Diversity & Inclusion: Networking the Future

Technology Strategies for a New-generation network

Interim Report

March, 2009

National Institute of Information and Communications Technology

Published by Strategy Headquarters of
New-generation network Research and Development

Researchers and Authors

Masayuki Murata, Masashi Eto, Kazuhiro Otsuki, Tetsuya Kawanishi, Ryutaro Kawamura, Yoshiaki Kiriba, Hiroaki Kojima, Toshiaki Suzuki, Toshio Soumiya, Hirotaka Terai, Kiyohide Nakauchi, Makoto Naruse, Nozomu Nishinaga, Homare Murakami, Toshiki Yamada

Contents:

1. Introduction

The National Institute of Information and Communications Technology (NICT) launched the Strategic Headquarters of New-generation network Research and Development (abbreviated as "Strategic Headquarters" below) on October 1, 2007, to strategically promote the research and development of the New-generation network (NWGN). The aims of the Strategic Headquarters include: (1) Plan the medium and long term R&D strategy for the New-generation network, (2) Play a leading/guiding role in international cooperation and competition, (3) Promote R&D talent related to ICT having a long term/global perspective. The organization is headed by the NICT President and is a departmentally cross sectional organization that extends over multiple research centers and co-operative research units without being enclosed in an existing organization. It thus ensures consistency and efficiency in the R&D policies of NICT, also enabling provision of strategic guidelines for R&D carried out by NICT.

Since its launch in FY2007, the Strategic Headquarters has developed a system for promoting industry/ academia/ government cooperation, and has built up relations for future international cooperation. Moreover, the Strategy Working Group ("Strategy WG") was set up following the establishment of the Strategic Headquarters. First class talent from companies and elite researchers from NICT were assembled in the Strategy WG, and they concentrated on examining R&D strategy in the ICT sector. Since April, 2008, the Strategy WG has conducted focused discussions on directions and technology requirements for solving social problems with the New-generation network, and on a vision for a future society based on the New-generation network and the technology requirements for achieving that vision. The results were summarized in October, 2008 in "Diversity & Inclusion: Networking the Future; Vision and Technology Requirements for a New-generation network". A revised edition was published on February 21, 2009.

Thereafter, the various technology requirements necessary to solve the social problems mentioned in the above stated report and to achieve the future vision were summarized into five network targets. The five network targets are "Value Creation Network", "Trustable Network", "Ambient/Ubiquitous Network", "Self-* Network", and "Sustainable Network". This report indicates the R&D strategies of these networks, i.e. how they should be achieved technologically, various important technologies and their roadmaps. Moreover, the "NWGN Fundamentals" show the R&D strategies related to the network science that serves as the backbone for achievement of these technologies.

This report was created by the Strategy WG by carrying out a series of tasks such as planning the social and economic future vision, identifying important technologies for realizing this vision, and planning the technical roadmap, by concentrating knowledge from industry/academia/government. We are proud of the fact that so far this report has remained unparallel in the field of ICT in Japan.

The planning of test bed strategy, technology transfer strategy, R&D funding strategy, standardization strategy, internationalization strategy, human resource development strategy, and innovation strategy that serve as the backbone of these technology R&D strategies has already begun, but they are not shown in this report. We plan to also contribute to the development of a New-generation network in Japan through these comprehensive strategies.

Below, Chapter 2 explains the development towards network target decisions from the previously mentioned New-generation network vision. Chapter 3 explains the R&D strategies of the five network targets, networks fundamentals R&D strategy, and outline of the technological roadmap. Finally, Chapter 4 summarizes this report.

2. From Vision to New-generation network Target

2.1. New-generation network Technology Area

Based on the New-generation network vision constructed from three viewpoints (“Solving emerging social issues”, “Creation of new world” and ”Inclusion”), 20 items of social issues and future social outlook were analyzed, and the functional requirements of a New-generation network were extracted [1]. Moreover, the extracted technology requirements were expressed as technology challenges as directions for innovative research, to achieve great innovation over the existing network. The New-generation network technology strategies to realize this New-generation network vision is described below in Chapter 3 of this report.

This chapter refers to the fundamental investigation process at the time of deriving the innovative network targets for creating innovations for realizing the New-generation network. Figure 2.1.1 shows this investigation process. An overview was taken of technical trends over a wide range of fields, using 1) New-generation network vision and its technical requirements, 2) Technical challenges, and 3) Technology elements. Meanwhile, the amount of impact from changes in the new generation and ease of understanding from the user viewpoint are considered. Then five innovative network targets were extracted, by packaging them as technology strategic solutions of the New-generation network R&D. Needs and desired points in the vision and technology requirements and technology elements were closely examined from the point of view of challenging aspects and thus five network targets were extracted.

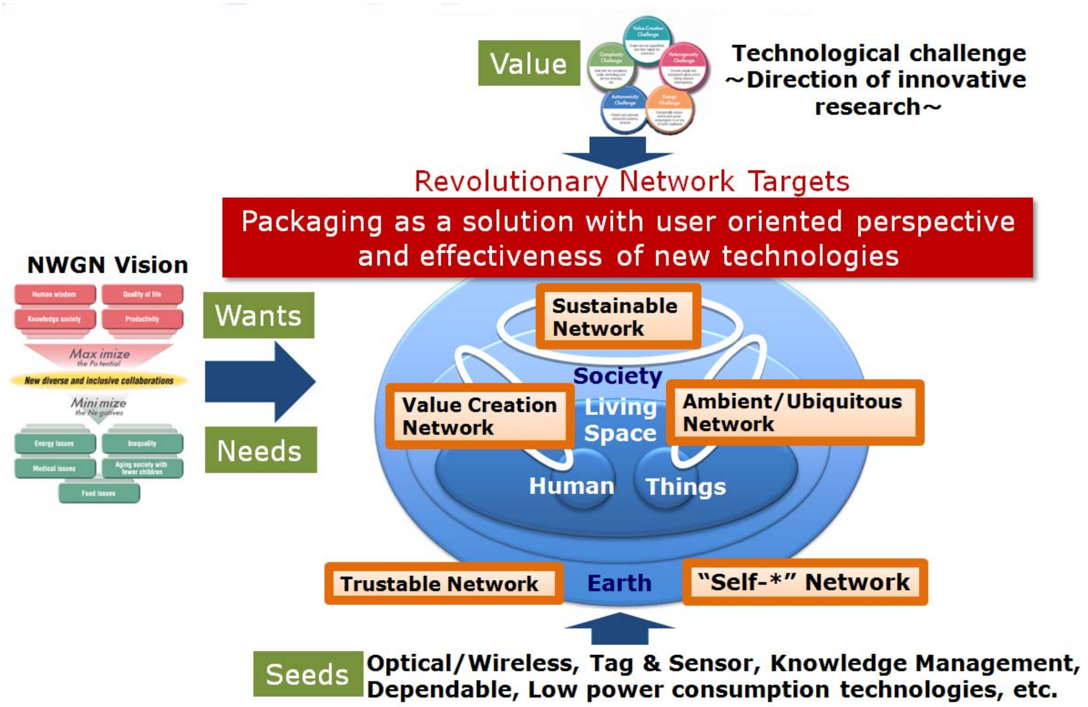

Figure 2.1.1 Relation among **New-generation network Vision, Technology Challenges, and five targets**

2.2. Focused Target Network

As described in above section, we analyzed social issues and social outlook covering 20 items, and enumerated the technology requirements of the New-generation network. At the same time, we investigated technology requirements that the New-generation network should have, but that cannot be achieved in the existing internet nor in the next generation network (NGN). More than 100 technology requirements for the New-generation network were extracted as a result, and these technology requirements were classified in several abstract categories. The classification was carried out by keeping in mind relation among the network, all things and people on earth, relation between the earth and sustainable society, trust between people and networking society, support relationships, etc. As a result, these are integrated to five network images which should be aimed for (Figure 2.1.1). These network images are network targets, and it shows the New-generation network direction which should be aimed for to realize the vision. As for these five network targets, each technology development element is bound to a technology requirement that contributes to solving social issues and to the future social outlook. (Figure 2.1.3)

Details of these five target networks are described in Chapter 3, but here we outline these network targets. **"Value Creation Network"** is a platform to create new value by changing from an information society to a knowledge society. These were previously called application platforms which used the network, and it keeps a distance from network R&D. However, unlike the previous R&D focus on only transmission technology, the New-generation network is only one step before the user and is based on the concept that it should offer all steps from service creation to innovation creation. **"Trustable network"** goes one step beyond the previous "dependable", aiming to build a network which people and society can trust each other. In the time of the New-generation network, a vast and complex network platform will support people's lives, but it requires flexible systems which enable continuous operation even if some of these elements are incomplete or defected. And this network platform must be socially trusted. Here we are aiming at an operating network that is trusted as social fundamental system. **"Ambient/Ubiquitous Network"** is a network achieving connections between all people and all things on this earth, and is actually a globally scalable sensor/actuator network. By this network, information from cellular level to planetary space level is distributed and recorded in the network, and there are expectations for new services using this vast information. **"Self-* network"** ("*" means a wildcard, e.x. configure, manage, discovery, etc.) targets offering a network environment in which the network can be used without restrictions from the point view of users. All the user is free from troublesome network settings and transmission loss due to the coverage without special attention to the network. **"Sustainable network"** aims at coexistence between sustainable development of the network itself and sustainability of the earth by using the network. It also aims at maximizing use of the two finite resources of energy and frequencies. These five network targets have **"New-generation network fundamentals"** as their common basic field.

