Part B: Wireless Technologies and Applications

Developing a framework for discussing and analyzing wireless technologies in the context of the National Information Infrastructure (NII) poses many challenges. Historically, systems and services were classified and regulated in terms of the technologies used to transmit or deliver them—broadcast, telephone, cable, satellite, cellular, microwave, and so on. Such distinctions, however, are less meaningful now because the diffusion of digital technology and the convergence of services have blurred the categories. Other categorization schemes have been suggested based on: 1) technology drivers, 2) differences in the type of service delivered (mobile or fixed access), 3) broadband or narrowband, and 4) level of interactivity.

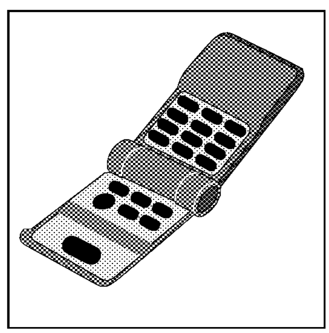
To present the technologies and their applications in the most intuitive and understandable way, the Office of Technology Assessment uses a scheme that divides wireless technologies and applications along functional, service-oriented lines: voice, data, and broadcast and high-bandwidth applications. This scheme is not perfect; there will be overlap among categories and between systems, particularly as technology continues to advance. Some, but not all, distinctions between the categories, for example, will likely disappear as different systems begin delivering similar services and information. However, many systems are likely to remain much the same well into the future. Different consumer and business needs and costs will drive users to make many tradeoffs—between cost and coverage and speed and cost, for example—allowing many different types of systems and services to survive and prosper. Chapters 3, 4, and 5 discuss the technologies being developed to provide wireless voice, data, and video/broadband services, respectively.

- Voice Technologies and Applications
- Wireless Data
- Broadcast and High-Bandwidth Services

Voice Technologies and Applications 3

Much of the media attention surrounding wireless technologies has focused on mobile telephone services, primarily cellular telephony and new Personal Communication Services (PCS). Industry representatives and analysts have pointed to the high growth rates of cellular service as evidence of pent-up demand for mobile voice services. In response to this perceived demand, existing wireless carriers and new companies are planning to greatly expand the capacity and variety of wireless voice services they provide. The first part of this chapter examines the systems—both existing and under development—that will offer mobile voice communication services. Mobile data services, often provided by the same physical systems, are discussed in the following chapter.

In addition to providing *mobile* services, wireless technologies can also be used in *fixed* applications—to provide telephone (and data) service to homes and businesses.[1] Radio-based technologies may serve some households more efficiently or easily than traditional wireline technologies, and, in particular, wireless may be less expensive than wireline in remote areas, where long copper loops are expensive to install and maintain. However, wireless may play a role even in urban areas because it may allow new competitors to enter the market for local telephone services. With a few transmitters, new entrants can provide local exchange service to a neighborhood, avoiding the expense of re-creating the incumbent local exchange carrier's extensive copper network.



[1] "Fixed" refers to the fact that the user's equipment is physically connected to a specific location.

Fixed wireless services are discussed in the second half of this chapter. Many of the issues and implications of deploying wireless voice services in the National Information Infrastructure (NII)—such as interconnection, health concerns, and standards—are discussed more extensively in later chapters.

FINDINGS

- **The regulatory distinction between mobile and fixed wireless services, while based on valid historical, technical, and regulatory reasoning, is becoming increasingly unclear and should be revisited.** The wireless technologies that will be used to provide mobile telephone services and fixed services are very similar. In fact, it is possible to serve both fixed and mobile users with the same network. Current regulations, however, continue to treat fixed and mobile voice services differently, based on technical limitations that no longer exist and the protection from competition that regulators afforded the local telephone companies. Under current rules, the treatment of various mobile service providers—including cellular and PCS—regarding services provided to fixed locations remains inconsistent and unclear. The Federal Communications Commission (FCC) may need to clarify the conditions under which wireless providers can provide fixed service. Without action on this issue, wireless will be unable to compete effectively in the market for local telephone service.
- **OTA finds that the amount of spectrum dedicated to terrestrial mobile voice services is currently adequate, but additional allocations may be required over the long term.** Over the last three years, the FCC has allocated a large amount of spectrum for terrestrial mobile services. This should provide adequate capacity for current mobile voice services until after the turn of the century. However, if current voice systems plan to upgrade their services to provide high-speed data, video, and multimedia applications, current spectrum allocations may be inadequate in the long term. If high-bandwidth services take off, additional spectrum may be needed.

The need for additional spectrum for commercial mobile satellite services, however, is less clear. U.S. satellite companies have long maintained that international and domestic frequency allocations are inadequate—limiting the services that can be provided and the number of companies that can compete in the market. The U.S. government has vigorously pursued additional spectrum allocations in international fora for a number of years, an effort that will continue at the 1995 World Radiocommunications Conference. However, at least five companies are poised to enter the satellite voice communications market over the next five years, and more firms may try to join in. Given the number of companies planning to offer satellite-delivered voice communications services and the uncertainty of the demand for such services, it is far from certain that the market will be able to support these firms.[2] Such spectrum needs should be carefully evaluated against other uses of the spectrum.

Public safety users have long fought for more spectrum, but their needs continue to be unmet. Congestion of public safety radio spectrum is common, and users report that it can seriously impact the usefulness of public safety radio systems. The growing use of data, images, and even video in law enforcement will severely tax public safety radio frequencies. A recent congressionally mandated FCC study of public safety spectrum needs has been criticized by the public safety community for seriously underestimating their needs. A more

[2] For a more complete discussion of the marketing and technical challenges facing mobile satellite companies, see U.S. Congress, Office of Technology Assessment, *The 1992 World Administrative Radio Conference: Technology and Policy Implications,* OTA-TCT-549 (Washington, DC: U.S. Government Printing Office, May 1993).

indepth evaluation of these needs is required, including an analysis of technology trends that could either alleviate the problems or exacerbate them.

- The emergence of competition in the market for mobile voice communications is likely to benefit consumers by lowering prices, encouraging higher quality and reliability, and promoting innovation that could lead to a wide range of new services. However, **new competitors to the incumbent cellular service providers will face technical and economic challenges that may ultimately result in the benefits of competition being less than proponents predict**. For example, although a given geographic area could potentially have up to 10 competing mobile telephone providers, it is unlikely that the more sparsely populated, rural areas of the nation will see this level of competition. These areas will not have enough prospective customers to support a large number of service providers. The long-term effect may be that in some areas, competition will not be sustainable and the benefits promised do not materialize. Although such shakeouts are a normal byproduct of competition, their longer term effects on prices and the diversity of services remain uncertain. If and when wireless communications systems become carriers of last resort, the effects of these long-term market structure concerns will be magnified.

MOBILE VOICE SERVICES

For most of the history of telecommunications, users have only been able to communicate to and from fixed locations—wherever the copper wires could reach. In the past few years, however, advances in wireless technologies have made it possible to imagine a future in which communication can take place anytime and anywhere. Mobile phone services, which allow users on the move to make and receive calls much as they would with an ordinary wireline phone, will play an increasingly important role in the NII. Within a decade, according to some projections, there could be almost 100 million mobile phones in use.[3] New wireless technologies may lead to a shift in the nature of communications, away from today's model of place-to-place communications to one based on person-to-person communications.

The Evolution of Mobile Telephone Service

Mobile telephone service began in 1946,[4] but subscribership grew very slowly. Because the FCC allocated only a small amount of spectrum to mobile telephony, systems were limited in the number of users they could support. Demand for service quickly outstripped capacity, leading to poor service at busy times of the day. Users often would have to try several times before their call went through. In some cities, carriers had to restrict the number of subscribers in order to maintain a reasonable level of service. For example, in 1978, the mobile telephone system in New York served only 525 customers, and there were 3,700 customers on the waiting list.[5] Even with restrictions on the number of subscribers, over half of the calls attempted did not go through.[6]

Wireless telephone service entered a new era when the first cellular telephone system began operating in Chicago in 1983. The FCC allocated much more spectrum to the cellular operators than it had previously allocated to mobile telephone

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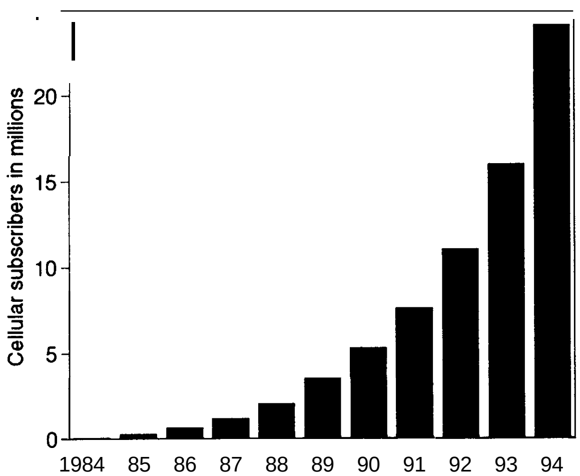
[3] Personal Communications Industry Association, "1994 PCS Market Demand Forecast" (Washington, DC: Personal Communications Industry Association, January 1995); Personal Communications Industry Association, "PCIA 1995 PCS Technologies Market Demand Forecast Update, 1994-2005," (Washington, DC: Personal Communications Industry Association, January 1995).

