Wireless Network Technologies to Support the Age of IoT

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It is said that the evolution of information and communications technology (ICT), such as downsizing and power saving design of sensors, diversification of networks and spread of cloud computing, will cause the number of things connected to the Internet to increase from 10 billion in 2013 to 50 billion in 2020. The Internet of Things (IoT) is expected to lead to the creation of new value in combination with big data analysis technology, and have a significant and positive influence on people's lives and the economy. To that end, it is essential to have continuous evolution and innovation of both wired and wireless network technologies, while developing input/output terminals and cloud computing. Wireless networks, in particular, have been driving progress in our lifestyles and business styles by once-a-decade technological revolution since the emergence of mobile phones. This paper first describes the state of technological studies with particular focus on the vision of the fifth-generation mobile communication system (5G), which is the next-generation technology of mobile communication networks, standardization trends, and Fujitsu's activities. It also discusses the usability of the Fujitsu Intelligent Networking and Computing Architecture (FINCA) concept for ICT virtualization and flexibility improvement proposed by Fujitsu, and themes for future network studies to realize wireless access technologies for 5G.

1. Introduction

It is said that the evolution of technologies, such as downsizing and power saving design of sensors, diversification of networks, and the spread of cloud computing, will cause the number of things connected to the Internet to increase from 10 billion in 2013 to 50 billion in 2020.

The "2015 White Paper on Information and Communications in Japan" issued by the Ministry of Internal Affairs and Communications describes the concept of the Internet of Things (IoT) as "a state where vehicles, white appliances, robots, facilities, and nearly all other things connect to the Internet and exchange information with each other. According to the concept, as things are converted into data and automation based on these data progresses, new added value will be generated." Further, with regard to the further evolution of information and communications technology (ICT), it touches upon the expectations for the new IoT utilization (IoT 2.0). Specifically, it states that "the development of innovative network technologies that minimize delays in the transmission of a huge amount of information from sensors will allow the collection of surrounding situation data in real time and prediction of the future through big data analysis for optimal control of robots, cars and the like."[1] This is a vision similar to the hyperconnected world defined in Fujitsu Technology and Service Vision, which holds that new value will be created by combining IoT and big data, which is expected to have an extremely beneficial effect on people's lives and the global economy.[2]

The above-mentioned white paper on information and communications presents also a future ICT roadmap like the summarized one shown in **Figure 1**, with IoT use cases that include biometric information monitoring in the living sphere, activity support, athletic performance assistance, autonomous driving cars, and remote operation of robots. Advances in input/output terminals and cloud computing, and the continuous evolution and transformation of both wired and wireless network technologies will be essential for the realization of such things. Particularly as regards

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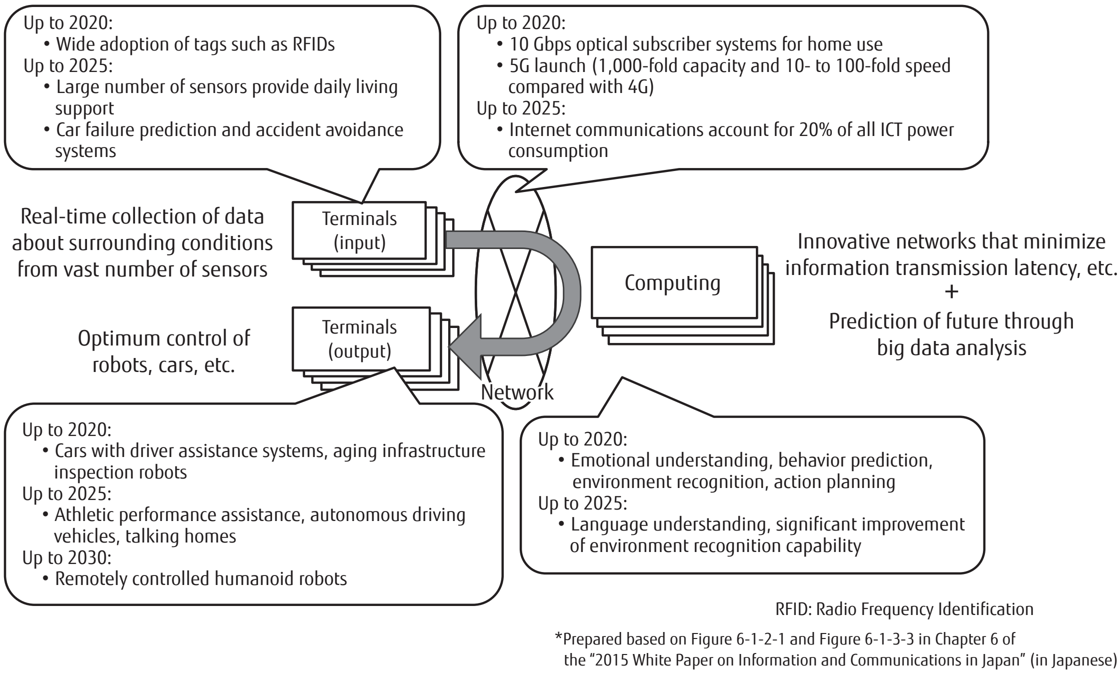

