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Japan's New Generation Network

– beyond next generation network

Andreas Göthenberg

This study has been supported by Vinnova

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Abbreviations

ANI	Application to Network Interface
ARPANET	Advanced Research Projects Agency Network
B2B	Business to Business
B2C	Business to Customer
CATV	Cable TV
DoS	Denial of Service
DSL	Digital Subscriber Line
FGCS	Fifth Generation Computer Systems
FIND	Future Internet Design
FMC	Fixed Mobile Convergence
FP7	Seventh Framework Programme
FTTH	Fiber to the Home
FWA	Fixed Wireless Access
GENI	Global Environment for Network Innovations
HDTV	High Definition TV
IEEE	Institute of Electrical and Electronics Engineers, Inc.
IMS	IP Multimedia Subsystem
IP	Internet Protocol
IPSec	Internet Protocol Security
IP-TV	Internet Protocol TV
IPv4	Internet Protocol version 4
IPv6	Internet Protocol version 6
ISP	Internet Service Provider
ITU-T	International Telecommunication Union, Telecommunication Standardization Sector
JGN	Japan Gigabit Network
KTH	Royal Institute of Technology
METI	Ministry of Economy, Trade and Industry
MIC	Ministry of Internal Affairs and Communications
MPLS	Multiprotocol Label Switching
NEDO	New Energy and Industrial Technology Development Organization
NGI	Next Generation Internet

NGN	Next Generation Network
NICT	National Institute of Information and Communications Technology
NNI	Network to Network Interface
NPN	New Paradigm Network
NSF	National Science Foundation
NTT	Nippon Telephone and Telegraph Corp.
NW	Network
NWGN	New Generation Network
NXGN	Next Generation Network
O-E-O	Optical-to-Electrical-to-Optical
P2P	Peer to Peer
PDMA	Packet Division Multiple Access
QoS	Quality of Service
RFID	Radio Frequency Identification
S2M	Satellite to Mobile
SDTV	Standard Definition TV
TCP	Transmission Control Protocol
u-Japan	Ubiquitous Japan
UNI	User to Network Interface
UNS	Ubiquitous Network Society
VINNOVA	Swedish Governmental Agency for Innovation Systems
WWW	World Wide Web

Summary

New Generation Network – Japan's future Internet.

This report is based on interviews in Japan with MIC (Ministry of Internal Affairs and Communications), NICT (National Institute of Information and Communications Technology) and NTT (Nippon Telephone and Telegraph Corp.) during October 2008 and published material in the field, see references.

The study has been funded by VINNOVA.

In late spring 2008, the number of FTTH (Fiber to the Home) subscribers became greater than the number of DSL subscribers in Japan. The number of FTTH users is more than 13 million today and are expected to be 30 million by 2010, which is more than 50 per cent of the Japanese households. In year 2020 the Internet traffic is expected to be 1 000 times larger than today. That implies for instance that the switch capacity is expected to be in the range of a few Pbit/s, the link speed over the core network in the range of 10 Tbit/s and the access network about 10 Gbit/s.

Next Generation Network (NGN, NXGN) service has been launched in Japan during 2008. NXGN is based on the IP network and is often characterized with the transition from IPv4 to IPv6. The transition to IPv6 means in practice that the number of IP addresses is drastically increased. However, there is an increasing level of concern and discussion in the networking research community as to how long it will be possible to do incremental changes and extensions to the IP-based network of today. It has become increasingly difficult to deal with the complexity of the Internet and it is suggested that it will ultimately reach a point where the maintenance and error recovery will be exceedingly difficult. Another issue is the future power consumption of Internet routers for example, which must be solved. It is argued that with current technology development an average ISP (Internet Service Provider) will consume the power equal to one power plant in the 2020's.

Japan is aiming to create a ubiquitous network society, u-Japan, to solve societal and economic challenges, but also to strengthen the international competitiveness of the Japanese IT industry. In addition to u-Japan, MIC has also launched a strategy for necessary R&D activities. The strategy is called UNS, Ubiquitous Network Society, which consists of three areas: Universal Communications, New Generation Network, and Safety and Security.

MIC presented in August 2007 that Japan is aiming for a New Generation Network (NWGN) that will replace today's Internet. It should be able to handle the requirements set forth by the society in year 2020 in terms of communication speed, capacity and security. The development of NWGN and coordination between industry, academia and government has been assigned to NICT, which has the central role within NWGN. NICT created the NWGN Promotion Forum during fall 2007. In the previous year, it had also launched the AKARI project, which encompasses NICT's R&D activities on NWGN. MIC is expecting Japan to become a leader in post-Internet technology and in creating global standards. NICT has created the NWGN Strategic Headquarters for this purpose. The core consists of the AKARI project and the testbed network JGN2plus.

NWGN is supposed to be different from NXGN and today's Internet, which implies introduction of post-IP protocol or dramatic changes to the current IP protocol. The term

clean slate network architecture is frequently used by both NICT and NTT. The intention is to create a new network architecture free from today's IP-based network. Although NWGN in Japan is still at an early stage, mainly in a study phase, the AKARI team has produced an extensive document describing the conceptual design. It unfolds NWGN from several view points: switching and transmission capacity, power consumption, ubiquity, mobility support, connectivity for versatile appliances, security, reliability and social safety. NWGN has been divided into four study items: application layer, overlay network, network (IP+ α or post-IP) and underlay network. The latter comprises photonic, mobile, sensor networks, etc.

It should be noted that NWGN has a Green IT aspect. When it comes to Green IT in Japan, METI (Ministry of Economy, Trade and Industry) has launched the Green IT project during the last year. It covers data centers, displays, routers and servers, while MIC covers the power consumption of the actual network with NICT's research on NWGN.