[4] The first system was in St. Louis. In less than a year, mobile telephone service was being offered in more than 25 cities. For a discussion of the early history of mobile communications, see George Calhoun, *Digital Cellular Radio* (Norwood, MA: Artech House, 1988).

[5] William C.Y. Lee, *Mobile Cellular Telecommunications* (New York, NY: McGraw Hill, 1995), p. 2.

[6] Ibid., p. 3.

FIGURE 3-1: Cellular Subscribership



SOURCE: Office of Technology Assessment, 1995.

gy allowed system operators to use their spectrum more efficiently. Subscribership grew steadily in the 1980s, as businesses and professionals recognized the advantages of being able to stay in touch at all times (see figure 3-l); in the early 1990s, subscriber growth reached 40 per cent per year.[7] As prices have decreased, however, the profile of the typical cellular user has changed. Cellular carriers have begun to tap the broader consumer market and attract customers who use their phones for personal, rather than business, calling. There are now over 24 million users of cellular service.[8]

Many believe that the high rate of growth in mobile telephony will continue for the foreseeable future. In part, these projections are based on the fact that cellular penetration is still only 10 percent of the potential market.[9] However, future growth will also be driven by technological advances that enable a more functional, lower cost service. Handsets are becoming smaller, lighter, and less expensive, continuing their evolution from bulky car phones to small portables. In addition, the transition from today's analog wireless technology to digital technology will allow wireless systems to support many more users at a lower cost per user. The combination of affordable service and small handsets has allowed service providers to envision a future in which tens of millions of users take pocket phones with them everywhere they go.

The projected growth in demand for mobile telephone service led the FCC to allocate a large amount of additional spectrum to mobile telephony in 1994. This new spectrum will be shared by up to six additional wireless operators in each market. The FCC refers to these new licensees as *Personal Communications Service* providers, reflecting the new vision of mobile communications systems targeted to users with pocket phones rather than car phones. PCS providers will compete with the existing cellular operators, driving the cost of mobile telephony down even further, and also will explore new niche services. Some PCS providers plan to offer service by the end of 1995, but most of the new operators will not begin service until the end of 1996 or early 1997. Additional competition will be provided by the Specialized Mobile Radio (SMR) operators, who are beginning to transform their dispatch systems into true mobile phone services by deploying a new generation of technology.

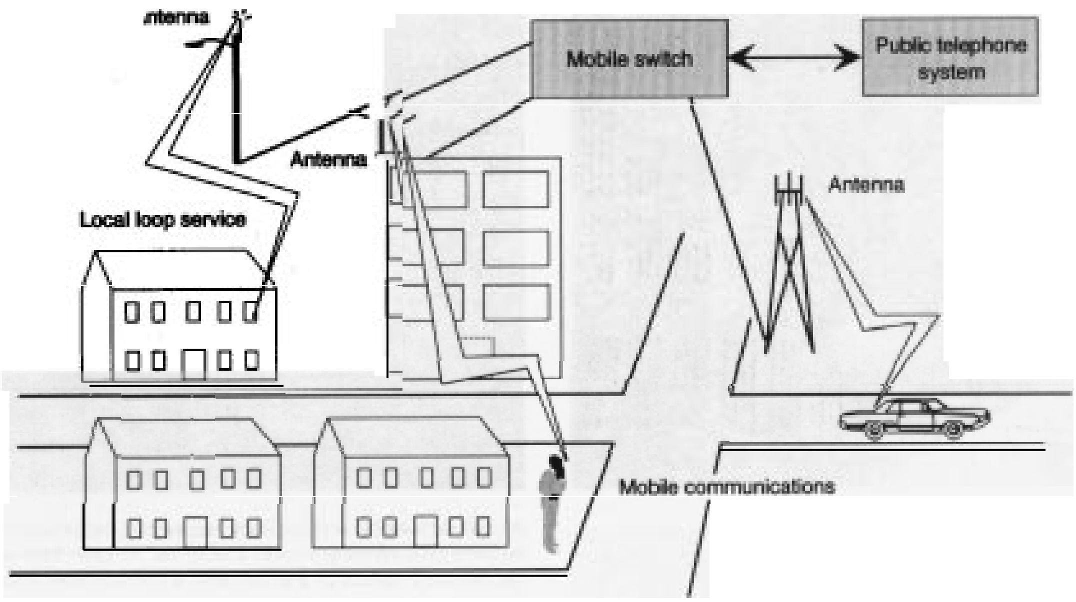
New technologies are also expanding the reach of mobile communications services. For example, network operators are increasingly providing in-building coverage in arenas, train stations, and public buildings. In addition, the deployment of a new generation of satellite systems will allow users to communicate wherever they are in the world-on ships, on airplanes, and in remote areas that could never support a terrestrial wireless service such as cellular. In the future, a single phone may be able to act as a cordless phone in the

[7] Cellular Telecommunications Industry Association, Indusrry Data Survey, December 1994-

[8] Ibid.

[9] Ibid.

FIGURE 3-2: Generic Wireless Communication Architecture



SOURCE: Office of Technology Assessment, 1995.

home, a cellular phone in the city, and a satellite phone when traveling in remote areas. Seamless systems that integrate all of these functions will help realize the vision of "anytime" and "anywhere" personal communications services.

Services and Users

Three mobile phone services--cellular, PCS, and SMR---use terrestrial wireless technologies, relying on antennas mounted on buildings and towers to provide radio coverage in cities and along highways (see figure 3-2). These terrestrial systems will be complemented by mobile satellite services, which can provide mobile telephone service in areas where terrestrial systems are not viable. It is difficult to draw distinctions between the three terrestrial mobile telephone services because the technology they use and the services they provide are similar. However, they differ to some extent in their history, industry structure, and target market.

Cellular Telephony

Cellular is the best known and most established mobile telephone service, drawing its name from a system design concept that allows for efficient use of the spectrum. At first, cellular operators designed their networks to provide a car phone service. Over the past decade, however, technological advances have allowed the manufacture of small portable phones that weigh only a few ounces. As a result, cellular systems increasingly are being designed to provide good coverage for pedestrian users as well, both indoors and on city streets. Cellular systems are operational in most cities and larger towns, and along most major highways as well.

The cost of becoming a cellular user has declined substantially over the past decade, due primarily to the impact of economies of scale on the cost of the phone. The apparent cost of the handsets is further reduced by subsidies that the cellu-

GREG WALLACE

GREG WALLACE

MOTOROLA, INC

As cellular telephone technology has advanced, phones have become progressively smaller and lighter, as seen here with a car-mounted cellular phone (top left), a transportable phone (bottom left), and a pocket-sized phone (above).

lar carriers use to attract new customers. Customers then pay a basic monthly rate, as well as a per-minute ***airtime*** charge. Airtime charges vary by company and by time of day, but typical rates during the day range from 30 to 40 cents per minute, with lower rates in the evening and on weekends. Carriers also offer a range of calling plans, targeted at different users, that include some “free” minutes. As lower volume customers who use their phones primarily for personal calling or in case of emergencies have signed up, the average monthly bill for cellular service has declined from $96.83 in 1987 to $56.21 in 1994.[10]

Cellular users can choose between two providers in each market. One of the carriers, the ***B-side*** or ***wireline*** carrier, is a subsidiary of the local telephone company; the other carrier, the ***A-side*** or ***nonwireline*** carrier, is independent-although many A-side carriers have been acquired by or entered into agreements with telephone companies operating out of their home territories. In creating the cellular industry, the FCC divided the country into 734 markets and assigned licenses separately for each market. As a result, ownership in the industry has been highly fragmented. Over the past several years, however, there has been considerable consolidation as carriers have acquired or merged with other carriers. [11] In part, industry consolidation has been driven by the need to assemble capital for the PCS auctions, but it also allows car-

[10] Ibid.

[11] See, for example, John J. Keller and Leslie Cauley, “Fear of Being Left Out of a Wireless Future Spurs Frantic Alliances,” *The Wall Street Journal*, Oct. 25, 1994, p. A1.

BOX 3-1: Roaming

When the Federal Communications Commission created the cellular industry, it divided the nation into many small license areas. Because users did not want to be restricted to using their home system, the cellular 'industry has worked to make it possible for users to make and receive calls while traveling outside the home area. This is called *roaming.*

One basic requirement for roaming—that a user's phone be compatible with all cellular systems—was met when the FCC instructed all cellular carriers to use the same technology, the Advanced Mobile Phone System (AMPS). In the future, however, compatibility may not be guaranteed. The FCC has not specified a standard technology that all carriers have to deploy as they upgrade to digital, the next generation of cellular technology. These standards issues are discussed in detail in chapter 6.

Roaming also requires that the home and visited systems be able to exchange messages about the roamers. Before it allows a roamer to make a call, the visited system checks with the roamer's home system to determine if they are a valid user or a fraud risk. The visited system also tells the roamer's home system where its customer is located. The home system is then able to forward any incoming calls to the visited system, allowing users to receive calls wherever they are located. To exchange messages about roamers, the cellular industry has set up roaming networks using leased lines and special computer communications systems.

