Progress and Results of New-Generation Network Research and Development

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With the goal of achieving a network based on new concepts that look forward to non-IP, research and development on the new-generation network started around 2006. The conceptual design phase to define the new-generation network was finished around 2010. We are about to finish the detailed design phase for studying how to create the new-generation network. We are now integrating elemental technologies that we researched and developed, constructing a prototype on the JGN-X testbed that NICT operates, and executing demonstration experiments, while we verify these infrastructure technologies.

1 Introduction

As a network that solves various problems in the current Internet, which has an architecture focused on the Internet Protocol (IP), the new-generation network is one of the future networks for which research and development are being advanced by industry, academia, and the government working together. The New-Generation Network Promotion Forum was organized by industry, academia and the government in November 2007; it has been promoting research and development of the new-generation network. In NICT, to advance research and development of the new-generation network, the New-Generation Network Strategic Headquarters was organized in 2007. It studies this research and development strategy, and at the same time, it has been advancing research and development of the new-generation network as a project under industry-academia-government cooperation. Furthermore, the Network Research Headquarters has been set up as the practical organization advancing this research and development, since the start of NICT's third medium and long-term target period that began in fiscal 2011. This paper describes the progress of research and development on the new-generation network. Section **2** explains an outline of the new-generation network research and development roadmap, and the technology strategy published from 2008 to 2010. Section **3** describes the new-generation network's research and development plan and its main results in NICT's third medium and long-term plan period.

2 Progress and conceptual design of the new-generation network

In the summer of 2005, a UNS Strategy Program under the title of "ICT R&D Programs for the Ubiquitous Network Society" was announced by the Telecommunications Council, Ministry of Internal Affairs and Communications (MIC). Regarding the new-generation networks to be the core, the goal was to create "networks based on innovative new concepts, using optical technology to extend into post-IP areas" as "network integration architecture with a long-term perspective into the future...independent of current Internet architecture." Under this UNS Strategy Program, research and development started on the new-generation network.

Figure 1 shows the roadmap for research and development on the new-generation network. NICT launched the New Generation Network Research Center in 2006, the first year of the Second Medium Term Target Period. During the phase for new-generation network conceptual design—the phase for studying what the new-generation network is—we set up an organization to carry out focused research on network architecture. The AKARI Architecture Design Project (hereinafter, "AKARI Project") started as the core of that organization, under cooperation between NICT and universities, and studied network architecture of new concepts that look forward to non-IP.

At that time, there were also projects in Europe and the U.S. doing research and development on a future Internet to replace the existing Internet. The AKARI Project also does design and long-term research from a clean-slate

