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130

Mobile and Cellular Radio Communications

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Mobile radio communication systems transport information using electromagnetic waves to provide a viable communication link between a transmitter and receiver, either or both of which may be in motion or stationary at arbitrary locations. A variety of mobile radio systems are in use today, and the industry is experiencing rapid growth. In the U.S. alone, for example, the number of cellular telephone users grew from 25000 in 1984 to about 15 million in 1994. In Sweden, cellular telephones are already used by over 10% of the population. This growth is expected to continue worldwide at an even greater pace during the next decade.

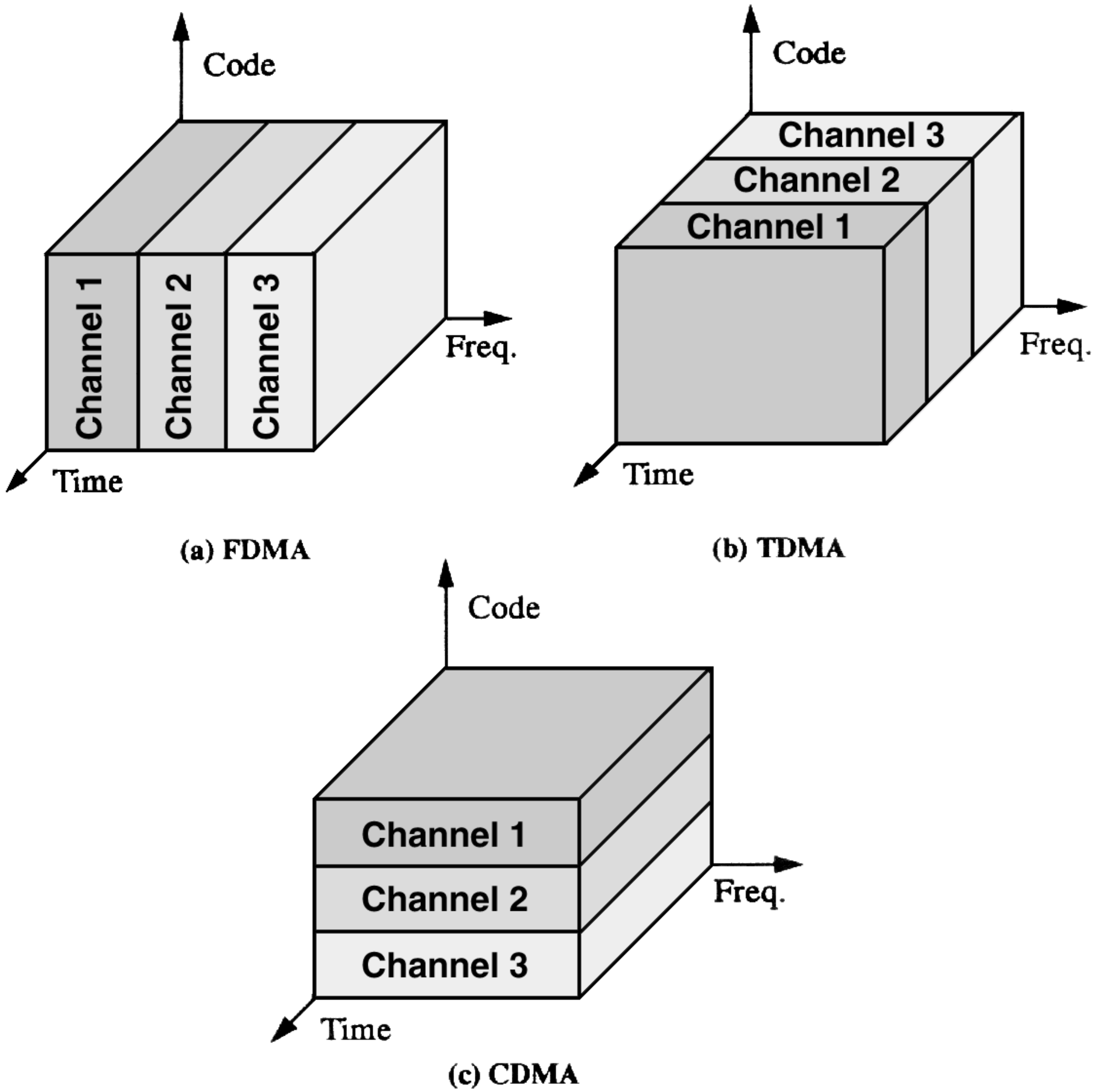
Mobile radio transmission systems may be classified as *simplex, half-duplex,* or *full-duplex.* In simplex systems communication is possible in only one direction. Paging systems, in which messages are received but not acknowledged, are simplex systems. Half-duplex radio systems allow two-way communication but use the same radio channel for both transmission and reception. This means that at any given time a user can only transmit or receive information. Constraints like "push to talk" and "release to listen" are fundamental features of half-duplex systems. Full-duplex systems, on the other hand, allow simultaneous radio transmission and reception by providing two separate channels or time slots for communication to and from the user. The channel used to convey traffic to the mobile user is called the *forward channel,* whereas the channel used to carry traffic from the mobile user is called the *reverse channel.* Full-duplex mobile radio systems provide many of the capabilities of the standard telephone, with the added convenience of mobility.