Roaming has become easier over the past five years, but can still be problematic. Not all carriers have deployed the most advanced roaming technology. In some cases, roamers have to give a credit card number before they can make a call or have to dial a special code in order to activate call delivery every time they enter a different service area. In addition, carriers often impose a daily fee on roamers, as well as per-minute charges much higher than their home airtime rates, although carriers have begun to compete with each other on roaming charges. Roaming is generally easiest among properties owned by the same carrier, or among carriers that have agreed to an alliance that includes a common brand name.

SOURCE: Office of Technology Assessment, 1995.

riers to offer a larger service area than their competitor, an important selling point.

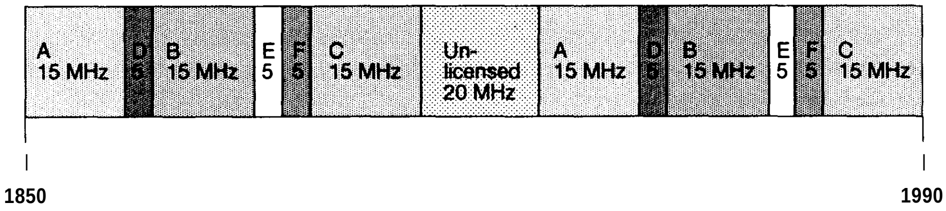
The recent consolidation is the latest effort by the cellular industry to overcome the fragmented licensing structure imposed by the FCC. In the early years of cellular, subscribers were limited to service within their home market. But users soon demanded the ability to make calls when they traveled in other cities or to continue calls when they drove into a neighboring license area. Users needed to be able to temporarily use another operator's system, which is known as *roaming (see box 3-l).* Cellular carriers have worked together to develop the technologies and business relationships that allow users to make and receive calls outside their home service area, but roaming is still not always seamless. Users may have difficulty placing calls, and calls to them may require callers to know where they are and dial access codes. Moreover, users incur substantially higher airtime charges when roaming, often $1 per minute or more.

Personal Communications Services

In 1993, the FCC reallocated 120 megahertz (MHz) of spectrum for PCS.[12] This spectrum is between 1850 and 1990 MHz, often referred to as the 2 *gigahertz* band (cellular, on the other hand, is

[12] Federal Communications Commission, *Second Report and Order, Amendment of the Commission's Rules To Establish New Personal Communications Services,* GEN Docket No. 90-314,8 FCC Rcd 7700 (1993).

FIGURE 3-3: PCS Spectru



SOURCE: Office of Technology Assessment, 1995.

in the 800 *megahertz band). The 120* MHz will be divided among six licensees in each market—three will get 30 MHz and three will get 10 MHz (see figure 3-3). The 30 MHz blocks are comparable in size to the 25 MHz blocks assigned to the cellular carriers, while the 10 MHz blocks could either be used for niche services or aggregated with other PCS or cellular spectrum. Depending on whether the 10 MHz blocks are used for a stand-alone service or aggregated with other spectrum, there will be between three and six PCS carriers in each market.

The FCC has defined PCS broadly as a "family of services" that will serve a variety of communications needs.[13] In practice, the term PCS is used less to define a particular wireless service and more as a label for the operators that will be using the new 2 GHz allocation. At frost, it was believed that PCS providers would offer a service somewhat distinct from that offered by the cellular operators. According to this concept, PCS would be a lower cost service than cellular, but would not offer the same functionality. It would be an *enhanced cordless phone* or *low-tier* service that would not support vehicular-speed mobility, but would still allow pedestrian users to make and receive calls. Because the system would not be required to support vehicular-speed mobility, the handsets could be simpler and therefore smaller, lighter, and less expensive.

Over the last several years, however, proposed PCS services have begun to look more like those offered by the cellular carriers. One reason is that potential licensees have come to believe that there is greater demand for a service that can be used in both the pedestrian and vehicular environments. Moreover, even *high tier* cellular-type handsets are becoming smaller and less expensive. As a result, it now appears that the main impact of the new PCS spectrum will be in providing competition to the two existing cellular carriers.

In 1994, the FCC *granted pioneer's preference* status to three companies that the Commission believed had done significant work in experimenting with new PCS technologies.[14] These licensees—in Los Angeles, New York, and Washington—have already begun constructing their networks and may be offering service by the end of 1995. The other PCS licenses are being assigned this year by auction. The first round of auctions, for two of the 30 MHz licenses, ended in March, and the remaining licenses will be auctioned later in 1995. The first of the systems built by an auction winner is not expected to be operational until the end of 1996.

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[13] Ibid., p. 7713.

[14] Federal Communications Commission, Tentative *Decision and Memorandum Opinion and Order, Amendment of the Commission's Rules to Establish New Personal Communications Services,* GEN Docket No. 90-314, Nov. 6, 1992. 'he FCC granted pioneer's preference licenses to American Personal Communications (AX) (for the Washington market), Cox Enterprises (LOS Angeles), and Omnipoint Communications (New York).

In the first round of auctions, three entities acquired many of the licenses. One consortium that acquired a large number of licenses consisted of Sprint and three major cable companies, Cox, TCI, and Comcast; they hope to attract customers with a package of long distance, local wireline, and local wireless service. AT&T, which also acquired many of the PCS licenses, hopes to use PCS spectrum to fill in the gaps between its cellular licenses, creating a nationwide wireless network. The third active participant in the auctions, a consortium of four cellular companies, Bell Atlantic Mobile, NYNEX Mobile, AirTouch, and US West New Vector, is pursuing the same strategy. They will offer their customers "dual-band" phones that work at the cellular frequencies where the carrier has cellular licenses and at the PCS frequencies where the carrier has PCS licenses.

Specialized Mobile Radio

Until the early 1980s, the primary use of wireless systems was for business and public safety dispatch communications. In dispatch communications, brief messages with a duration of less than a minute are exchanged between a control center and mobile users in the field. Dispatch systems are widely used by police and fire departments, taxicabs, delivery services, and construction companies. Because dispatch systems are used primarily for the internal communications needs of an organization, and are generally not interconnected with the landline public switched network, the FCC classifies them as private mobile radio services.

In some cases, organizations operate their own dispatch system. In others, they obtain service from a third party, known as a *Specialized Mobile Radio* (SMR) provider. Instead of each business operating its own dispatch radio system, the SMR carrier operates the system and sells dispatch service to several different businesses. Taxicabs, plumbing companies, and limousine services are good examples of customers that use SMR dispatch service. The SMR service was established by the FCC in 1974.

Although dispatch service is the traditional mainstay of SMR carriers, some SMR systems, especially those in rural areas, provide interconnected mobile telephone service. The spectrum inefficiency of SMR technology is not as critical in rural areas, allowing it to compete with cellular. In addition, cellular service came last to rural areas, many years after the cellular networks in the cities began operating; the last of the cellular Rural Service Areas licensed by the FCC did not get service until 1992. As of December 1993, about 425,000 of 1.5 million SMR handsets could be used for interconnected service.[15]

In the future, mobile telephone service may become an even more important part of SMR service. Driving this development is Nextel, a company that began buying many small- and medium-sized SMR operators in the late 1980s. With these acquisitions, Nextel has been able to acquire licenses and systems throughout the nation. While it still has less spectrum than a PCS or cellular licensee, Nextel believes that it has enough to deploy a digital technology known as Enhanced Specialized Mobile Radio (ESMR), which replaces the traditional single SMR antenna with a cellular architecture—allowing ESMR systems to use the spectrum more efficiently than traditional SMR technology, and potentially allowing Nextel to provide a true mobile telephone service.

The deployment of ESMR technology was expected to transform Nextel into a competitor to the cellular carriers for mass market mobile phone service. However, there have been reports that ESMR sacrifices voice quality to achieve reasonable capacity in the limited SMR spectrum.[16]

[15] Federal Communications Commission, *Second Report and Order, Implementation of Sections 3(n) and 332 of the Communications Act,* GN Docket 93-252, Mar. 7, 1994, p. 59, at footnote 294.

[16] For a discussion of this issue, see Judith S. Lockwood, "Considering Nextel? What Wireless Users Need To Know," *Wireless,* March/April 1995, vol. 4, No. 2, p. 30.

Nextel's Fully Integrated Digital Portable Flip Phone allows subscribers to place and receive voice calls, as well as receive messages, numeric pages, voice mail alerts. and text messages.

Nextel recently announced that it plans to scale back its plans to compete broadly with cellular in order to target business users, providing them with an integrated unit that combines telephone, paging, and dispatch capability in a single handset. Nextel will also try to capitalize on the fact that it owns licenses throughout the nation, allowing it to provide seauless roaming more readily than the cellular operators. There are currently about 10,000 ESMR customers[17] in Los Angeles and San Francisco, but Nextel plans to activate service in other large markets throughout 1995 and 1996.

Mobile Satellite Services

Terrestrial wireless services such as cellular are not economical in sparsely populated areas because there are not enough users to justify the cost of building a tower every few miles. Although there is at least one cellular licensee in each of the 734 license areas defined by the FCC, the licensees typically do not provide coverage to every square mile. In rural areas, especially west of the Mississippi, there are large areas where the only cellular coverage is along interstate highways. Satellite services can fill in the gaps in areas where terrestrial systems are not viable and help realize the vision of communications services available everywhere in the nation.