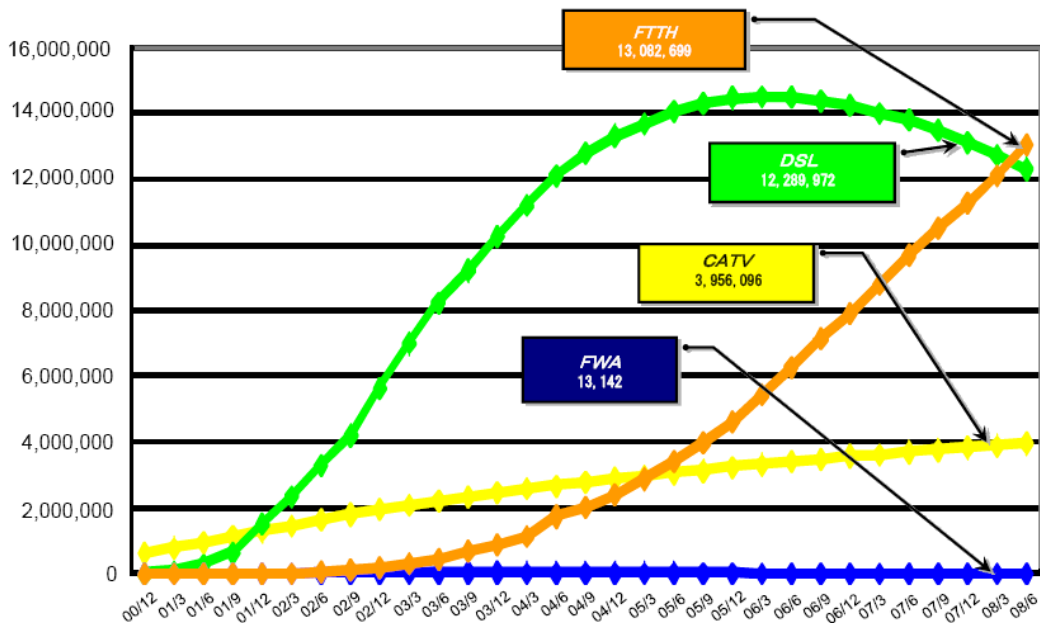
There are other activities similar to NWGN that has recently started in other parts of the world. The National Science Foundation (NSF) in the USA is supporting the GENI and FIND projects. In the EU there are related projects in FP7. Japan's advanced infrastructure for communication and high speed Internet, could give Japan advantages to other countries regarding the development of NWGN. NICT is in a rather unique position internationally since it is a research funding organization with its own research laboratory. This combined with Japan's leading position within several technology areas related to NWGN are tools that can make Japan a future leader in terms of creating future services and applications, as well as strengthening its IT industry globally.

Both NICT and NTT are very positive to a potential cooperation with Sweden in the field of NWGN. NICT and NTT have previously collaborated with KTH regarding a field trial of 4k digital video transmission from Japan to Sweden. The area of mobile/wireless network for future Internet has also been mentioned as a potential area for future bilateral cooperation.

1 Introduction

In late spring of 2008, the number of FTTH service contracts in Japan exceeded the number of DSL and reached 13 million. The number is expected to reach 30 million by 2010, which is more than 50 per cent of the Japanese households. The growth of FTTH also implies that the number of DSL contracts has been declining since 2006 (Figure 1). Furthermore, the estimated volume of data traffic on the Internet today is around 1Tbit/s in Japan alone. That is 1 000 times increase over the past 10 years. In the year 2020, it is expected to have increased another 1 000 times compared to today. Here it is noteworthy to remember that the origin of the Internet goes back almost 40 years to ARPANET and the transmission control protocol (TCP, which was published in IEEE Transactions on Communications in 1974). TCP was then separated into an internet layer protocol and a transport layer protocol in 1978. At that time nobody could probably have foreseen the enormous impact that ARPANET and TCP/IP have had on our lives and society. In the early seventies security and QoS (quality of service) were not even considered. Along with the introduction of new applications and the explosion of data transmission, several extensions and modifications have been made to the original TCP/IP in order to accommodate new requirements. However, since 2000 there has been an increasing level of concern and discussion in the networking research community as to how long it will be possible to do incremental changes to this patchwork. The perception is also that it has become increasingly difficult to deal with the complexity of the Internet and that it will ultimately reach a point where the maintenance and error recovery will be exceedingly difficult. Another quantitative argument is the limitation of today's Internet regarding the enormous power consumption of Internet routers in the future.

Figure 1 Number of broadband users.



Source: MIC.

1.1 Next Generation Network

The standardization body ITU-T is establishing standards for Next Generation Network (NGN), which is currently in a deployment phase. In fact, during 2008 NGN service has been launched commercially in Japan by NTT. It is based on the IP network and is often characterized with the transition from IPv4 to IPv6. In this report the term NXGN will be used onwards for Next Generation Network in order to avoid ambiguity. This term is used by NICT.