Figure 1
Future ICT roadmap and IoT.

wireless networks, since the emergence of mobile phones, technical breakthroughs in the form of a new communication system once every ten years have been a driving force for the transformation of our lifestyles and business styles.

This paper examines the evolution of wireless networks essential for future IoT, from the starting point of mobile communication networks. First, it describes the vision of and current status of studies on the fifth-generation mobile communication system (5G), practical implementation of which is expected to start in 2020, and Fujitsu's approach in this area. By the time the introduction of 5G starts, the provision of a variety of different IoT services will likely have already started. After sorting the requirements for future networks to ensure a smooth transition to the age of full implementation of 5G with flexible and integrated accommodation of various IoT services, this paper introduces the FUJITSU Intelligent Networking and Computing Architecture (FINCA)[3] concept proposed by Fujitsu.

2. 5G vision and 5G standardization initiatives

Mobile communication networks have undergone major evolutions generation by generation, from the second generation (2G) that provided voice calls through digital communication in the 1990s, to the current fourth generation (4G), which is called LTE or LTE-Advanced. Starting in the 2010s, various studies were carried out on the performance requirements and candidate technologies for the 5G vision expected post-4G and its use cases.

In Europe, various research projects were carried out as preliminary studies for 5G, including Mobile and wireless communications Enablers for the Twenty-twenty (2020) Information Society (METIS), which studies wireless technologies for the information society of 2020 as part of the Seventh Framework Programme for Research and Technological Development (FP7) of the EU, and Millimetre-Wave Evolution for Backhaul and Access (MiWEBA), which studies the application of millimeter-wave communication to wireless access and backhaul. Following that, new 5G research project groups were established, including the 5G Infrastructure Association-Public Private Partnership (5G PPP) for the purpose of promoting cooperation on 5G research within Horizon 2020, which was launched as the successor of FP7. In Asia, China and Korea respectively established the IMT-2020 Promotion Group (PG) and the 5G Forum in 2013, and announced a research collaboration. Further, in China, technologies for 5G are also being studied by the Future Technology of Universal Radio Environment FORUM (FuTURE FORUM).

In Japan too, starting in 2013, 2020 and Beyond Ad Hoc Group (20B AH) of the Association of Radio Industries and Businesses (ARIB) began organizing a vision of 5G and its candidate technologies, and in October 2014, published the results as a white paper.[4] Similarly, the Telecommunication Technology Committee (TTC) is studying the future direction of mobile networks from 2020 onward and the technological challenges and standardization issues that need to be addressed for their realization, and it has published its findings as a white paper.[5),6)] Further, in September 2014, the Fifth Generation Mobile Communications Promotion Forum (5GMF) was established, and it has started to study networks and applications in addition to 5G wireless access technology.

In parallel with these studies, the Working Party 5D (WP5D) under Study Group 5 of the ITU-R, which is an international standardization organization for radiocommunication is working on IMT-2020, in other words the creation of a recommendation for the 5G vision, resulting in the formal ratification of recommendation M.2083-0 in September 2015.[7] As a result, 5G is entering a concrete technology study phase that will lead to the establishment of technical specifications. Recommendation M.2083-0, along with presenting performance improvement indicators from 4G to 5G for wireless access, divides actual use cases into the following three categories, and organizes the important performance items for each as shown in **Figure 2**.

1) Enhanced mobile broadband communication (E-MBB)
2) Massive machine-type communication (M-MTC)
3) Ultra-reliable and low-latency communication (UR-LLC)

Thus, 5G is more than just mobile broadband communication that is an extension of the evolution up to 4G, and use cases of inter-device communication and ultra reliable and low-latency communication can also be envisaged. The latter two use cases assume the accommodation of a variety of communication services that will grow common in the upcoming age of IoT. Though these services can be accommodated by relatively low-speed network, performance improvements of other specific items are required.