Geostationary satellite systems[18]

Limited satellite telephone service has been available for several years through the International Maritime Satellite Organization (Inmarsat). The Inmarsat system was originally established to provide communications to ships, but now also provides land mobile communication. The phones are bulky, briefcase-sized units that weigh about 25 pounds and cost between $15,000 and $20,000. The service is expensive at $4.95 per minute. But Inmarsat provides telephone service almost everywhere in the world and has been widely used for disaster relief, news-gathering, and businesses such as oil exploration and mining. There are about 10,000 land mobile terminals operational in the Inmarsat system worldwide, accounting for about one-third of Inmarsat's customers.[19]

Later this year, American Mobile Satellite Corp. (AMSC) is expected to begin providing a more advanced mobile satellite service in the

[17] Because an ESMR customer is typically a business, each customer averages about 10 phones. Ibid.

[18] Geostationary satellites orbit the Earth 22,300 miles above the equator. At this altitude, they orbit the Earth at the same speed that the planet rotates. As a result, they appear fixed at a specific point in the sky, allowing satellite dishes on the ground to easily communicate with them.

[19] Jack Oslund, Director, External Affairs, Comsat Mobile Communications, letter to the Office of Technology Assessment, U.S. Congress, Washington, DC, Aug. 2,1994.

United States. AMSC, a consortium of large telecommunications firms, was formed in 1987, and is currently the only company in the United States authorized to provide mobile satellite services.[20] AMSC plans to market its service as an extension of terrestrial cellular telephone systems, primarily targeting the mobile user market, although offering some fixed services as well. AMSC will offer a car phone service with the transmitter installed in the trunk of the car, but because of the large amount of power needed for the signal to reach the satellite, handheld portable phones cannot be developed for the system. The car phones will have dual-mode capability—connecting users to the cellular network in areas where there is coverage, and switching to AMSC's satellite in remote areas beyond the reach of cellular. A total of 140 cellular carriers have signed on to market AMSC phones and service to their customers. In addition to traditional cellular phone users, such as business travelers, AMSC's service is expected to appeal to trucking companies, owners of corporate or general aviation aircraft, as well as remote populations currently without phone service. AMSC expects to offer its service for $25 a month, plus about $1 per minute of usage.[21]

Low-Earth orbiting (LEO) satellite systems

A new generation of mobile satellite services is expected to become operational in the late 1990s. Instead of using a small number of geostationary satellites like those employed in the Inmarsat and AMSC systems, these new systems will consist of a constellation of many smaller satellites in low-Earth orbit (LEO). Because the satellites orbit close to the Earth, LEO systems permit the use of a low-power handheld device about the same size as a portable cellular phone. There are two types of LEO systems. The so-called *little LEOs* are designed for low-speed data services only (see chapter 4), while the *big LEOs* are designed to provide both voice and data services.

Several companies have proposed big LEO systems (see box 3-2). Like the AMSC system, they will use a dual-mode phone that switches between cellular and satellite coverage as necessary. Handset costs will range from $500 to $3,000, and service costs are projected to range between $0.40 and $3.00 per minute. Unlike AMSC, big LEOs will offer global coverage, providing users with the convenience of service from a single provider anywhere in the world. Potential markets include international tourists, business travelers, relief organizations, and government agencies.

LEO proponents have overcome many hurdles. The first step was to obtain an international spectrum allocation at the 1992 World Administrative Radio Conference (WARC-92).[22] The five U.S. applicants who had sought approval to deploy big LEO mobile systems then had to work out a plan for sharing the small amount of available spectrum. Finally, in January 1995, the FCC granted licenses to three of the five applicants to begin construction of their systems.[23] The licensees still must obtain licenses to operate in other countries and assemble enough capital to deploy their systems, which will cost between $1.5 billion and $4

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[20] LEO systems have been given authority to construct, but not yet to operate their services. AMSC's singular status, and its consortium composition, is the result of an FCC decision to grant only one license for geostationary mobile satellite service due the limited amount of spectrum available at the time. Public investors now control roughly 34.6 percent of AMSC followed by Hughes Communications (27.2 percent), Singapore Telecommunications (13.6 percent), McCaw (now AT&T) (12.5 percent), Mobile Telecommunications Technologies Corp. (7 percent), and others (5.1 percent). American Mobile Satellite Corp., *1993 Annual Report.*

[21] AMSC is already offering commercial service to trucking companies with a leased satellite.

[22] See Office of Technology Assessment, op. cit., footnote 2.

[23] FCC licenses were issued to Iridium, Inc., TRW, and Loral Qualcomm. Systems proposed by Mobile Communications Holdings, Inc. and Constellation Communications did not receive licenses. Action on these applications was deferred until January 1996 to allow the firms to show their financial qualifications. "FCC Clears Global Satellite Projects of Motorola, TRW, Loral, Qualcomm," *The Wall Street Journal*, Feb. 1, 1995, p. A4.

BOX 3-2: Proposed Big LEO Satellite Systems

In late 1990 and early 1991, five companies applied to the FCC to provide mobile communications services using low-Earth orbiting (LEO) satellites. Three systems—lridium, Globalstar, and Odyssey—were later granted permission to construct, although final operating authority was withheld until international allocations for the links between the satellites and the gateways ("feeder" links) are agreed to and sufficient spectrum is available. The systems are now being built. Ellipso and Constellation were denied construction licenses until they could provide better financial qualifications, and have until January 1996 to do so. A sixth system, lnmarsat-P, has applied for a license in the United Kingdom.

Iridium (Motorola Satellite Communications, Inc.)

The Iridium system will consist of a constellation of 66 LEO satellites and 15 to 20 Earth-based gateways that connect users to the public switched telephone network. Iridium investors will own and operate the gateways and be responsible for obtaining national licenses for operation of subscriber handsets, spectrum utilization, transborder agreements, PSTN interconnection, service provision arrangements, and distribution agreements. The networked satellites will orbit the Earth on six different planes of 11 satellites each. They will travel longitudinally, ringing the planet from pole to pole, at an altitude of 770 kilometers and completing a full orbit in 100 minutes. The Iridium satellites will be capable of passing a telephone call directly from satellite to satellite--the only big LEO system to do so-making each satellite a small orbiting switch, and making the Iridium system the most technically complex.

Iridium plans to use dual-mode satellite/cellular handsets that will allow subscribers to use the terrestrial cellular infrastructure when available or the satellite network when the user is in an area not served by cellular. Handsets will cost up to $3,000 and calls will average $3 per minute. The system will use a combination of time division multiple access (TDMA) and frequency division multiple access (FDMA) schemes. Commercial service is expected to become available in 1998 with the company projecting a market of 1.5 million users by the year 2000,

The system is expected to cost $3.37 billion for design, production, and launch, plus $2.8 billion for operation and maintenance over the first five years of operation. Investments in Iridium totaled $1,57 billion as of February 1995, with Motorola, Inc. committed to meeting the construction costs and operating expenses necessary for system deployment. Motorola, Inc. is the largest investor with 27 percent of Iridium Inc.'s stock. Iridium's second largest investor is a consortium of 17 Japanese companies that invested about $235 million, led by DDI Corp., Japan's second-largest telecommunications company. Other investors include Vebacom GmbH, the telecommunications arm of German energy conglomerate Veba AG; Korea Mobile; Sprint; STET, Italy's PIT; Bell Canada; Raytheon; Lockheed and others.

Globalstar (Loral/Qualcomm L. P.)

The Globalstar system design calls for a network of 48 satellites located 750 nautical miles above the Earth that will relay global digital voice and data traffic from fixed and mobile handsets to a terrestrial gateway—there are no intersatellite links. Satellites have a 1,500-mile-wide footprint, and will be organized in eight planes with six satellites in each plane and provide "global" coverage between 70 degrees latitude north and south. The system will use code division multiple access (CDMA) transmission modulation. Globalstar predicts a handset priced initially at $700, and services will cost 30 cents per minute plus 10 cents per minute for interconnection. Monthly service charges will be $8 to $10. Service is scheduled to begin in 1998 with a company-projected market of 2,7 million users by the year 2002.

(continued)

BOX 3-2: Proposed Big LEO Satellite Systems (Cont'd.)

Loral/Qualcomm estimates the cost of the system at $1.554 billion, including system deployment and first-year operating costs. Globalstar, L. P., an international partnership founded by Loral Corp. and Qualcomm, Inc., invested $275 million in an initial financing round in March 1994. Funds totaling $492 million had been raised as of February 1995, including commitments from AirTouch Communications, Inc.; Alcatel N.V. and France Telecom of France; Vodafone plc of the United Kingdom; DACOM Corp. and Hyundai Electronics Industries Co. Ltd. of South Korea; Daimler Benz Aerospace AG of Germany; Finmeccanica of Italy; and the international Space Systems/Loral aerospace consortium.

