to support the diverse applications and services that will accelerate innovation in, and use of, advanced information-technology for the coming ubiquitous networking society.

2 Overview of JGNⅡ and its features

JGNⅡ is an open, ultra-fast, and high-performance network testbed for research and development, constructed and managed by NICT. The JGN (Japan Gigabit Network), a giga-bit network for research and development operated from FY 1999 to 2003, promoted research and development throughout Japan in ultra-high-speed network technology and in advanced applications via collaboration among industry, academia, and the government. These research and development activities included broadband development in Japan and the introduction of IPv6 to the Internet, in addition to numerous additional achievements. In line with the "e-Japan Strategy II" established by the government's IT Strategy Headquarters (July, 2003), NICT began operation of JGNⅡ in April 2004 as a new network testbed for research and development constructed based on JGN, with the overall aim of promoting greater sophistication in telecommunications.

The JGNⅡ is an IP-based optical network (using an optical-wavelength network and an optical testbed) providing an open research environment for researchers in universities, research institutions, private enterprises, municipal organizations, and other organizations. The network has also provided lines between Japan and the US (10 Gbps) since August 2004, spurring research in collaboration with overseas research institutions. The access points are located in all prefectures (total of 63 points). A potential user applies to NICT for permission to access the JGNⅡ for research and development purposes; if accepted the user independently establishes a communication line to an access point. Any user who has concluded a joint research agreement with NICT may use the network. Figure 1 provides an illustration of the network configuration.

The main network supports high-speed communication at a maximum of 20 Gbps (10 Gbps × 2). GMPLS routers and OXC devices for optical wavelength communication are installed in specific sections of the network. The system also provides an optical testbed environment, forming a network testbed amenable to a wide variety of experiments.