New-generation network fundamentals are common for all these network targets, such as research in the network science field for a network platform enabling sustainable development, and advanced device development.

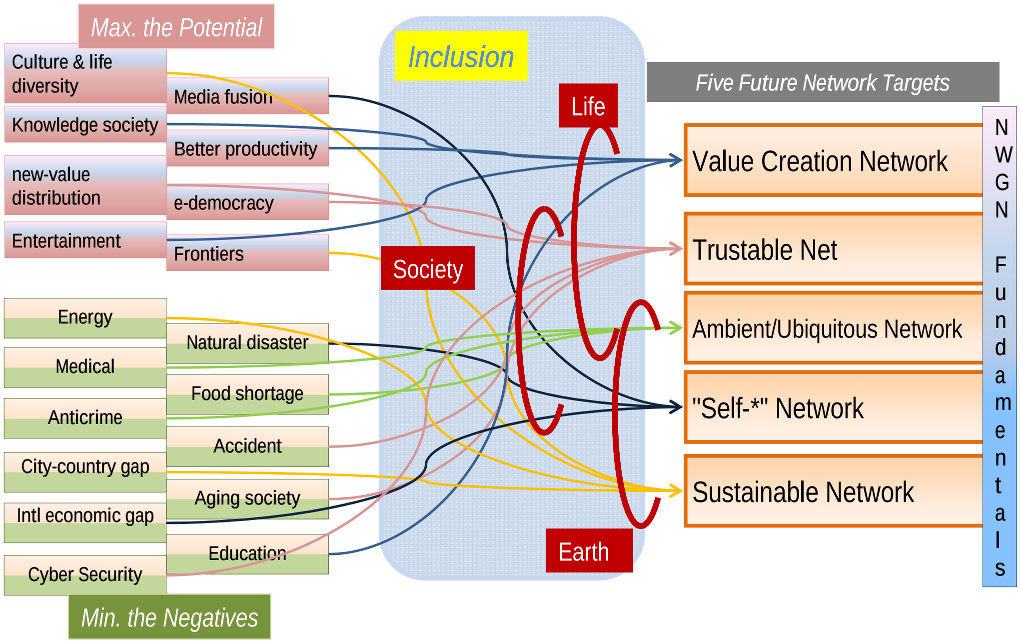

Figure 2.1.3 Technology Requirements of New-generation network and Five Network Targets

Reference documents:

[1] "Diversity & Inclusion: Networking the Future, Vision and Technology Requirements for a New-generation Network", Strategic Headquarters of NWGN R&D, NICT, Feb. 2009. http://nwgn.nict.go.jp/report/NWGN-Vision-NICT-Report-V2-2009-EN.pdf

[2-1-1] Ministry of Internal Affairs and Communications, ICT Growth Potential Discussion Group, Final Report, "xICT" Vision, July 2008 http://www.soumu.go.jp/s-news/2008/080703_6.html

[2-1-2] Ministry of Internal Affairs and Communications, Information and Communications Council Findings "ICT R&D/Standardization Strategy for Strengthening Japan's International Competitiveness", June 2008 http://www.soumu.go.jp/s-news/2008/080627_6.html

[2-1-3] Ministry of Internal Affairs and Communications, Report of Study Group on Next Generation Broadcast Technology, June 2007 http://www.soumu.go.jp/s-news/2007/070627_3.html

[2-1-4] Ministry of Economy, Trade and Industry, Technical Roadmap 2008, April 2008 http://www.meti.go.jp/policy/economy/gijutsu_kakushin/kenkyu_kaihatu/str2008.html

3. R&D Strategy for Implementing New-generation network Target

3.1. Value Creation Network R&D Strategy

3.1.1. Value Creation Network: Issues and Solution Scenario

- **Issues**

The aim of this target, the Value Creation Network, is to bring new service innovation [3-1-1, 3-1-2] in the network, growing beyond services simply offering connections. The issues are creation of new value chains for offering services from the users' standpoint, and coexistence of diversifying users' needs with sharing of functions for service execution. Furthermore, in the future, it will contribute to productivity of services by collecting and accumulating the services information in the network, combining business and human knowledge, aiming at building a platform that generates new services that were previously unavailable.

- **Scenario**

(a) As the network becomes the platform to create new values, the network itself modularizes the service functions in order to meet various user needs and must also promote openness (Step 1). Furthermore, visualization of the service processes offered through the network is achieved (Step 2). Finally, it aims at building a network platform that even combines dormant knowledge in people and society (step 3).

(b) It is also necessary to bring emergent innovations involving network users, and not just develop novel network functions. The information transmission environment of users is arranged (Step 1); Reliability is judged by information collection and analysis technologies (Step 2); The network aims at enabling provision of information having new value originating in each individual which cannot be offered by existing media, and acting as the platform for an information and communications environment that creates new value (Step 3).

- **Goal**

The goal is to build a platform to create new values by shifting the functions of networks from information delivery to knowledge delivery, and making *Made in Japan* a brand for service quality.

[1] Service creation network

This aims to make the network itself the platform for services innovation.

Step 1: Promote modularization of network service functions, achieving a "*Network only for you*" by which the user can customize network services.

Step 2: Achieve a mechanism to transmit and distribute the vast knowledge inherent in people.

Step 3: Implement basic functions into the network that enable versatile services, such as service process visualization functions. Build a platform which brings real service innovations by developing databases for collective knowledge, dormant human knowledge, business knowledge, etc.

[2] Media creation network

This aims at becoming an information and communications platform for the network itself to bring about new media innovations.

Step 1: Develop an information distribution environment wherein the users can transmit information to anyone, anytime, anywhere.

Step 2: Develop technologies that build database after collecting/analyzing transmitted information.

Step 3: Develop technologies which generate information that matches the user's needs.

3.1.2. Service Creation Network Technology

- **Targets to achieve**

The aim is to build a platform which creates new value by shifting from information delivery to knowledge delivery, and develop its supporting technologies.

For the network to become a platform that can create services, it requires information so that the network can know the service condition. Moreover, we should be aware that the network would deal with people's knowledge such as dormant knowledge and collective knowledge in society in the future. Therefore the aim is to achieve high service quality by autonomous control, using versatile knowledge information to harmonize the service corresponding to user actions with the system.

- **Significance of achieving targets**

Until now, only conventional types of services have been offered by the network industry, and the environment was not conducive for service innovations to take place. It is now possible to expect that previously unimagined services can appear from users, since customization is possible and the network itself can be used by anyone, like with the Web. It will pioneer a new service market, and it will also provide other business opportunities for carriers.

Today's Web services would not be possible without network infrastructure. This means that the network is very important social infrastructure. Process visualization has been provided for closed services and limited enterprises. However, the network is becoming a huge service platform as the services have been outsourced outside the enterprise.

Therefore, the network will provide service innovations and offer new services by service processes visualization of the network, by developing databases dealing with collective and dormant knowledge in people and society.

- **Targeted enabling technologies**

[1] Technology to modularize network services and make them into platform

- Shared module technology, module protection technology, and general purpose platform technology

[2] Technology to achieve large-scale knowledge delivery and distribution

- Knowledge collection technology, knowledge delivery technology, knowledge data analysis technology and knowledge data mining technology

[3] Large-scale distributed services knowledge database construction technology, network built-in service process visualization technology

- Technology for building extremely large-scale databases to store knowledge, support for virtualization functions provided by the network itself, and provision of its group of tools

- **Points of difference from existing networks**

As observed in today's Web applications, service functions provided on the Web have been modularized, allowing flexible services by these combinations. In the Next Generation Network (NGN), an architecture called Service Stratum has been provided, and various services will be provided by the "Application Support Function and Service Support Function". In addition, based on the concept of Service Oriented Architecture (SOA), a platform called Service Delivery Platform (SDP) has been discussed to implement network functions regarding for instance presence information and fee charge functions, where the functions of network services are modularized.

We consider that such a trend in modularization of services will progress further. Moreover, in the coming future, Web-based systems and network systems will be further unified where a service will be provided based on a mixture of web-based services and network-based services. For the Service Creation Network discussed in this section, the aim is to build a platform which creates value through the paradigm shift from an information society to a knowledge society as mentioned above. Therefore, in addition to enhancement of the existing network service platform, the Service Creation Network provides significant attributes over the existing network in its abilities in knowledge delivery, autonomous control harmonizing human behavior and system operations, etc.