The Internet is based on a best effort bearer function to interconnect multiple router based networks. This means that no overall network planning and no clear responsibility and control rule exist among networks. TCP/IP protocol is the only common rule and users have the freedom to install any applications. On the contrary, NXGN is regarded as an effort to re-establish QoS controlled bearer functions to interconnect multiple networks with clear responsibility, meaning: IP based network with network control functions and with clear responsibility for the control, QoS control and security functions installed, and maintaining the connection function of the Internet (Figure 2). Basically, the goals of NXGN are fourfold:

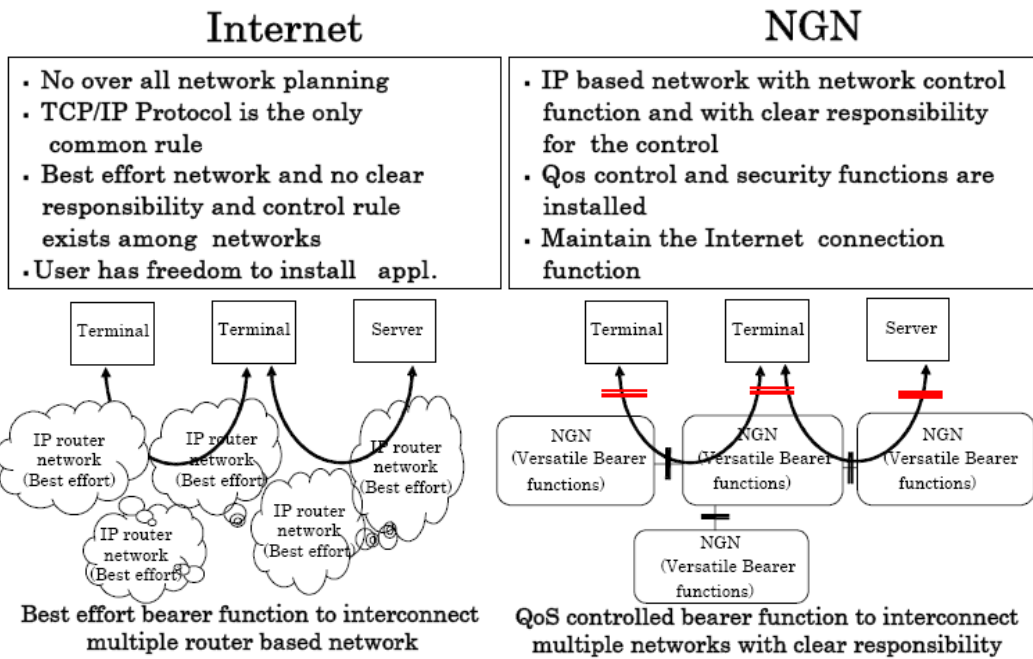
1. Replace legacy telephone networks with state-of-the-art IP-based networks.
2. Integrate various services over IP networks, such as triple-play services of voice, data and video, and quadruple play services adding cellular phone services to triple-play.
3. Solve the issues that the Internet is facing, namely: application-oriented QoS control, mobility support for FMC (Fixed Mobile Convergence), security weakness, etc.
4. Maintain safety and reliability at the level of telephone services to meet the requirements for the social infrastructure.

1.2 u-Japan

In order to solve the societal and economic challenges that Japan is facing, due to an ageing population and increased international competition from China and South Korea especially regarding the IT-industry, Japan has launched a strategy to create a ubiquitous network society: u-Japan. The goal of u-Japan is to create a society by 2010 where IT plays an integral part, interconnecting everything and everyone seamlessly, everywhere and always. The Japanese Ministry of Internal Affairs and Communications (MIC) has in connection with their u-Japan strategy also launched a strategy for necessary R&D activities, which is called UNS, Ubiquitous Network Society. It stands on three pillars: Universal Communications, New Generation Network, and Safety and Security. The main focus of this report addresses the second pillar, New Generation Network, which also involves the concept of ubiquity.

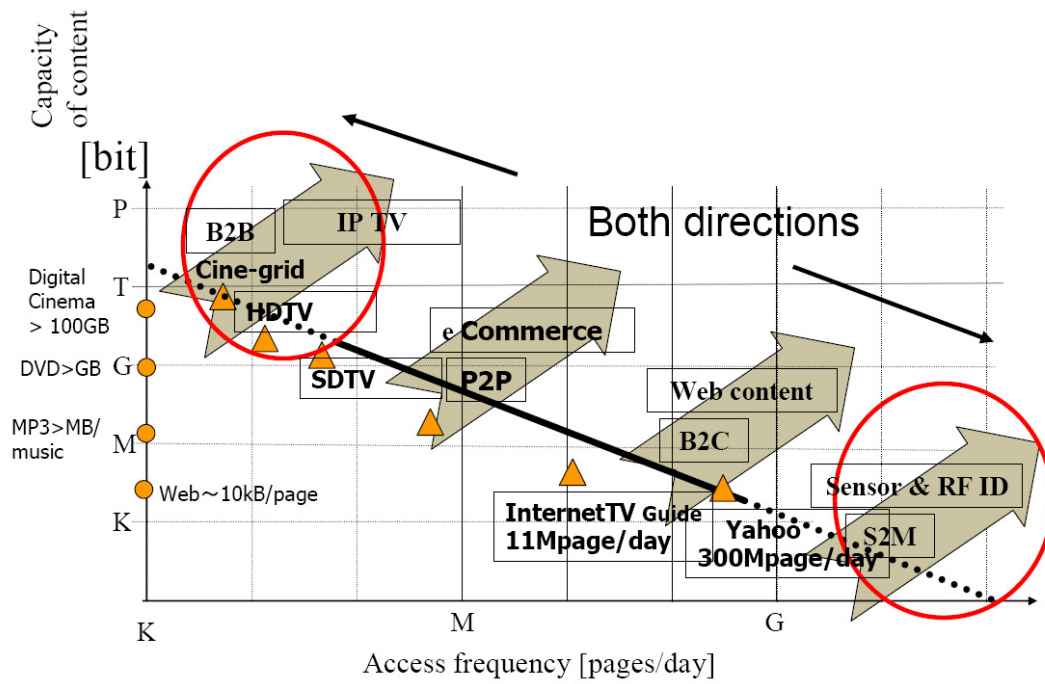
In the ubiquitous network society that Japan foresees there will be a huge number of sensors and appliances surrounding us. All of these devices will transfer content in various ways, from tiny sensors sending small amount of data very frequently to applications transmitting and receiving massive amount of data. An example is IP-TV, where large volume of data is accessed occasionally and another example is small RFID tags that only transmit small amount of data, but much more frequently (Figure 3).