JGNⅡ provides the following related ser-

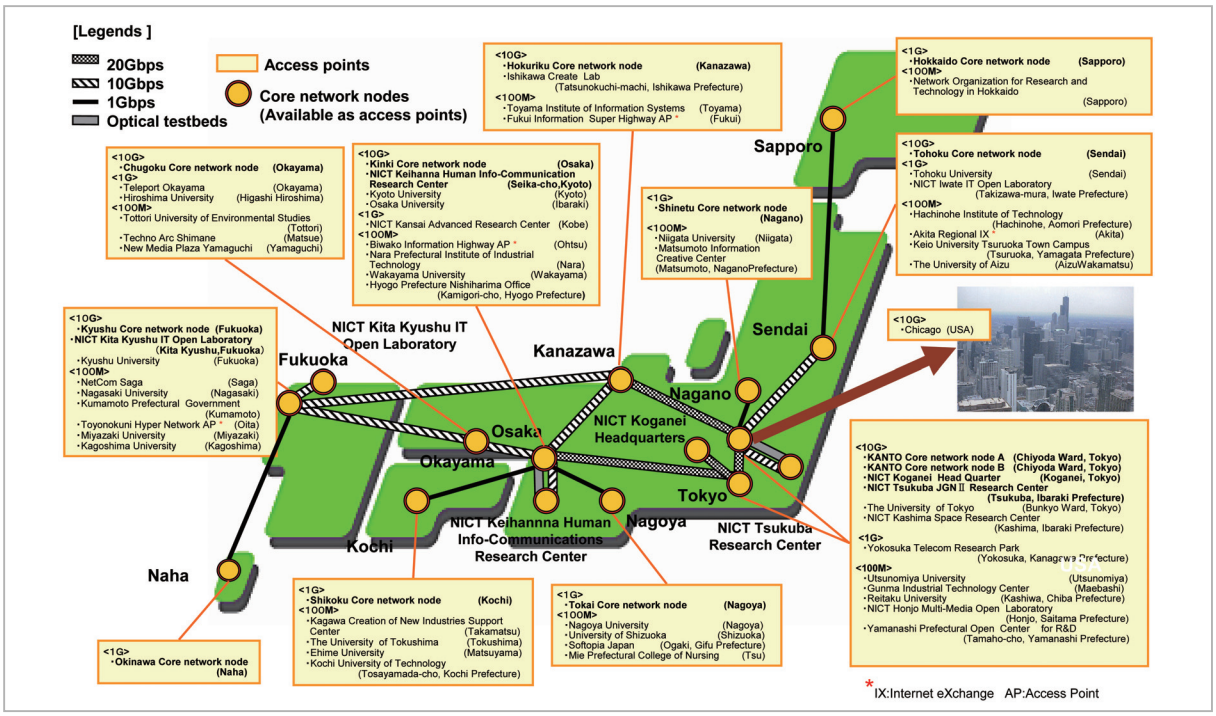

Fig. 1 JGNⅡ network configuration

vices:
- Ethernet connection (L2) service
- IP connection (L3) service (IPv4/IPv6 dual stack)
- OXC connection service (available at some access points)
- 10-Gbit connection service (available at some access points)
- Optical testbed service (available at some access points)

3 Collaborative research

NICT has established seven JGNⅡ Research Centers: in Touhoku, Ootemachi, Tsukuba, Osaka, Okayama, Kouchi, and Kitakyushu; NICT conducts its own research and development at these sites. Figure 2 indicates the locations of these Research Centers. NICT plans to conduct progressive collaborative research related to international standards at these Research Centers—work that the private sector is inherently incapable of pursuing. To increase the sophistication of network-related technology, to ensure interconnectivity, and to establish diverse applications for the coming ubiquitous networking society, the Research Centers are making steady progress in constructing research and development environments, based on the ultra-fast high-performance network testbed, both within and outside of Japan. The Centers also conduct leading-edge research and development of fundamental and application technologies for a next-generation high-performance network. When situating the Research Centers at these sites, NICT took into consideration the effective utilization of local research communities and resources cultivated through the JGN initiative, with particular emphasis on two points. First, the Centers needed to be close to the leading Japanese research organizations (such as universities and businesses) with specific strengths in technological fields related to the relevant research themes. This enabled close collaboration with such organizations and consequently led to more effective research and development. Second, the Research Centers situated throughout Japan had to be interconnected via JGNⅡ, to facilitate a distributed experimental environment permitting network collaboration among the Centers. Through consideration of the above factors and concerns, the Research Centers have been designed to allow for effective research and development through joint research projects among industry, academia, and the government. The Centers capitalize on the resources of the respective local communities, while at the same time making the most effective use of the JGNⅡ in a range of collaborative research projects and experiments among the Centers. The activities of each Research Center range from fundamental research and development to experiments promoting further sophistication in network-related technology and the development of a range of useful applications.

Eleven Expert Researchers are employed at the Research Centers (three at Kitakyushu, three at Tsukuba, two at Osaka, and one each at Ootemachi, Okayama, and Touhoku) as of the end of June 2005. There are 71 Guest Researchers, who provide advice to the research groups based on their respective fields of study. These Guest Researchers also participate in joint research. Depending on the content and progress of the research themes, NICT also promotes joint research with external organizations in a system designed to maximize network-based achievements.

3.1 Research and development themes

There are four core research and development themes. Each of the seven Research Centers (RCs) engages in one or two themes, in collaboration with the remaining Centers. Overviews of these themes are described below. Figure 3 shows the relationship between the various research themes and the relevant organizations.

Ⅰ Research and development of resilient core network technology

The goal of the study is to provide ultra-high-speed, high-quality network environ-

