Current and Future Infrastructure Networks Aimed at Resolving Issues Related to the Changing and Diversifying Activities in Society

● Kazuyoshi Kumatani ● Eiichiro Takahashi ● Tsuguo Kato

Communication is the basis for social interaction, and users continue to demand and be provided various new services. Communication networks supporting these new services have been developed, and connection technologies have evolved. Smartphones and cloud services are becoming key components of everyday life, so communication network providers now have a social responsibility to provide reliable connections. This paper discusses a number of issues facing network and service providers as communication changes both qualitatively and quantitatively and as social infrastructure becomes more and more important. It introduces the latest technologies from Fujitsu's research initiatives that resolve these issues, gives specific examples, and discusses future trends and directions in infrastructure networks.

1. Introduction

The problems facing us seem to be continuously increasing in number and diversifying, and concerns are increasing regarding the environment, energy supply, the aging society, safety, and security. We also face difficulties due to natural disasters such as earthquakes and typhoons. There are thus many problems in daily life that information and communications technology (ICT) could help solve.

Over the past several years, phrases such as "ubiquitous information society" and "ambient society" have been used to express innovation due to ICT in our everyday social environment. Currently, creating social infrastructure to control energy supply and demand is a problem-solving theme that is receiving particular attention, and there is a burgeoning market in the U.S. for SmartGrid and SmartCommunity products (SmartHouse, SmartCity, etc.) based on upgraded power networks.

ICT can also be used to solve significant problems in society as it continues to age ever more quickly. For example, in Europe, which leads Japan in confronting the problem of an aging society, policies are being advanced for "Fusion of Elderly Society and Information Society." They have even been given a place within the European Commission's information strategy of promoting ambient assisted living (AAL), which provides advanced health care through ICT to assist people in their daily activities, with the goal of independent life for the elderly. Initiatives promoting this social infrastructure reform have been introduced, but still more technical innovation is needed.

Lessons from earthquakes and typhoons have shown that un-interruptible, continuously connected networks must be constructed and that more R&D is needed. Technical innovation for safe and secure information-use environments that are resistant to targeted cyber-attacks is also a major issue for ICT use in social life.

Providing leadership in solving the major global ICT problems described above is an important theme for boosting and stimulating the economy in Japan.

In this paper, we describe Fujitsu's initiatives in line with its vision of "Realizing a Human-Centric Intelligent Society" in the area of networking, keeping in mind issues of life in society and an awareness of problems that need to be solved with ICT.

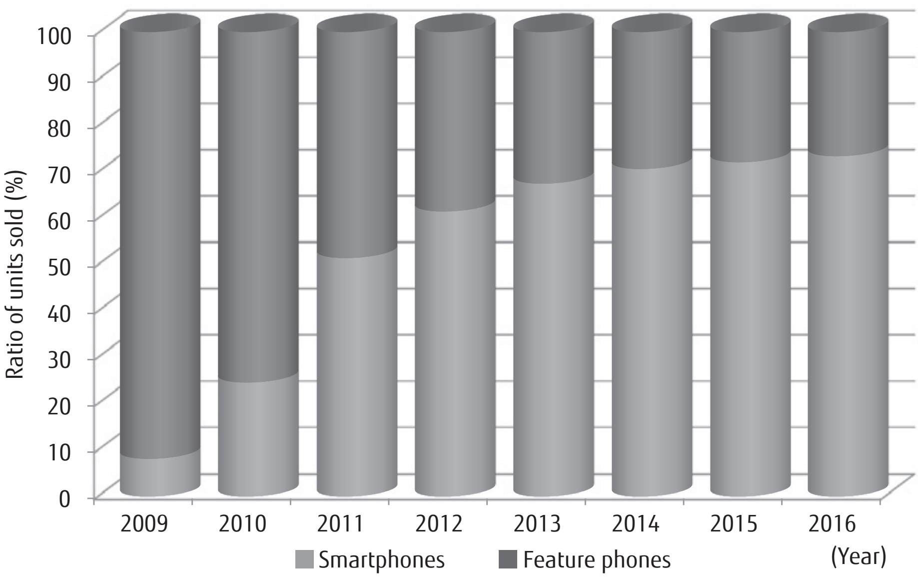
2. Current situation of networks and societal needs (problems, challenges)

