1

Background

Broadband wireless communications technologies promise the freedom of being constantly connected to the internet at high speeds without the limitation of connection cables. There is certainly a need for such a service and, therefore, there is a market. The size of the market depends on the cost of the technologies that can realise the service. As in any business, this cost is passed on to the end-user in the form of user equipment (e.g. mobile phone) price and usage tariffs. The lower the end-user cost is, the greater the market size becomes.

But how have we arrived at this point? Why have these technologies been developed? Why are there so many of them? (See Box: Broadband wireless technologies.) And what factors determine which technologies will ultimately emerge to dominate the market?

Some broadband wireless technologies

- WCDMA, standardised by 3GPP
- CDMA-2000, standardised by 3GPP2
- TD-CDMA, standardised by 3GPP
- Wireless LAN IEEE 802.11, standardised by IEEE
- WiMAX IEEE 802.16, currently being standardised by IEEE
- TD-SCDMA(MC), proprietary technology by Navini
- i-Burst, proprietary technology by Kyocera, Arraycomm
- Flash-OFDM, proprietary technology by Flarion

This book discusses the two parts of the broadband system as shown in Figure 1.1. One is the interface between the end-user device and a central station. In fixed-line systems,

Broadband Wireless Communications Business: An Introduction to the Costs and Benefits of New Technologies Riaz Esmailzadeh

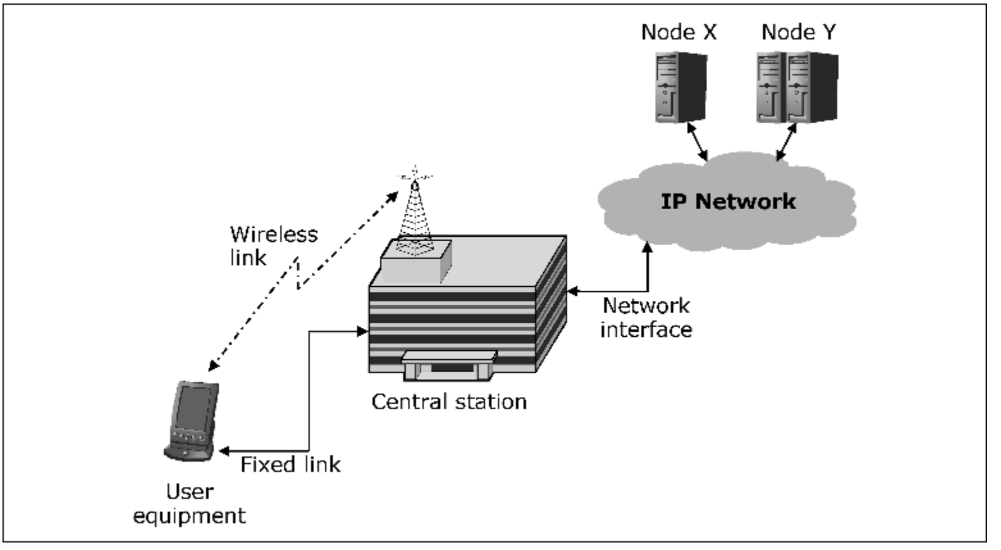


Figure 1.1 Interfaces for access to the internet

the central station may be a telephone exchange or a central office, or perhaps a TV cable operations centre that also provides internet connections. The connection may be an optical fibre or a twisted pair of copper wires. In wireless systems, the central station is, for example, a WCDMA base station. The connection is wireless, and the interface is referred to as *air interface*. The central station connects to the internet, usually through several intermediary devices or nodes. This is referred to as *network interface*. Most of the technologies discussed in this book concern the air interface. However, we will also discuss the network interface as this too significantly affects the systems' costs.

Before discussing the technologies and their relative merits and costs, let us go through a brief background on how broadband wireless communications have come about. In this chapter, we discuss the background of the two apparent parts of broadband wireless technology: (1) broadband access to the internet as developed for fixed communications; and (2) wireless communications as developed for cellular applications. The combination of these two fields has come about to address two particular needs: one is tetherless access to the internet and the other is access to the internet where the fixed option is impossible or comparatively uneconomical. This includes technologies that provide access to high-transmission-rate services, which are of particular benefit to a mobile end-user. In this chapter, the background will be discussed as follows:

- Fixed-line data communications development
- Broadband access market and its growth
- Mobile communications market, its growth, and evolution

- Wireless data communications
- Present status of wireless market.

From these, we draw conclusions on trends for future developments.

1.1 Fixed-line Data Communications

Computers connect to the internet in several ways. A large group of computers may use a local area network (LAN) to communicate with each other, to communicate with peripheral devices such as databases and printers, and to communicate with the internet. A home personal computer (PC) may dial up the internet using a normal phone line or may use a fixed cable that is connected to the net (often the same as that of a cable TV system), and so on. Fast connections to the internet from home were not readily available until very recently (see Box: Modem rates evolution). Fast connections have existed for larger, office-like environments for a long time. However, until very recently, connecting from the home was usually possible using these modems with a maximum rate of a few tens of kilobits per second (kbps). An alternative, Integrated Services Digital Network (ISDN) (see Box: Integrated services digital network) was standardised by the International Telecommunications Union (ITU) in the 1980s to provide up to 144 kbps transmission rates over telephone

Modem rates evolution

1981	Hayes Smartmodem	300 bps
Late 1980s		2.4 kbps
1991	Superfax 14400	14.4 kbps
Late 1990s		56 kbps

An acoustically coupled modem

Integrated services digital network

Original recommendations of ISDN were in CCITT Recommendation I.120 (1984). ISDN services did not become widespread owing to some differences in regional standards, delays in establishing a market and then reaching that market, which was soon better served by DSL. For example in Japan, ISDN services started in mid-1990s, flat-rate services started in late 90s (e.g. Flet's ISDN by NTT) and the subscriber numbers were growing. However, the emergence of DSL services almost at the same time (2000) ended that growth.

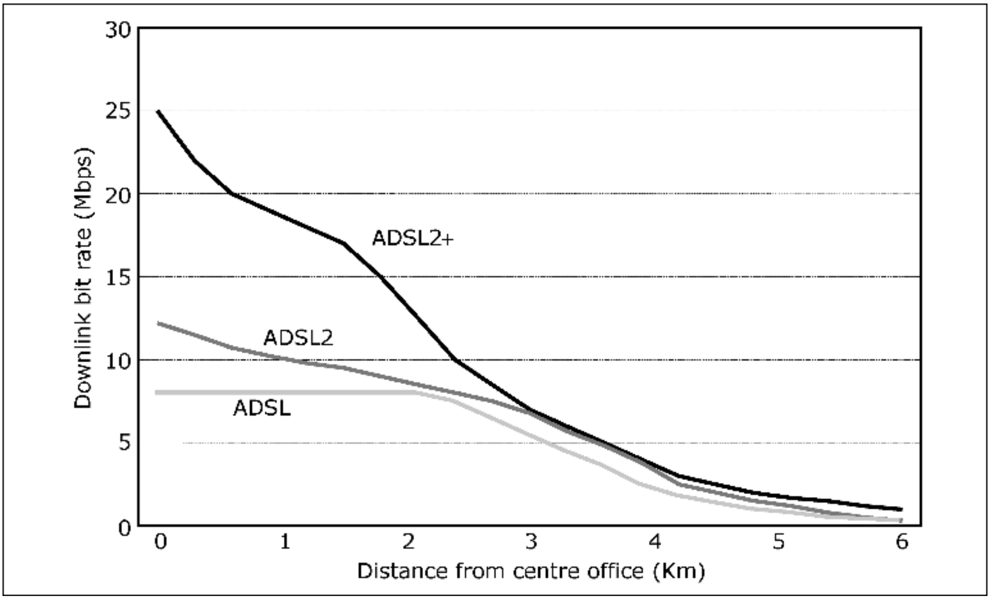


Figure 1.2 DSL rates versus distance. Reproduced by permission of DSL Forum

lines. However, the service was supported by only a few operators around the world. It was not until the late 1990s when the development of digital subscriber links (DSL) made inexpensive fast connections from the home possible.