Further, having established the specifications for 3G (W-CDMA) and 4G (LTE and LTE-Advanced), the 3rd Generation Partnership Project (3GPP), which has been leading technical specifications development from 3G wireless access networks, began studying the specific technical specifications for 5G in 2016.

A big concern regarding the development of future technical specifications for 5G and R&D for their practical implementation is the IMT-2020 specification fixing road map of ITU-R and the frequency determination timing for IMT-2020 at the World Radiocommunication Conference (WRC). These initiatives are too late compared with the activities in Japan, Korea, and so on aiming for the early commercialization of 5G by 2020, and may actually be unable to secure enough time in consideration of actual system development. For that reason, at 3GPP, as shown in **Figure 3**, the study of the standardization of 5G specifications is being done in two phases.[8] Phase 1 aims to complete the formulation of the specifications by September 2018, and to optimize them for the E-MBB use case as well as make them usable for the other two use cases. By completing the formulation of the specifications in Phase 2 ending in December 2019, optimization of the specifications for all three 5G use cases is being aimed for.

As part of studies for the realization of 5G as described above, Fujitsu and Fujitsu Laboratories are carrying out studies on element technologies for 5G such as described below, using the study of technologies for E-MBB as a starting point.[9)–12)]

1) For E-MBB

Use of ultra-small cells and spatial multiplexing through massive MIMO[note 1)] or distributed antennas, switch to broadband through introduction of high-frequency bands (such as millimeter wave), HetNet[note 2)] implementation through integration of different wireless access systems, and so on

note 1) Technologies that enable high directivity, high-speed communication through spatial multiplexing, and simultaneous connection of a large number of users through the use of a large number of antenna elements. MIMO stands for Multiple Input/Multiple Output.

note 2) Abbreviation for Heterogeneous Network. Technology that improves the capacity of the entire network through the combination and coordination of cells of different types (wireless access method and cell size).

	4G performance	5G performance requirements
Peak data rate	1 Gbps	20 Gbps
User experience data rate	10 Mbps	100 Mbps
Spectrum efficiency	x1	x3
Mobility	350 km/h	500 km/h
Area traffic capacity	0.1 Mbps/m^2	10 Mbps/m^2
Network energy efficiency	x1	x100
Connection density	10^5 units/km^2	10^6 units/km^2
Communication latency (over-the-air)	10 ms	1 ms

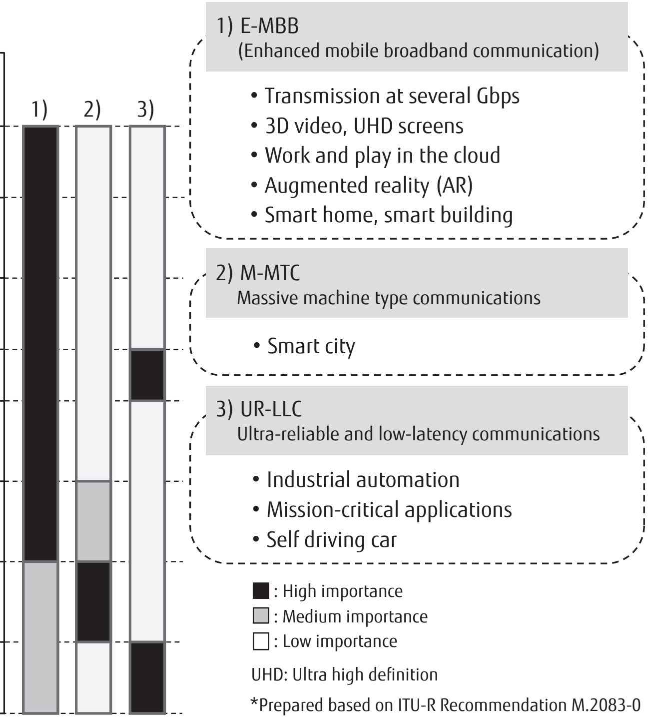

Figure 2
5G performance requirements and use cases.