Modern mobile communication systems are networked through a central switching system, called a *mobile telephone switching office* (MTSO) or a *mobile switching center* (MSC), and typically provide coverage throughout a large metropolitan area. Many mobile radio systems are connected to the *public switched telephone network* (PSTN), which enables the full-duplex connection of mobile users to any telephone throughout the world. In order to utilize the available spectrum and radio equipment efficiently, these networked systems rely on **trunking,** so that a limited number of frequencies can accommodate a large number of mobile users on a statistical demand basis. Trunking exploits the fact that not every user requires service at a particular time; hence it is possible for a large number of users to share a relatively small number of radio channels. When a subscriber in a trunked system engages in a call, the system searches for a free channel and allocates it to the subscriber. If all the channels are already in use, the user is *blocked,* or denied access to the system. The process of allocating a channel in a trunked radio system requires a dedicated control channel, called the *control* or *call setup* channel.

Multiple-access techniques such as *frequency-division multiple access (FDMA), time-division multiple access (TDMA),* and *code-division multiple access (CDMA)* are employed to provide simultaneous access to many users without causing mutual interference. In FDMA separate users are allocated separate frequency bands (channels) for their exclusive use for the entire duration of a call. In TDMA several users share the same radio channel but are assigned unique time slots in which they communicate. In CDMA every user transmits at the same frequency and at the same time, and interference is avoided by the use of specialized codes that are unique to each user and uncorrelated between users. Figure 130.1 illustrates the three multiple-access techniques.

Handheld walkie-talkies, paging receivers (pagers), cordless telephones, and cellular telephones are examples of mobile radio systems that are commonly used today. The complexity, performance, required infrastructure, and types of services offered by each of these systems are vastly different. In this chapter a variety of modern mobile radio systems are described with an emphasis placed on modern cellular radio systems. The chapter concludes with a summary of all major mobile radio system standards in use throughout the world.

Figure 130.1 Illustration of the three multiplexing techniques, and how multiple channels are provided without interfering with each other: (a) FDMA, (b) TDMA, and (c) CDMA.

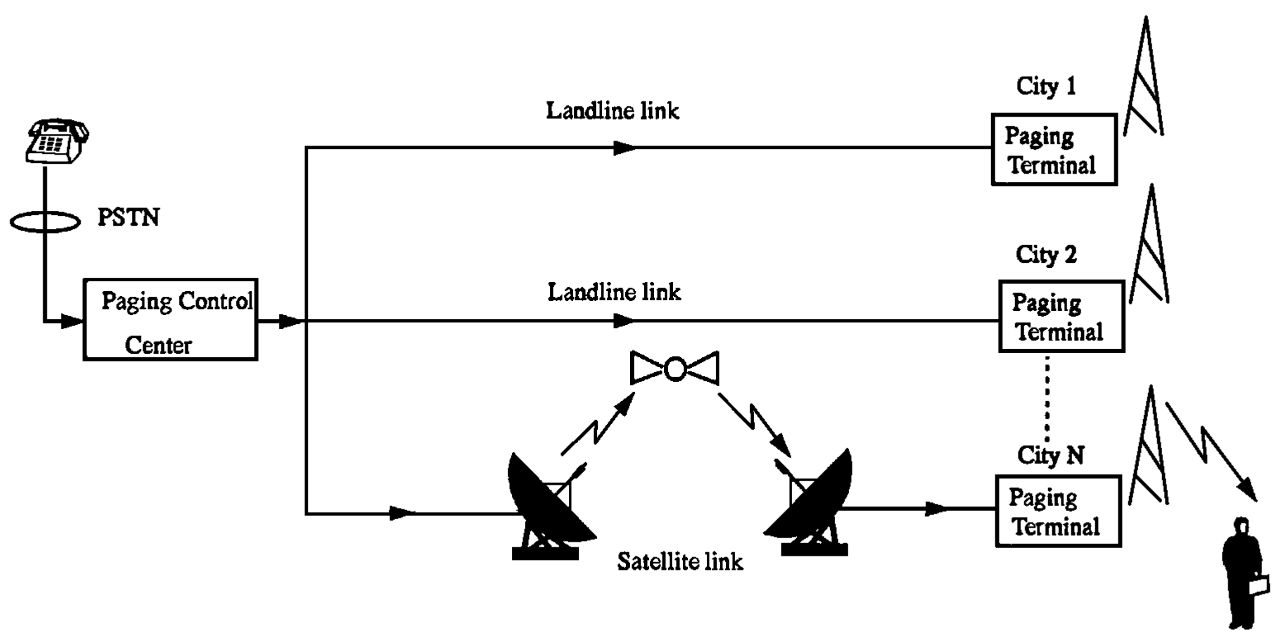


130.1 Paging Systems

Paging systems are simplex communication systems that can be used to send brief messages to a subscriber. Depending on the type of service, the message can be a numeric message, an alphanumeric message, or a voice message. Paging systems are typically used to notify a subscriber of the need to call a particular telephone number or to travel to a known location to receive further instructions. Anyone may send a message to a paging subscriber by dialing the paging system number (usually a toll-free telephone number) and using a telephone keypad or modem to issue a message, called a *page*. The paging system then transmits the page throughout the service area using base stations which broadcast the page on a radio carrier.

Paging systems vary widely in their complexity and coverage area. Whereas simple paging systems may only cover a limited range of 2–5 km, wide-area paging systems may provide worldwide coverage. Though paging receivers are simple and inexpensive, the transmission system required can be quite sophisticated. Wide-area paging systems consist of a network of telephone lines, large radio towers, satellite links, and powerful transmitters and simultaneously dispatch a page to many transmitters (this is called *simulcasting*), which may be located within the same service area or in different cities or countries. Paging systems are designed to provide reliable communication to subscribers wherever they are—whether inside buildings, driving on a highway, or in an airplane. This necessitates large transmitter powers (on the order of kilowatts) and low data rates (a few thousand bits per second) for maximum coverage. Figure 130.2 shows a diagram of a wide-area paging system.

Figure 130.2 Example of a wide-area paging system. The paging control center dispatches pages received from the PSTN throughout several cities at the same time.



