Towards the Development of Broadband Access by Merging Optical and Wireless Systems—Trends in Wireless Access System Technology

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Abstract

Wireless technology is an effective way to improve the broadband environment. This article reports on IEEE802.11 wireless LAN technology and its trends and on the current status of the 5-GHz frequency band that is being developed in combination with it. It also briefly describes the wireless IP access system (WIPAS), which combines optical and wireless technology, and presents actual examples of its introduction.

1. Introduction

The optical broadband environment has been developing at an extremely fast pace. The integration of optical technology with wireless technology offers superior responsiveness, flexibility, portability, and mobility. It is an effective way to provide broadband services of even higher added value in the future.

Broadband wireless access includes wireless local area network (LAN) and home links, as well as fixed wireless access (FWA), mobile wireless access (MWA), and nomadic wireless access (NWA), in which a mobile terminal connects to an access point. Wireless access provides users more freedom in terms of service reception locations. Looking at the trends in wireless access technology, we see that third-generation mobile communications (3G and 3.5G) have already been achieved, and the 3.9th generation (referred to as super 3G) and fourth-generation systems will soon arrive (**Fig. 1**). The data transmission speed increased remarkably from the second generation (2G) with a maximum throughput of from 9.6–28.8 kbit/s to the 3.5G maximum throughput of 2.4 Mbit/s for EV-DO (evolution-data only) and 14 Mbit/s for HSDPA (high-speed downlink packet access). Wireless LAN, on the other hand, is inferior to mobile communication in terms of mobility, but it is a step ahead in terms of transmission speed. In the 5-GHz band, a throughput of 54 Mbit/s is possible, and the next-generation wireless LAN that is now under development is expected to achieve speeds of over 100 Mbit/s per user.

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2. IEEE 802.11 wireless LAN technology

2.1 The 2.4- and 5-GHz bands

The rapid increase in wireless LAN users that has come with the expansion of "optical + wireless LAN" poses a major problem. The 2.4-GHz frequency band that has been used by the IEEE 802.11 standard wireless LAN specification [1] is referred to as the ISM (industrial, scientific and medical) band. Because this band can be used without a license for industrial, scientific, and medical purposes, it is widely used for amateur radio and for production management in factory automation and other places, and in various devices, such as microwave ovens and heat therapy equipment.

In Japan, 13 channels are defined in an 83.5-MHz-band region of the 2.4-GHz band and one channel is defined in a 26-MHz-wide region, but the very small frequency spacing between channels prevents their simultaneous use because of cross-channel interference. For actual simultaneous communication, only a total of four channels can be used: three channels in the 83.5-MHz band and the one in the 26-MHz band.

