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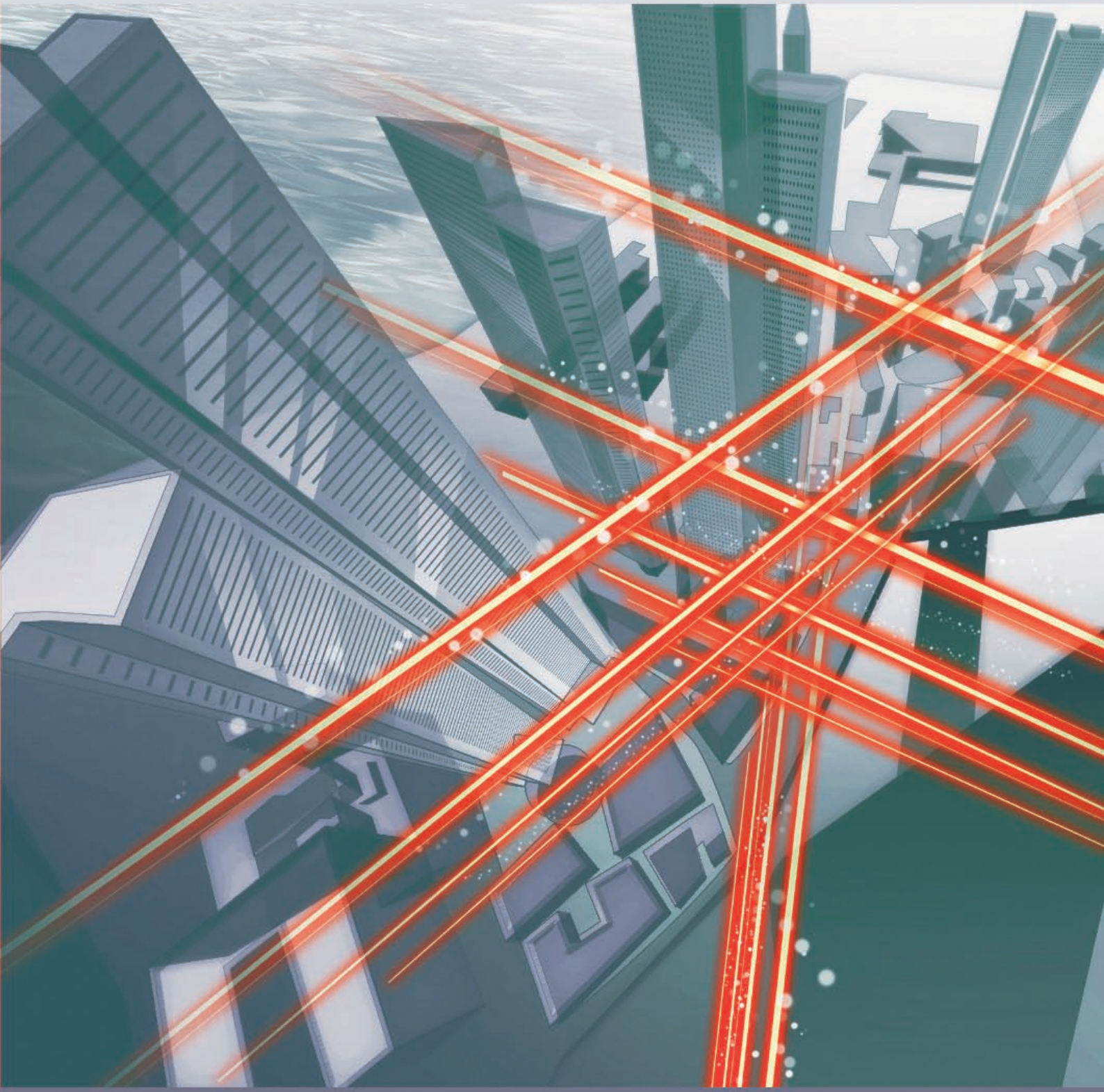

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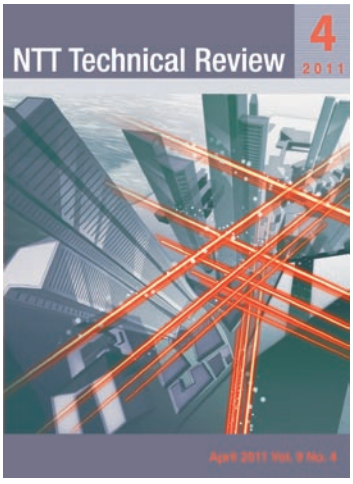


NTT Group's Business Strategy in the Fast-Changing Global Market

Satoshi Miura
President and CEO, NTT

Abstract

This article introduces NTT's research and development (R&D) activities aimed at supporting widespread use of information and communications technology and its activities in pursuit of global business expansion. It is based on the keynote address given in Japanese by Satoshi Miura, President and Chief Executive Officer of NTT, at the NTT R&D Forum 2011, held on February 21–23, 2011.

1. ICT: driving the economy

Although Japan still faces severe economic conditions such as appreciation of the yen and deflation, the third-quarter financial results for a number of businesses appear to signal some degree of recovery. The forces driving this development are said to be the penetration of smartphones and the growth of emerging countries. In particular, expanded use of smartphones is surpassing all forecasts. For example, NTT DOCOMO initially set a goal of selling 300,000 smartphones in fiscal year 2010, but made an upward adjustment to 2.5 million units in its third-quarter financial accounts. Moreover, the company expects to sell 6 million smartphones in fiscal 2011. Thus, smartphones are selling at an extremely fast rate. According to a research firm in the USA, worldwide shipments of smartphones exceeded those of personal computers during the period October through December 2010. Therefore, we can say that information and communications technology (ICT) is driving the economy.

2. Dramatic changes in ICT

2.1 Service integration and market restructuring

Service integration is taking place in all fields. Widespread use of smartphones, tablet terminals, and wireless local area networks (LANs) enables people to access a variety of services from anywhere. Convergence of fixed and mobile services is gathering momentum. New vertical integration-based business models, in which a single provider offers both terminals and content applications as a package, are emerging in rapid succession, spearheaded by offerings from Google and Apple.

2.2 User participation and personalization

User-participation-type, or interactive-type, social media have begun to exert a powerful influence. In particular, the number of Facebook users has been growing so fast that it has already reached 600 million worldwide. Facebook is said to have played an important role in igniting the movements toward democracy in nations in the Middle East and North Africa, touched off by events in Tunisia and Egypt. Such social media have become powerful enough to help bring down a government. Furthermore, personalized services, such as "i-concier" [1] (from i-concierge) provided by NTT DOCOMO, are also spreading.

2.3 From ownership to leasing (use of cloud computing)

Use of cloud computing is growing globally. Today, people frequently access clouds without realizing that they are doing so. The shift from ownership of systems to lease arrangements is accelerating. As shown in **Fig. 1**, the paradigm shifts mentioned above are spreading rapidly on a global scale.

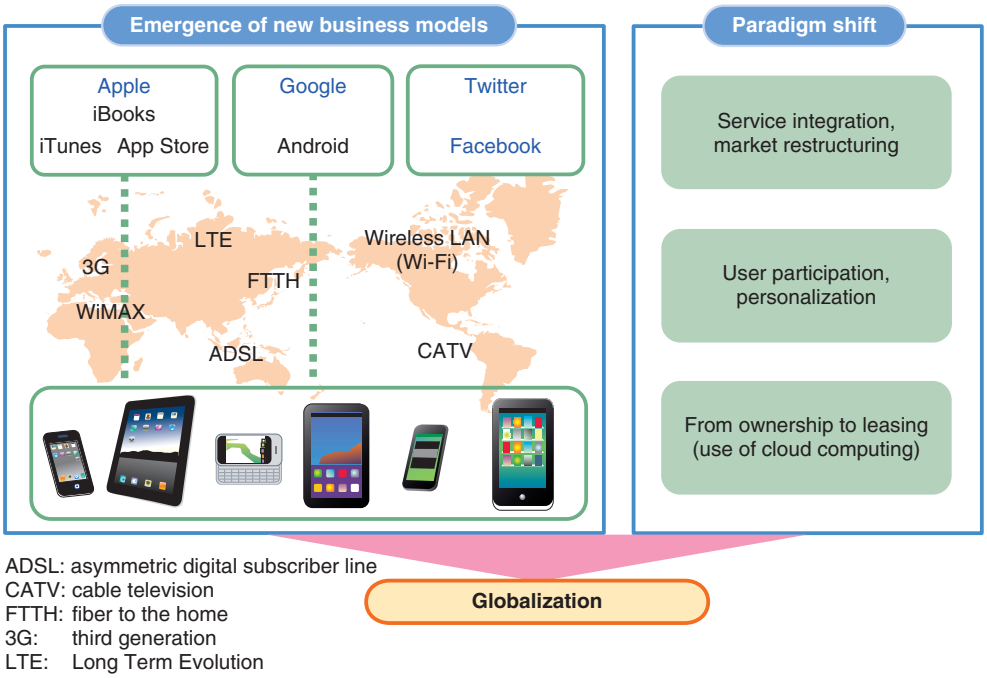


Fig. 1. Dramatic changes in ICT.

3. Road to service creation business group

Under these circumstances, we have sought to reinforce our network infrastructure and have met our progress goals, i.e., to achieve high penetration of optical services and expand the area in which the Next Generation Network (NGN) service is available. In the arena of mobile services, most phones now in use are 3G (third-generation) phones. We launched a Long Term Evolution (LTE) service, which we call "Xi", in December 2010. The NTT Group's next target is to provide a variety of services in our world-leading broadband environment. For this purpose, we have adopted a growth strategy comprising four key elements, as shown in **Fig. 2**. Research and development (R&D) activities being directed on the basis of this strategy are described below.

4. Innovation through R&D

4.1 R&D areas

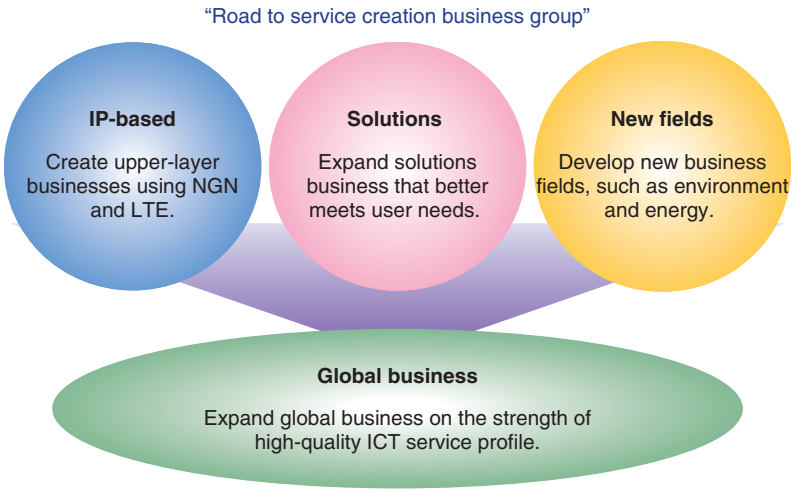
NTT is undertaking a broad spectrum of R&D activities in the following four areas: (**Fig. 3**).

(1) Core communications technologies: optical transmission, monitoring and analysis of large networks, virtualization, etc.
(2) New service-related technologies: cloud infrastructure, three-dimensional video encoding, Home ICT [2], security, etc.
(3) Innovative technologies: electronic/optical materials, cryptography, etc.
(4) Enhancement of the environment and service quality: environment, energy, etc.

In line with NTT's aims of contributing to the resolution of social issues and improvement of people's lives through ICT innovation, NTT's R&D seeks to play a leading role in the NTT Group's efforts toward becoming a service creation group by exploiting its R&D results.

4.2 Significance of R&D

Japan's world-class broadband environment is the outcome of a wide range of R&D activities, including years of research on optical transmission, for example, the development of technologies to reduce the costs of broadband networks and simplify the work involved in installing optical fibers. The inroads made by Internet protocol (IP) technology have prompted us to increasingly adopt commercially available products, which is a departure from the traditional emphasis on in-house-development, and have also



IP: Internet protocol

Fig. 2. Four key elements of growth strategy.

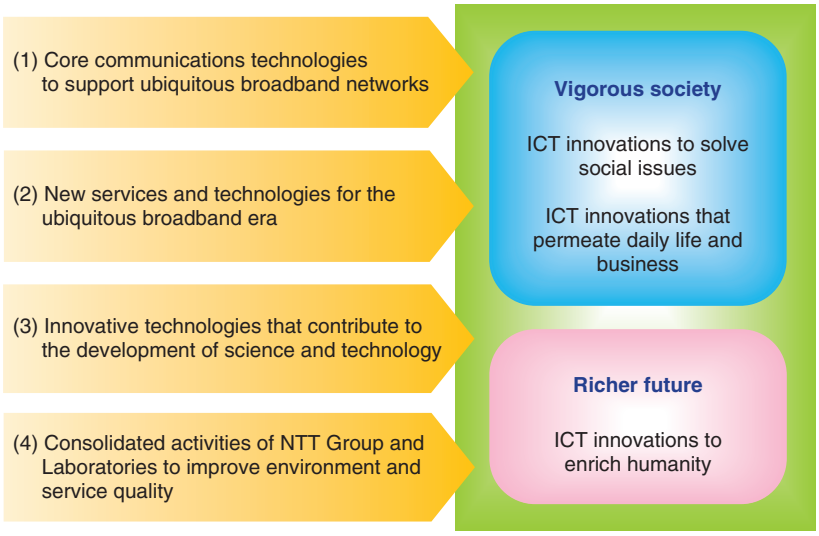


Fig. 3. R&D categories and target directions.

shifted the primary R&D focus away from hardware toward software. There are two good reasons why NTT, as a carrier, should engage in R&D. The first is the need to develop innovations that will enable networks as a whole, including the network operations aspect, to satisfy the requirements of serviceability and economy on the one hand and to achieve carrier-grade quality and reliability on the other hand. The second reason is an increased need for innovations that will enable a variety of services to be created in order to enhance user convenience and innovations that will make possible sophisticated linkages between these services and the networks.

4.3 Importance of expanding ICT utilization

The term *broadband network* embraces not only optical networks but also cable television (CATV), asymmetric digital subscriber line (ADSL), and wireless networks. In other countries, mobile networks are frequently the dominant broadband networks. A

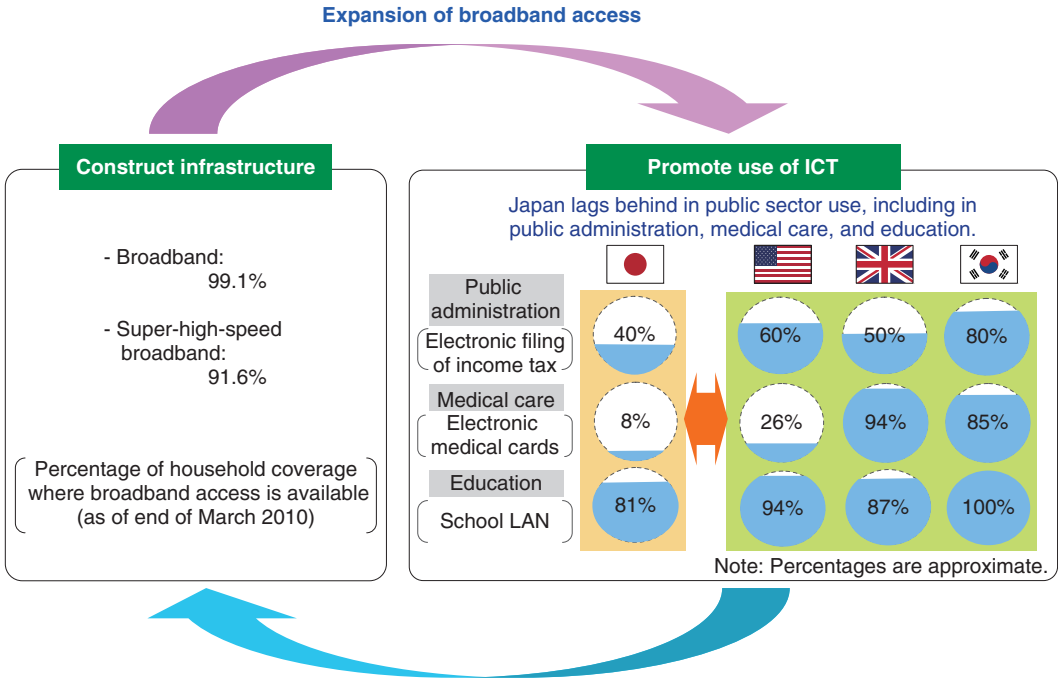


Fig. 4. Importance of expanding ICT utilization.

case in point is the U.S. market, where it has been promised that a next-generation wireless broadband network will become available to 98% of the population within the next five years.

Japan's broadband environment leads the world. The Ministry of Internal Affairs and Communications reports that broadband access covers 99.1% of households in Japan and that super-high-speed broadband access at 30 Mbit/s or more covers 91.6% (as of the end of March 2010) (**Fig. 4**).

However, Japan lags behind in ICT utilization in public service areas such as public administration, medical care, and education. There is an urgent need to strengthen efforts to correct this situation. Widespread use of broadband services prompts the construction of broadband infrastructures. The promotion of use and construction are as inseparable as the two wheels of a cart.

4.4 Vigorous society and richer future

Specific examples of ICT utilization are described below.

1) Enhancement and visualization of public administration services

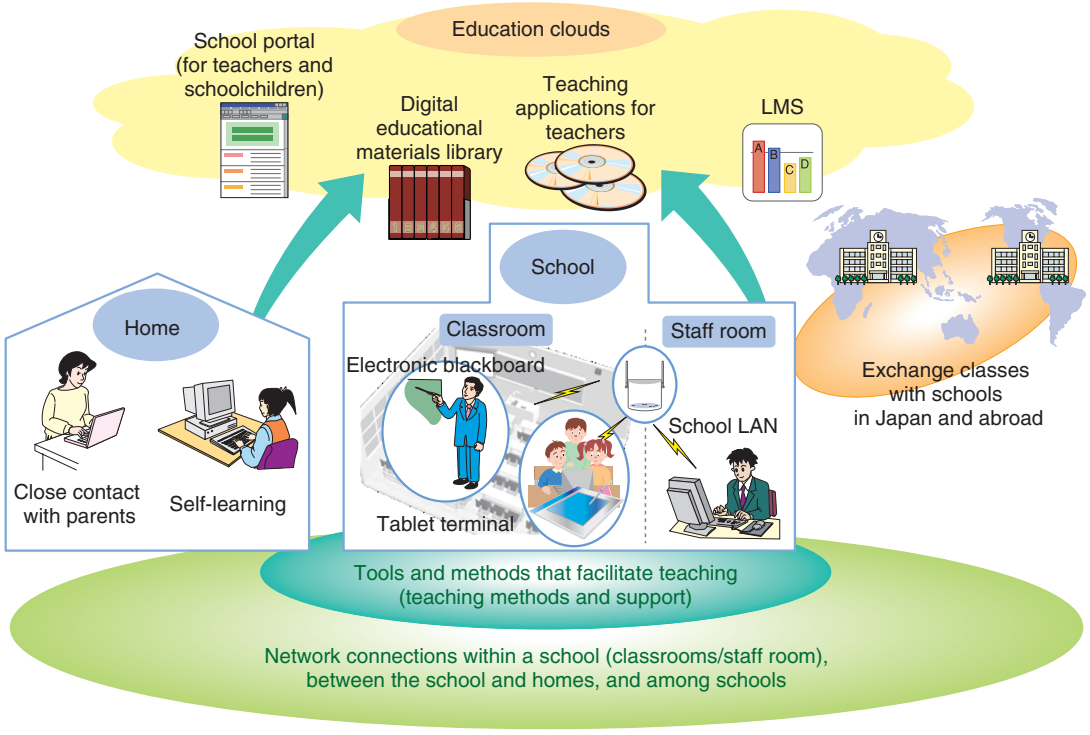
Most administrative agencies currently require mainly paper-based applications for services. Sharing of information within administrative offices is limited owing to the vertically segmented administrative setup. Full use of ICT could dramatically enhance both convenience for citizens and efficiency in administrative processes by, for example, providing a one-stop service from the user perspective, providing push-type services, and enabling citizens to control their personal information.

2) Linkage between healthcare and medical data

The use of clouds can enhance the quality of regional medical care because they enable patients' medical records and other data to be shared both within and among hospitals with high security. The NTT Group has conducted field trials on remote health consultation in the cities of Tono and Kurihara and on electronic medical records and remote support of regional medical care with NTT Medical Center in Tokyo. Our goal is to enable everyone in Japan to receive high-quality medical care wherever they are, as envisioned in the government's "My Hospital Anywhere" initiative.

3) Education Square × ICT

In a bid to create an educational environment in which teachers find it easy to teach and schoolchildren can take more interest in deepening their learning, we have launched the "Education Square × ICT" project (**Fig. 5**). In fiscal 2011, we will start field trials of this project in eight elementary schools in four



LMS: Learning management system for integrated management of educational material delivery, progress, and history of individual students' learning

Fig. 5. "Education square × ICT" project.

municipalities. These will be followed later by the addition of junior high schools. These trials will not only link classrooms within individual schools but also link the schools to the children's homes and interconnect schools to support all aspects of the envisioned new approach to education.

To promote widespread use of ICT in public sectors, it is important to ensure reliability and security. In pursuit of safe and secure clouds, the NTT Group is undertaking R&D of the construction of an infrastructure that links social information owned by different organizations. The infrastructure will interwork with sophisticated network functions to provide a wide range of security functions (**Fig. 6**).

4) R&D aimed at reducing environmental impacts

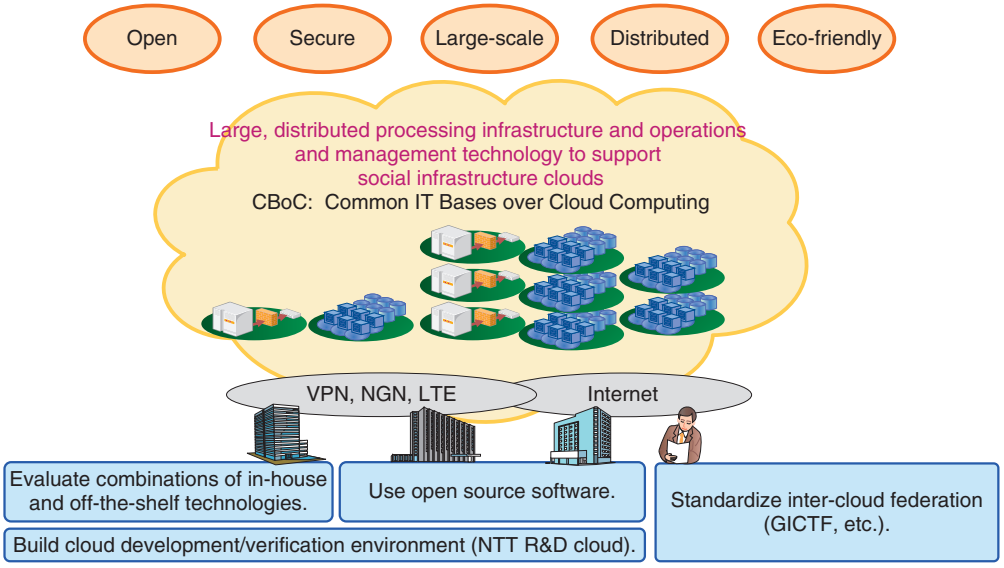
The exponential growth in ICT traffic requires an increasing amount of telecommunications equipment, which, in turn, rapidly increases power consumption. R&D for reducing environmental impacts is gaining in importance (**Fig. 7**). We are seeking to reduce CO_2 emissions by both the NTT Group (a program we call *Green of ICT*) and by society in general (*Green by ICT*).

- Green of ICT: To reduce power consumption by ICT itself, we are engaged in R&D of power-thrifty routers and servers, virtual datacenters, efficient air conditioning, and direct current power feeding.
- Green by ICT: To reduce power consumption by society in general through the use of ICT, our R&D aims at a smart community that optimally controls all power-related facilities, including the power infrastructure and smart meters.

The NTT Group's environment vision, called "THE GREEN VISION 2020", sets a target of a 15% reduction in CO_2 emissions by fiscal 2020 compared with the volume in fiscal 2008. We are intensifying our environmental efforts to achieve this goal.

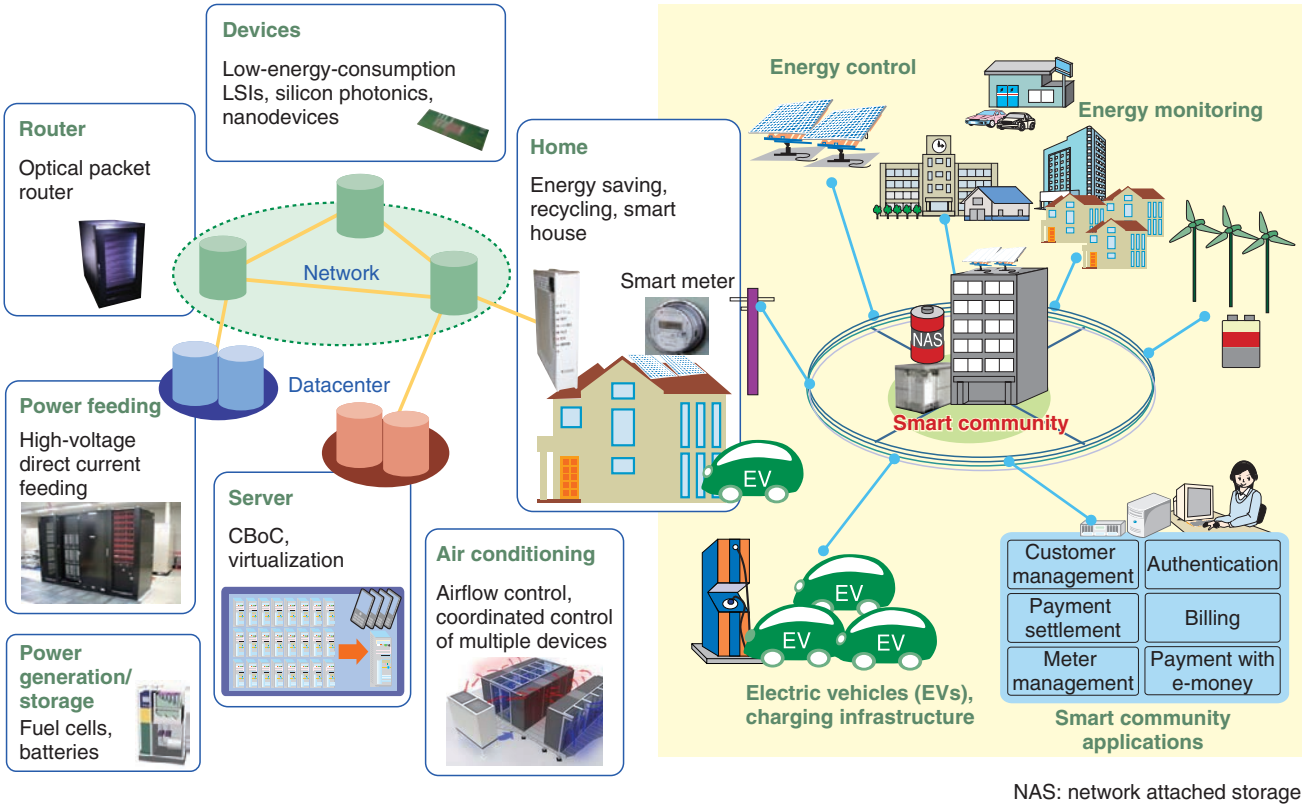
5. Expansion of global business

Among our global business activities, mobile communications business that targets consumers and systems integration and network integration business that targets corporate customers are described below.



GICTF: Global Inter-Cloud Technology Forum
IT: information technology
NGN: Next Generation Network
VPN: virtual private network

Fig. 6. Social infrastructure clouds.



NAS: network attached storage

Fig. 7. R&D for environmental impact reduction.

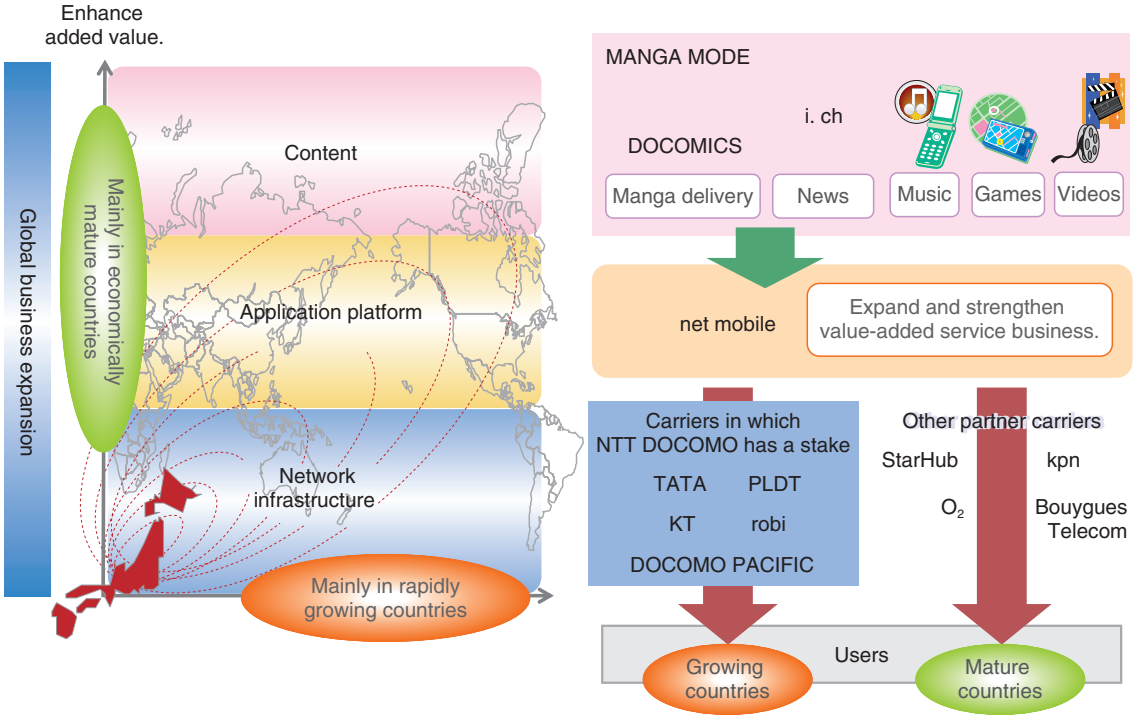


Fig. 8. Global expansion of mobile business.

5.1 Mobile business

The number of mobile phone subscribers worldwide exceeded 5 billion by the end of 2010, far surpassing the number of fixed-line phone subscribers (1.2 billion). A rapid increase in mobile phone numbers is particularly evident in emerging Asian and African countries, which are registering dramatic economic growth. Services that are possible only through the use of mobile phones are gaining in popularity. NTT DOCOMO is conducting the following activities aimed at capturing a significant share of this rapidly growing mobile market (**Fig. 8**).

1) Provision of network services in quickly growing countries

In quickly growing countries, particularly those in Asia, NTT DOCOMO is expanding its network base through investment in or partnership with local carriers that already have significant customer bases. Although most revenue is derived from voice calls, the company is seeking to capture the data communications market, which will be boosted by the economic growth of these countries.

2) Provision of value-added services

In countries where network infrastructures are well-developed, NTT DOCOMO will expand and strengthen its value-added services. For example, using the "net mobile AG" platform that it has acquired in Germany, NTT DOCOMO is collecting content, such as i-channel and *manga*, from around the world and delivering it to the world from its German platform. To expand its business overseas, the company will provide cloud-based services with a focus on platform services that can deliver a variety of content regardless of where in the world the content is produced or consumed.

5.2 Businesses for corporate customers

Anticipating rising demand in high-potential markets in emerging countries, enterprises are jumping on the bandwagon and accelerating expansion of their global businesses by entering these markets. Against this background, there is a growing need for ICT to provide solutions for business processes that have become too complex and tangled. Enterprises are also increasingly outsourcing the management of their ICT bases, which are becoming more and more sophisticated and complex. In other words, there is a steady shift toward the use of clouds.