As described above, striking changes are occurring in our social environment, with diversification in the styles of work, life, and activity of people facing various problems of daily life and with accelerating changes in the interests and motivations of people. The approaching wave of technical innovation in ICT is also diversifying and accelerating. This change is bringing rapid increases in the circulation and diffusion of information, in terms of both scale and speed. As a result, the importance of networks is being taken up as never before, as a topic itself and in practical situations in industrial fields and product technologies.

Networks are expanding continuously as usage scenarios diversify, and the range of devices connecting to networks is expanding in terms of the number of types and products. Network use is maturing as an infrastructure for life in society through network-native devices (smart devices) such as PCs, smartphones (**Figure 1**), and tablets capable of communication, which people use for various purposes. This rapid increase in the number of connected devices is bringing traffic increases and placing pressure on networks, and even more traffic is being added due to the advance of functions that use background communication for purposes such as launching applications autonomously and frequently performing automatic live updates. This is presenting technical problems that cannot be solved by extending traditional traffic theory and network design methods, so new approaches to technical development are needed.

Network use by these types of smart devices, with new communication characteristics, is increasing rapidly, but network use by non-network-native devices (machine devices) that have conventionally functioned separately and independently, such as automobiles, industrial machinery, and vending machines, and even home appliances, healthcare devices, and energy creation and storage devices is also increasing rapidly. The growing diversification of devices connected to networks is generally seen as a major driver of the structural changes in societal infrastructure systems.

The fact that phrases such as "Internet of Things" (IoT) and "machine to machine" (M2M) have become key terms in the networking industry is also an indication of the changing trends in social infrastructure and the everyday environments described above. These phrases can be said to give an overall expression of the innovation needed in network technology for ICT initiatives related to the types of problems facing society described above, such as aging populations, the environment, energy supply, safety, and security.



Data is from "Smart Device Front Lines" (Nomura Research Institute IT Roadmap Seminar SPRING 2012 documents), and "IT Navigator, 2012 Edition" (Toyo Keizai Inc.)

Figure 1
Shift in smartphone and feature phone ratios.

3. Network use by machine devices

Due to the expansion in the use of networks by machine devices through IoT and M2M, in addition to the rapid increase in use of smart devices, previously unknown communication characteristics are expected to emerge to which conventional traffic theory and network design techniques cannot be applied, so innovative technical advances in networking will be needed.

Because the changes seen during the past ten years are assumed to continue into the future, along with diversification of access methods and growth in the volume of communication (including both the amount of traffic and the amount of data transmitted), innovations in technology for handling communication are essential. There are a growing number of devices using networks, a growing number of sessions, and a growing number of services. The resulting diversification of communication characteristics is becoming a major issue in the effort to handle the increasing volume of communication.

Handling of the increasing volume of communication traffic requires that steady progress be made in the transmission technologies used in the transport layer. It is important that transport layer technologies in various categories advance in an aligned and integrated way, including those used in the access and core networks of the mobile and fixed-line services of wide area networks (WANs) and also in various other network environments, such as body area networks (BANs), personal area networks (PANs), local area networks (LANs), and ad hoc networks.

Furthermore, the growing and diversifying communication characteristics of machine devices using networks are highly dependent on the type of device, their internal functions, and the behavior of the services and business applications that control them. Network use by machine devices often has such characteristics as permanent connections, multiple locations, and burst communication. These characteristics derive from a model with countless sensor-type machine devices distributed throughout the environment, constantly connected to the network, handling diverse data from several bits to images, and transmitting at irregular intervals as changes occur in the environment.