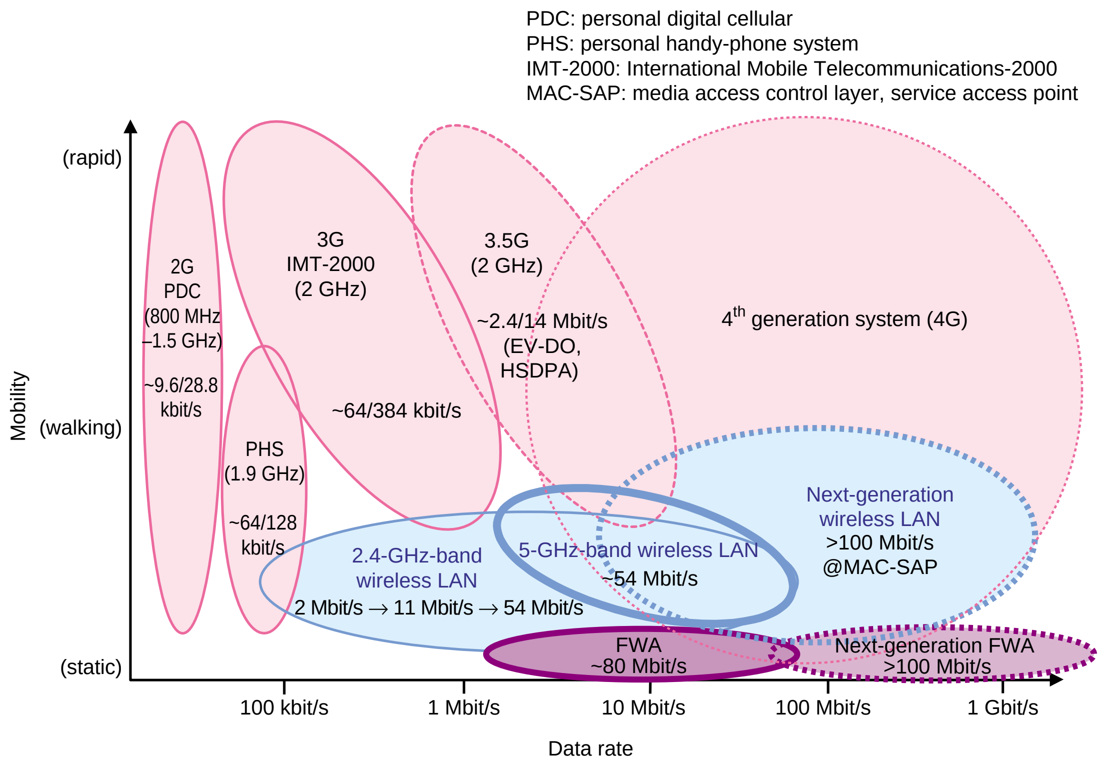

Fig. 1. Trends in wireless access.

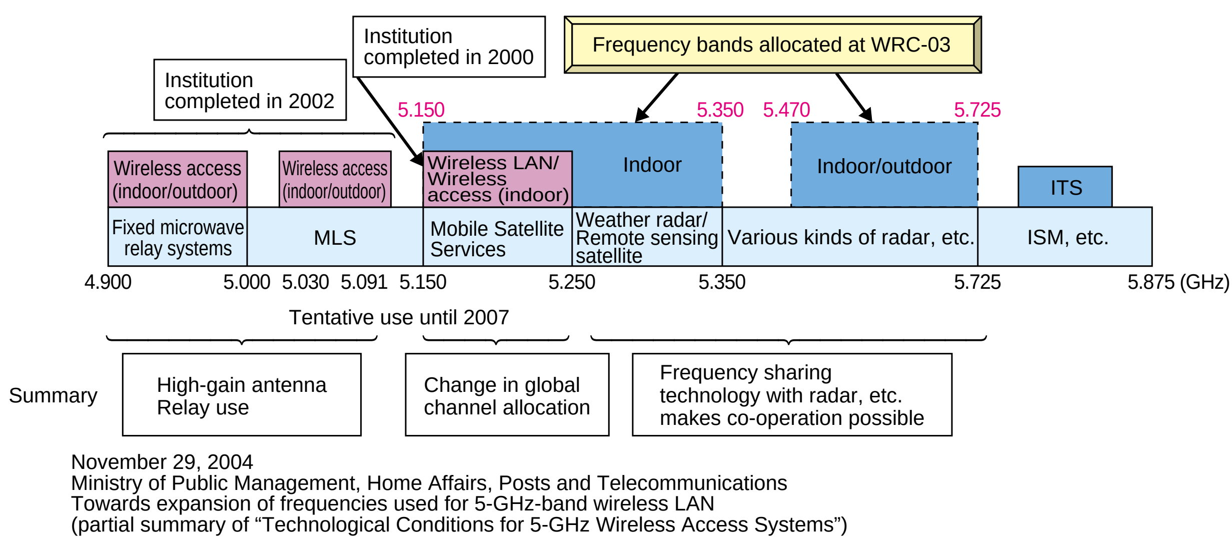

Fig. 2. The 5-GHz-band wireless access frequencies.

The sharing of these frequencies has resulted in near saturation of the frequency band.

As the interference problem worsened, rapid progress was made in the development of the new 5-GHz frequency band (**Fig. 2**). First, the band from 5.15 to 5.25 GHz was allocated in 2000 in Japan, but that frequency band is also used by mobile satellite systems, so its use has been limited to indoor environments. However, the demand for outdoor use was also high, so the regions from 4.9 to 5.0 GHz and from 5.03 to 5.091 GHz were added for use by outdoor wireless access systems in 2002. (The allocation of the frequency range from 5.03 to 5.091 GHz is temporary and effective only until 2007). Whatever the case, the frequencies allocated in 2002 were released for use in wireless access, but not for wireless LAN systems.

