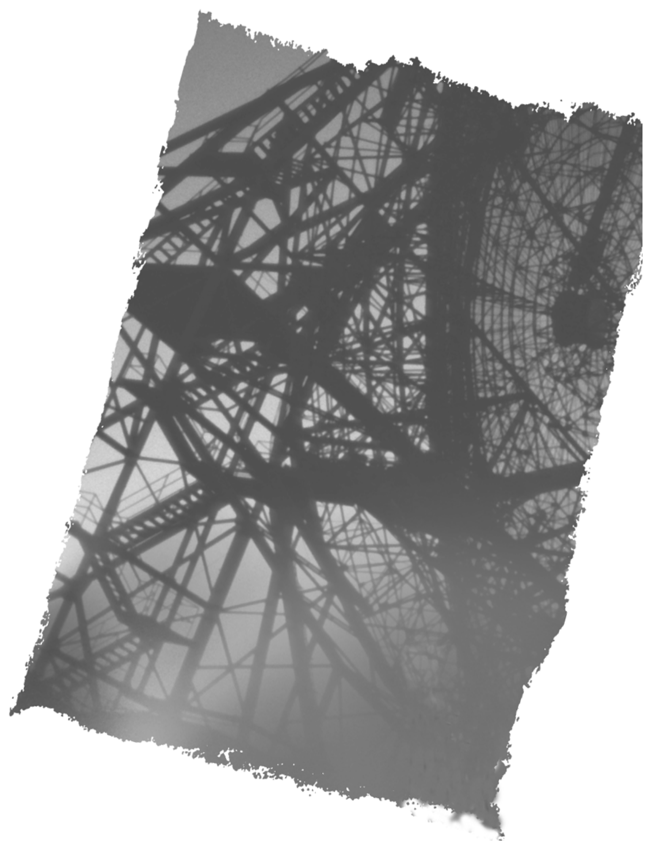
5 Third-Generation Standards

In this chapter...



Third-generation (3G) systems are critical to the wireless Internet services often touted as the future of mobile communications. At first, they will offer permanent access to the Web, interactive video, and voice quality that sounds more like a CD player than a cellphone. Many of their future applications are as yet unknown, with industry pundits saying that we will discover them as we go along.

The term *3G* has become rather vague, but it was originally quite specifically defined as any standard that provided mobile users with the performance of ISDN or better—at least 144 kbps. Some of the earlier $2^1/_2$G standards, such as GPRS and IS-95b, might be able to do this, but only under optimal conditions. Third-generation systems need to provide ISDN speeds for everyone, not just for people equipped with the most expensive terminals and standing next to a base station.

Technologically, the increased capacity is found in part by using extra spectrum and in part by new modulation techniques that squeeze higher data rates from a given waveband. At the very lowest level, this new modulation works by abandoning computing's traditional binary system and replacing it with a system such as *octal*, which allows every symbol to have eight values instead of only two. They also tend to be based on CDMA rather than TDMA because of its better ability to cope with new users.

The arguments over 3G are a continuation of the earlier battles between PCS systems. Vendors, operators, and regulators all accept that the move towards higher data rates and better services will be evolutionary, as illustrated in Figure 5.1. Standards have to be backward compatible with their predecessors so that phones can maintain a connection while moving between cells based on the old and the new.

Europe has defined a type of CDMA that will work with GSM, which may or may not be compatible with a system already being built by Japan. Elsewhere, cdmaOne supporters are split between several types known collectively as *cdma2000*, none of which will interwork with the Japanese or European standard. In America, D-AMPS and GSM operators want to stick with TDMA. The result is a "federal standard," more accurately described as a fudge. Global roaming will only be possible with special multimode phones.