Figure 2 Internet vs. NGN (i.e. NXGN)



Source: Aoyama, NICT

Figure 3 Contents in the ubiquitous society.

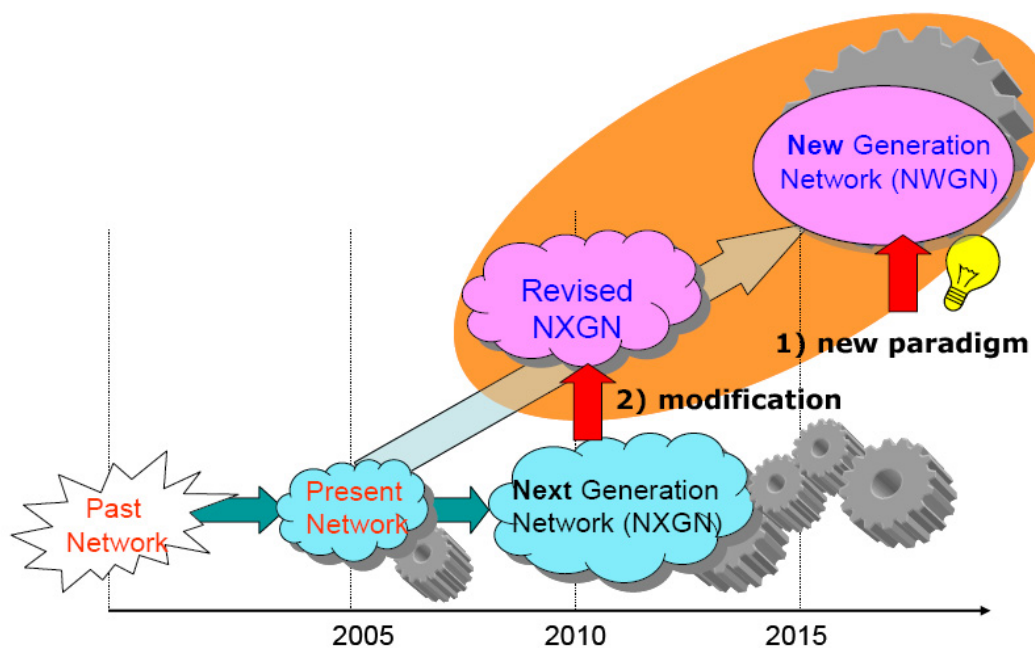


Source: NICT.

2 New Generation Network

On August 19, 2007, MIC (Ministry of Internal Affairs and Communications) announced that Japan is aiming for a new generation network that will replace today's Internet. It should be able to handle the requirements set by the society in 2020 in terms of communication speed, capacity and security. The New Generation Network is abbreviated NWGN and the term is used by NICT to distinguish it from NXGN. NWGN should also be distinguished from the term Next Generation Internet (NGI), which often refers to the migration from IPv4 to IPv6. NXGN, as mentioned in previous chapter, is considered as a replacement of legacy telephone network using IP-based networks, while NWGN is being proposed as a clean slate network architecture with main protocols that may not be IP-based (Figure 4). In Japan there is a clear difference between NWGN and NXGN. There seems to be a strong argument for a clean slate network that is not constrained by the IP-based network. As mentioned in the introduction, today's Internet has become very complex partly due to the patchwork of extensions and changes that have been introduced to accommodate all the traffic and applications that the IP based network were never intended for, not to mention the future requirements. Adding more functions is already troublesome and it is difficult to ensure reliability for the entire complex system. The advocates of a clean slate network architecture argue that compatibility issues with the current IP based network ought to be looked at only after the new network has been designed. Further, NWGN is targeted for a range of appliances, including ubiquitous appliances that will exist in the 2020's. It is intended to be designed flexible enough so that it can develop continuously over 50 to 100 years. The differences between NXGN and NWGN are described in the following table.

Figure 4 Positioning of NXGN and NWGN.



Source: NICT.

Attribute	Next Generation Network	New Generation Network
Assumed implementation time	By 2010	2015 or later
Creation method	Add QoS and authentication to existing IP	Create new network without being committed to IP
Trunk line capacity	O-E-O conversion: Less than Pbit/s capacity	All-Optical: Greater than Pbit/s capacity
Assumed terminals and applications	Integration and creation of advanced versions of existing terminals and applications such as triple- or quadruple-play services	Unknown but highly diverse ranging from devices acting in conjunction with massive information servers to tiny communication devices such as sensors
Power consumption	Power consumption at several megawatts (transformer substation scale)	Power conservation by a factor of at least 1/100 according to multi-wavelength optical switching
Security	Successive violations of principles such as firewalls, IPSec, and IP trace back	Control spam or DoS attacks by address tracing and end-to-end and inter-network security
Robustness	Supported by enhancement of management function by businesses	Robustness is provided by the network itself
Routing control	Distributed centralized control following IP, MPLS required for high-speed rerouting, long fault detection time	Introduction of complete distributed control, increase in failure-resistance and adaptability, inclusion of sensor nets or ad-hoc nets
Relationship between users and the network	Although there are some constraints on openness stipulated by UNI, ANI, and NNI, reliability is increased	Provides openness from a neutral standpoint, and users can bring new services
Quality assurance	Priority control for each class by using IP	Quality assurance that includes bandwidth for each flow using packet switching or paths appropriately
Layer configuration	Thick layer structure	Layer degeneracy and cross-layer control centered around a thin common layer
Integration model	Vertical integration orientation	Vertical or horizontal integration possible
Basic principles	Set from a business standpoint while using IP	Set from a clean slate to match future requirements
Sustainable evolution	Has limitations due to IP	Has sustainable evolution capability that can adapt to a changing society
Access speed for each user	Up to 1 Gbit/s	Over 10 Gbit/s
Wired-wireless convergence	IMS	Context aware
Mobile	(Under investigation)	ID locator separation
Number of terminals	Up to 10 billion	Over 100 billion