Later, at the World Radio Communication Conference in 2003 (WRC-03), it was decided to share the frequencies from 5.15 to 5.35 GHz (for indoor applications) and from 5.47 to 5.725 GHz (for outdoor applications) worldwide. In Japan, too, where the decision was accepted, the Ministry of Public Management, Home Affairs, Posts and Telecommunications proceeded with major studies on the frequency band for allocation to wireless LANs, and, coordinating with a number of other countries, has changed the channel allocation for the frequency range from 5.15 to 5.25 GHz. The Ministry is proceeding with work on multiple use of frequencies in the bands from 5.25 to 5.35 GHz and from 5.470 to 5.725 GHz by introducing technology for frequency sharing with various kinds of radar.

2.2 Trends in IEEE 802.11 development

The 802.11a standard, which deals with wireless LANs in the 5-GHz band, was a joint proposal by NTT and Lucent that was adopted in 1998 and was made into a standard in 1999. It employs the frequency band from 5.15 to 5.25 GHz and OFDM modulation to achieve communication at 54 Mbit/s [2].

The original IEEE 802.11 specification that was established in 1997 was for wireless LANs that initially used spread spectrum or infrared. After that came 802.11b (1999), which was linked to the rapid expansion in use of the wireless LANs, followed by 802.11a, which was standardized for development of the 5-GHz band. In addition, the 802.11g specification was positioned to achieve the same 54-Mbit/s data transfer speed allowed by 802.11a, but in the 2.4-GHz band. Now even higher speeds are being pursued, and the standardization of the 100-Mbit/s 802.11n specification is expected sometime around the spring of 2007 (**Fig. 3**).

New types of technology have been proposed for the development of 802.11n to use the limited frequency band as efficiently as possible and achieve high speed. One is multiple-input multiple-output (MIMO) technology, which makes it possible to send different data at the same time on the same frequency [3], [4], [5]. Each transmitter and receiver has two or more antennas, and multiple channels are established between them. Space-time signal processing allows multi-path transmission, which always used to be a problem, to be turned into an advantage [6], [7]. The theoretical increase in throughput with the number of antennas has been confirmed by experiments. Another new type of technology is channel bonding (band expansion), which expands frequency bands that independently do not exceed 20 MHz by bundling multiple channels.

In parallel with the development of such wireless LAN technology, applications that make use of it are also being developed. Mobile Centrex, a system for using VoIP (voice over Internet protocol) phones that carry voice over computer wired and wireless LAN networks for internal company communication, is already in operation. Such systems can also be used in the home for the enjoyment of digital cameras, personal computers, audio equipment, and other devices

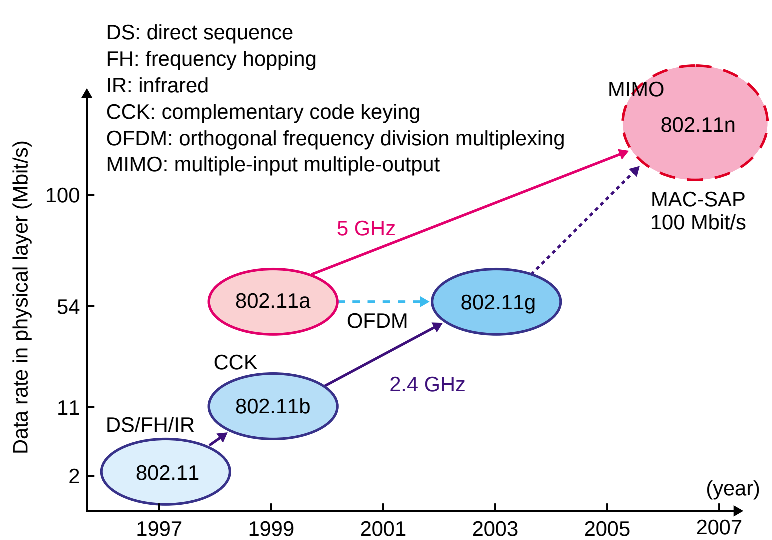

Fig. 3. IEEE802.11 high-speed wireless LANs.

at the high speed and quality of digital terrestrial broadcasting without the encumbrance of wiring.