With a view to supporting geographical business expansion by global enterprises, we have adopted

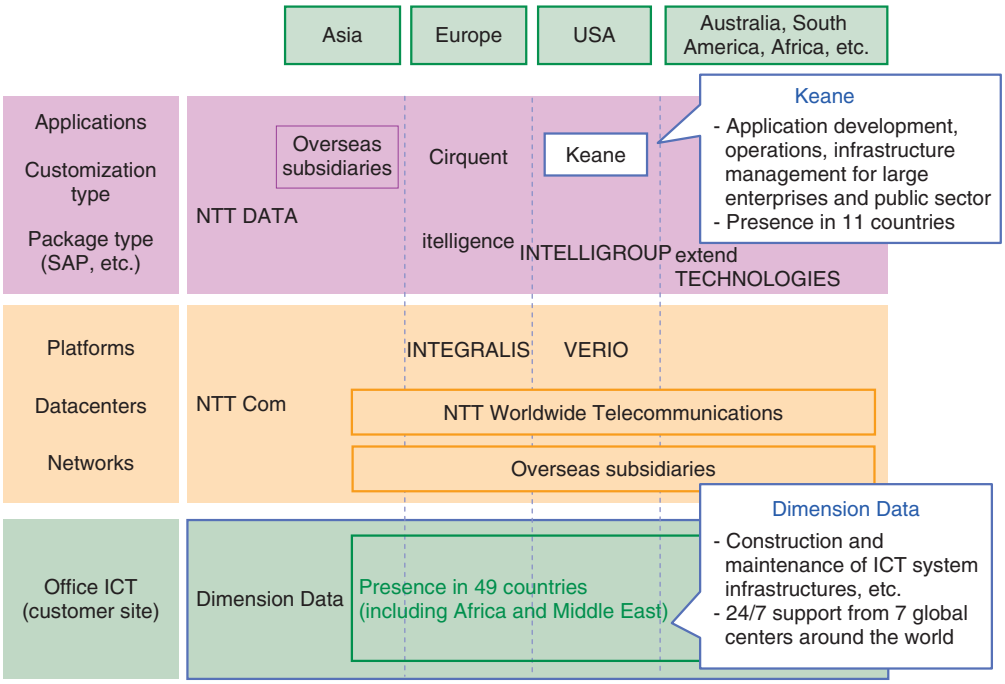


Fig. 9. Service profile and area coverage.

service profile reinforcement and geographical service coverage expansion as the main thrusts of our global business strategy and have been actively pursuing mergers and acquisitions (M&As) (**Fig. 9**). Global expansion by enterprises has proceeded faster than we anticipated, and it has become impossible to satisfy the increasingly diverse needs of our customers through only our own resources. We have moved swiftly to plug this gap through M&As; for example, Cirquent and itelligence, which have extensive skills in specialized applications such as SAP applications, and Keane, which was acquired last year. We also purchased Dimension Data because it has become important to rapidly support customers' business, including LAN installation, operation, and maintenance in customers' offices, and because we need to supplement our services in emerging countries where our current service coverage is inadequate.

These business expansions and M&As have begun to yield positive results; for example, we received consecutive orders from an energy-related company that has a presence in 30 countries and from a U.S. pharmaceutical company that has business sites in 15 Asian countries.

5.3 Future expansion of global business

Thanks to the provision of comprehensive ICT solutions and global expansion of services, the Group is expected to record sales of US$4 billion from overseas business in fiscal 2010, which is double the US$2 billion recorded in fiscal 2007. We are aiming at sales (simple addition) of about US$8 billion by fiscal 2011, and US$10 billion by fiscal 2012.

Following the above acquisitions, the number of overseas employees has increased to about 40,000, while the number of global enterprise customers is heading for about 10,000. These figures will rise as we continue to expand our global business.

5.4 Aiming to become a true global player

On the strength of various management resources and the business resources acquired through M&As, we have capitalized on our comprehensive *strength in connectivity* spanning all layers from applications and platforms to networks. As a result, we have continued to record steady growth in global business. However, the important challenges involved in becoming a true global enterprise acting as a main player in the coming era of clouds are still ahead. To meet those challenges, we need to pursue the following activities (**Fig. 10**):

(1) Globalization of the customer base. We will promote cross-selling on a customer base that has expanded by about 10,000 enterprises as a

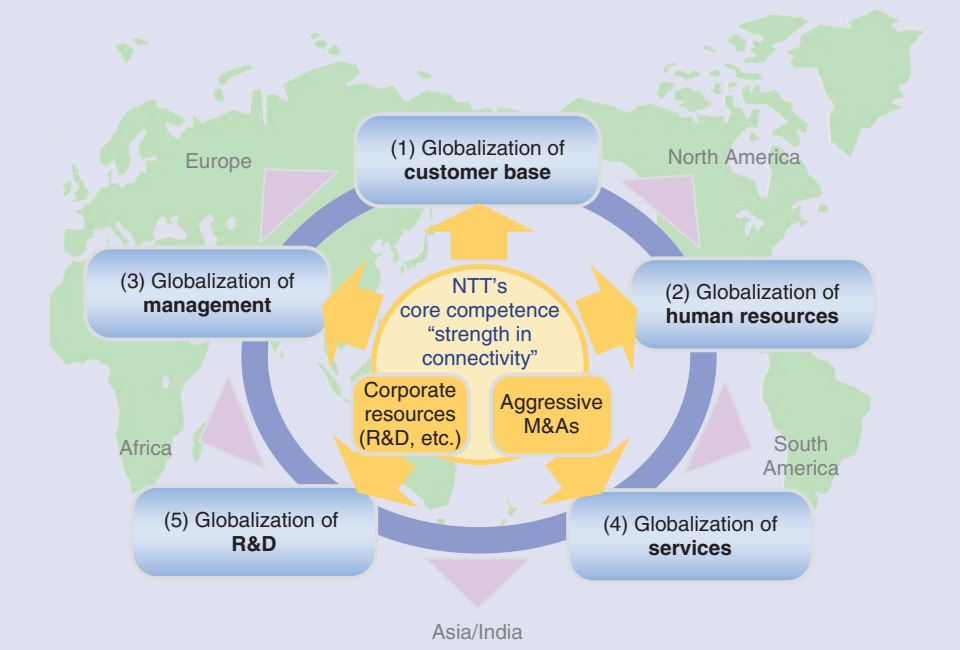


Fig. 10. Aiming to become a true global player.

result of the M&As of overseas companies and will also take advantage of synergy with these companies to capture global enterprises and large enterprises as new customers.

(2) Globalization of human resources. We will encourage globalization of human resources by increasing the employment of foreign students studying in Japan and of overseas local residents, bringing local employees to Japan, dispatching Japanese employees overseas, and conducting personnel exchanges among the acquired overseas companies.

(3) Globalization of management. While we respect the autonomy of management in individual companies, we will retain central governance in matters related to the NTT Group's global business strategies and management.

(4) Globalization of services. Globalization by our customers has given rise to increased diversity in service demands. We will build a varied and flexible service profile to satisfy those user needs.

(5) Globalization of R&D: We will increasingly globalize our R&D, which is one of our core competences.

5.5 R&D for global business expansion

Activities to globalize R&D, which is essential to our business expansion, are described below (**Fig. 11**):

1) Promotion of leading-edge R&D to support global business

This is an activity aimed at commercializing R&D results in the global market. We have a good track record in many product areas. Our free-bending optical fiber cords, small-diameter low-friction indoor optical fiber cables, and optical connecters have gained large shares of the respective world markets. Our video encoders were used at the Olympic Games and the World Cup by broadcasters from a number of countries. In developing cutting-edge technologies related to ubiquitous broadband networks and services, and products related to clouds and security, we urgently need to pay even greater attention to the global market and intensify global business, including stronger collaboration with acquired overseas companies.

2) Promotion of R&D to achieve international standardization or establish de facto standards

In addition to ongoing conventional standardization activities that have achieved good results in optical technologies, such as the passive optical network

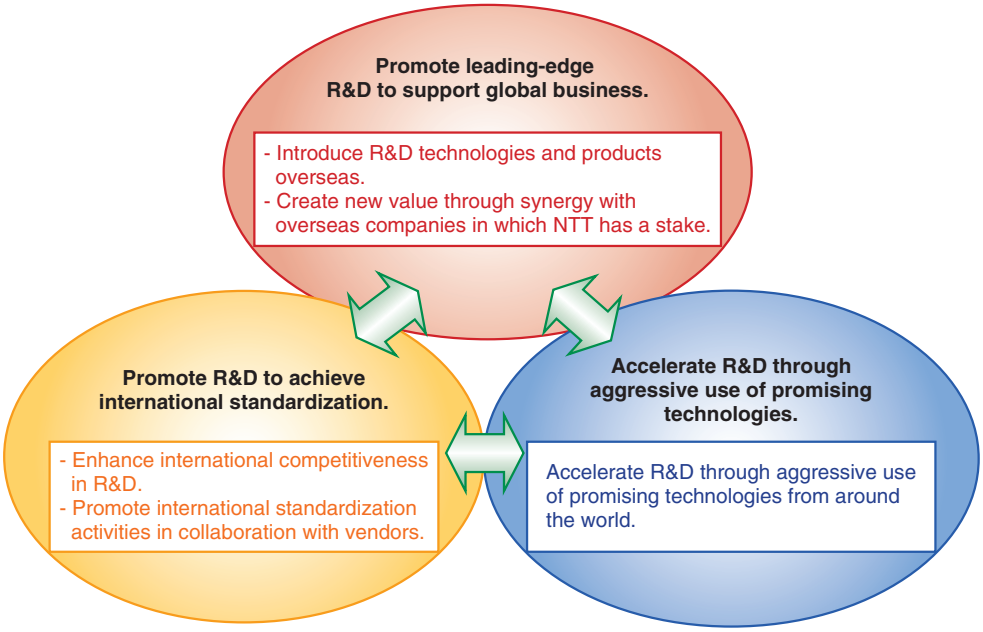


Fig. 11. R&D for global business expansion.

(PON) for fiber to the home (FTTH), technical specifications for video coding and Internet protocol television (IPTV), and encryption methods, we need to boost our efforts to establish de facto standards that are directly linked to our global business and are likely to increase our revenue.

3) Acceleration of R&D through aggressive use of promising technologies from outside the Group

As business models continue to change rapidly, driven mainly by standardized IP technology, it is necessary to collect relevant information by paying even more attention to developments taking place around the world and to adopt relevant technologies and products, or incorporate them into existing ones, in order to accelerate R&D.

6. Efforts to boost R&D

The world is undergoing a rapid paradigm shift of global magnitude. This has led many enterprises to strive harder to make their R&D activities more competitive. NTT R&D is no exception.

6.1 Swift and flexible R&D to respond to changes in the Group's business

Our business structure is changing rapidly. It has become more important than ever for R&D to adapt swiftly and flexibly in response to changes in the Group's business. For example, it is essential to target those businesses that have high growth potential. As mobile business gains weight within the Group, we must strengthen collaboration between NTT's laboratories and those of NTT DOCOMO and steer R&D through a more comprehensive approach combining fixed and mobile technologies. Since business focus is shifting from network-centric services to upper-layer services, it is also necessary to review the relative weights and balances among different R&D areas.

6.2 Reduced time from R&D to market and closer collaboration with operating companies

It is important to work closely and in a timely manner with operating companies. We have introduced commercialization assistance functions to overcome the *valley of death* that lies between R&D and commercialization. With respect to human resources, we have not only promoted personnel exchanges between our laboratories and operating companies but also introduced what we call *direct current*, whereby researchers are transferred to operating companies along with the products they have developed so that they can be directly involved in the commercial introduction of those products. It is necessary to reduce the time from R&D to market by accelerating these

activities, paying more attention to business needs, and collaborating with operating companies at even earlier stages of R&D.

6.3 Stronger competitiveness through R&D diversity

At the same time, it is also essential to strengthen competitiveness by ensuring diversity in R&D. In an effort to encourage innovative, leading-edge research, we have introduced a system of Fellows, a Senior Distinguished Researcher, and two Senior Distinguished Scientists. In addition, we need to hire more foreign researchers and intensify R&D collaboration with universities and enterprises both at home and abroad. Innovation is often created through an encounter with a dissimilar research area. Ensuring diversity in R&D will enable us to respond flexibly to the needs of the times, which continue to grow in diversity and complexity, thereby strengthening our competitiveness.

7. NTT Group's future activities

As a core competence of the NTT Group, R&D must contribute to the Group's business by forging paths into both the domestic and global markets and by translating its results into profitable businesses and services. We at the NTT Group will strive to assist in the economic development and resolution of social issues by further developing safe, secure, and open ubiquitous broadband networks and by creating more convenient services in collaboration with a variety of players. Through these activities, we seek to contribute to the creation of a vigorous society and a richer future.

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NTT's Persistent Dedication to Innovation

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Abstract

This article introduces NTT's research and development (R&D) activities aimed at maintaining and developing information and communications technology (ICT) services and pursuing further innovation as a carrier R&D organization. It is based on a lecture given by Hiromichi Shinohara, NTT Senior Vice President, Director of Research and Development Planning Department, at the NTT R&D Forum 2011 held on February 21–23, 2011.

1. Missions as a carrier R&D organization

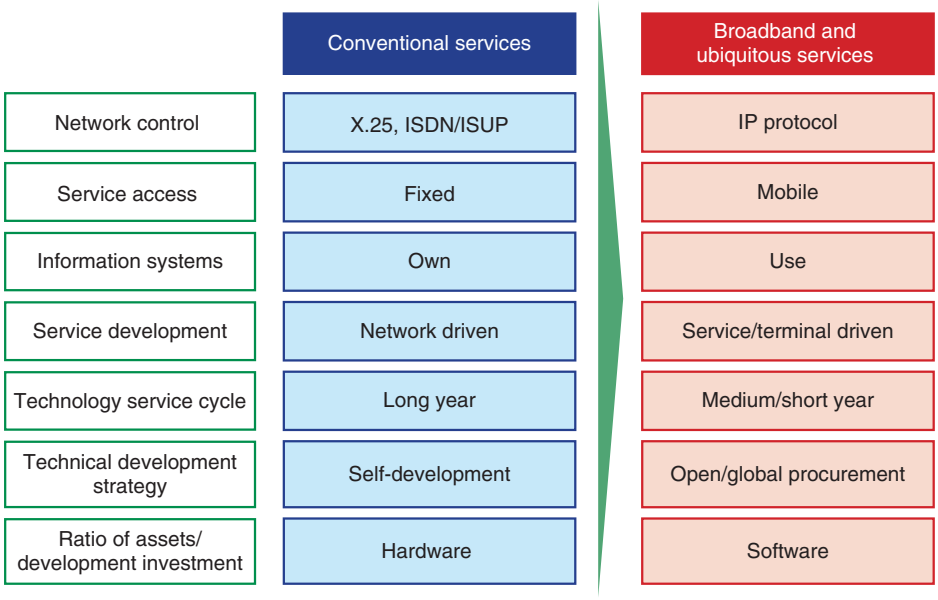
1.1 Changes in the surrounding environment

Recent changes in the environment surrounding telecommunication networks have been dramatic (**Fig. 1**). Internet protocol (IP) technologies have accelerated the integration of core networks. In the field of access networks, it has become important to create services that make the most of the convergence of fixed and mobile networks, which were previously regarded as being independent of each other. Part of the background to these changes is rising customer demand for seamless service environments and the increasing availability of customer terminals that are compatible with both fixed and mobile networks. Services and terminals have taken the place of networks as the drivers of information communication evolution. These changes are accelerating transitions in the technologies used for information and communications technology (ICT) services. The main thrust of the NTT Group's investment in facilities and research and development (R&D) has been shifting away from hardware toward software. The mode of access to information systems, including the quickly spreading cloud systems, is rapidly changing from ownership to leasing. To be able to respond to these major changes, our R&D strategy must be both open and global in many respects.

1.2 Why NTT, as a carrier, should engage in R&D

These extensive changes in the ICT environment prompt us to consider again the question of why a carrier should engage in R&D. From the perspective of providing good services to customers continuously and economically, the basic missions of NTT's R&D can be summarized as: (i) continuously developing services and networks, (ii) retaining the competitive edge of the NTT Group and enhancing the Group's value, (iii) creating new businesses and industries, and (iv) proposing the Group's visions of the future on the basis of anticipated technical trends. In the light of these basic missions and the latest changes in the ICT environment, the following seven types of activity explain why NTT, as a carrier, should indeed engage in R&D.

The first type of activity is R&D undertaken to sustain the core ICT technologies, such as ones for network security, traffic, quality, reliability and electromagnetic compatibility (EMC). The second is R&D of civil systems and operations, maintenance, and testing technologies, which are aimed at maintaining the health of networks. We will continue to pursue these two types of R&D activity regardless of how the ICT environment evolves. Although it is generally higher-layer applications that are currently attracting most attention, activities to sustain the underlying infrastructures of ICT systems are as important as



ISDN: integrated digital services network
ISUP: ISDN user part

Fig. 1. Changes in the surrounding environment.

ever. For example, we are working on a technology for cleaning and renovating buried conduits that already accommodate existing cables without any negative effect on them while creating space in the conduits for the insertion of new cables.

The third activity is the construction of networks that will support sustained development of services. In considering network architecture migration, it has become essential to develop systems that are consistent with the strategy for investment in services and facilities or identify and utilize appropriate products that are commercially available. In the same manner, we will maximize the benefits of this activity by either changing it drastically or reinforcing it, depending on how the environment evolves. For example, early R&D activities on optical access, spanning some 30 years and leading to the launch of the fiber-to-the-home (FTTH) service in 2000, were devoted to reducing the product costs; however, after that launch, they took another direction and began to focus on reducing the installation cost and time for optical fibers, which are more difficult to handle than copper cables (**Fig. 2**). Thanks to those activities, NTT has been able to provide FTTH to more than ten million customers to date. To continue to provide a stable service to this massive number of customers, it is timely to shift our efforts toward the facilitation of operations and maintenance. In a departure from the traditional emphasis on self-development, we developed the Next Generation Network (NGN) by incorporating both self-developed and off-the-shelf products. In this process, we, as a carrier R&D organization, succeeded in combining the convenience and economy of IP technology with the reliability and security that characterize the telephone service. In the field of network management, we have been working to reduce total operational costs by developing an element management system infrastructure, which fills the gaps between the different maintenance interfaces of off-the-shelf products.

The fourth activity is delivery of high-value services that capitalize on high network functionality. Today, some argue that networks only need to provide *dumb pipes*. However, we believe that we should be committed to developing functions and services that can be implemented or enhanced only by making the most of network functions. For example, it is thanks to the collaboration between the high-quality, real-time video transcoding technology of broadcasting centers and the guaranteed-bandwidth IP multicasting technology of the network that it has become possible to provide simultaneous IP retransmission of terrestrial digital broadcasting both economically and with quality equivalent to that of terrestrial

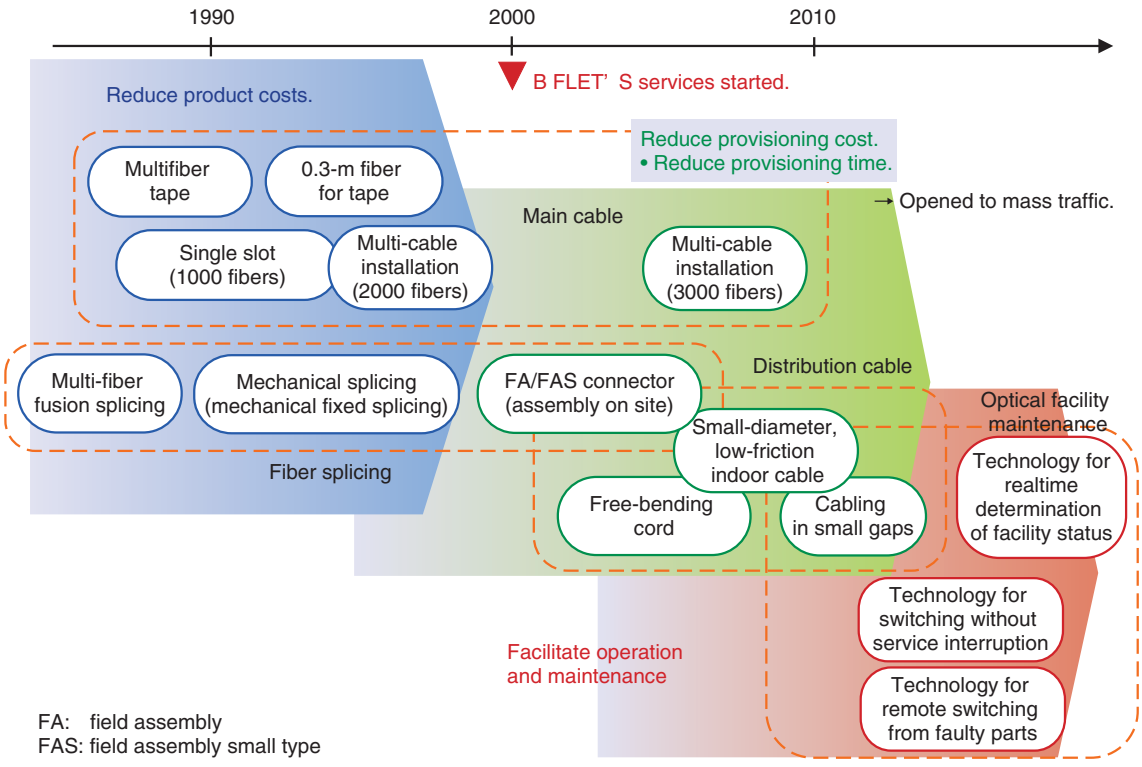


Fig. 2. Changes in optical fiber technology.

broadcasting. We will intensify our efforts to develop services that actively make use of network functionality.

The fifth activity is development of technologies to enable economical maintenance and enhancement of fast-growing software assets. In addition to the conventional approach of developing products that utilize our software assets, we will study ways to improve software usability. The sixth activity is expansion of the scope of carrier business, including the development of safe and secure cloud infrastructure technologies and cloud-based services, and the application of optical communication devices to equipment used in other industries, such as medical services. Finally, leading-edge R&D, such as device and materials research leading to breakthroughs in networking and systems, and communication science will bring about innovations in services. We will continue to pursue these types of basic research because they enable us to develop long-term business visions based on technological trends and provide the foundation for sustained development of our business.

2. Recent R&D activities

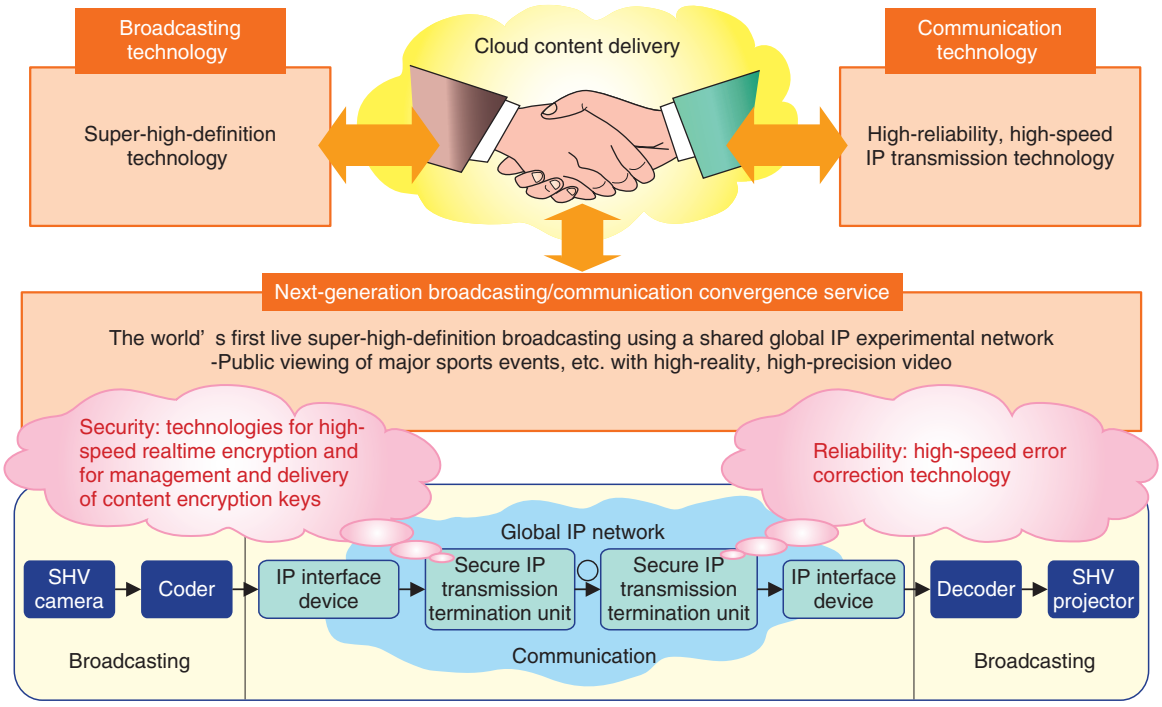
Some specific examples of our latest R&D activities are described below.

(1) Super-high-definition IP transmission

By combining broadcasting technology with NTT's high-speed, high-reliability IP transmission technology, we successfully implemented the world's first live super-high-definition broadcasting on a shared global IP experimental network (**Fig. 3**). We will continue our efforts to enhance customer convenience through the integration of broadcasting and telecommunications functions.

(2) New web search-based services

We are enhancing web search services to enable users to find the information they seek more conveniently, easily, and rapidly than ever. Our word-of-mouth summarization technology automatically generates a summary from multiple reviews of a certain product to enable users to obtain a general idea of the product's reputation at a glance. The first service in Japan based on this technology has been undergoing



Note: Transmission experiment was conducted jointly with NHK, which was in charge of technologies for capturing, displaying, and coding high-definition videos.

SHV: Super Hi-Vision (NHK term)

Fig. 3. Super-high-definition IP transmission.

field trials since January 2011.

(3) 69-Tbit/s super-high-speed optical transmission

As the volume of traffic flowing in networks continues to increase, R&D of high-speed, high-capacity transmission systems is gaining in importance. There are systems with a capacity of 1.6 Tbit/s currently in operation in NTT's networks. In the near future, ones capable of handling 10 Tbit/s will become available for commercial use. In March 2010, NTT developed a prototype that achieved a world record speed of 69.1 Tbit/s. We will continue to anticipate future increases in traffic and develop high-speed transmission systems to accommodate the expected growth.

(4) 1-Gbit/s wireless: multi-user MIMO transmission

Although a combination of wired, wireless, and power line communication (PLC) transmission links are frequently used in customer premises networks, we believe that wireless transmission provides the greatest flexibility to users and will become the favored technology in due course. Wireless transmission is unlikely to achieve the same speed as optical transmission because the frequency availability is limited. Nevertheless, in August 2010, NTT demonstrated wireless transmission at 1.62 Gbit/s for the first time in the world, using beamforming of radio waves. This allows multiple terminals to share the same frequency.

(5) Photonic crystal

The crystal of an ordinary material has a periodic structure with a lattice spacing equivalent to the wavelength of an electron (about 0.1 nm). Since such a material allows electrons to pass through it, it can exhibit a variety of properties. A photonic crystal, on the other hand, which is fabricated manually and has a periodic structure with a spacing equivalent to the wavelength of light (about 100 nm), is known to interact intensely with light, resulting in the exhibition of novel physical properties, such as optical insulation, slow light, and negative refractive index. These properties are expected to lead to the development

of optical devices that are highly compact and functional and consume extremely low amounts of energy. NTT has produced the world's most cutting-edge photonic crystals, such as a super-high-speed optical switch that consumes only 420 aJ, which is the lowest energy consumption achieved anywhere in the world, and a laser that can carry information with the world's lowest energy consumption of 8.8 fJ/bit (aJ: attojoule (10^{-18} J) and fJ: femtojoule (10^{-15} J)).

(6) Five-senses interface

Recent communication science activity has revealed that people compensate for missing information, even in the tactile sense, just as they do in the visual and auditory senses. We believe that it is important to explore basic knowledge about the transmission of information as recognized by all five senses if we are to achieve more natural sensations in communication, as will be described later.

(7) Green R&D

In November 2010, the NTT Group announced its environmental vision, THE GREEN VISION 2020. It calls for NTT's R&D to make a significant contribution to the reduction of CO_2 emissions by both the Group (Green of ICT) and society in general (Green by ICT) in order to achieve a low-carbon society. We are taking a multifaceted approach to meeting this expectation.

One activity for reducing total power consumption by combining leading-edge technologies is an energy management system for datacenters (DEMS). It mobilizes power generation/feeding technology, coordinated server/air conditioner control technology, and virtual server control technology to reduce the power consumed by datacenters, for which demand is certain to increase.

At the systems level, we are working to reduce the power consumed by passive optical network (PON) systems, which are widely used to provide the FTTH service. The power supply for optical network units (ONUs) is usually left on all the time; however, by suspending the power feed, except for the power required to sustain minimum functions, while the user is not communicating, we can reduce the power consumed by the access networks, which account for a large proportion of the power consumed by telecommunication networks because they are connected to a huge number of terminals.

At the device level, we are developing nanomechanical logic circuits. When a cyclic voltage is applied to microscopic plate springs (thickness: 1.4 μm) to cause microscopic vibrations (about 10 nm), the springs can perform multiple AND and OR operations simultaneously. When this technology matures and a nanocomputer is eventually developed, its power consumption will be only 1% of that of current computers.

In addition to these activities, we have been seeking to make the work processes of our researchers more energy efficient. At the R&D Forum held a year ago, we announced our goal of increased ICT-based remote conferencing and teleworking. The track records since April 2010 show that we have more or less attained the teleconferencing goal but achieved only about 60% of the teleworking goal. In order to fully attain these goals, we will improve operational procedures and develop necessary ICT tools.

3. Next steps for service creation

3.1 Safe and secure clouds

Although Japan leads the world in the construction of an environment for broadband services, such as FTTH, it lags behind in the exploitation of ICT services. We should address social issues to encourage the use of such services. We believe that safe and secure cloud systems will be required as the underlying technology to resolve these issues.

NTT's cloud infrastructure R&D activities can be broadly classified into three areas: (i) provision of a large-scale processing infrastructure, (ii) collection of data, and (iii) processing and analysis of data accumulated in clouds. By making the most of knowledge generated in clouds, we will help improve the sophistication of enterprise activities, enhance the activities of individuals, and resolve social issues. For clouds to be widely accepted and used, they need to be safe and secure. We are working on technologies to ensure security and simple operation within clouds, in addition to ensuring safe and secure communications by making clouds interwork with relevant network functions (**Fig. 4**).

Data trace management technology prevents data falsification and unauthorized access to data by monitoring data movements within a cloud and data access. Although encryption and decryption have conventionally been associated through a one-to-one relationship, intelligent encryption technology has succeeded in expanding this relationship to one-to-many by using attribute-related logic (**Fig. 5**). This technology enables both security and flexible access control by encrypting data in clouds.

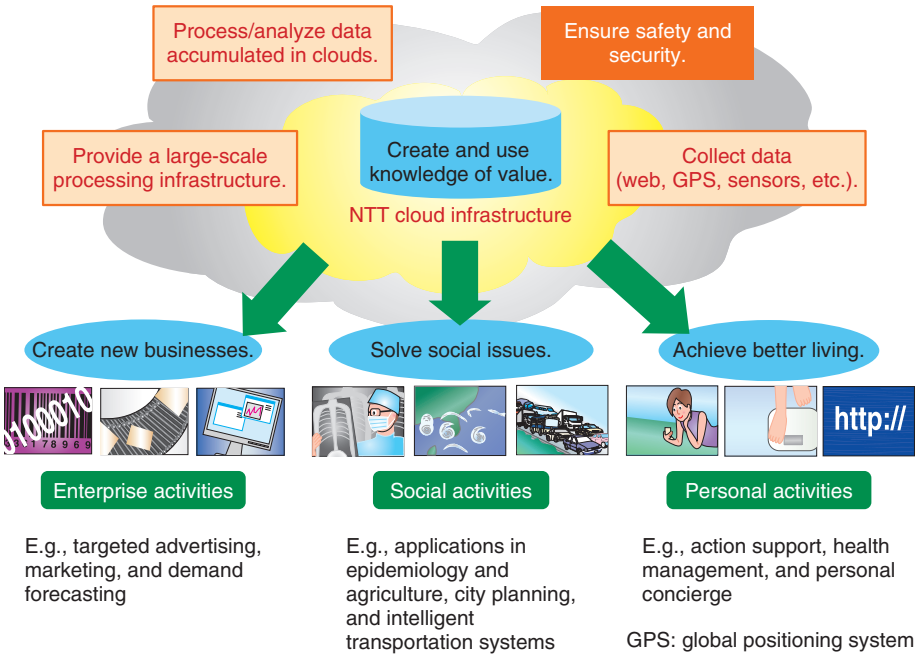


Fig. 4. Cloud infrastructure activities.

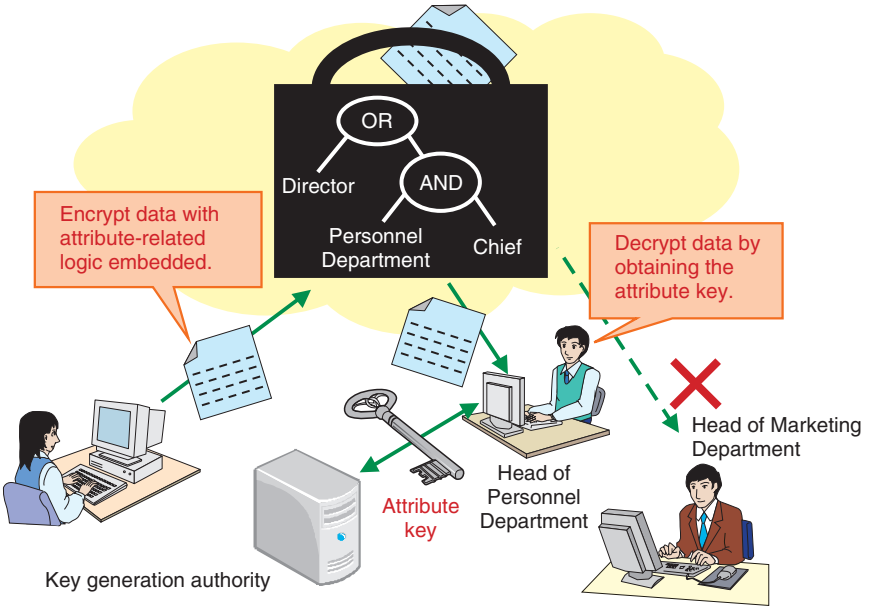


Fig. 5. Intelligent encryption technology.