Odyssey ('TRW, Inc. and Teleglobe)

Unlike the Iridium or Globalstar systems, the Odyssey system is technically a medium-Earth orbiting system. Twelve satellites, equally divided into three orbital planes at an altitude of 10,354 kilometers, will provide global digital voice and data communications by linking mobile handsets with ground-based cellular and terrestrial networks via 10 or 11 earth stations, using CDMA/FDMA modulation schemes. No inter-satellite communications are planned. Handsets are expected to be priced at less than $500, and service will cost approximately 65 cents per minute, plus 10 cents per minute interconnection fees and a monthly charge of $24.

Odyssey will be established as a limited partnership, with TRW and Teleglobe serving as the founding general partners and jointly managing the project. TRW, Inc. estimates $1.8 billion to construct, launch, and operate the system for one year. Teleglobe and TRW will provide 5 percent and 10 percent of the equity, respectively. They are seeking financing for the remaining 85 percent, most of which is expected to be in equity and the balance a combination of debt and vendor financing. TRW said it has sufficient current assets and operating income to finance the project, and submitted a declaration during the licensing process committing TRW to expend the funds necessary to construct, launch, and operate the Odyssey system.

Ellipso (Ellipsat/Mobile Communications Holding, inc.)

Ellipso plans to provide global digital voice and data services to mobile or handheld terminals through two constellations of medium-Earth elliptical orbit satellites designed to maximize service to the Earth's populated land masses. The Borealis subconstellation of 10 satellites would service northern latitudes and operate in two elliptical orbits of five satellites each with apogees of 7,846 kilometers. The six-satellite Concordia subconstellation would cover tropical and southern latitudes and operate in a single circular equatorial orbit at 8,068 kilometers. Like Globalstar and Odyssey, the satellite will serve as relays between users and gateways on Earth---no intersatellite links are planned. User terminals are expected to cost approximately $1,000 within one to two years of service initiation and 50 cents a minute for usage. They will use CDMA technology.

The system will cost $564 million to construct, launch, and operate for the initial year. MCHI said in its statement of financial qualifications that it would rely on internal support from its shareholders, vendor financing (including committed funds from Ariansespace in the form of convertible debentures), equity investments, and other committed funds to cover the expected system costs. MCHI shareholders include Barclays de Zoete Wedd Ltd. of London, Westinghouse Electric Corp., and Fairchild Space and Defense Co. Cable & Wireless plc of the United Kingdom recently acquired 50,000 shares or 2 percent of its stock with an option to acquire an additional 600,000 shares.

(continued)

BOX 3-2: Proposed Big LEO Satellite Systems (Cont'd.)

ECCO (Equatorial Constellation Communications)

Initially, 12 satellites will orbit in a single ring around the equator. The complete constellation would add seven planes of six satellites each (five operational and one spare) for a total of 54 satellites in orbit (46 operational, eight spares). The system is designed to provide mobile and fixed-site voice, data, facsimile, and position location services in more than 100 countries in Central and South America, Southeast Asia, India, Africa and the Middle East.

Constellation Communications, Inc. filed the original license at the FCC, but recently, Constellation, Bell Atlantic Enterprises International, and Telecommunicacoes Brasileiras S.A. ("Telebras") signed a Memorandum of Understanding as a framework for discussing the creation of a joint venture to own and operate a LEO satellite system. Constellation Communications, Inc. submitted commitment letters and balance sheets for its newly disclosed equity investors, Bell Atlantic and E-Systems, Inc. Constellation also said that Telecommunicacoes Brasilerias S.A. (Telebras) of Brazil intends to take an equity stake in the project later. Constellation estimates that constructing and launching the total system will cost $1.695 billion and that $26.4 million will be required to cover the first year's operating costs.

Inmarsat-P (ICO Global Communications Limited-a consortium including Inmarsat and 38 Inmarsat signatories)

Inmarsat-P, sometimes referred to as Project-21, would employ 10 or 12 satellites in intermediate circular orbits (10,355 km). Each satellite would have the capacity for 4,000 circuits and an expected lifetime of 10 years. Inmarsat handsets are expected to cost between $1,000 to $1,500 and calls will cost $2 per minute. Inmarsat has started the licensing process in the United Kingdom and hopes to begin offering service in 1999, with the system fully operational by the year 2000.

The cost to construct, launch, and operate the system for one year is expected to be $2.8 billion. $1.4 billion in initial financing was committed by 39 signatories to Inmarsat including a commitment of $150 million by Inmarsat as an organization. The Inmarsat Council has indicated that Inmarsat and its affiliates will maintain at least 70 percent ownership. Additional pledges of $900 million were turned away and the remaining $1.4 billion will be financed through equity and debt. The U.S. investor is Comsat Corp., the US. government's signatory to Inmarsat. In Europe, the biggest investors are Deutsche Telekom AG's mobile-phone unit and the Swiss, Spanish and Dutch state phone companies. Other major investors are: the Beijing Maritime & Shipping Co., an arm of the Chinese Ministry of Transport; Japan's main international phone carrier, KDD, Ltd.; India's international phone company; and Singapore Telecom.

SOURCE: Office of Technology Assessment, 1995

billion. Many analysts do not believe that there are enough customers to support all of the proposed systems.[24]

Technology

Advances in technology underlie the vision of small and light handsets and low-cost wireless service. Developments in semiconductor and micoprocessor technology allow the functionality of a mobile phone to be squeezed into a small package. New technologies also permit power-efficient systems that can use a smaller battery, usually the heaviest part of the handset. But the most important development in wireless telephony is

[24] For a more complete discussion of the challenges facing the LEOs, see OTA, op. cit., footnote 2.

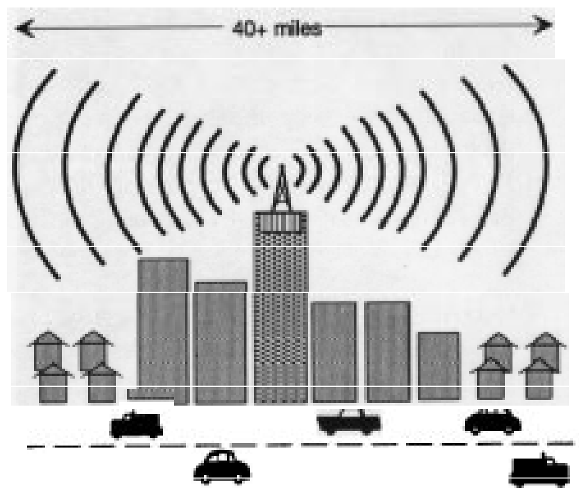
Dual-mode portable telephones, such as this prototype from Iridium, will first attempt to connect to a local cellular system. If no system can be accessed, the telephone will then use the satellite system to complete the call.

the evolution to digital transmission, which will allow network operators to serve three to 10 times as many users as today's analog systems with the same amount of network equipment. This capacity increase will translate into a substantially reduced cost to serve each user.

Terrestrial Wireless Technology

Terrestrial wireless systems provide radio coverage to their service area with antennas mounted on towers or on buildings. Until the early 1980s, terrestrial mobile telephone systems used a single, high-power transmitter on a tall tower or skyscraper to cover a metropolitan area. Any user within the signal's range, usually up to about 40 miles away, could get service. This single-tower architecture is still used for most SMR systems today (see figure 3-4), and is adequate when the predominant type of communication is short dispatch messages.

FIGURE 3-4: Single-Tower Mobile Telephone System

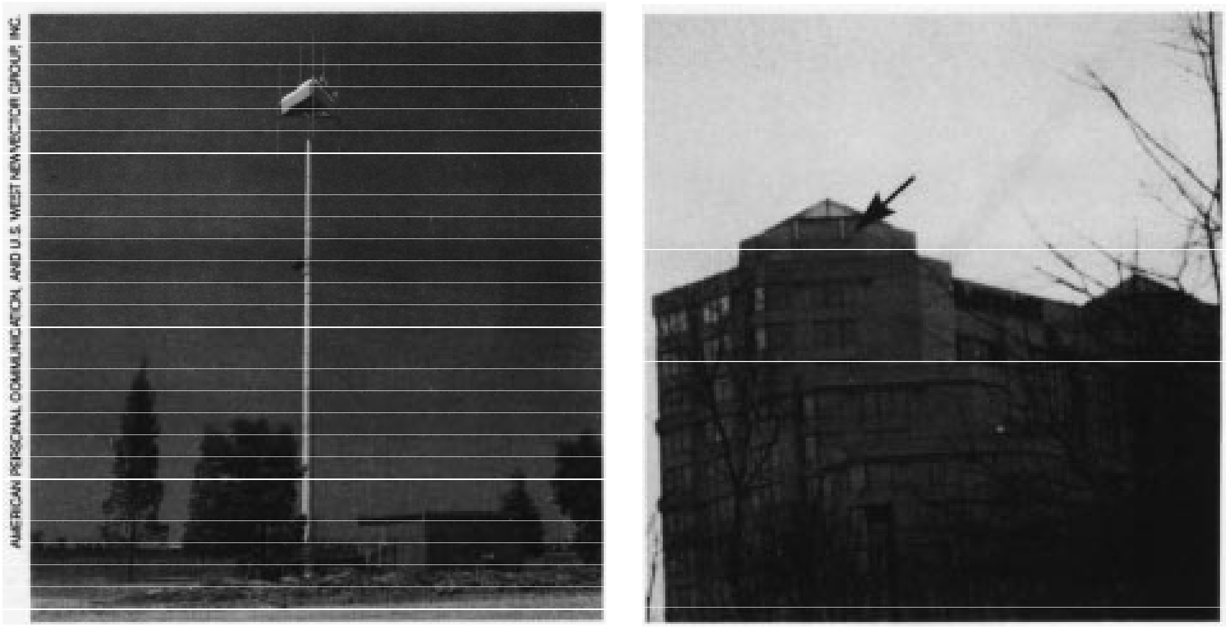


SOURCE: Office of Technology Assessment, 1995.