DSL technology utilises the standard telephone's twisted copper-wire phone connection. Because of losses over these links, the maximum transmission rates are a function of the distance between the telephone exchange and homes. Figure 1.2 shows the possible rates versus distance. As the distance between exchanges themselves is a function of population density, the denser the population, the higher the density of exchanges and therefore the higher the possible average DSL rates. This means that while in countries such as Japan and Korea very high DSL rates of tens of Mbps are being offered, DSL operators in less densely populated countries offer services at 256–512 kbps. Latest DSL systems do offer rates in the order of several Mbps, but still only for users near the exchanges. The transmission rates for users separated from the station by more than 5 kilometers is very low.

Higher transmission rates, even in excess of 100 Mbps, are available with fibre-to-the-home (FTTH) solutions. These are optical fibre connections that directly connect a home to a network, which itself is connected to the internet. This service, however, is almost confined to highly populated urban centres.

1.2 Mobile Communications

'Phenomenal', 'unprecedented', and 'explosive' are but a few of the adjectives that have been used to describe the growth of the mobile communications industry over the past

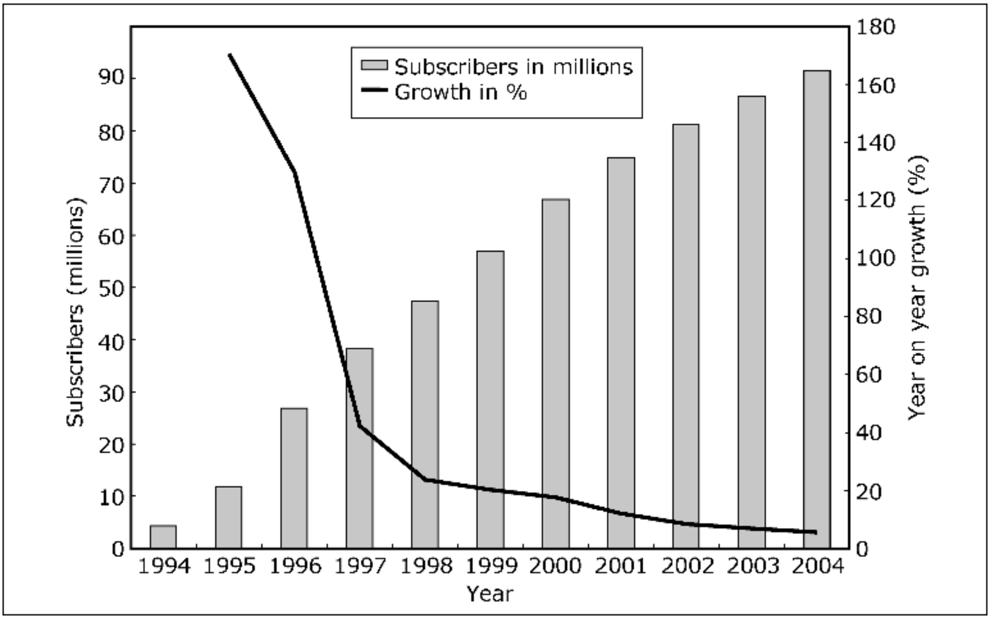


Figure 1.3 Subscriber growth in Japan. Reproduced by permission of Japanese Ministry of Internal Affairs and Communications (MIC)

decade. Modern mobile communications date to the early 1980s, but growth in those early days was extremely slow. Constrained by the high cost and bulky size of mobiles as well as high tariffs, these services were kept out of the reach of most consumers. In the mid-1990s, however, this scenario started to change as smaller and less-expensive handsets started to appear in the market, and operators started to offer affordable service packages. In many developed countries, the growth rate has been so fast that in less than a decade virtually all of their population have become mobile phone subscribers. Figure 1.3 shows how the market has grown in Japan. In less than six years, market penetration grew from less than 10% in 1995 to more than 60% in 2000. Market penetration has been highest among young people – as of April 2004, more than 99% of people in their twenties and 95% of people in their thirties had a mobile phone. Similar growth rates are observed elsewhere in the developed world. Table 1.1 shows the penetration rate for several highly market-saturated countries. Owing to some interesting peculiarities of their mobile market development, there exist countries with more than 100% market penetration. That is, a significant proportion of the population have more than one subscription. The 100%+ penetration rates are partly due to the following: (1) many of the subscribers may be foreign workers; (2) some subscribers have two or more prepaid subscriptions; and (3) coverage for one mobile technology (e.g. GSM) services are not available in the countryside, and there is a need to be connected while on holidays, using older analogue technologies. The rate of growth in developing countries more and more mirrors that of the developed world of earlier years. The compound annual growth rate (CAGR) of several countries is shown in Table 1.2.

Table 1.1 Mobile penetration rate for several countries. *Source*: ITU statistics, March 2005

Country	Market penetration %
Luxembourg	119.4
Taiwan	114.1
Hong Kong	107.9
Italy	101.8
Sweden	98.1

Table 1.2 Compound annual growth rate (CAGR) for subscribers in several countries, over 1998–2003. *Source*: ITU statistics, March 2005

Country	CAGR %
Sweden	16.5
Japan	12.9
Tajikistan	157.6
Jamaica	87.0
Uganda	91.7

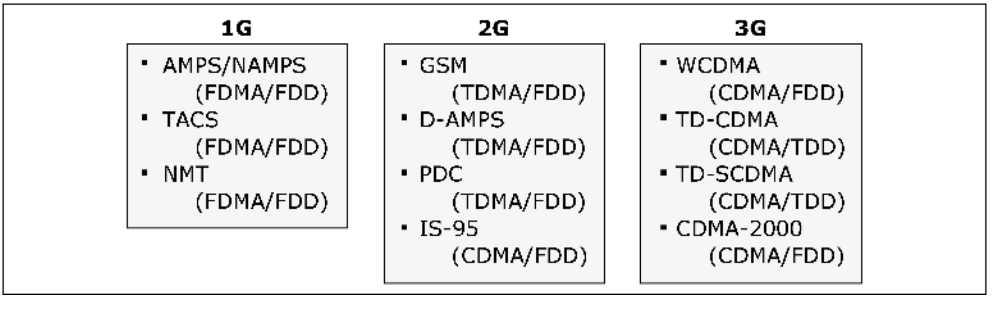


Figure 1.4 Three generations of mobile communications technologies

The technologies for these services are generally considered to have gone through three generations. A typical classification of these technologies is shown in Figure 1.4. While the first-generation devices used analogue technologies and provided primarily voice services, second- and third-generation devices have been digital, and suitable for data communications. Some of these technologies have been jointly developed by a group of companies. They have gone through a thorough evaluation and revision process, and have become worldwide standards. Some of these are now in service or are being commercialised.

Table 1.3 Typical cost figures for new subscribers for 2G and 3G mobiles in Japan

Model	Type	Operator	Manufacturer	Price ($)
FOMA-N901	3G high end	DoCoMo	NEC	110
MOVA-P700i	2G high end	DoCoMo	Panasonic	70
M1000	3G high end with PDA	DoCoMo	Motorola	460
WIN	3G high end	KDDI	Toshiba	130
Au	2G high end	KDDI	Casio	120
Tuka	2G low end	Tuka	Kyocera	40

Meanwhile, some other proprietary technologies have been developed mainly through the efforts of individual companies. First-generation (1G) systems have been almost totally replaced by second-generation (2G) systems, while third-generation (3G) systems are starting to augment, and gradually replace, those of 2G.