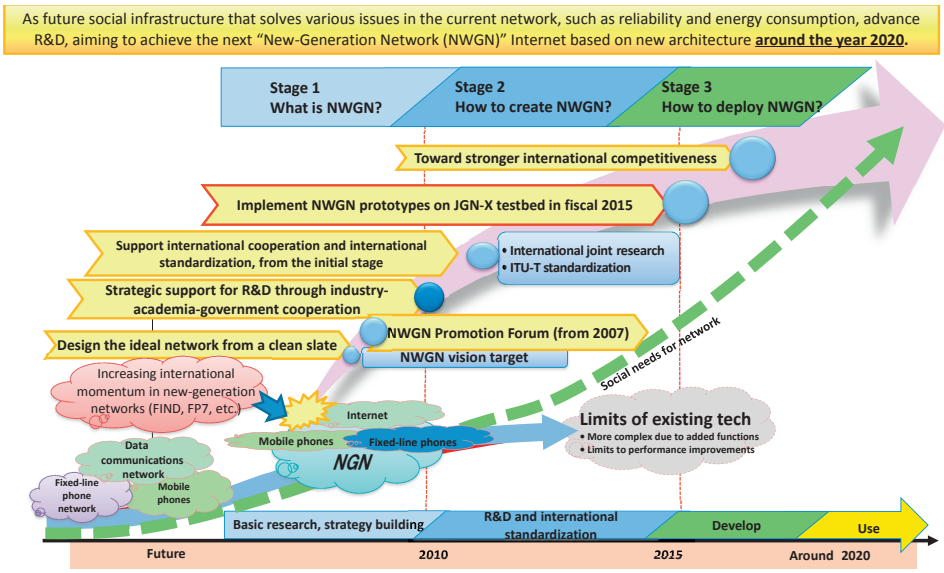


Fig. 1 New-generation network research and development roadmap

perspective, with the same level target of implementation that gives plenty of thought to migration from existing technology. The "New-Generation Network Promotion Forum" was established in November 2007, as the main body to create a roadmap from basic research to applications, study social and economic aspects, and advance international standardization, demonstration experiments, etc. NICT served as the secretariat, along with the MIC. Also in 2007, to strategically advance research and development on the new-generation network, NICT organized the "New-Generation Network Research and Development Strategic Headquarters" (hereinafter "Strategic Headquarters"). The Strategic Headquarters aims to create a medium and long-term research and development strategy for the new-generation network, play a leading and guiding role amidst international cooperation and competition, foster ICT-related R&D human resources who have a long term, international perspective, etc. To achieve these aims, the Strategic Headquarters has developed an organization to advance research and development through industry-academia-government cooperation, and has built relationships for international cooperation. It also invited excellent researchers from industry to establish the internal Strategy Working Group (hereinafter, "Strategy WG") that focuses on studying future research and development strategy in the ICT field. This Strategy WG created a vision of the new-generation network, created a medium and long-term technology strategy that guides research and development, strategically communicated its research and development strategy and roadmap in Japan and overseas, and then disbanded at the end of fiscal 2010. This vision

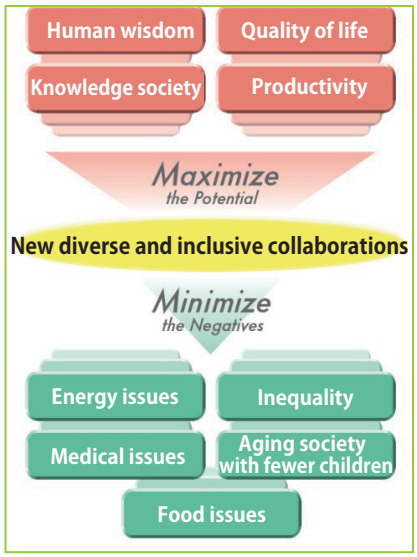


Fig. 2 New generation network vision

and technology strategy also play important roles in the international standardization described in Chapter **8** of this special issue, and formed the origin of an international standardization recommendation derived from the new-generation network, ITU-T Y.3001. The vision and technology strategy issued by the Strategic Headquarters are described below.

To define the new-generation network, the Strategy WG first took a top-down approach, starting with high-level discussions on such a network's roles in society, etc. To do this, it first studied directions the new-generation network could take to solve social problems, and the technology required for this. It also studied a vision of the future society with the new-generation network, and the technology