However, it is not rational to assume that countless machine devices can connect to a network and communicate autonomously with no order in the actual market situation. There are domain definitions based on some sort of order for each service or business application, and it is realistic to operate networks in accordance with these definitions. Thus, a valuable network function for establishing a new business landscape and expanding a market on the basis of concepts like IoT and M2M is one that enables design of spaces that can differentiate communication characteristics derived from a domain-defined order and that can handle them independently. Network virtualization can provide such a function.

Over the past several years, new network operation technologies based on concepts of self-organizing networks (SONs) and software-defined networks (SDNs) have been proposed. SON technologies are used to operate networks autonomously while SDN technologies are used to control network functions and configuration through software. These technologies increase operation and management efficiency. SON technologies were developed for Long Term Evolution (LTE) base stations, and SDN technologies were developed for data centers. However, they have also become important elemental technologies in network virtualization, which has supported the emergence of IoT and M2M markets.

Figure 2 shows a model of network value provision. Technical innovation that aligns and integrates the different categories at the WAN transport layer and domain definitions providing network service spaces for handling the various communication characteristics using virtualization technology have supported the emergence of the necessary network value.

A network solution providing service domains defined in accordance with a regularity determined by the characteristics of a service or business application and the devices using the network, with platform and infrastructure as a set of resources, forms a base that will bring about the innovation in network services expressed by terms like IoT and M2M in the near future. In such a network solution, the WAN, data centers, and various BANs, PANs, LANs, and ad hoc networks will need to be operated in a unified manner.

In the following sections, we describe research initiatives at Fujitsu aimed at this necessary technical innovation.

4. Transport layer technology initiatives

As discussed above, one of the essentials

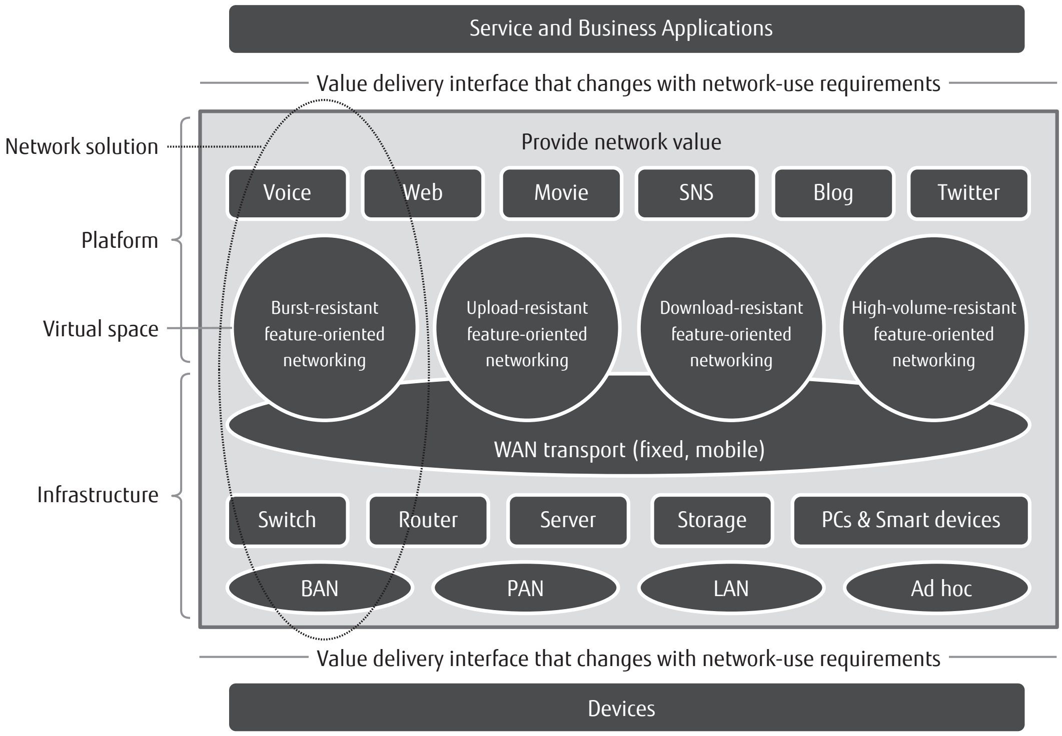


Figure 2
Provision of network value.

supporting realization of network value in the future is that transmission technology at the transport layer will continue to advance, and Fujitsu has various initiatives in this area.