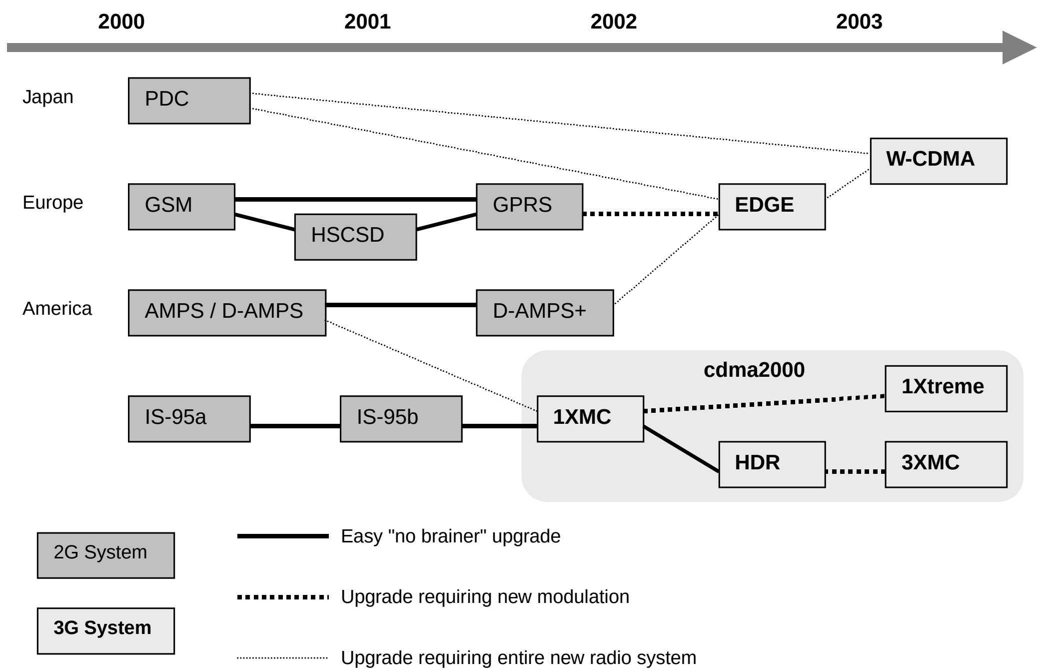


Figure 5.1
Upgrade path to third generation

IMT-2000

Third-generation systems were first planned in 1992, when the ITU realized that mobile communications was playing an increasingly important role. An international study group predicted that mobile phones would rival fixed lines within ten years, a prediction that came true somewhat earlier in some countries. It began work on a project called *FPLMTS* (Future Public Land Mobile Telecommunications System), aiming to unite the world under a single standard.

The acronym was awkward even compared to other telecom jargon, so the ITU soon adopted the (slightly) friendlier name *IMT-2000*. IMT stands for *International Mobile Telecommunications*, and the number 2000 had three meanings. It was supposed to represent:

- The year 2000, when the ITU hoped the system would become available
- Data rates of 2000 kbps
- Frequencies in the 2000 MHz region, which the ITU wanted to make globally available for the new technology

None of these aspirations were fulfilled entirely, but the name has stuck. Though prototypes were built in 1999, the “phones” were the size of a truck, and widespread commercial service is not expected before 2003. The target data rate *is* achievable, but only under optimal conditions.

Perhaps most important, not every country handed over the ITU’s requested frequencies. Europe and many Asian countries did, but the U.S. has made no spectrum at all available for IMT-2000. The technology is still relevant to American operators, who will deploy it in place of their existing networks, but the lack of new bandwidth may entrench the U.S.’s backward position in mobile communications.

More than Mobile?

With the more general moniker came a more general set of requirements. While FPLMTS just dealt with mobile phones and mobile data, IMT-2000 was supposed to encompass everything in the wireless Universe:

- *IMT-2000 wireless LANs (Local Area Networks) would give users even higher data rates when they were inside their own office or home.*
- *IMT-2000 satellites would allow people to access basic voice and low-rate data services from literally anywhere on Earth, even when they moved outside an area covered by the cellular network. These are sometimes called MSS (Mobile Satellite Service) or GMPCS (Global Mobile Personal Communications Service).*
- *IMT-2000 fixed wireless networks would bring telecommunications to poorer countries for the first time, providing a cheaper and faster alternative to laying landlines.*

The theory was that by basing all types of wireless services on a single radio system, many people would need to carry only one device—they could use their home cordless phone as a mobile, or even to make calls via satellite from the middle of the ocean. The industry would also save money, because components developed for one type of technology could easily be used for another.

Most of this vision had been abandoned by 1999, when vendors built the first prototype IMT-2000 equipment. Fixed wireless systems work best at much higher frequencies than mobiles, while satellite phones are more expensive and much bulkier than most people are prepared to carry around. Wireless LANs are still mandated in some official standards, but they too seem unlikely to be implemented. IMT-2000 has effectively reverted to FPLMTS's original aim—a cellular network for high-speed data.

3G Defined

The ITU's original definition of IMT-2000 concerned only the data rate. Three different rates were suggested, each corresponding to a different type of ISDN, then the standard for carriers' core voice networks.

- 144 kbps was the absolute minimum acceptable capacity. It is the same speed as a B-rate ISDN line, the type that can be deployed over ordinary telephone wires. B-rate ISDN makes up a large proportion of regular phone lines in some European countries, especially Germany. It is also marketed as a high-speed fixed Internet access technology in areas where DSL and fiber have yet to arrive.
- 384 kbps was the ideal capacity, which the system should aim for. It corresponds to an H-rate ISDN channel, often used for videoconferencing. Though video is possible at much slower speeds, this was considered the minimum necessary for picture quality approaching that of television.
- 2 Mbps was the capacity that should be achievable inside a building. It corresponds to a European P-rate ISDN line, which is usually a fiber-optic cable carrying up to 30 separate phone lines into an office switchboard. The idea was that small picocells could be set up in public areas, such as on trains or in airport departure lounges, giving people access to very high data rates.

These recommendations, shown in Figure 5.2, were made back in 1992, when the Internet was still not widely known outside of academic and technical circles. Politicians talked vaguely of an "information superhighway," but no one knew what form it would take. IMT-2000 was supposed to form the mobile part of this highway, complementing the interactive TV that it was assumed would reach people through cables in the ground.

As the Internet hit the public and commercial consciousness, the ITU realized that Net surfing would become one of IMT-2000's most important uses. This entailed an additional requirement: that it support the Internet protocols and be based on a packet-switched network backbone. The previously set data rates remained, but circuit-switched ISDN itself was abandoned.

