Enhancing Wireless Access Technologies Using Multiple Frequency Bands to Enable the Widest Range of Internet of Things Applications

Ryutaro Kawamura, Shuichi Yoshino, Masato Mizoguchi, and Takehiro Nakamura

Abstract

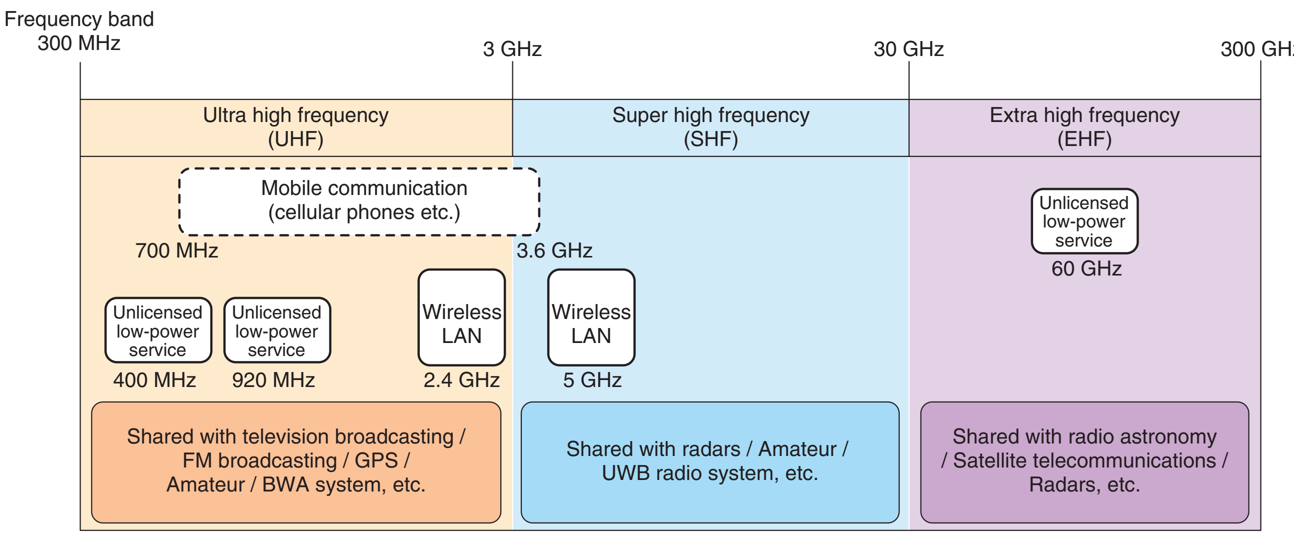
In the future vision of society, wireless communications will play a more critical role in every aspects of our lives, because the advent of the Internet of Things (IoT) is expanding the application of wireless technology beyond human usage such as mobile or smartphones to *thing* usage such as industrial applications. It is therefore essential to develop efficient wireless technologies for the wide variety of frequency bands available—from the efficient use of conventional bands to the use of pioneering EHF (extremely high frequency) bands (millimeter wave band). This article introduces such development efforts in three areas: 5G (fifth-generation mobile communications systems), wireless LAN (local area network), and wireless access for IoT.

Keywords: 5G, Wireless LAN, IoT

1. Introduction

The advances made in wireless technologies, facilitated by the widespread adoption of smartphones, tablets, and personal computers, have created an environment in which cellular phones and wireless local area network (LAN) services enable us to exchange and retrieve various kinds of information via networks anytime and anywhere, both indoors and outdoors, even while moving. Mobile services in Japan have been migrating to the fourth generation, and the number of total handsets amounts to more than 160 million [1], far exceeding the population. In addition, the annual shipment of wireless LAN devices surpassed 50 million in 2016 [2] and is expected to increase in the coming years. The aggregated traffic generated by wireless applications is increasing substantially and is being carried not only by mobile services provided by operators, but also by wireless LAN services in what is called off-loading. To accommodate the traffic increase, new wireless technologies for pioneering frequency bands are necessary in addition to those that can expand the capacity of existing mobile and wireless LAN services.