4.1 Wireless traffic initiatives

Wireless traffic has continued to grow vigorously over the past several years, particularly with the appearance and spread of smart devices and the resulting rapid increase in the downloading of mobile applications such as games and video, which has been nearly doubling each year. There are three basic approaches to addressing this increase in wireless traffic.

1) Increase efficiency of wireless technology itself

Orthogonal frequency division multiple access (OFDMA) and multiple-input multiple-output (MIMO) technologies increase the amount of data transmitted per frequency. Current LTE using 4×4 MIMO improves spectral efficiency to approximately 2.7 b/s/Hz/cell. However, this technology is thought to be reaching its limits. Theoretically, spectral efficiency can be improved by increasing the number of MIMO antennas, but it is not practical to increase the number of antennas indefinitely, considering how cellular systems are used, economic factors, and frequency bands.

2) Reduce cell size

Using smaller cells reduces the area covered by a single base station and increases the density of the base stations. It also reduces the number of users per base station and increases the amount of bandwidth available per user, which enables the total traffic capacity to increase. Using smaller cells requires increasing the spatial reuse of frequencies. At Fujitsu, we have developed an LTE femto-cell. A femto-cell is a compact base station for installation in homes, offices, or shops that connects to the mobile operator's network through a broadband connection such as asymmetric digital subscriber line (ADSL) or fiber-to-the-home (FTTH). This is a particularly effective approach to improving network speed (i.e., throughput) indoors where it is hard to receive the signal from an outdoor base station. Another method being proposed is to accommodate multiple compact remote radio heads (RRHs), connected to a base station by optical fiber or other means, and to combine them with a larger base station. This architecture is referred to as a heterogeneous network

(HetNet). Using a HetNet improves spectral efficiency through centralized control of multiple compact RRHs and the large base station.

3) Expand bandwidth of frequencies used

As an example, the 800-MHz and 2-GHz bands have conventionally been used for cellular networks in Japan, but adding the 700-MHz, 900-MHz, 1.5-GHz, and 1.7 GHz-bands as well as over-3 GHz bands for LTE-Advanced is being studied. A technology for carrier aggregation is currently being developed. It will enable multiple LTE/LTE-advanced frequency bands to be used together to improve per-user throughput. LTE and Wi-Fi interworking or aggregation technologies are also being developed to improve per-user throughput. Wi-Fi has already penetrated many homes and offices, so it is a reasonable means of reducing cell size and improving the throughput, particularly indoors. In the future, ultra-high-speed wireless bands such as microwave and millimeter-wave bands may also be interworked or aggregated with LTE/LTE-Advanced bands.

Conversely, for transmitting outdoors, linking with TV white (empty) spaces may also be an effective way of expanding bandwidth. Commercial use of TV white spaces for communication has already begun in some areas outside of Japan, but except for some advanced research facilities, study has only just begun in Japan. Fujitsu is collecting basic data regarding the extent to which TV white spaces can be used as radio resources.

4.2 Backbone traffic initiatives

While Fujitsu has undertaken initiatives in line with these three approaches to handling the increases in wireless traffic, photonics networks, the backbones supporting wireless traffic, are starting to become practical for 100-Gb/s long-distance optical transmission. Conventional single-wavelength, on/off methods are limited, so it is essential to introduce digital coherent technologies in order to implement high-speed (100 Gb/s), wideband, long-distance optical communication. This involves using ultra-high-speed digital signal processing technologies such as multi-value modulation and distortion compensation as used with wireless transmission.