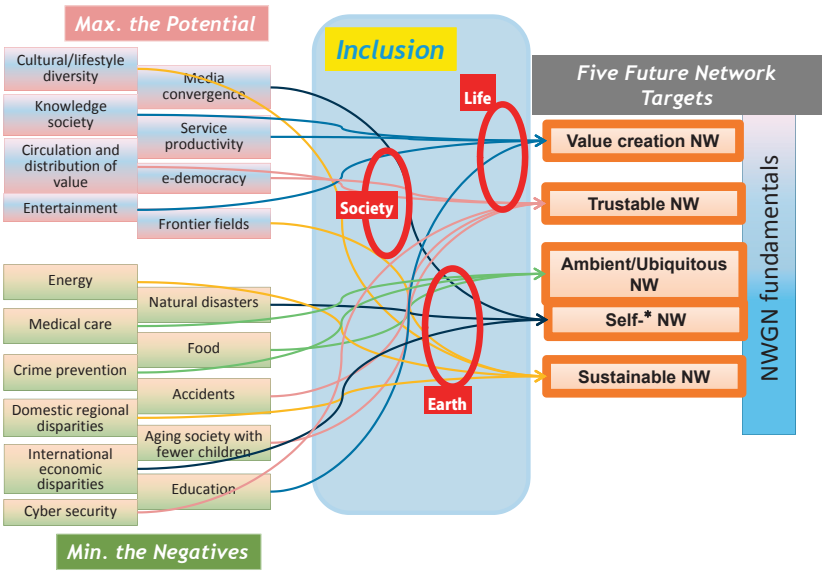
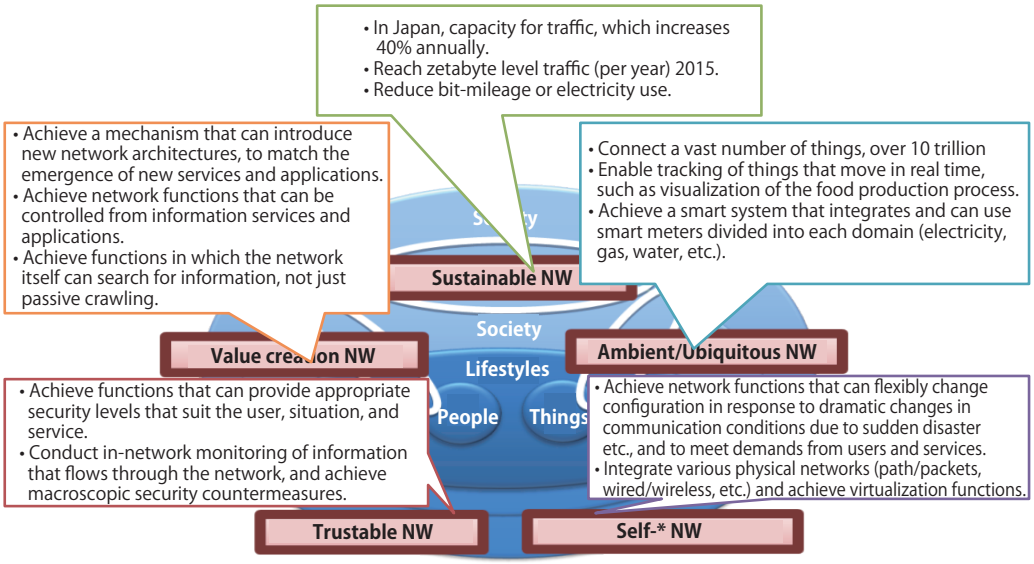


Fig. 3 From vision to design goals (NW = "Network")

required to achieve this. A report titled "Vision and Technology Requirements for the New-Generation Network" was published in 2008, and revised in 2009[1]. The need to do the following three things were raised in the vision, based on using ICT to solve various social problems and issues. First, minimize the negative aspects of current social problems (energy issues, disasters, medical issues, inequality in society, aging society with fewer children, food issues, etc.). Second, maximize new value: increase the fields of human knowledge, improve the quality of life, improve productivity, etc. Third, for problems due to increasing globalization, such as conflicts, confrontations, inequality and depopulation, construct a network that respects diversity and encourages new cooperation (Fig. 2). At that time, investigations of a future Internet and future networks that are superior to today's Internet were also progressing in Europe and the U.S. In the U.S., in September 2008, the National Science and Technology Council announced the "Federal Plan for Advanced Networking Research and Development"[2] as the direction of research and development. This published a vision and research and development strategy, especially for the NSF and public institutions. In Europe, the European Commission supervises the European Technology Platforms (ETP). Five ETP for research and development of networks cooperated to announce the "Future Internet: the Cross-ETP Vision Document"[3] in January 2009. This vision document basically resulted from study and writing by industry researchers in Europe, and became the model for a later huge research and development investment program implemented by the European Commission: the FP7 research and development investment portfolio for future Internet related fields. We should also note that this document mentions four pillars of the future Internet: Internet by and for People, Internet of Contents and Knowledge, Internet of Things, and Internet of Services.

After that, we extracted a variety of 19 technology requirements for achieving the vision described above. Among those, we hammered out five network targets for designing the new-generation network. These are "Value Creation Network," "Trustable Network," "Ambient/Ubiquitous Network," "Self-* network"—a "pleasant network which can be used without feeling network restrictions" and "Sustainable network." Their network research and development strategies were shown in the "New-Generation Network Technology Strategy (Interim Report)" published in 2009[4] (Fig. 3). Also, "New-Generation Network Fundamentals" was proposed as the research and development strategy for network science that supports achieving these technologies. Figure 4 shows a simple explanation of the design goals. One can say that the new-generation network research and development is the development of network technology that can achieve the goals shown in Fig. 4. The creation of these visions and design goals ended the concept design phase for studying what the New-Generation Network is. Then, based on this strategy, aiming to achieve the new-generation network, the New-Generation Network Promotion Project began in 2010, to comprehensively work on development without a boundary between wired and wireless, from the physical layer to the application layer, from innovative technologies to applied technologies.