The Internet of Things (IoT) concept is driving the interconnection of devices in many places and is creating many opportunities for new wireless services including those in the areas of factory control, industrial machinery, transportation, agriculture, city planning, healthcare, security, consumer electronics, education, medical care, and countermeasures against disasters. The use cases and application environments for such services are obviously very diverse. For example, real-time communications are needed for



*The information here is based on “Principal Uses and Characteristics of Radio Wave” from the Ministry of Internal Affairs and Communications website.

BWA: broadband wireless access
FM: frequency modulation
GPS: Global Positioning System
UWB: ultra-wideband

Fig. 1. Principal uses of radio waves.

factory control and autonomous driving since their control functions must be implemented within the determined duration. Low power communications are needed in infrastructure monitoring and metering, since the devices that are scattered over a wide area need to be active for a number of years without having to frequently maintain them. Wireless technologies must offer a variety of quality and performance levels in addition to higher capacity.

A wireless communication link is established by selecting a certain frequency band on which to transmit. The basic characteristics of a radio wave depend on its frequency. Technical standards set by governing organizations determine the allocation of frequency bands by the radio wave characteristics in order to make the best use of the frequency bands. The principal uses of the major frequency bands in Japan are illustrated in **Fig. 1**. In general, lower frequency bands are appropriate for wide area communications, since low-frequency radio waves can propagate well beyond the line-of-sight area. However, capacity is rather small.

In contrast, high frequency bands are appropriate for high capacity communications, but high-frequency radio waves have poor propagation performance. Applications should be assigned frequency bands that suit the service characteristics. UHF (ultra high frequency) and SHF (super high frequency) are the frequency bands that are most access-friendly in terms of propagation and capacity. Mobile services and wireless LAN services are allocated to those bands. It is expected that new technologies will be necessary to improve the frequency usage efficiency and to increase capacity in order to accommodate the increasing traffic. In addition, emerging IoT services, which have various quality and performance demands, have created the opportunity to pioneer the extreme high frequency (EHF) millimeter band.

Technology developments and standardization activities in a range of frequency bands have been progressing worldwide, and the NTT Group has been actively contributing to these efforts in order to meet the demands of our customers. The activities for fifth-generation mobile communications systems (5G), wireless LAN, and wireless access for IoT are described in the following sections.

2. 5G

In Japan, the first-generation mobile service started in 1979 and used analog technology. The second generation introduced digital technology and expanded

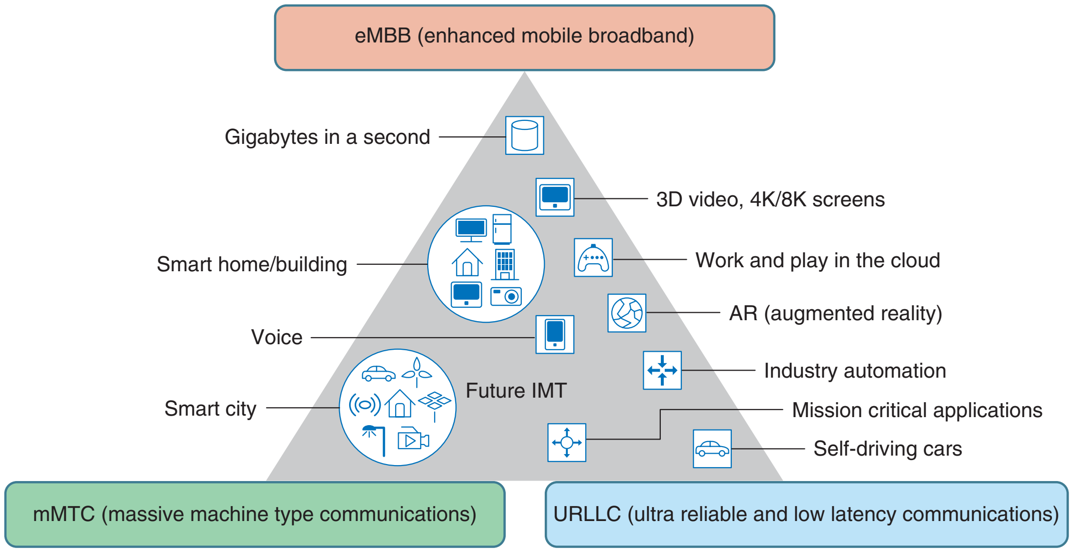


Fig. 2. Technical directions identified by the ITU-R recommendation.

mobile services substantially, while the third generation provided mobile data services to allow Internet access. The fourth generation enabled broadband data access, making mobile streaming services widely available. Today, research and development (R&D) activities for the fifth generation are progressing in order to increase capacity as well as to support emerging IoT applications.