3.1.3. Media Creation Network Technologies

- **Targets to achieve**

The aim is to provide a platform for an information and communications environment whereby the network itself will give rise to the innovations of new media. This network will provide the users with truly necessary information in a reliable and user friendly manner, and handle without differentiation both the rich contents created and transmitted by mass media such as broadcasting stations and newspapers, and niche contents created with micro media transmitted by each individual, and it will be able to provide information having new value generated by each individual that could not be provided by existing media, and set up a communication platform where information can be easily transmitted at an individual level.

- **Significance of achieving targets**

Each individual will be able to transmit information as micro media, and by collecting a lot of information and making it function as new media, it will be possible to provide varied information to many people, not only information which is transmitted by the mass media, but also more diverse information having new value.

As for the contents which the mass media produces, the reliability of content will be ensured by the source (broadcasting station, newspaper, etc.) and in case of an individual if it will be possible to judge the current reliability of the individual from the personal history etc. of previous actions (content of transmissions) in addition to judging the reliability of the information according to the content itself, then various information can be handled jointly without differentiating mass media vs. individuals.

Ultimately, without differentiating the source of the transmission as to mass media or the individual and so on, information will be offered with ensured reliability so the user of this information can be relieved and can properly receive the information that he requires. Moreover, the user can become an information provider, thereby making it possible to construct a large information and communications environment in the network.

- **Targeted enabling technologies**

Establish a new method of uniting the mass media and micro media

[1] Micro media distribution environment technology (wired and wireless integrated transfer technology and compatible terminal interaction technology)

To collect information from micro media, it is necessary that information from each individual is transmitted easily. Wired/wireless integrated transfer technology and compatible terminal interaction technology with which anyone can easily transmit information anytime and anywhere, are technologies required for information collection, and it is necessary to establish such an information distribution environment.

[2] Information reliability evaluation technology
(Various processes for content analysis and database construction technologies)

Selecting very accurate and significant information from the vast amount of mixed information becomes a very important factor for effective use of information from micro media. Information analysis technology and database construction technology are very important and indispensable technologies for this purpose.

[3] User adapting new media generation technology
(User situation understanding technology and technology responding to user needs)

When information is finally provided to the user, it is extremely important that it is information having new value which cannot be provided by existing media. Technology for generating information in conformity with the user's needs and understanding of the user's situation is vitally important technology.

- **Points of difference from existing networks**

There are already many services that offer a communication place such as SNS Web applications, especially through information which is transmitted by individuals, for example blogs and video sharing sites. On the other hand, there is no proper assurance of reliability and credibility of information, and it is also a fact that not all network users can transmit information easily and securely without constraint.

In the Media Creation Network, the main points of difference from the existing network can be: the possibility of collection of various information and providing information with new value corresponding to the individual network user, by assuring reliability of information and security of network communications and lowering the technological burden of information transmission.

3.1.4. Trends in Other Countries

In the United States, the service industry grew considerably in the 1990's and it became an industry employing large numbers of people. The reasons for increased productivity in the service industry in the United States are as follows: (a) Industries that use ICT accomplished greater productivity improvements than industries that produce ICT equipment, (b) There was a trend of high productivity in "ICT using countries" with more investment in ICT, (c) Companies in the service sector that use ICT succeeded in drawing out the potential power of ICT by using ICT effectively [3-1-3, 3-1-4].

The service industry of the United States that uses ICT has reached the current stage with the appearance of service innovation leaders such as Google and Amazon. In particular, since Facebook and MySpace attract many members, and blog sites have obtained strong support from many general readers, SNS is establishing its position as media that will have a great influence on the formation of public opinion, etc. Moreover, the United States is still the innovation leader in the field of services, with video sharing sites led by YouTube, and new communications services like Twitter with which individuals transmit information.

Much like Japan, the service industry of Europe is following the service industry of United States, and is promoting the R&D in FP7 through the Network European Software & Service Initiative (NESSI) and the PARADISO project to create new services.

3.1.5. Value Creation Network R&D Promotion Strategy

The strategy is shown below.

・Promote services research and its applied technologies

・Promote joint research with social economics and human behavioral sciences, etc.

・Develop excellent software human resources and idea creation

・Know-how accumulation in service innovation platform

・Stronger support for launching service ventures

[Bibliography]

[3-1-1] Ministry of Internal Affairs and Communications, “Strategy for Productivity Enhancement by ICT”, FY2007

[3-1-2] Ministry of Internal Affairs and Communications, “ICT R&D/Standardization Strategy for Strengthening Japan’s International Competitiveness”, FY2007

[3-1-3] Fujitsu Research Institute, Service Innovation Workshop, July 2006

[3-1-4] Service Computing Symposium 2009, March 2009

3.2. Trustable Network R&D Strategy

3.2.1. Trustable Network Issues and Solution Scenario

The information and communications network is absolutely essential in all social activities of individuals and organizations, and the stability and trustability of the network itself are important for maintaining continuous network functions. Here, achievement of new infrastructure to trust the society-wide network becomes an issue: Advanced failure tolerance and prompt recovery from failure, guarantees for service that can give stable operation in case of human error or cyber attack, and a network usage environment in which safety and trust are assured.

Actually, the existence of threats such as cyber attacks is unavoidable, in addition to failures associated with its larger scale, including human errors. Though such vulnerabilities are assumed, it is important to develop a sustainable and stable network. In the networked living environment and society-wide network environment, the improvement of reliability for various services is demanded and at the same time a network usage environment with both high level stability and user-friendliness for privacy protection is also demanded from the user viewpoint.

Towards achieving a trustable network which handles these points, the following two broad issues can be raised.

[1] Securing stability and reliability of the network itself

Uniform dependable network technology is sought, to offer continual and stable network functions from the user terminal to network infrastructure, and online services. While one assumes vulnerabilities such as cyber attacks and human errors, functions are required which achieve stable network operation, including advanced failure tolerance and prompt recovery from failure. In addition to such survivability of the network itself, it is also very important to prepare social infrastructure to provide survivability for people during disaster emergencies.

[2] Securing reliability of service and network entity

A service usage environment is demanded in which reliability is assured to network entities such as individuals and enterprises, when the network is extended to include a social environment such as online public services and banking operations. New trust infrastructure technologies are required which focus on the coming ubiquitous environment: advanced security infrastructure technology, personal authentication technology, privacy protection technology, identity management technology, service reliability technology, etc.

3.2.2. Trustable Network Social Infrastructure Technology

- **Target to achieve**

Dependability, typified by disaster tolerance and prompt recovery from failure in response to threats like cyber attacks by malicious users and human errors in network operation, is developed at each layer from network terminal to infrastructure, and it supports the core of the information and communications network for individuals and society.

- **Significance of achieving target**

Today, the information and communications network is a lifeline in social activities of individuals, and its continual and stable operation is extremely important. To realize such a network, it is crucial to achieve network functions which can obstruct cyber attacks, are continual and stable, and which can recover promptly after failure occurs. It is also important to develop a network system that can avoid fatal overall system failures, even though vulnerabilities like system malfunction and human errors are assumed. Achieving such diverse attributes concerning a continual and stable network in each layer from network to infrastructure supports the core of the information and communications network, which supports individuals and society.

- **Target enabling technologies**

[1] Trustable terminals, infrastructure and service applications

It is necessary to provide the trustability function in each layer, from network terminals to infrastructure and services.

Especially on the network terminal side, secure operating system technology is necessary that includes:

- Buffer overflow attack detection and avoidance functions
- Illegal program detection and removal functions
- More advanced network convergence control functions
- Access control function of file and memory regions

Also, on the network infrastructure side, functions including the following are demanded:

- Autonomous path control, network reconfiguration, and convergence control functions
- Advanced redundant path management functions
- Functions for automatic detection and removal of illegal traffic
- Functions to distribute loads on fixed nodes
- Virtual network management functions

Further, in individual service applications:

- Functions to detect and exclude illegal service usage are very necessary

[2] Trustable application development / verification environment

Many security incidents have been induced in existing networks by developers creating individual service applications that contain vulnerabilities. To solve this problem, it is important to detect and remove vulnerabilities at the development stage of the service application. More specifically, it is important that the programming supporting technology has:

- Function to detect buffer overflow vulnerabilities
- Function to verify access to various variables
- Program logic verification function

At the same time, it is necessary to develop a secure compiler that has these detection/verification functions.

[3] Trustable network management / operation technology

Various human errors are caused in existing network operations, as network administrators have a heavy burden. To reduce burdens of network operation and thereby reduce human errors, it is necessary that traffic intermediary devices have more advanced autonomy and there should be support mechanisms to minimize operation work of administrators. Specifically, there is a need to achieve:

- Network management agent functions
- Network operational support mechanisms
- Simulation function for setting verifications
- etc.