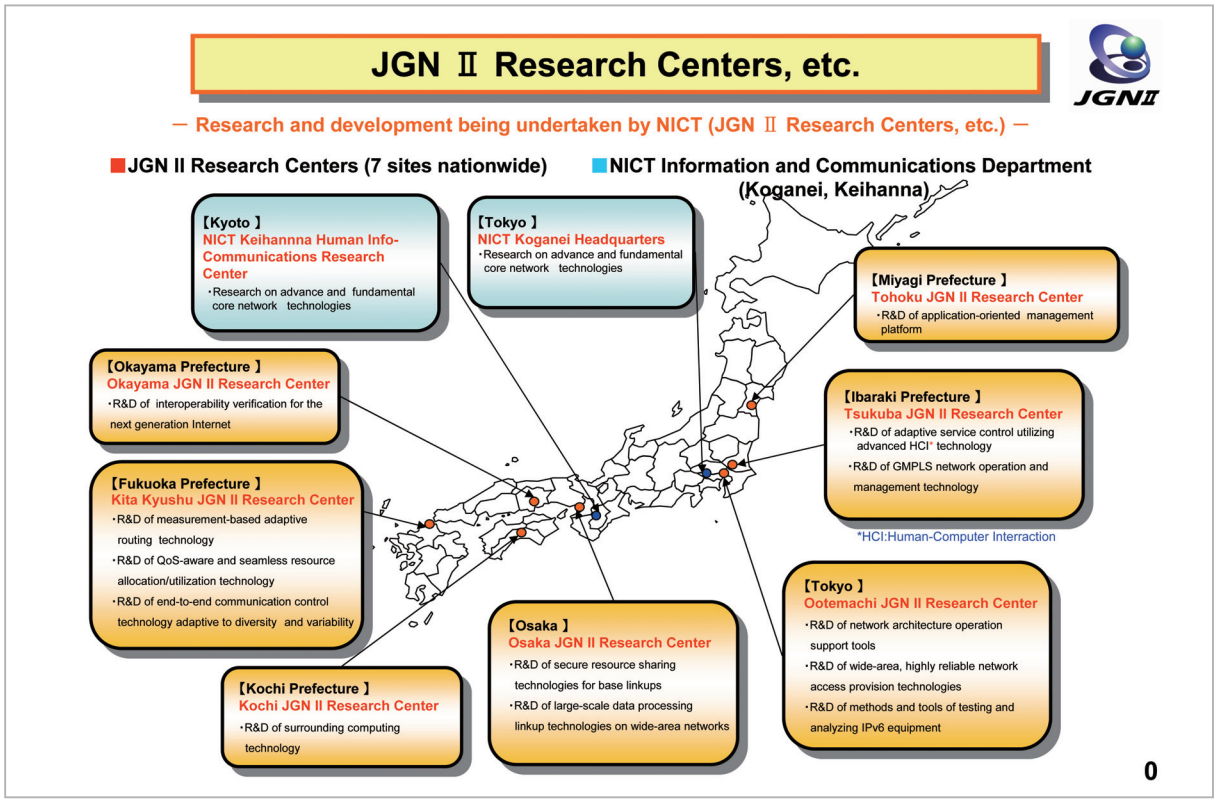

Fig.2 *JGNⅡ Research Centers*

ments that can support a wide range of large-capacity network services, content, and applications. To accomplish this goal, the project constructs resilient core networks, conducts research and development on interconnectivity and operations management technology for networks and their equipments and establishes comprehensive evaluation environments.

This research theme is divided into the following five categories.

1) Research and development of network construction and operation support tools (Ootemachi JGNⅡ RC)
2) Research and development of wide-area resilient network connectivity support technology (Ootemachi JGNⅡ RC)
3) Research and development of IPv6 device evaluation methods and tools (Ootemachi JGNⅡ RC)
4) Research and development for evaluation of next-generation Internet interconnectivity (Okayama JGNⅡ RC)
5) Research and development of GMPLS network operations management technology (Tsukuba JGNⅡ RC)

Ⅱ Research and development of access network technology

The goal of the study is to take maximum advantage of the ultra-high-speed core network and the heterogeneous access networks (including wireless and mobile networks) in order to ensure high end-to-end quality of service in various communications across these networks. To accomplish this goal, the project is pursuing research and development of technology for optimal division of the terminals, access networks, and the core network, as well as technology for dynamic and global assignment and use of various network resources based on observations of network conditions and traffic properties.

This research theme is divided into the following three categories.