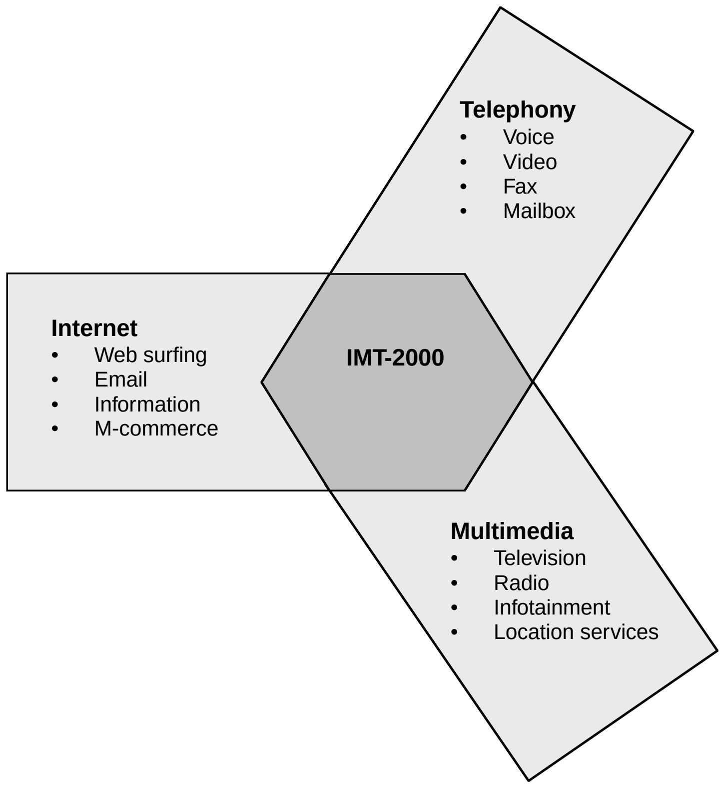


Figure 5.2
Convergence of services in IMT-2000

Service Requirements

Just as none of 3G's 1992 founders foresaw mobile Web access, many of its ultimate applications may still not have been discovered. However, the industry is clear about the direction in which it wants to move. The trend is towards *convergence*: Third generation aims to combine the Internet, telephones, and broadcast media into a single device.

To achieve this, IMT-2000 systems have been designed with six broad classes of service in mind. None of them are yet set in hardware; operators will be able to offer whatever data rates they want up to the maximum 2 Mbps or more, and customers will be free to buy whatever they can afford. But they are useful for regulators planning coverage and capacity, and perhaps for people buying terminals when they finally become available. It's likely that 3G devices will be rated according to the types of service they can access, from a simple phone to a powerful computer.

Three of the service classes are already present to some extent on 2G networks, while three more are new and involve mobile multimedia. In order of increasing data rate,

- **Voice.** Even in the age of high-speed data, this is still regarded as the "killer app" for the mobile market. 3G will offer call quality at least as good as the fixed telephone network, possibly with higher quality available at extra cost. Voicemail will also be standard and eventually integrated fully with email through computerized voice recognition and synthesis.
- **Messaging.** This is an extension of paging, combined with Internet email. Unlike the text-only messaging services built into some 2G systems, 3G will allow email attachments. It can also be used for payment and electronic ticketing.
- **Switched Data.** This includes faxing and dial-up access to corporate networks or the Internet. With always-on connections available, dial-up access ought to be obsolete, so this is mainly included to support legacy equipment. In 3G terms, *legacy* means any product that doesn't support a fully packet-switched network. This includes many $2^1/_2$G products that at the time of writing are not yet available, such as phones and data cards based on the GSM upgrade HSCSD.
- **Medium Multimedia.** This is likely to be the most popular 3G service. Its downstream data rate is ideal for Web surfing, assuming that the Web has not changed beyond recognition by the time that 3G becomes available. Other applications include collaborative working, games, and location-based maps.
- **High Multimedia.** This can be used for very high-speed Internet access, as well as for high-definition video and CD-quality audio on demand. Another possible application is online shopping for "intangible" products that can be delivered over the air; for example, a music single or a program for a mobile computer.

- **Interactive High Multimedia.** This can be used for fairly high-quality videoconferencing or videophones, and for *telepresence*, a combination of videoconference and collaborative working.

The data rates of these services are shown in Table 5.1, together with their level of asymmetry and switching mode. Although three of them require circuit switching, this is likely to be accomplished via *virtual circuits* rather than real ones. Everything is packetized, including voice, fax, and video, but packets in a virtual circuit are given priority over others. This guarantees capacity to a customer who has paid for it and frees it up for others when not in use.

Table 5.1 *Service Types Available over IMT-2000*

Service Classification	Upstream Data Rate	Downstream Data Rate	Asymmetry Factor	Example	Switch
Interactive Multimedia	256 kbps	256 kbps	Symmetric	Videoconference	Circuit
High Multimedia	20 kbps	2 Mbps	100	Television	Packet
Medium Multimedia	19.2 kbps	768 kbps	40	Web Surfing	Packet
Switched data	43.2 kbps	43.2 kbps	Symmetric	Fax	Circuit
Simple messaging	28.8 kbps	28.8 kbps	Symmetric	Email	Packet
Speech	28.8 kbps	28.8 kbps	Symmetric	Telephony	Circuit

The classic example to show how virtual circuits are more efficient than real ones is a system that sends data during the gaps in conversation, but there are others. Most videoconference and videophone protocols send only the parts of a picture that have changed rather than a complete new image for each frame, allowing significant bandwidth savings. A videofeed of someone sitting in an unchanging room can be transmitted using very little data, though the rate shoots up as soon as they start moving.

At present, voice accounts for the lion's share of traffic across mobile networks, with messaging and data services small but growing fast. The UMTS Forum has carried out detailed research into customer demand and predicted that these types of traffic are likely to keep growing until around 2005. It believes that by then nearly everyone within the IMT-2000 service area will have a mobile phone of some kind. There will still be growth after that, but it will be accounted for mainly by multimedia. This continued growth, according to the Forum, will put serious pressure on even 3G systems. Figure 5.3 shows how new services will require additional spectrum.