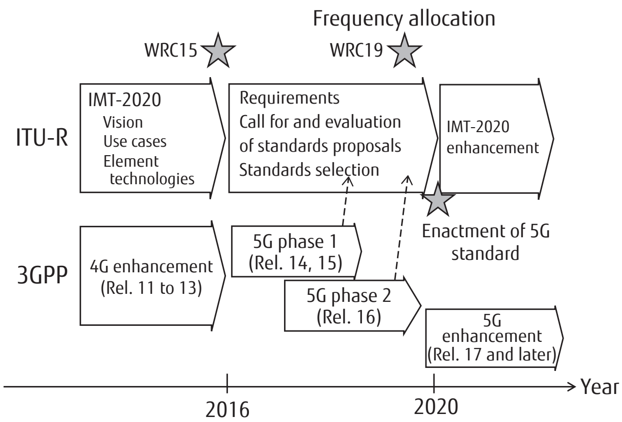

Figure 3
Flow of 5G technical specifications standardization.

2) For M-MTC

Superposition of new wireless access system for narrowband communication

3) For UR-LLC

Reliable packet transmission method that does not require retransmission, radio frame period shortening, introduction of mobile edge computing that places computing resources and data storage around base stations, and so on

Also, continuation of activities for 5G in coordination with overseas R&D centers in Europe, China, and North America. In Europe, we are participating in the Horizon 2020 project and the 5G Innovation Centre promoted by the University of Surrey in the UK. Moreover, we are actively involved in region-specific activities such as FuTURE FORUM in China, and ARIB, TTC, and 5GMF in Japan. Going forward, we will promote research and development toward the early commercialization of 5G while contributing to 5G-related standardization activities centering on 3GPP.

3. Basic requirements of IoT networks in 5G era

IoT at present makes selective use of wired networks for fixed devices, short range wireless such as wireless LAN, Bluetooth, ZigBee, and Wi-SUN, and mobile communication systems such as 3G and 4G, or combinations thereof. Further, to link wireless front networks that accommodate IoT devices such as terminals and sensors, and wired and wireless access networks, IoT gateways (IoT-GW) are also introduced in many cases. As mentioned in the previous section, in