The development of NWGN and the coordination between industry, academia, and government have been assigned to the National Institute of Information and Communications Technology (NICT). It is a national research institute in the information and communications field that conducts its own technical research and contributes to national policies in the field. Thus, NICT has the central role regarding NWGN in Japan. It is also coordinating with similar efforts in the U.S., Europe, and elsewhere (2.6). Moreover, NICT has created the NWGN Promotion Forum in the second half of 2007. The forum has more than 250 members today, representing Japanese industry, academia, and government. Already in 2006, NICT launched the AKARI project (2.1), which encompasses NICT's R&D activities on NWGN. MIC is expecting that Japan becomes a leader in post-Internet technology and creates global standards. NICT has created the NWGN Strategic Headquarters in order to meet MIC's expectations. The core of the headquarters consists of the AKARI project as well as the test network JGN2plus (2.3).

The NWGN headquarters has announced a vision for NWGN that addresses five challenges: value creation, heterogeneity, energy, autonomicity, and complexity.

There are three major projects for funding the NWGN R&D activities in academia, industry and at NICT. The projects are: Ubiquitous Networking Platform, Photonic Network Technology and NWGN Technology. The budget for these projects in 2008 is 1.5 billion yen (about 130 million SEK)¹, 3.6 billion yen (320 million SEK)¹ and 2.1 billion yen (190 million SEK)¹, respectively.

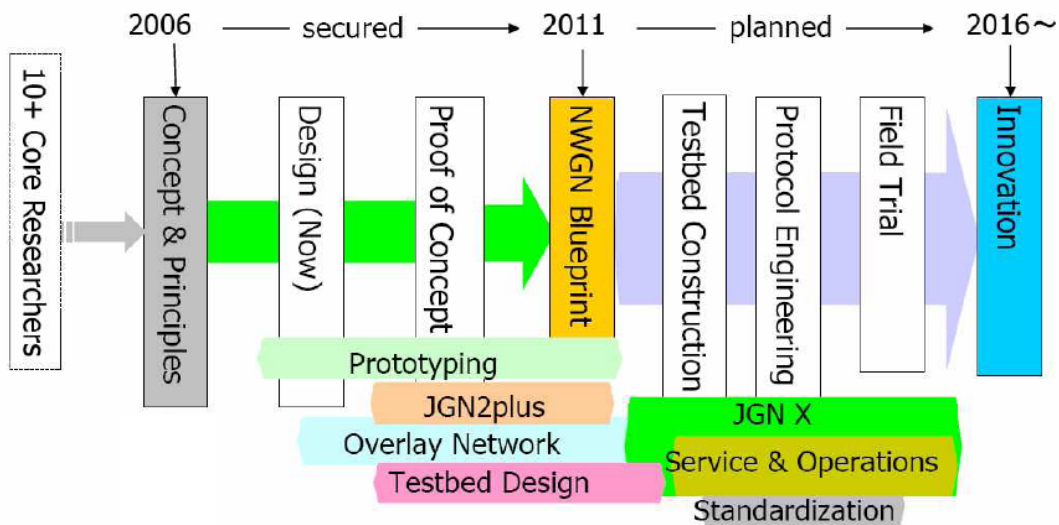
2.1 AKARI project

The primary goal of the AKARI project is to design a network for the future. It aims to build technologies for NWGN by 2015, developing a network architecture and creating a network design based on that architecture (Figure 5). The philosophy is to pursue an ideal solution by researching new network architectures without being impeded by existing constraints. The AKARI project, which started in 2006, consists of researchers at NICT and professors from academia. An AKARI workshop is held annually to disseminate and discuss the progress of the project.

NWGN is considered to become an evolution of NXGN and today's Internet. It means introduction of post-IP protocol or drastic changes to IP. In the AKARI project there is an emphasis on a clean slate design for the NWGN network architecture, different from today's IP based network. NICT has made an impressive start and produced a very extensive conceptual paper of the AKARI project, which has been updated from the previous year and is currently around 250 pages long. It describes a broad range of component technologies, anticipated needs and related design requirements to handle the forecasted network traffic. It discusses candidate network components, such as optical processing, radio access networks, algorithms for transport, addressing, routing, security and QoS.

¹ As per exchange rate of Dec 2008.

Figure 5 Time plan for the AKARI project.



Source: NICT.