3.2 New forms of value provision

To promote widespread use of ICT services, R&D should reinforce innovation-oriented activities in addition to addressing social issues. Although a variety of ICT services have become available, enabling users to participate more extensively in the cyber world, the information available on the Internet still appears as a huge and complex mixture of *wheat and*

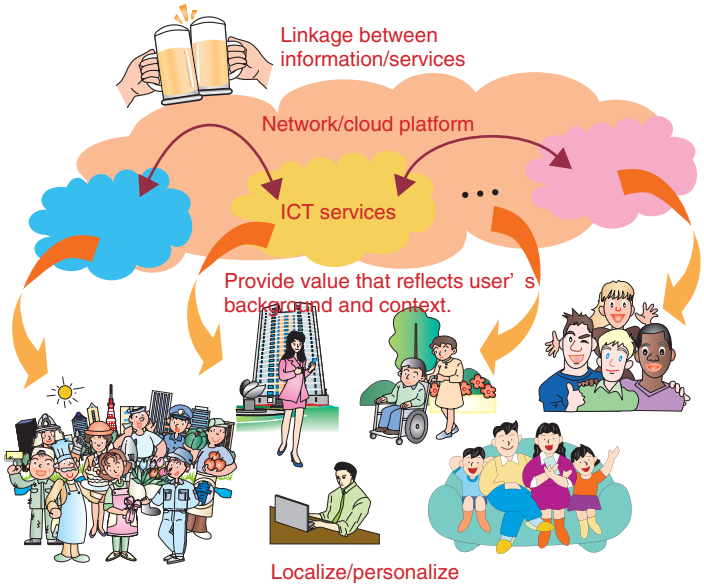


Fig. 6. Organic interworking among ICT services.

chaff to everyone except advanced users. The pursuit of economy and efficiency in Internet business activities has driven service providers to globalize, standardize, and consolidate services, resulting in a situation whereby the services market is controlled by a limited number of players.

Although these changes in ICT services have brought many benefits to users, the services tend to target average users and to provide information selected on the basis of statistically derived average user behavior. They do not necessarily suit the needs and preferences of all types of users. We believe that ICT services should take account of each user's background and context and provide value that is localized, without sacrificing a global perspective, and personalized for individual users (**Fig. 6**).

3.3 New forms of expression in communications

Progress in user interfaces for terminals, such as the development of touch panels, has led to widespread use of smartphones and tablet terminals, lowering the barrier to the accessibility of ICT services for general users. However, the progress made to date in forms of expression in communications, such as high-definition video and three-dimensional video, has been targeted mainly at a small number of advanced users. Insufficient attention has been paid to improving the ease of use for general users and for physically challenged persons.

NTT's R&D will take two approaches in moving toward the ultimate goal of providing communications with a high sense of reality. The first is aimed at achieving super-high reality by using leading-edge technologies. This has been our primary focus thus far. We will continue activities in this area, such as development of super-high-definition video and free-viewpoint video. However, considering that the amount of information that people actually obtain through their five senses is somewhat limited, what people actually find realistic is not necessarily equal to how realistically information is presented. In this sense, it will be important to pursue a new approach of *meta-reality* whereby information is presented in ways that allow people to feel realistic sensations. Such ways will be based on cognitive science, which focuses on understanding the five senses and emotions. We believe that, by combining these *super-* and *meta-realities*, we can provide natural sensations and new forms of expression in communications that will compensate for parts missed by people with physical handicaps or inadequate ICT literacy (**Fig. 7**).

3.4 Seamless network

Network services now provide users with many options from a variety of aspects, such as speed and bandwidth, quality, and reliability. To enable users to make the most of these broad options according to their needs, it is important to make the communications

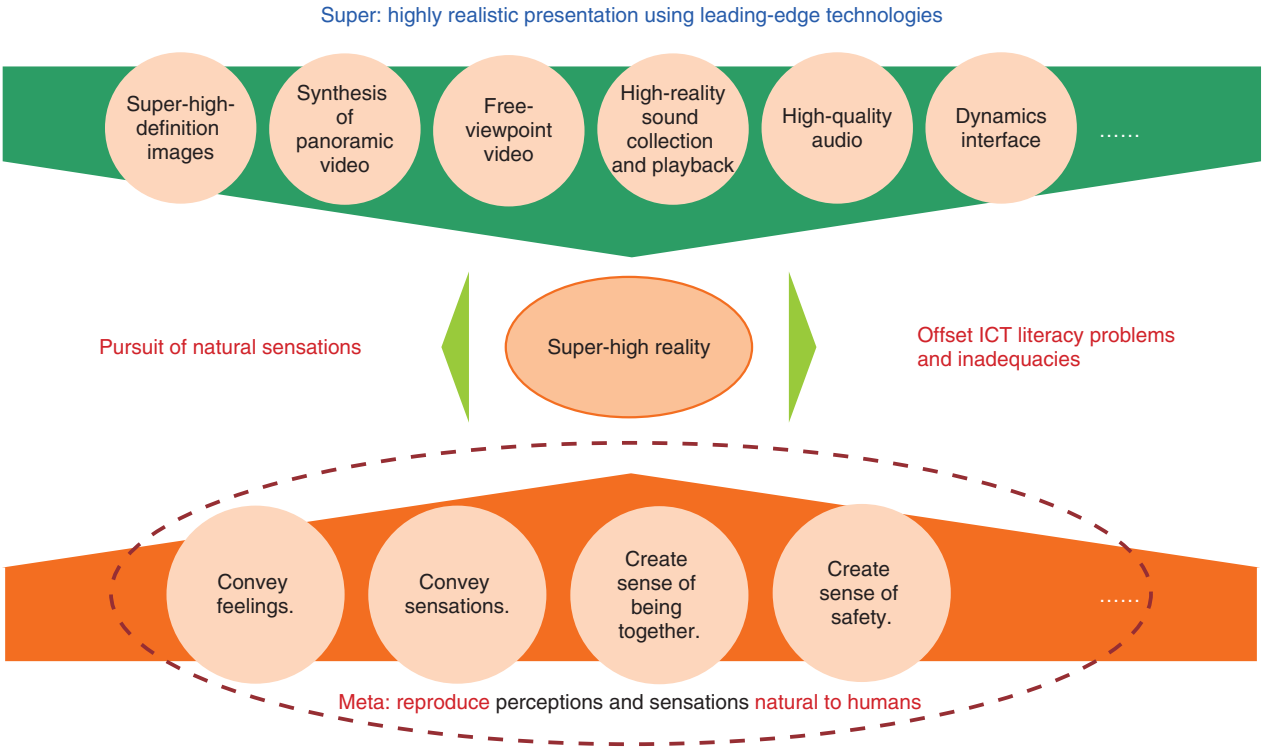


Fig. 7. Proposal for new communication methods.

environment seamless and provide services rapidly and economically.

Specifically, we should enhance serviceability, economy, and cost elasticity by integrating clouds and virtual networks rather than constructing and operating separate networks for individual services and individual network hierarchies, as has been the case, so that customers can access the necessary network functions and resources only when they need them (**Fig. 8**).

3.5 Directions of innovation

Let us consider how the overall directions of R&D change with the needs of the times. During the period when broadband environment construction was our primary concern, we pursued efficiency, convenience, and economy following global standards. Now, as we seek to enable a broad spectrum of customers, from elderly persons to children, to fully benefit from ICT services, we must shift the center of gravity of R&D toward enhancement of personalization, localization, and diversity in services and networks in addition to pursuing the previous objectives (**Fig. 9**).

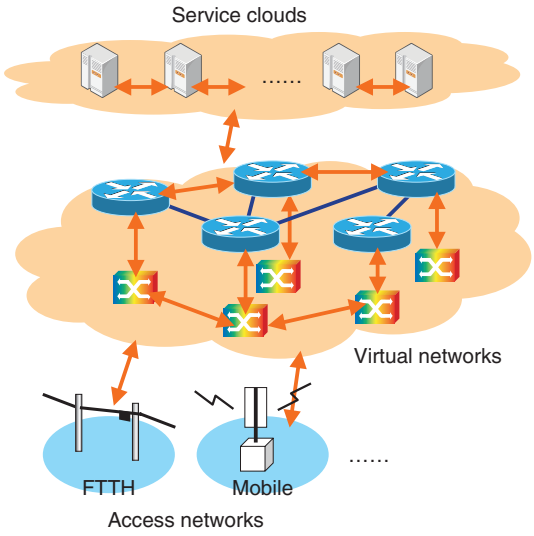


Fig. 8. Seamless network.

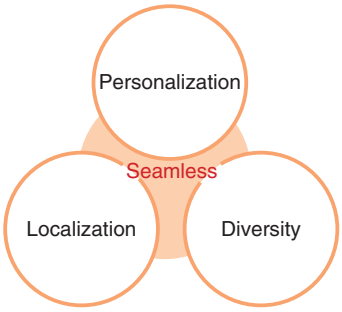


Fig. 9. Directions of innovation.

4. Activities for further development

4.1 Aspirations of NTT's R&D

In order to achieve further innovation, our researchers must renew their commitment to upholding the three aspirations that have been fostered in our R&D activities over the years and embrace new approaches:

(i) Master: Study technology with confidence while assessing its future impacts on business and society.

(ii) Act responsibly: Develop ICT services with a strong sense of responsibility for fostering their use and accessibility throughout Japan.

(iii) Raise each other's abilities: Create new value through teamwork and interaction.

4.2 Accelerating and strengthening research on leading-edge technologies

Another aspect of NTT's R&D strength is its diversity. There are some 3000 researchers working in a variety of technological fields at various stages of technical development. Last year, to enable the whole R&D organization to benefit from this diversity and produce specific results, we defined six roles to ensure the dynamism of our R&D activities (**Fig. 10**).

As part of these efforts, we newly appointed one Senior Distinguished Researcher and two Senior Distinguished Scientists in addition to the two existing NTT Fellows in order to relieve excellent researchers of managerial responsibilities and clearly define their roles as leading the world in cutting-edge research (**Fig. 11**). Through these efforts, we hope to build an organizational system that will ensure that NTT continues to be a frontrunner in basic research.

4.3 Increasing pace and efficiency of R&D

NTT has selected its R&D projects on the basis of its own understanding of what is likely to be needed. However, given the rapid changes currently taking place in our communications environment, there are more and more cases where NTT's R&D, which is

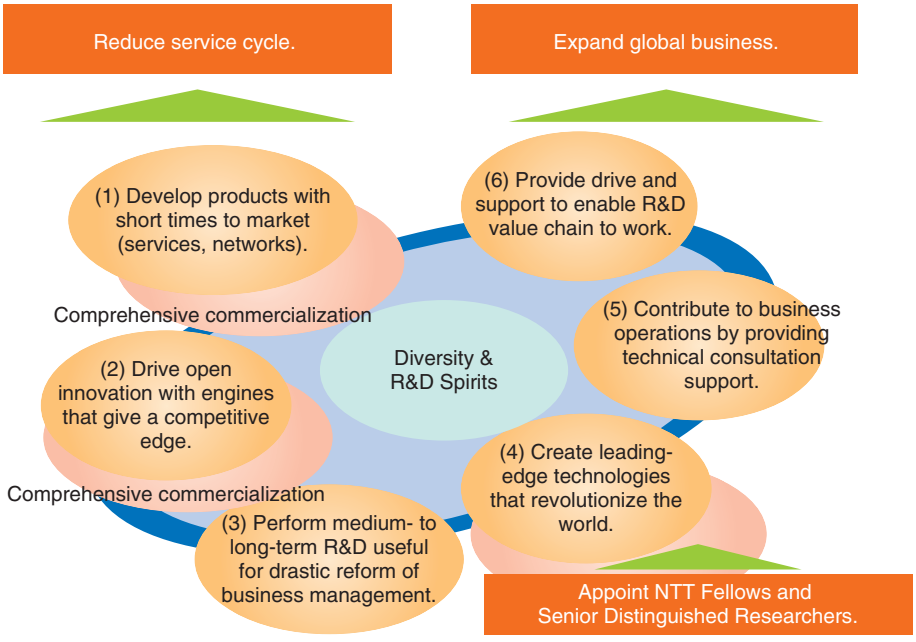
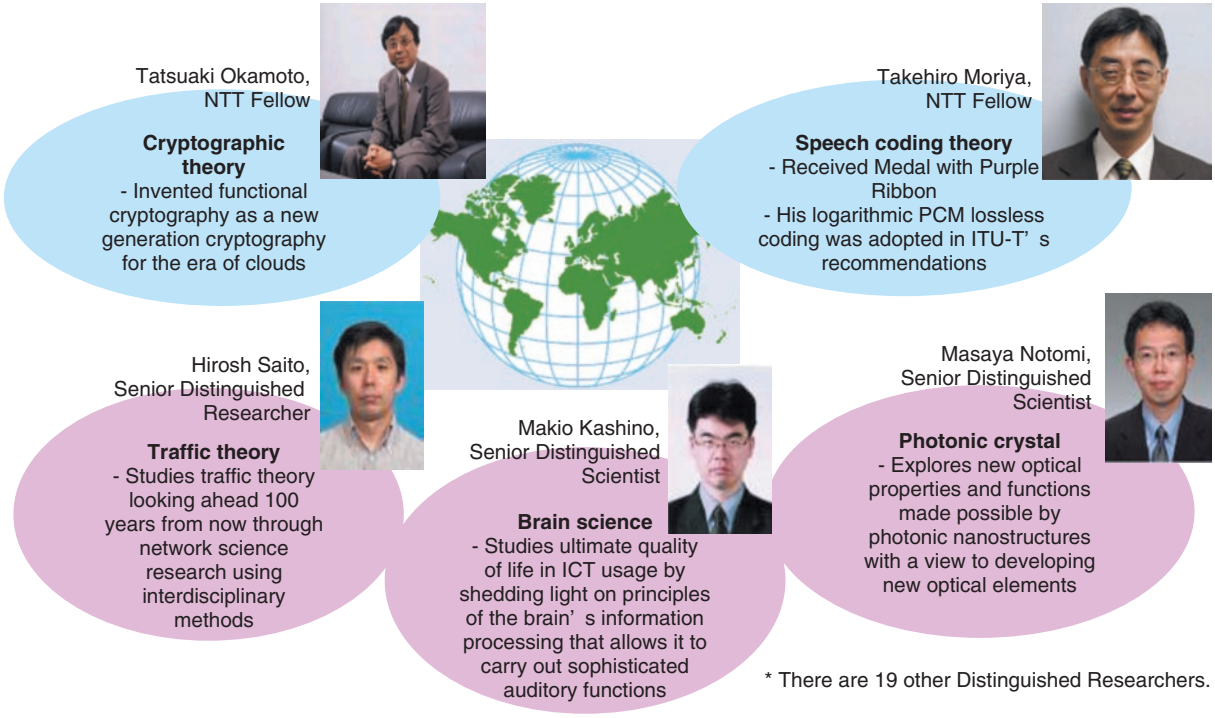


Fig. 10. Activities for further development.



ITU-T: International Telecommunication Union, Telecommunication Standardization Sector
PCM: pulse code modulation

Fig. 11. Acceleration and strengthening of leading-edge technologies.

somewhat distant from its actual business operations, cannot adequately respond to the ever-changing needs of the operating companies. Last year, we began implementing specific solutions to this problem. For example, we introduced a mechanism whereby the needs of NTT's business operations are reflected in the R&D stage for core technologies, and we have encouraged NTT Laboratories to develop systems in collaboration with operating companies from the early stages of R&D projects. We will continue to strengthen these approaches by various means, including collaborations with external players (**Fig. 12**).

4.4 R&D for global business expansion

In the sphere of global activities, we have promoted collaboration with major foreign carriers for standardization and joint activities with overseas researchers, mainly in the field of basic research. Recently, we have been reinforcing our ability to achieve global expansion of the use of the latest, world-leading technologies and services introduced by NTT, such as the NGN, FTTH, and IPTV (Internet protocol television).

We are also working with partners that are not telecommunication carriers. For example, when a mine in Chile collapsed last year, Micomo, a local NTT-affiliated venture company that provides ICT services for mine operators, contributed to the rescue of the trapped miners by providing optical fibers and wireless technologies.

We intend to raise the importance of achieving synergy between NTT Laboratories and NTT Group companies overseas, such as Dimension Data, and other companies in which NTT has a stake. We will review the targets and directions of our R&D and create new value to address the NTT Group's global business needs. We will pursue early establishment of a mechanism to accelerate R&D by exploring and adopting promising technologies from around the world, instead of stressing self-development.

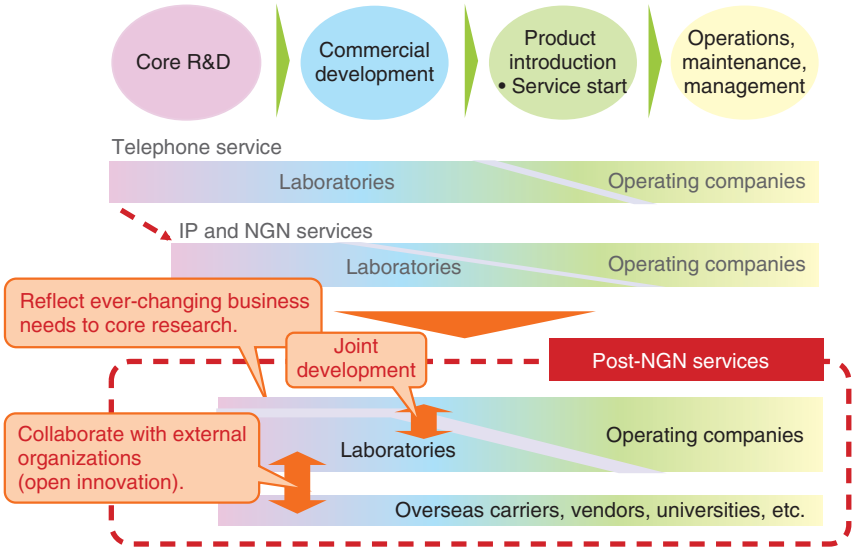


Fig. 12. Increasing pace of R&D.

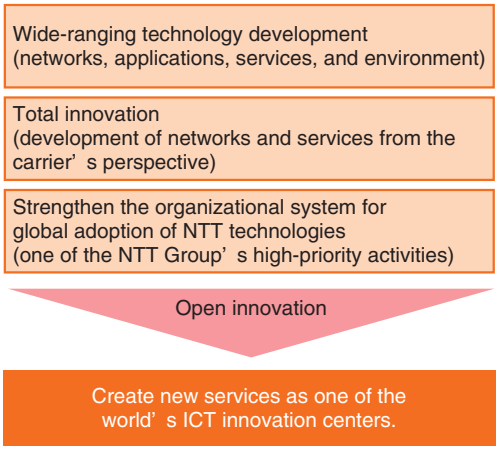


Fig. 13. Aiming to become a world ICT innovation center.

5. Conclusion

NTT will focus its R&D activities in three directions: (i) undertaking R&D on a wide range of technologies, (ii) creating innovations from a carrier's perspective, and (iii) strengthening the organizational system in order to expand global activities. We aim to continuously create new value as one of the world's ICT innovation centers through open collaboration with partners both at home and abroad (**Fig. 13**).

New NTT Group Environmental Vision: Looking to 2020—THE GREEN VISION 2020

Kazuhito Nishi†, *Takeshi Komatsu, and Hironori Shiosaki*

Abstract

In November 2010, the NTT Group formulated its new Environmental Vision, called THE GREEN VISION 2020. The Group identified three environmental themes: creating a low-carbon society, implementing closed-loop recycling, and conserving biodiversity. For each of these themes, we will drive those efforts through three approaches: *Green of ICT*, *Green by ICT*, and *Green with Team NTT* (ICT: information and communications technology).

1. Introduction

Since the beginning of the first commitment period of the Kyoto Protocol in 2008, there has been rapid worldwide growth of interest in environmental problems centering on global warming. In particular, in the quest for international agreements on the post-Kyoto protocol that is due to take effect from 2013, there was intense debate in the Fifteenth Session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP15), held in Denmark in December 2009, and at COP16, held in Mexico in December 2010. In October 2010, the tenth meeting of the Conference of the Parties to the Convention on Biological Diversity (COP10) was held in Nagoya, Japan. This meeting aroused new interest in enterprise-level efforts to help conserve biological diversity.

As global concern regarding global warming mitigation and biodiversity conservation intensifies, there are growing expectations that business enterprises should play key roles. The NTT Group recognizes that it is an important mission of the leading information and communications technology (ICT) service enterprise in Japan to formulate a new environmental vision that looks to 2020 and to publicly announce its commitment to environmental protection.

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2. Environmental actions taken to date

In 1991, the NTT Group formulated the NTT Global Environmental Charter, which aimed to ensure the entire Group's organizational commitment to protection of the global environment (**Fig. 1**). This was followed by the Principal Activity Plan Targets, which spelled out three action plan targets for fiscal 2011: prevention of global warming, reductions in discharged waste, and reductions in paper consumption. In 2006, the Group looked at ways in which the use of ICT services can reduce the environmental impacts of both its customers and society as a whole and formulated the NTT Group Vision for Environmental Contribution, which defined the target of helping to reduce CO_2 emissions by 10 million tons by fiscal 2011. In November 2010, with the achievement of all of these targets clearly in sight, the Group added the conservation of biodiversity to the basic principles of the NTT Global Environmental Charter (**Fig. 2**) and formulated a new vision called THE GREEN VISION 2020 (**Fig. 3**).

3. Concepts of THE GREEN VISION 2020

The objective of THE GREEN VISION 2020 is to harness ICT and the collective strength of Group

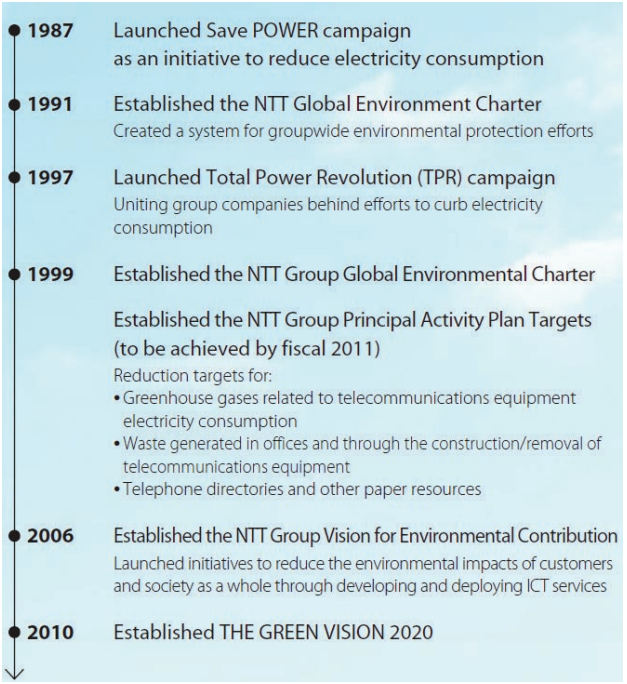


Fig. 1. Timeline of NTT Group's environmental initiatives.

company employees to help encourage people to live in harmony with Planet Earth and thereby ensure the sustained development of society. Specifically, the

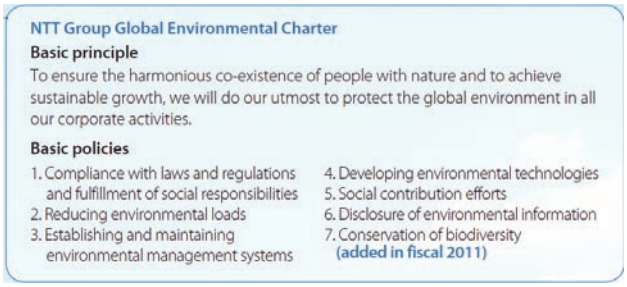


Fig. 2. NTT Group Global Environmental Charter.

Group identified three environmental themes that must be addressed well into the future: creating a low-carbon society, implementing closed-loop recycling, and conserving biodiversity. For each theme, the Group will make positive efforts through three approaches: *Green of ICT*, *Green by ICT*, and *Green with Team NTT*.

These three environmental themes spell out what the NTT Group needs to focus on and sets specific targets. For example, in pursuit of a low-carbon society, we aim to reduce CO_2 emissions from Group companies throughout Japan and also reduce CO_2 emissions made by society at large through the provision of ICT services. Similarly, quantitative targets and specific action plans are defined for the creation

Fig. 3. THE GREEN VISION 2020.

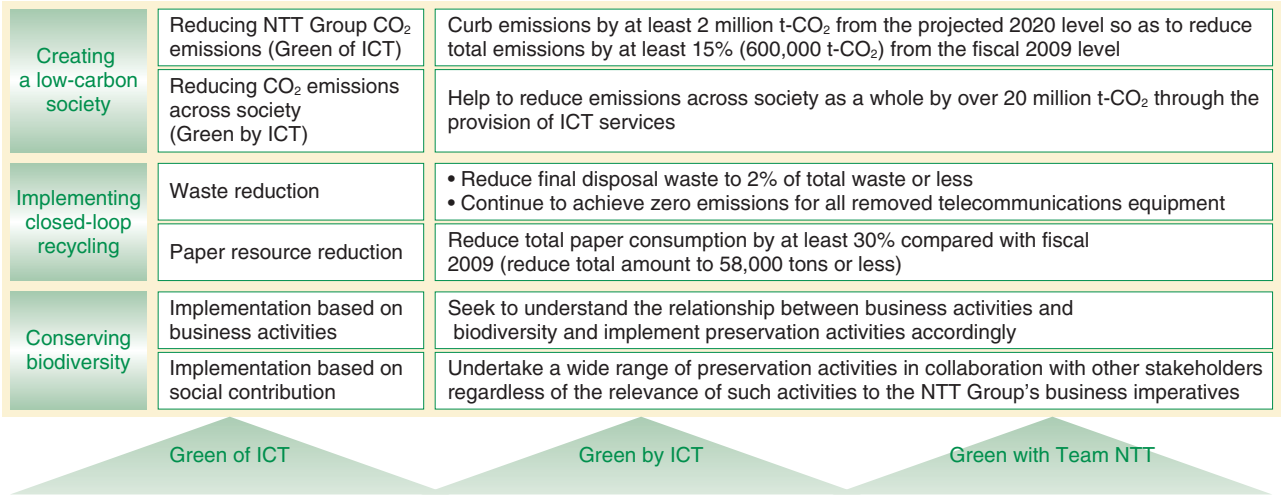


Fig. 4. Targets and concepts of activities for fiscal 2021.

of a recycling-oriented society and conservation of biodiversity. The Group will contribute to the sustained development of society through the achievement of these targets (**Fig. 4**).

The abovementioned action terms have the following meanings: Green of ICT means reducing the environmental impacts of the NTT Group's business activities, Green by ICT means contributing to reductions in the environmental impact of society at large through the provision of ICT services; and Green with Team NTT refers to contributions to be made by NTT Group company employees and members of their families to a variety of environmental conservation activities in their homes and local communities as well as workplaces.

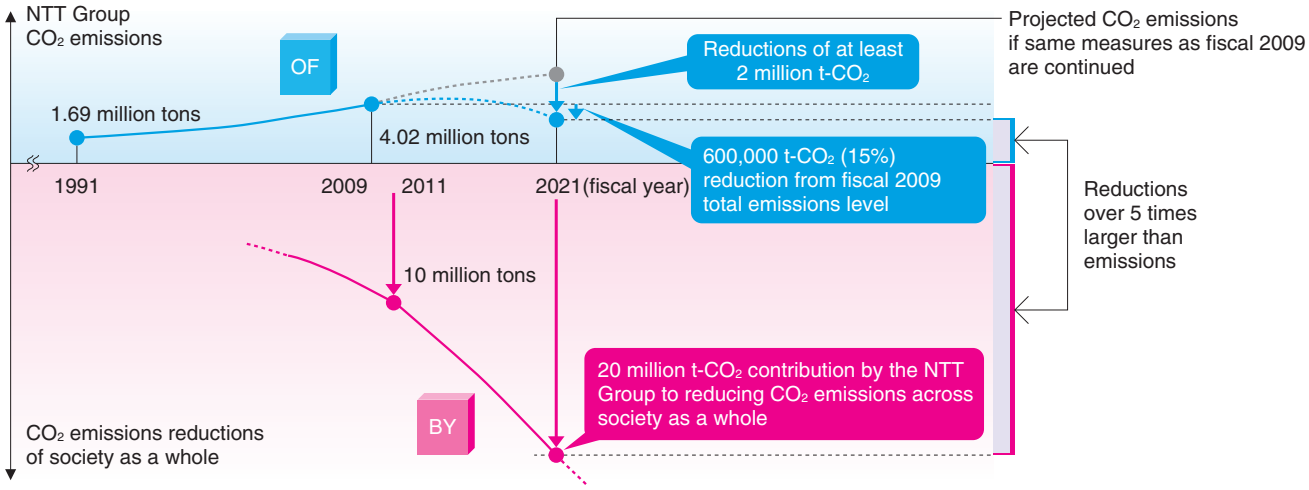
4. Creating a low-carbon society

With a view to mitigating global warming, the NTT Group aims to help achieve a low-carbon society by reducing CO_2 emissions generated by its regular business operations and by contributing to reductions in CO_2 emissions produced by society at large by promoting widespread use of ICT services (**Fig. 5**).

4.1 Reducing NTT Group CO_2 emissions

As a consequence of the increase in power consumption resulting from the explosive growth in the use of the Internet and mobile phones since 1990, CO_2 emissions from the NTT Group increased about 2.4-fold between fiscal 1991 and fiscal 2009. If we were to simply maintain our current energy-saving efforts, our predicted CO_2 emissions would further increase owing to the greater power consumption involved in building the advanced broadband network infrastructures that will be required in order to expand the area served by the Next Generation Network (NGN), introduce the high-speed, high-capacity mobile broadband network called Long-Term Evolution (LTE), and increase the number of datacenters.

To counter this trend, we will make stronger efforts to reduce power consumption through what we call the Total Power Revolution campaign, which involves the entire NTT Group. This campaign entails a broad spectrum of activities ranging from improving or upgrading telecommunications facilities, including air conditioning facilities, in order to reduce their energy consumption, to encouraging individual employees to save energy by, for example, dressing for work in ways that help minimize the need for air-conditioning and turning off unnecessary lighting. Furthermore, we will introduce highly energy-saving ICT facilities that conform to the NTT Group Energy Efficiency Guidelines, implement research and development (R&D) of energy-saving technologies, and promote the policy of Green NTT, which calls for increased use of natural energy with an emphasis on photovoltaic power generation. Through these efforts, we aim to reduce CO_2 emissions by at least 2 million tons by fiscal 2021, which is a proposed 15% (0.6



- Using the Federation of Electric Power Companies of Japan's value of 0.33 kg/kWh as the emission coefficient for setting the fiscal 2021 target

Fig. 5. Reduction in CO_2 emissions by fiscal 2021.

million tons) decrease from the fiscal 2009 level.

4.2 Reducing CO_2 emissions across society

The use of ICT services is expected to contribute to reductions in CO_2 emissions by society as a whole because it can potentially reduce the amount of physical movement of people and things, thereby improving the efficiency of energy usage. The NTT Group will contribute to a reduction in CO_2 emissions across society by more than 20 million tons through its efforts to achieve smart communities. Such efforts include the provision of ICT services such as video-conferencing, teleworking, telemedicine, and electronic filing of applications and requests via the Internet; provision of services that help occupants to visualize energy use in homes and other buildings; and control of energy generation and energy storage devices.

To calculate and publicize reductions in public CO_2 emission levels, it is necessary to identify the amount of reduction achieved through the provision of specific services, and it is important to standardize the method of calculating CO_2 emissions reductions so that the measurements can be used for international comparison. The NTT Group will work to achieve international standardization of such methodology.

5. Implementing closed-loop recycling

With a view to helping to achieve effective use of non-renewable natural resources, the NTT Group is working to help create a recycling-oriented society by reducing the waste discharged and paper consumed in its regular business operations.

5.1 Waste reduction

The various types of waste generated by the NTT Group's business operations can be broadly classified into construction waste generated when buildings are constructed or dismantled; telecommunications facility waste generated when telephone poles, switches, or telecommunication cables are dismantled; and office waste, such as glass and plastic bottles and cans. As of fiscal 2009, thanks to our long-established programs for reusing and recycling waste materials, we had reduced the proportion of waste subject to final disposal to 2.4%. However, because it is unlikely that our current activities will sustain this low proportion in light of an anticipated increase in the number of old buildings that need to be demolished, we will endeavor to achieve a sub-2% level of disposable waste by adopting design, operation, and disposal methodologies that are conducive to extending the lives of buildings, by reusing and recycling wherever possible, and by reinforcing intermediate treatment of waste materials, thereby eliminating the need to send any waste materials directly to final disposal sites. In particular, we will continue to target *zero emissions* (defined as final disposal proportion under 1%) in terms of telecommunications facility waste (**Fig. 6**).