130.2 Cordless Telephone Systems

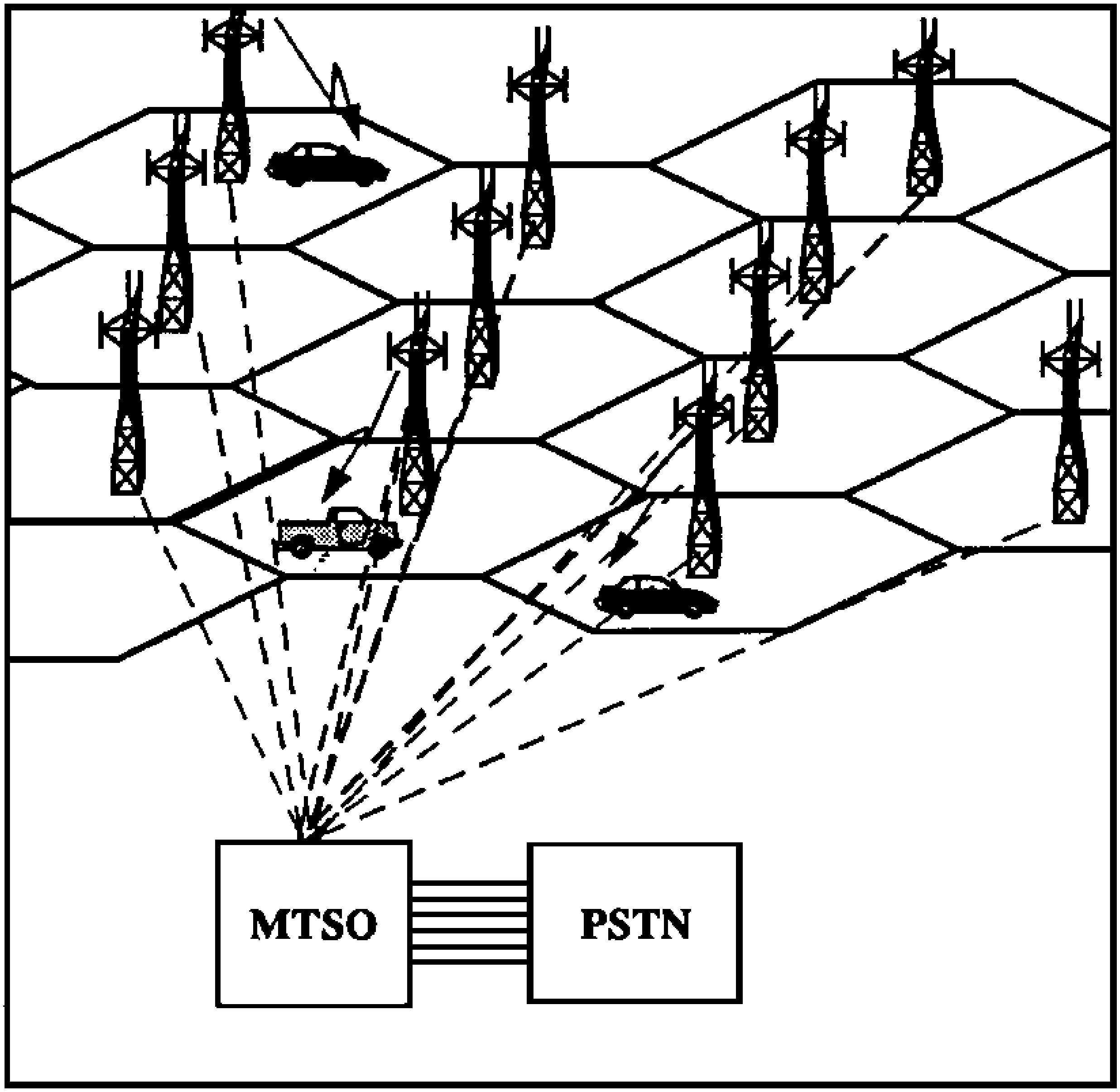
Cordless telephone systems are full-duplex communication systems that use radio to connect a handset to a dedicated base station. The base unit is connected to a dedicated telephone line with a specific telephone number. In first-generation cordless telephone systems (manufactured in the 1980s), the portable unit communicates only to the dedicated base unit, and only over distances of a few tens of meters. Early cordless telephones operate as extension telephones to a **transceiver** connected to a subscriber line on the PSTN and were developed primarily for in-home use. Second-generation cordless telephones have recently been introduced that allow subscribers to use their handsets at many outdoor locations within urban centers, such as London or Hong Kong. Modern cordless telephones are sometimes combined with paging receivers so that a subscriber may first be paged and then respond to the page using the cordless telephone. Cordless telephone systems provide the user with limited range and limited mobility, as it is usually not possible to maintain a call if the user travels outside the range of the base station. Typical second-generation base stations provide coverage ranges of a few hundred meters.

130.3 Cellular Telephone Systems

A cellular telephone system provides wireless access to the PSTN for any user located within the radio range of the system. Cellular systems accommodate a large number of users over a large geographic area, within a limited frequency spectrum. Cellular radio systems provide high-quality service, often comparable to that of landline telephone systems. High capacity is achieved by limiting the coverage of each transmitter to a small geographic area so that the same radio channels can be reused by another transmitter located a small distance away. A sophisticated switching technique called a **handoff** enables a call to proceed uninterrupted when the user moves from one area to another.

