mobile communications series

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BROADBAND WIRELESS ACCESS AND LOCAL NETWORKS: MOBILE WiMAX AND WiFi

Broadband Wireless Access and Local Networks

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To our wives
Hyeon Soon Kang and Yoonjung Ryu

Preface

The recent trend of the convergence and diversification of data services and the growth of data traffic is truly phenomenal. The convergence of various different types of services (e.g., of voice, data, and video services), the convergence of conversational bidirectional services with distributive unidirectional services, the convergence of narrowband and broadband services, and the convergence of wireline and wireless services is now an established trend that is augmented by the convergence of user terminals. The growth of data traffic is exponential with the deep penetration of mobile wireless services, the popularization of music, video, and other forms of downloading and exchange, and the convergence of communications, entertainment, broadcasting, and financial services. The diversification of services has been driving a paradigm shift in communication services today toward *user-created content* (UCC). This grand trend has made the concept of *prosumers* (producers + consumers) a reality in the communication world and has brought other new terminologies into use as well, such as *motizens* (mobile citizens), *cyberlations* (cyber relations), and *digital natives*. In response, the Web has evolved to Web 2.0, with an increasing movement from Internet portal services to mobile Internet services.

Underlying the grand trend, and functioning as the enabler of the convergence, growth, and diversification of data services, is the *Internet protocol* (IP), which is a packet-mode technology designed to support the processing and transport of data in packets among different types of communication networks. Convergence of a diverse set of data services, for which circuit-mode technologies tried to offer a platform of service integration in the past, can now find a flexible and dependable platform in IP-based protocol stacks. The rapid growth of data services relies on the widely accepted means of processing and transport supported by IP-oriented technologies. The diversification of data services is also supported by IP technology with most emerging data services built upon IP.

The environment for data services now and in the near future is the Internet, or more generally, the networks using the IP. Originally developed for data communication among computers and terminals, IP has become a foundation of networking for all services in its short history of existence (only four decades). The key to today's success of IP technology is the omnipresence of Internet devices and IP's robust capability for realizing interoperability among many networks. The abundance of software that operates on top of IP is another strength of the IP technology. The secret behind the wide acceptance of IP was the simplicity of the IP. It was designed to support intermittent data communications among computers and terminals, based on *best effort* routing of packets in a variety of physical configurations, including bus, ring, and mesh. This simple protocol was generally considered not sophisticated enough to support real-time services. It targeted academic research networks, supporting the limited world of computer professionals. Even after opening to the commercial world, IP for a long time covered only the data portion of the business world, as the simple skeleton of IP had to be augmented with many other protocols to accommodate the real-time multimedia part of the commercial world.

IP-based networking, with its (originally) modest goal and simple architecture, has spread to encompass the last meters of every computer network. IETF *requests for proposals* (RFPs), together with IEEE 802 PHY/MAC standards, contributed significantly to the wide penetration of IP to the customer end, strengthening reliability and capacity and reducing costs. IEEE 802.3 Ethernet, as the name predicted, has become an ether-like network, existing everywhere computers meet users. Its predominance in the local area was followed by IEEE 802.11 WiFi when the wireless technology became practical for end-user services. Over two decades, *carrier-sense multiple access with collision avoidance* (CSMA/CA)-based wireless *local area network* (LAN) technology has frequently replaced *CSMA with collision detection* (CSMA/CD)-based wireline LANs, establishing a truly ether-like presence in the air. Today laptop computers, *personal data assistants* (PDAs), and other user-carried devices are mostly equipped with the WiFi capability from the manufacturing stage. For personal area networks, Bluetooth is often the choice because of its very low power and cost.

On the other side of the communication world, there still exists circuit-mode communication technology with the star-topology network architecture. It was born with the invention of the telephone. Over 125 years, the telephone network has spread all over the world, covering all inhabited areas down to almost every residence. Throughout this long period of development and deployment, the copper-based telephone network became omnipresent but, in contrast, the service concentrated mainly on voice. Technology was developed with the spread of the telephone network, but the technology development was focused more on providing high-quality voice services by expanding the transmission distance, increasing the transmission capacity, and accelerating the switching speed, than on developing new protocols and architecture to accommodate new types of service. As a consequence, the central offices in the telephone network were filled with intelligent transmission, switching, and signaling devices, but the subscriber's telephone set has been providing the same function for more than 100 years. The main reason for this voice-centric development was probably the lack of visible demand for data services during that long development period of telephone networks. Even after data services began to grow, telephone service providers were not successful in migrating into the data service market for various reasons. The long tradition of voice-centric telephone service made it difficult to admit the importance and the potential growth of data services. The circuit-switched telephone network, with dumb end-user devices and central operation, was not well suited to effectively accommodate data services. The growth of data services was not fast enough to justify big investments for renovating the huge established telephone network and installing new data-centric equipment. Lacking a competitive option in the switched services of the telephone network, new IP-based networks (using, however, physical lines provided by the telephone carriers) were readily established and widely accepted among end data users.

Throughout the long development period of the telephone network and the comparatively short development period of computer networks, the two were living in quite different worlds, though the computer networks such as ARPANet used the leased lines of the telephone network for wide area networking. The circuit-based telco network served the large commercial voice market using telephone, and the packet-based research networks served the small computer-communication community with noncommercial operation. They maintained these totally different identities until data services began to indicate some potential growth in the 1980s and the Internet was opened to the commercial world in the 1990s. Around that time, there appeared the first attempt to combine circuit-based voice services with packet-based data services, based on circuit-mode technology. It was the first encounter of the two different worlds, which was made in the context of wireline networks. The second encounter came later in the arena of wireless networks with an effort to harmonize circuit-mode and packet-mode wireless services based on packet-mode (or IP) technology.