In addition, we will contribute to reductions in the

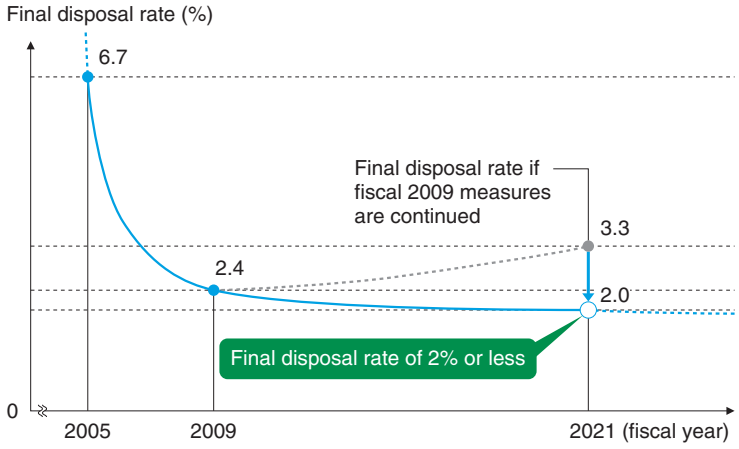


Fig. 6. Reduction in the proportion of waste subject to final disposal by fiscal 2021.

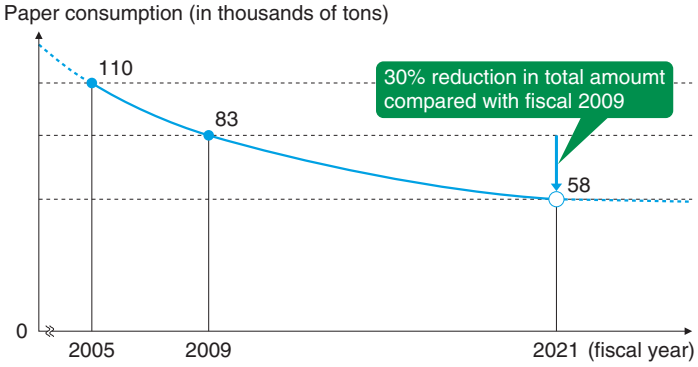


Fig. 7. Reduction in use of paper resources by fiscal 2021.

waste generated by society as a whole by promoting our business of reusing or recycling personal computers and by providing appropriate ICT services and solutions that will encourage paperless transactions.

5.2 Paper resource reduction

The NTT Group sends a substantial amount of paper to its customers in the form of telephone directories and bills. To help create a recycling-oriented society, it is important to reduce this paper consumption. We aim to make effective use of paper resources by closing the loop to create a recycling system whereby new telephone directories are produced using recycled paper from obsolete directories and by checking whether or not each customer wants a telephone directory when he or she moves or subscribes to a telephone service in order to eliminate unnecessary printing of telephone directories. We will reduce the need for paper bills by expanding our e-billing service whereby customers can view their bills online or receive details by email. We will also reduce the use of paper in offices by making the amount of paper consumed clearly visible, promoting paperless conferences, and using electronic booking systems. Through such measures, we aim to reduce paper consumption by more than 30% from fiscal 2009 levels (to below 58 thousand tons) as of fiscal 2021 (**Fig. 7**).

6. Conserving biodiversity

To help conserve biodiversity, the NTT Group will enhance and reinforce its existing activities on the basis of two new approaches formulated in accordance with the basic principles of the NTT Global Environmental Charter (**Fig. 8**).

Fig. 8. NTT Group's policy for biodiversity.

In the approach based on business activities, the NTT Group will seek to better understand the relationships between its business activities and biodiversity and will continue to pursue those activities that are effective in helping to conserve biological diversity. Specifically, we will ascertain the impact made by the construction of telecommunications facilities on the ecosystem by carrying out assessments before construction starts and through ongoing monitoring after construction has been completed, and we will implement conservation activities accordingly. Paper for use in our business operations will be procured in an environmentally friendly manner, and we will continue to work on ways to minimize water usage. We will also strengthen conservation activities by making the most of our R&D results and technologies developed in the course of our business operations and our processes for transmitting relevant information to the public via the Internet.

In the approach based on contributions to society, we will undertake a wide range of conservation activities regardless of their relevance to the NTT Group's business imperatives. For example, we will collaborate with local communities and non-governmental organizations on the promotion of forest conservation activities, and we will contribute to the protection and nurturing of forests that play important roles in sustaining biological diversity.

7. Green with Team NTT

In addition to activities undertaken in the context of the NTT Group's business operations, individual employees of the Group will seek to be eco-friendly in the office, at home, and in local communities in order to contribute to reductions in the environmental impacts of human activities. The Environmental Vision adds Green with Team NTT to the ongoing activities of Green of ICT and Green by ICT. Harnessing the powerful resource of the many people involved in or with the NTT Group, such as employees, family members, and retirees, we will undertake activities that help to preserve the environment and contribute to local communities. For example, our people will contribute to CO_2 emissions reductions by saving energy at home, by practicing eco-friendly driving as learned through in-company training, and by participating in activities to clean up local environments under the Operation Clean Environment.

8. Future activities

Activities in pursuit of THE GREEN VISION 2020 will get underway in fiscal 2012. To achieve this Vision, NTT Group companies and their employees need to make concerted efforts to reduce environmental impacts on an ongoing basis. Therefore, we will review the organizational structure for promoting environmental protection activities throughout the Group and ensure that the performance of these activities is well managed.

Looking toward to fiscal 2021, we will contribute to the sustained development of a society in which humans live in harmony with the Earth by harnessing ICT and our human resources, which are the NTT Group's strengths, in order to reduce the environmental impact of society as a whole.

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Green R&D Activities

NTT Information Sharing Laboratory Group[†1] ,
NTT Cyber Communications Laboratory Group[†2] ,
and NTT Science and Core Technology Laboratory Group[†3]

Abstract

This article describes NTT's green research and development for reducing the environmental impact of society by reducing the impact of information and communications technology (ICT) installations in telecommunication centers, datacenters, and customers' offices and homes (Green of ICT) and by reducing the impact in other sectors by providing various kinds of ICT services (Green by ICT).

1. Introduction

The NTT Group seeks to reduce the environmental impact of society as a whole by reducing the environmental load of information and communications technology (ICT) platforms and changing lifestyles through the use of ICT. However, it is difficult to achieve this goal by using conventional technology. Therefore, we think that a breakthrough is needed. NTT seeks to provide ICT services that contribute to the resolution of global environmental issues. All of our research laboratories are engaging in green R&D.

We have created four categories of ICT-related research and development (R&D) for contributing to reduced environmental impact.

(1) Technology that contributes to reducing CO_2 emissions in our telecommunication buildings and datacenters and by telecommunication equipment/facilities required for telecommunication service provision
(2) Technology that contributes to reducing CO_2 emissions from telecommunication devices in offices and homes
(3) Technology that contributes to resource savings for telecommunication facilities/equipment
(4) Technology that evaluates the environmental effect by quantifying CO_2 reductions achieved by using ICT

The collaboration of all research laboratories is essential to effectively and efficiently promote the abovementioned R&D. An overview of the R&D themes for CO_2 reductions and resource savings technology categories is given in **Table 1**. We have also organized meetings for discussing strategies, policies, and tasks related to CO_2 emissions and sharing information about these themes. Furthermore, to achieve the goals of THE GREEN VISION 2020 and realize further drastic CO_2 reductions, we are conducting a plan-do-check-act (PDCA) cycle for each of the themes.

Moreover, to promote the procurement and development of ICT equipment that achieves further energy savings, all laboratories are actively participating in the establishment and revision of the NTT Group Energy Efficiency Guidelines that were established in April 2010.

Specific actions are described below.

2. NTT's Green R&D

2.1 CO_2 reductions in telecommunication buildings and datacenters

The configuration of telecommunication installations in NTT's telecommunication buildings has changed rapidly along with the spreading use of the

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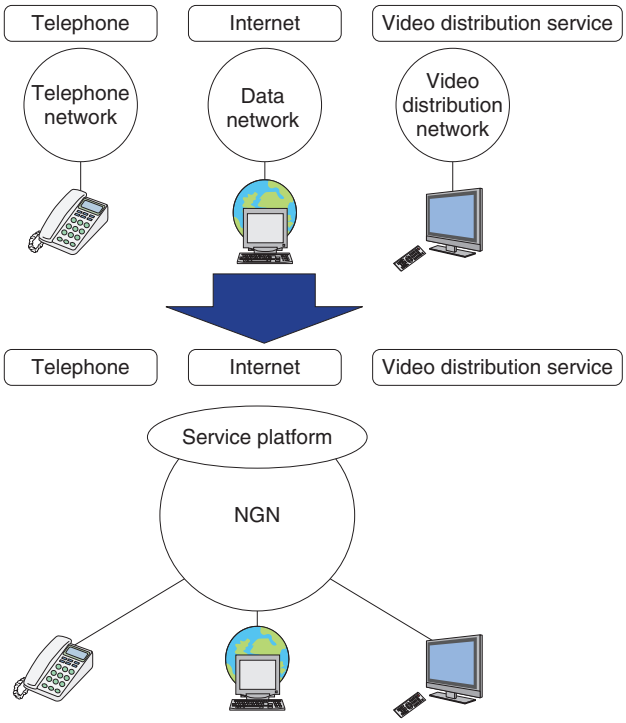
Table 1. R&D themes for achieving environmental load reductions.

Categories	R&D themes
CO_2 reductions in telecommunication buildings and datacenters	Core network: low power consumption of telecommunication equipment, architecture, migration, etc.
	Access systems: low power consumption of telecommunication equipment, sleep-mode function, etc.
	Energy saving through use of cloud computing
	Reduced power loss by distribution method, CO_2 reductions through use of fuel cells
	Ultralow-power devices based on innovative technologies
CO_2 reductions in office buildings and homes	Energy reductions for telecommunication devices in offices and homes
	Energy management system, DC power distribution in homes
Resource savings for telecommunication facilities/equipment	No-dig technologies for repairing underground conduits
	Repair technologies for conduits attached to bridge
	Reduction in use of volatile organic compounds in paint

Internet. The change from the plain old telephony system to optical fiber has created high-speed broadband communication, which has helped to make a more convenient society. However, this change has also resulted in increased power consumption of telecommunication equipment and facilities.

Therefore, NTT is working to develop technologies for achieving efficient usage and reducing the energy consumed by various network facilities and equipment owned by the NTT Group. Furthermore, we are cooperating with NTT Facilities in regards to air-conditioning technology that is expected to show significant power savings for telecommunication installations. In addition, to achieve effective ventilation control, we are conducting R&D to achieve energy savings in telecommunication installations that are linked with highly efficient air-conditioning systems.

As part of our efforts to achieve low power consumption for all of the telecommunication networks, we are working to provide multiple services within a single network and reduce power consumption through network integration that efficiently uses network facilities (**Fig. 1**). We are also promoting R&D aimed at low power consumption for each individual network device. Particular attention is being given to the access networks, which account for more than half of the power consumed by the entire network. We are focusing on achieving low power consumption for network devices by integrating chips and reducing the number of components. Furthermore, we are conducting research on lower power consumption in future networks. One such research topic is hybrid optoelectronic router technology ((1) in **Fig. 2**),



NGN: Next Generation Network

Fig. 1. Representative example of network integration (NGN case).

which enables a dramatic reduction in a router's power consumption by minimizing optical-to-electrical and electrical-to-optical signal conversions while maintaining high-efficiency operation. This will become one of the foundations of future high-speed

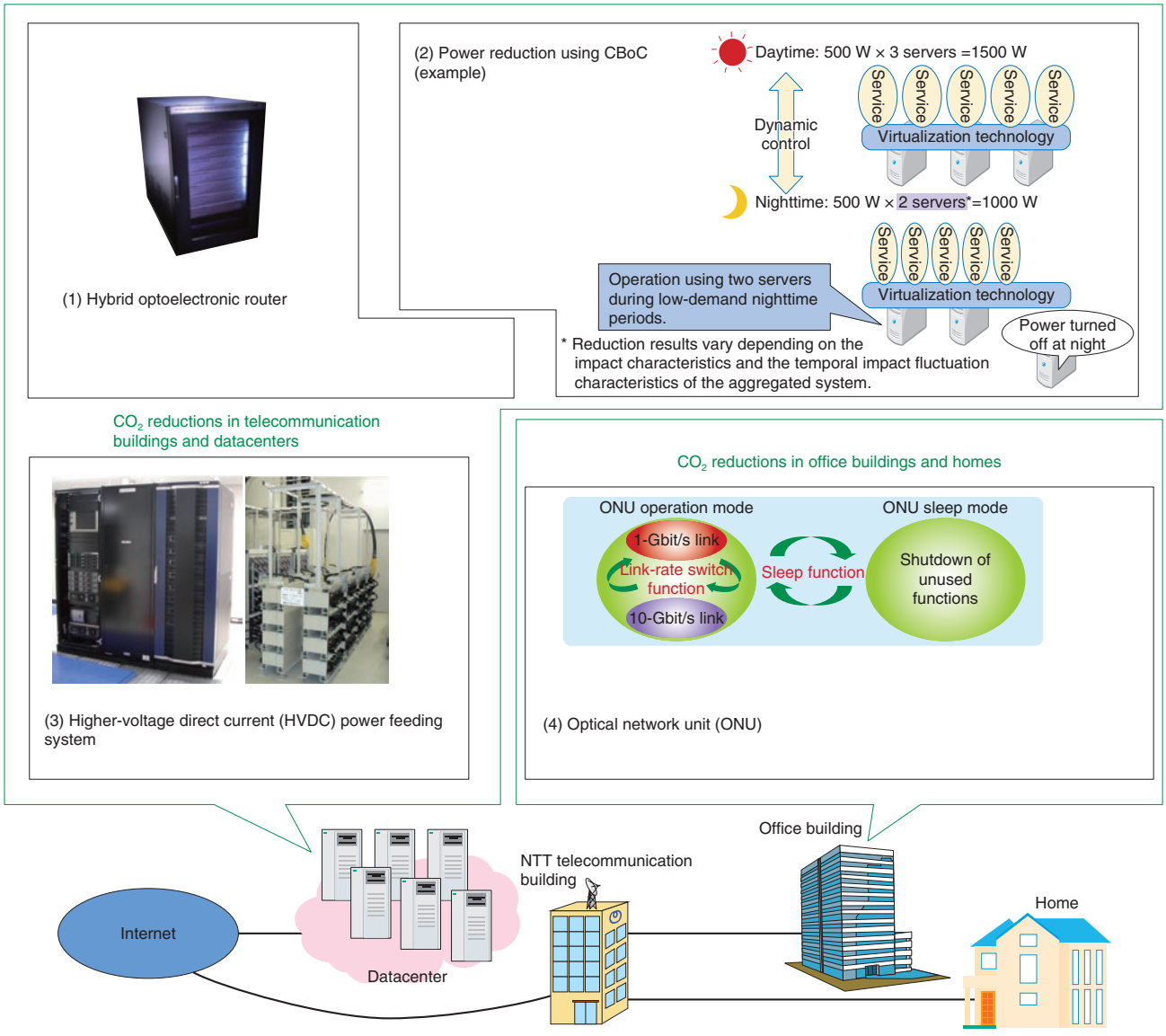


Fig. 2. Examples of technologies for reducing CO_2 emissions in telecommunication services.

large-capacity telecommunications.

In the future, in response to forecasts of increased power consumption in datacenters, we will examine the energy saving effects of cloud computing technologies called CBoC (Common IT Bases over Cloud Computing (IT: information technology)) [1]. They aim to create a safe and secure open cloud that can be utilized for electronic government, core corporate functions, and other social infrastructures that require a high degree of reliability and public functionality. Furthermore, virtual operation management functions can be used to reduce the number of physical servers, aggregate operating servers, and perform dynamic control in accordance with traffic conditions. This will reduce power consumption by decreasing unnecessary server operations ((2) in Fig. 2).

In addition to focusing on power consumption, we are also conducting R&D to increase the efficiency of the energy supply to equipment located within telecommunication buildings and datacenters. This research has resulted in the higher voltage direct current power (HVDC) feeding system [2] ((3) in Fig. 2), which was developed through cooperation with NTT Facilities. To handle the rising power consumption of ICT equipment, the conventional 48-V power supply system feeds an electrical current of several hundred

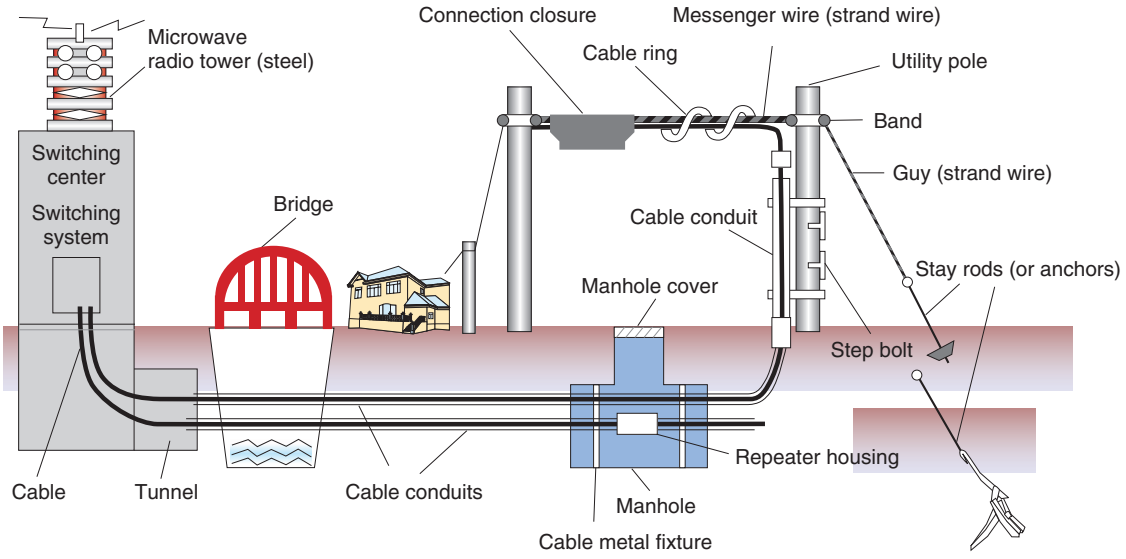


Fig. 3. Typical outdoor structures and equipment.

amperes. As a result, there is a loss of current due to the resistance of the power cable (heat loss). Another problem is that the cable is heavy and hard to bend, which leads to poor workability. Even worse, it uses a lot of copper. Moreover, since installations such as existing datacenters use alternating current (AC) power supplies, there are many AC-DC and DC-AC conversions before the power reaches the ICT equipment. This also results in power losses. The HVDC power feeding system is effective for solving these problems. Using this technology, we have raised the power supply voltage to approximately 380 V and now supply power to ICT equipment by DC. This has enabled us to reduce the number of conversions and decrease the power loss. Furthermore, decreasing the electric current makes it possible to use thinner and lighter cables. This leads to decreased use of resources such as copper and plastic.

As breakthrough technology for achieving the drastic CO_2 reductions that will be required after 2020, we are actively researching fundamental technologies such as single-electron devices, nanoelectromechanical systems (NEMS), and silicon photonics. To examine the direction of future network architectures and elemental technologies, we plan to work toward Ultra Green ICT, which will achieve efficient and dramatic reductions in the amount of energy used.

2.2 CO_2 reductions in office buildings & homes

The spread of the Internet has resulted in increased use of telecommunication devices in homes and offices. The amount of power consumed in homes accounts for approximately 14% (FY2008) [3] of domestic power consumption when classified by industrial field. Furthermore, the amount of home power consumption related to telecommunication devices has also increased.

Telecommunication devices installed in customer offices and homes are used 24 hours a day, 7 days a week. Therefore, even a small reduction will lead to a large overall reduction. Focusing on this fact, NTT is conducting R&D for technology that will decrease power consumption associated with telecommunications in offices and homes. For example, we will develop advanced energy-saving technology for optical network units (ONUs) and low-power-consumption devices for broadband routers.

In the case of ONUs, in addition to achieving lower power consumption for the equipment while it is operating, we are actively examining a sleep function that will shut down some ONU functions [4] when the amount of traffic is low and a link rate switch function that will change the speed of the link between the ONU and the optical line terminal located in the telecommunication building in accordance with the traffic volume ((4) in Fig. 2).

2.3 Resource savings for telecommunication facilities

The NTT Group owns a large number of facilities

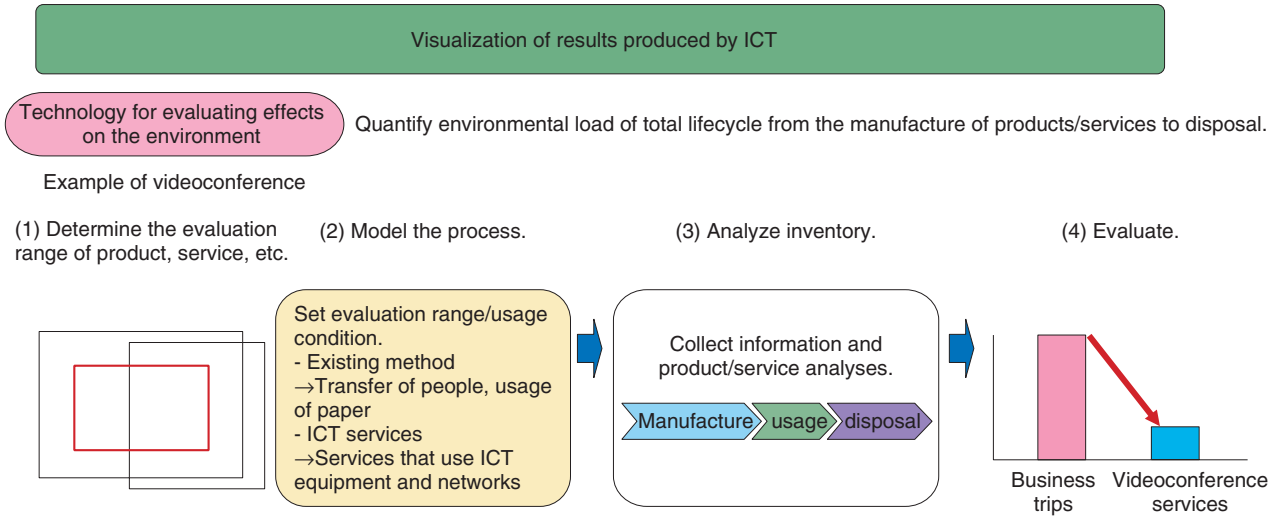


Fig. 4. Visualization of results by produced ICT.

for providing communication services (**Fig. 3**). These facilities are renewed as necessary at the end of their useful lifespans or replaced in order to support new services. The facilities contain rare earths and scarce metals and use plastic derived from fossil fuels as well as base metals such as copper and iron.

NTT is conducting R&D to reduce the amount of resources used in telecommunication facilities and equipment. Our research focuses on extending the lifespans of current facilities, reducing the consumption of resources by increasing the density and compactness of facilities, and reducing the use of resources through new methods and technologies.

For example, we are conducting R&D for technology to repair conduits used to lay cable underground and conduits for attaching cables to bridges. Moreover, in consideration of the environment, we are reducing the use of volatile organic compounds (VOCs) in paint utilized to prevent corrosion on various building structures. Other research topics include technology for evaluating quality [5].

2.4 ICT-based visualization of environmental impact reduction results

ICT can increase the efficiency of manufacturing, consumer, and business activities, provide alternatives to physical movement and distribution, and alleviate traffic jams. It can also reduce power consumption and CO_2 emissions while contributing to decreased environmental impact. As a method for quantitatively and objectively evaluating such results, we are currently studying and standardizing [6] the visualization of results produced by ICT, i.e., a technology for evaluating effects on the environment (**Fig. 4**).

Fig. 5. Label for certified eco-friendly solutions.

One specific activity is the environmental label system for eco-friendly solutions [7], [8] that was established in 2009 (**Fig. 5**). This system evaluates the environmental effect of ICT solutions provided by the NTT Group. Solutions with results that exceed defined criteria are certified as environmentally friendly solutions. Through this system, we hope to provide customers and society with easy-to-understand information regarding services that are highly effective at reducing environmental impact.

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High-speed Low-power Digital-to-Analog Converter Using InP Heterojunction Bipolar Transistor Technology for Next-generation Optical Transmission Systems

Munehiko Nagatani† *and Hideyuki Nosaka*

Abstract

We have developed a high-speed low-power 6-bit digital-to-analog converter (DAC) for next-generation optical transmission systems. To achieve both high-speed and low-power performance, we used a simple R-2R ladder-based current-steering architecture and devised a new timing alignment technique. A DAC test chip was fabricated using our in-house InP-based heterojunction bipolar transistor (HBT) technology. It operates at a sampling rate of up to 28 giga-samples per second (GS/s) with low-power consumption of 0.95 W and achieves a better figure of merit (0.53 pJ per conversion step) than any other previously reported DAC with a sampling rate above 20 GS/s. It also provides a clear multilevel modulated signal and can be applied to post-100-Gbit/s/ch multilevel optical transmission systems.

1. Introduction

Coherent optical data transmission schemes with multilevel modulation formats are now attracting a great deal of attention and are being investigated in terms of suitability for future cost-effective optical transport networks. High-order multilevel modulation formats, such as 16-QAM and 64-QAM (QAM: quadrature amplitude modulation), are especially promising techniques for constructing post-100-Gbit/s/ch optical transmission systems [1]–[3]. An example of a transmitter for such systems is shown in **Fig. 1**. In the transmitter, high-speed digital-to-analog converters (DACs) are key components for generating modulated signals. DAC performance requirements depend on the target bit rate and the modulation format. For example, for a 160-Gbit/s/ch-class polarization-division-multiplexing (PDM) 16-QAM system, which has a baud rate of 20 Gbaud, a sampling rate of above 20 giga-samples per second (GS/s) and a resolution of 6 bits or more are needed.

Recently, high-speed (> 20 GS/s) 6-bit DACs based on SiGe heterojunction bipolar transistor (HBT)

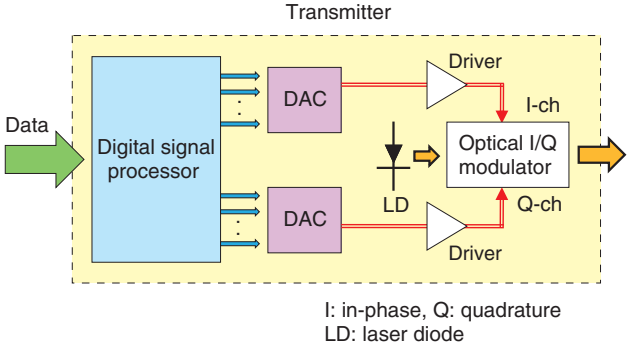

Fig. 1. Transmitter for multilevel optical transmission.

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technology for such optical transmission systems have been reported [4]–[6]. Recent scaled SiGe HBT technology offers high-speed operation, but care is often needed to avoid device mismatch, such as transistor variation, especially for mixed-signal integrated circuits (ICs), such as DACs. They achieve a sampling rate of over 20 GS/s, but consume more than 2 W owing to their complicated circuit architectures to overcome device mismatch and improve their linearity.

This article describes the circuit design and measured performance of a high-speed low-power DAC using InP HBT technology. InP HBT technology offers high-speed operation with larger devices than SiGe HBT technology because of its inherent excellent high-speed performance. Therefore, it provides higher tolerance to device mismatch and a higher breakdown voltage with the drawback of smaller-scale integration. It enables us to choose a simpler circuit architecture and helps achieve low-power operation. InP HBTs are attractive for making high-speed, low-power, high-sensitivity mixed-signal ICs, such as DACs. We previously reported a 32-GS/s 6-bit 1.4-W DAC [7] using our in-house 1-μm-emitter InP HBT technology, which yields a peak cutoff frequency (ft) of 175 GHz and a peak maximum oscillation frequency (f_{max}) of 260 GHz. In this article, we present our updated lower-power DAC using the same technology [8]. To achieve high speed, lower power, and higher dynamic linearity, we used a simple R-2R ladder-based current-steering architecture and devised a new timing alignment technique, which helps suppress the glitch noise in the analog output and achieve high dynamic linearity. The DAC with the timing alignment technique can operate at a sampling rate of up to 28 GS/s and has, at the same time, high dynamic linearity with low-power consumption of 0.95 W. It also provides a clear multi-level modulated signal and can be applied to post-100-Gbit/s/ch optical transmission systems.

This article is organized as follows. Section 2 describes the circuit design of the high-speed low-power DAC. Section 3 presents measurement results for the test chip. Section 4 compares our DAC with state-of-the-art DACs. Finally, section 5 summarizes this work.

2. Circuit design

2.1 Current-steering DACs

Most high-speed DACs are based on a current-steering architecture [9], [10]. There are three main ones for high-speed DACs, as shown in **Fig. 2**: binary-weighted current-steering DAC, R-2R ladder-based current-steering DAC, and segmented current-steering DAC.

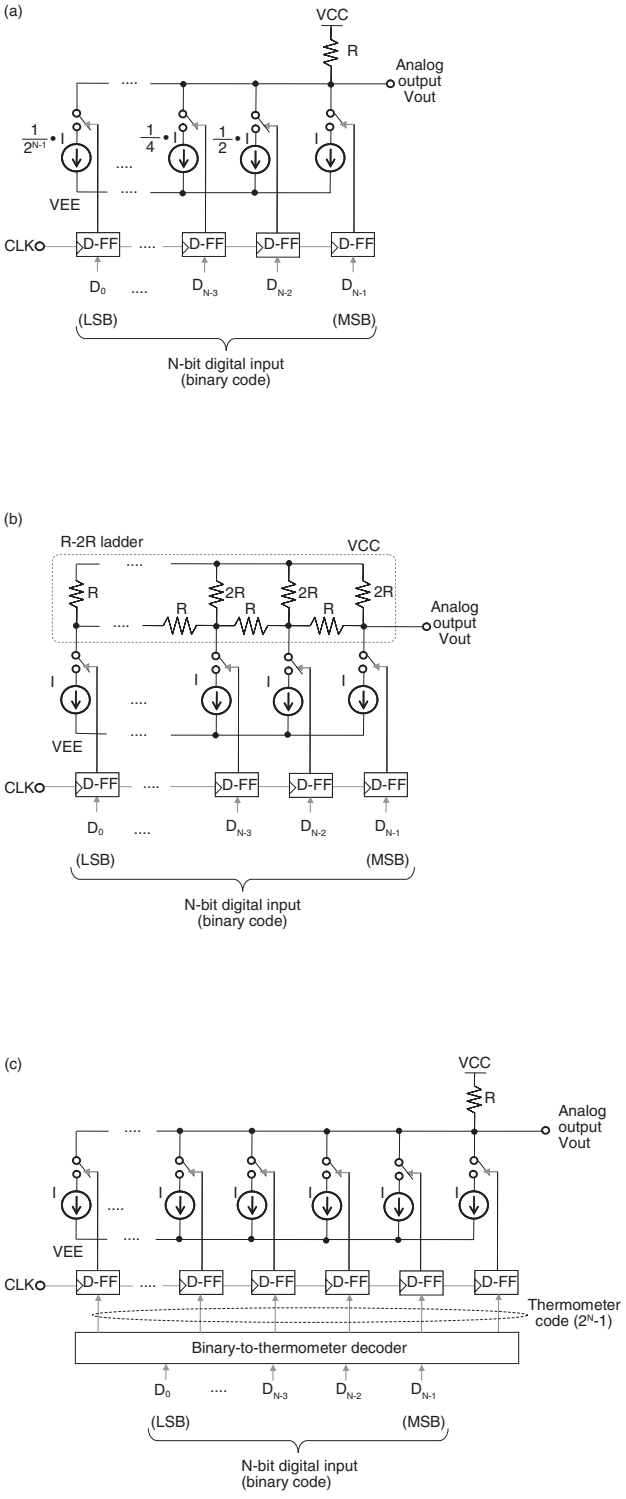
The binary-weighted current-steering DAC consists of binary-weighted current sources, current switches, a single resistor (R), and D-type flip-flops (D-FFs). The D-FFs are placed just before current switches to reduce the timing skew of incoming digital data (D_0–D_{N-1}). This DAC has the simplest architecture but the highest demand for the matching requirement. It is hard to implement accurate binary-weighted current sources for high-resolution DACs.

The R-2R ladder-based current-steering DAC is one solution for achieving higher resolution. In this architecture, each current source has the same value. The R-2R ladder network can be implemented with a combination of unit resistors. Therefore, it is easier to achieve relative matching among devices and implement higher resolution.

The segmented current-steering DAC has a binary-to-thermometer-code decoder and 2^{N-1} identical current sources. This architecture has the highest tolerance to device mismatch, but needs additional building blocks and many parallel current switches and consumes much more power than the other two.

A simpler architecture is a better choice for achieving both high-speed and low-power operation. However, one should choose an architecture by considering the strengths and weaknesses of the given technology. For example, high-speed 6-bit DACs with scaled SiGe HBT technology are based on a partially segmented architecture, which is a combination of segmented and binary-weighted architectures, to overcome device mismatch and achieve high linearity. On the other hand, our in-house InP HBT technology enables us to choose a simpler R-2R ladder-based architecture for 6-bit resolution. Therefore, an R-2R ladder-based current-steering architecture is an appropriate choice for our InP HBT technology to achieve a DAC that features both high speed and low power.