Another development in progress is the public wireless LAN service (nomadic wireless access), which will employ wireless LAN terminals to meet the demand for the broadband environment while users are away from the home or office. This will provide a seamless broadband environment that will allow, for example, a business person who is out of the office on business to download materials at the train station, exchange large amounts of data at high speed with multiple users at the office by wireless LAN, access the Internet from a coffee shop for e-mail or file transfer, and access his home network at home.

3. Wireless IP access system (WIPAS)

3.1 WIPAS development concept and technology

The wireless IP access system (WIPAS) was developed by NTT as a way to provide services to areas that are difficult to serve by optical fiber alone because of their location [8]. WIPAS uses the 26-GHz band with FWA to provide broadband IP (Internet protocol) service by combining optical and wireless technologies (**Fig. 4**). The main features of WIPAS are listed below.

(1) Rapid service provision

In addition to easily providing services to apartment buildings and other such locations where it is difficult to lay optical fiber, this is an effective tool for eliminating the digital divide.

(2) Stable high-speed communication

Stable, high-quality, high-speed communication at a data transfer rate of 80 Mbit/s and a throughput of 46 Mbit/s can be provided in the 26-GHz band, where frequencies are abundant and interference is low.

(3) Lower costs for facilities and installation

Simple installation in residential buildings is achieved by a reduction in equipment size that allows a subscriber station (wireless terminal (WT)) to be installed on a balcony and the access point (AP) to be installed on a utility pole and by a mount that allows the antenna direction to be adjusted.

The subscriber wireless service was originally a very expensive and large-scale service that mainly targeted business users and was not suitable for individual or SOHO (small office, home office) users. Reconsidering these mass-market users in a comprehensive way, NTT designed WIPAS with the following features (**Fig. 5**).

- Focus on IP services for efficient use of limited frequency bands
- Limited transmission distance up to about 700 m to