2.1.1 Challenges

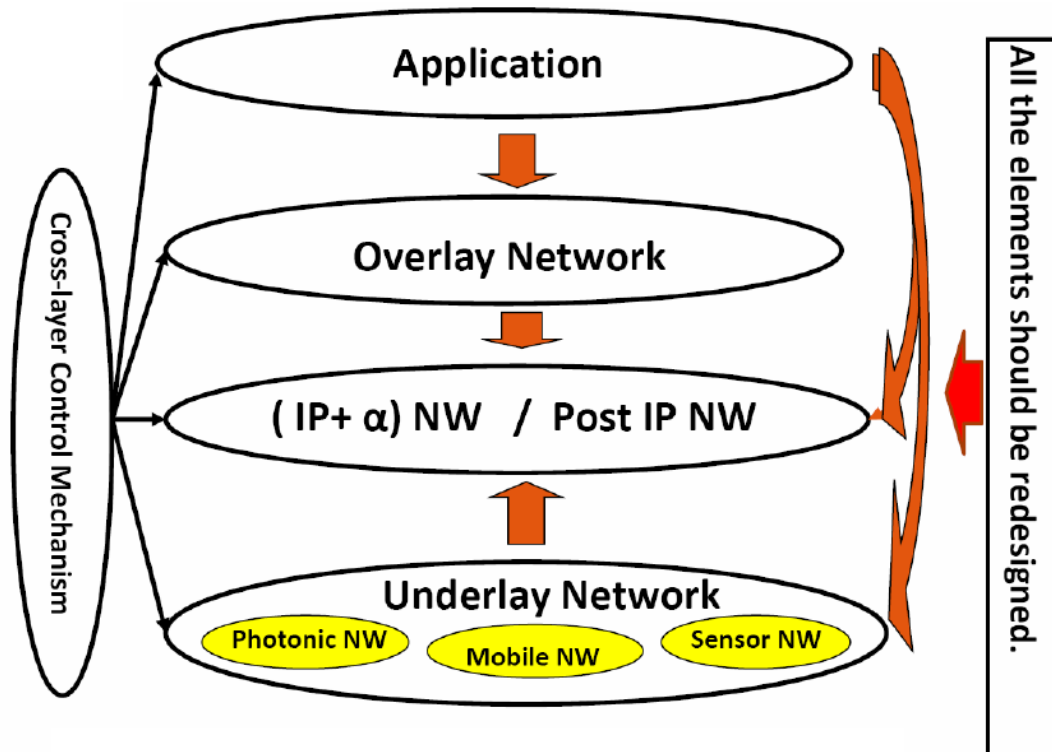
The conceptual paper focuses on several areas, e.g. switch and transmission capacity, power consumption, ubiquity, mobility support, connectivity for versatile appliances, security, reliability and social safety. In other words, the new network must be able to handle the previously mentioned range of tiny to huge terminals as well as the enormous amount of data traffic in 2020. The data traffic is estimated to about 1 000 times more than today. This would mean that for instance the required switching capacity will be some Pbit/s (1 000 000 Gbit/s), the link speed of the core network will be in the range of 10 Tbit/s (10 000 Gbit/s) and the access network will have 10 Gbit/s links. These estimations are supported by high-definition video transmissions and 4k digital cinema (2.3.1), which is currently under development. Regarding the energy consumption of such vast amount of data traffic, it would mean that each Peta bit/s router would consume about 10 MW. Furthermore, according to this projection an average ISP in the 2020's is expected to consume as much power as a nuclear power plant, which is obviously not sustainable.

2.1.2 Study items

NWGN has been divided into four study items in the AKARI project: application layer, overlay network, common network (IP+ α or post-IP) and underlay network (Figure 6). The latter encompasses photonic, mobile, sensor networks etc. The common network will be developed to replace today's IP network. The overlay network will provide a flexible, customizable layer on which applications will run. The application layer will have universal access. The cross-layer control mechanism will operate across the layers to enable them to cooperate and provide users with services in the appropriate layers. The control mechanism of the cross-layer is considered as one of the most challenging technologies in the study.

The study items on NWGN architecture have been chosen with an evolutionary goal from current connectionless datagram architecture to a hybrid architecture of packet and circuit switching. Most of the research resources are currently invested into this hybrid switch architecture with packet and path switching.

Figure 6 Study items in AKARI.



Source: NICT.

2.1.3 Design principles

The AKARI conceptual paper focuses on three core design principles for the creation of the new generation network architecture. These three design principles are: 1) simple and smart, 2) reality connection, and 3) sustainable and evolutionary. Basically, it is important for the network to have a simple structure that can evolve and develop in response to changing requirements. The intention is that NWGN should be designed in such way that it can be developing continuously over 50 to 100 years, not just two or three decades, as it will constitute the information infrastructure in our society. The new architecture must avoid the same dangers that confront today's Internet. The three design principles are described as follows:

Simple and smart principle (frequently called KISS – “Keep it Simple, Stupid” or lately “Keep it Simple and Smart” – by AKARI):

- When choosing among technologies and integrating them, simplification is considered most important in order to reduce complexity.
- Maintaining independence of each layer and letting the network layer be the common layer. Hence, other layers do not need the functions that are implemented in the common layer
- A network should not be constructed based on specific applications.

Reality connection principle:

- Separation of physical and logical addressing, so that entities in space on the network are not disassociated from the real world (currently a problem on the Internet, since it was not designed for mobility).
- The network should be designed so that bidirectional authentication is always possible. The authentication information must also be located under control of the particular individual or entity.
- Individuals or entities must be traceable to reduce attacks on the network and it should be a principle when designing addressing and routing as well as transport over them.

Sustainable and evolutionary principle:

- A self organizing network, which must be designed sustainable and adaptive, so that it can be developed continuously. Individual entities within the network must be designed so that they can operate in a self distributed manner.
- Self organizing controls or autonomous actions at each node to sufficiently scale controls in large scale or topologically varying networks.
- Robust large scale network designed to handle simultaneous or serious failures that may occur.
- Controls for a topologically fluctuating network are necessary for mobility, e.g. for finding resources on demand.
- Controls based on real time traffic measurement are required to avoid failures when the scale of the network increases.
- Openness should be provided to users facilitating the creation of new applications.