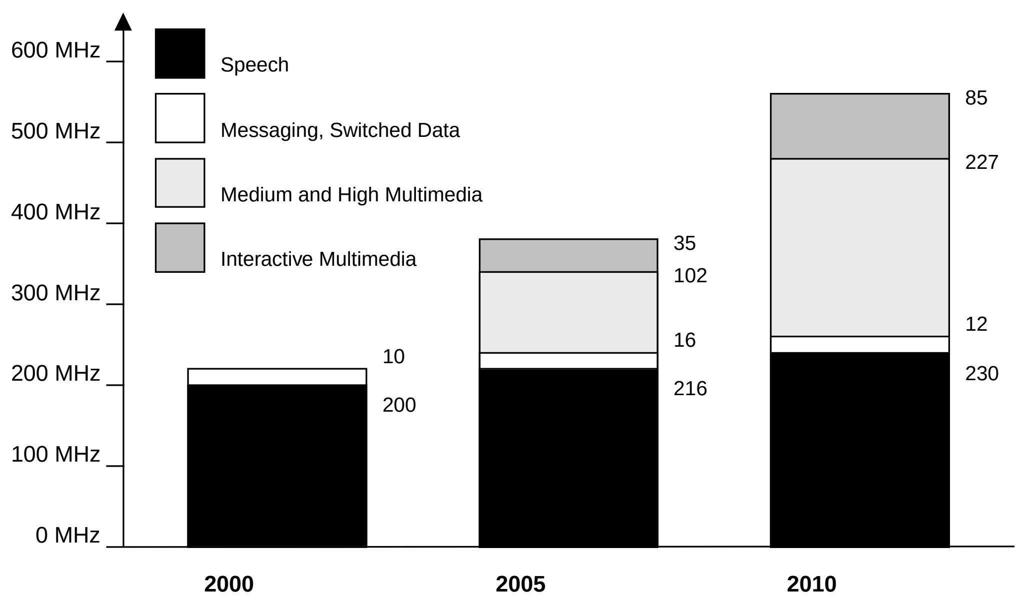


Figure 5.3
Use of spectrum by different mobile communications services

Spectrum Requirements

In 1992, the ITU recommended that the entire world allocate the same frequencies to 3G services. This would enable easy global roaming, particularly if everyone was using the same IMT-2000 standard. No matter the location, the user could be sure that his or her mobile phone or data device would work.

Unfortunately, the only large country that actually followed the ITU's recommendation exactly was China. As shown in Figure 5.4, the Europeans and Japanese were already using part of the spectrum for cordless phones and GSM, while America had already used *all* of it for PCS or fixed wireless. The result is that U.S. carriers will need 3G networks that can be deployed gradually in place of their existing infrastructure.

The only part of the 3G spectrum available worldwide is that dedicated to satellite services, which of course has to be the same everywhere. The problem is that while cellular 3G is only a year or two behind its original schedule, many analysts doubt that satellites capable of mobile 144 kbps operation will ever get off the ground. Broadband satellites tend to need much higher frequencies, leading many in the industry to suggest that the band now allocated to MSS be released for cellular IMT-2000.

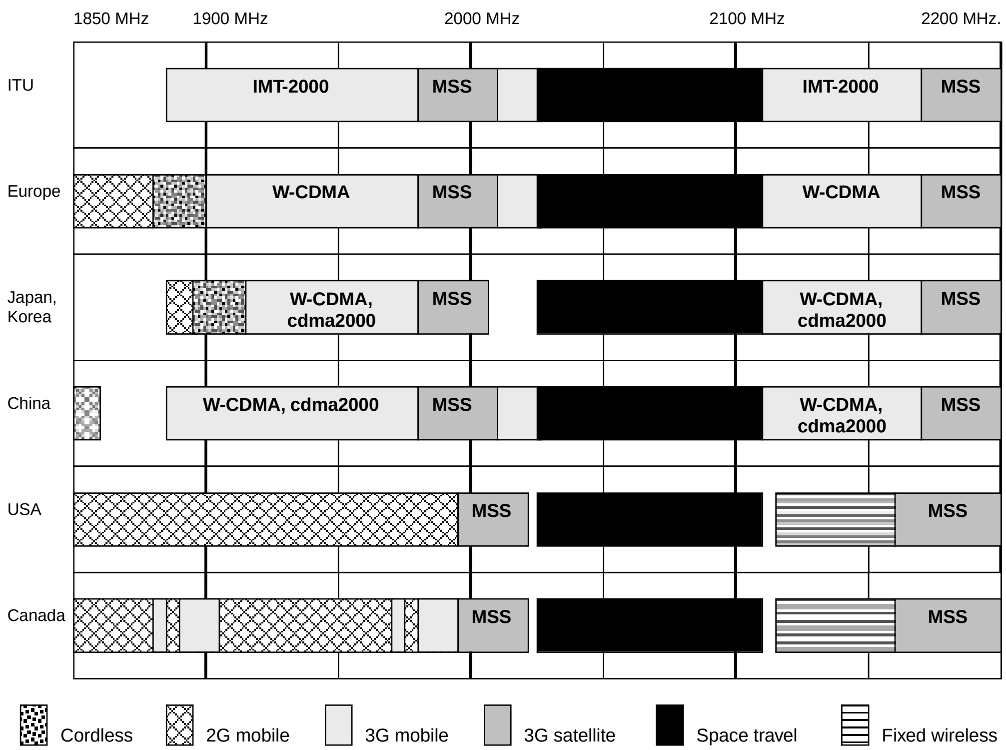


Figure 5.4

Spectrum allocation for 3G cellular and MSS (Mobile Satellite Service) in major world economies

If analysts' predictions of mobile growth are accurate, there will certainly be a need for extra spectrum. Accepting the UMTS Forum's forecasts of traffic growth, the ITU in 2000 calculated the extra spectrum needed to accommodate it in each of its three global regions. Its results are shown in Figure 5.5, together with the spectrum already used by 2G services and allocated to 3G.