1) Research and development of adaptive routing technology based on network measurements (Kitakyushu JGNⅡ RC)
2) Research and development of control technology for seamless utilization and assign-

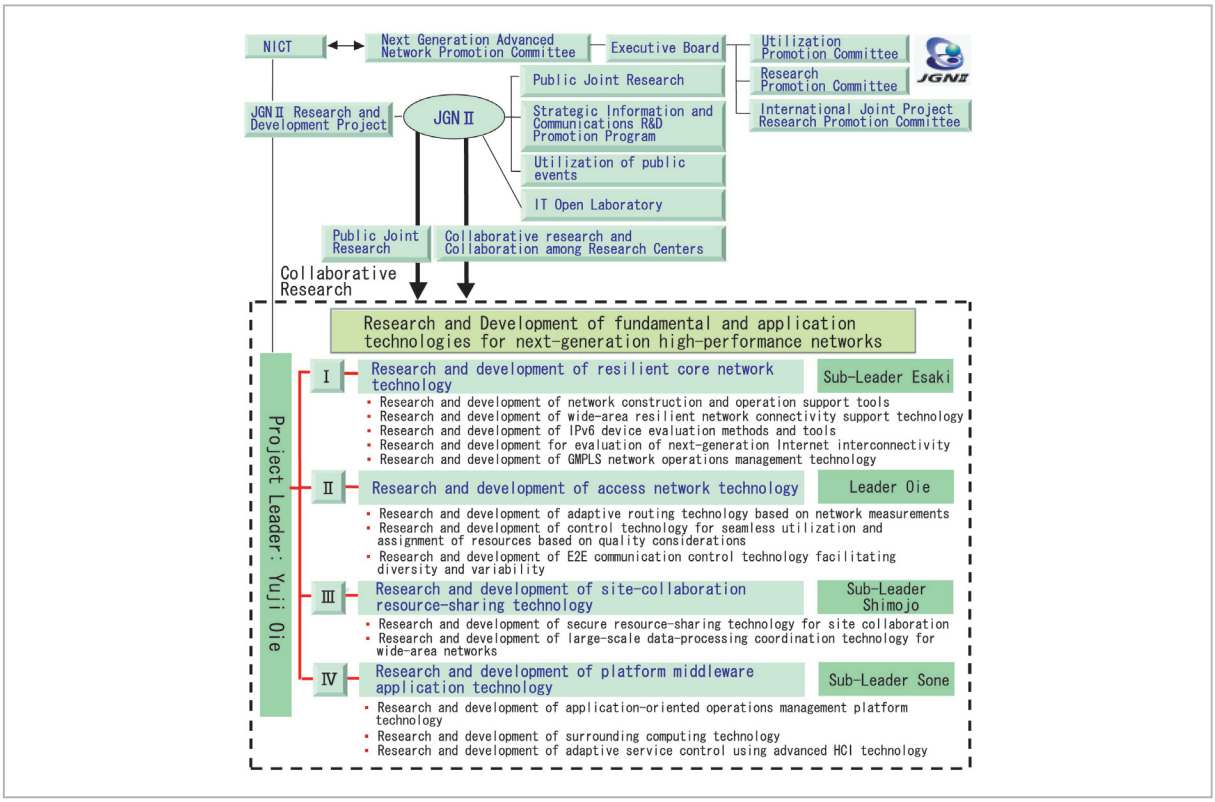

Fig.3 *Relationship between research and development themes and related organizations*

ment of resources based on quality considerations (Kitakyushu JGNII RC)

3) Research and development of E2E communication control technology facilitating diversity and variability (Kitakyushu JGNII RC)

Ⅲ Research and development of site-collaboration resource sharing technology

The goal of the study is to implement networks that allow for the sharing and management of application and service resources at the Research Centers situated in local communities; these networks should provide resources tailored to user needs, circumstances, and environments. To accomplish this goal, the project pursues research and development of resource assignment methods based on secure data sharing and high-capacity data processing.

This research theme is divided into the following two specific categories.

1) Research and development of secure resource-sharing technology for site collaboration (Osaka JGNII RC)

2) Research and development of large-scale data processing coordination technology for wide-area networks (Osaka JGNII RC)

Ⅳ Research and development of platform middleware application technology

The goal of this study is to realize effective use of high-capacity broadband information (such as image information) in a practical societal context. To accomplish this goal, the project pursues research and development of platform technology enabling optimal operations management for each application, of communication technology for real-time synthesis and control of remote images and marker information in combination with body-movement data, and of signal-processing technology to ensure unencumbered use of network-distributed resources and effective transmission and reproduction of information.

This research theme is divided into the following three categories.