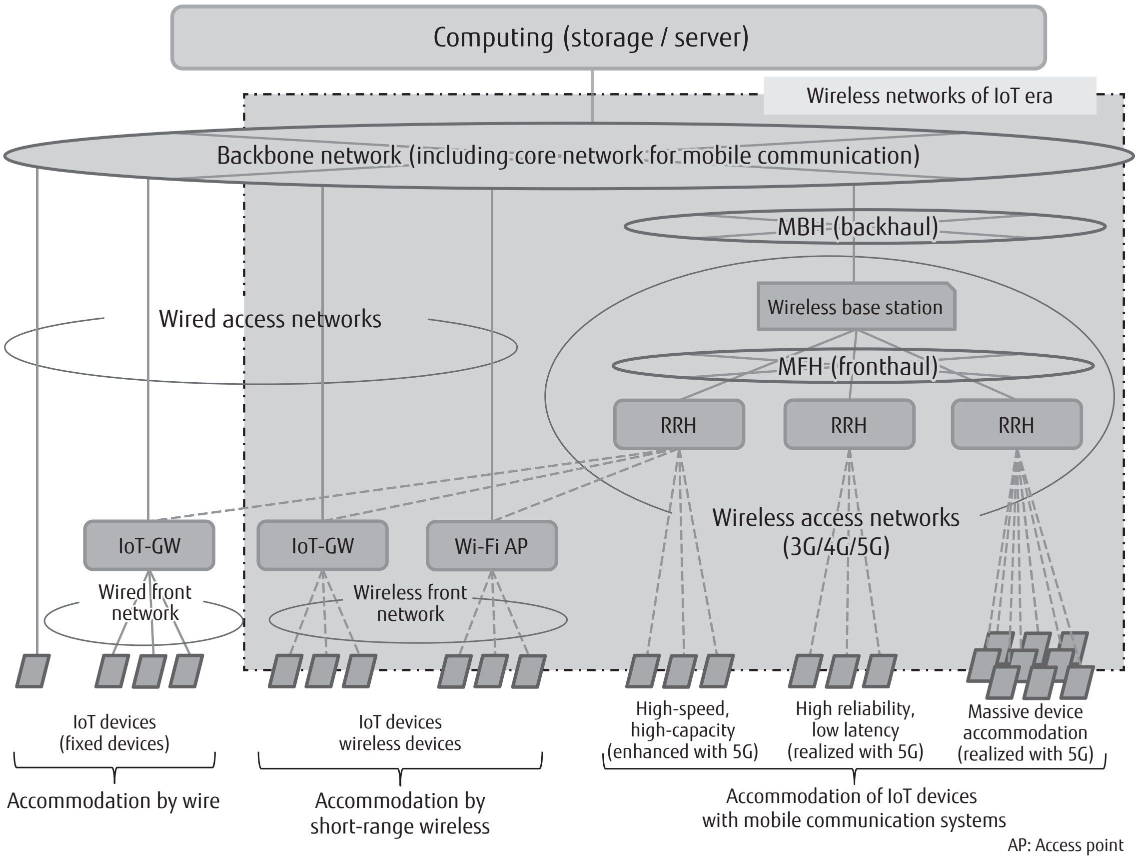

Figure 4
IoT device accommodation methods.

the case of 5G, the accommodation of a large number of IoT terminals and the provision of ultra-reliability and low-latency services, which could not be realized in mobile communication networks until 4G, are also being envisioned. The accommodation of IoT devices in the 2020s, as shown in **Figure 4**, can be done in a number of ways, including 5G. For the sake of simplification, this section considers the basic requirements and direction demanded for the backbone networks that support diversified high performance for 5G wireless access as shown in Figure 2. The next section considers more realistic and sophisticated approaches to wireless networks for IoT in the 5G era, including wireless front networks.

As IoT spreads and its uses become increasingly sophisticated, along with increases in traffic[13] as the mobile Internet becomes increasingly used, the traffic of the services accommodated by 5G will become increasingly diversified, both quantitatively and qualitatively. Furthermore, the construction of highly flexible networks capable of withstanding large fluctuations of indoor and outdoor traffic between daytime and nighttime, and temporary spikes in traffic when events such as international sporting events are held, is likely to become necessary. Increasing the speed and capacity of wireless access networks will require increasing the speed and capacity of the mobile backhaul (MBH) that provide either wired or wireless connection between backbone networks and wireless base stations, and the mobile fronthaul (MFH) that provides either wired or wireless connection between wireless base stations and their remote radio heads (RRH).

In the case of M-MTC, the accommodation of a large number of devices for IoT will require significant improvement (on the order of 10 to 100 fold) in the call processing ability of backbone networks to control device connections. On the other hand, the market for general users who use mobile phones, smartphones, tablets, and the like and constitute the main source of revenue from conventional mobile communication services, is becoming a mature market and average revenue per user (ARPU) is close to topping out. Therefore, the investment structure of the mobile operators who provide mobile communication services is also changing, and at least capital investment and operating costs (CAPEX/OPEX) per transmitted information bit need to significantly come down.

In view of such environmental changes, the major requirements of future wireless networks in the 5G era are considered to be as follows.

1) Provision of networks offering different characteristics according to the diverse requirements of users
2) Provision of networks whose functions and configurations change dynamically according to the movement of people and environmental changes
3) Provision of networks that are easy to operate and manage while using commoditized network equipment and open source software (OSS)
4) Provision of highly scalable networks that offer large capacity and programmability

In order to realize networks that satisfy these requirements, it will be necessary to increase the performance of physical infrastructure systems. At the same time, it will be necessary to virtualize the entirety of the wireless networks for IoT, including 5G, for the various IoT services, making them appear as SDN[note 3). In addition to the white paper by the TTC mentioned in a previous section, these directions are also mentioned in the network model announced in the NGMN 5G white paper of March 2015 put out by the Next Generation Mobile Networks (NGMN) Alliance, in which many of the world's largest operators participate.[14) This white paper describes the 5G vision of NGMN as "5G is an end-to-end ecosystem to enable a fully mobile and connected society. It empowers value creation towards customers and partners, through existing and emerging use cases, delivered with consistent experience, and enabled by sustainable business models." Based on the foregoing, three hierarchical architectures consisting of a 5G infrastructure resources layer, business enablement layer, and business application layer, are presented for the purpose of enabling system sharing among operators and network slicing for different services.

In the future, in conjunction with the development of concrete specifications centering on 5G wireless access and R&D for practical implementation, it will be important to determine how to concretely implement virtualization and stratification as wireless network systems for IoT so as to allow flexible configuration and control. When considering the latter, the focus of investigation will likely be directed at how to define application programming interface (API) serving as the interface of functions between layers, along with how to determine the approach to virtualization and stratification.