2.1.4 Configuration of the new architecture

The design principles described in the previous section have resulted in the following component technologies, which constitute the basic configuration of the new network architecture:

Optical packet switching and optical paths

Packet switching technologies make use of the broadband nature of optical technology and provide possible methods required for the integration of switching principles having different requirements for various service provisions.

Optical access

New generation FTTH concepts providing higher speed and are more suitable for various services than existing concepts.

Wireless access

New generation wireless communication technologies and wireless network configurations that will exist in the environment. For example, users will be surrounded by various sensors and personal communication devices in the ubiquitous network society.

PDMA

Packet Division Multiple Access (PDMA) is a paradigm for mobile wireless communication that adapts to the communication characteristics of a packet network, where cell design and channel assignment are redundant.

Transport layer control

The prospect for universal support, migration scenarios and fairness of transport layer control is another important component in the new architecture. A self-organizing control type TCP is also introduced.

Network architecture with separate structure for identification and location

Another important research focus is to introduce a separate structure for identification and location. It is considered necessary to adopt an architecture where identifier and locator are separated, in order to construct a scalable network, simplify mobile communication, and multi-homing, as well as protecting privacy.

Layering

Introduction of a cross-layer architecture for exchanging control information between layers that are not limited to adjacent layers.

Security

Security configuration that consists of distributed security management.

QoS routing

The new network should also address the importance of routing from the user perspective, hence scalable QoS routing is proposed to achieve optimization.

Network model

The network model is defined by openness, in order to make network functions available for users to create diverse services.

Robustness control

A self organizing approach is proposed for implementing scalability and adaptability for variations and failures in the communication environment.

Layer degeneracy

The new architecture should implement a policy for simplifying the network and eliminating duplicated functions in multiple layers.

IP simplification

The network layers should be redesigned using a clean slate approach.

Overlay network

A virtualization technology for building a virtual network on an upper layer to conceal the diversity or limitations of lower layers, which enables diverse network services to be developed quickly in an upper layer without taking the lower layers into account. It also enables new network architecture experiments to be conducted without changing the underlying physical network.

Network virtualization

The necessity of network virtualization technology has been proposed to enable diverse virtualization, including parts closer to the core network, in order to promote research of network architectures, i.e. not only network services, which is done in the overlay network.

2.2 Enabling technologies

The document that describes the conceptual design of AKARI presents several technologies that are expected to enable the realization of NWGN. Optical and wireless technologies are given special attention. Technologies such as quantum communication and time synchronization are examples that are taken into consideration as part of basic technologies for future networks.

2.2.1 Optical technologies

As previously mentioned, one major challenge for NWGN will be to reduce the power consumption of the network. Photonic technology is a powerful tool to reduce the power consumption at each network node as well as to increase the switching speed. Research areas within optical technologies that are addressed are: optical transmission, new optical fiber, wavelength and waveband conversion, optical 3R, optical quality monitoring, optical switch and buffer, as well as silicon photonics.

2.2.2 Wireless technologies

Since wireless access and mobility are important parts of NWGN, research areas such as software radio and cognitive radio are identified as enabling technologies. Various types of sensors and personal communication devices are connected wirelessly to the network and will configure personal area networks, ad-hoc networks, and wireless multi-hop networks. These networks will in turn be connected to each other and enable communication to the optical core network. On the wireless access network side, base stations will be interconnected wirelessly, so that they can be placed more densely, increasing communication speed and using less power.

2.2.3 Sensor networks

As described earlier, NWGN is intended to handle a huge amount of terminals including wired and wireless sensors. These sensors may often be minimal (e.g. “smart dust”), operating at minimal external power and just generating tiny amounts of data. In many of these cases a more efficient protocol than IP is preferred. There is a great interest in a sensor network that is secure, but also enables information to be freely obtained and processed by general users.

2.3 JGN2plus

NICT is operating the R&D network testbed JGN2plus, which started in 2008. It has evolved from the JGNII and JGN network testbeds that were operated in 2004–2008 and 2000–2004, respectively. JGN2plus is a nationwide network in operation until 2011, when it is proposed to be succeeded by an evolved testbed (Figure 5). From a research point of view JGN2plus is the backbone for new R&D activities on network technology, e.g. NWGN, and a vehicle for international collaboration, among others. It consists of three network services: layer 3 IP connection, layer 2 Ethernet connection (over 1 Gbit/s, 10 Gbit/s lines) and an optical testbed. It has direct international connections to the US, Thailand, Singapore, China and Korea.

2.3.1 4k digital cinema

One application that sets high requirements on the network is 4k digital cinema. It is currently being used by NICT and NTT as a high capacity and high speed application. The hopes are that it will follow the trend of other long tail applications, such as Internet, WWW, search engines, etc., and eventually become a major service within the near future. It has a resolution of 4096 x 2160 pixels, which is roughly twice the resolution of digital high definition TV. It provides movies in 24 frames/s progressive mode and the average bit rate is 7.6 Gbit/s. Two hour content has the size of about 5 TB in non-compressed form. NTT developed the prototype system in 2001 and joint field trials have been made between NTT, Warner Brothers, Sony Pictures and Paramount. There have been other trials to Europe as well, for instance a 4k digital video live streaming from Kyoto to KTH, Stockholm, of the Kyoto Prize ceremony.

2.4 New Paradigm Network

NTT has been and is very active in the area of NXGN, which has been commercially launched in Japan in 2008. NXGN is based on IP network and is often characterized with the transition from IPv4 to IPv6. In order to position itself strategically for the future, NTT is also working actively on NWGN, supporting NICT. NTT has included the operator perspective to NWGN and refers to it by the name New Paradigm Network (NPN). This includes network operation and customer support.