1) Research and development of application-oriented operations management platform technology (Touhoku JGNII RC)

2) Research and development of surrounding computing technology (Kouchi JGNⅡ RC)
3) Research and development of adaptive service control using advanced HCI technology (Tsukuba JGNⅡ RC)

3.2 Research themes and characteristics of each Research Center

(1) Touhoku JGNⅡ Research Center (RC)

Touhoku JGNⅡ RC mainly engages in research and development of application-oriented operations management platform technology, under the fourth JGNⅡ R&D project theme, designated as "research and development of platform middleware application technology". With an emphasis on applications, Touhoku RC is developing operations management platform technology that will provide specific on-demand network information required by applications, with the required quality.

Touhoku JGNⅡ RC has established three sub-themes of this research and development theme, forming a research group for each subtheme. All three themes are supervised by two advisors (Professor Norio Shiratori of Tohoku University and Professor Yoshiaki Nemoto of Tohoku University), the Sub-Leader in charge of the RC (Professor Hideaki Sone of Tohoku University), and a Visiting Researcher. The staff consists of an Expert Researcher (Hisanori Masuda) and 10 Guest Researchers. The specific sub-themes are as follows.

1) Development of network measurement and analysis technology for ultra-high-speed large-scale networks
2) Development of application-oriented operations management technology and security technology
3) Development of flexible network middleware technology

In terms of the development of network measurement and analysis technology for ultra-high-speed large-scale networks, recent network management efforts have faced difficulties in the constantly increasing amount of network equipment to be managed, some as mobile elements of ubiquitous networks. The purpose of this sub-theme is to detect events that will affect service through network traffic prediction. Based on the detection of singularities using time-series multivariate analysis and probability process, the sub-theme focuses on technology to detect traces of such events by assessing discrepancies between predicted and measured values.

In the development of application-oriented operations management technology and security technology, Touhoku RC studies network observation technology for individual applications. The studies involve the extraction of application control information from observed data and methods for the efficient measurement, compilation, and collection of communication characteristics at the application level. Touhoku RC also works on technology for high-quality, high-efficiency network management, including intelligent operations management based on application characteristics and user activity, fair resource-sharing among diverse applications, and optimal global control. This Center is also investigating service maintenance technology to protect against network attacks.

In the development of flexible network middleware technology, Touhoku RC aims to implement knowledge-based networks based on the "flexible network" concept. Studies in this area include flexible response to user and application demands or to the network environment and features. Research and development of flexible network middleware (FNM) is now focused on agent middleware components that enable dynamic construction and reconstruction using domain data. Specifically, this research includes a proposal for a new functional layer that will operate above the transport layer, the development of an FNM agent-oriented architecture, and the implementation of FNM as agent middleware (FNM/A).

To promote the use of JGNⅡ and to disseminate JGNⅡ application technology, Touhoku JGNⅡ RC also supports local events and collaborates in local initiatives. For example, Touhoku RC is working on application development in collaboration with the local

community, including broadcasting within and between communities and the implementation of remote-education applications.

(2) Ootemachi JGNⅡ Research Center (RC)

Ootemachi RC is located in the NTT Communications Ootemachi Building in Ootemachi, Chiyoda-ku, Tokyo. The staff consists of an Expert Researcher (Masafumi Yamamori) and 12 Guest Researchers. Ootemachi RC in engaged in (a) research and development of network construction and operation support tools, (b) research and development of wide-area resilient network connectivity support technology, and (c) research and development of IPv6 device evaluation methods and tools.

The following describes the current status and achievements in the specific research themes. All themes essentially involve collaboration and cooperation with parties fully engaged in commercial activities. In other words, the main goal in this context is to bridge the gap between research and actual business. Accordingly, Ootemachi RC is working to help establish and disseminate the relevant technologies based on discussions with its counterparts in the industrial world.

1) Research and development of network construction and operation support tools

This research is aimed at the development of the network construction and operation support tools required in real networks and the provision of these tools as open software, wherever possible. FY 2005 saw the development of two types of such tools. One is specifically a tool assembly to support LSP configuration and management (and which also supports MPLS network operation). The other is a multi-layer network topology management tool that integrates layer-3 information with layer-2 or layer-1 information. This research was conducted in collaboration with DISTIX.