It was the *International Telecommunication Union* (ITU) CCITT, later renamed ITU-T, that initiated the first encounter. It standardized the *integrated services digital network* (ISDN) with the goal of integrating voice and data services on a circuit-based platform, and it advanced digitization, which had been successfully completed in the core network, down to the access network by digitizing subscriber lines. This visionary project, started at the turn of the 1980s, was followed by the standardization of the *broadband ISDN* (BISDN), which progressed in harmony with the standardization of optical transmission in the *synchronous optical network* (SONET) and the *synchronous digital hierarchy* (SDH). BISDN introduced a new technology for integrating voice, data, and other broadband services in the *asynchronous transfer mode* (ATM), which gracefully combines circuit switching with the packet format. Moreover, it supports distribution services in addition to conversational services, and real-time services in addition to nonreal-time services. As a services integration strategy, ATM was ideal in theory but less successful in reality because of its relative complexity and high overhead cost. Moreover, the deployment of broadband optical networks was not done in a timely manner. The promotion of ATM technology in the 1990s, ironically, aroused a strong reaction in the Internet world, stimulating it to strengthen the competitiveness of the Internet. It is worth noting that the ATM concept lives on in IP networks in the form of *multiprotocol label switching* (MPLS).

The second encounter between circuit-mode and packet-mode networks began recently in wireless communications, encouraged by the booming success of mobile wireless businesses. The circuit-mode wireline telephone network was succeeded by cellular mobile communications in two major streams—the GSM/WCDMA family harmonized in the *Third Generation Partnership Project* (3GPP) and the IS-95/cdma2000 family harmonized in 3GPP2. Both were rooted in circuit switching, with packet-mode hybridization introduced in the course of evolution. The competing streams penetrated wide area networks within most countries and expanded coverage through international roaming services. They were very successful in providing voice services and began to provide high-quality data services to mobile users with comparatively low data rates and comparatively high service charges.

At the same time, the packet-mode Ethernet LAN was followed by the WiFi WLAN, using CSMA/CA instead of CSMA/CD. It has been very successful in providing data device users with the last 50-m access service into a wired LAN. It provides very high data rates to *hot spot* users at very low cost, but service quality is often unpredictable, and both mobility support and coverage are limited. The harmonization of those wireless extensions of the telephone and computer networks, constituting a second encounter of those communication worlds, is taking several paths, one of which is the handoff of multimode devices between cellular mobile and WLAN networks and a second, more intense path is the development of Mobile WiMAX networks. Whereas the first attempt of integration was made by the ITU, this second attempt was made by the IEEE, specifically the IEEE 802.16e standard working group. In contrast to the first attempt that adopted circuit-mode and then ATM technology, which is midway between circuit and packet modes, this second attempt employs IP-packet technology as the common vehicle for harmonization. Mobile WiMAX was designed on an IP foundation, maintaining the spirit of support for an IP network level seen in all IEEE 802 standards, thereby realizing efficient deployment of all types of data services. For effective provision of real-time multimedia services, it adopted a connection-oriented approach, not the connectionless approach of WiFi. It was designed to be capable of providing high-rate, high-quality data services to mobile users in medium to wide areas at very reasonable service charges.

Mobile WiMAX is very new, with the first IEEE 802.16e standard published in 2006 and the first system development and commercial service launched in 2007 in Korea. Commitments to Mobile WiMAX service are being made in a large number of countries, and allocations of frequency spectrum for Mobile WiMAX services have been announced in many countries. Furthermore, Mobile WiMAX has been accepted as a viable technology for the *fourth generation* (4G) mobile communications and was recently adopted as an IMT-2000 standard by ITU-R. Mobile WiMAX is now a reality. It incorporates many strong technologies, such as *orthogonal frequency division multiple access* (OFDMA), *time-division duplexing* (TDD), *multi-input multi-output* (MIMO), *adaptive modulation and coding* (AMC), IP, and security features, that can be combined to produce high spectral efficiency and resilient channels, resulting in high-rate, low-cost, wide-area, mobile multimedia services. Singling out OFDMA, Mobile WiMAX is the first mobile wireless specification to adopt this technology. Everything is ready to realize the second encounter of the descendents of the traditional communication and computer worlds. It is the investment made by network operators that will dictate the success of this second attempt for a harmonious services integration.

This book introduces the network technologies adopted by Mobile WiMAX for the implementation of IP-based broadband mobile wireless access and the WiFi technologies that have steadily evolved for the past 10 years, establishing a firm foundation for IP-based wireless local network access. These access and local technologies have many things in common, most prominently that both are oriented toward IP traffic and standardized by IEEE 802 working groups. The book is organized in two parts separately addressing Mobile WiMAX and WiFi, plus a preliminary chapter to provide a common ground of discussions for the two network technologies.

For the Mobile WiMAX part, we collected the most recent experience and knowledge of the design and field engineers, especially from Samsung Electronics and the Korea Telecom (KT) Corporation, who have been involved in the first development and deployment of Mobile WiMAX systems in Korea (with the nickname of "WiBro," an abbreviation for *wireless broadband*). The WiFi part is based on the extensive experience of one of the authors in IEEE 802.11 standards and on industry collaboration among Philips Electronics as a chip vendor, Samsung Electronics as a chip/system vendor, and KT as a service provider. The authors believe that understanding these two IP-oriented wireless network technologies will help readers deepen their insight into today's wireless networks and enhance their competence and competitiveness in the design of future wireless networks.

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