All along, advances in microelectronics and the economies of scale have driven down the cost of both mobile handsets and network equipment, allowing operators to offer less-expensive plans to attract more subscribers. The end-user cost of devices has remained very much a function of competition in the marketplace. In many instances, operator subsidy has driven the end-user price to zero. Meanwhile, increasingly abundant and diverse accessory features, such as cameras, large displays, radios, and even televisions, have been packaged in the mobile handset. These new features are reasons why the price of a handset has not fallen even more dramatically. Table 1.3 shows the present cost of different 2G and 3G end-user mobiles in Japan. These are the prices a new subscriber would pay after operator subsidy, which in Japan differs for various models, but on average it is around $400 per handset.

Competition between operators has been the major factor deciding the monthly tariffs, usually expressed as average revenue per user (ARPU). This is the total a subscriber pays to the operator each month for mobile services, including a basic fee, for talk-time charges as calculated per unit of time for voice services, and data communications charges as calculated per unit of data. The ARPU trend in Japan over the past few years is shown in Figure 1.5. Generally, ARPU figures have been falling over the past few years in Japan and most other countries. One important reason has been price competition between operators. Another reason is the fact that most new subscribers are older people, who do not use their mobiles so often. A third factor, as observed from Figure 1.5, is the decline in average voice revenue in comparison to data revenue.

1.3 Wireless Data Communications

Initially, mobile communications systems provided telephony services (paging services also existed, but we do not consider those services in this text). Soon, however, data services emerged. Initially, these were short messaging services (SMS). With the great spread of the internet in the fixed networks, similar services started to appear in the mobile networks. The Japanese i-mode service (see Box: Japanese i-mode service) and Wireless Access Protocol

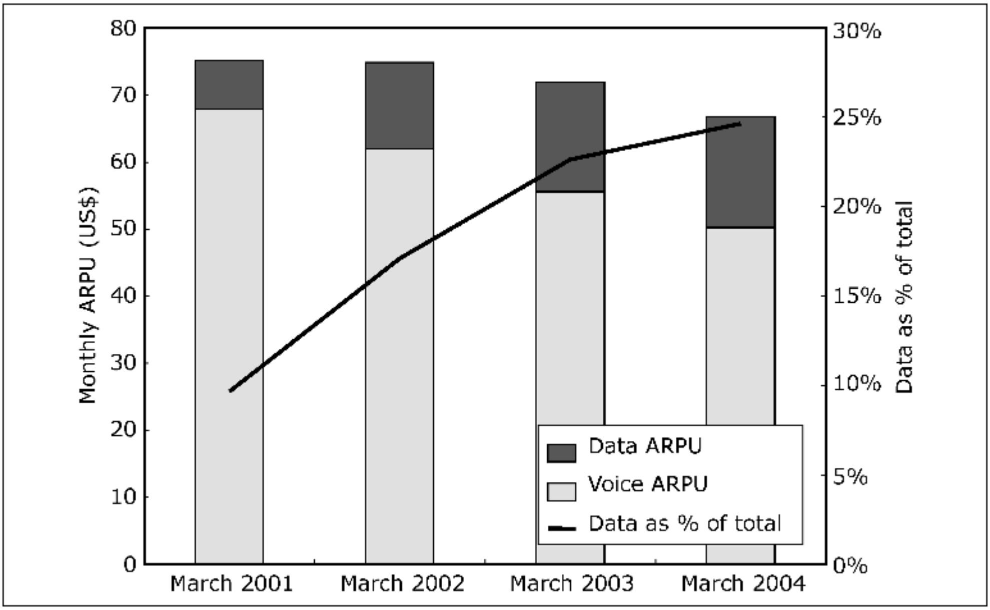


Figure 1.5 ARPU trend in Japan. Reproduced by permission of Japanese Ministry of Internal Affairs and Communications (MIC)

Japanese i-mode service

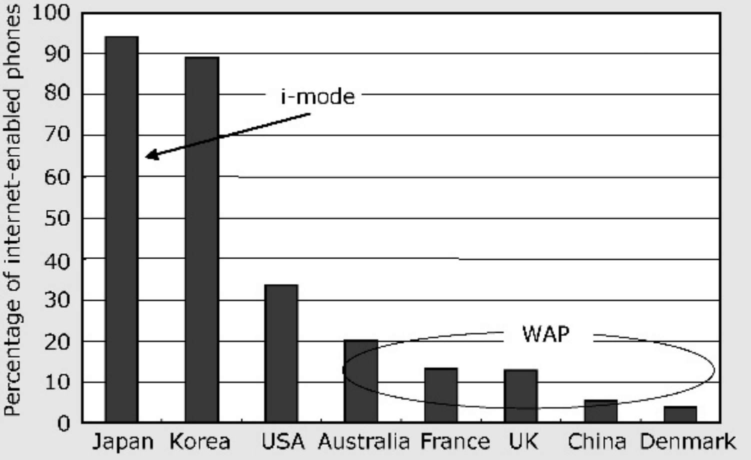
NTT DoCoMo introduced i-mode in February 1999. Because of low PC penetration at home, and the high cost of dial-up internet connection, i-mode services caught on very quickly. It was also because i-mode provided SMS functionality, which was then not widely available for mobile subscribers.

DoCoMo's use of simplified web-browsing language, a content provider system, and a handset maker alliance ensured the great commercial success of i-mode. Nowadays, i-mode, and similar services by other Japanese operators, enable users to connect to the internet. The percentage of internet-enabled mobiles in Japan is the highest in the world. The success of i-mode in Japan has attracted the attention of operators in other countries. Here are some examples of (mainly) GSM operators who are adopting i-mode:

Mar 2002	E-Plus, Germany
Apr 2002	KPN, The Netherlands
Jun 2002	KG Telecom, Taiwan
Nov 2002	BASE, Belgium
Nov 2003	Wind, Italy
May 2004	Cosmote, Greece

Wireless Access Protocol (WAP)

First released by WAP Forum in 1999, and then later released by Open Mobile Alliance (2001), WAP is designed to enable mobile handset connection to the internet. It uses standard internet protocols, and browsing languages. WAP has not been as successful as i-mode in Japan in attracting users. WAP-enabled phones are only a small portion of all mobiles.



Source: MIC White paper

(WAP) (see Box: Wireless Access Protocol (WAP)) are examples of these services. I-mode and other similar services in Japan have been particularly successful because they provided e-mail/short messaging capability, which was not otherwise readily available, as well as provided access to information via their internet browser. Because of its great success in Japan, i-mode has been copied by several European operators, but with mixed results. The general ARPU trend, however, has been the growth of data communications, and the decline of voice communications as shown in Figure 1.5.

Wireless data communications is therefore viewed as the growth component of a mobile operators' business. But this growth can be maintained only if present services are enhanced and new services are introduced. The pace of data ARPU is already slowing down as can be seen form Figure 1.5, perhaps as a result of insufficient new data service offerings. Most new services are likely to include large-sized content, including video and audio, as well as rich-content multimedia. Much higher data rates will be required for these new services and applications, and this has been one of the main drivers of the evolution from 2G to 3G, and a driver for the development of related technologies.

Wireless (mobile) data communications services became available initially with 2G systems. These systems provide transmission rates of up to a few tens of kbps, which, although sufficient for SMS or simple web browsing, cannot support applications with larger file sizes and transmission speed requirements. A major factor in the development of 3G standards has therefore been to provide technologies that can deliver much higher data rates. Table 1.4 lists the possible transmission rates for several present technologies.

Table 1.4 Data transmission rates

Access technology	Transmission rate
2G (GSM, PDC, D-AMPS)	~10 kbps
Enhanced 2G (GPRS, D-AMPS)	~144 kbps
3G (WCDMA, TD-CDMA)	384 kbps ~ 2 Mbps
Enhanced 3G	Up to 14 Mbps

1.4 Broadband Wireless

Considering the saturation of the mobile telephony market, the emergence of mobile data services, and the growth of fixed broadband services, it is logical to assume that movement into broadband wireless services is the natural evolution of the present wireless market. Although expectations of market size vary, there is a broad consensus that broadband wireless is the next 'big thing' for the industry.