However, with an R-2R ladder-based current-steering DAC, one must pay careful attention to glitch noise in the analog output, which is caused mainly by the timing skew of the digital data that controls the current switches. As the sampling rate increases, it becomes more difficult to distribute the clock signal simultaneously among the retiming D-FFs. In other words, when the sampling rate is very high, the D-FFs cannot suppress the timing skew of the incoming data, resulting in large glitches in the analog



CLK: clock
LSB: least significant bit
MSB: most significant bit
VCC: collector supply voltage
VEE: emitter supply voltage

Fig. 2. Current-steering architectures. (a) Binary-weighted, (b) R-2R ladder-based, and (c) segmented.

output, especially when the data changes from "011111" to "100000" where all current switches change. Thus, this DAC requires very strict timing alignment. In our previous work [7], to overcome this problem we devised a novel double-sampling technique that relaxes the speed restraint on the clock distribution. However, it needs additional circuits and therefore consumes additional power. In this work, to achieve high speed, lower power, and higher dynamic linearity, we devised a new timing alignment technique that helps achieve accurate timing alignment for the current switches and suppress the glitch noise in the analog output without any additional circuits, as explained in section 2.2.

2.2 Timing alignment technique

A simplified schematic of the R-2R ladder-based current-steering DAC used in this work is shown in **Fig. 3**. The building blocks have a differential architecture (**Fig. 4**). The incoming data (D_M) is converted into a differential signal in the input buffer. This differential signal is then latched and retimed by the D-FF on the basis of a standard master-slave flip-flop. There is a two-stage buffer between the D-FF and current switch to eliminate clock noise and suppress the data feed-through. The retimed and smoothed differential signal drives the current switch, which is based on a differential pair with emitter-degeneration resistors to suppress the overshoot in the analog output. We carefully designed the differential R-2R ladders to have an output impedance of 50 Ω to match the 50-Ω load.

As mentioned in section 2.1, we devised a timing alignment technique to help achieve accurate timing alignment for the current switches. This technique is based on the layout and wiring techniques. The rough layout of the 6-bit DAC test chip is shown in **Fig. 5**. The DAC core consisting of six current-switching cells and differential R-2R ladders was placed at the center of the chip. Six retiming D-FFs were symmetrically placed around the DAC core. The clock paths from the clock distributor to the upper four D-FFs (L_{CLK5}–L_{CLK2}) were designed to be equal in length. The data paths from the upper four D-FFs with the two-stage buffers to the upper four current switches (L_{D5}-L_{D2}) were also designed to be equal in length. Therefore, the clock and data paths for the upper four bits are fully symmetrical. On the other hand, the clock paths from the clock distributor to the lower two D-FFs (L_{CLK1} and L_{CLK0}) were designed to be equal in length but shorter than the upper four. The difference in length between the upper four and the

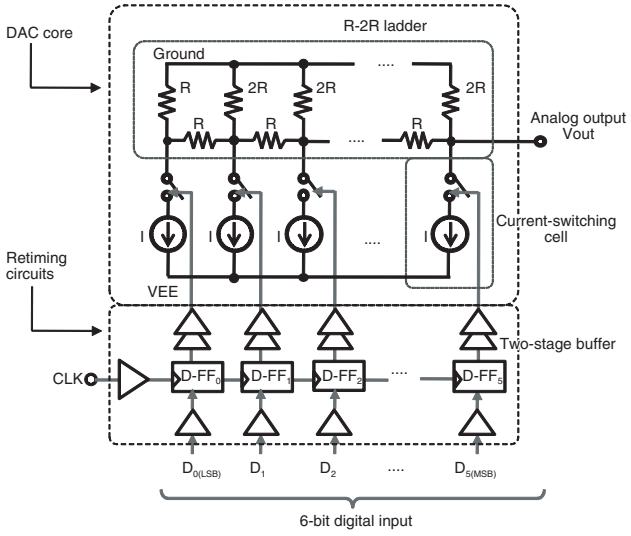


Fig. 3. Schematic of the DAC.

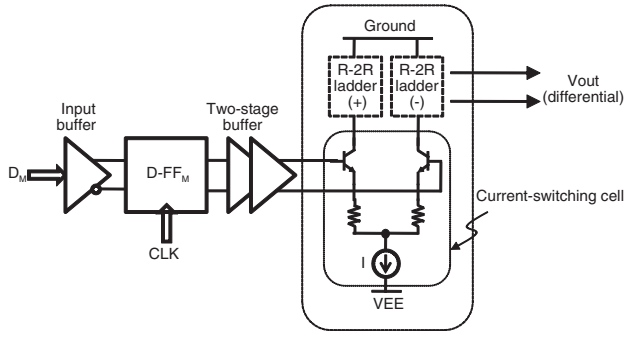


Fig. 4. Differential architecture.

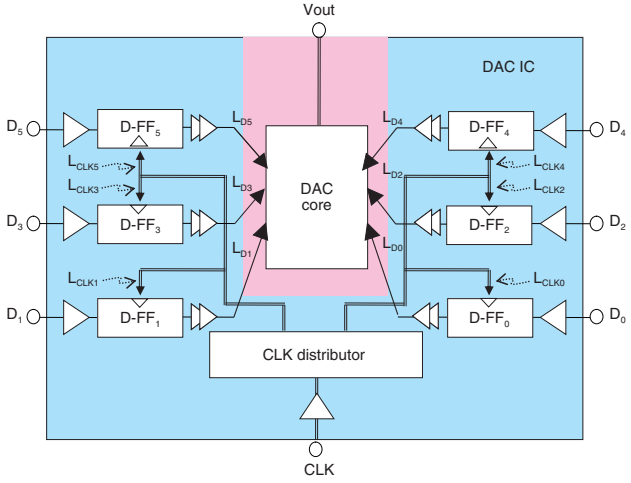


Fig. 5. Rough layout of the DAC.

lower two causes timing skew between the upper four data and the lower two data. To suppress this timing skew, the paths from the lower two D-FFs with the two-stage buffers to the lower two current switches (L_{D1} and L_{D0}) were designed to be longer than the upper four. In short, we designed the interconnect paths to satisfy the following equation:

$$L_{CLK5}+L_{D5}=L_{CLK4}+L_{D4}=L_{CLK3}+L_{D3} =L_{CLK2}+L_{D2}=L_{CLK1}+L_{D1}=L_{CLK0}+L_{D0}. \quad (1)$$

With these layout and wiring techniques, all 6-bit data (D_0–D_5) can be aligned accurately at the current switches. The DAC consequently has small glitches and achieves good dynamic linearity without additional circuits.

3. Measured results

3.1 Process technology

The 6-bit DAC test chip was fabricated using our in-house InP HBT technology [11]. Each HBT has a 70-nm-thick undoped InP emitter, a 50-nm-thick carbon-doped InGaAs base, and a 300-nm-thick InGaAs collector. The size of the lateral emitter of the standard HBT is 1 μm × 4 μm. The fabricated HBTs have a peak cutoff frequency (f_t) of 175 GHz and a peak maximum oscillation frequency (f_{max}) of 260 GHz. The technology also features two metal interconnect layers.

3.2 Performance

A microphotograph of the R-2R ladder-based current-steering DAC with the timing alignment technique is shown in **Fig. 6**. The chip contains approximately 1100 elements and measures 3 mm × 3 mm.

The DAC was tested on-wafer using a probe station and high-frequency probes. It consumes total power of 0.95 W with a supply voltage of –4.0 V. Approximately 75% of the power is consumed by the retiming circuits consisting of the clock and data buffers, clock distributor, D-FFs, and two-stage buffers. The DAC core consumes only 0.24 W.

The measured differential nonlinearity (DNL) and integral nonlinearity (INL) are within +0.68/-0.16 LSB and +0.17/-0.68 LSB, respectively, where LSB stands for the least significant bit (**Fig. 7**). These results demonstrate that the R-2R ladder-based architecture is an appropriate choice for our InP HBT technology to achieve 6-bit resolution. The measured sinusoidal output waveforms for 72.5 MHz at a sampling rate of 13.5 GS/s are shown in **Fig. 8**. The

measured spurious-free dynamic range (SFDR) versus output frequency is summarized in **Fig. 9**. The SFDR remained above 36 dB up to the Nyquist frequency. These results show that the DAC has very good dynamic linearity over the entire Nyquist bandwidth.

Owing to the limited output data rate of our pulse-pattern generator, we could not measure the dynamic characteristics for a sinusoidal output at rates above 13.5 GS/s. Instead, we measured ramp-wave outputs

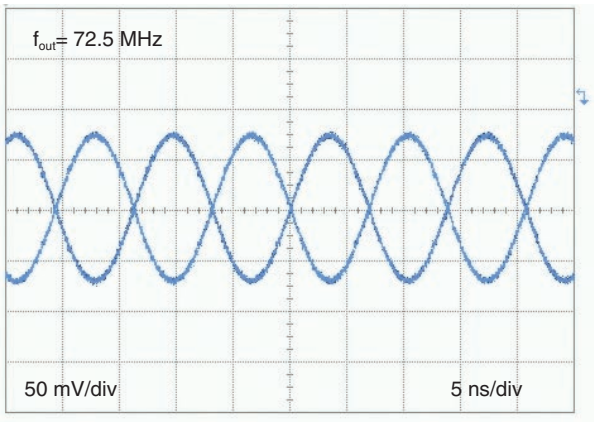


Fig. 8. Measured sinusoidal output waveform at 13.5 GS/s.

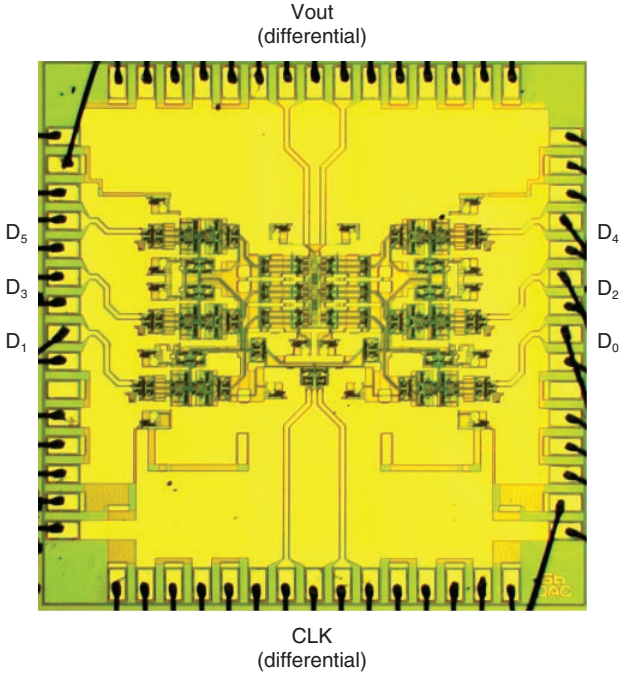


Fig. 6. Microphotograph of the DAC with timing alignment.

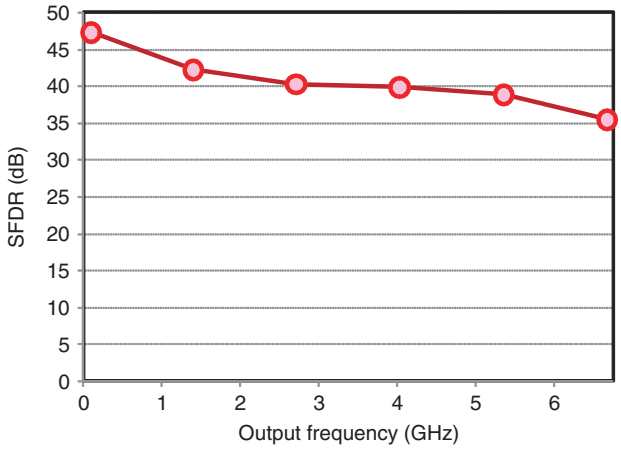


Fig. 9. Measured SFDR versus output frequency at 13.5 GS/s.

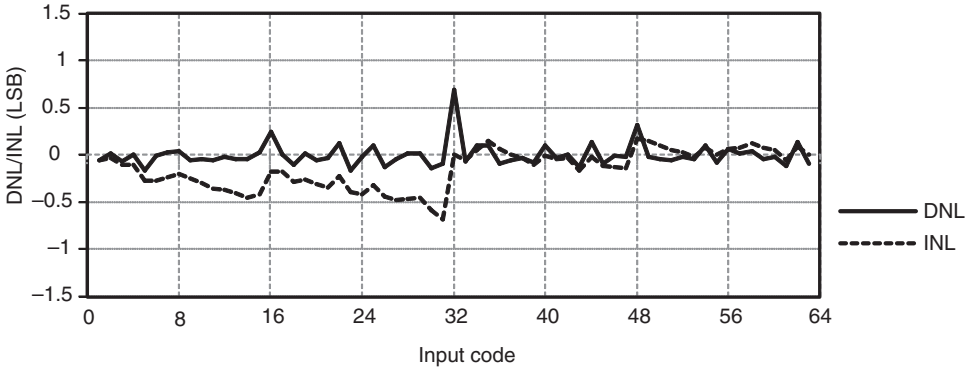


Fig. 7. Measured DNL and INL.

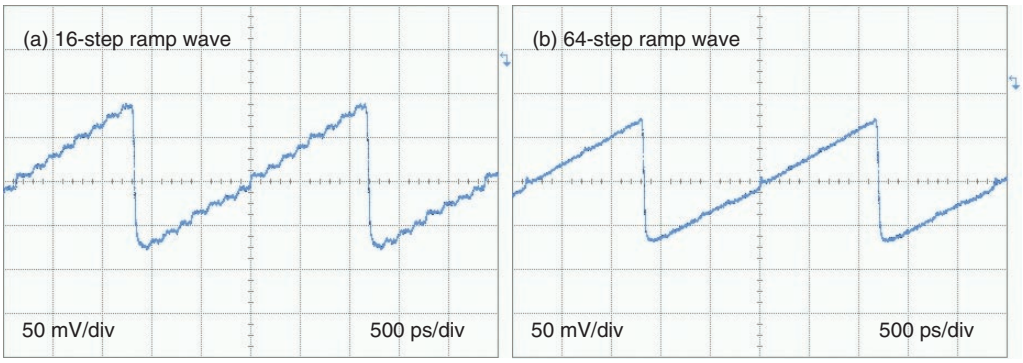


Fig. 10. Measured ramp-wave output waveforms at 27 GS/s. (a) 16-step ramp wave and (b) 64-step ramp wave.

to characterize the DAC at higher speeds. A ramp-pattern test is often utilized to characterize the dynamic performance of high-speed DACs. The measured 16- and 64-step ramp-wave outputs at a sampling rate of 27 GS/s are shown in **Fig. 10**. In Fig. 10(a), the 16-step output changed every four sampling-clock cycles, while in Fig. 10(b), the 64-step output changed every sampling-clock cycle. The glitches were well suppressed, and linear ramp-wave outputs were obtained as expected. These results demonstrate that the timing alignment technique works as well as could be expected. The output transient time is less than 20 ps.

Since the R-2R ladder-based current-steering DAC achieved very good performance, we assembled it into a metal package with high-frequency connectors (**Fig. 11**) [12] to facilitate its use in an optical transmission experiment. The measured four-level signals for 16-QAM transmission are shown in **Fig. 12**. The

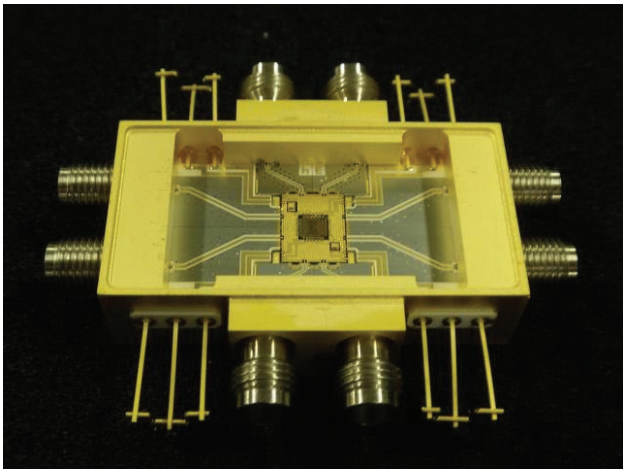


Fig. 11. Photograph of the DAC module.

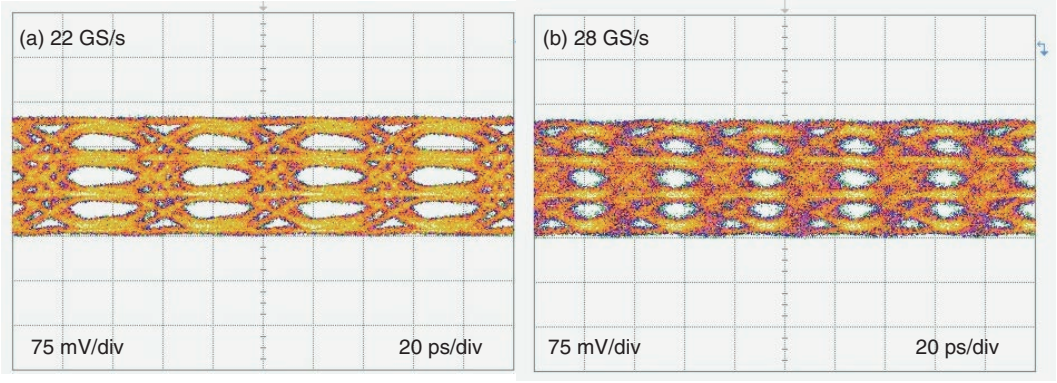


Fig. 12. 4-level signals for 16-QAM transmission for two sampling rates: (a) 22 GS/s and (b) 28 GS/s.

Table 1. Comparison of DACs with sampling rates above 20 GS/s.

	This work [8]	Previous work [7]	[4]	[5]	[6]
Sampling rate	28 GS/s	32 GS/s	22 GS/s	22 GS/s	34 GS/s
Resolution	6 bits	6 bits	6 bits	6 bits	6 bits
DAC power	**0.95 W**	1.4 W	2.0 W	2.1 W	3.75 W**
FOM	**0.53 pJ**	0.68 pJ	1.42 pJ	1.49 pJ	1.72 pJ
Technology (ft, fmax)	InP HBT (175, 260 GHz)	InP HBT (175, 260 GHz)	0.13-μm SiGe (150, 150 GHz)	0.18-μm SiGe (200 GHz, N/A)	SiGe (200, 250 GHz)

N/A: not applicable
** Total power is 12.5 W (30% for the DAC and 70% for the FPGA (field programmable gate array) interface)

DAC module provided a clear four-level signal with full-scale rise and fall times shorter than 20 ps at a sampling rate of up to 28 GS/s. This DAC module has been used to demonstrate 11 × 171-Gbit/s PDM 16-QAM optical transmission [13]. Thus, this DAC can be applied to post-100-Gbit/s/ch multilevel optical transmission systems.

4. Comparison

Our DAC is compared with other state-of-the-art DACs designed for optical transmission systems with a sampling rate above 20 GS/s in **Table 1**. The figure-of-merit (FOM) for energy per conversion step is defined as

$$FOM = \frac{Power}{2^N \bullet f_{sampling}}, \quad (2)$$

where *Power* is the total power consumption, N is the physical resolution, and $f_{sampling}$ is the maximum sampling rate.

Our DAC shows outstanding performance. It operates at a sampling rate of up to 28 GS/s, consumes only 0.95 W, and has a better FOM (0.53 pJ per conversion step) than any previously reported DACs with sampling rates above 20 GS/s.

5. Summary

In this article, we presented the circuit design and measured performance of a high-speed low-power DAC using InP HBT technology. To achieve both high-speed and low-power operation, we used a simple R-2R ladder-based current-steering architecture and devised a new timing alignment technique. The 6-bit DAC with timing alignment can operate at a sampling rate of up to 28 GS/s, consumes only 0.95 W, and has a better FOM (0.53 pJ per conversion step) than any previously reported DACs with sampling rates above 20 GS/s. It provides a clear multilevel modulated signal for QAM transmission and can be applied to post-100-Gbit/s/ch 16-QAM systems. Our DAC will be effective for next-generation optical transmission systems.

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Flexible-format Optical Modulators with a Hybrid Configuration of Silica Planar Lightwave Circuits and $LiNbO_3$ Phase Modulators

Hiroshi Yamazaki† *and Takashi Goh*

Abstract

We have devised and fabricated two types of flexible-format optical modulators that let us flexibly change the modulation format: a single-carrier modulator, which supports 4-, 8-, and 16-level modulations, and a multicarrier modulator, which provides a selectable combination of the number of frequency carriers and modulation levels. Both were fabricated using a hybrid integration of silica planar lightwave circuits and $LiNbO_3$ phase modulators and successfully operated at high baud rates corresponding to >100 Gbit/s. These technologies are promising for future spectrally efficient optical networks in which various modulation formats are used flexibly and adaptively.

1. Introduction

Multilevel modulation formats, such as N-level phase-shift keying (N-PSK) and N-level quadrature amplitude modulation (N-QAM), are the keys to achieving a large transmission capacity and high spectral efficiency (SE) in wavelength-division multiplexed (WDM) optical transmission systems. A record transmission capacity of 69.1 Tbit/s with SE of 6.4 bit/s/Hz has been achieved using polarization-division-multiplexed (PDM) 16QAM [1]. However, a higher modulation level, which offers higher SE, also leads to lower receiver sensitivity, which means a shorter transmission distance [2]. Because of this trade-off, the choice of modulation level may vary with the system design, so a transmitter that supports multiple modulation formats will be useful. Furthermore, flexible switching of modulation formats in response to optical path switching will be beneficial for maintaining the maximum SE for each channel in future all-optical networks (also called transparent networks) in which signals are switched without optical-to-electrical and electrical-to-optical conversion [3].

To generate multilevel optical signals, multilevel electronics, such as arbitrary waveform generators or digital-to-analog converters, have been used in many transmission experiments [3]–[5]. With such multilevel electronics, we can cover various modulation formats with a simple optical setup. On the other hand, optical multilevel-signal syntheses, in which only binary electronics are used, have also been studied extensively [1], [2], [6]–[10]. Those schemes are promising for high-speed multilevel modulations because binary electronics pose fewer challenges for high-speed operation than multilevel electronics do [6], [7]. However, they have lacked flexibility; different optical configurations have been required for different modulation formats.

In this study, we devised two types of flexible-format optical modulator using optical multilevel-signal syntheses. One is a single-carrier flexible-format modulator, which supports 4-, 8-, and 16-level modulation formats [11]. The other is a multicarrier flexible-format modulator, which provides frequency-division-multiplexed (FDM) multilevel modulation

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with a selectable combination of the number of frequency carriers and modulation levels [12]. Both modulators let us change the SE at the cost of a reduced transmission distance without changing the baud rate. The main difference is that the single-carrier type changes the bit rate and keeps the spectral bandwidth, while the multicarrier type changes the spectral bandwidth and keeps the bit rate. We fabricated them using a hybrid integration of silica planar lightwave circuits (PLCs) and $LiNbO_3$ (LN) phase modulators, which is promising for fabricating advanced multilevel modulators with both a large electro-optic bandwidth and complicated optical configurations [10]–[13]. The modulators successfully operated at high baud rates corresponding to bit rates of >100 Gbit/s.

2. Single-carrier flexible-format modulator

2.1. Design and fabrication

The single-carrier modulator was designed to support quadrature-PSK (QPSK), 8PSK, 8QAM, and 16QAM. These 2^N-level signals (N=2, 3, 3, and 4, respectively) can be generated through optical signal syntheses using N binary-driven Mach-Zehnder modulators (MZMs) [6]. We designed the modulator so that it has four MZMs and tunable circuits with which we can select the number of MZMs contributing to the modulation.

The optical-circuit configuration of the modulator is shown in **Fig. 1**. It has a two-stage lattice configuration. In the first stage, each arm has an MZM. In the second stage, the upper arm has two MZMs connected in parallel plus a pair of tunable couplers while the lower arm does not have any functional components. The couplers at the input of the first stage and between the first and second stages are static 3-dB couplers, while the one at the output of the second stage is another tunable coupler. The four MZMs (denoted MZMs 1–4) are driven in push-pull conditions with different binary data signals, Data 1–4, respectively. All data signals have an amplitude of $2V\pi$, so the MZMs operate as binary-PSK (BPSK) modulators. MZMs 2 and 4 are followed by $\pi/2$ phase shifters. The power coupling ratios of the tunable couplers, α:1-α and β:1-β (upper to lower arms), as denoted in the figure, are varied for different modulation formats. The relative optical phase between the upper and lower arms of the second stage, φ, is also varied.

The operating principle is as follows. The signal constellations at points A, B, and C and at the final

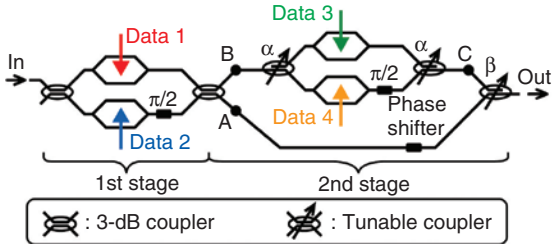

Fig. 1. Optical-circuit diagram of the single-carrier flexible-format modulator.

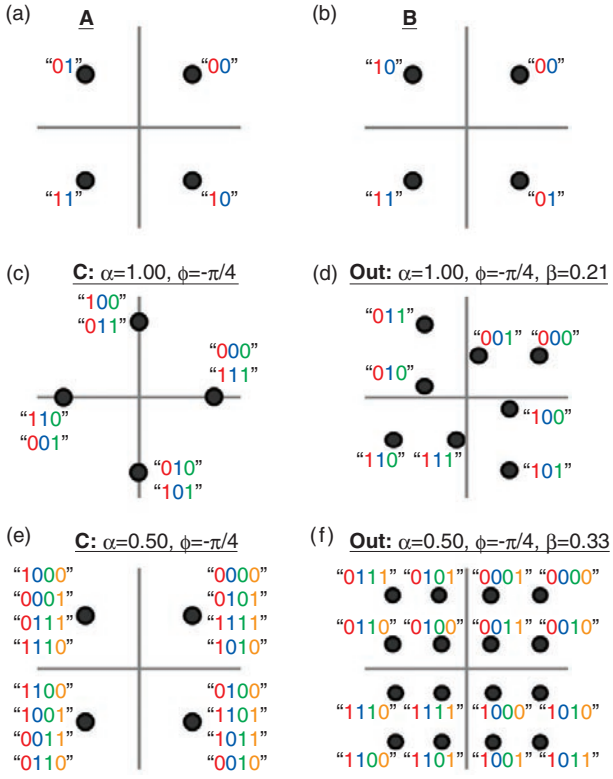

Fig. 2. Schematic constellations and data mappings at A, B, C, and Out in Fig. 1.

output port are shown in **Fig. 2**. Here, the data values 1 and 0 are allocated to optical phases 0 and π, respectively, in each BPSK signal generated with an MZM. A binary data string at each signal point (e.g., 1100) represents the values of Data 1–4 from left to right. As shown in Figs. 2(a) and (b), the first stage sends two QPSK signals to the two arms of the second stage. Those two signals have the same amplitudes but different (mirror-symmetric) data mappings. By setting β=0, we can obtain the QPSK signal

shown in Fig. 2(a) as the modulator's final output. An 8QAM signal is generated when α=1, φ=-π/4, and β=1/(3+$\sqrt{3}$)≈0.21. In this case, MZM 3 converts the QPSK signal shown in Fig. 2(b) into the signal shown in Fig. 2(c), in which eight values of 3-bit data degenerate to four signal points. This double degeneracy is broken when the signals from the upper and lower arms (Figs. 2(c) and (a)) are coupled, and the modulator outputs the 8QAM signal shown in Fig. 2(d). An 8PSK signal can also be generated in the same manner with α=1, φ=-π/2, and β= $\tan^2(\pi/8)/\{1+\tan^2(\pi/8)\}$≈0.15. To obtain a 16QAM signal, we set α=0.5, φ=-π/4, and β=1/3≈0.33. With this condition, the upper-arm signal has quadruple degeneracy (Fig. 2(e)), which is broken by the coupling with the lower-arm signal (Fig. 2(a)). The final output is the 16QAM signal shown in Fig. 2(f). As described above, we can flexibly switch the modulation level simply by using tunable couplers and a phase shifter. Furthermore, with the lattice configuration, the modulation losses for 8- and 16-level modulations are smaller than those with previously reported schemes [11].

We fabricated the modulator with the configuration shown in **Fig. 3**. We used two PLCs (PLC-L and -R) and an X-cut LN chip and implemented the modulator circuit with a compact loop-back configuration. The LN chip has an array of eight straight phase modulators, four signal electrodes (coplanar waveguides), and a passive straight waveguide. The PLCs contain all other circuit components: Y-branches for MZMs, 3-dB wavelength-insensitive couplers (WINCs), tunable couplers, and U-turn waveguides. Each tunable coupler consists of Mach-Zehnder circuits with a thermo-optic phase shifter in each arm. We bonded the chips to each other with ultraviolet-curable (UV-curable) adhesive and then mounted them on an SUS package with radio-frequency connectors. The PLC-L, LN, and PLC-R chips are 29.0 mm × 6.5 mm, 64.0 mm × 6.0 mm, and 17.0 mm × 6.5 mm, respectively, giving a total chip length of 110 mm.

2.2. Characteristics

At a wavelength of 1550 nm, the insertion loss of the modulator with β=0 is 7.3 dB and that with β=1 and α=0.5 is 7.5 dB. The difference of 0.2 dB corresponds to the excess loss in MZMs 3 and 4 and in the two tunable couplers. The 3-dB bandwidths of the electro-optic frequency responses are around 25 GHz for all MZMs.

We tested the modulator in the single-polarization back-to-back setup shown in **Fig. 4**. The light source

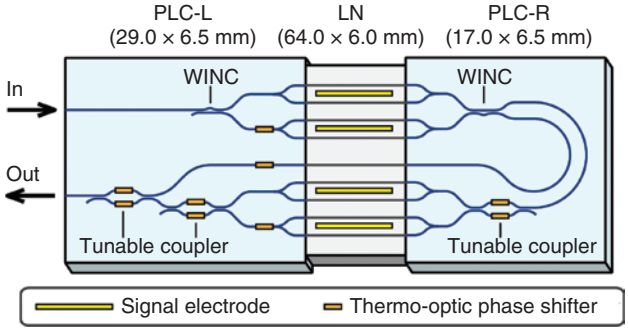

Fig. 3. Configuration of the single-carrier flexible-format modulator.

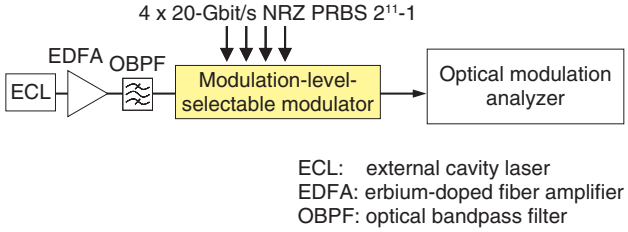

Fig. 4. Experimental setup.

was an external-cavity laser with a wavelength of 1551 nm and linewidth of ~30 kHz. The modulator was driven with four 20-Gbit/s non-return-to-zero (NRZ) 2^{11}-1 pseudo-random bit sequences (PRBSs) with different delays. We switched the modulation formats by using the tunable couplers as described above, while making no change in the driving signals. The output optical signal was received with an optical modulation analyzer (Agilent Technologies, N4391A), combined with a 50-gigasample-per-second (GS/s) storage oscilloscope (Tektronix Inc., DPO72004B), and analyzed offline.

As shown in **Fig. 5**, clear constellations were obtained for the 20-Gbaud QPSK, 8PSK, 8QAM, and 16QAM signals, which correspond to 80, 120, 120, and 160 Gbit/s, respectively, if we use PDM. The bit-error rates (BERs) for QPSK, 8PSK, and 16QAM were $<10^{-6}$ (no errors in 2×10^6 symbols), 1.9×10^{-5}, and 3.1×10^{-4}, respectively. BER measurement for 8QAM is not currently supported by the analyzer software, but the BER was estimated to be well below 10^{-4} from the measured error-vector magnitude of 9.8%. Optical signal spectra with these four formats are shown in **Fig. 6**. They almost completely overlap

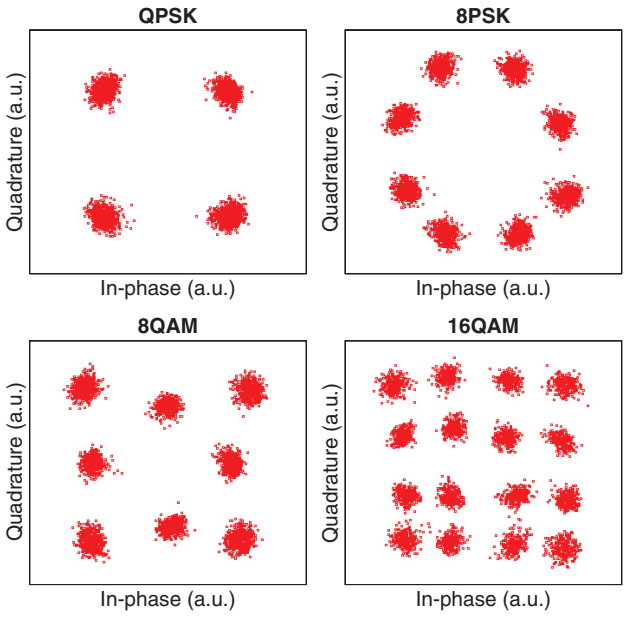

Fig. 5. Constellations of 20-Gbaud QPSK, 8PSK, 8QAM, and 16QAM signals.