[4] Survivable network

In contrast to trustability and survivability of the network itself as mentioned above, information and communications technology is necessary to secure the survivability of the network users themselves during emergencies like natural disasters. More specifically, the information and communications network has to include capabilities such as:

- Disaster information management technology
- Safety information acquisition technology
- Technology for network configuration by portable terminal during emergencies

- **Points of difference from existing network**

In existing networks, network interruptions are frequently caused by human error. More specifically, there are cases where the entire internet stopped functioning for several hours because the administrator of an internet service provider made mistakes in routing information settings. Phenomena led by botnets, such as DDoS attacks and junk emails caused by the spreading of malware, are carried out by criminal groups, which have become a serious social problem today.

Comprehensive measures are considered from the user terminal to network infrastructure in the New-generation network, after taking the cases mentioned above into consideration, and so it is necessary to make provisions for tolerance to adverse effects brought by human errors and organized crime.

3.2.3. Network Technology which People and Society Can Trust

- **Targets to achieve**

For the network user, it is important to ensure safety and trustworthiness in the environment for the usage. Moreover, in the networked living environment and social environment, ensuring safety and trust have also become new important requirements. Specifically, not only at the network entity (communications equipment such as servers, etc.) level but even at the communicating entity (individual or organization) level, it is necessary to solidly certify the other communicating party by asking "Who am I dealing with now?" In addition, in order to control cyber crimes it is necessary to construct a mechanism wherein a third party agency is established to objectively verify the communicating entities, so the network users can safely enjoy the services.

- **Significance of achieving targets**

For the network user, it is extremely important that there is a secure network environment and improved reliability of online services, with no threat of cyber crimes nor leaks of private information, etc. On the other hand, it is also necessary that the network service is so user-friendly that the network user can enjoy the service without worrying about security threats nor about countermeasures. With the advent of a ubiquitous society, there is further diversification and increase in network terminals, and as such it is necessary to secure safety and reliability in the networked living environment.

Achieving these requirements will enable eliminating acts which come under cyber crimes such as network use crimes or unlawful computer access, along with absolutely minimizing leaks of private and secret information. Consequently, by removing the psychological anxiety factor of the network user regarding the information and communications network, beneficial uses of the network will be promoted further.

- **Target enabling technologies**

[1] Network entity authentication infrastructure technology

In an existing network, the server client authentication technology has been generally used to certify that the service provider node is the proper server which the user intends to use, or it is used so the service provider side may identify a proper client node. For this, conventional authentication infrastructure technology was designed assuming client-server type communications, but with the progress in advanced functionality of end user terminals, it is predicted that P2P-type communication will become more universal in future networks. Therefore, a novel authentication infrastructure technology with considerations of P2P-type networks becomes required. Moreover, there is demand for devices which can easily carry out authentication settings, assuming that communications will be with many users. To be specific, it is necessary to achieve the following:

・Authentication infrastructure technology which supports P2P type communications

・Authentication technology built into the operating system (lower layer)

・Simple authentication setup function

・etc.

[2] Communication entity authentication infrastructure technology

Authentication of the network devices of client and server is regarded as a main issue in existing networks. However, it is difficult to ease the apprehension of users unless it is proved that the actual individual or organization with whom communication is carried out is a trustworthy communication partner. Therefore, a mechanism is needed that can distinctly manage the identity of the communication partner as well as evaluate the reliability objectively. This requires:

・Identity management technology

・Infrastructure for communication entity evaluation by third parties

[3] Advanced information management technology

When assuming construction of technology to achieve the trustability which has been described so far, it should be considered that illegal information acquisition by a malicious user is quite possible. Moreover, with the advent of cloud computing in recent years, we assume that vast information on service users is collected by specific service providers. Therefore, a technology is required which enables the primary information creator to centrally manage the private information of the individual, and confidential information of the organization. Specifically, this requires:

・Technology for the protection of private information and secret information

・Centralized information management technology

・Data falsification prevention technology

- **Points of differences from existing networks**

Although online network services such as online public services and banking services etc. have become very common at present, there is still scope for expansion in the number of users. In this background, as there are many problems in the existing network such as cyber crimes, phishing scams, spoofing, and leaks of private information and confidential information, there is vague anxiety among network users.

In the New-generation network, it will be possible to achieve safer network services by providing certain protection to network users, using technology to authenticate the network entity and communication entity, and also by advanced information management technologies.

3.2.4. Trends in Other Countries

For the In-Network Management of Europe FP7 (4WARD), a network operated autonomously by management agents installed in all traffic intermediary devices has been proposed. Here, decreased network operation cost and human errors are expected because the network operator needs to convey only minimum requirements to the agents. Besides this, the security functions of the New-generation network are defined as “Built in Security” in GENI. Moreover, identity management technology and trust infrastructure technology in Web services are proposed in NGN.

3.2.5. Trustable Network R&D Promotion Strategy

・Coexistence of leading research promotion and continuous development
・Stimulate R&D by combining different fields and interpersonal exchanges
・Reinforce awareness campaigns by coordinating with assessment examinations

3.3. Ambient/Ubiquitous Network R&D Strategy

3.3.1. Ambient/Ubiquitous Network: Issues and Solution Scenario

Environmental problems, food problems, ageing problems, etc. can be raised as social problems closely related to the social life of humanity that are foreseen in the time of the New-generation network. In such an environment, to achieve a life supporting society in which humans can live decent lives and achieve high quality of life, support is needed from ICT for all living situations. There has been internationalization of distribution and progress in international cooperation, especially for environmental problems and food problems. Thus it is believed that cross-border food distribution management, environmental monitoring, traffic accident prevention using information networks, remote health care for senior citizens, support for humans by network robots, etc. can be achieved if it becomes possible to perceive, pursue and as necessary collect and process sensor information generated by humans, things and living environments on a broad global scale, or to drive actuators, then New-generation network technology can be useful in solving the above mentioned social issues. Achieving the above requires a global-scale environmental-sensing system, i.e. a “global sensor actuator cloud” infrastructure to universally connect and manage sensor actuators in the living environment, and middleware that can adaptively and flexibly handle data in the cloud infrastructure.

A network will be achieved that supports a living environment in which sensor information generated by the living environment that includes all existing people and things can be sensed and tracked, and if necessary collected and processed and the decision then transmitted to drive the actuator. The aim is to establish a management technology to realize a global sensor actuator cloud and scalable large-scale sensor actuator cloud for universally connecting the sensor actuators existing in the living environment, and to establish sensor actuator middleware that can process highly flexible data. Two main problems in achieving a living environment supporting network are given below.

[1] Network to handle the quantitative explosion

Establish a configuration, control and management technology for a global sensor actuator cloud that can sense and track information generated by all existing people, things and living environments, and drive actuators.

[2] Life-supporting network

Establish a middleware infrastructure technology for environment adaptable sensors and actuators that can flexibly sense, track, collect and process data, restore data and drive actuators in response to changing conditions and various demands.

3.3.2. Network Technology to Handle the Quantitative Explosion

- **Targets to achieve**

Establish infrastructure technology for configuring global sensor actuator cloud that can sense and track sensor information generated by all existing persons, things and living environments, and if necessary can collect and process data and transmit the decisions to drive actuators.

- **Significance of achieving targets**

If it is possible to configure a sensor actuator cloud that can respond to a flow at the level of 10 trillion/year of things on a global scale, then all foods on the table can be tracked, food resource distribution can be managed, and food security can be ensured. Moreover, if these systems are achieved at the body cell level and applied to health care, sensors in the body and in medical institutes will always be connected, and incidents that occur in the body will be reported and stored in the medical institute and it will be possible to inform about the detection of abnormalities and countermeasures and to execute treatments using body micro machines. If we consider the future aging society where not everyone enjoys perfect health and people commonly spend many years with some illness, these technologies will enable them to have a social life with high quality of life at minimum medical expense and minimum visits to hospitals. With network virtualization technology, it will be possible to construct super large scale global cloud networks having a global spread and vast number of nodes, by making clouds of sensors and actuators that will span multiple different carriers.

- **Target enabling technologies**

[1] Sensor and actuator node technology

Various function performances are required for sensor, actuator and node hardware, as there are diverse existing environments. For instance, nodes that accompany the sensors that are incorporated in the body are implant type, and there are also various types that are power conserving, highly accurate, lightweight, etc., depending on the environment. Therefore, R&D shall be done on technology necessary for nodes that are placed in such limiting conditions.

[2] Sensor actuator cloud configuration and control technology

Scalable architecture is essential for networks that are used to administratively manage, from the body's internal micro machines, up to vast spaces of earth and space. Moreover, it is necessary to establish this technology through demonstration experiments.

When there are many end-to-end routes, and the temporal connectivity of some of these routes cannot be guaranteed, it is necessary to use a technology that is different from security technology with the typically single connections until now, in order have both efficient data transfer and stability of the data that passes through these routes.