2) Research and development of wide-area resilient network connectivity support technology

The aim of this research is the development of fundamental technology to provide highly reliable ultra-wideband connectivity. Activities in FY 2005 include fundamental studies on a next-generation routing architecture (or IRIDES, an acronym for "invitation routing information advertisement for a path engineering system), research and development of multi-home service provider architecture, research and development to establish interconnectivity between VoIP and SIP systems, and R&D involving measurement and analysis of total Internet traffic in Japan. This research was conducted in partnership with numerous organizations, including JPNIC, TTC, the VoIP Deployment Consortium, HATS, and major ISPs.

3) Research and development of IPv6 device evaluation methods and tools

In a partnership with the TAHI Project, the IPv6 Promotion Council, and the IPv6 Forum, Ootemachi RC has contributed to the IPv6 Ready Logo initiative promoting the evaluation of IPv6 devices, providing support in basic evaluation specifications and test software. The project includes both MIP and IPSec activities.

4) Research and development of next-generation Internet interconnectivity validation

Activities in FY 2005 include (a) transition from JGN to JGNⅡ and establishment of an associated operations management system, (b) validation of interconnectivity in terms of IPv6 and wide-area Ethernet technology, (c) cooperative activities involving local and research networks. In particular, the RC performed large-scale experiments on JGNⅡ using IPv6, with the aim of establishing high-quality multi-cast technology.

(3) Tsukuba JGNⅡ Research Center (RC)

Tsukuba RC has assembled researchers from universities, public research institutions, and private enterprises at Tsukuba Science City to conduct leading research and development in the telecommunications field. Tsukuba RC also conducts experiments using the local community network with the participation and cooperation of municipal organizations, public institutions, and private individuals, aiming to make the best use of the unique cooperative research resources of the Research

Center. Tsukuba RC thus goes beyond leading-edge research and development to contribute to overall progress in the "computerization" of the local community.

Tsukuba RC is a connection point for the JGNⅡ (10 Gbps) network testbed for research and development. From this Center one can connect to the 63 JGNⅡ access points in all over Japan. The Tsukuba WAN (10 Gbps), which connects universities and research institutions in Tsukuba Science City within a high-speed access ring, is also connected to JGNⅡ at the Tsukuba RC facility, allowing researchers in organizations participating in the Tsukuba WAN to access the JGNⅡ.

Tsukuba RC engages in two core themes: research and development of GMPLS network operations management technology (GMPLS: Generalized Multi Protocol Label Switching), and research and development of adaptive service control using advanced HCI technology (HCI: Human-Computer Interaction), in addition to numerous related sub-themes. Specifically, these sub-themes are as follows.

Sub-themes related to GMPLS:

- Research and development related to network control for multimedia distribution
- Optimal routing and flow control in GMPLS networks
- Research and development of GMPLS network application technology based on Grid middleware
- Demonstration of effectiveness of JGN in Grid computing

Sub-themes related to HCI:

- Haptic communication
- Research on SAT remote counseling system for local healthcare initiatives
- Research on "Embodied Spaces", enabling physical communication between remote places
- Research on real-space video avatar communication technology
- Research on HyperMirror communication through gigabit lines
- Research and development related to collaborative environments using mirror interfaces on gigabit networks

The staff of Tsukuba RC consists of 24 members: the Director (Tatuzo Koga), three Expert Researchers (Junzo Okunaka, Shuichi Okamoto, and Sukehide Okano), and 20 Guest Researchers.

Tsukuba RC calls together members and other relevant parties every month for a staff meeting to establish research plans, improve research achievements, and ensure communication among members. Tsukuba RC also holds a regular Tsukuba JGNⅡ RC seminar, which is open to the public.

(4) Osaka JGNⅡ Research Center (RC)

Under the theme of "site-collaboration resource-sharing technology", Osaka RC conducts research and development related to the use of resources such as CPUs, storage, and network bandwidth in the provision of calculation services using a group of computers installed at two or more sites.