Figure 130.3 shows a basic cellular system that consists of **mobile stations, base stations,** and a **mobile telephone switching office (MTSO).** Each user communicates via radio with one of the base stations and may be handed off to any number of base stations throughout the duration of a call. The mobile station contains a transceiver, an antenna, and a control unit and can be mounted in a vehicle or handheld package. The base stations consist of several transmitters and receivers and generally have towers that support several transmitting and receiving antennas. The base station serves as a bridge between all mobile users in a geographic area and is connected via telephone lines or microwave links to the MTSO. The MTSO coordinates the activities of all the base stations and connects the entire cellular system to the PSTN.

Figure 130.3 An illustration of a cellular system. The towers represent base stations that provide radio access between mobile users and the mobile telephone switching office (MTSO).



Communication between the base station and the mobile takes places over four distinct channels. The channel used for voice transmission from base station to mobile is called the *forward voicechannel (FVC),* and the channel used for voice transmission from mobile to base station is called the *reverse voice channel (RVC).* The other two channels are the forward and reverse *control channels.* Control channels transmit and receive data messages that carry call initiation and service requests. Control channels are always monitored by mobiles that do not have an active call in progress.

Most cellular systems provide a special service called *roaming,* which allows subscribers to move into service areas other than the one from which service is subscribed. Once a mobile enters a city or geographic area that is different from its home service area, it is registered as a roamer in the new service area. Roaming mobiles are allowed to receive and place calls from wherever they happen to be.

130.4 Personal Communications System (PCS)

In the mid-1990s the worldwide demand for cellular telephone service led to the development of the personal communication system (PCS). PCS offers personal wireless communications and advanced data networking using the cellular radio concept. PCS has been allocated the radio spectrum in the 1.8–2.0 GHz band in many countries throughout the world. Under the auspices of the International Telecommunications Union (ITU), an international consortium is developing a universal standard for PCS, so that the same equipment may be used throughout the world. This consortium, called the Future Public Land Mobile Telecommunications System (FPLMTS), and recently renamed IMT-2000, is considering local, regional, national, and international networking using cellular and satellite radio communication.

130.5 The Cellular Concept and System Fundamentals

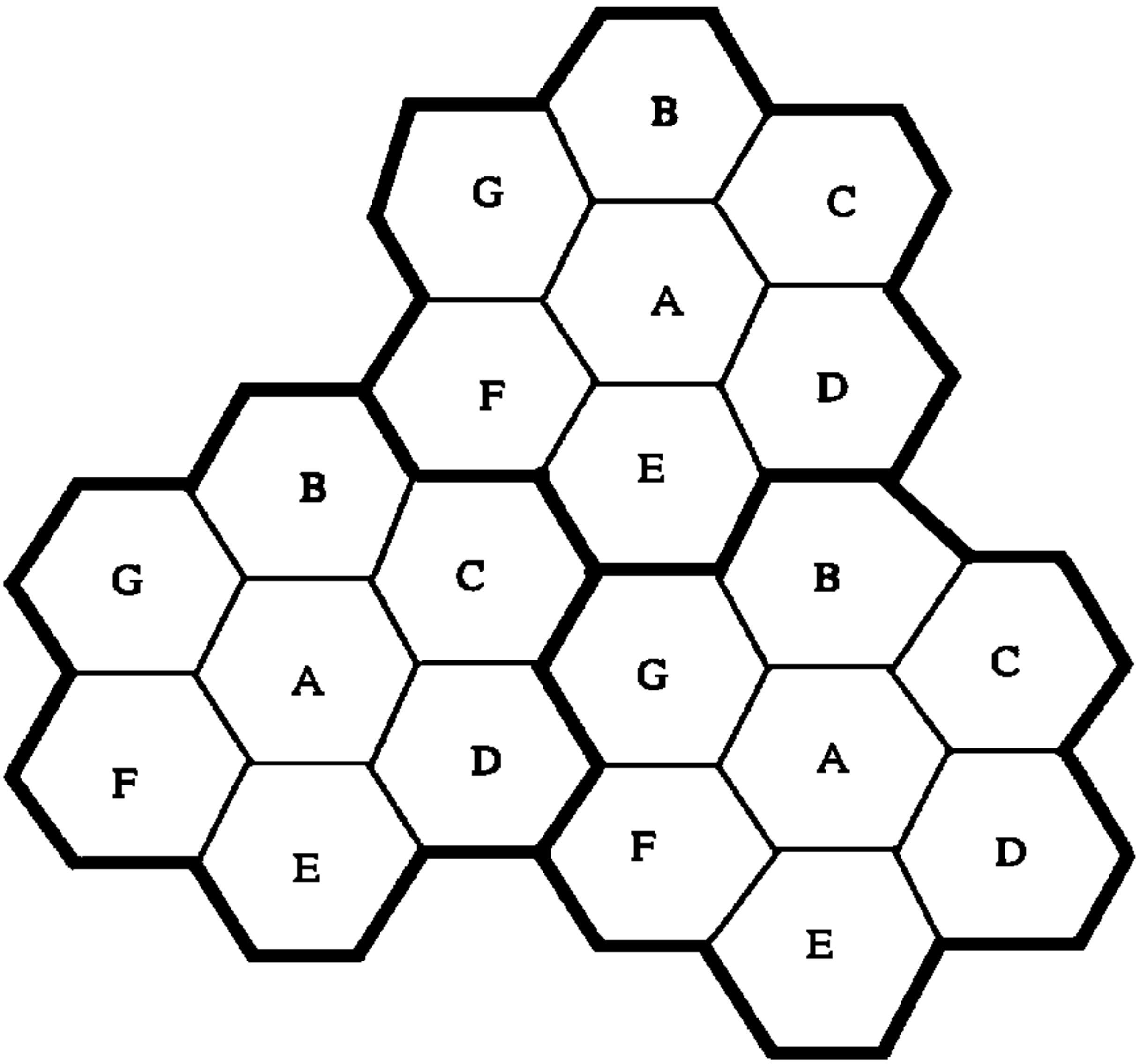
The need to grow a mobile subscriber population within a limited radio spectrum led to the development of systems based on the cellular concept [MacDonald, 1979]. The key to providing capacity in a cellular system is a technique called **frequency reuse.**

Frequency Reuse

Cellular radio systems rely on an intelligent allocation and reuse of channels throughout a coverage region. A subset of channels is assigned to a small geographic area called a *cell.* Each cell is served by a base station that uses the assigned channel group. The power radiated by a base station is deliberately kept low, and antennas are located so as to achieve coverage within the particular cell. By limiting the coverage area within a cell, the same group of channels can be used to cover various cells that are separated from one another by distances large enough to keep the cochannel interference level within tolerable limits.