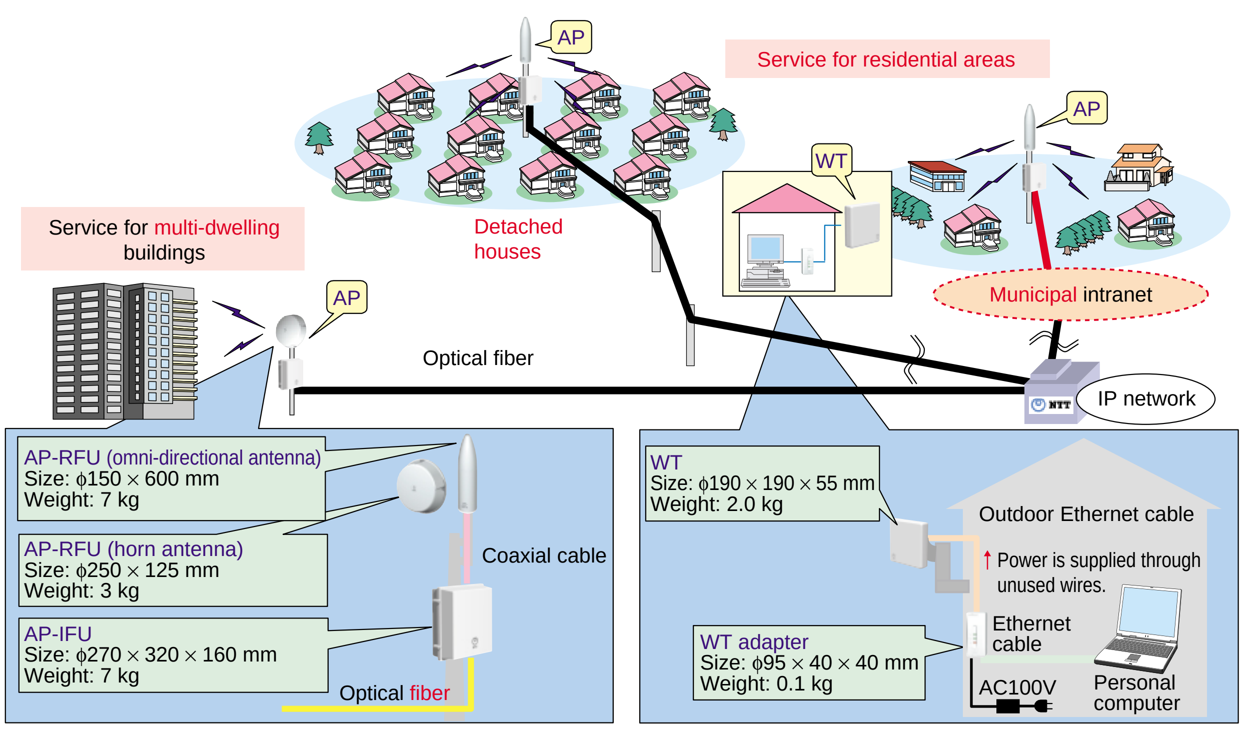

Fig. 4. WIPAS service concept and hardware configuration.

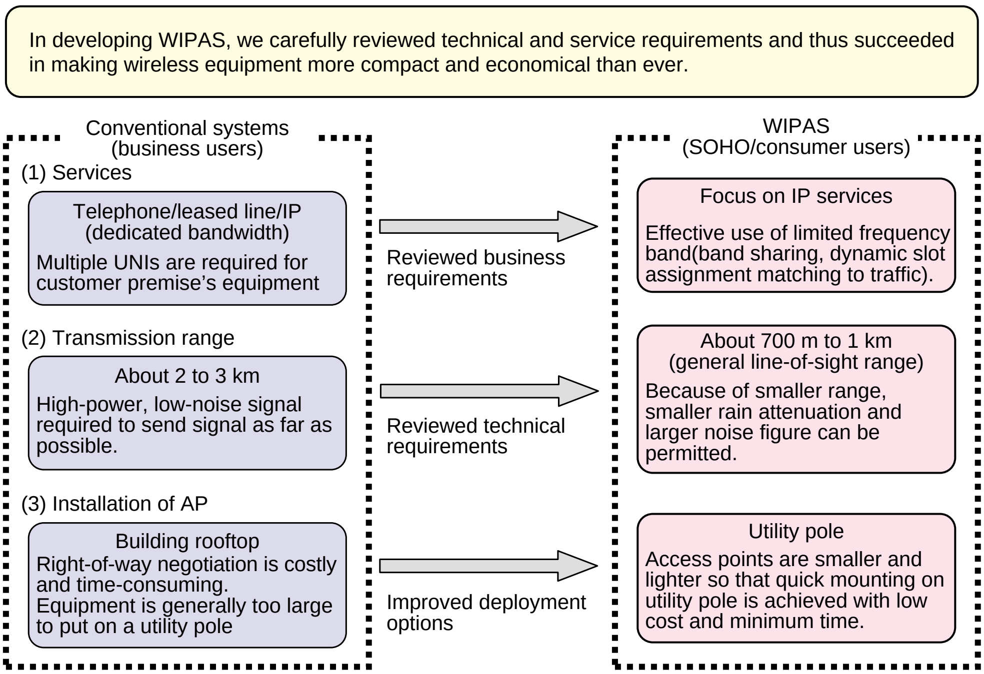

Fig. 5. WIPAS development concepts.

1 km ordinary line-of-sight distances to suppress the effects of external factors such as rain attenuation

- Smaller and lighter equipment to allow low-cost installation of wireless access points on utility poles

The access point mounted on a utility pole consists of an antenna (AP-RFU) and an interface unit (AP-IFU). There are two types of antenna: a horn antenna is used for apartment buildings and an omni-directional antenna is used mainly for ordinary residential areas. On the subscriber side, a wireless terminal (WT-RFU), that consists of the main unit and an antenna, is installed outdoors and connected to an Ethernet cable inside the subscriber's premises via a WT adapter. The wireless terminal can be installed on a balcony, rooftop, or other location, depending on the type of residence. All of the equipment is designed for compactness. (See Fig. 4 for the weights and dimensions.)