The cellular concept

Modem terrestrial systems use a *cellular* architecture that provides coverage with many low-power transmitters. Cellular technology provides the foundation for amass market service by allowing a large number of users to share the limited spectrum more efficiently than the single-tower approach. Because it has now been proven over a decade of service, cellular technology will no longer be used only by the cellular carriers. In 1991, the FCC allowed Fleet Call (now Nextel) to deploy its ESMR technology by shifting from one high-power broadcast tower to a cellular architecture in six of the largest U.S. markets. New PCS providers will also use a cellular architecture.

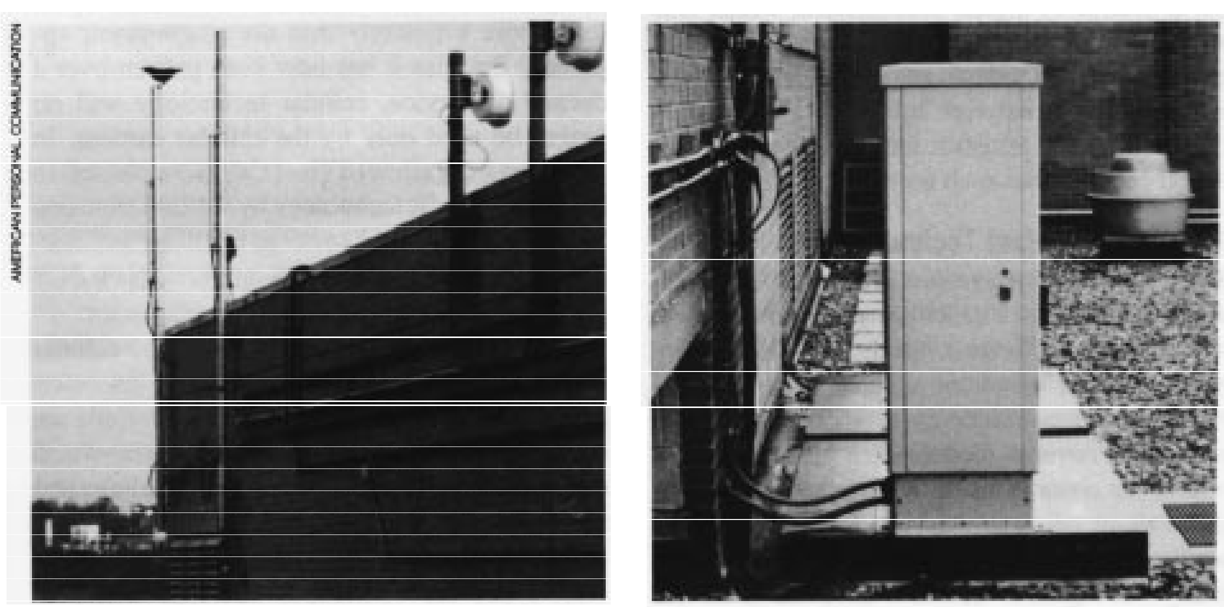
Each of the low-power transmitters in a cellular system provides coverage to an area a few miles across, known as a *cell* (see figure 3-5). Cells are often drawn as circles or hexagons, but real-world cells are irregular in shape because buildings and trees obstruct the radio waves. By deploying enough transmitters or ***base stations,*** cellular operators provide continuous coverage wherever their customers are likely to be. Because users often pass through several cells as they travel



Wireless antennas come in manyshapes and sizes, from large, conspicuous monopole designs, to practically invisible building mounted panel antennas.

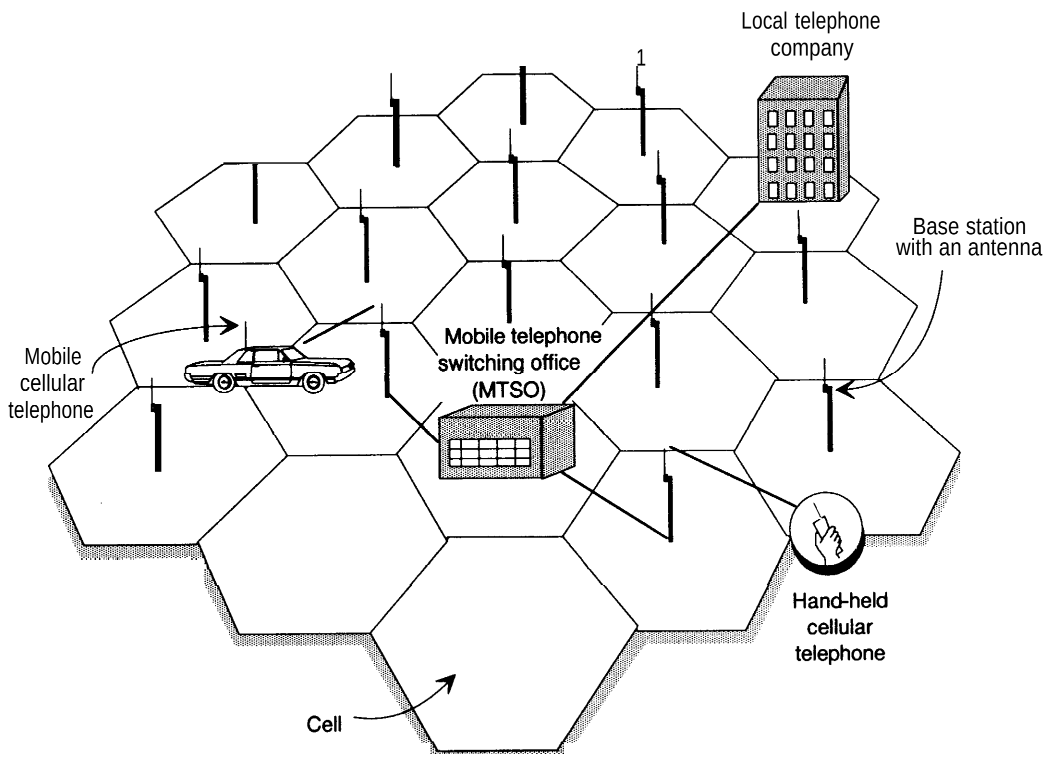
through a city, a cellular system has to automatically *hand off* the call from base station to base station. As the user nears the edge of a cell, the system reassigns the user to anew cell by determining which of the other base stations in the area can provide the strongest signal.

The cellular architecture makes efficient use of the spectrum and increases system capacity. In a conventional single-tower system, each channel can only be used by one customer at anyone time. By contrast, a cellular system allows a channel used in one cell to be ***reused*** by a different user in



PCS antennas (left) and roof top base stations (right) are smaller than their cellular counterparts.

FIGURE 3-5: A Typical Cellular System Architecture

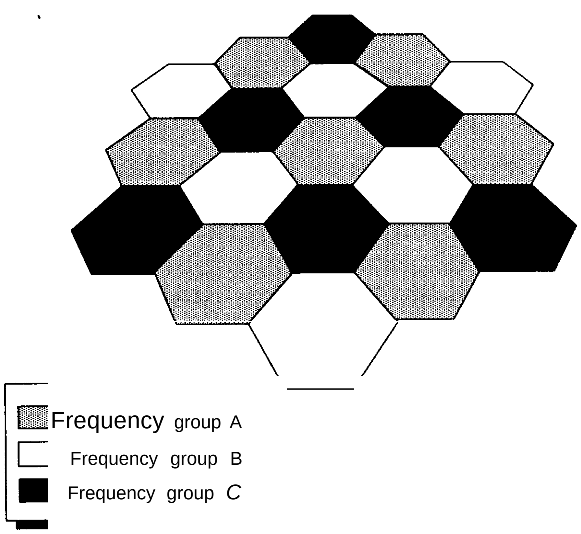


SOURCE: Office of Technology Assessment, 1995.

another cell, as long as there is enough separation between the cells to minimize interference (see figure 3-6). Network operators can further increase system capacity by splitting large cells into several smaller ones. The greater the number of cells, the greater the number of users who can use a channel at the same time. In typical systems, cells at highway interchanges or in downtown areas are less than a mile in diameter, while in areas where the traffic is light they may be up to 20 miles across (see figure 3-7).