1.4.1 Edholm's Law

With the growth of transmission rates on both the fixed and wireless sides, it is fair to assume that sometime in future fixed and wireless rates will become comparable, if not equal. A comparison of transmission rates is shown in Figure 1.6. Attributed to Phil Edholm, Nortel

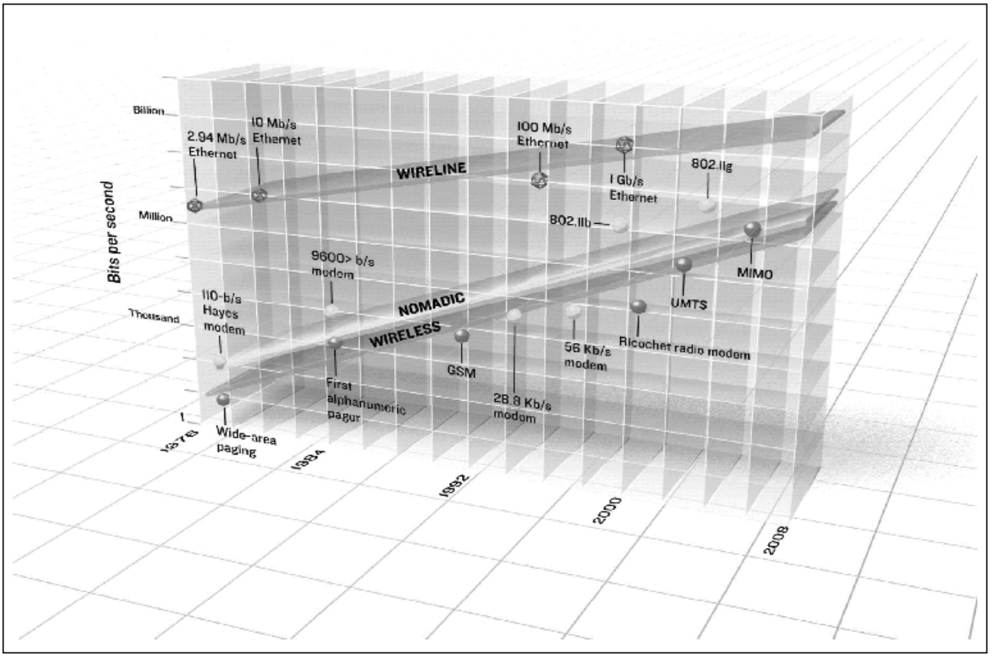


Figure 1.6 Edholm's Law: fixed and wireless transmission rate trends. Reproduced by permission of IEEE Spectrum Magazine, July 2004

Inc. chief technology officer, this figure shows that wireline (fixed), Nomadic (wireless without mobility), and wireless (mobile) communications have been growing 'almost in lock step'. The rate of growth for wireless (mobile and nomadic) communications is faster than that of wireline communications. Extrapolating forward, it appears that we may someday see a convergence between wireline and wireless rates. If the cost of wireline infrastructure remains higher than that of wireless, as it is today, then the end of wireline communications may very well arrive.

There are two desirable aspects to internet connection: fast transmission rates and seamless, constant connectivity. Fast transmission rates require wide frequency bandwidths, as well as high bandwidth utilisation efficiency. Wider bandwidths must be decided by governments and agreed upon internationally, a subject we will discuss more in the next chapter. Discussions on possible bands for broadband wireless systems are already under way in many parts of the world, as listed in Figure 1.7. As increasingly wider bandwidth is required for future systems, it is inevitable that higher frequency bands should be used. There are however, advantages as well as disadvantages to operating in higher bands. We will discuss these in the next chapter. While in fixed-line communications between two users the whole medium is dedicated for their connectivity, the available bandwidth for wireless communications is limited and must be shared among many users. The challenge of all wireless technologies is how to use this common resource efficiently. Moreover, the resource must be allocated in such a way that each user *experiences* uninterrupted connectivity.

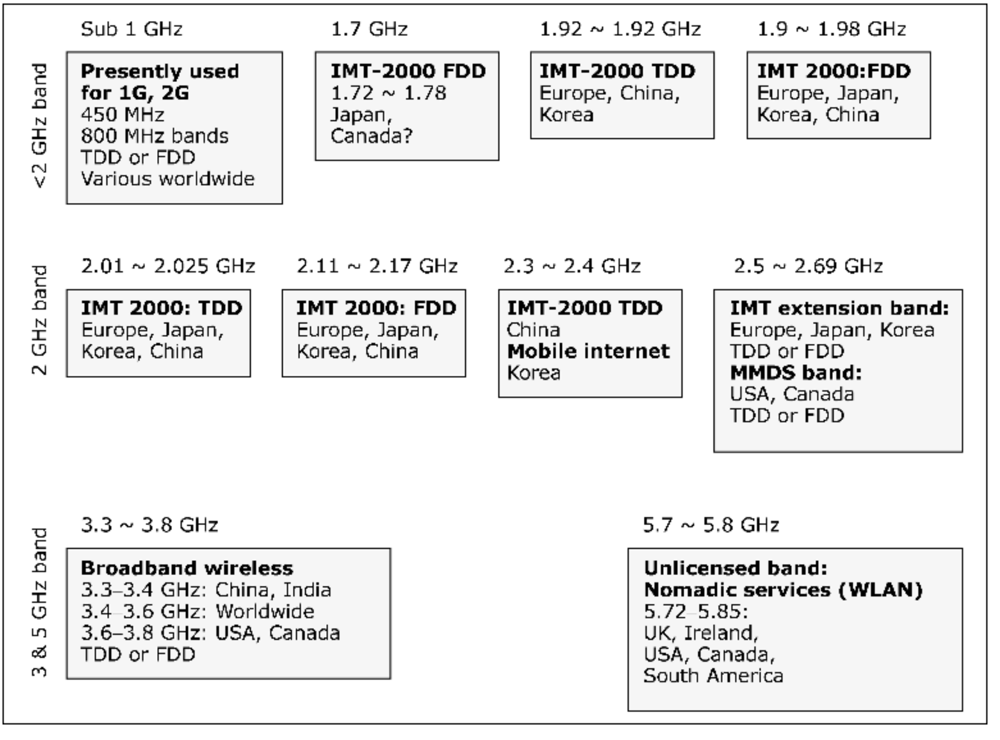


Figure 1.7 Possible spectrum for broadband wireless

Research and development for the next-generation systems, sometimes referred to as 4G, are following two different paths. One is an evolutionary track from the present 3G systems, sometimes referred to as super 3G. The research is focused on adapting the present standards to full data communications, and includes technologies to increase transmission rates. The second is a revolutionary track, proposing new radio access technologies designed specifically for broadband wireless communications.

1.5 Duplex Modes

Duplex communications between a central BS and end-user equipment can be carried in two modes. In the first mode, two separate frequency bands are used for downlink (DL), or BS to end-user, and uplink (UL), or end-user to BS transmissions. This is called *frequency division duplexing* (*FDD*). FDD mode is used in most 1G and 2G systems as it is well suited for voice communications. In the other duplex mode, UL and DL transmissions are carried out in the same frequency band. The band, however, is alternately switched for BS and end-user transmissions. This is called *time division duplexing* (*TDD*) and has been used in some short-range 2G systems such as Personal Handyphone Systems (PHS) and Digital Enhanced Cordless Technologies (DECT). For 3G systems, two FDD standards Wideband CDMA (WCDMA and CDMA2000) and two TDD standards (Time Division CDMA – TD-CDMA and Time Division – Synchronous CDMA – TD-SCDMA) have been defined. At this point in time, it is unclear whether 4G systems will be based on TDD or FDD. These two duplexing systems, FDD and TDD, are illustrated in Figure 1.8.