[3] Cloud self-organizing technology

Sensors and actuators for fixed point observations and associated actions are installed in fixed places, and the networks for connecting these sensors and actuators are often explicitly assigned. However, if the sensors and actuators are mobile, there must be connectable network sensing in order to establish connections in the environment where these sensors and actuators exist. Wireless connections are generally used to connect mobile nodes and networks, thus the key issues are detection and establishment of connections for connectable wireless network resources.

Mobile sensors and actuators autonomously detect and connect to available networks, but they are sometimes completely disconnected, and connectivity cannot be guaranteed from the network. On the other hand, there are cases where two or more networks can be accessed when restarting the connection (for instance, many networks can be accessed at the moment of emerging from a tunnel). In this case, the environment is a multi-home and Delay Tolerant Network (DTN). The issue in this case is improving efficiency of data transfer.

- **Points of difference from existing networks**

Differences from existing technology are given below.

- Configuration of embedded system cloud on a global scale with overwhelming numbers of sensors and actuators
- Integrated control of sensors and actuators
- Feedback to users using actuators, and direct action on user or user environment
- Network self-organizing technology including up to actuators
- Multi-home DTN routing technology for sensors/actuators/cloud

3.3.3. Life-supporting Network Technology

- **Targets to achieve**

The objective is to establish an environment-adaptive sensor and actuator middleware infrastructure technology that can accommodate various types of sensors and actuators, and can sense and track attributes information and changes in the conditions of people, things, living space and environment, collect/process/recover data, and drive in real-time with adequate accuracy.

- **Significance of achieving targets**

- Achieve safety and security (food security, danger/abnormality detection) and context-aware society and environmental protection, by supporting and promoting significant interaction between people, things and living space/environment.

- Enable real-time collection through the network of vast amounts of primary data, such as tracking data on 10 trillion/year of foods distribution, bio monitoring information on the scale of 10 million users, in-vehicle sensor information of intersections with high traffic volume, etc. Process that data to extract environmental changes and knowledge.
- If necessary, enable notification of analysis results (dangers and abnormalities) to appropriate actuators and users in real-time.
- Make it unnecessary to adjust individual settings for sensing accuracy and driving accuracy for various sensing tracking targets and their changes, and with no special manual tuning of sensors and actuators for various demand conditions (terminal performance, individual context, privacy, plans).
- Make it easy to extract knowledge and anomalies from the collected primary data.

- **Target enabling technologies**

[1] Environment-adaptive sensing technology

Enable detection of the moment when the environment changes or when the degree of risk is amplified, and enable automatic setting of sensing and driving accuracies. Specifically, automatically learn the environment or individual user profile or context by mining the collected primary data, and automatically specify the settings of the sensors and actuators on the basis of that data. In addition, provide context information for in-network processing, and achieve actual global interaction based on the context, using actuators.

[2] In-network processing technology

Enable highly flexible reversible consolidating type in-network processing in real-time, by using data oriented network technology that gives high flexibility and scalability and dynamic data structure to sensor data. Execute demonstration experiments on large scale sensors/actuators/clouds.

[3] Wireless virtualization technology

Enable dynamic construction of multiple individual secure virtual networks on an on-demand basis depending on the objective, usage or individual context, and enable free definition of the data processing method for each virtual network. In addition, achieve small volume network virtualization for built-in devices, or super-parallel network virtualization for providing individual secure virtual networks on a scale of 10 million users.

- **Points of difference from existing networks / technologies**

- Environment-adaptive automatic settings technology for sensors and actuators
- Data processing technology for vast amount of primary sensor information for wired and

wireless integrated networks

- Data oriented network technology based on data semantics
- Instantaneous construction and control technology for large amount of secure private networks

3.3.4. Trends in Other Countries

General trends in sensor network R&D in Europe and the U.S. are given below.

- Europe and Japan have taken an overall lead in ubiquitous network technologies.
- US TinyOS/Mote has taken a lead in the development of wireless sensor network platforms.
- GENI in the U.S. and FIRE and SENSEI Projects in Europe FP7 have taken respective leads in R&D on wired/wireless integrated test beds including sensor networks. Standardization is also in view in Europe.
- Wireless sensor networks and wired/wireless integrated networks will be competitive areas.

3.3.5. Ambient/Ubiquitous Network R&D Promotion Policy

To develop an ambient/ubiquitous network, it is necessary to first of all establish a component technology and construct in parallel a large-scale wired/wireless integrated sensor/actuator test-bed in an environment that has a mixture of multiple users, and establish a chain of: development-demonstration-verification. Also, it is necessary to establish a verified sensor actuator API as the de facto standard. As a promotion strategy, it is necessary to build up know-how in cooperation with industry from an early stage, and to accelerate R&D by cooperating in innovation promotion measures while demonstrating applications and services.

3.4. Self-* Network R&D Strategy

3.4.1. Self-* Network: Issues and Solution Scenario

The network is being used for various applications like Web and email, and also to transmit sensor data and streaming data like voice and video. There is also rapid progress in diversification of services, such as offering applications and platforms through the network, called PaaS (Platform as a Service). On the other hand, though the accompanying conditions required for services are also diversifying, they are not fully satisfactory, and dramatic problems are foreseen. A network that everyone can use unburdened shall be achieved, which can respond flexibly to conditions requesting services.

In order to achieve a network society focusing on persons and services which are freed from network restrictions, the New-generation network which has the following three main functions shall be achieved.

[1] Diversity network

In order to operate so that the network can provide various types of services at the same time, it meets various demand conditions of the usage purpose of the network, and a network shall be achieved which can operate multiple types of networks at the same time.

[2] Network unification

In order to fulfill various conditions which network services demand, optical/electronic, wireless/ wired, and path/packet integration networks shall be achieved in which services can be enjoyed in the best environment without considering the complicated network.

[3] "OMOTENASHI" (hospitable) network

In order to enable network services that everyone can easily enjoy unburdened, a user friendly, simple and easily used network shall be achieved.

3.4.2. Diversity Network Technology

- **Targets to achieve**

Achieve multiple networks which can operate simultaneously without considering complex physical resources. Provide the best network environment for the change in necessary network and conditions (network topology, traffic, etc.). Achieve a highly adaptable network which enables highly flexible introduction of network technologies which are constantly advancing.

Significance of achieving targets

・Virtual networks of two or more different types in a physical network can be built by network virtualization, and the optimal network environment matching the characteristics of the network demanded can be provided. Various networks can coexist and operate simultaneously, for example networks with and without QoS (Quality of Service), and a network which has processing functions.

・The burdens of design, operation and management of networks can be decreased by reducing direct control of complicated physical resources, and by focusing on control and management of simple virtual networks.

・Functions and services necessary only during emergencies can be started and used in an appropriate place only during emergencies. Network environments matching dynamic changes in demand conditions can be offered.

・Verification of a new network function is possible in a different virtual network even during network service operation, and smooth shifting is possible to a new network which has the new function after verification.

● **Target enabling technologies**

[1] Virtualization of nodes and network resources

To provide virtual networks in multiple layers, technology for virtualization of nodes and network resources including processing functions, in multiple layers

[2] Virtual networks on physical networks

Technology for network construction, operation and management, in order to map virtual network resources to heterogeneous physical network resources, and build multiple virtual networks

[3] Adaptive custom network

Technology to launch dynamic functions using appropriate resources, to enable handling of dynamic changes in network composition and traffic, handling of dynamic addition of new functions, etc.

● **Points of difference with the existing network**

In existing networks, data transmission is mainly executed based on IP packets. On the other hand, customized network environments can be provided in the New-generation networks accommodating diversity, based on characteristics of the service or application, or specifications desired by the service provider and users. This feature differs from existing networks. A specific example of this difference is data transmission wherein the routing algorithm is different for each user.

3.4.3. Network Unification Technology

- **Targets to Achieve**

Architecture wherein data is transferred by a path network (connection type) and packet network (connectionless type) are integrated, which is achieved under conditions of data transmission by optical, wireless and electronic networks, along with dynamic arrangement control of resources. The integrated network provides optimal data transmissions for offered services and data flows.

- **Significance of achieving targets**

・ Data transmissions which are optimal for application demands at the time of contents transfer will be carried out automatically, by achieving an integrated network. For example, in ultra-high definition video, data would be transferred by a path network without packet loss, and in data transmission like the Web, data would be automatically transferred by a packet network wherein the circuit is shared at packet level with other users.

・ Traffic requiring QoS will be transmitted by a path network, thereby requiring no excessive traffic engineering, with balance maintained between network efficiency improvement and operation management load reduction, and reducing the network's operation management load.

・ Network services can be offered by reallocating autonomous resources during a large-scale disaster, by achieving a wide area integrated network that includes wireless communication using satellites and airships.