Figure 130.4 shows a cellular layout where cells labeled with the same letter use the same group of channels. Due to random propagation effects, actual cell coverage areas are amorphous in nature. However, for system design purposes it is useful to visualize cells as hexagons.

Figure 130.4 Illustration of the cellular concept. Cells labeled with the same letter use the same set of frequencies. A cell cluster is outlined in bold and is replicated over the coverage area. In this example the cluster size, *N*, is equal to 7, and each cell contains 1/7 of the total number of available channels.



To understand the frequency reuse concept, consider a cellular system that has a total of *S* duplex channels available for use. If each cell is allocated a group of *k* channels ($k < S$), and if the *S* channels are divided among *N* cells into unique and disjoint channel groups with the same number of channels, the total number of available radio channels can be expressed as

$$S = kN \qquad (130.1)$$

The factor *N* is called the *cluster size* and is typically equal to 7 or 4. The *N* cells that use the complete set of frequencies are collectively called a *cluster*. If a cluster is replicated *M* times within the system, the total number of duplex channels, *C* , available to the system is given by

$$C = MkN = MS \qquad (130.2)$$

As seen from Eq. (130.2), the capacity of a cellular system is directly proportional to the number of times a cluster is replicated in a given service area. If the cluster size N is reduced, more clusters are used to cover a given area and hence more capacity (larger value of C) is achieved. The choice of N depends on the cochannel interference level that can be tolerated, as discussed later.

Channel Assignment and Handoff Strategies

For efficient utilization of the radio spectrum, a frequency reuse scheme that is consistent with the objectives of increasing capacity and minimizing interference is required. Channel assignment strategies can be classified as either fixed or dynamic. The particular type of channel assignment employed affects the performance of the system, particularly in how calls are managed when a mobile user travels from one cell to another [Tekinay and Jabbari, 1991].

In a fixed channel assignment strategy, each cell is allocated a predetermined set of channels. Any call attempt within the cell can be served only by the unoccupied channels in that particular cell. If all the channels in that cell are occupied, the call is blocked and the subscriber does not receive service. In dynamic channel assignment, channels are not allocated to various cells permanently. Instead, each time a call is attempted, the cell base station requests a channel from the MTSO, which allocates a channel based on an algorithm that minimizes the cost of channel allocation.

Since neighboring cells use separate channels, when a mobile passes into a separate cell while a conversation is in progress, it is required to transfer the connection to the new cell base station automatically. This handoff operation not only involves identifying a new base station, but also requires that the voice and control signals be allocated to channels associated with the new base station.

Processing handoffs is an important task in any cellular mobile system. Many system designs prioritize handoff requests over call initiation requests. It is required that every handoff be performed successfully and that they happen as infrequently and imperceptibly as possible. In cellular systems the signal strength on either the forward or reverse channel link is continuously monitored and, when the mobile signal begins to decrease (e.g., when the reverse channel signal

THE ENVOY

The Envoy wireless communicator is creating a whole new industry by enabling mobile professionals to exchange Internet messages, send faxes, check flight schedules, and manage appointments, addresses, and other personal information from wherever they happen to be—even an airport lounge. This handheld device uses Motorola two-way wireless communications and thus requires no phone lines or external connection to access information. Wireless products, like the Envoy, will enable millions of travelling workers to have the same tools as those workers who are at their desks. (Courtesy of Motorola.)

strength drops to below between -90 dBm and -100 dBm at the base station), a handoff occurs. In first-generation analog cellular systems, the MTSO monitor(s) the signals of all active mobiles at frequent intervals to determine a rough estimate of their location and decide if a handoff is necessary. In second-generation systems that use digital TDMA technology, handoff decisions are mobile assisted. In a **mobile-assisted handoff (MAHO)** the mobile stations make measurements of the received power from several surrounding base stations and continually report the results of these measurements to the base station in use, which initiates the handoff. The MAHO method enables faster handoff than in first-generation analog cellular systems since the MTSO is not burdened with additional computation.

130.6 System Capacity and Performance of Cellular Systems

Interference is the major limiting factor in the capacity and performance of cellular radio systems. The source of interference may be from an adjacent channel in the same cell, a signal from other base stations operating in the same frequency band, or signals from cochannel mobiles. Interference caused by signals from adjacent channels is called *adjacent channel interference,* and the interference between signals from different cells using the same frequency is called *cochannel interference.* Adjacent channel interference occurs due to imperfect receiver filtering, especially when an undesired transmitter is significantly closer to a receiver than the desired source. Adjacent channel interference is reduced by maximizing the frequency separation between channels in each cell through careful frequency planning in the cellular system.