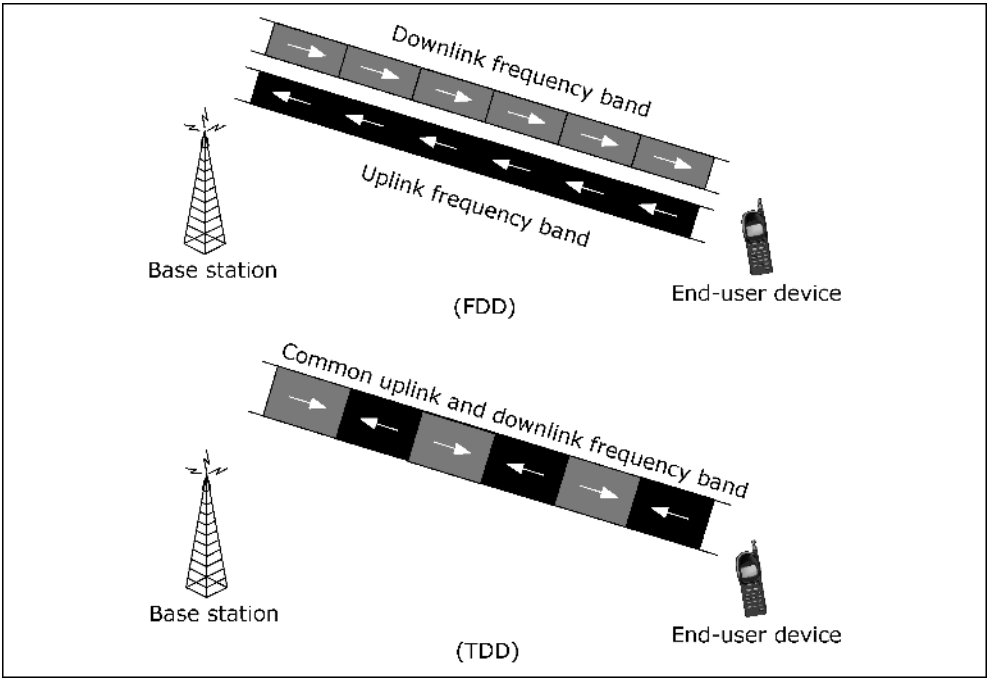


Figure 1.8 FDD and TDD modes

Reciprocity

A major characteristic of TDD systems is channel reciprocity. The performance of radio communications systems is highly dependent on transmission channel characteristics. Because the channel is highly time variant, equalising for channel variations is very important. Since channel variations depend on the frequency band, channel variation characteristics are uncorrelated for the UL and DL of FDD systems, which use two separate bands for DL and UL. For this reason, feedback processes are required for channel equalisation in FDD systems. However, for TDD systems, since the same frequency is used for both DL/UL transmissions, channel variations are highly correlated. This is known as *TDD channel reciprocity* because variations between UL and DL are reciprocal. This means TDD systems do not require feedback for most of their channel equalisation purposes.

Resource allocation

DL and UL resource allocation is an issue of great importance to broadband wireless systems. Voice communications require equivalent resources for UL and DL. For data communications, however, traffic amounts are not necessarily equivalent. That the traffic volumes for DL and UL vary in an unexpected fashion is a phenomenon we will discuss below. What resources ratio will be required for each link in the future broadband wireless systems remains uncertain.

A major advantage of TDD over FDD is its flexibility of resource allocation. As capacity allocation can be carried by allocating a portion of time to each link, reallocation can simply be done by moving the time switch, or changing slot allocation ratios as illustrated in Figure 1.9. In fact, capacity allocation can be varied as often as desired, and even independently at the cell level. In contrast, it is nearly impossible to reallocate an FDD spectrum once it has been decided. This is one reason TDD systems are considered to be a stronger candidate for broadband wireless systems of the future. We will illustrate this effect using an example, in Chapter 9.

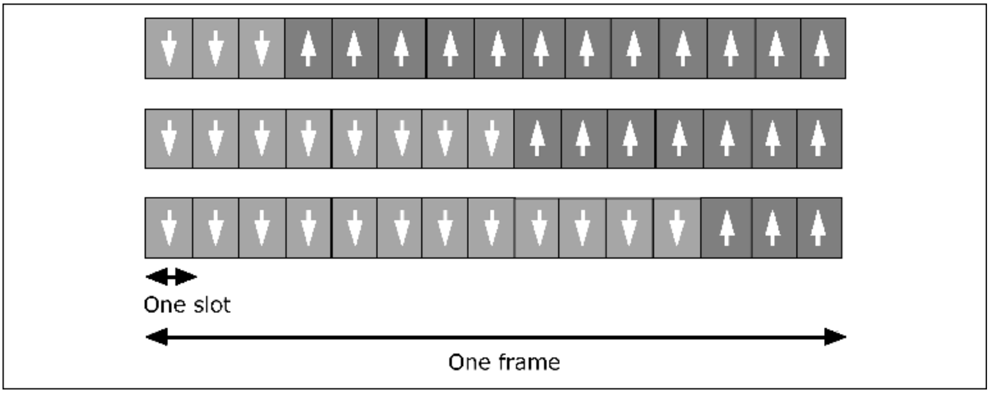


Figure 1.9 Downlink/Uplink slot allocation in TD-CDMA standard: one frame is 10 ms and is divided into 15 slots that can be allocated to either downlink or uplink

1.6 Voice to Data

For almost the entire first century of telecommunications history, voice had been by far the primary service provided over fixed links. In contract, over the past two decades, it is fixed-link data communications traffic volumes that have been growing. As shown in Figure 1.10, they have now surpassed the voice traffic volume.

The same is expected to happen with wireless data and voice traffic. The transition from a voice-centric service, as 1G and 2G systems have been, to what will be data-centric services is one of the most significant aspects of system design and operation for 3G and post-3G systems. Voice communications generally require connectivity for the duration of a call, and resources are allocated on a continuous basis. This is known as *circuit switching*. The technology dates back to telephony days when circuits were switched, manually, for each voice call. Data transmissions, however, do not require continuous allocation: resources can be allocated on per-packet basis. This is known as *packet switching*.

1.6.1 Voice-over internet protocol

With the emergence of full packet-switched networks, voice communications, both fixed and wireless are also going through a revolution. In fixed-line communications, Voice-over IP (VoIP) is fast replacing old circuit-switched voice networks. It is expected that by 2008–2009 the bulk of voice traffic will be carried using VoIP technology.

Wireless, mobile voice communications of 1G, 2G, and 3G still use circuit switching. The more recent 3G systems, however, are standardised to use an all-IP backbone and packet