Various ways to facilitate installation of the wireless terminal have been implemented. The signal from the access point can be checked by simply opening the connector cover and plugging in a test set that consists of a PDA (personal digital assistant), battery, and connector. The antenna can be aimed at the access point in a manner similar to using a rifle scope by mounting a direction-finding fixture.

The LAN cable to the residential user terminal is normally fed through an air-conditioning conduit or other duct, but sometimes there is no suitable hole in the wall of apartment buildings, etc. To avoid having to drill a hole through the wall, we developed a thin but sturdy flat LAN cable [9]. At 14 mm wide and 1.1 mm thick, this cable can be snaked in through a window frame. In this way, WIPAS can be made available to residences and other locations where the providing of broadband services has been problematic for structural reasons.

For optimum access point placement, on the other hand, we created a tool to support service area design using map information and service order decisions in the determination of lines of sight.

3.2 WIPAS application examples

We are progressing with the development of WIPAS services for high-density residential areas where it is difficult to lay optical cables and for apartment buildings. These services basically use subscriber optical fiber lines up to the access point and wireless from that point on.

3.2.1 Application to high-density residential areas

NTT West has been developing a B-FLET'S wireless family-type service. A major feature of access point placement in that system is that the overlapping of access point service areas in regions where trees cause poor line-of-sight conditions and degrade radio receiving power is taken into account in selecting access point locations.

In another example, to provide a high-speed public Internet connection service, WIPAS was combined with an optical fiber network installed for a local intranet service provided by a local government. Although broadband service had already been available within the town via the existing optical cable, the use of WIPAS made it possible to expand the service area.

3.2.2 Application to apartment buildings

WIPAS application to services for apartment buildings is also being developed. In many old student dormitories and corporate housing units, for example, telephone lines do not extend to individual quarters and telephones are placed only in common-use areas of the buildings. Furthermore, as most people have cellular phones these days, there is little justification for the high cost of constructing new wiring conduits to each individual room. Therefore, providing broadband access from private rooms remained a problem. To solve that problem, NTT East made use of WIPAS to provide the B FLET'S service to individual rooms without constructing new conduits or wiring.

3.2.3 Provision of services by " optical + wireless + wireless" systems

The "optical + wireless + wireless" configuration has been introduced to further expand the service area of "optical + wireless" [10]. For areas that are not serviced by optical fiber, broadband service can be provided with greater efficiency by setting up a wireless entrance line for the WIPAS equipment. In this configuration, an antenna for simple wireless entrance is placed on the utility pole where the access point is installed to serve as a wireless connection to another access point, thus expanding the service area by branching out to new areas. With this method, service can be provided easily to places where it is difficult to lay cable or where detours were required by highways or rivers. Another form of "optical + wireless + wireless" is "optical + WIPAS + wireless LAN". Various future applications are also expected.

4. Conclusion

The development of optical broadband access has been accompanied by a rapid development of ubiquitous broadband services that combine the merits of optical broadband with the merits of wireless access. We expect that wireless access technologies such as wireless LAN and WIPAS will increase in importance as key technologies for that synthesis as we move into the future.

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Profile

■ Career highlights

Senior Research Engineer, Supervisor, Project Manager, Wireless Access Systems Project, NTT Access Network Service Systems Laboratories.

He received the B.E. degree in engineering from the University of Electro-Communications, Tokyo in 1980 and the Ph.D. degree in engineering from Osaka University, Osaka in 1995. Since joining Nippon Telegraph and Telephone Public Corporation (now NTT) in 1980, he has been engaged in R&D of forward error correction schemes and modulation-demodulation schemes for satellite and personal communication systems, research of software defined radio systems, and development of wireless LAN systems and wireless access systems. From 1991 to 1992, he was with the University of California, Davis as a visiting researcher. He is a member of the Institute of Electronics, Information and Communication Engineers of Japan and IEEE.