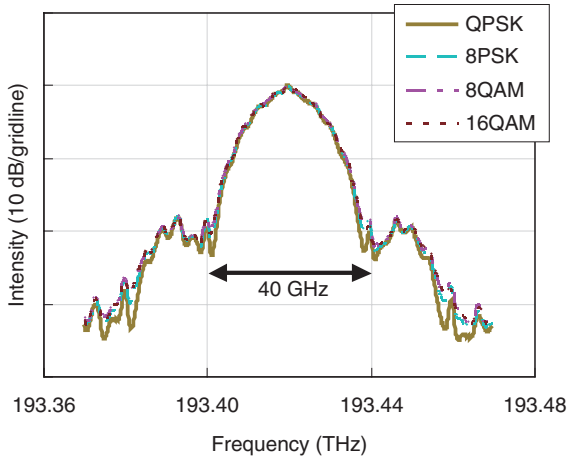

Fig. 6. Optical signal spectra.

and their main-lobe bandwidths are 40 GHz.

3. Multicarrier flexible-format modulator

3.1. Design and fabrication

The multicarrier flexible-format modulator was designed to support four-carrier BPSK, two-carrier QPSK, and one-carrier 16-QAM. With a fixed baud rate, all these formats give the same bit rate. By increasing the modulation level and decreasing the number of carriers, we can increase the SE at the cost of reduced receiver sensitivity (transmission distance) [3].

If we were to design separate modulators for the three formats, we would use some straightforward optical-circuit configurations such as those shown in **Fig. 7**. The four-carrier BPSK modulator consists of three interleave filters (ILFs) for demultiplexing carriers, four MZMs as four BPSK modulators, and three 2×1 couplers. The two-carrier QPSK modulator consists of one ILF, two pairs of MZMs as two QPSK modulators, and one 2×1 coupler. The one-carrier 16-QAM consists of a parallel-quad MZM as a 16-QAM modulator. These modulators have almost the same configuration except for certain passive components, such as the ILFs and couplers.

To provide these three configurations in a common design, we devised a modulator with a novel configuration consisting of three tunable ILFs (TILFs), four MZMs, two 2×1 couplers, and one tunable coupler as shown in **Fig. 8(a)**. To use the modulator as a four-carrier BPSK modulator (four-carrier BPSK mode), TILFs 1–3 are operated normally as carrier-demultiplexers, as shown in **Fig. 8(b)**, and then the tunable coupler is set with a 3-dB coupling ratio. To use the modulator as a two-carrier QPSK modulator (two-carrier QPSK mode), TILFs 2 and 3 are changed so that they operate as 3-dB couplers at the carrier frequency for carrier channels 1 and 2, respectively, to tune the phase condition of the TILFs. For use as a 1-carrier 16-QAM modulator (1-carrier 16-QAM mode), TILFs 1–3 are changed so that they operate as couplers with coupling ratios of two-to-one, 3 dB, and 3 dB, respectively, at the carrier frequency, and then the tunable coupler is set with a two-to-one coupling ratio. Thus, the devised modulator lets us select the modulation format flexibly from among three formats: four-carrier BPSK, two-carrier QPSK, and one-carrier 16-QAM.

The configuration of the fabricated modulator, which generates an optical signal with a total rate of 200 Gbit/s by using eight 25-Gbaud electrical signals in dual polarization operation, is shown in **Fig. 9**. We used two PLCs (PLC-I and -O) and an X-cut LN chip. The LN chip has an array of sixteen straight phase modulators with eight signal electrodes (coplanar waveguides). PLC-I consists of three TILFs and 1×2 couplers. Each TILF is composed of three Mach-Zehnder interferometers (MZIs) with thermo-optic phase shifters. One MZI is the main TILF, which has two output ports. The others, which have only one output port each, are added to obtain high isolation

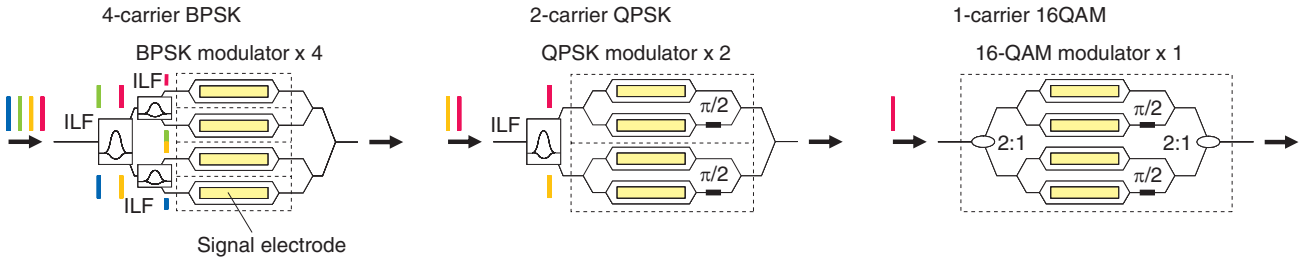

Fig. 7. Optical-circuit diagrams of the four-carrier BPSK, two-carrier QPSK, and one-carrier 16QAM modulators.

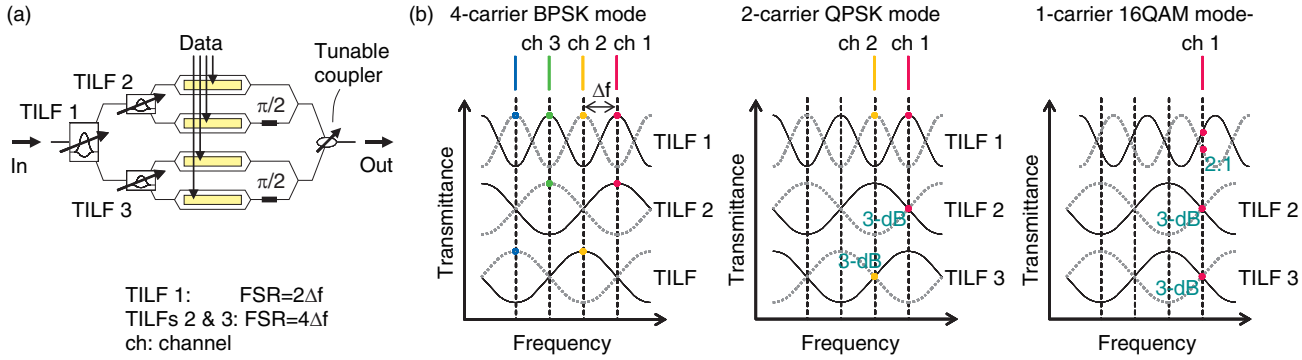

Fig. 8. (a) Optical-circuit diagram of the multicarrier flexible-format modulator. (b) TILF operation for each format mode.

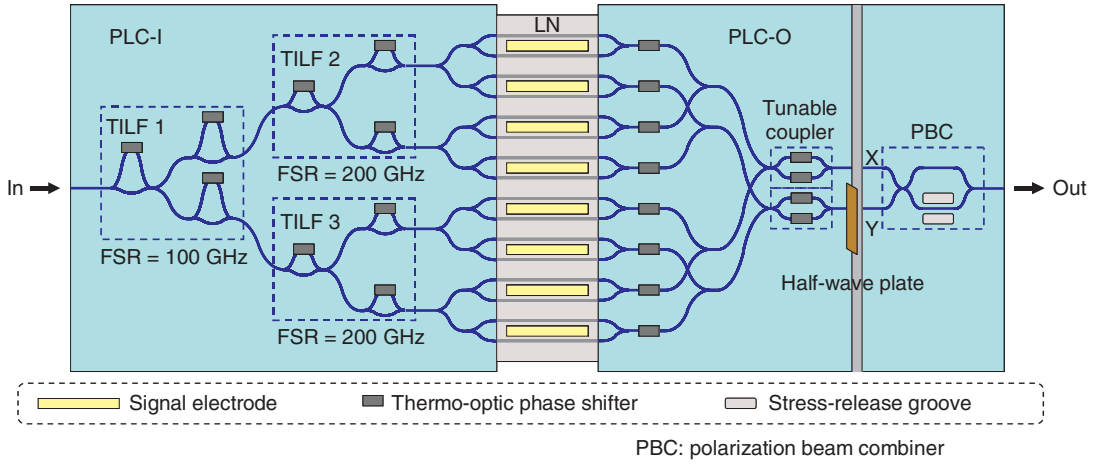

Fig. 9. Configuration of the multicarrier flexible-format modulator.

for demultiplexing. The free spectral range (FSR) of TILF 1 is 100 GHz. TILFs 2 and 3 each have an FSR of 200 GHz. PLC-O consists of 2×1 couplers, thermo-optic phase shifters for IQ (in-phase and quadrature) phase tuning, tunable couplers, a half-wave plate as a polarization rotator, and a polarization beam combiner. The polarization beam combiner consists of an MZI with stress-release grooves to control waveguide birefringence [14]. We arranged the MZMs in an alternating layout to share the TILFs

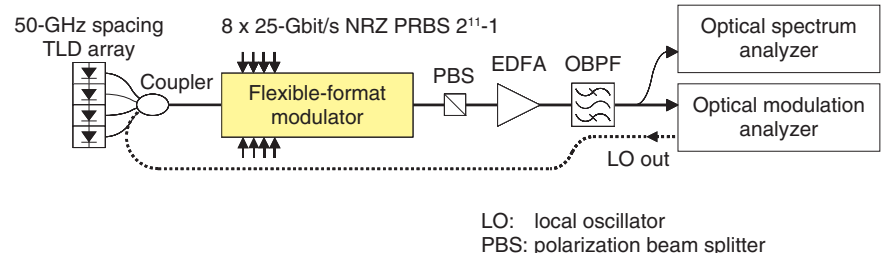

Fig. 10. Experimental setup.

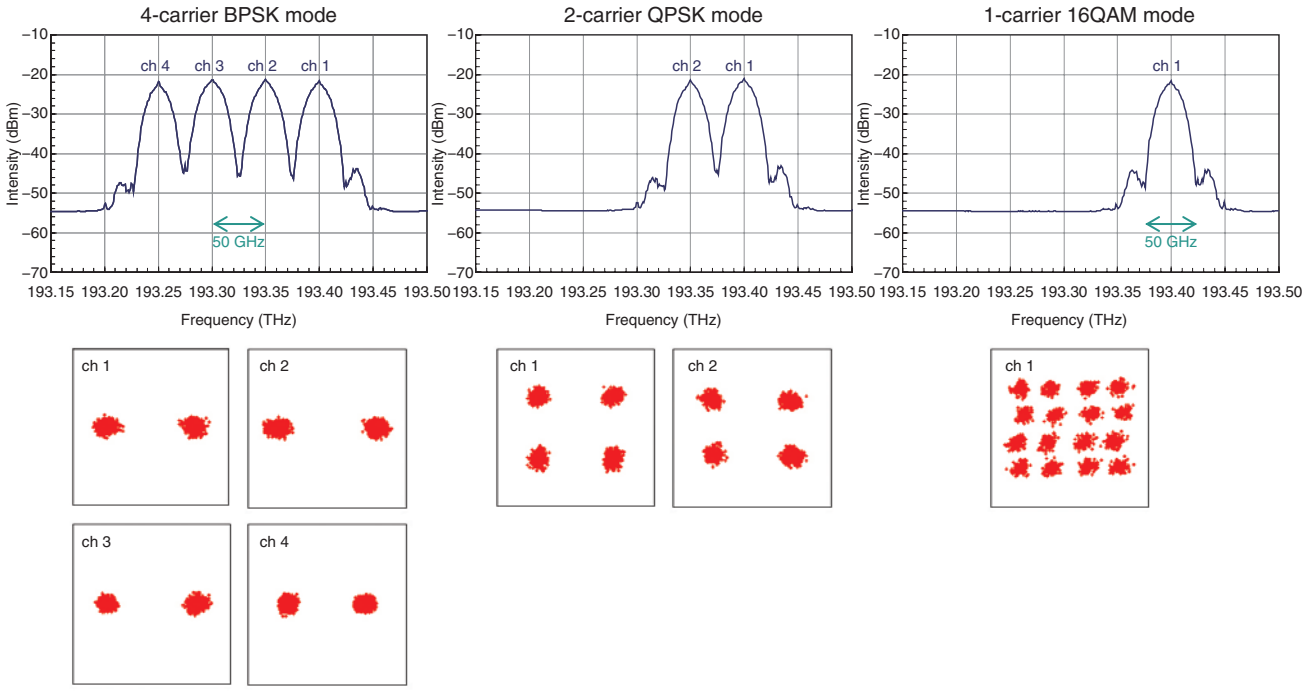

Fig. 11. Measured optical output spectra and constellations of X-polarization signals for 200-Gbit/s operation in four-carrier BPSK, two-carrier QPSK, and one-carrier 16-QAM modes.

for X- and Y-polarizations. We bonded the chips to each other with UV-curable adhesive and then mounted them on an SUS package with radio-frequency connectors. The PLC-I, LN, and PLC-O chips are 33 mm × 13.5 mm, 64 mm × 6.0 mm, and 35 mm × 4.4 mm, respectively, giving a total chip length of 132 mm.

3.2. Characteristics

The insertion loss of the modulator was 8.8 dB at a wavelength of 1550 nm when all the thermo-optic phase shifters were tuned so that the transmittance was maximum. The 3-dB bandwidths of the electro-optic frequency response were around 25 GHz for all the MZMs.

We tested the modulator in the back-to-back self-homodyne setup shown in **Fig. 10**. Four tunable laser diodes (TLDs) with 50-GHz spacing were used as a multicarrier light source. The modulator was driven with eight 25-Gbit/s NRZ 2^{11}-1 PRBSs with different delays for 200-Gbit/s operation. We changed the modulation modes by using the TILFs and tunable couplers as described above, while making no change to the driving signals. The number of TLDs constituting the multicarrier source and the TLD wavelengths were changed with the modulation mode. The output

optical signal was received with an optical spectrum analyzer and an optical modulation analyzer, combined with a 50-GS/s storage oscilloscope, and analyzed offline. To enable self-homodyne detection to be used for constellation measurement, the light from the TLD corresponding to the measured carrier channel was changed to that from the local-oscillator in the optical modulation analyzer.

Measured optical output spectra and constellations of X-polarization signals transmitted via a polarization beam splitter are shown in **Fig. 11**. Those for the Y-polarization signals were almost the same. Clear spectra and constellations were obtained in each modulation mode. This means that we were able to select the operating format as four-carrier BPSK, two-carrier QPSK, or one-carrier 16-QAM. The signals with all these formats have the same bit rate of 200 Gbit/s with a symbol rate of 25 Gbaud. Although we used FDM with a frequency spacing twice the baud rate in this first demonstration, we can also readily cover orthogonal frequency division multiplexing (OFDM), in which the frequency spacing equals the baud rate, by changing the FSR of the TILFs.

4. Conclusion

We devised and demonstrated single-carrier and multicarrier flexible-format modulators fabricated with a hybrid configuration of PLCs and LN phase modulators. These modulators let us flexibly select the modulation format simply by using tunable optical circuits while driving the data electrodes with only 2Vπ binary signals. Thanks to the hybrid configuration, the modulators show small optical insertion losses of 7.5 and 8.8 dB, respectively, despite their complicated optical configuration. Flexible-format operations with high baud rates corresponding to bit rates of >100 Gbit/s were successfully demonstrated. These technologies are promising for future optical networks in which various modulation formats will be used flexibly to exploit spectral resources efficiently.

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Development of Aerial Optical Closure for the High Demands of FTTH Service

Chihiro Suzuki†, *Yuji Takahashi, Atsushi Hamaoka, and Tetsuhiro Numata*

Abstract

New components have been developed to enable aerial optical closures to accommodate a larger number of splitters. The maximum capacity has been increased from four to eight. This development will reduce aerial facility congestion and cut construction costs.

1. Introduction

The number of broadband subscribers in Japan reached 34 million in September 2010. Of these, around 19 million, or more than 56% of the total, were fiber-to-the-home (FTTH) subscribers [1]. In response to the diversification and spread of FTTH services, we have studied conventional and new aerial optical closure components with a view to improving the splitter accommodation capacity [2].

2. Development overview

Technologies that enable a huge number of optical facilities to be efficiently and economically operated and maintained are needed. In the usual configuration used for providing FTTH services to residential premises in Japan, a customer's home is connected to a central office via a splitter installed in an aerial closure (**Fig. 1**). For construction and maintenance efficiency, several splitters are installed in one place, i.e., in a single closure. The maximum number of splitters being installed in existing aerial closures is four. However, more and more splitters are being installed in Japan because of the recent increase in optical service demand and service diversification. As a result, many aerial optical closures are already full and cannot accommodate any more splitters. Therefore, additional aerial optical closures and cables frequently need to be installed, but this involves high construction costs.

2.1 Design goals

To cope with this problem, we identified the problem with conventional closures and set new design goals. The conventional aerial optical closure contains a certain number of trays: the number is chosen and fixed at the time of closure installation according to the predicted demand. It can accommodate four splitter modules if the maximum number of trays (two) are installed.

Our design goals for the new aerial optical closure were to (1) design a new closure that can accommodate a larger number of splitter modules, (2) design components that can be installed in conventional aerial optical closures as well as in the new one, and (3) ensure that a field worker can install the larger number of splitter modules in a closure with the same ease.

2.2 Development results

We increased the number of splitter modules that can be installed from four to eight by developing smaller splitter modules that can also fit in a conventional closure. We increased the number of connections

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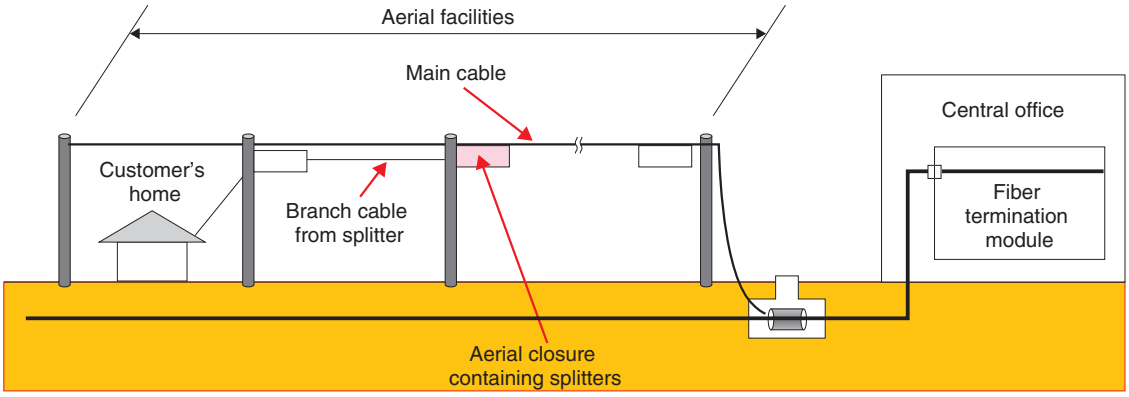

Fig. 1. Configuration of Japanese FTTH service facilities.

from a main cable to branch cables from 32 to 64 by developing components that let us double the number of branch cable connections in a closure space of the same size while still being compatible with conventional trays. As a result, we increased the number of main cable connections from 8 to 16. Since the number of main cable connections increases as the number of installed splitter modules increases, we developed components that allow the number of main cable connections to be increased when required.

3. Development details

This section describes the new aerial optical closure components in more detail.

3.1 Splitter module

To increase the number of splitter modules in a closure we had to develop a smaller splitter module that can be installed by using the free space in a conventional tray more effectively. In collaboration with the splitter module development department, we examined the basic structure. As a result, a new splitter module that is only 40% of the volume of the conventional one was developed.

3.1.1 New splitter modules in conventional tray

We developed an attachment (splitter tray guide) that can accommodate two of the new splitter modules in the space available previously occupied by one old splitter. Since two of these new attachments fit in a conventional tray, a conventional tray can accommodate four new splitter modules instead of two (**Fig. 2**). One feature of this attachment is that it can be used in either the right or left half. The bottom cover of the attachment prevents any sagging of the splitter cord.

3.1.2 New tray optimized for new splitter modules

Installing a splitter that uses two conventional trays and attachments increases costs, so we developed a splitter installation component (new splitter tray) for accommodating the new splitter modules. It has a two-layer structure: each layer can house two new splitter modules (**Fig. 3**). This component facilitates installation work by optimizing the positions of the new splitter modules.

3.2 New tray for branch cable connections

To increase the number of splitters that can be installed, we doubled the connection capacity of the conventional aerial optical closure. To achieve this, we developed a component (a new tray for connections with branch cables) that can accommodate twice as many branch cable connections in the same space (**Fig. 4**). Moreover, it is compatible with the conventional branch cable tray. With the conventional one-layer tray structure, the fibers are congested. Our new two-layer structure makes it possible to connect 16 fibers: each one-layer tray for branch cable connections can connect 8 fibers, which prevents congestion. To ensure that fibers are not bent too tightly, we choose the locations of the new and existing connector connections to be different. As shown in Fig. 4, the fixed positions of the eight connectors in the upper layer and of the eight connections in the lower layer are out of alignment: this ensures that each optical fiber has a sufficiently large radius of curvature. On

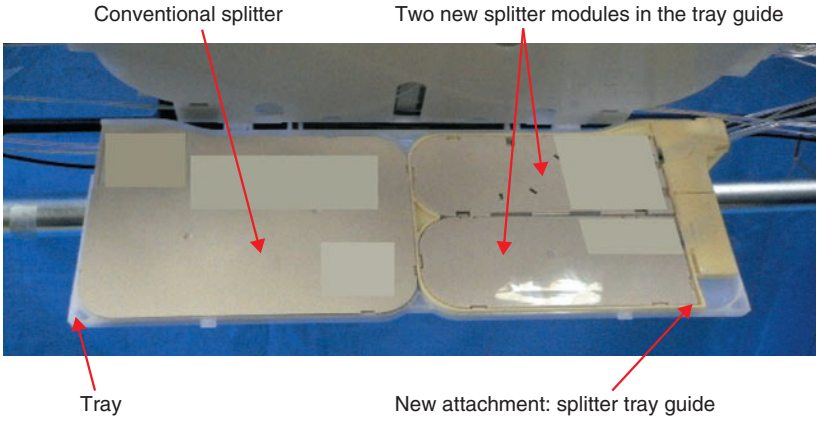

Fig. 2. Installation of new splitter components in conventional tray.

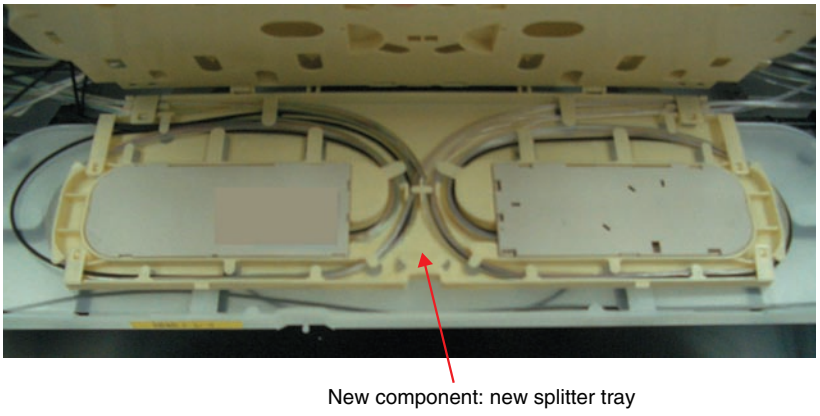

Fig. 3. New splitter tray optimized for new splitter modules.

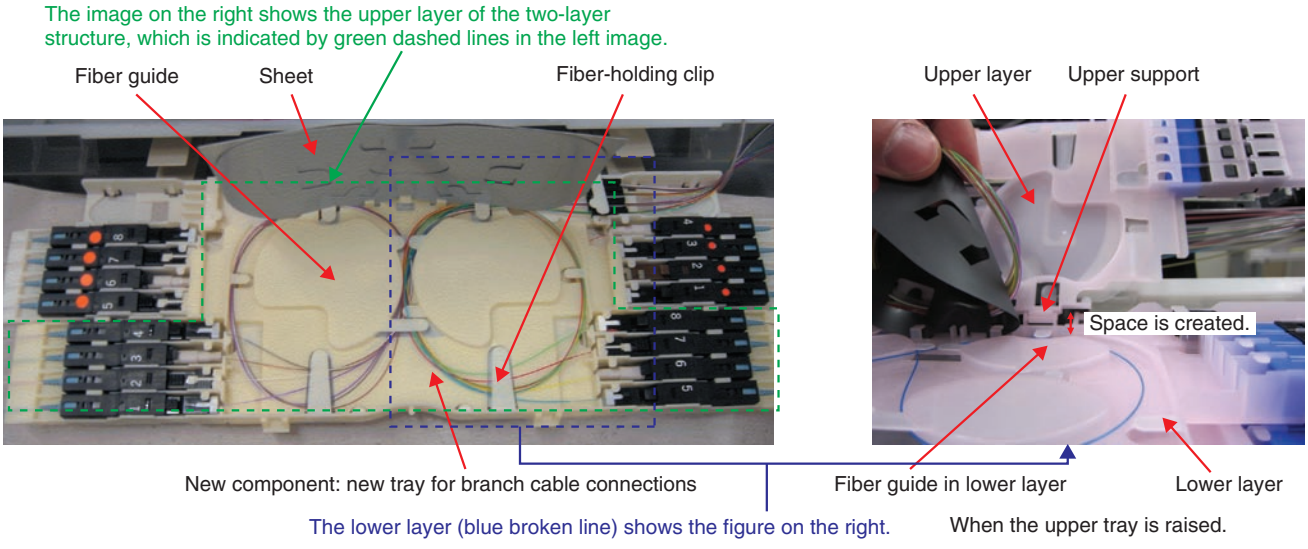

Fig. 4. New tray for branch cable connections.

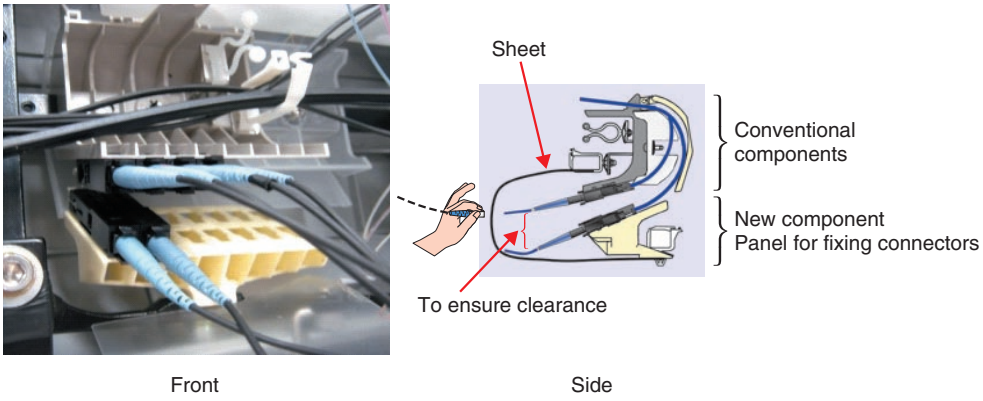

Fig. 5. Panel for fixing main cable connectors.

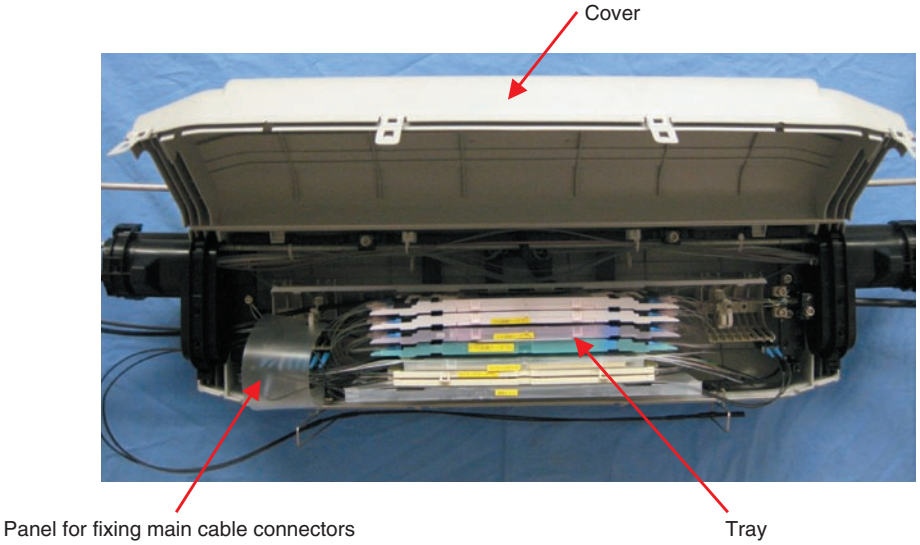

Fig. 6. Aerial optical closure with new components.

the basis of further feedback from field engineers, we designed a two-layer structure that incorporates measures to prevent fibers catching during field work. Fiber-holding clips were placed at appropriate positions. Furthermore, we redesigned the shape of the fiber guide. We designed the fiber guide configuration by enlarging the fiber-holding clip and we curved the fiber guide. As a result, the fibers are unlikely to pop out. The height of the fiber guide is set to be lower than the upper support. The fiber-holding section between the top and bottom layers must have sufficient space to prevent a fiber catching when the top and bottom layers are closed. Next, we created the fiber holding space using a conventional plastic case design. However, the resulting double-decker design was too thick and we could not make it the same size as the conventional case. Therefore, we decided to create a thin sheet to form the fiber-holding section. This sheet is hinged so that it normally lies flat against the case and cannot be removed. This design prevents the sheet from falling out during field work. The sheet is a self-supporting structure that stays open by itself during field work, so it does not impede the field worker. Sheets are provided for both layers; they act as lids that prevent the case from catching the fiber.

3.3 Panel for fixing main cable connectors

The number of main cable connections increases as the number of installed splitters increases. Therefore, we developed a component (panel for fixing connectors to a main cable) that allows the number of main cable connections to be increased when required (**Fig. 5**). We decided to place the additional components in the vacant space below the existing ones because it was difficult to make drastic changes to the existing positions considering the fiber's extra length. Since that would leave no space between the conventional and new components, there might be contact between the conventional and new component connectors. To ensure clearance between them, we gained space by setting the new component connectors at the maximum possible angle to the conventional ones. As a result, we faced the new worry that the cord from a connecter connected to a new component might get pinched when the cover is opened and closed (**Fig. 6**). However, we were able to protect the cords by attaching a sheet to the new component.

4. Concluding remarks

We have developed new components to increase the number of splitter modules that can be accommodated in aerial optical closures. They effectively utilize the free space in the current aerial optical closure and enable eight splitter modules to be accommodated in both the conventional and new closures. Workability is not reduced even in a high-capacity aerial optical closure. This development overcomes congestion in closures and will allow us to reduce construction and operating costs for the FTTH service.

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Trends, Standardization, and Interoperability of Healthcare Information

Yasuo Ishigure†

Abstract

This article introduces formats for storing medical and healthcare information, their advantages, the ways in which they are approached in Japan and overseas, and trends for ensuring standardization and interoperability.

1. Introduction

Various systems are currently being implemented to take advantage of information and communications technologies (ICT) to effectively and efficiently store and utilize medical and healthcare information, which is usually stored in a dispersed manner. The purpose is to address social challenges in the medical and health fields, as typified by soaring medical expenses. In this article, I introduce formats for storing medical and healthcare information, their advantages, the ways in which they are approached in Japan and overseas, and trends for ensuring standardization and interoperability.

2. Storage formats

Information related to medical and health matters covers a wide range, from that with a direct relationship with medical care, such as checkup results and prescriptions, to client management, accounting, and requests for medical care repayment. This article treats the electronic storage of records related to the medical and healthcare concerns of individual patients.

There are three main types of medical and healthcare information: electronic medical records (EMRs), electronic health records (EHRs), and personal health records (PHRs). EMRs are medical and health records shared within a medical organization; EHRs are ones shared among several medical organizations, such as through cooperation within a region; and PHRs are ones managed by individuals themselves (**Fig. 1**).

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3. Definitions of EMR, EHR, and PHR

Detailed definitions for EMR, EHR, and PHR have not yet been fixed. According to a report related to the definitions of medical information technology (IT) terminology written by the USA's National Alliance for Health Information Technology (NAHIT) in April 2008 [1], there are many definitions in existence: 35 for EMR, 99 for EHR, and 52 for PHR, as listed in **Table 1**. Excluding definitions that have duplicate contents, the numbers of unique definitions are 26, 63, and 36, respectively. Thus, if it is not yet possible to achieve a consensus on definitions, we have a situation in which opinions among specialists are divided. New, integrated definitions of these terms proposed by NAHIT in that report are given in **Table 2**.

4. Advantages of implementation

The advantages of implementing EMRs, EHRs, and PHRs differ for each type of record (see **Fig. 2**).