4. IoT accommodation approach to wireless networks

In the section 2, we sorted the directions of future mobile communication systems based mainly on 5G trends. And in the preceding section, we discussed the requirements for the networks that will serve as the backbones of mobile communication networks in the 5G era, and the necessity of the virtualization of the physical networks that constitute the infrastructure. Likewise, the white paper[15) on the 5G vision published by the 5G PPP in February 2015 also regards meeting the diverse requirements for IoT, which is expected to spread by 2020, as an important scope of 5G besides human-centered use.

However, when 5G will initially be introduced in 2020, it will likely still be difficult to directly accommodate all devices with 5G wireless access systems. Therefore, wireless front networks that can accommodate various IoT devices, and IoT-GW, which can accommodate them by concentrating them toward existing 3G or 4G networks, will be required. Figure 4 sorts the IoT device accommodation methods including the above. This section presents an overall image of wireless networks for IoT and an overview of the major implementation approaches from the following three perspectives shown in **Figure 5**.

1) High-performance physical network layer

While aiming for the full-fledged enhancement of mobile communication systems from the existing LTE to LTE-Advanced, it will be necessary to migrate to 5G systems and promote even further performance and functionality improvements for 5G. As advances are

note 3) Acronym that stands for software-defined networking. This term covers all technology for building networks whose configuration and functions can be defined and controlled by software.

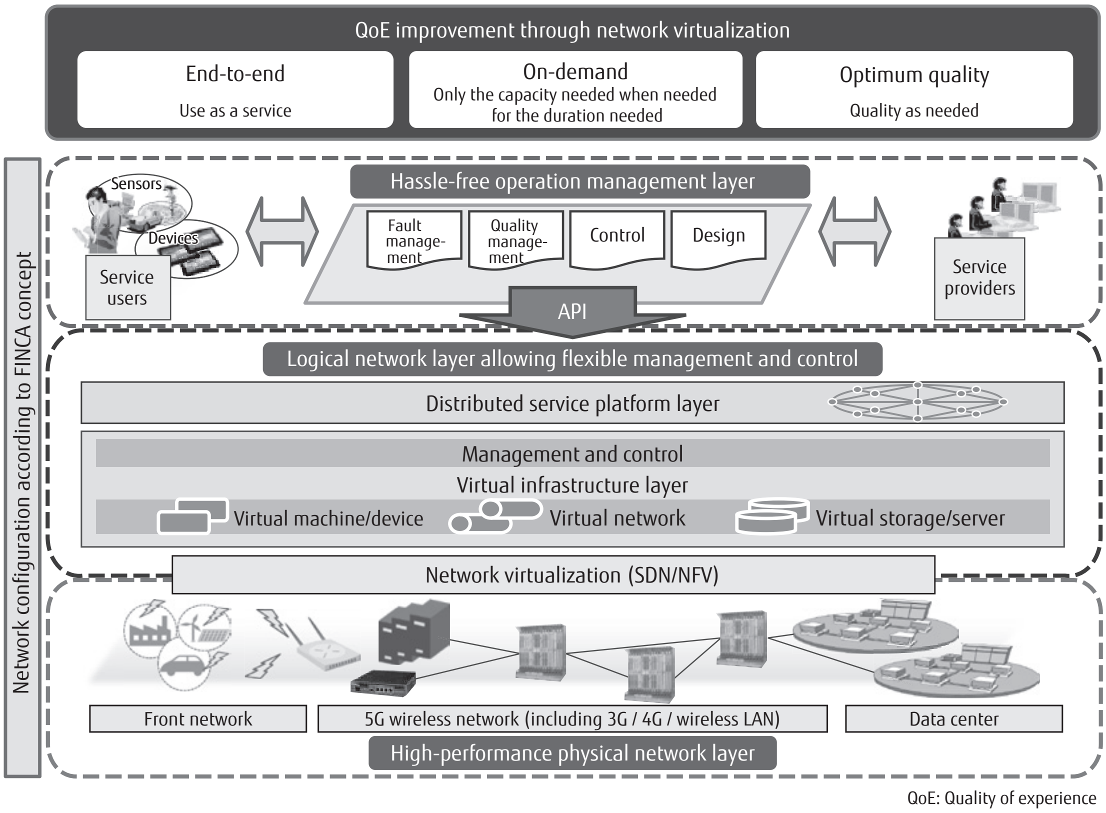

Figure 5
Network configuration of IoT era.

made not only for wireless access technologies for 5G, but also the accommodation of different wireless systems (3G, 4G, wireless LAN, and so on), MBH and MFH transmission speeds and data transmission capacities are also expected to gradually change.