2.5 Green IT

Aside from the green aspect of AKARI, there are also other efforts in Japan regarding reduction of the power consumption of the IT infrastructure. NEDO (New Energy and Industrial Technology Development Organization) has launched several projects in the field of electronics and IT. One example is the project “Development of Next-generation High-efficiency Network Device Technology”, which is running from 2007–2011 and aiming at developing optical/electronics device technology and related technologies for the purpose of establishing fundamental next-generation high-efficiency networks. The budget for 2007 and 2008 was 1.16 billion yen (100 million SEK)¹ and 1.04 billion yen (90 million SEK)¹, respectively. Furthermore, METI (Ministry of Economy, Trade and Industry) has launched a Green IT project this year that aims at making data centers, displays, routers and servers more energy efficient, while MIC with NWGN is covering the energy consumption of the network itself.

2.6 Rest of the world

There are activities similar to NWGN that have recently begun in other parts of the world. For instance, the National Science Foundation (NSF) has launched the GENI and FIND projects in the US. NICT's collaboration with the US and the NSF is tight. The EU has some related activities within FP7. Japan's advanced communication infrastructure and high-speed Internet may give Japan advantages in the competition with other countries in terms of developing NWGN.

From an international point of view, NICT is in a rather unique situation being a funding organization with its own research laboratory. Japan's leading position in a number of technology areas related to NWGN can pave the way for Japan to becoming a future leader in creating services and applications.

2.7 Challenges for the AKARI project

AKARI is definitely an ambitious project with its aim to create a new generation network that will be able to handle the requirements in the 2020's and be flexible enough to develop over 50 to 100 years. The greatest challenge is said to probably be the resistance of those who continue to push for evolutionary changes of the current IP based network.

The AKARI project team has made an impressive start by generating the comprehensive document which explains the conceptual design of AKARI. Some concerns have been raised at an early stage that refers back to the Fifth Generation Computer Systems (FGCS) project in the eighties. Before FGCS, Japanese R&D teams had often shown that they could be effective and productive in reaching common targets in an orchestrated effort, as long as the goal and direction are clearly defined. It is argued that the FGCS project got too focused too soon. Instead it has been proposed that this kind of large scale projects should have multiple competing groups, open standards, open platforms and mostly open source software results. This would allow focus on demonstrating key architectural principles and delivering enabling system components. It has been recommended that the AKARI team should focus on a tentative direction, stay alert, be attentive and observe emerging enabling technologies and how they may have an impact on the candidate architectures, and be open to other research groups both in Japan and internationally. Intellectual property matters and technology transfer are examples of other issues that have been brought to attention at an early stage.

With these challenges and recommendations being pointed out at an early stage combined with the rather unique position of NICT and an ambitious start of the project, the AKARI project has definitely been equipped with promising initial conditions.

2.8 Opportunities for bilateral collaboration

Both NICT and NTT have shown positive interest in a possible collaboration with Sweden. The area of mobile/wireless network for future Internet has been mentioned as a potential area for research collaboration, since Sweden is especially recognized for its strength in the mobile/wireless field. As previously mentioned there has already been collaboration between NTT, NICT and KTH regarding a field trial transmission of 4k digital video from the Kyoto Prize ceremony. This could also be a prospective starting point for a bilateral collaboration.

3 Conclusion

Next Generation Network (NXGN) has been launched in Japan during 2008. It is characterized by the transition from IPv4 to IPv6. However, there is an increasing level of concern and discussion in the networking research community as to how long it will be possible to do incremental changes and extensions to the IP-based network of today. It has become increasingly difficult to deal with the complexity of the Internet and it is suggested that it will ultimately reach a point where the maintenance and error recovery will be exceedingly difficult. Another argument is for example the limitation of today's Internet regarding the drastically increasing power consumption of Internet routers with the current technology development.

Hence, Japan is aiming for a new generation network that will replace today's Internet and be able to handle the requirements set by the society in 2020 in terms of communication speed, capacity and security. The New Generation Network (NWGN) is being proposed as a clean slate network architecture with main protocols that may be dramatically different from today's IP-based protocols. The intention is also that NWGN should be designed in such way that it can be developing constantly over 50 to 100 years, not just two or three decades as it will constitute the information infrastructure in our society.

MIC is expecting that Japan becomes a leader in post-Internet technology and creates global standards. Japan's leading position in a number of technology areas related to NWGN can pave the way for Japan to becoming a future leader in creating services and applications.

NICT has created the NWGN Strategic Headquarters in order to meet MIC's expectations. The core of the headquarters consists of the AKARI project as well as the test network JGN2plus. The AKARI project describes several components and enabling technologies necessary to realize NWGN, examples are optical and wireless technologies.

The work on NWGN is still at an early stage, basically at a study level. However, both NICT and NTT are very positive to a possible collaboration with Sweden in the field. NICT has expressed an interest in getting in contact with Swedish experts in the field of mobile/wireless networks for future Internet. NICT and NTT have done a field trial 4k digital video transmission from Kyoto to KTH earlier and that has been suggested as a possible starting point for a potential Swedish-Japanese collaboration on NWGN.

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Changes in policy should be based on:

- Statistic data and analyses of the structure and dynamics of industry – to obtain an up-to-date view of future challenges and opportunities.
- Evaluation of results and effects of policy measures and programmes – to provide benchmarks and learn from measures implemented earlier.
- Policy intelligence in order to look outwards and ahead – what issues are likely to come on the growth policy agenda in the future?

These represent the principal missions of ITPS.