Recording patients' medical care information electronically as EMRs within a medical organization enables that information to be collected and utilized

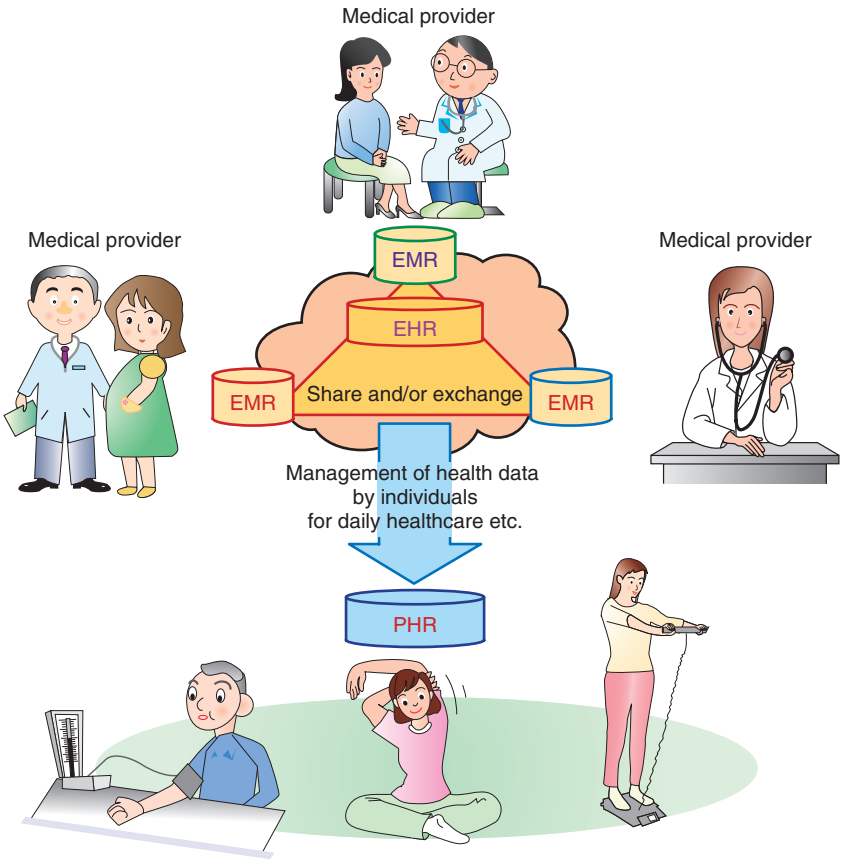


Fig. 1. Concepts of EMR, EHR, and PHR.

Table 1. Multitude of definitions.

	EMR	EHR	PHR
Number of unique (overlapping) definitions identified by NAHIT in its report.	26 (35)	63 (99)	36 (52)

Table 2. Definitions proposed by NAHIT.

EMR: electronic medical record	An electronic record of health-related information on an individual that can be created, gathered, managed, and consulted by authorized clinicians and staff within one health care organization.
EHR: electronic health record	An electronic record of health-related information on an individual that conforms to nationally recognized interoperability standards and that can be created, managed, and consulted by authorized clinicians and staff across more than one health care organization.
PHR: personal health record	An electronic record of health-related information on an individual that conforms to nationally recognized interoperability standards and that can be drawn from multiple sources while being managed, shared, and controlled by the individual.

within that medical organization. It also reduces the dangers of paper dust and misreading of records that occurs with paper cards, so we can expect it to lead to greater medical safety.

In addition, along with the process of converting records to electronic form as EMRs, EHRs can be implemented by connections via networks to outside medical organizations. Once EHRs have been

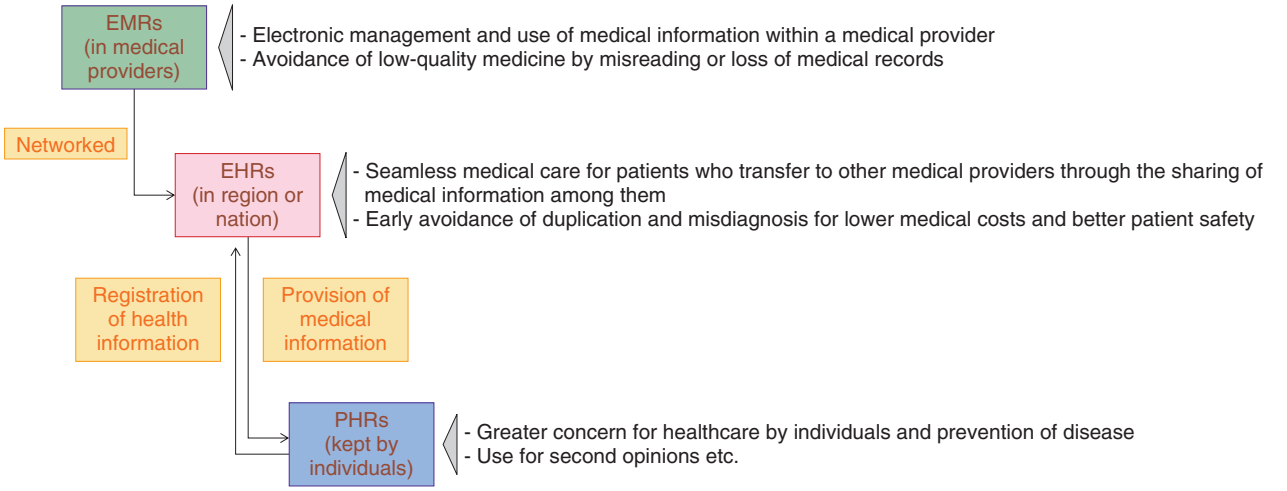


Fig. 2. Benefits of EMRs, EHRs, and PHRs.

implemented regionally or nationally, patients' medical care information can be shared among medical organizations, enabling seamless medical continuity by access to the same medical care information even when, for example, patients transfer to other hospitals. In addition, by eliminating duplicate examinations and misdiagnoses at an early stage, this system can be expected to lead to more efficient medical fees and increased medical safety.

The use of PHRs to enable individuals to manage and make use of their own medical and healthcare information recorded in EMRs and EHRs should lead to improvements in general health consciousness and comprehension, avert adult-onset diseases, and prevent any worsening of existing conditions. Furthermore, these records can be used for second opinions and other medical care as the individual patients wish, so various improvements, such as improvements in the quality of medical care, including emergency care, and reductions in unnecessary procedures can be expected.

Below, I give an overview of trends for EHRs and PHRs, which can be expected to contribute to the medical and health fields in the future through the use of networks and which are currently being reviewed and configured both in Japan and overseas.

5. Overseas trends for EHRs and PHRs

Over the past ten years or so, various EHR and PHR systems have been constructed in developed economies overseas, mainly as the result of national policies.

In 2002, the UK's National Health Service started a ten-year project called "Connecting for Health" [2], which is intended to implement a mechanism for sharing records that have been converted into electronic form. In addition to enabling the sharing of patient information summaries online, various other functions are in operation such as electronic management of prescriptions, medical appointment services, effective secondary utilization of data, email, medical service analysis systems, and a newborn registration system.

The Canadian Infoway system has been set up to ensure that much of the work of confirming consultation history, checkup results, medication history, and medical images within the country can be done by means of EHRs.

In the USA, the Bush administration set up an initiative with the objective of "EHR for All Americans by 2014" in April 2004. It has been handed over to the current Obama administration. The American Recovery and Reinvestment Act of 2009 [3], which was approved in February 2009, ensures various budgets, such as US$2 billion for government-affiliated medical IT promotions and US$20.8 billion for incentives to introduce medical IT systems. These measures are forecast to improve medical safety and quality through the sharing and utilization of information both within and among medical organizations, and hence reduce the public's medical expenses. There are also procedures under way at the moment to provide subsidies for the meaningful use of such data.

Similarly, initiatives related to EHRs and PHRs are also in progress in the Asian and Oceanic regions in various places from Australia and New Zealand to China, South Korea, Taiwan, and Singapore.

6. Domestic trends for EHRs and PHRs

Within Japan, businesses that utilize ICT in the medical and health fields have been doing so for some time, but the debate into the proactive utilization of networks that would enable EHRs and PHRs started in earnest in 2007 with the Ministry of Health, Labour, and Welfare's (MHLW's) Grant-in-Aid for Creative Scientific Research "Research Aimed at Implementing Japanese-version EHRs" and the Ministry of Economy, Trade, and Industry's (METI's) "Research into New Health Service Utilizing Japanese-version PHRs". In 2008, a three-year project entitled "Healthcare Information Utilization Foundation Demonstration" was initiated through cooperation between the Ministry of Internal Affairs and Communications, MHLW, and METI, and examination of actual operations for EHRs and PHRs is well under way. In addition, in June 2010, the Japanese government's IT Strategic Headquarters published the "New Information Communications Technology Strategy Schedule" [4], which describes the initiative called "My Hospital Everywhere (Japanese Personal Health Record)" and seamless regional healthcare enterprises, which are closely linked to the use of EHRs and PHRs. At present, specific reviews into what kind of system the IT Strategic Headquarters should implement in accordance with this schedule are under way.

7. Standardization activities related to EHRs and PHRs

Standardization is important in order to enable the use of networks to share and utilize medical and healthcare information. Information related to medical and health matters comes in many different forms; in addition to the names of diseases, drugs, and treatments, there is also other data such as images, numerical values of examination results, graphs, and text. Furthermore, to ensure the connection of different systems among institutions, regions, and nations, it is necessary to integrate details such as terminology, encoding, protocol, and security. Standardization is also likely to play an extremely large role in facilitating long-term storage. At the moment, there are many standardization organizations, such as the International Organization for Standardization (ISO) and the Comité Européen de Normalisation (CEN). They are all actively working towards the standardization of both EHRs and PHRs. Below, I introduce some representative examples of these activities [5].

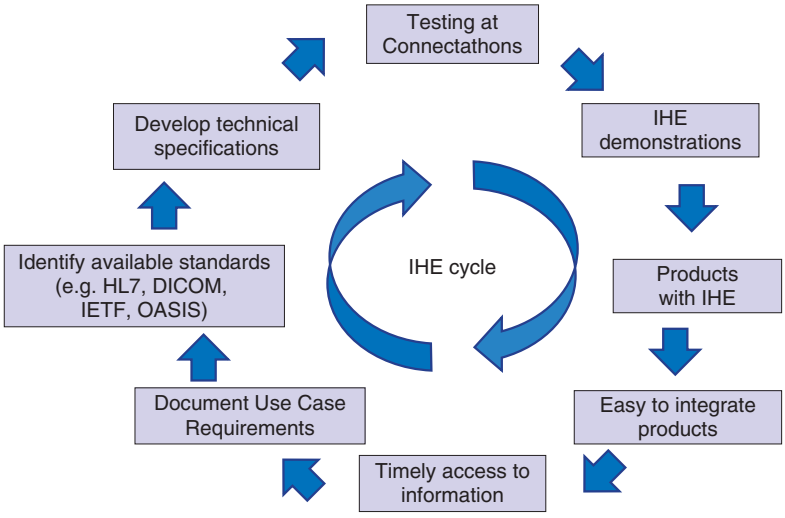
Health Level Seven (HL7) is a standards agreement for the exchange of medical information, such as measurement data and text, that was established in the USA in 1987. In Japan, the HL7 Japan branch was established in 1998 and is still currently active. The name HL7 comes from the seventh level (application level) of the communications model for Open System Interconnection (OSI), which is ISO's communications specifications. These specifications lay out details such as data definitions, the timings of information exchange, and application error processing.

The Japan Industrial Association of Radiological Systems [6] has been tackling standardization and legislative problems in the field of radiological sciences since its establishment in 1924. In particular, the Digital Imaging and Communication in Medicine commission has been set up within the Medical Imaging Systems Committee to develop, spread, and promote standards specifications that have defined the formats and communications protocols for medical images captured by devices such as magnetic resonance imaging and computed tomography equipment.

The Japanese Association of Healthcare Information Systems Industry is conducting investigative research and promotion related to improving the relevant technology and ensuring both quality and safety. It is also conducting activities related to participation, policies, and institutions from a technological viewpoint for standardization and promotion.

The Continua Health Alliance [7] was established with the objective of digitizing health-related and medical equipment and integrating communications specifications to improve the quality of health management of individuals, and over 230 businesses worldwide have become members, including 40 within Japan. Health-related and other equipment developed by member companies is developed in accordance with Continua's design guidelines. Continua-compliant approval ensures that health-related equipment for the home, such as blood-pressure monitors and weighing machines, and medical equipment used in medical organizations can work together seamlessly with these systems and services.

In this manner, standardization activities are progressing in various different organizations. In Japan, the Health Information and Communication Standards



http://www.ihe.net/Connectathon/upload/mendelson_ihe_na_connectathon_conference_2008_01_29.pdf

Fig. 3. IHE cycle.

Board (HELICS) holds talks concerning the details and directions of standardization with the aim of implementing consistent activities among organizations working to standardize healthcare and welfare information. HELICS conferences do not implement standardization themselves: they review the standards specifications of Japanese standardization bodies and issue recommendations to MHLW as medical information standardization guidelines.

MHLW provides a forum for discussing specifications that ought to be accepted as standards specifications in the healthcare information field at the Healthcare Information Standardization Conference. On March 31, 2010, it set out eight standards specifications as MHLW Standards Specifications [8]. Their implementation is not compulsory by law, but considering the advantages of complying with the standards, measures based on MHLW Standards Specifications will be specified in various requirement and subsidiary businesses related to medical information systems implemented in MHLW in the future.

8. Ensuring interoperability

As we have shown in this overview, there are various different standards specifications in existence, but even if they are followed, there will often be interoperability problems in practice when actual products are connected. The initiative for Integrating the Healthcare Enterprise (IHE) is working to resolve such problems.

In 1998, IHE started operation in collaboration with the Radiological Society of North America (RSNA) and the Healthcare Information and Management Systems Society (HIMSS), and it has since expanded internationally. Japan joined in 2001 and has recently become more active.

IHE clarifies how standards specifications should be applied for information exchange by setting up a workflow for each sequence of actions, such as from the issue of a request for a checkup to receipt of the results. This ensures interoperability that is even easier to implement. This workflow, which is called an *integration profile*, is laid out in a document called an IHE technological framework.

IHE also conducts a connection test called a Connectathon (a portmanteau word combining connect and marathon) and is active in providing information about connectivity by publishing the results of this test.

The cycle of IHE activities, including the above, is shown in **Fig. 3**. [9]. Medical organizations that have IT-related problems, such as interoperability ones, are implementing information systems that can operate with other systems, even with types of medical equipment and equipment from other vendors, by using IHE to draw up an integrated profile and technological framework, implementing them in workshops and products through the vendors, and then selecting a vendor on the basis of an integrated statement

that summarizes the Connectathon results and the IHE response.

9. Future directions

In the past, Western countries have enthusiastically promoted EHR and PHR structures, and in Japan, the "My Hospital Everywhere (Japanese Personal Health Record)" initiative and regional healthcare enterprises are progressing steadily, mainly due to government initiatives. More specifically, standard documentation formats are being maintained for purposes ranging from medical care statements and dispensing information to medical checkup information, hospital discharge summaries for the patients themselves (hospitalization record summaries), and checkup data. These will be utilized in services such as regional healthcare enterprises [4].

In moving towards the implementation of EHRs and PHRs for managing and utilizing such medical and healthcare information, it is essential to conform to standardization and ensure interoperability, and activities to those ends are being performed vigorously. Once EHRs and PHRs have been implemented, it will be possible to configure an environment in which information can be utilized far more significantly, which should have a huge effect on problems such as rapidly rising medical expenses and medical quality.

NTT research laboratories utilize ICT in the medical and health fields and are responding towards technology development and standardization intended to implement an even better society for our customers.

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He received the B.E., M.E., and Ph.D. degrees in electronic and information engineering from Toyohashi University of Technology, Aichi, in 1995, 1997, and 2000, respectively. In 1997, he was a trainee visiting researcher at ATR Human Information Processing Research Laboratories. He pointed out the distortion along the left and right frames in stereoscopic 3D displays and proposed a correction method called "Virtual Frame". He received Student Awards from the Institute of Electronics, Information and Communication Engineers (IEICE) and from the Telecommunications Advancement Foundation in 1997 and 1998. After finishing his research at University and ATR, he joined NTT Cyber Space Laboratory in 2000 and studied super-high-reality communication technologies including super-high-resolution (4K/2K) and 3D image display systems and their human factors like visual fatigue evaluation. He promoted the Super High Reality Communication Service via the broadband optical fiber network and received the Japanese 3D Image Conference Award in 2005. During 2005–2007, he was Deputy Manager of the Life Science Business Promotion Office, Business Innovation Sector, in NTT DATA. During 2007–2010, he was Deputy Senior Analyst at the Research Institute for System Science, Research and Development Headquarters, in NTT DATA. He was active in proposing EHRs and PHRs in Japan and wrote a published Japanese translation of a book on PHRs. Since 2010, he has been studying technologies related to e-Health services including EHRs, PHRs, and mental healthcare systems in NTT Service Integration Laboratories.

NTT America—
The Chief Technology Officer's Perspective

Doug Junkins†

Abstract

NTT America, with its prominent headquarters in New York City, is the sales and operations group for NTT Communications' products and services throughout North, Central, and South America. In this article, I would like to give readers a comprehensive look at NTT America's capabilities, an assessment of some of its core assets and technologies, and a synopsis of the Office of the Chief Technology Officer (CTO). The synopsis will showcase a few of the current technology trends observed from NTT America's viewpoint and detail many of the activities undertaken by the CTO.

1. Overview of NTT America

NTT America, the U.S. subsidiary of NTT Communications (NTT Com), is headquartered in New York. The Chief Executive Officer is Kazuhiro Gomi, who was appointed in June 2010. The 600+ strong workforce supports the three primary business divisions.

NTT America's private network services are grouped under Arcstar™, the brand name that is fast becoming synonymous with advanced telecommunications technology and superior service. With its leased-line services, IP-VPN (Internet protocol virtual private network), and MPLS (multiprotocol label switching) network access, Arcstar is leading the way for multinational corporate sales. The Arcstar sales team targets both Japanese companies doing business in the USA and U.S. companies expanding their networks to Asia with comprehensive support services conducted in both English and Japanese. With NTT Com's purchase of Pacific Crossing, owners of the PC-1 transpacific submarine cable system, NTT America now has two of the most attractive low-latency routes targeted at the financial services segment: New York to Tokyo and Chicago to Tokyo.

NTT Com's Global IP Network (or GIN, as it is known inside NTT Com) owns and operates a Tier-1 IP network that is one of the largest Internet backbones in the world. Driven by financially backed service level agreements (SLAs), secure networking and managed VPNs, reliable content distribution capability via Smart Content Delivery™, and NTT Com's award-winning commercial implementation of IPv6 (Internet protocol version 6), the GIN team targets Internet service providers, web hosting providers, content providers, broadband providers, and large enterprises throughout North, Central, and South America. Known for its rapid provisioning of new customers and excellent customer support in both English and Spanish, the U.S. GIN team is a segment leader. Renesys Corporation[*1], the leading network operator research firm, recently noted that GIN had risen to fourth place among global operators. Soon after that report, GIN took over third place from Sprint. NTT America's Enterprise Hosting services leverage the company's strong customer care and

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*1 Renesys Corporation, "A Baker's Dozen, 2010 Edition." http://bit.ly/gHZiCK

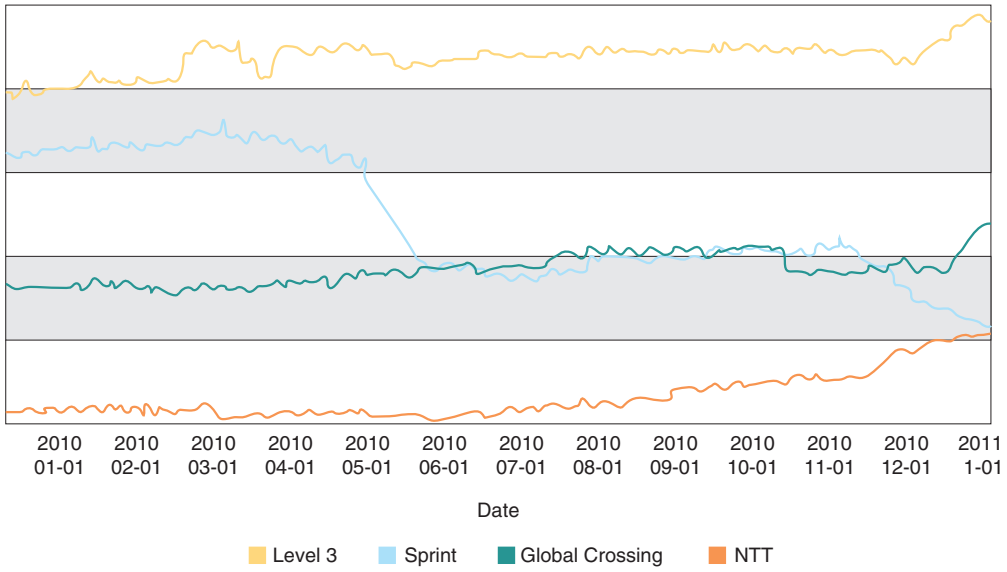


Fig. 1. First cluster (providers 1–4).

engineering quality to provide application hosting, collaborative messaging, colocation, managed hosting, private and public cloud computing, and a range of managed services from five company-owned data-centers in the USA. The Gartner Group recently added NTT Com to the web hosting and cloud computing Magic Quadrant[*2], noting that "NTT has a global carrier's breadth of product portfolio, and it is willing to take on highly customized engagements. NTT executes well in its target deal profile—large, complex and customized, for a global customer with needs spanning multiple data centers in different regions." With brand-name clients like Twitter, the Enterprise Hosting sales teams target social media and gaming companies, Web 2.0, media and entertainment, systems integrators, information technology (IT) consulting businesses, e-commerce, and enterprise customers in North and South America (**Fig. 1**).

2. Technical trends seen by NTT America's CTO

From the Office of the CTO, it's a front-seat view of the technology trends in the USA and abroad. NTT America benefits from the increased use of networking and hosting services, which are the key components for Internet and data-intensive communications. Below are a few noteworthy U.S. trends.

2.1 Mobility and wireless

There is a proliferation of smartphones in the USA driven by the iPhone and Android phones. Broadband access, which was once limited to homes and offices, is fully available on the go at 3G (third generation) speeds, and in some cases the higher speeds offered by LTE (Long Term Evolution). As more people have Internet-connected devices as constant companions, the amount of time they spend using applications, browsing, and downloading video continues to increase. This is great news for network access and hosting providers like NTT America.

2.2 Exponential growth in connected devices

With Wi-Fi, 3G, Ethernet, and other forms of Internet access becoming increasingly available, the number of connected devices is growing exponentially. In homes, it's not uncommon to see smartphones, laptops, personal computers, gaming consoles, media centers, handheld devices, tablets, and other devices all using the home's broadband connection. It's no wonder that the number of IPv4 addresses is rapidly becoming depleted. On February 1, 2011, IANA (Internet Assigned Numbers Authority) allocated the final /8 blocks of IPv4 addresses to the Regional Internet Registries (RIRs). While it will take some

*2 Gartner Group, "Magic Quadrant for Cloud Infrastructure as a Service and Web Hosting." http://bit.ly/fwL9vs

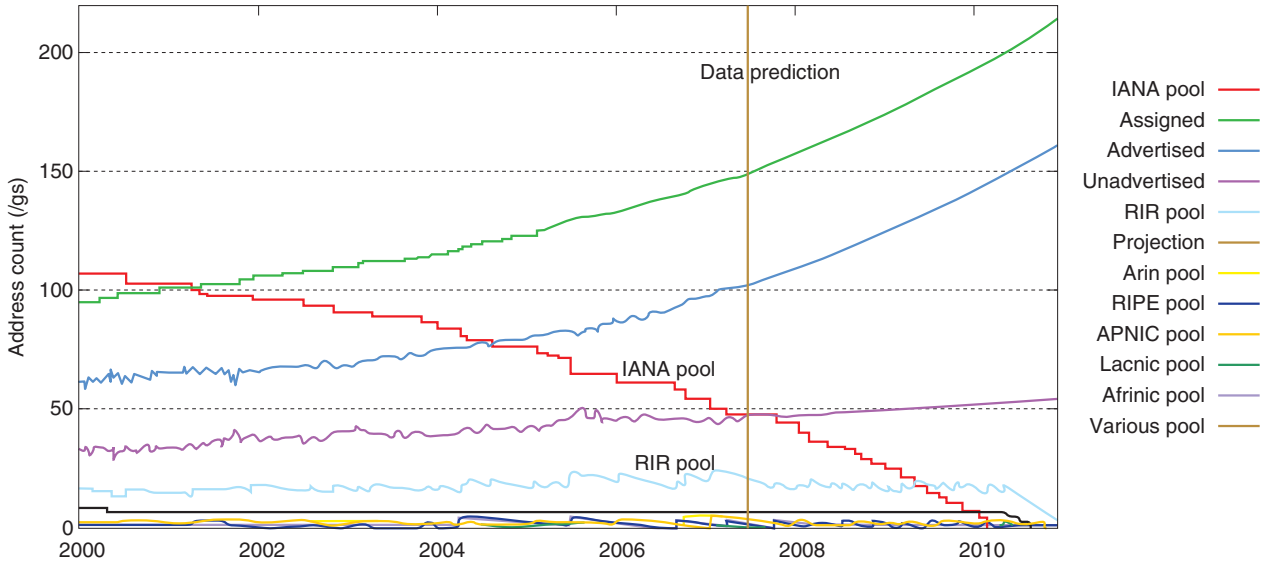


Fig. 2. Address consumption model.

time before all of those addresses are used, the available addresses will soon be gone (**Fig. 2**).

2.3 100-Gigabit/s Ethernet

At the end of the day, data networking is the backbone of a wired world. Whether they use submarine or terrestrial cable systems, networks utilize fiber optics to transmit their data, and network sizes keep on growing. After years of 70% annual growth rates, GIN grew by more than 100% in 2010. Currently, GIN's solution is to bundle 10GbE (10 Gigabit Ethernet) connections, but this won't scale much longer. Today, we need about 100 10G edge ports per point of presence (PoP). By the end of 2011, we will require about 200 10G edge ports per PoP, with most of those ports in large link aggregation bundles. Network operators, like GIN, must move to routers that support 100-Gbit/s port connections sooner rather than later. The issue of cost is paramount, and equipment must become relatively affordable (at about 8–10 times 10GbE pricing) and offer routers with 400–500 Gbit/s per slot.

2.4 IPv6

With the proliferation of connected devices, IPv6 was devised as the next-generation network protocol to provide IP addressing to usher the Internet through its next phase of growth. The ability to give each device an IP address, coupled with built-in IPSEC, (IP security) network self-discovery, and a host of other features will open up endless new possibilities. For network operators or enterprises operating large networks, it will be possible to obtain address blocks for contiguous addressing of devices.

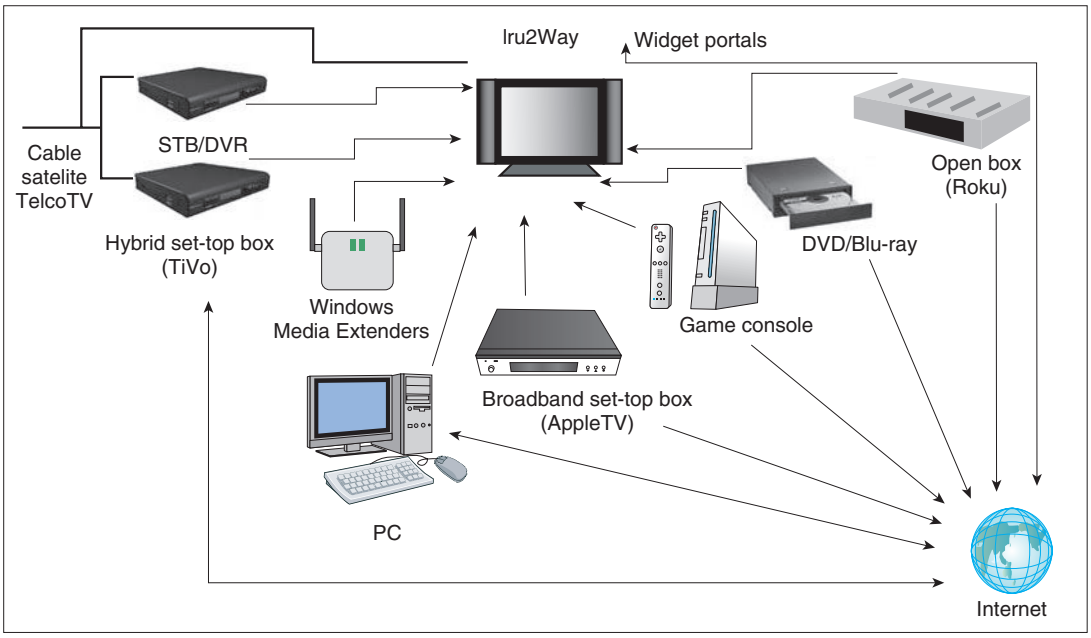
2.5 Cloud computing and virtualization

The Internet has become the de facto media transmission network for news and movie distribution, television broadcasting, ebooks, music, etc. The datacenters hosting these data types must be highly connected and highly available so that users can maintain constant access.

From Facebook apps to Salesforce.com, a multitude of server-based systems were deployed in 2010 and will be deployed in 2011 and beyond. The cost savings, resiliency and uptime, service level guarantees, and the ability to let a business focus on its core strengths and not the technology are just a few of the key reasons why and how cloud computing is making a fundamental impact on server deployment (**Figs. 3** and **4**).

2.6 Social networking

The global importance of social networking almost goes without saying. With 25 billion tweets in 2010, Twitter grew by 100 million users. Facebook now claims over 600 million users (out of 2 billion Internet users, or 30%), had 36 billion photos uploaded to its server last year, and has an estimated market capitalization of US$50 billion. We've seen only the tip of



DVD: digital versatile disc
DVR: digital video recorder
PC: personal computer
STB: set-top box

Fig. 3. Networks in the Cloud.

Fig. 4. NTT America Cloud video.

the iceberg in this segment.

2.7 High-frequency trading

High-frequency trading and algorithmic trading have dominated the world's stock, commodity, and currency trading systems, accounting for, at times, up to 70% of the volume. In these applications, highly advanced computer systems can receive data, analyze it, and execute trades in a matter of milliseconds. As such, the latency in the networks between the computer systems and exchanges is of critical importance. Financial firms are willing to pay premium prices for network access that can produce the lowest latency or shave milliseconds off their current latency. Such time differences translate into huge profits for the traders.

2.8 Greening of datacenters

Datacenters consume massive amounts of electricity, sometimes up to megawatts at each installation. Because of their drain on the electrical grid, rising costs of fossil fuels, and unending demand, intense scrutiny must be placed on the efficient use of electricity by datacenter operators. Some tactics might be as simple as using air curtains to separate and direct

the flows of cold and hot air. Other tactics could be more complicated but pay huge dividends. These include the use of solid oxide fuel cells, which can convert natural gas or even methane gas, and produce electricity onsite (**Fig. 5**). The technological development of super-high-efficiency computer room air-conditioning systems, combined with temperature sensors linked to server utilization monitors, can offer significant savings while not wasting precious resources.

3. Activities of the CTO

As the CTO for NTT America, I see across the entire company's technology portfolio and into many different areas on the business side.

On the business side, I represent technology leadership for the company, and I am utilized in press and media relations on a regular basis. This can be as simple as providing a quote for a press release, giving media interviews for industry journals, or leading panels and presentations at industry conferences, including speaking at the Ethernet Expo event in New York, the CTO Telecom Summit, FutureNet, and the Consumer Electronics Show—a Digital Hollywood event in Las Vegas.

The technology side of my job is what I like most, as I'm a trained electrical engineer. I spend a lot of time on vendor management, not only to control the cost of the components that we purchase, but also to understand the vendor's technology roadmaps and how they might fit with our product roadmaps and customer responsibilities. I also act as a bridge between the IT department and OSS (operations support systems) development teams to ensure that they are fully aligned with one another. We are making significant efforts to improve our automation systems in 2011 and are actively exporting our systems to other NTT Com affiliates. We are leveraging those relationships in 2011 to understand the technological capabilities of other parts of NTT and how we can leverage those capabilities to strengthen the solutions we bring to our customers, such as developing services for carriers in emerging markets in South America by leveraging the technology that NTT uses to manage consumer networks in Japan. Lastly, I see

Fig. 5. 100-kw solid oxide fuel cell at a datacenter.

myself as the advocate for the many technologies that we have developed here at NTT America. There are three examples I'd like to share.

1) GNOME

GNOME is used for operational management and monitoring of network connections and assets. It is being used by both NTT Com in Japan and NTT Europe to manage GIN customer information.

2) GMP

GMP is another OSS system developed to help manage the hosting line of business. It is one of the cornerstones of the Global Virtualization Service, which is poised to offer unprecedented cloud computing services on a global scale.

3) ConfigTools

By operating a network of such size and scale, we realized as long ago as 1997 that we needed to have a way to upload new system images, configurations, and changes to our backbone routers while eliminating any possibility for human error. From this requirement, we developed ConfigTools, which is now the system used NTT-wide for making router changes in GIN.

Comment from NTT America

After the devastating earthquake and tsunami in the northeast part of Japan on March 11, 2011, many non-profit organizations in New York established special funds to aid victims and help the disaster recovery effort. NTT America has already made a donation to the special fund sponsored by the Japanese Chamber of Commerce in New York.

On March 17th, hundreds of Japanese residents in New York gathered in Union Square, the central part of Manhattan, to collect funds and spread awareness for Japan's ongoing recovery from earthquakes and tsunamis. Families and other groups wore white and red T-shirts with slogans like "Japanese United" to collect checks and small cash donations for organizations.