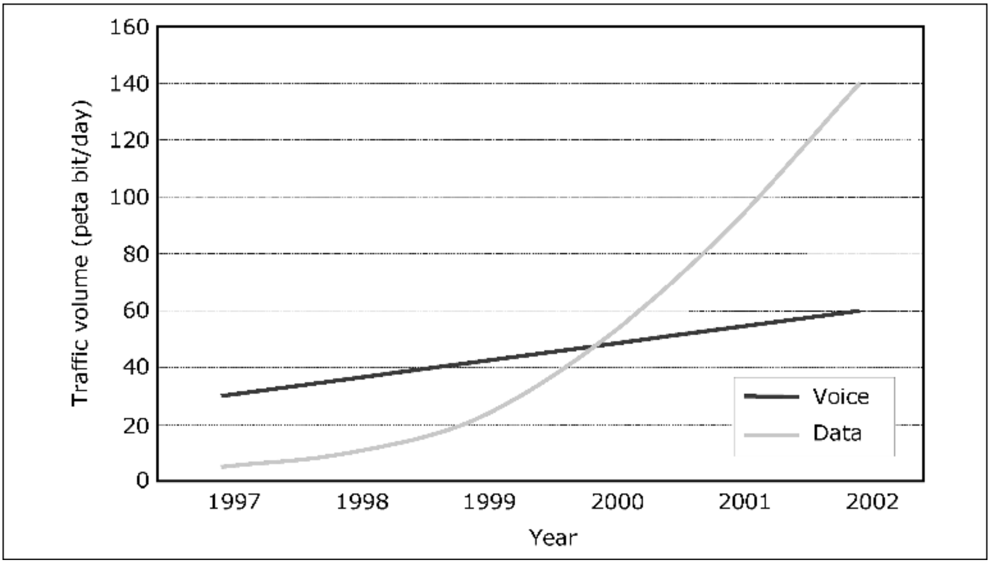


Figure 1.10 Voice and data traffic. Reproduced by permission of IEEE

Table 1.5 Packet switching in 3G

Service	1G and 2G	3GPP Release 99	3GPP Release 5 and beyond
Voice	Circuit switched	Circuit switched	Packet switched
Video	—	Circuit switched	Packet switched
SMS	Circuit switched	Packet switched	Packet switched
WAP	Circuit switched	Packet switched	Packet switched
E-mail	Circuit switched	Packet switched	Packet switched
Web	—	Packet switched	Packet switched
MMS	—	Packet switched	Packet switched
Streaming	—	Packet switched	Packet switched

switching as shown in Table 1.5. However, transmission of VoIP packets over the air is not efficient as packet overheads are mostly unnecessary. Quality of service requirements need to be considered in air-interface design for VoIP services. We will discuss this issue further in the next chapter.

1.7 Traffic Profiles

Another issue affecting business decisions in the development of the next-generation wireless communications system is the user's service requirements. Both 1G and 2G systems were designed for voice communications. Voice traffic characteristics had been studied for over a century and were well known. It was easy to calculate the required number of voice channels based on population density and market expectations. Moreover, the DL and UL traffic characteristics were highly similar. FDD systems are well suited to this kind of traffic (symmetric up and DL capacities), with the precedent that the public, fixed-line telephone systems also used an FDD mode of operation.

In contrast, the next-generation broadband wireless systems are mostly for data transmission applications such as sending and receiving files and browsing the internet. Models for this kind of traffic have been developed only recently. In particular, web browsing had been considered the major traffic activity on the internet, where a user accesses a web site using a short data burst, downloads a rather large-sized web page, and spends a certain time reading the downloaded information.[1] It was therefore believed that the DL traffic is comparatively larger than the UL, implying that spectrum allocation should be larger for the DL.

However, a recent boom in peer-to-peer (P2P) file exchange, particularly audio and video files, is expected to balance the UL and DL traffic volumes for personal communications. Napster, Kazaa, and other file sharing P2P programs (see Box: File sharing programs) well represent this trend. In fact, Kazaa is currently the most downloaded software. The following observations on P2P traffic in 2004 in Europe signify this trend:

- P2P file sharing accounts for over 70% of the traffic on ISP networks.
- P2P traffic volume accounts for 95% of uplink traffic over networks' last mile.

[1]UMTS document TR 101 112 defines a web-browsing model for a WWW browsing session.

File-sharing software

Sharing files over the internet has become easily possible using any one of a number of freely available file-sharing programs, such as Napster, KaZaA, eDonkey, iMesh, Lime Wire, and so on. Among these, KaZaA has the reputation for being the most downloaded software program (389 million downloads and counting).

- An average of five million people were connected to a P2P network.
- Thirty-five million people in Europe had downloaded music from a P2P network.

How long will this trend last? And what does this fixed-link communication trend mean to wireless communications? Does this mean that the same amount of spectrum must be allocated to UL and DL? There are no models yet defined for this kind of traffic for wireless, and it is still too early to accurately indicate how DL and UL traffic patterns will develop, even in general, for the next generation of broadband wireless systems. A flexible design that allows for dynamic reallocation of capacity to UL and DL will prove valuable.

1.8 Access Technologies

Several access technologies have been proposed for wireless broadband. Some of these technologies are presently being used in 2G and 3G systems. A summary of the present technologies and their applications for broadband wireless is presented in the following sections. Table 1.6 shows the duplex mode and carrier bandwidth specifications for several standards.

1.8.1 Frequency division multiple access

Frequency division multiple access (FDMA) is the oldest of the multiple access technologies, and was primarily used in the analogue 1G systems. In FDMA, the total available bandwidth is divided into a large number of small carriers, each of which is used to

Table 1.6 Carrier bandwidths of several standards

	AMPS	GSM	WCDMA	TD-CDMA	WiMAX
Duplex mode	FDD	FDD	FDD	TDD	FDD & TDD
single channel bandwidth	30 kHz	200 kHz	5 MHz	5, 10 MHz	1.25 $\sim$ 20 MHz

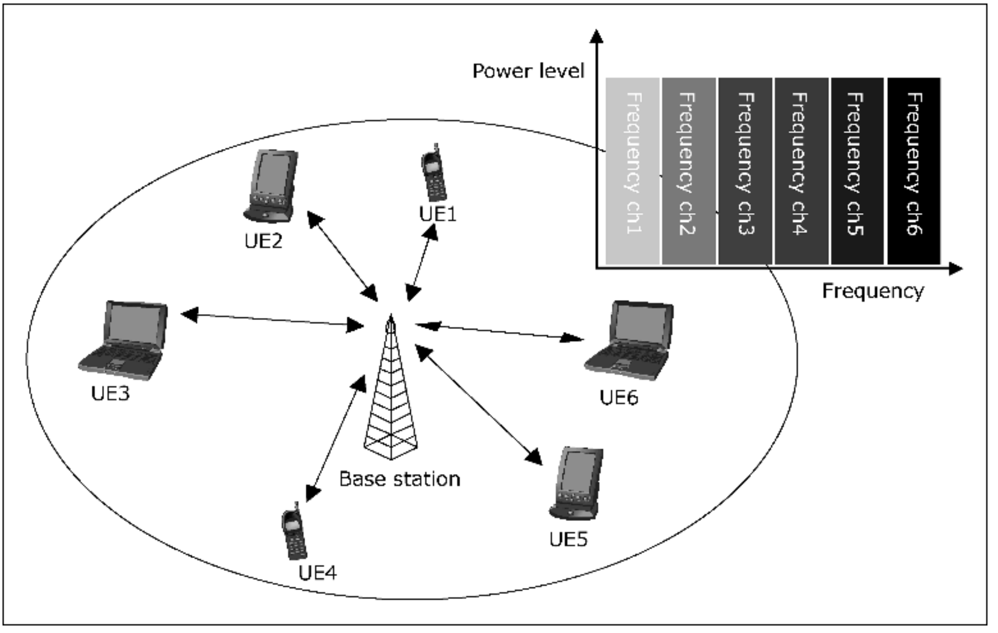


Figure 1.11 Frequency division multiple access

carry voice traffic from a base station to a mobile device (and vice versa), as illustrated in Figure 1.11. FDMA technology, in its initial form, was abandoned in favour of more advanced, more efficient digital technologies in 2G systems. Frequency division multiplexing has appeared again in a more advanced format, as will be discussed in Chapter 2.

1.8.2 Time division multiple access

In Time Division Multiple Access (TDMA) technologies, several users access the central base station using the same frequency band, but not all at the same time. Each of them takes turns to connect to the base station one at a time as shown in Figure 1.12. This technology is used in most 2G systems, such as Digital AMPS (D-AMPS), PDC, and GSM.