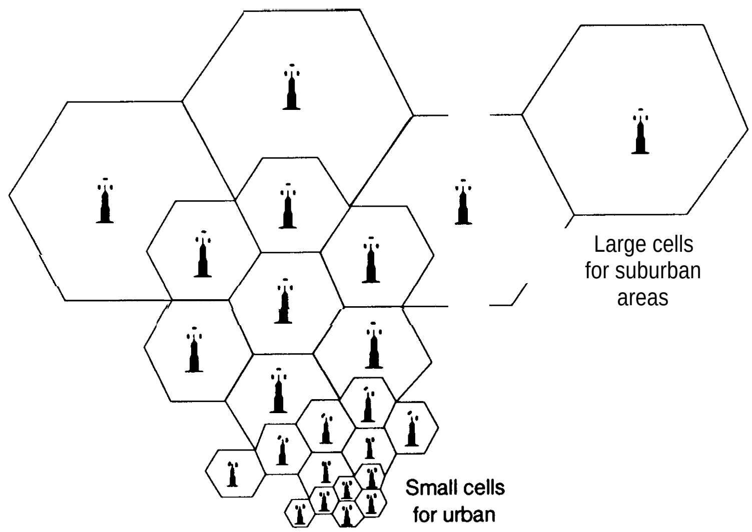
The heart of a cellular system is the Mobile Telephone Switching Office (MTSO), which is connected by microwave or landline links to all of the base stations. It is also connected via a high speed digital link to the public switched telephone network. The user's voice signal is transmitted from the phone through the air to a base station, back to the MTSO, and then through the landline

FIGURE 3-6: Frequency Reuse Concept



SOURCE: Office of Technology Assessment, 1995.

FIGURE 3-7: Cell-Splitting



SOURCE: George Calhoun, *Digital Cellular Radio* (Norwood, MA: Artech House, Inc., 1988), p. 43.

network to its destination. The MTSO is responsible for managing the assignment of radio channels to users. When the user dials a number and presses the "send" button on their phone, the MTSO checks to see if there is a channel available and then assigns the channel. During the call, the MTSO monitors the signal strength to see if it should initiate a handoff to a nearby cell.

Digital transmission

Although the cellular concept is the foundation of terrestrial wireless technology, it is the transition to digital transmission that is most responsible for the vision of low-cost personal wireless services. Today's cellular technology, known as the Advanced Mobile Phone Service (AMPS) system, is based on an analog frequency modulation (FM) transmission scheme and dates from the mid-1970s. AMPS systems in large cities are starting to reach capacity limits that cannot be overcome by further cell-splitting. Digital systems are being deployed to provide higher capacity.

One way that digital systems increase capacity is by making extensive use of voice compression technologies. Once a voice signal has been transformed into digital form, complex mathematical manipulations can be used to reduce the amount of information that needs to be sent for good-quality speech. Reducing the amount of information that needs to be sent also reduces the amount of spectrum needed for each user, allowing more users to share the spectrum. For voice quality that is comparable to an AMPS system, at least three times as many users can be accommodated by a digital cellular network with the same number of base stations. Because voice compression technology will continue to improve, future systems will be able to achieve even greater increases in capacity.

The deployment of digital systems in the United States has been slowed by battles over standards. For the first generation of cellular technology, the FCC selected AMPS as a national standard and required all operators to use it. But with digital cellular, the FCC has left technology

BOX 3-3: TDMA and CDMA

In a cellular system, many users make calls at the same time in each cell. Clearly, it is necessary that these users' transmissions not interfere with each other. One solution to this "multiple access" problem is to ensure that each user transmits on a separate frequency or "channel. " When a user initiates a call, the system tells the user's phone which frequency to tune to, much as a radio listener tunes to a particular station. This approach, known as Frequency Division Multiple Access (FDMA), is used in today's analog cellular systems.

Digital cellular systems could also use FDMA; the only difference would be that the information sent through the channel would be in digital, not analog form. However, it is more likely that digital cellular systems will use one of two alternate schemes, either Time Division Multiple Access (TDMA) or Code Division Multiple Access (CDMA). The TDMA and CDMA approaches differ from FDMA in that several users may share the same channel.

In a TDMA system, several users are assigned to a single channel, and they take turns. Each user's phone transmits a short burst of data, waits as the other users assigned to the channel transmit their data, sends another burst, and so on. At the receiver, the bursts are reassembled into a continuous signal and turned back into speech. In the U.S. TDMA system, three users share the same channel that the analog Advanced Mobile Phone Service (AMPS) system uses for a single user. Digital compression technology allows a user to send a good-quality speech signal even when using the channel only one-third of the time, tripling the capacity of the system.

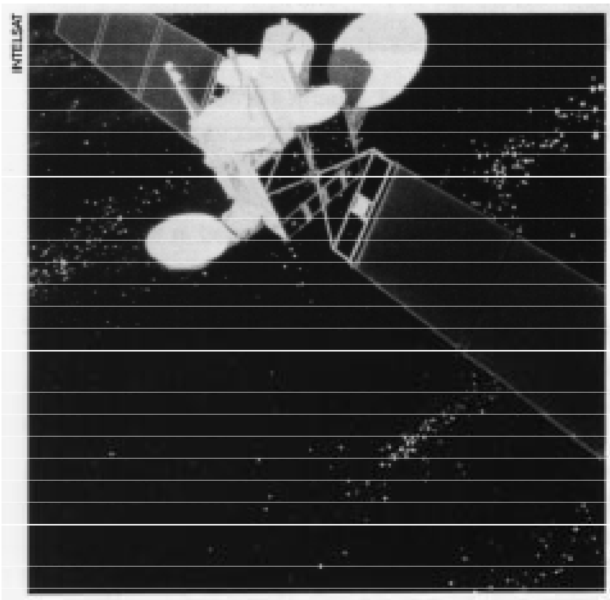
CDMA systems use a much wider channel than TDMA or FDMA systems, and share it among a larger number of users. The users can all use the channel at the same time, but each user's transmission is uniquely coded. If the receiver knows the code, it can pick out a particular user's transmission from the combined signal. There is no strict limit to the number of users in each channel, but it becomes more difficult to pick out individual users' transmissions as the channel becomes crowded. Because CDMA uses a wider channel than FDMA or TDMA, it is sometimes referred to as a "spread spectrum" technology.

Both CDMA- and TDMA-based systems have been proposed for use as a replacement to AMPS. Over the past several years, there has been a debate about which approach is better. TDMA proponents have argued that TDMA is a more proven technology, whereas CDMA proponents have argued that their system will offer higher capacity-not just three times more users than AMPS, but 10 or 20 times more. TDMA-based digital cellular systems entered commercial service in 1992, and have several hundred thousand users. No CDMA systems are expected to be operational until late 1995 or early 1996.

The capacity estimates for CDMA are higher because it appears to overcome a fundamental challenge that faces designers of TDMA systems. In a TDMA system, the same channel cannot be used in adjacent cells because of excessive interference. A channel can only be safely "reused" in cells some distance away. As a result, only a fraction of the operator's spectrum can be used in each cell: typically one-seventh or less. CDMA systems, on the other hand, allow all of the spectrum to be used in each cell, increasing system capacity.

SOURCE: Office of Technology Assessment, 1995.

selection to the industry. Cellular industry standards committees have been unable to choose between two systems, one based on a technology called Time Division Multiple Access (TDMA) and the other based on Code Division Multiple Access (CDMA) (see box 3-3). Similarly, seven different technologies have been proposed for use in the new PCS band. There are more PCS than



Satellites in geosynchronous orbit 22,300 miles above Earth are being used to provide a variety of mobile communication services to aircraft, ships, and vehicles.

cellular technologies under consideration because the PCS band may be used for a wider variety of services. See chapter 6.

While ESMR and PCS operators will use digital technology from the beginning, cellular operators will have to deploy digital technology while also continuing to provide service to the millions of users who still have analog phones. Because it will take several years to convert every base station to digital, the new digital phones now being sold are also capable of analog transmission. The user can "fall back" to analog in areas where there is no digital service or where a different digital system has been deployed. Over time, network operators will add digital capability to more and more cell sites and continue to expand the amount of spectrum dedicated to digital service, while continuing to reserve some channels for users who still have analog-only phones. The transition to digital has only just begun and is expected to take about a decade.