Fujitsu has already implemented a 100-Gb/s long-distance optical transmission module using dual-polarization quadrature phase shift keying (DP-QPSK) and a system incorporating this module. Currently, we are developing another modulation scheme and also developing the technology to increases the density of wavelength channels, with the goal of achieving 400-Gb/s and 1-Tb/s long-distance optical transmission.

Universal optical transceiving is another important technology for achieving such transmission. The use of digital signal processing technology would make it possible to control through software the degree of multi-value modulation and the frequency band occupied. This would enable implementation of, for example, a transmitter and receiver for 100-Gb/s transmission over 2000 km and a transmitter and receiver for 400-Gb/s transmission over 500 km using the same modules and the same platform. This would enable implementation of optical paths that can be reconfigured dynamically as demand changes during operation in accordance with the required bandwidth, the distance, and the target quality. The result would be more efficient operation of photonic networks.

While core networks require transmission over long distances, access networks require wider bandwidth. There is no need to span long distances in the access field, but much lower cost is necessary. Fujitsu is focusing on the lower end of digital signal processing technology, with R&D on an extremely low-cost broadband photonics communications technology using inexpensive optical components based on a technology called discrete multitone (DMT).

5. Communication diversification initiatives

Moreover, it will also be important to handle diversification of communication to support realization of network value in the future. In particular, network use by machine devices for M2M and IoT together with the spread of cloud computing is expected to lead to the appearance on the network of many separate and independent virtual systems with different communication characteristics. While many issues will likely arise during the implementation of this sort of world, an initial one will be how to accommodate the diversity of machine devices.

5.1 Front-end networks

As machine devices diversify, front-end networks that directly accommodate such devices will also diversify. For wireless networks in particular, various wireless technologies based on system requirements such as distance and speed will be needed while others based on such factors as power consumption and device size will be needed.

Fujitsu has been developing technologies based on using UHF-band RF tags and multi-hop wireless systems for smart-meter applications. We are also conducting R&D on BANs for use in medical fields. Each of these R&D efforts involves different requirements. For example, looking at RF tags, it must be possible to immediately read tags on all test tubes even if they contain differing amounts of liquid, while for disk tags, even if the center material is different, it must be possible to read them. Medical BANs are also involved in protecting patients' lives, so systems must be highly reliable while at the same time not requiring frequent battery changes or other maintenance so as not to increase the workload of the medical staff. With such developments in machine devices, individual systems will need to be developed in accordance with the communication between machine devices and the solutions incorporating them. The large numbers of devices also raises various issues, including simply how to manage them. At this point, specialists with wireless networking skills are still needed to build and operate the front-end wireless networks that can accommodate such devices. In the future, as M2M and IoT become mainstream, the number of front-end wireless networks will increase rapidly, so requiring a wireless specialist to build, operate, and manage them will become a limitation. Anticipating such a situation, Fujitsu has begun to study systems that will enable those with no wireless network skills, or solution providers offering systems integration staff or services, and even users of front-end wireless networks, to build, operate, and manage such networks themselves. This does not mean simply leaving everything to the user—the key idea is that the work of building, operating, and managing these networks will be offloaded appropriately to users, so that M2M and IoT can propagate widely.

5.2 Core networks

For core networks, a common architecture that can handle such diversity is required. SDNs will play an important role in this. There are various definitions of SDN, but one definition is an abstraction. Each layer of the network is abstracted and commoditized by defining open interfaces between them, enabling capital expenditure to be decreased while enabling users to freely define their own networks. Thus, the work of building, operating, and managing networks can be appropriately offloaded to users, as it can be with front-end wireless networks, as discussed above.