1.8.3 Code division multiple access

The CDMA technology (Figure 1.13) became popular thanks mainly to the pioneering work of Qualcomm Inc. The technology is based on the spread-spectrum technique, known and well practised in military communications for over 50 years. In one form of spread spectrum, the signal is spread over a wide bandwidth through multiplication with a pseudorandom code. The signal can then be detected by similar multiplication by exactly the same code. CDMA systems work on the principle that two or more users' signals may be transmitted, and distinctly received, in the same band as long as they use distinct spreading codes for their signals. After spreading, all signals occupy the same bandwidth and appear

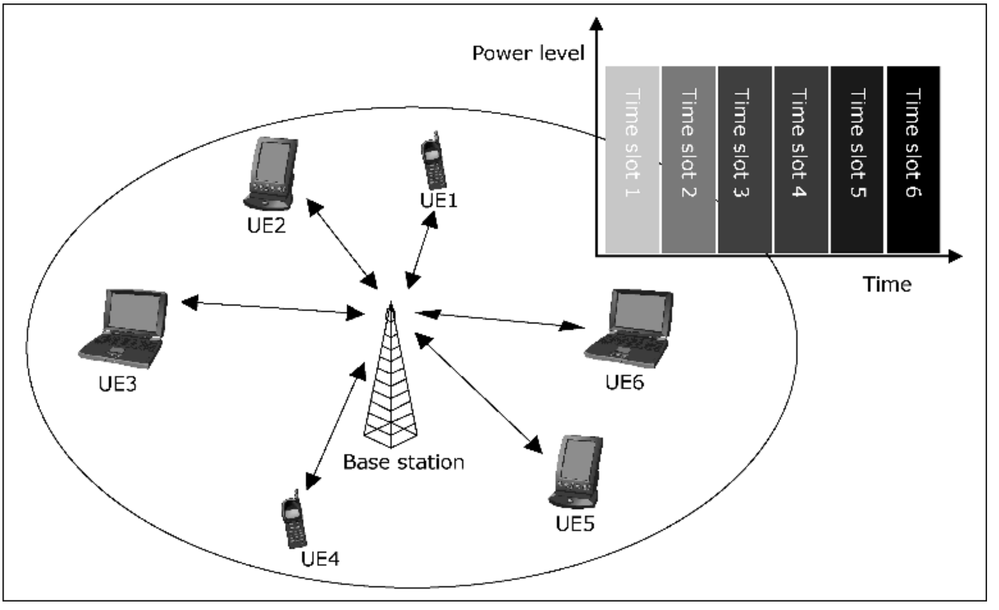


Figure 1.12 Time division multiple access

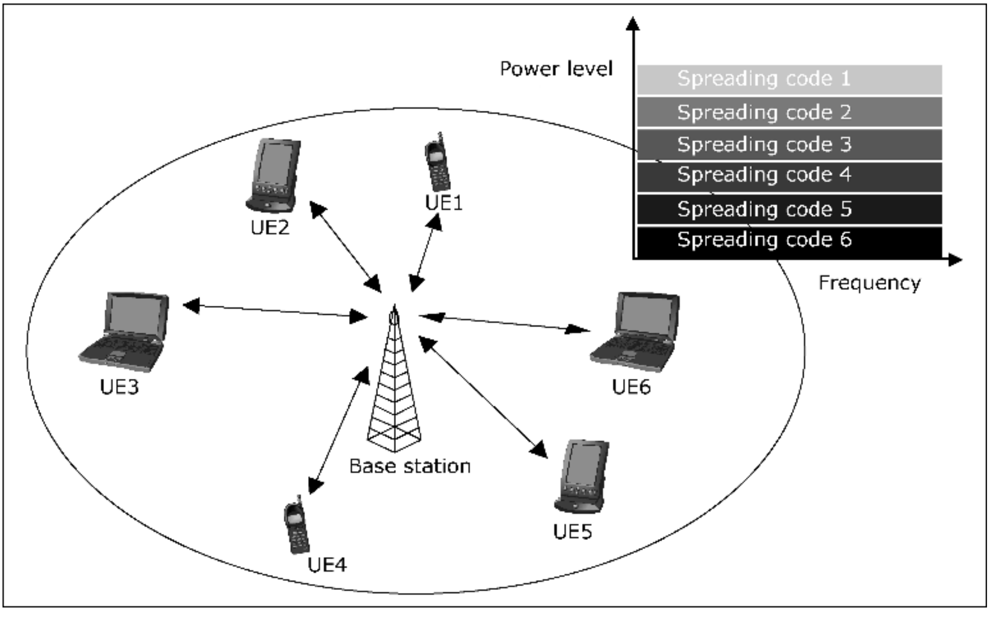


Figure 1.13 Code division multiple access

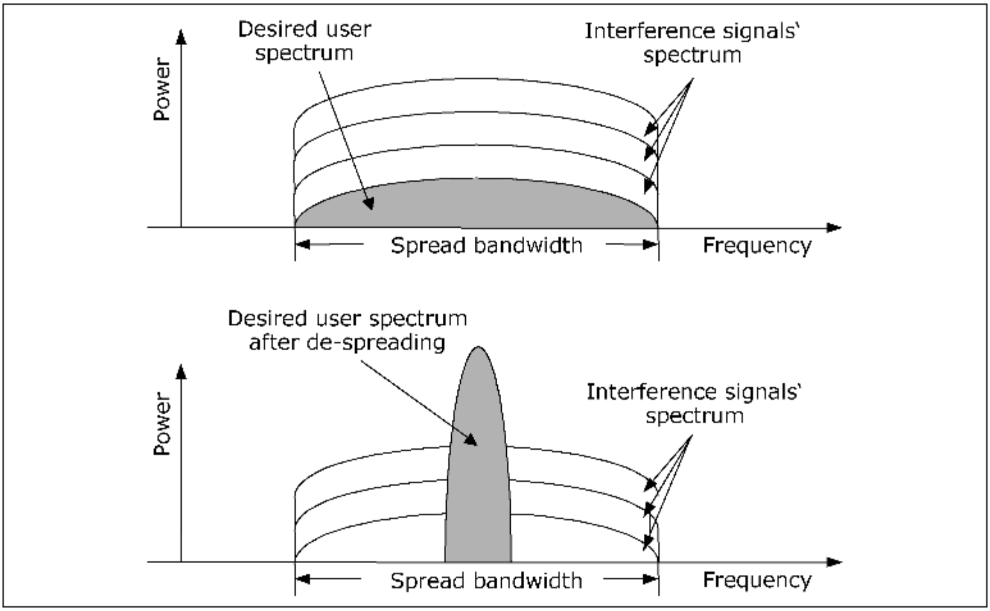


Figure 1.14 Wide-band spread signals and narrow-band desired signal after de-spreading

to each other as noise. At the receiver side, a de-spreading function is carried out, which restores only the desired signal to the original narrow band, as shown in Figure 1.14.

CDMA was used in the IS-95 standard, and competed directly with TDMA systems such as D-AMPS and GSM for the 2G market share. CDMA systems can be said to form the basis for all 3G systems. Although some evolutions of 2G TDMA systems have been considered for 3G, the mainstream systems are based on CDMA. There are two leading sets of 3G standards: one comes from the third-generation partnership project (3GPP) and presently has three modes: WCDMA, TD-CDMA and TD-SCDMA. The other 3G standard has been developed by 3GPP-2, and is an evolution of the 2G IS-95 standard.

1.8.4 Channel sense multiple access

Wireless LAN (WLAN) network operations are based on a self-organising decentralised transmission control topology. In WLANs, each user monitors the carrier transmission channel to detect whether any other user is transmitting. The process is to carry request-to-send (RTS) and clear-to-send (CTS) signalling between two users. This is known as *channel sensing*, and this mode of channel access is known as *Channel Sense Multiple Access* (*CSMA*). If no other device is using the channel, then the user equipment proceeds to transmit its message.