- **Target enabling technologies**

[1] Data transmission in unified path/packet network

Network architecture which unifies path/packet networks, and technology to achieve data transmission by route and transmission method according to the flow's characteristics

[2] Data transmission in wired/wireless unified network

Network architecture which unifies transmissions in rough and precise wireless networks and optical fiber networks, and technology to achieve data transmission by route and transmission method according to the flow's characteristics

[3] Network which unifies multiple aspects: optical/electronic/wireless and path/packet

Technology for operation, management and data transmission in unified network which integrates wired/wireless, optical/electronic and path/packet networks

- **Points of difference from existing networks**

Integrated networks where all factors like path/packet, optical/electronic, wired/wireless etc. are considered were not achieved in previous networks. On the other hand, an integrated network considering all these factors shall be in the New-generation network which achieves unification. This feature is a point of difference from existing networks. As a specific example of its difference, the data transmission procedure (i.e. optical path or optical packet) is selected automatically in conformance with the characteristics of data to be transferred.

3.4.4. "OMOTENASHI" (Hospitable) Network Technology

- **Target to achieve**

For using network services, complicated settings and control are necessary in the network or at the terminal, thus the benefits of network services cannot be easily received satisfactorily. Therefore, in R&D on the New-generation network, a network with which everyone can enjoy services shall be developed.

- **Significance of achieving target**

・Everyone, regardless of age and sex, can enjoy network services after being freed from the burden of complicated network settings, by achieving functions which automatically adjust network settings corresponding to the abilities of the network service user.

・More people will be able to enjoy network services, by achieving functions in which the intentions of the network user shall be recognized via various interfaces other than the keyboard, and are reflected in network control automatically.

・When a network problem occurs, by easily understood visualization of what problem occurred and how the problem can be solved, the network service can be enjoyed while improving service user abilities, along with better network service. Moreover, the network problem can be solved according to the user's intention by implementing problem-solving execution functions which recognize the user's intention.

・Enables control of private data diffusion without depending on user decisions, by achieving control architecture for user related data which is spread in the network.

- **Target enabling technologies**

[1] Automatic network configuration

Ease of use technology to enable unburdened use of unified network which integrates wired/wireless, optical/electronic and path/packet

[2] Network status visualization and autonomous networks

Technology for visualizing network status and various network problems, and for autonomous networks which optimally maintain the network while providing problem solutions corresponding to user intentions

[3] User data control network

Architecture which finds and manages network user's data, and technology which enables control of user data in the network, according to user desires

- **Points of difference from existing networks**

In previous networks, complicated settings were necessary to use network services. In the New-generation network where "OMOTENASHI" can be provided, network services can be used as easily as electricity by inserting the plug in an outlet, or like using water service by just twisting the faucet. This characteristic is one of differences from existing networks.

3.4.5. Trends in Other Countries

- **Europe and America actively engage in research on virtual networks:** In the U.S., research related to virtual networks is advancing on a large scale in PlanetLab (An open platform for developing, deploying, and accessing planetary-scale services) and GENI (Global Environment for Network Innovations). In Europe, research related to virtual networks is actively advancing in PlanetLab Europe, OneLab2 (An Open Federated Laboratory Supporting Network Research for the Future Internet) and FEDERICA (Federated E-infrastructure Dedicated to European Researchers Innovating in Computing network Architectures).

- **Europe (FP7) concentrates on federation network research:** Research on a large-scale federation network incorporating a satellite system network is advancing in the PII (Pan-European Laboratory Infrastructure Implementation), which is a European Union project.

- **United States (FIND) concentrates on future internet architecture research:** Various new networks are researched in FIND (Future Internet Design), which is a research fund program of the National Science Foundation (NSF).

- **Unified network research is a future competitive field:** Even in Europe and America, network technology integrating all factors (path/packet, optical/electronic, wireless/wired) will be a future competitive research field.

3.4.6. Self-* Network R&D Promotion Strategy

- **Strengthen development based optical/wireless technology:** Work to shorten development periods and further strengthen network related technology, by promoting R&D on the New-generation network, focusing on wireless technology and optical technology.

- **Strengthen competitiveness by early construction of a unified network testbed:** Construction of a unified network is a future competitive field. Quickly construct a testbed which can test unified large scale network operation, then first of all discover issues and countermeasures, and then develop a competitive New-generation network.

- **Strengthen differentiation by promoting integral technology improvements using the federation testbed:** For network integration management of various specifications, achieve clean slate network functions, by further improving integrated technologies.

- **Strengthen network operating technology by fostering operation managers through testbed management:** Quickly construct and operate a testbed adopting advanced network technologies, thereby fostering operation managers, and strengthening competitiveness in operation management aspects.

3.5. Sustainable Network R&D Strategy

3.5.1. Sustainable Network: Issues and Solution Scenario

Network services such as cellular phones, Internet, email, search engines, etc. have already become indispensable infrastructure for the modern society. These services have been achieved through synergistic effects of breakthrough innovative technologies, such as broadband communication technology typified by optical fibers, Internet, cellular phones, computer technology, etc. On the other hand, with the rapid innovation and spread of these services, this field is now facing many problems that can be called limits of the earth's capacity, and these problems are becoming the constraints for further development of the network society. Therefore, in the New-generation network, it is necessary to find methods for solving the global problems that surround networks and to achieve sustainability of the networking society and make further developments. Two leading issues are given below.

[1] Energy Problems

The power consumption of ICT already accounts for around 5.8% of Japan's total power consumption, and is expected to rise even further. This trend results from the increase in network traffic, due to the increase in users and the amount of data transmitted by each user. There has been a sharp increase in this network traffic in recent years, and recent surveys have forecast that traffic volume will reach 1000 to 100,000 times the current level in 15 years. Therefore, even greater increases in power consumption are inevitable if the present network technologies are used as is.

If we consider recent international trends in energy problems (i.e. CO_2 gas emission reduction), innovative technologies are required in NWGN in order to achieve continuous progress in the network society and increase the number of users including in developing countries.

[2] Spectrum resource problem

Demands to obtain new radio spectrum for new radio communication systems are growing, due to the rapid increase in the population using wireless communications, e.g. cellular phones, and faster transmission rate. Considering the growing demand for higher transmission rates and capacity for new types of applications on New-generation networks, such as ubiquitous communications and sensor networks, etc., a key issue is finding solutions with great technical breakthroughs for spectrum resource problems.

3.5.2. Green Network Technology

- **Target to achieve**

Dramatic improvement shall be achieved in energy efficiency of information transfer (target value established: 1000 times) in order to construct a sustainable network infrastructure.

The aim is to significantly improve the energy efficiency of the entire network/ICT, by even considering redesign of the network architecture, going beyond energy conservation of individual devices based on the present network architecture.

- **Significance of achieving target**

By seizing on the opportunity of putting the New-generation network to practical use, achieve a sustainable information society with network energy consumption at or even below current levels, with drastic technological developments centered on (1) Creation of an innovative network architecture oriented towards low power consumption, (2) Low power information distribution technology covering the entire ICT, (3) Visibility of energy consumption.

- **Target enabling technologies**

Activities for making individual devices with lower power consumption such as routers have already started. All these activities are based on the present network architecture, and reduction in power consumption is being achieved by improving the internal configuration, devices used, systems, etc. in each network device. However, a research project forecasted, that the amount of reduction in power consumption by those efforts will reach an upper limit of 10 times higher energy efficiency, which will fall far short of the target value of the New-generation network. Therefore, it will be necessary to handle this by going beyond the scope of the current network architecture.

Figure 3.5.1 shows the multilayer technology field that focuses on energy consumption. The lowest layer is the hardware level and lower order protocol level layer. This layer takes the lead in reducing the use of electric energy, by means of innovations in methods of configuring the functions of each equipment innovations in device technology, and by means of the sleep function when idle and reducing clock speed during low speed communication. There are also great expectations for reducing power by using photonic network technology. At layers 3 and 4, communication protocols can take into consideration the change of bandwidth or temporary disconnection due to sleep or power management of the device. The content distribution platform is a middleware layer that distributes information with energy optimization as the target function. For example, although the present content delivery network (CDN) method does not consider energy used, we could optimize the location of content to minimize the total power used by the network and servers. The last is application architecture. This field can also include redesign taking energy into consideration.

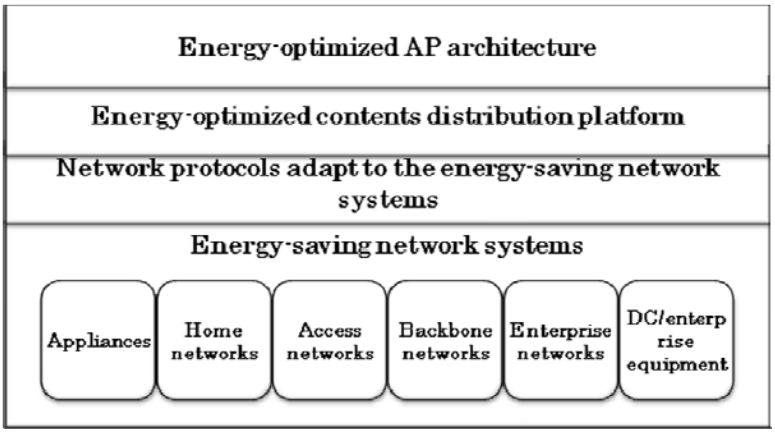

Figure 3.5.1 Multilayer Technology Area Focused on Energy Consumption

Areas of research that especially need focused R&D and each R&D roadmap are given below.