Even assuming that existing 2G networks will eventually be upgraded to 3G, the ITU believes that at least 160 MHz more will be needed in each region before 2010. Where this spectrum will come from is not yet clear, though the ITU and various industry groups are considering several proposals. The obvious bands—around the spectrum already allocated—are not an option. They're already widely used by the likes of NASA to keep in touch with astronauts and space probes. The latter can still transmit useful information for many decades after they have been launched, so adjusting them to use different frequencies is impossible.

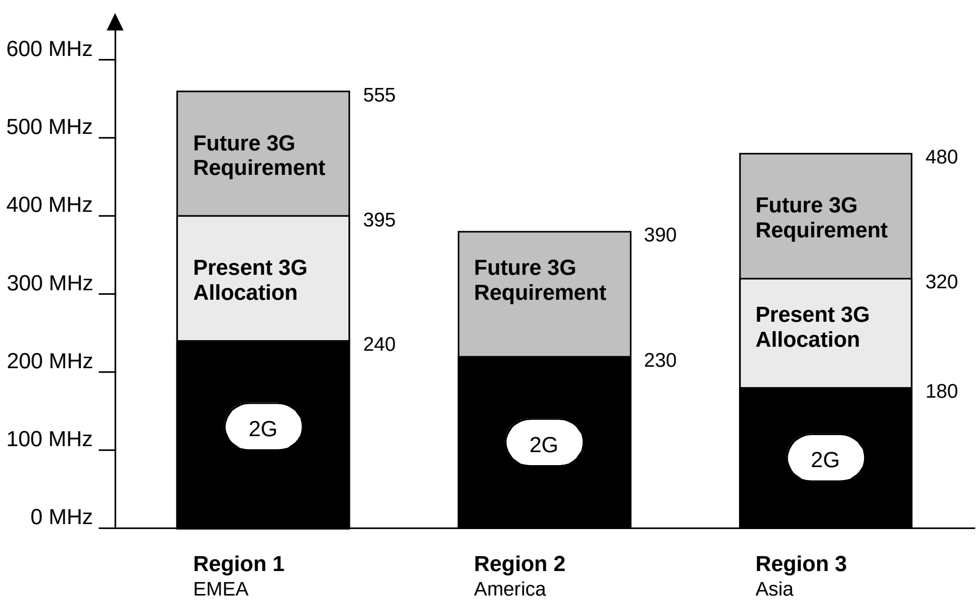


Figure 5.5
Spectrum required by cellular systems in different ITU regions

The suggested extension bands are

- **420–806 MHz.** Better known as UHF, these frequencies are used for analog TV broadcasting in most countries. They may be turned over to mobile phones when digital TV becomes ubiquitous, though this is unlikely to happen everywhere before 2010.
- **1429–1501 MHz.** This band is used for several different purposes worldwide, including cordless phones, fixed wireless, and broadcasting. Parts of it are unused on Earth, kept free so that scientists can listen for possible signals sent by an alien civilization.
- **1710–1885 MHz.** Some parts of this band are already used for mobile services in Europe and Asia, but it may provide additional capacity in America (ITU Region 2). Other parts are used worldwide for air traffic control.
- **2290–2300 MHz.** This very small slice of spectrum is used for fixed wireless and by radio astronomers conducting deep space research.
- **2300–2400 MHz.** This band is used for fixed wireless and some telemetry applications. It is fairly close to the spectrum already allocated to IMT-2000, so is favored by many operators and regulators.
- **2520–2670 MHz.** Different countries use this band for different applications, such as broadcasting and fixed wireless. Some parts are also used by satellites communicating with Earth. This is the extension band favored by the UMTS Forum.
- **2700–3400 MHz.** Frequencies above 2.7 MHz are used mainly for radar, though some have other applications, such as satellite communications. In particular, the bands 3260–3267 MHz, 3332–3339 MHz, and 3345.8–3352.5 are needed by radio astronomers, as they correspond to important radiation emitted by stars.

Compatibility

The ITU originally wanted a single global standard, but this has not been achieved. Instead, there are two main types of CDMA, and a third based on TDMA. The main reason for the dispute is compatibility with existing systems, which can be defined in three ways.

- **Direct Upgrades.** Network operators without a license for new spectrum need to deploy a system that is essentially just an improvement of what they already have, so that new phones will work with the older base stations and vice versa. Upgrades typically add packet-switching and better modulation, but keep existing cell sizes and channel structure. This limits their operators' options substantially; in particular, most 2G systems are based on TDMA, so direct upgrades need to retain the TDMA structure.
- **Roaming.** In principle, a mobile terminal can be made to support any number of different systems, enabling them to be used worldwide. This is how the ITU can get away with calling IMT-2000 a standard: it involves multiple modes of operation, each representing a different 3G system. Some phones may well support all the IMT-2000 systems, but the first and the cheapest will probably be based only on one.
- **Handover.** Roaming is inconvenient for most users, as phones have to be reset to use a different network. To make it easier, a 3G system can be built so that it actually hands over users to a 2G network as they move outside its coverage area. The user should notice no difference, unless she is accessing a 3G service, such as multimedia, that is not available under 2G. This places some constraints on the design of the 3G system and means that phones have to able to operate in both 2G and 3G modes at once.