Radio Interference and System Capacity

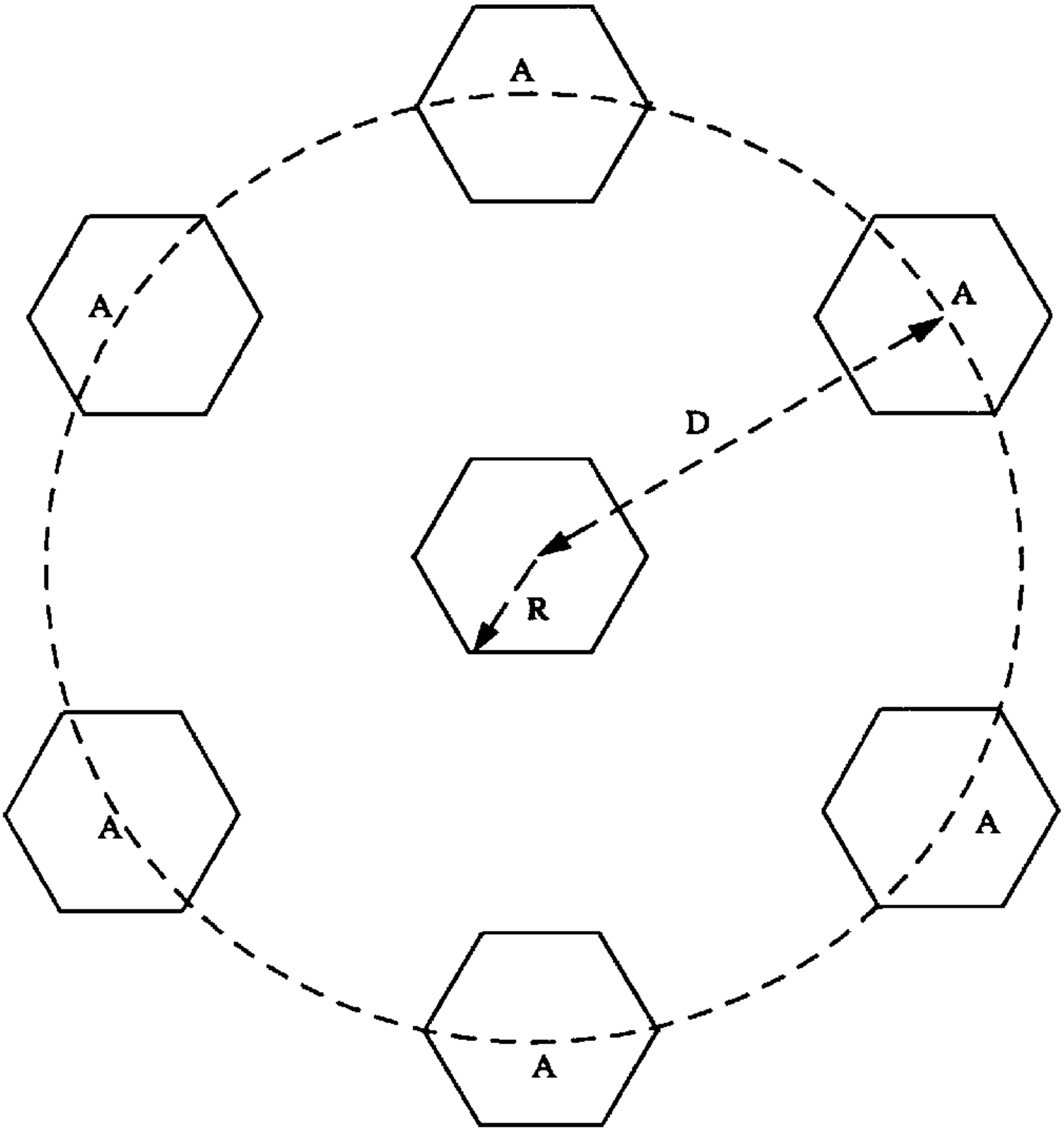
Cochannel interference is the major bottleneck for increasing capacity. Unlike noise, cochannel interference cannot be combated by simply increasing the carrier power. This is because an increase in carrier transmit power increases the interference as well. To reduce cochannel interference, cells using the same set of frequencies (cochannel cells) must be separated to provide sufficient isolation.

When the size of each cell in a cellular system is roughly the same, cochannel interference is independent of the transmitted power and is an increasing function of a parameter Q, called the **cochannel reuse ratio.** The value of Q is related to the cluster size N and is defined for a hexagonal geometry as

$$Q = \frac{D}{R} = \sqrt{3N} \qquad (130.3)$$

where R is the major radius of the cells and D is the separation between cochannel cells as shown in Fig. 130.5. A small value of Q provides larger capacity for a particular geographic coverage region, whereas a large value of Q improves the transmission quality, due to a smaller level of cochannel interference. A trade-off is made between these two objectives in actual cellular design.

Figure 130.5 Illustration of the first tier of cochannel cells for a cluster size of $N = 7$.



If i_0 is the number of cochannel interfering cells, the signal to interference ratio (*S/I*) at a receiver on the forward link can be expressed as

$$\frac{S}{I} = \frac{S}{\sum_{i=1}^{i_0} I_i} \qquad (130.4)$$

where *S* is the desired signal from the desired base station and I_i is the interference caused by the $i\text{th}$ outlying cochannel cell base station. If the signal levels of cochannel cells are known, then the *S/I* ratio for the reverse link can be found using Eq. (130.4).

Propagation measurements in a mobile radio channel show that the average received power at any point decays exponentially with respect to distance of separation between the transmitter and the receiver. The average received power P_r at a distance *d* from the transmitting antenna is approximated by either of the following:

$$P_r = P_0 \left(\frac{d_0}{d}\right)^n \qquad (130.5)$$

$$P_r(\text{dBm}) = P_0(\text{dBm}) - 10n \log_{10} \frac{d}{d_0} \qquad (130.6)$$

where P_0 is the power received at a close-in reference point in the far-field region of the antenna at a distance d_0 from the transmitting antenna, and *n* is the path loss exponent. Therefore, if D_i is the distance of the $i\text{th}$ interferer from the mobile, the received power at a given mobile due to the $i\text{th}$ interfering cell will be proportional to $(D_i)^{-n}$. The path loss exponent typically ranges between 2 and 4 in urban cellular systems [Rappaport and Milstein, 1992] .