The study of flexible, high-performance, and sophisticated networks capable of accommodating in an integrated manner such diversified wireless access has already begun. Furthermore, such networks need to be able to flexibly cope with the uneven distribution of terminals and various types of IoT devices, as well as traffic fluctuations. To this end, the study of system construction methods that allow integrated control including also wireless front networks and IoT-GW, along with methods to virtualize them will enable the realization of more sophisticated operation and management of physical network layers.

2) Logical network layer allowing flexible management and control

While, with the advent of the IoT era, high-performance and sophisticated physical networks will be required, their provision and their use as services are expected to be complex. In this context, the concept of network virtualization for connecting physical resources and services is useful. We at Fujitsu have already announced the concept of FINCA for the realization of this concept. FINCA proposes optimization by applying SDN/NFV[note 4)] to the entire ICT infrastructure. As a result, in the SDN area, it will be possible to build optimum virtual networks, achieve operational efficiency through the automation of operations, and improve service quality and reliability through timely and easy network settings via software. Further, in the NFV area too, it will be possible to achieve automation of the operation life cycle, reduce the time required for the introduction of infrastructure and services, and raise the efficiency of service operations. How these FINCA concepts should be built in coordination with 5G systems depends

note 4) Acronym that stands for network functions virtualization. This covers the totality of the technologies for the virtualization of the network functions of existing networks.

on future 5G specifications and practical application trends. At present, the following are the two basic approaches to the practical application of 5G systems.

- Through the fusion of virtualization technologies such as the above-mentioned SDN and NFV, operate the physical network layer flexibly and autonomously.
- By defining APIs between layers, manage and control in an integrated manner the resources of the entire system built physically as logical resources that correspond to services.

As a result, flexible management and control that provides on an individual basis limited physical resources as logical resources of the entire network in the necessary amount, at the necessary time, for the necessary duration, and with the necessary quality, will be achieved. Further, higher efficiency of capital investments and operating costs for networks for service providers, and higher quality and reliability for service users will be aimed for.

Through these approaches, Fujitsu will provide total support for the entire life cycle of network services with products and services that integrate SDN and NFV, and offer solutions that enable faster and more flexible IoT services for the 5G era.

3) Hassle-free operation management layer

For existing mobile communication systems and 5G, the general approach is for each country (in Japan, the Ministry of Internal Affairs and Communications) to decide the frequency bands to be made available for each system, and assign them in the form of licenses to mobile operators, a scheme that is referred to as licensed bands. As a result, communication quality and mobility are managed by mobile operators, and users are able to use secure networks. On the other hand, in the case of unlicensed bands used with wireless LAN, Bluetooth, Bluetooth Low Energy (BLE), ZigBee, Wi-SUN, or the like, no grant of license from the government is required, and anybody can freely and at comparatively low cost build a wireless network for short-range communication, but there is also the risk of a jumble of networks and the impossibility of ensuring quality. Under these circumstances, efficient and hassle-free network operation in the IoT age can be achieved by using SDN/NFV for fault/quality management, control and design in unlicensed bands, and then performing interworking or aggregation properly with existing short-range communication, 3G, 4G and 5G. Further, the above-described FINCA concept does take into consideration the operation and management of existing networks, and it provides for support from coexistence of short-range communication, 3G, 4G, and 5G, to smooth migration in the future.

IoT services are expected to start through use of existing wireless front networks and mobile communication systems such as 3G, LTE, and LTE-Advanced, without waiting for the realization of 5G, with the above-mentioned quality and cost trade-off. Seen from the perspective of users who want to use IoT services, many different options are available, including mobile communication systems, in terms of network service providers. In this situation, how to introduce or build a wireless front network, and how to secure an optimal IoT environment at all times according to changing usage modes and the evolution of wireless networks such as 5G, are expected to be some of the questions to be faced in the future. Therefore, ways to facilitate the operation and management of wireless front networks, which can assume a variety of configurations depending on the various usage modes of IoT services, must be considered.[16] Moreover, with the development of high-performance, high-functionality mobile communications through 5G, virtualization will be promoted through a function shift toward 5G and the cloud for IoT-GW, which integrates IoT devices and front networks. This is expected to facilitate configuration changes to wireless front networks and dealing with the evolution of IoT services, as well as accelerate the transition to hassle-free wireless network management.