The fundamental problem for IMT-2000 is that no single standard could both upgrade cdmaOne and handover to GSM. This means that two very similar CDMA-based IMT-2000 standards are set for deployment, and which one is deployed depends entirely on the local 2G system.

W-CDMA

Wideband CDMA (W-CDMA) is the system favored by most operators able to obtain new spectrum. It has been designed to allow handovers to GSM, but is otherwise unlike it. GSM networks cannot be upgraded to W-CDMA, though some components, such as the GPRS backbone, can be reused.

The *wideband* designation refers to the channel bandwdith of 5 MHz. This is four times that of cdmaOne, and 25 times that of GSM. A wider bandwidth was chosen to allow higher data rates, though only in uncrowded areas with very clear reception. Unlike cdmaOne, which automatically sends every bit of information 64 times, W-CDMA adjusts the gain depending on the signal strength. Every bit is sent between 4 and 128 times, which means that greater bandwidth is available in areas with a stronger signal.

The other major difference between W-CDMA and cdmaOne is the need for time synchronization. W-CDMA was designed to operate without GPS clock signals, and so needs a slightly different coding technique, called *Gold* codes. Combined with the same QPSK modulation as cdmaOne, these give a maximum data rate of around 4 Mbps per channel per cell, exceeding the IMT-2000 requirements.

Each channel is reused by every cell, boosting spectral efficiency compared to TDMA systems and enabling soft handovers. However, handovers to GSM are still hard because GSM doesn't support soft handover.

TD-CDMA

Time Division W-CDMA (TD-CDMA) sounds like a contradiction and is often referred to as a hybrid between TDMA and CDMA. This is somewhat misleading; the multiplex technique is still CDMA, but time division *duplexing* is used to share a channel between uplink and downlink. This makes the most efficient use of spectrum, as it means that spare capacity not used for the uplink can be used for the downlink.

TD-CDMA is not without cost in additional overhead, so W-CDMA operators tend to use it only for one channel, pairing the others off in the same way as other cellular systems. For example, Canadian company Telesystem International bought spectrum in the UK totaling 35 MHz, at a cost of around $8 billion. It is using this to give a core capacity of 15 MHz each way (three pairs of channels), plus an extra 5 MHz (one TDD channel) that can be reallocated in real time to either.

This is not as flexible as it sounds. Telesystem's decision, like that of every operator, was already made by regulators and equipment manufacturers. To keep cost and complexity down, W-CDMA terminals and carrier-side infrastructure is hardwired with specific access methods in mind for every frequency. Each channel is licensed with a requirement specifying whether it is to be used for uplink, downlink, or TDD. Europe's precise layout is illustrated in Figure 5.6. Shared between all operators, there are 12 paired and 7 unpaired channels.

The UMTS Forum has calculated that to offer multimedia, each operator will need at least three pairs, as Telesystem has. However, several governments are issuing spectrum in smaller amounts than this; the UK gave operators British Telecom, Orange, and One2One only two pairs each, and the German government considered giving some only a single pair. They say that this is necessary to encourage competition, and that the Forum is biased because it consists mainly of existing operators. User groups point out that if governments actually had allocated all the spectrum that the ITU originally told them to, there would be enough for both competition and bandwidth-hungry services.

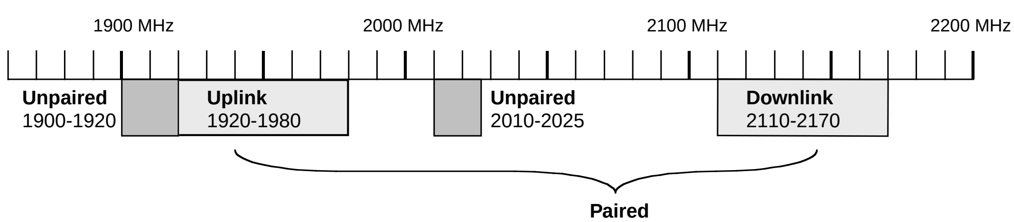


Figure 5.6
Initial frequency use by W-CDMA/UMTS

UMTS

Since 1996, the planned European W-CDMA standard has been known as the *Universal Mobile Telecommunications System* (UMTS). Its development was spearheaded by the UMTS Forum, an industry and government group charged with developing a successor to GSM. Its plan was that the new standard would be as successful as GSM, quickly spreading to the rest of the world.

The UMTS Forum succeeded in developing a draft W-CDMA proposal that was compatible with GSM, but it underestimated worldwide demand for mobile communications. Before a full UMTS standard could be tested and ratified by Europe's relatively bureaucratic procedures, the proposal was picked up the Japanese. Their operators needed a new 3G system fast because they were so short of 2G capacity. The first W-CDMA networks are being deployed in Japan by the operators NTT DoCoMo and J-Phone. Both began trials in 2000 and hope to have commercial services in operation by 2002.

DoCoMo has defined three applications it ultimately wants to support, which are slightly more ambitious than the ITU's. As well as voice and video over 8 kbps and 64 kbps respectively, it wants a two-way 348 kbps connection for cars that can be connected to "Intelligent Transportation Systems," a central traffic computer that will be able to drive them by remote control.