When I walk in front of Grand Central Station, the largest train station in the USA, I see several small grass-roots groups in front of the station building and hear calls for help. In response to that, many New Yorkers pull bills or coins from their purses and put them in the *bokin-bako* (donation box). It seems to me that New Yorkers usually have little interest in foreign affairs outside the USA, but for this devastating event they may want to make some contributions to the people in Japan.

Moreover, through word-of-mouth communication in New York's Japanese communities and through Twitter and Facebook, some grass-roots charity events will be held in New York such as auctions of paintings, 12-hour music concerts performed by famous musicians, sake-tasting events, and charity marathons in Central Park.

When I send email to my colleagues across the USA for various projects, they always ask if my family and relatives in Japan are okay before getting down to business. NTT America has offices in various locations in the USA such as Virginia, Chicago, Dallas, Denver, Seattle, San Jose, and New York, but most of the American workers respond in the same way. For that, I am deeply grateful.

Finally, my colleagues and I would like to express our profound sympathy to the victims of the 2011 Tohoku earthquake and tsunami and offer our deepest condolences to their families and friends. We sincerely hope that the afflicted areas can recover quickly.

Satoru Fujimoto, NTT America

EMC Countermeasure Products for DSL Services

Abstract

This article introduces EMC countermeasure products for overcoming electromagnetic compatibility problems in digital subscriber line (DSL) services, i.e., noise filters, which have been developed by NTT EAST. It is the fourth in a bimonthly series on the theme of practical field information about telecommunication technologies. This month's contribution is from the EMC Engineering Group, Technical Assistance and Support Center, Maintenance and Service Operations Department, Network Business Headquarters.

1. Introduction

Broadband services typified by digital subscriber line (DSL) and fiber to the home (FTTH) have been spreading rapidly. Among DSL services, very-high-bitrate DSL (VDSL) has been widely used as a means of providing FTTH services to individual user premises in multi-dwelling units like apartment complexes or dormitories. However, users' homes often contain inverter noise generated by home electronics, fluorescent lights, and other devices as well as electromagnetic noise from broadcast signals, amateur radio, and other sources. In short, the electromagnetic environment in the home has become increasingly bad, and electromagnetic noise may affect DSL communication signals, so undesirable phenomena such as drops in transmission speed and lost links may occur.

To solve this problem of electromagnetic noise that affects DSL services, the EMC Engineering Group has developed noise filters for use with DSL. This article introduces these products.

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2. Environments surrounding broadband services

2.1 Transmission signals and noise over a wide band

Transmission frequency bands for VDSL, asynchronous DSL (ADSL), other services, and typical sources of electromagnetic noise are shown in **Fig. 1**. The transmission band of POTS (plain old telephone service; the standard telephone service) is an audible band covering the frequencies of the human voice. For this band, typical types of electromagnetic noise are low-frequency noise from fluorescent lights and electromagnetic induction noise from power lines and electric railways. In contrast, ADSL and VDSL use a wide band from about 20 kHz to 30 MHz, in which a variety of electromagnetic-noise sources are known to exist such as inverters, motors, ultrasonic devices, medium-wave and shortwave radio, and amateur radio. Thus, broadband signals may be affected by electromagnetic disturbances generated from a variety of electromagnetic noise sources.

2.2 Installation environments

The number of sites installing telecommunication equipment to get broadband services is increasing. These include not only general households but also office buildings. Since telecommunication equipment connects to power systems just like electronic devices, low-frequency noise from inverters and impulsive (high-frequency) noise generated by on/off switching

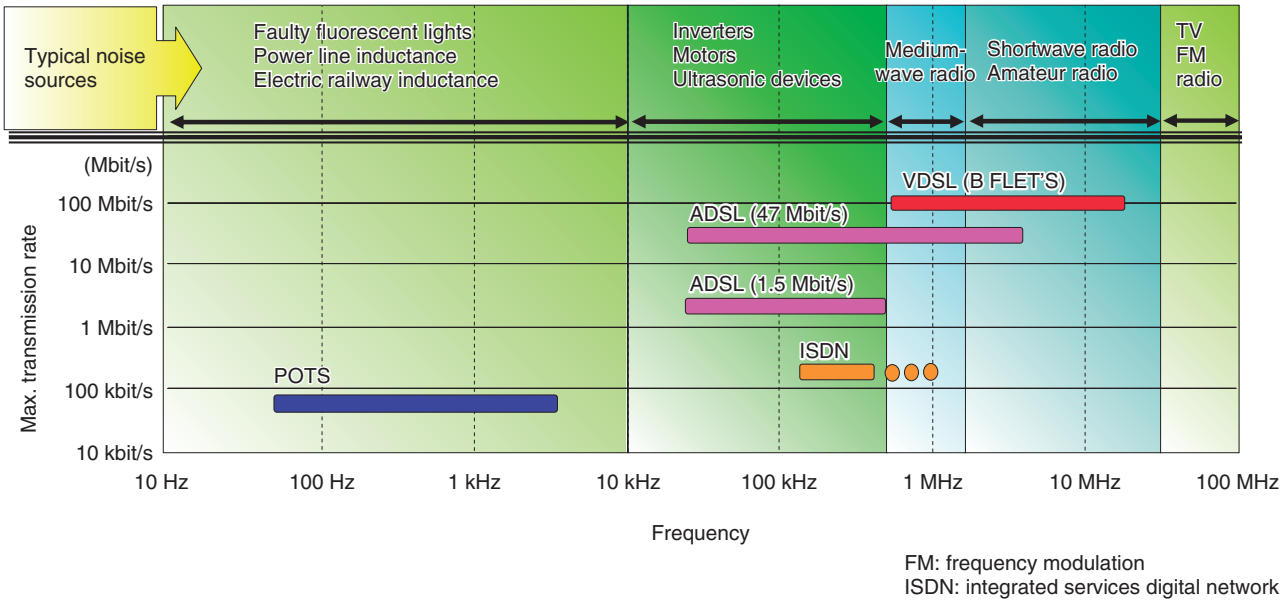


Fig. 1. DSL transmission bands and typical noise sources.

of power supplies can enter telecommunication equipment through power lines. This can cause undesirable phenomenon like transmission speed drops and lost links. Furthermore, it is not uncommon in some types of installation environments for telecommunication equipment to be installed without ground connections even though the equipment itself may include ground terminals. The roles of a ground are to protect the human body, secure a reference potential, and improve the balance between a communications device and the earth's surface. But in actual environments, there are many situations in which ground connections cannot be performed, and inserting noise filters in such a situation has been found to have no effect. There is therefore a need for strong electromagnetic compatibility (EMC) effects (noise countermeasures) even in environments in which ground connections cannot be performed.

3. EMC countermeasures for DSL services

3.1 EMC problems

A number of EMC-related problems need to be solved to improve the reliability and convenience of DSL services, and to this end, the following technologies are needed.

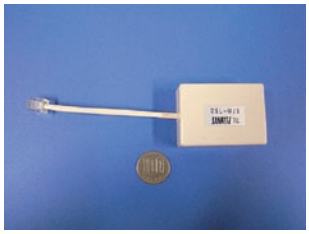
(1) Noise-filtering technology for communication lines causing little attenuation (insertion loss) of transmission signals (normal mode) while having a large electromagnetic-noise (common mode) suppression effect
(2) Noise-filtering technology for wideband power-supply systems targeting both low-frequency noise from inverter equipment and other devices and impulsive noise generated by on/off switching of power supplies
(3) Noise-filtering technology that can achieve a strong noise-suppression effect even in installation sites where grounding cannot be performed

To satisfy these three technology requirements, NTT EAST has developed noise filters for DSL lines (DSL-MJS and DSL-F Type B<4>) and a power-supply tap with a built-in noise filter (BMFU-5A). These products are described below.

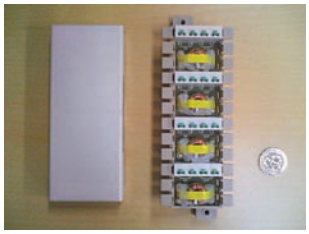
3.2 EMC countermeasures for communication lines (noise filters for DSL lines)

The noise filters for DSL lines developed by NTT EAST come in two types: DSL-MJS for DSL modems connects by a modular jack and DSL-F Type B<4> for VDSL aggregators connects by spring-lock terminals.

The appearances of these filters are shown in **Fig. 2** and their features are listed in **Table 1**. Owing to the difference in the way that these filters connect, the DSL-MJS filter is effective against noise for ADSL/VDSL modems while the DSL-F Type B<4> filter is



DSL-MJS



DSL-F Type B<4>

Fig. 2. Noise filters for DSL lines (communication lines).

Table 1. Features of noise filters for DSL lines (communication lines).

Noise filters for DSL lines	(1) DSL-MJS	(2) DSL-F Type B<4>
External dimensions	50 mm × 40 mm × 20 mm	155 mm × 55 mm × 33 mm
Application	ADSL/VDSL modems	VDSL aggregators
Connection terminal	Modular jack	Spring-lock terminal
Attenuation	Normal-mode attenuation: 0.5 dB or less (10 kHz to 10 MHz) Common-mode attenuation: 30 dB or greater (10 kHz to 10 MHz)	

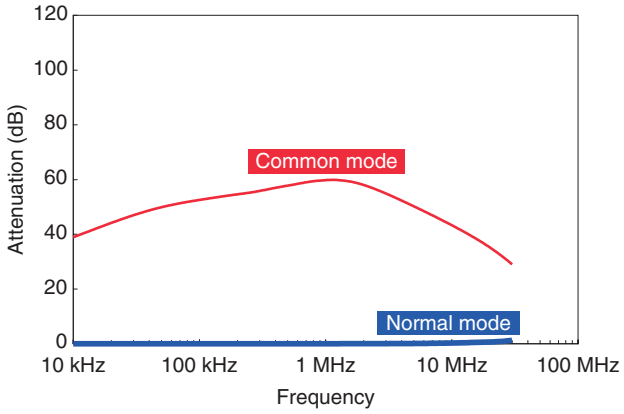


Fig. 3. Characteristics of the noise filters for DSL lines (communication lines).

effective for VDSL aggregators. The common- and normal-mode attenuation characteristics of these noise filters for DSL lines are shown in **Fig. 3**. These filters are of the toroidal* type that uses core materials with high magnetic permeability. In the frequency range from 10 kHz to 10 MHz, they achieve common-mode attenuation of 30 dB or more and suppress normal-mode attenuation to less than 0.5 dB. These filters therefore provide more effective EMC countermeasures for DSL services than existing ones.

3.3 EMC countermeasure for power-supply lines (power-supply tap with built-in noise filter)

The appearance of the power-supply tap with built-in noise filter (BMFU-5A) developed by NTT EAST is shown in **Fig. 4**. This product has a three-pin plug on the primary side and provides five 2-pin sockets, each with a ground terminal, on the secondary side. Its features are listed in **Table 2**. Compared with a noise-cutoff transformer with the same rated capacity, this equipment is compact and light, which makes it suitable for installation in tight spaces like a main distribution frame (MDF) room housing a VDSL aggregator in a multi-dwelling unit. The common- and normal-mode attenuation characteristics of this power-supply tap with built-in noise filter are shown in **Fig. 5**. They show that common-mode attenuation

* A toroidal filter has wire wound around a doughnut-shaped magnetic core to confine magnetic flux within the coil. This configuration simplifies coil design and implementation.

Fig. 4. Power-supply tap with built-in noise filter (power-supply lines).

Table 2. Features of power-supply tap with built-in noise filter (power-supply lines).

External dimensions		255 mm × 175 mm × 55 mm
Configuration	Primary side	3-pin plug
	Secondary side	2-pin plug × 5 plus 5 ground terminals
Rated capacity		AC 125 V, 5 A (500 W or less)
Attenuation		Normal-mode: 40 dB or greater (30 kHz to 30 MHz) Common-mode: 20 dB or greater (10 kHz to 20 MHz)

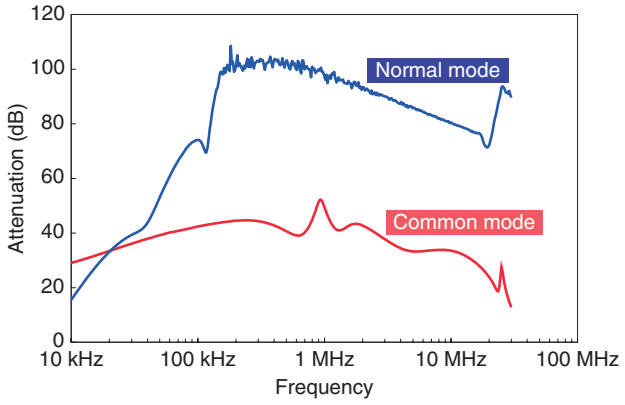


Fig. 5. Characteristics of power-supply tap with built-in noise filter (power-supply lines).

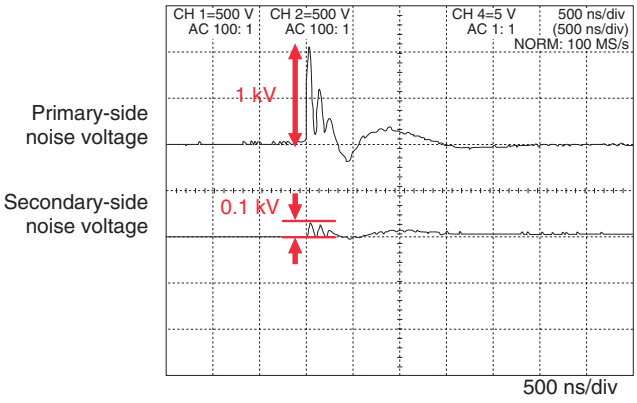


Fig. 6. Effect on impulsive noise.

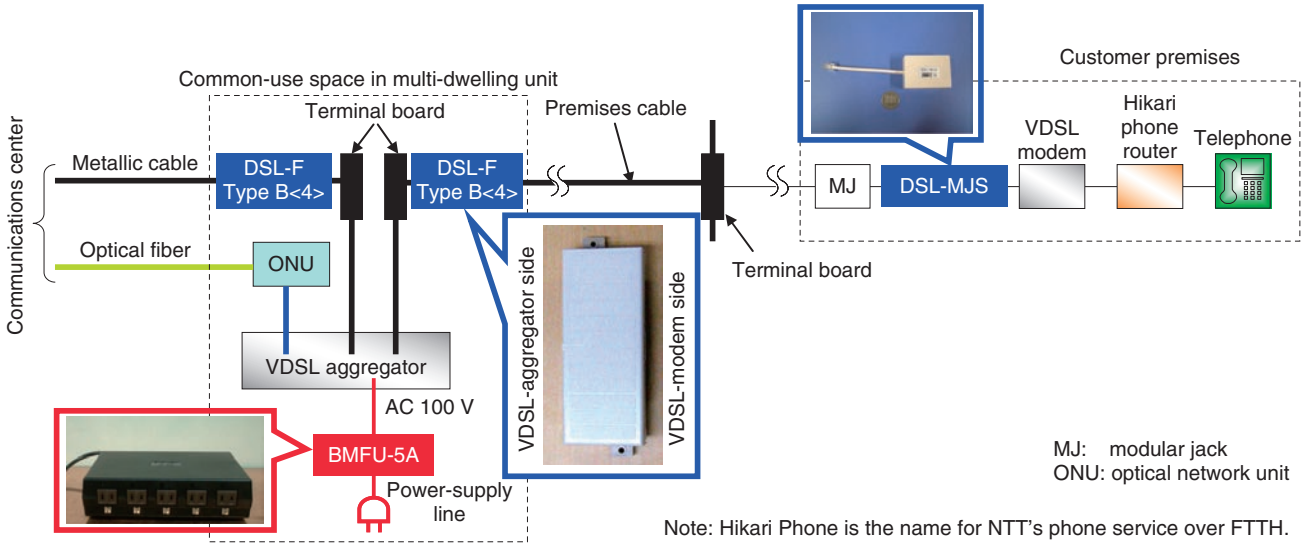


Fig. 7. Example of EMC countermeasures for VDSL services.

in a state with no ground connection is high—20 dB or greater in the frequency range from 10 kHz to 20 MHz—and that normal-mode attenuation is also high: 40 dB in the frequency range from 30 kHz to 30 MHz. This product is therefore effective against noise over a wide band including inverter noise and impulsive noise caused by on/off switching. Its normal-mode attenuation is higher than that of noise filters for DSL lines, but since the amount of attenuation at a frequency of 50/60 Hz in AC power supplies is small enough to be ignored, there is no effect on the AC feed.

As described above, the product has a noise-suppression effect of 20 dB or greater in situations with no ground connection, but an even greater noise-suppression effect can be obtained if the ground terminal is connected to the building or another ground.

For reference purposes, **Fig. 6** shows the results of measuring the noise-suppression effect of this product when a 1-kV impulse wave was applied to the power-supply line as specified in the fast transient/burst test at an AC power-supply port in NTT's technical requirements (TR549001). These results show that a burst impulse of 1 kV is attenuated to 1/10 or less on the secondary side, which indicates that this product also has a sufficient noise-suppression effect

on impulsive noise.

4. Example of EMC countermeasures for VDSL services

An example of implementing EMC countermeasures for VDSL services provided for a multi-dwelling unit is shown in **Fig. 7**. In this scenario, metallic cable and optical fiber from a communications center connect to a VDSL aggregator in the building's common-use space, and the VDSL aggregator connects to the VDSL modem inside the customer's premises via metallic cable inside the building.

The places where electromagnetic noise can enter telecommunication equipment are mainly power-supply lines and communication lines. Electromagnetic noise can also propagate via metallic cables inside the building. The filters introduced in this article are used at these locations. The setup in Fig. 7 shows how a BMFU-5A filter can be used as an EMC countermeasure on the power-supply line of a VDSL aggregator. Moreover, DSL-F Type B<4> filters can be used as an EMC countermeasure on communication lines while a DSL-MJS filter can be used on the communication-line port of the VDSL modem. Using filters in this way at locations where noise can enter can mitigate the effects of noise on telecommunication equipment.

5. Conclusion

This article introduced noise filters for DSL lines and a power-supply tap with a built-in noise filter as EMC countermeasure products for DSL services. Looking forward, the Technical Assistance and Support Center at NTT EAST will continue its work on solving noise problems with the aim of providing NTT customers with stable broadband services.

External Awards

Certificate for Special Merit Awards for Outstanding Paper

Winners: Shunichi Seko, Manabu Motegi, Takashi Yagi, and Shinyo Muto, NTT Cyber Solutions Laboratories
Date: Jan. 10, 2011
Organization: The International Conference on Consumer Electronics (ICCE)

For "Video Content Recommendation for Group Based on Viewing History and Viewer Preference".

This paper proposes an algorithm for estimating useful content for known groups. The method enables recommendations for a group such as friends, a couple, and a family. As the first step, we focused on preferences among group members. Our algorithm estimates the preferences using the rating for individuals for video genres and viewing history shared together. Then we judge whether the content is useful for the group on the basis of the preferences. Evaluation tests show that our algorithm is serendipitous.

Published in: 2011 IEEE International Conference on Consumer Electronics (ICCE)
To be published in: IEEE Xplore Digital Library.
http://www.ieeexplore.ieee.org/

NWS Research Award

Winner: Yuusuke Nakano, NTT Network Service Systems Laboratories
Date: Feb. 23, 2011
Organization: Technical Committee on Network Software

For "Method for Using Computational Resources in PCs via Their Web Browsers".

NWS Research Award

Winner: Satoshi Kondoh, NTT Network Service Systems Laboratories
Date: Feb. 23, 2011
Organization: Technical Committee on Network Software

For "Parallel Processing for Sequential Pattern Recognition in HTTP Traffic".

English Session Encouragement Award

Winner: Rie Hayashi, NTT Network Service Systems Laboratories
Date: Mar. 10, 2011
Organization: IEICE Technical Committee on Information and Communication Management

For "Design and Implementation of an Optical Plug and Play Technique (2010 IEICE Society Conference BS-7-27)".

This paper proposes an optical plug and play (PnP) function that enables generalized multiprotocol label switching (GMPLS) networks to be constructed automatically. We establish the architectural requirements for PnP in end-to-end wavelength-division-multiplexing (WDM) networks including routers and optical cross connects (OXCs) and confirm its feasibility through a demonstration using commercial routers and OXCs.

Papers Published in Technical Journals and Conference Proceedings

Approach to Achieving a Carrier-envelope Phase-locked Frequency Comb with Wide Mode Spacing at Telecommunications Wavelengths

T. Nishikawa, A. Ishizawa, A. Mizutori, H. Takara, H. Nakano, A. Takada, and M. Koga

Proc. of the 2nd STAR Symposium on UILS, STAR Cooperation on Ultrafast Intense Laser Science, Amoy, China, 2010.

In this talk, I will present our recent approach to achieving a carrier-envelope phase-locked (CEP-locked) frequency comb with 25-GHz mode spacing at telecommunications wavelengths. First, we tried to reduce the required laser pulse energy to lock the CEP. For this purpose, we used a tellurite photonic crystal fiber and a direct-bonded quasi-phasematched $LiNbO_3$ ridge waveguide for the generation of an octave-bandwidth spectrum and the second harmonic in an *f*-to-2*f* self-referencing interferometer, respectively. We succeeded in making a CEP-locked frequency comb at telecommunications wavelengths with a fiber-coupling pulse energy of 230 pJ. Next, we tried to create a high-repetition-rate optical pulse train seeded from a continuous-wave semiconductor laser without using a mode-locking technique. The combination of phase modulation and dispersive fiber is essential for its generation. With our method, a 250-fs optical pulse trained at 25-GHz can be generated.

Convergence-guaranteed Multiplicative Algorithms for

Nonnegative Matrix Factorization with β-divergence

M. Nakano, H. Kameoka, J. L. Roux, Y. Kitano, N. Ono, and S. Sagayama

Proc. of the 2010 IEEE International Workshop on Machine Learning for Signal Processing, Kittilä, Finland, 2010.

This paper presents a new multiplicative algorithm for nonnegative matrix factorization with β-divergence. The derived update rules have a similar form to those of the conventional multiplicative algorithm, only differing through the presence of an exponent term depending on β. The convergence is theoretically proven for any real-valued β based on the auxiliary function method. The convergence speed is experimentally investigated in comparison with previous work.

Statistical Model of Speech F_0 Contours

H. Kameoka, J. L. Roux, and Y. Ohishi

Proc. of Statistical and Perceptual Audition 2010, ISCA, pp. 43–48, Makuhari, Japan.

This paper proposes a statistical model of speech fundamental frequency (F_0) contours based on the formulation of the discrete-time stochastic process version of the Fujisaki model, which is known as a well-founded mathematical model representing the control mechanism of vocal fold vibration. There are two important motivations for this statistical formulation. One is to derive a general parameter estimation framework for the Fujisaki model that allows the introduction of powerful statistical methods and the other is to introduce a measure of speech naturalness into terms of F_0 contours through a probability distribution assumption, which can be incorporated into many statistical speech processing problems such as speech analysis, synthesis, separation, denoising, and dereverberation.

Fixed Mobile Convergence Application Services Using ID Mapping Database on IMS (IP multimedia subsystem)

A. Kurokawa, I. Inoue, and N. Takaya

Proc. of World Telecommunications Congress 2010, OVE-Austrian Electrotechnical Association, Vol. 2010, No. 1, pp. 31–36, Vienna, Austria.

This paper proposes a new concept of a fixed mobile convergence (FMC) application architecture by using an identity (ID) mapping database for accommodating many kinds of devices on different fixed and mobile networks. We propose two approaches for creating new FMC services. One is linked multiple call sessions over multiple terminals and the other is an approach that focuses on customer ownership of multiple terminals. We also describe a method of implementing linked network services to be used for personal computers on a fixed network and for mobile phones on a mobile network by using a common application accessed by each network and an ID mapping database. Lastly, we describe an implementation approach applied to a prototype system.

Simple Sets of Measurements for Universal Quantum Computation and Graph State Preparation

Y. Takahashi

International Journal of Quantum Information, Vol. 8, No. 6, 2010.

We consider the problem of minimizing resources required for universal quantum computation using only projective measurements. The resources we focus on are observables, which describe projective measurements, and ancillary qubits. We show that the set of observables $\{Z \otimes X, (\cos\theta)X + (\sin\theta)Y \text{ all } \theta \in [0, 2\pi)\}$ with one ancillary qubit is universal for quantum computation. The set is simpler than a previous one in the sense that one-qubit projective measurements described by the observables in the set are ones only in the (X,Y) plane of the Bloch sphere. The proof of the universality immediately implies a simple set of observables that is approximately universal for quantum computation. Moreover, the proof implies a simple set of observables for preparing graph states efficiently.

Authentication Platform for VPN Services (invited paper)

K. Matsui, K. Ota, and H. Kurita

IEICE Technical Report, Vol. 110, No. 224, pp. 25–30, 2010 (in Japanese).

Virtual private network (VPN) services are widely used especially by corporate users to connect to remote networks. Because VPN services are constructed on public IP (Internet protocol) networks, VPN authentication for user validation is needed. To improve the safety and convenience of VPN services, the following are required: multifactor authentication that combines authentication by password and by other attributes and cooperation with the application service that uses VPN and VPN authentication. Moreover, high availability of VPN authentication is also important because VPN service is becoming the basis of corporate activities. To meet these requirements, we are researching and developing a VPN authentication platform that has functions for multifactor authentication, authentication cooperation, and high availability. This paper outlines VPN authentication and its trend and describes our developed VPN authentication system "AAA".

Anonymity, Privacy, Onymity, and Identity: A Modal Logic Approach

Y. Tsukada, K. Mano, H. Sakurada, and Y. Kawabe

Transactions on Data Privacy, IIIA-CSIC, Vol. 3, No. 3, pp. 177–198, 2010.

In this paper, we propose a taxonomy of privacy-related information-hiding/disclosure properties in terms of the modal logic of knowledge for multi-agent systems. The properties considered here are anonymity, privacy, onymity, and identity. Intuitively, their meanings are as follows: anonymity hides who performed a certain specific action, privacy hides what was performed by a certain specific agent, onymity discloses who performed a certain specific action, and identity discloses what was performed by a certain specific agent. Building on Halpern and O'Neill's work, we provide formal definitions of these properties and study the logical structure underlying them. In particular, we show that some weak forms of anonymity and privacy are compatible with some weak forms of onymity and identity, respectively. We also discuss relationships between our definitions and existing standard terminology, in particular Pfitzmann and Hansen's consolidated proposal.

Indoor Air Monitoring Using Newly Developed Portable Formaldehyde Monitoring Device

Y. Y. Maruo and J. Nakamura

Indoor Environment, Vol. 13, No. 2, pp. 163–172, 2010 (in Japanese).

We have developed a portable device for monitoring formaldehyde and have carried out indoor air monitoring in several houses. The absorbance difference of the developed sensor element is measured at regular intervals in the monitoring device and converted into

formaldehyde concentration. This is possible because the rutidine derivative formed as a yellow product of the reaction between β-diketone and formaldehyde is stable in the sensor element. The device contains a light-emitting diode as a light source and photodiodes as photodetectors. It is sufficiently small (10 cm × 10 cm × 4 cm) to be installed at a desired location in a house. In addition, the device can monitor a closed area without a convection flow because it does not use a pump for air sampling. The detection limit is 5 ppb·hour, and we estimated that it took about 1 hour to detect a formaldehyde concentration of 94%. The developed sensor device is small and easy to use and we successfully carried out hourly formaldehyde monitoring using our device under several indoor conditions. We found that a high formaldehyde concentration could be measured in a room containing furniture and clothes. We also found that, although the formaldehyde concentration decreased rapidly when ventilation was provided, it recovered rapidly in a few hours when we stopped ventilating the room.

Sound and Vibration Integrated Cues for Presenting Virtual Motions

T. Saito, Y. Ikei, T. Amemiya, and K. Hirota

Proc. of ICAT 2010, VRSJ, pp. 216–217, Adelaide, Australia.

In the present study, we discuss the characteristics of sound and vibration integrated cuing for presenting virtual motions. Three-dimensional sound via 7.1-channel speakers and cutaneous vibration stimuli on the back and thigh are controlled to create the sensation of motion of virtual objects and the self body. The cuing system is designed as part of a multisensory display for an ultra-realistic experience. The system was used to investigate fundamental motion perception regarding onset timing factors for creating the sensation of motion.

High-sensitivity Charge Detection Using Antisymmetric Vibration in Coupled Micromechanical Oscillators

H. Okamoto, N. Kitajima, K. Onomitsu, R. Kometani, S. Warisawa, S. Ishihara, and H. Yamaguchi

Appl. Phys. Lett., Vol. 98, No. 1, p. 014103, 2011.

High-sensitivity charge detection using antisymmetric vibration in two coupled GaAs oscillators is demonstrated. The antisymmetric mode under in-phase simultaneous driving of the two oscillators disappears with perfect frequency tuning. The piezoelectric stress induced by a small gate-voltage modulation breaks the balance of the two oscillators, leading to the re-emergence of the antisymmetric mode. Measurement of the amplitude change enables detection of the applied voltage or, equivalently, added charges. In contrast to frequency-shift detection using a single oscillator, our method allows a large readout up to the strongly driven nonlinear response regime, providing high room-temperature sensitivity of 147 e/Hz$^{0.5}$.

Improving Power Spectra Estimation in 2-Dimensional Areas Using Number of Active Sound Sources

Y. Hioka, K. Furuya, Y. Haneda, and A. Kataoka

IEICE Trans. Fundamentals, Vol. E94-A, No. 1, pp. 273–281, 2011.

An improvement of estimating sound power spectra located in a particular two-dimensional area is proposed. We previously proposed a conventional method that estimates sound power spectra using multiple fixed beamformings in order to emphasize speech located in a particular two-dimensional area. However, the method has one drawback that the number of areas where the active sound sources are located must be restricted. This restriction makes the method less effective when many noise source located in different areas are simultaneously active. In this paper, we reveal the cause of this restriction and determine the maximum number of areas for which the method is able to simultaneously estimate sound power spectra. Then we also introduce a procedure for investigating areas that include active sound sources to reduce the number of unknown power spectra to be estimated. The effectiveness of the proposed method is examined by experimental evaluation applied to sounds recorded in a practical environment.

Vibration Amplification, Damping, and Self-Oscillations in Micromechanical Resonators Induced by Optomechanical Coupling through Carrier Excitation

H. Okamoto, D. Ito, K. Onomitsu, H. Sanada, H. Gotoh, T. Sogawa, and H. Yamaguchi

Phys. Rev. Lett., Vol. 106, p. 036801, 2011.

Carrier-induced dynamic backaction in micromechanical resonators is demonstrated. Thermal vibration of an *n*-GaAs/*i*-GaAs bilayer cantilever is amplified by optical band-gap excitation, and for the excitation power above a critical value, self-oscillations are induced. These phenomena are found in the [110]-oriented cantilever, whereas the damping (deamplification) is observed in the [$\bar{1}$10] orientation. This optomechanical coupling does not require any optical cavities but is instead based on the piezoelectric effect that is generated by photoinduced carriers.

End-User QoE Estimation for Video Communication Services by Packet-layer Model

M. Kasuda, K. Ushiki, T. Tominaga, T. Hayashi, A. Takahashi, and K. Kawashima

IEICE, Vol. J94-B, No. 1, pp. 24–35, 2011 (in Japanese).

In IP (Internet protocol) video communication services, not only bearer quality on the IP network but also the implementation of end-terminals strongly affects end-users' quality of experience (QoE). We propose a packet-layer model for estimating the video quality of IP video communication services from information in packet headers. Our model is an end-users' QoE estimation method using invalid frames, which are quality-degraded video frames, whose duration depends on the type of picture with invalid packets and on the structure of a group of pictures. The invalid packets are the sum of data loss in the IP network and end-terminals. Experimental results show that the proposed model performs well, achieving sufficient accuracy for use in quality monitoring of IP videophone and IPTV services.

Multimedia Quality Estimation Model for Video Streaming Services

T. Tominaga, K. Yamagishi, T. Hayashi, and A. Takahashi

IEICE, Vol. J94-B, No. 1, pp. 49–60, 2011 (in Japanese).

This paper proposes a multimedia quality estimation model for high-definition television (HDTV) video streaming services. The model is expressed by audio quality, video quality, and the quality of their multiplicative interaction term. First, we performed tests using two subjective assessment methods to clarify an adequate method based on the model's structure. We found that the method of evaluating the individual quality separately was adequate for measuring audio and video quality. Then we performed multiple regression analysis and constructed the multimedia quality estimation model.

Finally, we showed the model's accuracies for a real system's degradation pattern and for unknown content.

LEAVES: Legend Enhanced Application Virtual Environment System

S. Hashimoto, Y. Seki, and H. Suwa

Information Processing Society of Japan, Vol. 52, No. 1, pp. 121–130, 2011.

Organizations that have a rapid turnover of staff face difficulties in passing on the knowledge possessed by experienced people to the next generation. Our goal was to build a system for smoothly passing on notes gained from experience and to make notes containing important information more "visible". Our system, Legend Enhanced Application Virtual Environment System (LEAVES), was built on the basis of a related study of an input format for formalizing notes, a system for sharing information, an algorithm for automating information organization, and an expression method that is easily understood by an inexperienced person. We tested how well the system could be used to handle notes related to two logistical challenges: moving a laboratory and setting up an exhibition. We found that LEAVES could be used to effectively create and pass on notes.