The site-collaboration resource-sharing technology theme consists of two sub-themes, both of which Osaka RC pursues on its own. These sub-themes consist of "research and development of secure resource-sharing technology for site collaboration" and "research and development of large-scale data processing coordination technology for wide-area networks". The former deals with security in sharing computational resources, and the latter addresses the characteristics and effective use of networks for distributed processing.

This research field crosses over various areas of study—from networks and middleware to applications. As a result, Osaka RC works to improve the effectiveness of its research through collaboration with related research projects within and outside of Japan. Through such collaboration, Osaka RC also hopes to adapt the developed technologies to applications and to perform large-scale experiments. Among the achievements of this collaboration to date, the RC performed an application demonstration with a large electron microscope in FY 2004 using the international JGNⅡ line between Osaka and the US.

In addition to presentations at academic meetings and other demonstrations, Osaka RC

works in many ways to publicize JGNⅡ and Osaka RC activities. For example, the Osaka RC shared its projects among others in a joint booth at SC2004, with display panels and demonstration exhibits.

(5) Okayama JGNⅡ Research Center (RC)

Okayama JGNⅡ RC selects its research themes not only with an eye to research and development but also to what must be disseminated in the market if we are to ensure the future growth of a next-generation Internet. Seamless connection to the Okayama Information Highway, the local community network, has now been completed, and the municipal organization is eager to promote a research and development environment that is unified with this network. The Okayama Information Highway was thus the first to support IPv6 among municipal networks in the early stages. The network has since acquired independent pTLA (pseudo top-level aggregation) and provides full support.

Using this environment, Okayama RC conducts research and development based on three primary methods and concepts: (1) identification of technical problems, (2) feedback to the market, and (3) early dissemination of IPv6 networks.

Given this environment, Okayama RC focuses not only on research and development but also works to refine its research content based on the wide-ranging demands of enterprises and consumers.

(6) Kouchi JGNⅡ Research Center (RC)

The Kouchi JGNⅡ RC is one of seven Research Centers in Japan participating in the JGNⅡ RC research project; moreover, this Center is also planning to participate in research and development specifically using the JGNⅡ in Shikoku, conducting joint interconnection experiments in its role as the only JGNⅡ RC in the area. Kouchi JGNⅡ RC is located in the Kochi University of Technology (Education and Research Building A501–503, A552, Collaboration Research Center 101). Masahiro Fukumoto is responsible for the Center, and the members mostly consist of Guest Researchers from the Department of Information System Engineering at the Kochi University of Technology (Kazunori Shimamura, Masanori Hamamura, Makoto Iwata, Keiichi Sakai, and Takahiko Mendori), along with others from the Faculty of Engineering of Ehime University (Shinji Tsuzuki), Kochi National College of Technology (Takumi Yamaguchi) and Japan Telecom Co., Ltd. (Hideki Hayashi).

Kouchi JGNⅡ RC is engaged in research and development involving surrounding computing, part of the fourth theme, “research and development of platform middleware application technology”. Surrounding computing technology seeks to realize a flexible, easy-to-use information environment for the coming ubiquitous network society. This involves implementation of a system that can effectively transfer the enormous amounts of information exchanged in next-generation high-speed networks (such as JGNⅡ) within a ubiquitous networking environment for display in a user-definable manner. Kouchi RC thus conducts research and development mainly related to information transfer within a ubiquitous networking environment based on data-driven processors; this R&D includes the effective utilization of distributed network resources, automated delivery processing of distributed information, and information reconstruction technology tailored to the user’s environment.

In cooperation with the Kouchi JGNⅡ Users Conference, Kouchi RC continues its collaboration to promote research and development within the local community using JGNⅡ and to promote the effective use of the Kochi Prefectural Information Highway. These efforts rely on the interconnection between the information highway and organizations providing its access points—such as universities, research institutions, local municipalities, elementary schools, junior-high and high schools, and private enterprises located in Kochi prefecture. Also in collaboration with the JGNⅡ Shikoku Users Liaison Council (an organization of network researchers, users, research institutions, and enterprises in the four prefectures of Shikoku), Kouchi RC is

working on publicizing the JGNⅡ, promoting its use, and encouraging progress in interconnection among local networks in Shikoku.