From "Diversity & Inclusion: Networking the Future, New-Generation Network Technology Strategy," National Institute of Information and Communications Technology, New-Generation Network Research and Development Strategic Headquarters, October 2009

Fig. 4 Five network targets for new-generation network (NW = Network)

3 New-generation network research and development in NICT Third Medium and Long Term Target Period

Fiscal 2011 to 2015 corresponds to the Third Medium and Long Term Plan Period. In this phase, we make detailed designs for the new-generation network, that is, we decide how to create the new-generation network. NICT launched the New-Generation Strategy Project in fiscal 2010, one year ahead of schedule. Aiming to construct a new-generation network prototype in NICT's JGN-X by the end of fiscal 2015, industry and academic institutions are cooperating on research and development.

The basic plan for new-generation network research and development was made to achieve the third medium and long-term targets provided by the competent government agency, the MIC. The third medium and long-term targets raise the research and development of new-generation network infrastructure technologies as a research and development issue, as follows: "Aiming to achieve by around 2020 a new-generation post-Internet network, as a future social infrastructure network that solves various issues that current networks face, such as reliability and security, that is flexible and sustainable, and that anyone can use securely and reliably at any time, combine efforts of industry, academia and government to advance the research and development of infrastructure technologies." For this goal, NICT's third medium and long term plan describes new-generation network technologies as follows: "Toward achieving a new-generation network, organically combine elemental technologies of the optical, wireless and security fields, to achieve platform technologies etc. that host system configuration technologies and diverse network services. Work to integrate these, and utilize a testbed etc. to demonstrate these. Thereby establish a robust new-generation network platform technology that can flexibly rebuild its network configuration in response to changes in traffic or partial malfunctioning of the information and communications infrastructure when a disaster strikes, etc." Based on this plan, in order to organizationally support new-generation network related research and development in NICT, the Network Research Headquarters (hereinafter, "Research HQ") was organized in fiscal 2011, especially to execute research and development and strategy planning for the new-generation network, as part of research and development on optical networks, wireless networks and network security. Figure 5 shows the Research HQ's mission. In addition to its own research, the Research HQ makes full use of various schemes such as joint research with external parties, consigned research, and joint research and development in cooperation with overseas funding bodies. It thus implements research and development toward the achievement of a new-generation network.

In order to easily understand the elemental technology groups needed to construct a wide variety of new-generation networks, the goals are considered as two broad groups: research and development on component technologies of the basic structure of the new-generation network, and

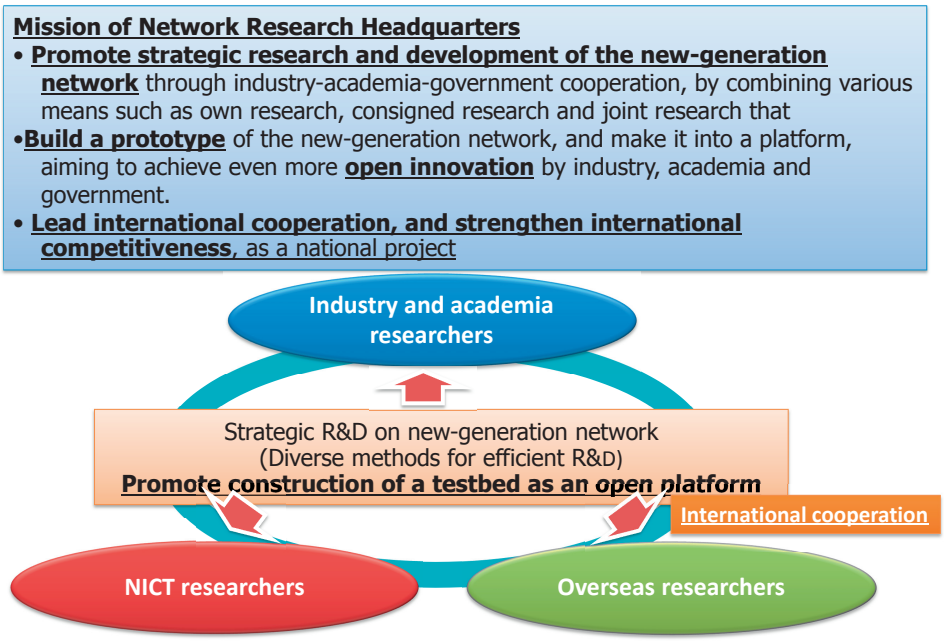


Fig. 5 Mission of the Network Research Headquarters

research and development on platform technologies for networks that have combined services, and systemization of these technologies.