Fujitsu is also studying mechanisms for providing network environments on physical resources such as switches, routers, and other communication devices as well as on servers, storage devices, and terminals, as shown in Figure 2. These mechanisms will be used to provide several common virtual networking spaces (virtual spaces) in anticipation of the various applications and services that users and service providers may select. They will enable users and service providers to define a virtual space suitable for their own service or application quickly and easily.

6. Current technology innovations and future directions

In the previous section, we discussed networking issues related to handling the diversification of activities in society as well as examples of related initiatives at Fujitsu. In this section, we review the current innovations in communications technology and consider future directions for network technology.

6.1 Current communications technology innovations

Services being provided to end users are driving the changes being made in communication networks, and the "connecting" function, which is an important factor in communication, advances in accordance with the requirements. This functions evolves mostly in terms of quality and quantity. Starting with voice communication, we can see that recent communications technologies have gone through three main innovations as providers seek to achieve more efficient and economical deployment.

1) Digitalization

The first innovation in connection technology occurred in the latter half of the 1970s, when the communications field adopted digitalization for voice and data communications. While the main voice services based on analog technology (frequency division multiplexing, FDM) had spread widely, digital had already become the de facto standard in information processing technology and was spreading as a basic approach to stimulating the economy. Under these conditions, digitalization of communication networks, including switches and transmission equipment, was a rational means of linking networking and information processing technologies.

2) Increasing capacity and speed

Starting in the early 1980s, the use of voice services increased as immediate and automatic connection was realized nationally, and communication networks for enterprises, such as the digital data network (DDN) and the integrated services digital network (ISDN), began to spread. At the same time, the second connection technology innovation appeared. Capacities and speeds increased through improvements in optical communication, multiplexing architectures, and component technologies due to the standardization of such technologies as optical communication, synchronous digital hierarchy (SDH), and wavelength division multiplexing (WDM). WDM technology in particular contributed to a marked increase in communication line capacities.

3) Sweeping change to next-generation networks

Moving from the late 1990s into the early 2000s brought the age of human migration on a global scale, and this accompanied the global expansion of network traffic, broadband able to handle voice and data communication at the same time, and the rapid advance into the age of the Internet, which transcends geographical distances. To enable connection to the Internet, communication networks adopted Internet protocol (IP) technology in a sweeping change to next-generation networks (NGNs). This provided the infrastructure to handle the diversification of services anticipated in the future. This was the third innovation in connection technology.

In the late 2000s, wired broadband technologies (xDSL, FTTH, etc.) became the main access technologies, providing reliable connections between PCs and between PCs and data centers. As 2010 approached, the main access technologies for NGN networks began a shift to mobile broadband, with technologies such as 3G and 4G (especially LTE). A major factor in this was that mobile phones, which had mainly been for voice, became terminals that can also access the Internet and run applications. Consolidating the infrastructure controlled by NGNs expanded access temporally and geographically and expanded the range of access methods, enabling anyone, anywhere, and at any time to connect easily.

6.2 Future directions

The services provided by communications providers enable people to connect with each other through telephones, cell phones, tablets, and PCs. By implementing the three technical innovations described above in turn, they have expanded their earnings. As a global leader in the development of communications technologies, Fujitsu has played a key role in these efforts.

However, with the appearance of application providers offering services such as search, Internet retailing, and social networking, the resulting increase in communication has not equated to increases in the earnings of communications providers; i.e., the structural model has changed. Users creating traffic on networks by participating in social networking services (SNSs), content delivery networks (CDNs), online games, and other services have introduced new external factors from the network's perspective. Rather than the traffic on the network simply increasing, a mechanism that increases traffic now exists within the network itself. The players controlling the amount of traffic on the network are also moving from the conventional communications operators to service providers holding users and high-volume content service providers. Network models have also begun expanding to include cloud services and business models connecting objects to objects and objects to people. These factors mean that the mechanisms causing increases in traffic on the network will continue to expand further.