Japan's development has meant that Europe and UMTS have been somewhat eclipsed. When the British government was auctioning its 3G spectrum, it even went so far as to break European Union rules by telling its licensees to base their services on W-CDMA rather than UMTS.

The distinction is *probably* just semantics. When European operators finally roll out W-CDMA services, they are likely to use the same system as the Japanese but call it UMTS. However, there could be subtle differences, as Japan's operators have no need to handover to GSM.

CDMA 2000 ....

Of the 2G systems, only cdmaOne is already based on CDMA. This gives it a head start in the race to 3G, as operators are able to upgrade their existing networks with new software or modulation rather than by building a new radio system. These upgrades are collectively known as cdma2000, and all are backward compatible with existing IS-95 systems.

Until mid-2000, the upgrade path for cdmaOne seemed clear. The end result was supposed to be a system named *cdma2000 3XMC*, so called because it combines three channels together, resulting in a wider band. Unfortunately, this system was not compatible with the form of W-CDMA favored by Europe and Japan, though its specifications are almost identical. The difference is the *chip rate*, the frequency at which the transceiver resonates. cdma2000's chip rate needs to be a multiple of cdmaOne's, while W-CDMA's has to fit the GSM framing structure.

In 2000, Motorola and Nokia together launched a system called *1Xtreme*, which they claim can reach speeds similar to that of 3XMC, but using only one channel, and hence a third of the spectrum. Their claims are as yet unproven, and some analysts say they are simply trying to avoid many of rival Qualcomm's CDMA patents. However, if their assertions are justified, 1Xtreme does present cdmaOne operators with a chance to increase their capacity beyond that of any rival system.

The competing CDMA upgrades are listed in Table 5.2, along with IS-95b and W-CDMA. The real capacities are only manufacturers' estimates, and so should not be fully trusted until actual systems have been tested.

Table 5.2 *CDMA Systems Compared*

CDMA System	Channel Bandwidth	Chip Rate	Max. Capacity	Real Capacity
cdmaOne IS-95b	1.25 MHz	1.2288 MHz	115.2 kbps	64 kbps
cdma2000 1XMC	1.25 MHz	1.2288 MHz	384 kbps	144 kbps
cdma2000 1Xtreme	1.25 MHz	1.2288 MHz	5.2 Mbps	1200 kbps
cdma2000 HDR	1.25 MHz	1.2288 MHz	2.4 Mbps	621 kbps
cdma2000 3XMC	3.75 MHz	3.6864 MHz	4 Mbps	1117 kbps
W-CDMA (UMTS)	5 MHz	4.096 MHz	4 Mbps	1126 kbps

1XMC

For all cdmaOne operators, the next step up from IS-95b is a system called 1XMC (the MC is for *Multi Carrier*). It requires new hardware in base-station controllers, but no new radio interface, and claims to double capacity by using each of IS-95's Walsh codes twice. Because it is so similar to the previous standards, it is sometimes called *IS-95c*.

3XMC

3XMC is the cdma2000 proposal accepted by the ITU as part of IMT-2000. Its claimed performance is almost identical to that of W-CDMA, except that it uses less spectrum and inherits some of cdmaOne's features, notably the chip rate and the need for GPS timing. The ITU hopes that phones will be produced with a variable chip so that they can easily be used for both W-CDMA and 3XMC.

HDR

High Data Rate (HDR) is an upgrade to 1XMC proposed by Qualcomm. It turns a single 1.25 MHz channel over to data and increases the rate by using different types of modulation. Instead of QPSK, it can use 8-PSK (8-Phase Shift Keying) or 16-QAM (16-Quadrature Amplitude Modulation). The *8* and *16* refer to the number of shapes that the waves can take, compared to four under QPSK. Extra shapes in the wave mean a higher data rate; four can represent only two bits, while eight can represent three and sixteen can represent four bits.

Using 16-QAM, the maximum data rate is increased to 2.4 Mbps on the downlink, with 307.2 kbps on the uplink. This has to be shared between all users in a cell and can only be used by a maximum of 29 at once. The number 29 is not picked at random; there are 32 Walsh codes available for the uplink, of which three are needed for signaling. The uplink is more flexible, using TDMA as well as CDMA to divide a channel into 240 time slots, each of which can be allocated to a different user. However, the limit still applies because the system is designed for two-way communications. Users can only be sent data that they have actively requested.

The capacity is lowered in conditions of heavy interference because 16-QAM requires a very clear connection. As a signal becomes weaker, the modulation drops down to 8-PSK or QPSK. Because HDR can only be used for data, it is not supposed to be a rival to 3XMC. Qualcomm says that it is an intermediary step, which will be available before the full 3XMC system.

1Xtreme

Developed jointly by Nokia and Motorola, 1Xtreme is marketed as a rival to both HDR and 3XMC itself. It employs the same modulation techniques as HDR, but uses them for voice as well as data. This means they can be applied to the entire network rather than a single channel.

EDGE

Not all 3G systems are based on CDMA. The TDMA camp is promoting a technology called EDGE, which originally meant *Enhanced Data Rates for GSM Evolution*. As the name indicates, it was planned as an upgrade for GSM networks, one more step for operators who had already deployed the $2^1/_2$G HSCSD and GPRS.