(7) Kitakyushu JGNⅡ Research Center (RC)

Kitakyushu JGNⅡ RC is engaged in the second theme, "research and development of access network technology". Working to ensure efficient sharing of finite network resources through the effective distribution of roles and coordination of resource controls, Kitakyushu RC focuses on three component technologies in parallel and in collaboration with others: optimal routing and traffic control technology (so-called "access integration", optimization of an ultra-high speed core network to accommodate traffic between locally integrated access networks), control technology that adaptively assigns diverse wireless and mobile network resources with a focus on communication quality under the given restrictions (access deployment), and adaptive communication control technology that enables effective and fair implementation of end-to-end communication via diverse networks for various levels of required quality (communication control between terminals, in short).

In particular, Kitakyushu RC has established the three sub-themes described below. An Expert Researcher and numerous Guest Researchers are assigned to each sub-theme in the context of joint research with private enterprises and universities. The Director and the Chief Expert Researcher are responsible for all themes and guide work accordingly. Research and development is conducted through collaboration among industry, universities, and the government. These three subthemes together foster effective use of ultra-high-speed core networks, effective use and assignment of access network resources, and optimal end-to-end communication for applications—anywhere, anytime.

(A) Adaptive routing based on network measurements

Based on techniques such as traffic flow measurement, route selection, and traffic control, this research is aimed at routing and traffic control at the network edge to improve communication quality and usability across an ultra-high-speed core network. This research also fosters collaboration with the GMPLS research group (Theme I). The main researchers involved include the Kitatsuji Expert Researcher and Guest Researchers (from Kyushu Electric Power Co., Inc., KDDI R&D Laboratories, and the Kyushu Institute of Technology).

(B) Control for seamless utilization and assignment of resources based on quality

Based on technologies such as those related to wireless networks, multihop wireless networks, and mobile terminals, this research is aimed at resource use and assignment control that will improve communication quality and usability within diverse wireless networks. In addition to proposing methods for resource use and assignment technologies, particular focus is placed on developing prototypes and securing patents for practical applications. The main researchers include the Koga Expert Researcher and Guest Researchers (from Panasonic Mobile Communications Co., Ltd., Panasonic Communications Co., Ltd., Yasukawa Information Systems Corporation, Tokyo Institute of Technology, and the Kyushu Institute of Technology).

(C) E2E communication control capable of handling diversity and variability

Based on technologies such as end-to-end communication protocol (both for transport and applications) and packet processing within routers, this research is aimed at communication protocols and router support that will improve the quality and efficiency of E2E communications through a diverse range of variable networks. This research also involves international joint experiments (with the University of Illinois) dealing with high-speed transport protocol technology, using the JGN Ⅱ international lines. The main researchers include the Kumazoe Expert Researcher and Guest Researchers (from Kyushu Electric Power Co., Inc., INTEC Web and Genome Informatics Corporation, Kyushu University and the Kyushu Institute of Technology).

Kitakyushu JGNⅡ RC is on the same floor as NICT's Kitakyushu IT Open Laboratory. The floor provides one of the two JGNⅡ core access points in Kyushu. The RC and IT Support Center collaborate to support various network events using JGNⅡ, together playing a central role in JGNⅡ activities in the Kyushu district.

3.3 Research meetings and other JGNⅡ activities

Given that JGNⅡ will form the central community of network studies in Japan—from fundamental technology to applications—the Research Centers naturally cooperate in a range of research activities. Their achievements are published and also made public through presentations and demonstrations in various JGNⅡ Workshops (held at Ootemachi in June 2004, Kitakyushu in November 2004, and in Touhoku in May 2005), and at the JGNⅡ Symposium (held in Osaka in January 2005).

4 Summary

This article describes the JGNⅡ network testbed for research and development, launched in April 2004 as part of the JGNⅡ research and development project. We also present an overview of research and development led by the various NICT Research Centers. We plan to continue to upgrade and expand the JGNⅡ network (including its international lines) in FY 2005 and beyond, and plan a series of research activities related to four high-priority themes, using JGNⅡ for collaboration among the Research Centers. Further, we will hold workshops to encourage the sharing of information and further collaboration with other research organizations and intend to focus specific efforts on collaboration with industry, in our efforts to promote the convenient application of our research achievements.

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