Traffic can also be characterized by volume and frequency: e.g., frequent transmissions of small amounts of data, infrequent transmissions of large amounts of data, and transmissions falling in between. As the number of players controlling traffic volume increases, service models are expanding. Moreover, the number of devices making connections is increasing dramatically, and the type and quality of traffic is diversifying. At the beginning of this paper, we described a method of classifying and virtualizing network use by purpose in accordance with how users are using the network that is based on the model shown in Figure 2. In the future, however, traffic control will be a key to classifying traffic and selecting efficient connection methods on the basis of quantity and quality.

For communication, which is the basis for social interaction, to connect smoothly and without congestion in the future, control of traffic flowing into the network could be assigned to both physical and logical connections in accordance with the services they provide. Traffic caused by service requests from users consists of communication between persons and between persons and objects, and these types of traffic currently account for the majority of traffic. On the other hand, traffic caused by service requests from objects consists of communication between objects and between objects and persons. We expect this type of traffic to increase and account for more of the traffic volume in the future.

An example of an architecture enabling such traffic to flow naturally on the network is shown in **Figure 3**. It introduces the concept of a traffic control function, which classifies traffic in accordance with its purpose. It allocates traffic with large amounts of physical traffic to a physical layer and traffic that is dependent on the service to a logical layer in accordance with the type of service applied, thus virtualizing the physical and logical networks in accordance with the purpose. With this function, virtual spaces having networking oriented to various characteristics, as shown in Figure 2, can be used to distribute and reduce traffic loads, thereby providing smoother communication.

Figure 4 shows the innovations in and evolution of communications technology. As described in the first part of this paper, technical innovation till now has centered on connections for communication. In future communication network infrastructures, rather than users selecting a network, networks will autonomously select a network environment that matches the user's purpose, bringing us closer to "naturally connected" communication. Through appropriate virtual control of the mechanisms leading to an increase in traffic volumes, such as by using the concept of a traffic control function as shown in Figure 3, physical connections not visually seen (i.e., the Internet) support connections between people. Thus, by naturally connecting virtual networks to our daily activities, we should be able to achieve more comfortable lives.

7. Conclusion

While maintaining a physical network infrastructure that can be relied upon will continue to be important in realizing networks with natural connectivity, there are also many other significant issues such as ensuring the security of the data being processed. Following the current paradigm shifts in business structures, the next new innovation in network technology will include linking and integration of the hardware and software that comprise networks, as discussed in this