In September 2015, the ITU (International Telecommunications Union) published a vision of 5G systems and identified three technical directions for R&D. These are indicated in **Fig. 2**, along with their relationship with the expected applications; eMBB (enhanced mobile broadband) supports broadband data access via larger capacity, mMTC (massive machine type communications) enables massive numbers of devices to be connected in a certain area, and URLLC (ultra reliable and low latency communications) achieves reliable data exchanges within short periods. 3GPP (3rd Generation Partnership Project), the standards organization for 5G services, has been developing detailed specifications of wireless technologies to suit the three directions. The article entitled "Standardization Status towards the Introduction of 5G in 2020" [3] in the Feature Articles in this issue details the latest stage in this study.

3. Advanced wireless LAN

Smart devices such as smartphones and tablets are usually equipped with wireless LAN functionality and are widely used in gathering places such as stadiums, airports, and shopping malls. In such environments, people can efficiently utilize the broadband wireless LAN services provided in addition to mobile services. Accordingly, there is a growing need to install wireless LAN access points in an extremely dense manner at various gathering places in order to provide more fast and reliable access even in crowded situations. With legacy wireless LAN technologies, service capacity is limited by the interference created by the high density of access points. The NTT laboratories have been contributing to the new technical specifications being developed to overcome this issue by developing more advanced antenna systems and intelligent control methods for multiple access points. The article in this issue entitled "New Trends in Wireless LAN and Cooperative Wireless LAN Technology" [4] details IEEE 802.11ax, the in-progress wireless LAN standard being developed by the Institute of Electrical and Electronics Engineers (IEEE). IEEE 802.11ax will improve the frequency usage efficiency of wireless LANs in dense installation environments. The article also introduces the cooperative wireless LAN, which reduces interference by intelligent control and the use of distributed antenna systems, leading to improvements in the quality of wireless LAN services, especially 5G applications.

4. Wireless technology for emerging IoT applications

The use cases and environments of emerging IoT applications are rapidly diversifying, so the wireless technologies for them must advance in many directions. For example, it is expected that extremely wide coverage will be needed to connect the sensing devices of certain IoT services, as many will be placed where people cannot easily access them even for infrequent maintenance.

A number of new wireless technologies for the 920-MHz band have recently emerged worldwide that support IoT services needing wider coverage. The 920-MHz band is useful for this purpose, as such radio waves propagate further than those at 2.4 GHz. This band has until now been utilized by wireless LAN and Bluetooth*. The article entitled "Development Efforts on Wide Area Wireless Access to Accelerate Its Use for M2M" [5] details the activities of NTT laboratories involving wireless access technologies for the 920-MHz band.

IoT devices typically exchange small amounts of data. However, the capacity to handle much larger amounts of data is needed to support intelligent security services. For example, high quality moving images must be transferred to enable detection of infrastructure anomalies by using advanced data analysis schemes based on artificial intelligence algorithms. The greater frequency resources available in the EHF band are promising for developing new wireless technologies for such new bandwidth-demanding IoT applications.

Furthermore, it is expected that ultra-reliable and low latency wireless communications will be necessary to support connections to self-driving cars, as they must support data interaction for remote control and for obtaining prompt environmental information on other cars and roadside infrastructures. The article entitled "A Study on Wireless Technologies to Improve Communication Performance by Utilizing Multi-frequency Bands" [6] examines the activities of NTT laboratories in wireless access technologies for pioneering frequency bands to achieve greater capacity and higher reliability with lower latency.

5. Future developments

Recent advances in information technologies based on wireless communications have created abilities that will benefit all industry sectors by enabling them to apply information technologies to improve their existing workflows. Accordingly, wireless communication is expected to be a key part of the social infrastructure. NTT will continue its R&D activities on efficiently matching frequency bands to the new applications and creating new value in this emerging IoT-enabled world.

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* Bluetooth is a registered trademark of Bluetooth SIG Inc.

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