(1) Low-power oriented network architecture

Technology to create and verify new network architecture with lower power consumption information transfer as the primary objective.

(2) Total power-minimization in ICT overall

Technology to optimize mechanisms for allocation and transfer of distributed content in the network

(3) Low power consumption photonic network, optical access, wireless access

Technology for lower power consumption in network equipment.

(4) Technology for lower power consumption in home networks

Lower power consumption technology for in-home communication devices, which comprise a large share of power consumption today

(5) Protocols for low power consumption networks

Communication protocols to handle lower communication bandwidth and temporary appliance disconnection from the network due to sleep function, etc.

(6) Real-time measurement and methods to calculate power use in network and appliances

Technology for methods to calculate power amounts in network equipment and appliances, and real-time measurement and information distribution to give feedback

- **Points of difference from existing technologies**

As mentioned above, efforts for making low power consuming network equipment such as current routers, etc. have already started. However, it is calculated that the improvement will be limited to around 10 times the current efficiency. Therefore, if traffic volume grows by 1000 ~ 100,000 times at the time of NWGN, even more dramatic increases in electric power will be required.

Consequently, with the increasing traffic in the New-generation network, it will be necessary to at the least achieve networking at the same level as currently, or preferably with lower power consumption. To achieve this, it is necessary to go beyond the current approach and create a network architecture taking into consideration the reduction of energy consumption, and improve energy efficiency by 1000 ~ 100,000 times by making drastic approaches.

3.5.3. Spectrum Resource Usage Technologies

- **Target to achieve**

Develop various wireless usage technologies which achieve transfer of 100 times as much traffic as transferred today by radio spectrum.

- **Significance of achieving target**

It is forecast that the need for wireless communication will increase explosively with the increase in wireless communication users, switching of devices currently connected by cables to wireless systems, increased number of devices supporting new applications and devices supporting wireless technologies, etc. In order to successfully introduce new types of uses and application innovations to everyone in the New-generation network, connecting to the network shall be easy without requiring users' attention. From this viewpoint, it is inevitable that the first hop when the user (end node) connects to the network will be a wireless connection.

If the amount of traffic to be handled by the New-generation network increases to 1000 times the current amount, the traffic to be handled by wireless communication will naturally increase the same or even more. A wireless usage environment that fulfills these ever increasing communication needs will have to be provided.

- **Target enabling technologies**

To satisfy demands for both continually increasing communications capacity and high-speed communications, the following will be achieved:

(1) Develop technologies for using unused frequency bands such as the millimeter wave and terahertz wave bands,

(2) Improve utilization efficiency of spectrum currently in use,

(3) Develop technologies for dynamic reallocation of spectrum resources depending on the requirements of users' applications.

In the technologies for using unused frequency bands of (1), it will be necessary to enable use of frequencies that unused today. Therefore, device technologies to utilize millimeter wave or terahertz bands are required, and in addition it is necessary to find a way of effectively using such bands. For improving the efficiency of spectrum utilization of (2), spectrum utilization efficiency, for instance quantity of information transmission per 1Hz per unit area [bit/Hz/km^2], shall be improved by carrying forward R&D on spectrum sharing technologies such as cognitive wireless technology, etc.

Generally, actions such as using more effective modulation schemes, SDMA techniques with adaptive array antenna and MIMO, shortening reuse distances of the same frequency band by reducing cell size, etc. are considered for improving the efficiency of spectrum usage. But it may be difficult to provide mobility functions under these technologies requiring higher SNR, frequent inter-cell handover, or complex signal processing consuming more power. Consequently, in dynamic reallocation of resources of (3), it is necessary to balance the two conflicting needs by switching to the best strategy depends on the users' characteristics (high-efficiency, respond to movement, low power consumption, etc.). For example, it is good to allocate high frequency bands to users who are not moving. In decisions on selection of suitable communication media and parameters, "switching to wired links" can also be one possibility for users who do not require mobility. Therefore, it is believed that even if the total communication need (wireless and wired combined) is 1000 times the current level, the wireless usage rate can be held down to a certain degree by coordinating the usage of wired and wireless communications, and by applying various usage efficiency improvement technologies.

- **Points of difference from existing technologies**

Although the circumstances vary in each country, up to now, the organization that manages spectrum usage, e.g. the Ministry of Internal Affairs and Communications in Japan, generally makes a spectrum allocation plan. A fixed frequency is allotted for a specific wireless system, and gives usage rights to persons who fulfill the conditions as to provided communication method and power output, etc., thereby operating in such a way that there is logically no interference among different systems and their users. In the allocation scheme, it is not possible to expect efficient spectrum utilization in each band operated by different systems, and further, it is difficult to re-allocate frequencies to different systems following the changes of different systems after they are once allocated. These problematic conditions occurred not only due to spectrum management techniques, but also largely due to cost and technical constraints such as the necessity of altering hardware and systems.

When the technologies described in previous section will be available, first of all total quantity of usable bandwidth will be increased due to high-frequency bands, and with advancements in communication methods and signal processing technology, efficiency of spectrum utilization per frequency will also be increased. Therefore the amount of information that can be handled by wireless communication will be much larger than today. Moreover, it will be possible to dynamically reallocate spectrum resources to select a suitable frequency or communication system depending on the users' needs, conditions and QoS requirements.

3.5.4. Trends in Other Countries

[1] Energy problems

(1) Europe: Activities with major emphasis on green networks
(2) US: Launch of green technology strategy (Green New Deal Strategy) by the new administration
(3) Launch of "Focus Group on ICTs and Climate Change" in ITU, and full scale investigation

[2] Frequency resource problems

(1) Standardization and competition in practical use of cognitive wireless technology based on spectrum sharing (use of white space)
(2) Re-examination of spectrum management techniques, taking into consideration spectrum sharing

3.5.5. Sustainable Network R&D Promotion Policy

[1] Energy problems

(1) Major emphasis on R&D for low power consumption technologies, and commitment of funds
(2) International standardization strategy considering the industry

[2] Frequency resource problems

(1) Promotion of spectrum sharing technology trials (experiments) in specific areas
(2) Development and promotion of spectrum efficiency improvement technologies, and in conjunction with this accelerate the development of FMC technology to enable end-to-end quality assurance

3.6. New-generation network Fundamentals R&D Strategies

3.6.1. New-generation network Fundamentals: Issues and Solution Scenario

Each of the "five targets" presented in the preceding sections is demanded for the New-generation network. Those five targets indicate the most important features expected in the New-generation network. The "New-generation network Fundamentals" discussed in this section also signify the features of the New-generation network, and are in response to essential requirements faced in the new generation. However, rather than discussing individual specific technological requirements to achieve, this area, the New-generation network Fundamentals, aims to adapt to the essential trends expected in the period of the new generation, and for stronger medium and long-term R&D competitiveness, strengthen basic research, pioneer emergent research areas, etc. In addition, there are important fundamental issues common to the "five targets"; this section also tries to more clearly characterize those commonly important fundamental matters in the New-generation network. In this section, we first introduce the background and positioning of the "New-generation network Fundamentals" by considering the following three aspects.

The first is that the technological challenges posed on the New-generation network, have scales and properties that quantitatively and qualitatively far exceed those handled in conventional networks. The scale, complexity, and diversification of networks are significantly greater, and the functionalities and performances expected in networks highly complex. It is extremely difficult to solve these challenges by classical theoretical methodologies for networks. Therefore, it is necessary to establish novel network architecture fundamentals that can cope with the requirements posed in the New-generation network.

The second is that the network will have vast impacts on people and society; the New-generation network will not just link persons and things. It is expected to offer various emergent values for people and society. We have to be aware that societal and industrial structural changes have been moving towards the so-called knowledge-society. Particularly in developed countries, industrial competitiveness and the source of added-value has shifted to knowledge. The network must deal with highly abstract attributes such as knowledge and value. Those attributes expected in networks need fundamentals that include aspects of, for instance, social sciences, economics, neuroscience, and so forth, which have conventionally been considered outside the scope of network technologies. In other words, here we need to strengthen the knowledge-society network fundamentals.

The third is related to physical aspects of networks. As pointed out in "Sustainable network" of the "five targets", power conservation is one of the most important requirements for the New-generation network. Here, the physical attribute of energy is a task immediately faced by the network. Other than the energy, tough technological challenges exist at physical levels, such as technologies to expand available communications frequencies, innovative physical layer principles enabling trustable networks, innovative physical layer technologies required for network unification, and so forth. Furthermore, as typically observed in sensor networks, the diversity of physical phenomena occurring in the real world, that is, the effects and facts originating from uncertainty in the physical world, is a source of added-value for network systems. Also, remarkable innovations have been developed in physical sciences and technologies in electronics, photonics, materials and devices sciences and technologies, etc. It is necessary to take those innovations as principles by which novel system functionalities in the network are achieved. In other words, it is important to strengthen fundamental areas that are based on both the physical aspects and various functional viewpoints of the New-generation network; namely, New-generation network physical architecture fundamentals are required.