The medium and long term plan contains the following concerning research and development on component technology for the basic structure of the new-generation network. "Toward achieving the new-generation network, consider security requirements and disaster resistance etc. needed in future social infrastructure, and establish platform technology that comprises the basic structure of the new-generation network, including the application layer. Also, in order to enable simultaneous operation of different network services with different required conditions, such as reliability of transfer speeds and size of connection terminals, newly achieve virtual network nodes that can provide various communication services on one network on a packet/path integrated network that can easily achieve separation of network resources (bandwidth, etc.) At the same time, conduct research and development on wireless access virtual network construction technology that expands virtual networks in wireless access circuits, and establish virtual network platform technology that enables construction on virtual networks, of systems that can share various required information, using transfer methods that suit the information, including during disaster recovery." For this plan, to establish the platform technology (architecture) that comprises the basic structure of the new-generation network, a study of network architecture that considered the network requirements needed by society in

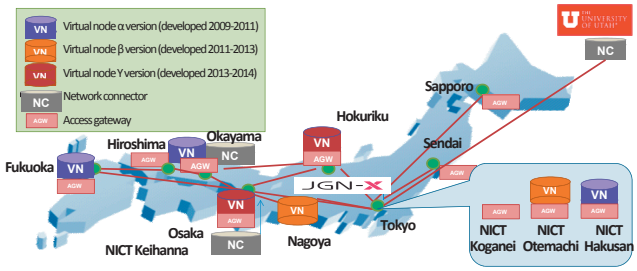


Fig. 6 Network virtual nodes and network virtual testbed deployed throughout Japan

the year 2020 was done for 2 years starting 2011, under industry-academia-government cooperation, and was published in April 2012[5] as a white paper; it was revised in September 2013. The architecture studied here was architecture studied in the AKARI Project, improved to be a model closer to implementation, so the study results were input into research and development on elemental technologies already implemented, and we are working toward international standardization and commercialization of elemental technologies developed based on this architecture. The results of the research and development on architecture are described in Chapters **4-7** and **6** of this special issue. Regarding construction of virtual networks on a packet/path integrated network architecture, we newly developed a network virtual node that combines optical path and electronic packets, deployed that developed device on JGN-X, and constructed a network virtual testbed on the scale of a country the size of Japan (Fig. 6).

We studied the framework of network virtualization and its requirements, and made them into the international recommendations ITU-T Y.3011 and Y.3012, respectively. Also, the optical packet/optical path integrated node that enables an even broader band was improved as a system that operates using the OpenFlow interface that is one kind of practically implemented SDN technology, then we co-operated with research centers of carriers and vendors, and implemented a mutual connection demonstration (Fig. 7). The wired network virtualization results are described in Chapters **4-1** to **4-4** of this special issue. Regarding wireless access virtual network construction technology, we proposed a new concept of virtualization of wireless interface, and in 2013 successfully prototyped a network virtualization compatible wireless base station that applies this concept to WiFi, and constructed a wireless network virtualization testbed in NICT headquarters (Koganei). We also combined wireless access virtual network construction technology with the network virtualization node described above, and succeeded in the construction of an end-to-end virtual network system. These results are described in Chapters **4-5** and **4-6** of this special issue. Moreover, as an application that cannot be achieved in the current Internet, we did four research and development projects focused on content transmission based on new identifiers, and implemented a demonstration experiment. The results are described in Chapter **5** of this special issue.