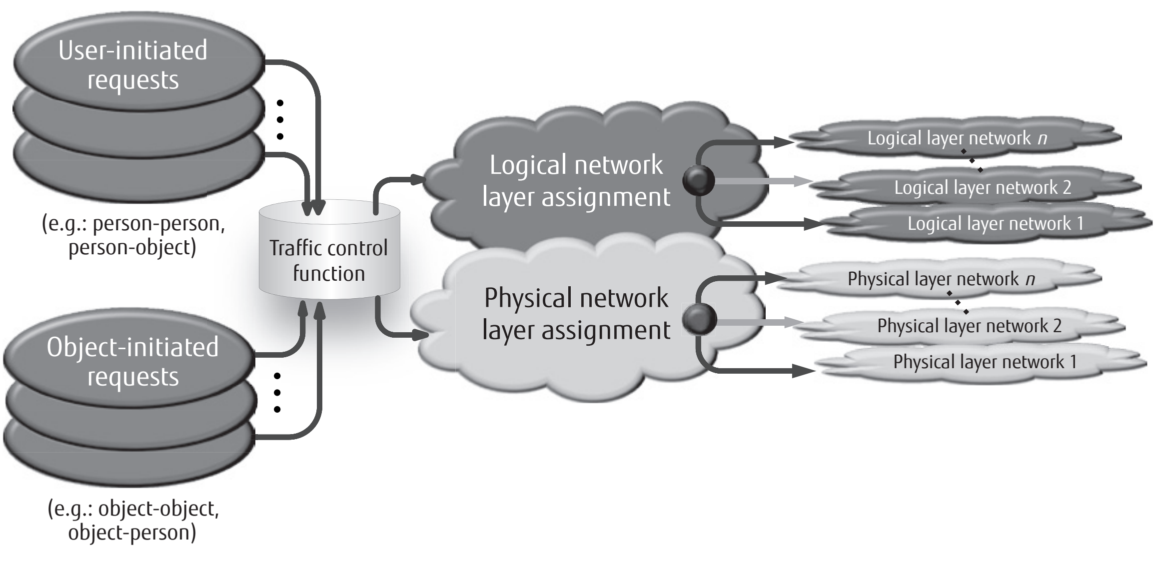


Figure 3
Traffic control concept example.

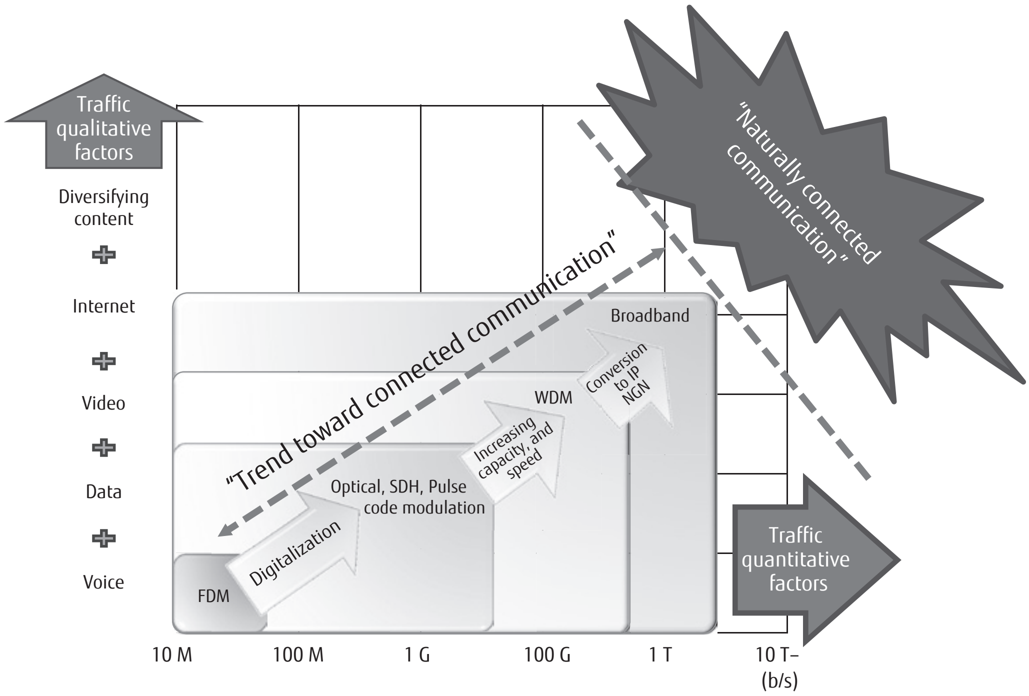


Figure 4
Innovations in and evolution of communications technology.

paper, and may also involve layering violations of the network model. Innovative theories of traffic must also be created, and we can expect social transformation due to future innovations in connection technology.

In this special issue, we introduce Fujitsu's initiatives aimed at developing advanced connection technologies along with platforms for network services and management and the latest network transport infrastructure that supports them. These initiatives support the realization of a rich, human-centered society.

Kazuyoshi Kumatani
Fujitsu Ltd.
Prior to his retirement, Mr. Kumatani was engaged in international business and external activities related to communications as well as in promoting standardization.

Tsuguo Kato
Fujitsu Laboratories Ltd.
Mr. Kato is currently engaged in research and development of photonics, wireless, and IP networks.

Eiichiro Takahashi
Fujitsu Ltd.
Mr. Takahashi is currently engaged in product planning and development for networking systems.