Assuming that the transmit power of each base station is equal and the path loss exponent is the same throughout the coverage area, the *S/I* ratio can be approximated as

$$\frac{S}{I} = \frac{R^{-n}}{\sum_{i=1}^{i_0} (D_i)^{-n}} \qquad (130.7)$$

Considering only the first layer of interfering cells, if all the interfering base stations are equidistant from the desired base station and if this distance is equal to the distance *D* between cell centers, then Eq. (130.7) simplifies to

$$\frac{S}{I} = \frac{(D/R)^n}{i_0} = \frac{\left(\sqrt{3N}\right)^n}{i_0} \qquad (130.8)$$

Equation (130.8) relates S/I to the cluster size *N,* which in turn determines the overall capacity of the system. Hence, it is clear that cochannel interference determines the capacity of cellular systems.

Grade of Service

Cellular systems rely on **trunking** to allow a large population of users to share a finite number of radio channels. The quality of service in any trunked system is often measured using a benchmark called the **grade of service** (GOS). The grade of service is a measure of the ability of a particular user to access a trunked system during the busiest hour. GOS is typically given as the likelihood that a call is blocked or the likelihood of a call experiencing a delay greater than a certain queuing time.

The GOS for a trunked system that provides no queuing for blocked calls is given by the Erlang B formula,

$$\Pr[\text{blocking}] = \frac{A^C/C!}{\sum_{k=0}^{C}(A^k/k!)} \qquad (130.9)$$

where *C* is the number of channels offered by the cell and *A* is the total traffic offered. The total offered traffic *A* is measured in erlangs, where one erlang represents the load over a channel that is completely occupied at all times. For a system containing *U* users, the total offered traffic can be expressed as

$$A = U\mu H \qquad (130.10)$$

where μ is the average number of call requests per unit time and *H* is the average duration of a typical call.

For trunked systems in which a queue is provided to hold calls that are blocked, the likelihood of a call not having immediate access to a channel is determined by the Erlang C formula:

$$\Pr[\text{delay} > 0] = \frac{A^C}{A^C + C![1-(A/C)]\sum_{k=0}^{C-1}(A^k/k!)} \qquad (130.11)$$

The GOS for a queued system is measured as the probability that a call is delayed greater than *t* seconds and is given by the probability that a call is delayed by a nonzero duration of time, multiplied by the conditional probability that the delay is greater than *t* seconds, as shown in Eq. (130.12):

$$\begin{aligned}\Pr[\text{delay} > t] &= \Pr[\text{delay} > 0]\Pr[\text{delay} > t \mid \text{delay} > 0] \\ &= \Pr[\text{delay} > 0]\exp[-(C-A)t/H] \qquad (130.12)\end{aligned}$$

130.7 Mobile Radio Systems Around the World

Numerous mobile radio systems and services are in use around the world. There is a repertoire of standards that have been developed for the operation of these mobile radio systems, and many more are likely to emerge. Tables 130.1, 130.2, and 130.3 provide listings of the most common paging, cordless, and cellular telephone standards in North America, Europe, and Japan.

Table 130.1 Mobile Radio Standards in North America

Standard	Type	Year of Introduction	Multiple Access	Frequency Band	Modulation	Channel Bandwidth
AMPS	Cellular	1983	FDMA(FDD)	824–894 MHz	FM	30 kHz
NAMPS	Cellular	1992	FDMA	824–894 MHz	FM	10 kHz
USDC	Cellular	1991	TDMA(FDD)	824–894 MHz	$\pi/4$-DQPSK	30 kHz
IS-95	Cellular	1993	CDMA	824–894 MHz	O-QPSK	1.25 MHz
GSC	Paging	1970s	Simplex FDM	Several	FSK	12.5 kHz
POCSAG	Paging	1970s	Simplex FDM	Several	FSK	12.5 kHz
FLEX	Paging	1993	Simplex FM	Several	4-FSK	15 kHz
PACS	Cordless/PCS	1993	TDMA/FDMA	1.8–2.2 GHz	$\pi/4$-QPSK	300 kHz

Table 130.2 Mobile Radio Standards in Europe

Standard	Type	Year of Introduction	Multiple Access	Frequency Band	Modulation	Channel Bandwidth
E-TACS	Cellular	1985	FDMA	900 MHz	FM	25 kHz
NMT-450	Cellular	1981	FDMA	450–470 MHz	FM	25 kHz
NMT-900	Cellular	1986	FDMA	890–960 MHz	FM	12.5 kHz
GSM	Cellular	1990	TDMA	890–960 MHz	GMSK	200 kHz
C-450	Cellular	1985	FDMA	450–465 MHz	FM	20 kHz/10kHz
ERMES	Paging	1993	FDMA	Several	4-FSK	25 kHz
CT-2	Cordless	1989	FDMA/(TDD)	864–868 MHz	GFSK	100 kHz
DECT	Cordless	1993	TDMA/(TDD)	1880–1900 MHz	GFSK	1.728 MHz
DCS-1800	Cordless	1993	TDMA	1710–1880 MHz	GMSK	200 kHz