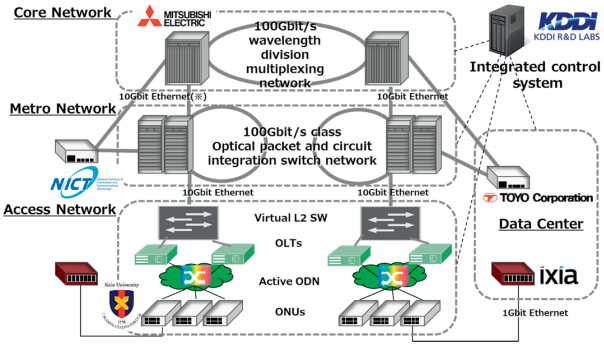


Fig. 7 Experiment of mutual connection between packet/path integrated network nodes and optical SDN (iPOP 2014)

The medium and long-term plan includes the following concerning the research and development of network platform technology that hosts composite services: "In order to dynamically obtain different required resources (network bandwidth, storage, calculation capacity, etc.) on the network for each user, and flexibly achieve network services sought by each user, work to establish technology for a network platform that hosts composite services and has adjustment functions such as additional allocation of resources, while doing demonstration experiments that assume future new-generation network use scenarios." Regarding a network platform that hosts composite services, we prepared on a national scale the Japan-wide Orchestrated Smart/Sensor Environment (JOSE, Fig. 8), which is an information processing platform that combines a ubiquitous computing platform that works on a P2P basis, with a distributed, hierarchical cloud and SDN. With this, we developed and constructed a system that can greatly reduce the time needed to allocate resources to users. It previously took from 4 days to 2 weeks, but this system only needs from a half day to 2 days. This system is now being provided as a testbed, and 27 experimenters are now doing demonstration experiments while obtaining

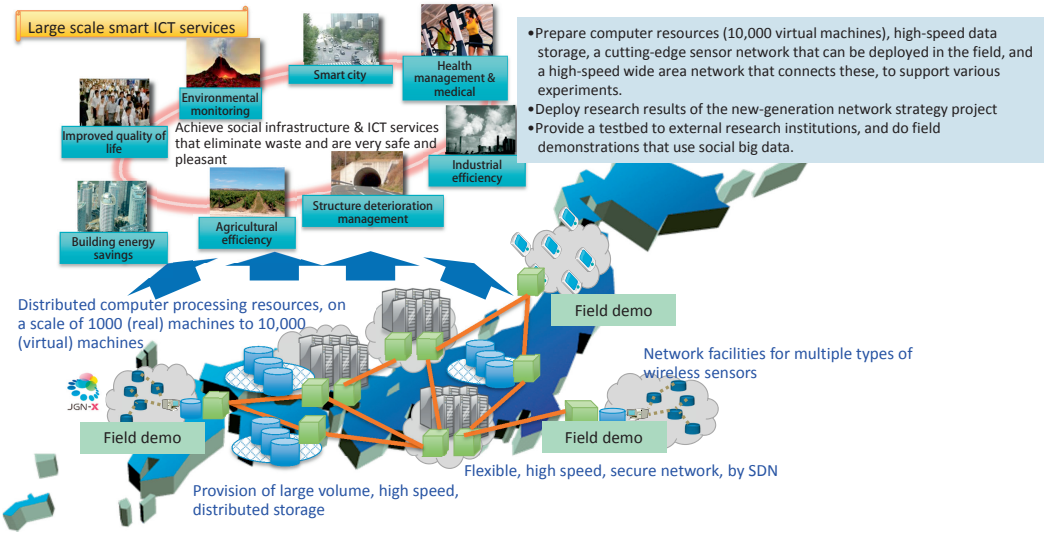


Fig. 8 JOSE prototype platform that hosts composite services

different resources. We are also developing a demonstration that combines this with an SCN that dynamically controls the network from applications and services. The results of these are in Chapter **7** of this special issue.

4 Summary

This paper gives a chronological overview of the research and development on the new-generation network. The research and development that started in 2007 studied what the new network is using a top down approach. As a result, we did research and development on a distributed and hierarchical cloud system for smart ICT services including content transmission and IoT, based on network virtualization and new identifiers. One of the goals was to demonstrate the usefulness of these technologies, by developing a new large testbed or deploying on JGN-X, and making it widely available to internal and external researchers, thereby attracting various demonstration experiments to produce results, and verify that platform technology. We hope that the results of this research and development are studied more and more in various forms, and will be finally implemented in practice as parts of future networks in future social infrastructure.

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