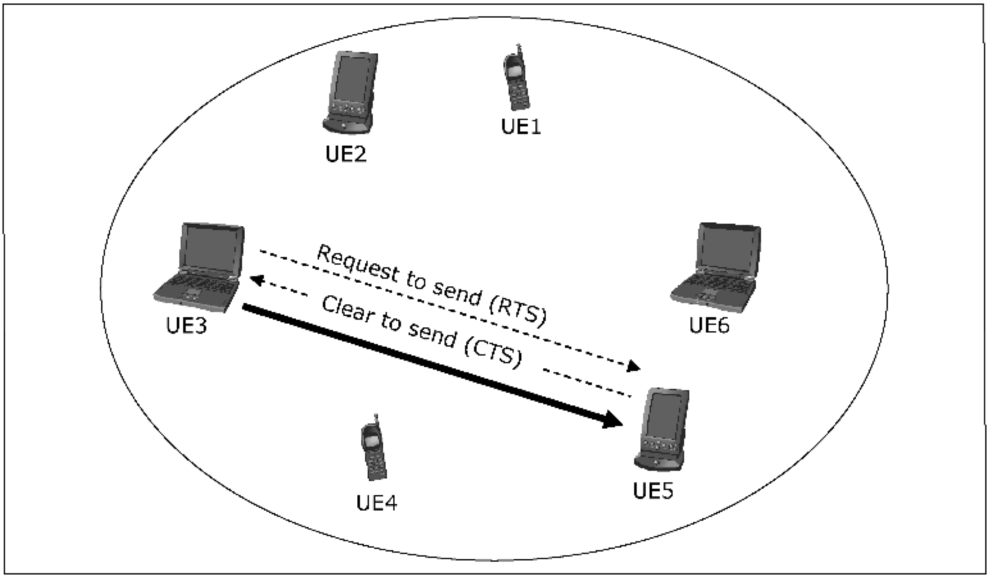


Figure 1.15 Channel sense multiple access

Table 1.7 Communications technologies and their multiple access domains

Communication technologies	Multiple access domain
AMPS	Frequency
GSM	Time and frequency
WCDMA	Code
TD-CDMA	Code and time
WLAN	CSMA + frequency/code and time
WiMAX	Frequency and time

Collisions may occur if two users decide to monitor the channel at the same time and, upon detecting that it is free, proceed to transmit. Collision avoidance algorithms are utilised to reduce the probability of occurrence of such an event. Figure 1.15 illustrates the operation of CSMA systems.

Wireless LAN system have been standardised through organisations such as IEEE and ETSI (see Glossary). Several WLAN standards, and versions, exist, where each uses a specific combination of CSMA and modulation, coding, and antenna technologies. In general, present mobile and nomadic technologies use one or a combination of the above access techniques. Table 1.7 summarises examples of present communication technologies and the multiple access methods they use.

1.9 Telecommunications Operator Business

The telecommunications operator business can generally be described as a fixed-cost business. The initial costs for designing and construction of a network are quite high. In comparison, operating costs per single subscriber are small. Similar to other fixed-cost businesses, airlines, for example, an operator needs to attract as many customers as possible to the service in order to recover the initial costs, and to operate profitably.

With (virtually) unlimited capacity, and in the presence of competition, costs to end users will shrink to leave the operator with only marginal profits. This is what has happened to long-distance telephone businesses. Many such carriers have faced financial troubles, and have been trying to find new revenue-generating activities. Some have filed for bankruptcy protection, and some have even ceased to exist as independent companies. A few prominent examples are shown in the box 'Long-distance operators in trouble'. However, when capacity is limited, the operators can maintain a healthy profit margin. This is because competitors cannot add more subscribers when their networks reach full capacity, and therefore the competition for attracting new subscribers is not very fierce. A look at the ARPU figures for different countries provides a good indication of the demand and supply of mobile telephone capacity. Table 1.8 shows the ARPU figures in 2004 for several countries for subscriber contracts (excluding prepaid ARPU). Of course, other factors such as a lack of (real) competition as well as government regulation also determine the end-user costs.

Long-distance operators in trouble

Worldcom: Filed for bankruptcy protection in July 2002

Global Crossing: Filed for bankruptcy protection in January 2002

Japan Telecom: Acquired by Softbank in May 2004

AT&T: Acquired by SBC Communications in January 2005

As governments release more spectrum for wireless communications, the danger of ARPU meltdown to existing operators becomes more and more real. Will wireless communications go the way of long-distance telephones? Will these operators also become the supplier of a transmission pipe and no more?

Table 1.8 ARPU figures for operators in several countries

Country	Operator	ARPU (US$)
Australia	Vodafone	55.47
Singapore	StarHub	42.36
Japan	DoCoMo	73.16
UK	T-Mobile	69.51
South Africa	Vodacom	83.93
USA	Cingular	50.32
Argentina	Nextel	40.00

1.9.1 From pipe to content provider

Two strategies are being followed by wireless operators. One is to increase the traffic per subscriber, and thereby keep traffic demand equal to possible supply. The increase in voice traffic responds to lower costs, but is limited by size of population. The other is to rise in the value chain, and engage in providing content to the end-user. The operator could become an outright content provider or at least a stakeholder in providing content. An example is the i-mode model of Japan, as shown in Box 'Japanese i-mode service' on page 8.

1.9.2 Flat rate

Once operators start to charge for content, a possible new tactic to increase usage may be to offer flat-rate subscriptions. Already two operators in Japan, KDDI and DoCoMo, provide flat-rate subscriptions for data-only services. It can be expected that broadband wireless systems will be operated with flat-rate charges.

Summary

We have made a review of broadband and wireless telecommunications, providing a background of the technologies used for these systems, and a history of how they arrived. From a market point of view, the broadband data communications field is growing very fast. On the other hand, the growth of mobile/wireless telephony systems is beginning to plateau as market penetration rates near 100%. The next stage in wireless communications is believed to be a combination of broadband and wireless. We have given a review of technologies used in successive generations of mobile telephony and their user capacity characteristics.

In relation to broadband wireless technology, we have discussed the characteristics of the traffic likely to be carried over these networks. Furthermore, we have briefly discussed how a broadband wireless operator may choose to do business. In the following chapters, we will go into further detail on the topics discussed here.

Further Reading

- On ISDN:
  - "ISDN Basic user-network interface – Layer 1 specification" International Telecommunication Union-Telecommunications Standards Section (ITU-T) I.430.
- On DSL:
  - Technical and marketing reports from DSL Forum: `http://www.dslforum.org/`, 2005
- Statistics on mobile market development in Japan:
  - Yearly white paper by the ministry of home affairs and communication: `http://www.johotsusintokei.soumu.go.jp/whitepaper/eng/WP2005/2005-index.html`
- On i-mode:
  - Natsuno, T., *The I-Mode Wireless Ecosystem*, John Wiley & Sons, 2003a.
  - Natsuno, T., *I-Mode Strategy*, Halsted Pr, 2003b.
- On WAP:
  - WAP forum web site: `http://www.wapforum.org/`, 2005
- 3G standards:
  - 3GPP specifications: `http://www.3gpp.org/`, 2005
  - 3GPP2 specifications: `http://www.3gpp2.org/`, 2005
  - Holma, H., Toskala, A. (Editors),*WCDMA for UMTS: Radio Access for Third Generation Mobile Communications, 3rd Edition*, John Wiley & Sons, 2004.
- On IEEE Standards:
  - IEEE 802.11 family, (WLAN Standards): `http://grouper.ieee.org/groups/802/11/index.html`, 2005
  - IEEE 802.16 family, (includes WiMAX standard): `http://grouper.ieee.org/groups/802/16/index.html`, 2005
- On Wireless technologies:
  - Pahlavan, K., Levesque, A. H., *Wireless Information Networks*, John Wiley & Sons, 1995.
  - Rappaport, T. S., *Wireless Communications: Principles and Practice, 2nd Edition)*, Prentice Hall, 2001.