5. Conclusion

This paper has introduced the requirements for future wireless networks and the activities of Fujitsu regarding the main approaches for their realization, with a focus on trends in 5G, which is expected to become the core of networks in the IoT era. We are aiming for the rapid implementation of 5G, which will usher in an era in which a wide variety of IoT services can be enjoyed easily, quickly, flexibly, and economically. At the same time, we will continue working to provide optimal wireless networks, including wireless front networks, quickly and easily according to individual IoT services.

References

1) Ministry of Internal Affairs and Communications: 2015 White Paper on Information and Communications in Japan—Past, Present, and Future of ICT. July 28, 2015 (in Japanese).
http://www.soumu.go.jp/johotsusintokei/whitepaper/h27.html
2) Fujitsu: Fujitsu Technology and Service Vision.
http://www.fujitsu.com/global/vision/
3) Fujitsu: Software-Defined Connected Infrastructure.
http://www.fujitsu.com/global/vision/products/sdci/
4) ARIB 2020 and Beyond Ad Hoc Group: White Paper—Mobile Communications Systems for 2020 and beyond. Ver. 1.0.0. October 8, 2014.
http://www.arib.or.jp/ADWICS/20bah-wp-100.pdf
5) TTC: "Ad Hoc Group on Future Mobile Networking" White Paper. Ver. 1.0 March 2015.
http://www.ttc.or.jp/files/5514/2856/3199/White_paper_on_Future_Mobile_Networking_by_TTC_20150409.pdf
6) TTC: "Ad Hoc Group on Future Mobile Networking" Phase 2: Standardization Task Analysis White Paper. Ver. 1 October 2015 (in Japanese).
http://www.ttc.or.jp/files/9714/4532/5029/FMN2-AH_TTC5Gadhoc_PH2_WP_1.0.pdf
7) ITU-R: Recommendation ITU-R M.2083-0: IMT Vision - Framework and overall objectives of the future development of IMT for 2020 and beyond. September, 2015.
http://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2083-0-201509-I!!PDF-E.pdf
8) 3GPP: RAN 5G Workshop—The Start of Something. September 2015.
http://www.3gpp.org/news-events/3gpp-news/1734-ran_5g/
9) Y. Kimura et al.: Research and Development and Related Activities at Fujitsu Laboratories Overseas Bases. FUJITSU Sci. Tech. J., Vol.52, No.1, pp.9–18 (2016).
http://www.fujitsu.com/global/documents/about/resources/publications/fstj/archives/vol52-1/paper02.pdf
10) T. Dateki et al.: From LTE-Advanced to 5G: Mobile Access System in Progress. FUJITSU Sci. Tech. J., Vol.52, No.2, pp.97–102 (2016).
http://www.fujitsu.com/global/documents/about/resources/publications/fstj/archives/vol52-2/paper15.pdf
11) D.Kimura et al: Wireless network technologies toward 5G. APSIPA Transactions on Signal and Information Processing, Volume 4 (2015).
http://journals.cambridge.org/action/displayFulltext?type=6&fid=9967539&jid=SIP&volumeId=4&issueId=-1&aid=9967538&fulltextType=RA&fileId=S2048770315000025
12) A. Itoh et al.: Next-generation Network Architecture Led by Information-Centric Networking. FUJITSU Sci. Tech. J., Vol. 52, No. 1, pp. 53–60 (2016).
http://www.fujitsu.com/global/documents/about/resources/publications/fstj/archives/vol52-1/paper08.pdf
13) Ministry of Internal Affairs and Communications: Current state of Japan's mobile communication traffic (in Japanese).
http://www.soumu.go.jp/johotsusintokei/field/data/gt010602.pptx
14) NGMN Alliance: NGMN 5G WHITE PAPER Version 1.0 February 17, 2015.
https://www.ngmn.org/uploads/media/NGMN_5G_White_Paper_V1_0.pdf
15) 5G PPP: 5G Vision: the next generation of communication networks and services. February, 2015.
https://5g-ppp.eu/wp-content/uploads/2015/02/5G-Vision-Brochure-v1.pdf
16) H. Fujita et al.: Method for Remotely Diagnosing Failures in Wireless LAN Systems. FUJITSU Sci. Tech. J., Vol. 52, No. 1, pp.46–52 (2016).
http://www.fujitsu.com/global/documents/about/resources/publications/fstj/archives/vol52-1/paper07.pdf

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