3.6.2. Network Architecture Fundamentals

- **Targets to achieve**

The most significant attributes in the era of the new-generation of network include the vast scale and complexity of networks. However, it is difficult for traditional network fundamentals to solve quantitative challenges such as the scale and complexity, and to resolve the qualitative requirements posed in the networks. That is, new fundamentals are indispensable which overcome the limitations of classical methodologies, and enables coping with various new situations and demands in the New-generation network.

The network architecture fundamentals should be developed so that we can cope with the attributes and situations in the New-generation network; for example, super-large scale complexity and diversification should be resolved, and it also should handle various performance measures expected in the New-generation network.

- **Significance of achieving targets**

▪ The theoretical basis for the New-generation network will be developed for the first time. Attributes and situations of the New-generation network shall be generally characterized, and a theoretical basis shall be offered to design and operate the networks.

▪ New control principles such as an autonomous decentralized mechanism or a self-organizing mechanism are indispensable in coping with the network's large-scale complexity. Their fundamentals shall be developed in universal forms. Moreover, basic theory shall be developed for stable operation of networks even when they include imperfect elements.

▪ New performance evaluation fundamentals shall be developed, and a theoretical basis shall be developed by which various complicated demands and conditions can be evaluated.

- **Target enabling technologies**

[1] Network architecture fundamentals

[2] Network performance evaluation fundamentals

3.6.3. Knowledge-Society Network Fundamentals

- **Targets to achieve**

Value creation of people and society is important in the New-generation network. This is also emphasized repeatedly within the "five targets", particularly with the "value creation network" and the "ambient/ubiquitous network". In achieving those targets, we have to consider highly abstract and value-related matters such as creativity of people and society. In other words, the network performs not only conventional communications roles, namely, connecting logically and physically persons and things, but also creates and provides emergent values by incorporating knowledge in people, environment, and society. Thus the network has an inseparable relationship, on a fundamental level, with perspectives of human sciences, social sciences, economics, neuroscience, and so forth. Its scope would include the behavior and emotions of people, implicit knowledge in the environment and society, etc. In other words, knowledge-society network fundamentals are required.

- **Significance of achieving targets**

  - Contribute to value creation and a knowledge-society
  - Fundamentals for service science and advanced service creation
  - Fundamentals for creating new value wherein regional characteristics, history and culture are reflected.

- **Target enabling technologies**

[1] Network fundamentals for a knowledge-society

[2] Network fundamentals for supporting people

3.6.4. Network Physical Architecture Fundamentals

- **Targets to achieve**

Some of the most important challenges in the New-generation network include physical issues. A typical example is creating energy-saving networks for the "Sustainable network" which is one of the "five targets". There are also other important technological challenges wherein innovations of enabling technologies in physical aspects or in physical layers are indispensable, such as in pioneering available frequency resources for communications, basic physical technologies for trustable networks, network unification, etc. In other words, innovation is demanded in physical aspects of the New-generation network. Japan's material and devices technologies are globally competitive, while Japan's industrial competitiveness at the systems level is severely low. Thus, it would be very important strategically for Japan to adopt advantages in cutting-edge physical layer technologies to boost its abilities in producing competitive, world-leading functional systems. At the same time, it is difficult to anticipate what technological innovations will occur in physical principles and enabling technologies in cutting-edge material and devices sciences, and technologies in the fields of, for instance, electronics, photonics, materials, nanotechnologies, or biology, by the time of the New-generation network. What is strategically important is to seek and exploit beneficial aspects in innovative sciences and technologies for the New-generation network.

- **Significance of achieving targets**
  - Competiveness by harmonizing physical layers and functional layers
  - Creating value by applying cutting-edge innovations in physical properties, materials, and devices to networks
  - Fundamentals to handle uncertainties in the physical world

- **Target enabling technologies**

[1] Harmonize cutting edge physical layer technologies with functional systems

[2] New ICT physical principles for novel network applications

3.6.5. Trends in Other Countries

Regarding fundamental aspects in network architectures, large-scale increased complexity is widely recognized as one important research agenda. Many approaches have been explored intensively, such as based on self-organization and autonomous operation. In addition, network science is attracting attention with, for instance, deeper insights into emergent attributes in the network. There is also active interdisciplinary research between networking and related areas; for example international conferences such as NetSci [3-6-1] are being organized.

In fundamental areas related to the knowledge-society, there is an intense competition in R&D for creating emergent value; the emergence of service science and IBM's radical transition into services businesses are examples of the significance of the trend towards a knowledge-society. Regarding investigations from societal, economical, and human sciences, one widely known project is PARADISO, which is an FP7 project in Europe. PARADISO tries to incorporate findings from a wide range of areas from all over the world [3-6-2].

Regarding physical architecture, we have to be aware of strategic trends in recent global-scale digital information technology businesses and rapid technological innovations in cutting-edge devices. In fact, a single company dominates globally the market of, for instance, microprocessors and core network systems. This is based on the strategy of open interfaces while closing the internal systems or preserving the rights to control the core protocols [3-6-3]. This suggests that it is critically important to find where the added-value exists in the chain or hierarchy ranging from materials to services. Remarkable advances are being made in physical sciences and technologies, including electronics, photonics and materials. Europe and America are traditionally active in exploiting these advances in systems and architectures [3-6-4, 3-6-5].

3.6.6. New-generation network Fundamentals R&D Promotion Strategies

(1) Foster Network Infrastructure Architect Talent and Publicize in the World

As for strengthening network fundamentals, it is important to acquire and foster excellent talented people who can exercise and lead advanced discussions in basic architectures. The New-generation network would be a good chance for Japan to recover in fundamental architectures, in which leading positions have recently been dominated by western countries. It is important to foster excellent talent and publicize their research to boost their presence in the world.

Specific methods on how to accomplish these tasks should be studied further. They should take into account strategies including (1) Promote many new ideas, and purify competitive and high-quality ones in global competition, (2) Strengthen competiveness by a coordinated system towards global cooperation even from the early stages of research, (3) Foster world-class human resources based on projects.

(2) Promotion Scheme for Multidisciplinary Research

Cooperation and coordination between different research areas is indispensable for promoting knowledge-society network fundamentals and network physical architecture fundamentals. To that end, it is important to develop an environment enabling liaison, cooperation and coordination between researchers and developers.

Such R&D schemes partially have been observed in frameworks such as the Center-of-Excellence (COE) programs. By analyzing the potential issues in those schemes, the design of concrete programs for the New-generation network is a future task. There are also emerging activities in academia, such as “service computing” in computer- and software-related fields. While trying to combine network- and communication-related fields with service computing field as the first step, we need to investigate how to realize active and fruitful collaboration among network, societal, economic, and human sciences.

(3) Strategic Strengthening in Fundamental Fields

In the fundamentals for network physical architecture, the recognition of open standardization is particularly important while preserving competitiveness in internal systems. We have to be aware of those matters in transforming cutting-edge physical enabling technologies to added-value in the network. Such recognition would also be important in deciding the direction of R&D in future and emergent technologies.

With fundamental technologies which are difficult to easily imitate as the source of competitiveness, we have to build an open business environment for broad utilization by competing players, with practical application and commercialization of systems, including peripheral technologies. We also have to design strategies concerning the entire technology lifecycle, including how to achieve and maintain leadership in technology and the market.

[Bibliography]

[3-6-1] International Workshop and Conference on Network Science
http://www.ifr.ac.uk/netsci08/

[3-6-2] PARADISO
http://www.paradiso-fp7.eu/

[3-6-3] Koichi OGAWA, "Standardization and Business Strategy as New Japanese Innovation"
O plus E, April 2008 edition

[3-6-4] Nanoelectronic Devices for Defense & Security Conference
http://www.nano-dds.com/

[3-6-5] International Nanotechnology Conference on Communications and Cooperation
http://www.inc-conf.net/

4. Summary

This report defined five network targets of the New-generation network and New-generation network fundamentals which are the common technology infrastructure for these targets form technology requirements for the New-generation networks that derived from three New-generation network visions. Further, this report derived elemental technologies that comprise each network target and technological infrastructure, and the development items for these respective technologies were sorted out.

This report presented a technology strategy, aims to define the innovative network required after 15 to 20 years and propose the execution of its research & development. However, execution of this strategy requires planning and execution of strategies including testbed strategy/technology transfer strategy, R&D funding strategy, standardization strategy/ internationalization strategy, human resources development strategy, and technology innovation strategy. Therefore, we have already started such planning. Especially in R&D on network technologies for the new generation, both deskwork investigations and testbed demonstrations are necessary, and its investigation is proceeding towards building the testbed strategy.