EDGE was never intended to be a competitor to CDMA-based 3G technologies. The plan was that GSM operators would deploy it in their existing networks, while building UMTS to take advantage of the newly licensed IMT-2000 spectrum. Because UMTS can handover calls to GSM, the two would even be compatible; many handsets sold in Europe would support both.

This changed when EDGE was adopted by the UWCC (Universal Wireless Communications Consortium), a group representing the American TDMA industry. Working with the GSM Association, they developed a way to migrate D-AMPS to EDGE. The rationale for doing so was that traditional D-AMPS had run its course, so operators needing 3G would have to build new networks.

Both cdma2000 and W-CDMA were considered for these new networks, but their wide channel sizes were a problem. Any radio system needs at least one channel to work; for an operator without a new license, this channel represents spectrum that can't be used for D-AMPS services. The aim is to move spectrum from the old to the new network in blocks as small as possible.

EDGE's channel size is only 200 kHz, the same as GSM's. Even allowing for the inability of adjacent cells in TDMA to reuse channels, an EDGE system can be deployed in only 600 kHz. This is less than half of that needed by even narrowband CDMA, making it very attractive to D-AMPS operators. In 2000, the ITU accepted EDGE as a mode of IMT-2000, and standardized it as *UWC-136*.

Enhanced GPRS

EDGE inherits almost all its main features from GSM and GPRS, including the eight-user TDMA structure and even the slot length of 0.577 ms. The *only* difference is in the modulation scheme. Instead of the binary GMSK, it uses *8-PSK*, the same as HDR. This immediately triples the capacity compared to GSM.

Keeping the same GSM slot layout shown in Chapter 4, Figure 4.1 (but with every “bit” having eight states instead of two), the raw data rate per slot is increased from 21.4 kbps to 64.2 kbps.

EDGE *could* be applied to a regular GSM system, giving every user a landline-quality voice or data connection, but it is such a major upgrade that every operator who installs it will also use GPRS and perhaps HSCSD. For this reason, the services deployed over EDGE are sometimes referred to as *EGPRS* and *EHSCSD*. For customers who don’t have an EDGE-equipped phone, it is fully compatible with regular GSM, HSCSD, and GPRS.

Because 8-PSK is more susceptible to errors than GMSK, EDGE has nine different *MCSs* (Modulation and Coding Schemes), each designed for a different quality connection. They differ in how much forward error correction is needed and in whether 8–PSK can be used at all—for noisy connections, it automatically drops down to GMSK. The type of modulation and amount of FEC necessary for each is shown in Table 5.3, along with the data capacity available from a single slot and from the entire channel. Voice will either use ordinary GSM or be packetized and carried as data.

Table 5.3 The Nine Modulation and Coding Schemes of EDGE

MCS	Slot Capacity	FEC	Modulation	Channel Capacity
MCS-1	8.8 kbps	143%	GMSK	70.4 kbps
MCS-2	11.2 kbps	91%	GMSK	89.6 kbps
MCS-3	14.8 kbps	45%	GMSK	118.4 kbps
MCS-4	17.6 kbps	22%	GMSK	140.8 kbps
MCS-5	22.4 kbps	187%	8PSK	179.2 kbps
MCS-6	29.6 kbps	117%	8PSK	236.8 kbps
MCS-7	44.8 kbps	43%	8PSK	358.4 kbps
MCS-8	54.4 kbps	18%	8PSK	435.2 kbps
MCS-9	59.2 kbps	8%	8PSK	473.6 kbps

EDGE Compact

To make EDGE deployment easier for D-AMPS operators, the UWCC has defined a simplified standard called *EDGE Compact*. This can be used only for data, not voice, and so omits many of the control channels found in the full-scale system, which in the context of EDGE compact is referred to as *ETSI EDGE* or *EDGE Classic*.

EDGE Compact is regarded as an intermediary step, not a complete system. The plan is for customers to continue to use D-AMPS for voice, with EDGE Compact as an overlay data service rather like HDR on CDMA networks. As customers buy new phones, EDGE Classic will be deployed and customers will gradually migrate over to the full system.

WEB RESOURCES

www.itu.int/imt2000/

The IMT-2000 site, set up by the ITU, charges for the detailed technical standards needed to actually build a system, but also has plenty of free background information for non-engineers.

www.3gpp.org

The Third Generation Partnership Project, an alliance of vendors and regulators, tries to stay neutral in the standards war.

www.umts-forum.org

The European forum set up to promote W-CDMA, it emphasizes backward-compatibility with GSM, but is also a useful source of information on 3G deployment worldwide.

www.uwcc.org

The Universal Wireless Communications Consortium promotes TDMA as a 3G access technology, and in particular, the EDGE standard.

www.comsoc.org/pubs/surveys/

The IEEE (Institute of Electrical and Electronic Engineers) publishes a journal called Communications Surveys, much of which is available on the Internet. It contains highly detailed technical proposals for future systems, including 3G and even 4G mobile.

SUMMARY

- There are three main 3G systems: W-CDMA, cdma2000, and EDGE. They are collectively known as *IMT-2000* and will offer packet-switched data at rates exceeding 384 kbps.
- *W-CDMA* is designed to be backward-compatible with GSM, and requires new spectrum. It is also known as UMTS.
- *cdma2000* is a straightforward upgrade to cdmaOne, but itself consists of two competing proposals.

- *EDGE* is a straightforward upgrade to GSM and is also compatible with other TDMA systems, such as D-AMPS and PDC.
- The first 3G systems are being deployed in Japan, using W-CDMA technology.