Table 130.3 Mobile Radio Standards in Japan

Standard	Type	Year of Introduction	Multiple Access	Frequency Band	Modulation	Channel Bandwidth
JTACS	Cellular	1988	FDMA	860–925 MHz	FM	25 kHz
JDC	Cellular	1992	TDMA	810–1513 MHz	$\pi/4$-DQPSK	25 kHz
NTT	Cellular	1979	FDMA	400–800 MHz	FM	25 kHz
NTACS	Cellular	1993	FDMA	843–925 MHz	FM	12.5 kHz
NTT	Paging	1979	FDMA	280 MHz	FSK	12.5 kHz
NEC	Paging	1979	FDMA	Several	FSK	10 kHz
PHS	Cordless	1993	TDMA	1895–1907 MHz	$\pi/4$-DQPSK	300 kHz

The two most common paging standards are the POCSAG (Post Office Code Standard Advisory Group), and GSC (Golay Sequential Code) paging standards. POCSAG was developed by British Post Office in the late 1970s and supports binary FSK signaling at 256 bps, 512 bps, 1200 bps, and 2400 bps. GSC is a Motorola paging standard that uses 300 bps for the pager address and 600 bps binary FSK for message transmission. New paging systems, such as FLEX and ERMES, will provide up to 6400 bps transmissions by using 4-level modulation.

The CT-2 and DECT standards developed in Europe are the two most popular cordless telephone standards throughout Europe and Asia. The CT-2 system makes use of microcells that cover small distances, usually less than 100 m, using base stations with antennas mounted on street lights or at low heights. The CT-2 system uses battery efficient frequency-shift keying along with a 32 kbps ADPCM speech coder for high-quality voice transmission. Handoffs are not supported in CT-2, as it is intended to provide short-range access to the PSTN. The DECT system accommodates data and voice transmissions for office and business users. In the U.S. the PACS standard, developed by Motorola and Bellcore, is likely to be used inside office buildings as a wireless voice and data telephone system.

The world's first cellular system was implemented by NTT in Japan. The system was deployed in 1979 and uses 600 FM duplex channels (25 kHz per one-way channel) in the 800 MHz band. In Europe the Nordic Mobile Telephone system (NMT450) was developed in 1981 for the 450 MHz band and uses 25 kHz channels. The Extended European Total Access Cellular System (ETACS) was deployed in 1985 and enjoys about 15% of the market share in Europe. In Germany a cellular standard called C-450 was introduced in 1985. The first-generation European cellular systems are generally incompatible with one another because of the different frequencies and communication protocols used. These systems are now being replaced by the Pan-European digital cellular standard GSM (Global System Mobile), which was first deployed in 1990. The GSM standard is gaining worldwide acceptance as the first digital cellular standard.

Unlike the incompatible first-generation cellular systems in Europe, the Advanced Mobile Phone System (AMPS) was introduced in the U.S. in 1983 as a nationwide standard ensuring that all cellular telephones are compatible with any cellular radio base station within the country. AMPS, like other first-generation cellular systems, uses analog FM modulation and frequency-division multiple access. As the demand for services continues to increase, cellular radio systems using more efficient digital transmission techniques are being employed. A U.S. TDMA-based digital standard called U.S. Digital Cellular (USDC or IS-54) has been in operation since 1991. In order to be compatible with the existing analog system, the IS-54 standard requires that the mobiles be capable of operating in both analog AMPS and digital voice channels. TDMA systems are able to provide capacity improvements of the order of 5−10 times that of analog FM without adding any new cell sites [Raith and Uddenfeldt, 1991]. Using bandwidth efficient $\pi/4$- DQPSK modulation, the IS-54 standard offers a capacity of about 50 $\mathrm{erlangs/km^2}$.

A CDMA-based cellular system has been developed by Qualcomm, Inc., and standardized by the Telecommunications Industry Association (TIA) as an interim standard (IS-95). This system supports a variable number of users in 1.25 MHz wide channels. Whereas the analog AMPS system requires that the signal be at least 18 dB above the interference to provide acceptable call quality, CDMA systems can operate with much larger interference levels because of their inherent interference-resistant properties. This fact allows CDMA systems to use the same set of frequencies in every cell, which provides a large improvement in capacity. Unlike other digital cellular systems, the Qualcomm system uses a variable rate vocoder with voice activity detection, which considerably reduces the effective data rate and also the battery drain.

Defining Terms

Base station: A station in the cellular radio service used for radio communication with mobile stations. They are located either in the center or edges of every cell and consist of transmitting and receiving antennas mounted on towers.

Cochannel reuse ratio: The ratio of the radius of a cell to the distance between the centers of two nearest cochannel cells.

Frequency reuse: The use of radio channels on the same carrier frequency to cover various areas that are separated from one another so that cochannel interference is not objectionable.

Grade of service: Likelihood that a call is blocked or delayed in a trunked system.

Handoff: The process of transferring a mobile station from one channel to another.

Mobile-assisted handoff (MAHO): A process in which a mobile, under directions from a base station, measures signal quality of specified RF channels. These measurements are forwarded to the base station upon request to assist in the handoff process.

Mobile station: A station in the cellular radio service intended to be used while in motion at unspecified locations. They could be either handheld personal units or units installed in vehicles.

Mobile telephone switching office (MTSO): Switching center that coordinates the routing of cellular calls in a service area. The MTSO connects the cellular base stations and mobiles to the PSTN.

Transceiver: A device capable of both transmitting and receiving radio signals.

Trunking: Method of accommodating a large number of users using a small number of radio channels by allocating them on a demand basis.

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Further Information

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A special issue on mobile radio systems published in the *IEEE Transactions on Vehicular Technology,* May 1991, contains papers on emerging mobile radio systems and technologies.
The *IEEE Communications Magazine* and the *IEEE Personal Communications Magazine* are good sources of information for the latest developments in the field.