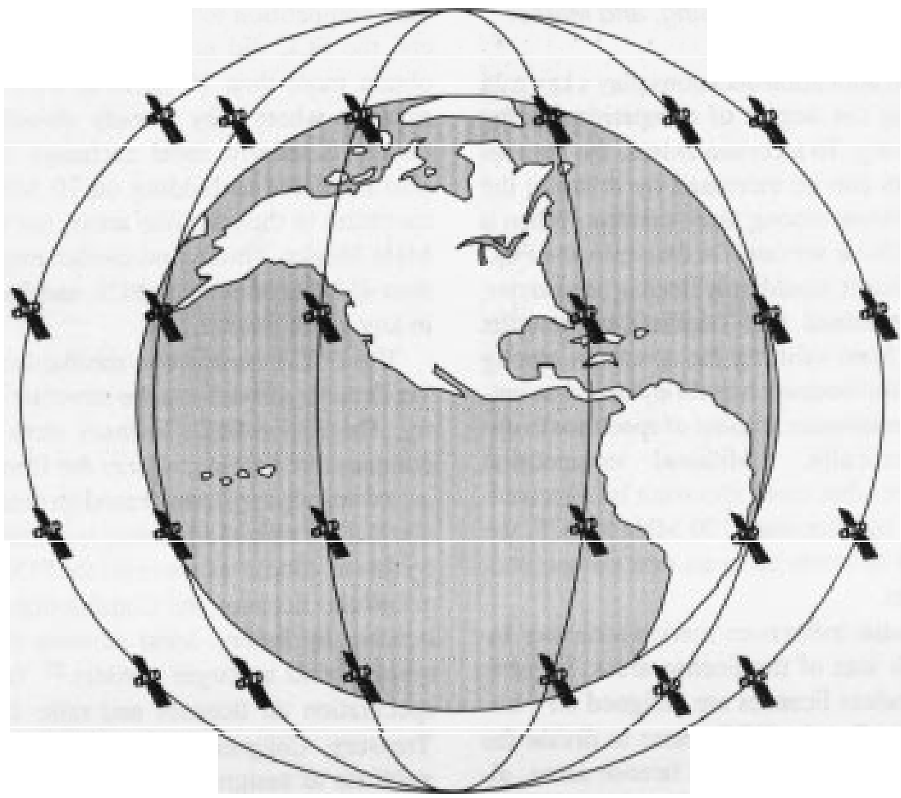
Mobile Satellite Technology

In a satellite telephone system, instead of sending the radio signal to abase station, the mobile phone beams the radio signal up to a satellite. In many ways, satellite systems are benefiting from the same technological advances as terrestrial systems. By using multiple ''spot beams" in place of a single beam, satellite systems can exploit the same concept of frequency reuse that terrestrial systems use. They will also use digital voice compression to dramatically increase the number of users that can be served from each satellite, reducing the cost per user considerably. But the most significant new concept in satellite system design has been the development of nongeostationary LEO or Medium Earth Orbit (MEO) systems.

The Inmarsat and AMSC systems use satellites in geostationary orbit, 22,300 miles above the equator. At this altitude, the satellite appears to remain at a freed point above the Earth. This simplifies system operation, but has several drawbacks. First, it takes a considerable amount of time for the signals to travel up to the satellite and back down to Earth, resulting in a noticeable and annoying delay. Second, because the satellite is so far above the Earth, considerable power is needed to transmit the signal up to the satellite, requiring bulky transmitters. Therefore, the AMSC system can only be used with car phones, not portables.

With a nongeostationary LEO or MEO system, on the other hand, the satellites orbit much closer to the Earth at altitudes between 500 and 7,000 miles. This reduces power requirements, allowing the use of handheld portables. Moreover, the delay incurred in sending the signal up to the satellite and back down to Earth is significantly reduced. But LEO systems are also more complex. While a geostationary system can provide global coverage with a small number of satellites, LEO systems plan to use constellations of 10 to 66 satellites (figure 3-8). The satellites move relative to the surface of the Earth, complicating system coor-

FIGURE 3-8: Low-Earth Orbit Satellite System



SOURCE: Office of Technology Assessment, 1995.

dination. Moreover, satellite lifetimes are significantly reduced, requiring replacement satellites to be launched continuously.

■ Regulatory Framework

The FCC is responsible for managing the spectrum used by commercial wireless services, and ' sets the rules regarding their licensing and operation. Historically, the FCC has regulated wireless services less than wireline services, believing that the wireless market is more competitive than the traditional monopoly wireline market. The FCC has relied on market forces to determine the prices of wireless services, within the regulatory framework it established for each service.

As technology has advanced, the distinctions between different mobile telephone services have become less clear. Cellular, PCS, and ESMR will provide similar services. To streamline regulation of these existing and emerging services, Congress directed the FCC in the Omnibus Budget Reconciliation Act of 1993 (Public Law 103-66) to set up a new regulatory classification-commercial Mobile Radio Services (CMRS)--that would allow the FCC to "treat like services alike," forbear from imposing some elements of common carrier regulation, and preempt state regulation of CMRS rates.

Spectrum Allocation, Licensing, and Market Structure

FCC spectrum allocation decisions play a key role in determining the degree of competition in the wireless industry. To a certain extent, the number of competitors can be increased by dividing the available spectrum among more carriers. When it created the cellular service, for example, the FCC first thought that it would only license one carrier, but then determined that competitive benefits would result from splitting the spectrum among two carriers. But because a mobile telephone network needs a minimum amount of spectrum to operate economically, additional competition usually requires that more spectrum be allocated. For example, by allocating 120 MHz to PCS, the FCC was able to create up to six new competitors in each market.

The FCC also influences market structure by specifying the size of the license areas. In most countries, wireless licenses are assigned on a nationwide basis. But the FCC chose to divide the United States into many small license areas, allowing a larger number of companies to take part in the industry. For cellular, the FCC divided the nation into 734 separate market areas—306 Metropolitan Statistical Areas (MSAs) and 428 Rural Service Areas (RSAs). PCS licenses, on the other hand, are being allocated on the basis of either 493 Basic Trading Areas (BTAs) or 51 Major Trading Areas (MTAs). Two of the 30 MHz PCS licenses are being allocated on the basis of MTAs, while the other PCS licenses will be allocated on the basis of BTAs. SMR service areas are defined by the propagation distance of signals transmitted from the operator's tower, but there are proposals to establish standardized service areas such as BTAs or MTAs.

Other FCC rules seek to maintain competition by limiting concentration of ownership. To ensure that the new PCS spectrum would be used to provide competition to the incumbent cellular carriers, the FCC did not permit cellular carriers to obtain more than 10 MHz of PCS spectrum in markets where they already owned cellular licenses. Similarly, local exchange carriers were also restricted to bidding on 10 MHz blocks of spectrum in their service areas, not the larger 30 MHz blocks. Finally, no carrier may have more than 45 MHz of cellular, PCS, and SMR spectrum in any given market.

The FCC's choice of a mechanism for assigning licenses also affects the structure of the industry. The first cellular licenses were assigned by comparative hearings where the Commission selected among applicants based on detailed proposals. But the task of allocating hundreds of licenses by this method overwhelmed the FCC. For the later cellular licenses, the Commission assigned the licenses by lottery. Most of these licenses were quickly sold to larger carriers.[25] To reduce the speculation on licenses and raise funds for the Treasury, Congress authorized the FCC to use auctions to assign licenses.[26] The first round of PCS auctions raised $7.7 billion.

Commercial Mobile Radio Services

PCS, cellular, and most SMR and mobile satellite services are regulated as CMRS carriers. The creation of the CMRS classification was a response to disparities in the regulation of SMR and cellular carriers, which became increasingly significant as the deployment of new technologies allowed SMR carriers to compete with cellular carriers. Beginning in August 1996, PCS and SMR carriers that provide mobile telephone service will be subject to the same rules as cellular carriers. The FCC has launched a series of proceedings to define the

[25] "Stanley Says 70% of Lottery Cellular Licenses Transferred," *Telecommunications Reports,* Apr. 26, 1993, p. 16.

[26] Public Law 103-66, section 309(j).

BOX 3-4: CMRS Proceedings

In the Second Report and Order that was issued in the proceeding that defined the rules governing CMRS carriers, docket No. 93-252, the FCC identified several issues that required further study:

- **The interconnection obligations of CMRS licensees**
The FCC issued a Notice of Inquiry as part of docket number **94-54** in June, 1994. In April, 1995, the Commission issued a Notice of Proposed Rule Making (NPRM) in which it tentatively concluded that it was premature to impose rules requiring CMRS carriers to interconnect with other CMRS carriers.

- **The imposition of equal access obligations on CMRS licensees**
The FCC issued an NPRM, in docket number *94-54,* in which it tentatively concluded that cellular carriers should be required to give their customers a choice of long distance carriers. It also asked for comment on whether equal access rules should be imposed on other CMRS carriers. No order has been issued in this docket.

- **The reclassification of private radio licensees as CMRS**
The FCC has completed work on the technical and licensing rules that will apply to CMRS carriers, issuing a Third Report and Order and Fourth Report and Order in docket number 93-252 in early 1995. Among the issues addressed in this proceeding was the spectrum cap limiting CMRS carriers to 45 MHz of cellular, PCS, and SMR spectrum in any market.

- **Tariffing of local exchange carrier(LEC)/wireless interconnection**
The FCC issued an NPRM as part of docket number 94-54 in which it requested comment on whether LECs should be required to file tariffs specifying the rates charged for interconnection, or whether interconnection rates should be negotiated. No order has been issued in this docket.

- **Monitoring of competition in the cellular marketplace**
In the second report and order in docket 93-252, the FCC concluded that the cellular marketplace was not fully competitive and proposed collecting more information about competition in the cellular industry. The FCC has not acted on this issue.

- **Further forbearance from regulating certain types of CMRS carriers**
In the Second Report and Order in docket number 93-252, the FCC decided to forbear from applying some aspects of common carrier regulation to CMRS carriers. In docket number 94-33, the FCC issued an NPRM asking whether the regulation of some CMRS services should be relaxed further. No order has been issued in this docket.

- **Provision of dispatch service by CMRS carriers**
In March, 1995 the FCC issued an order permitting CMRS carriers to provide dispatch service.

SOURCE: Office of Technology Assessment, 1995.

regulations that will apply to CMRS providers, described in box 3-4.

CMRS carriers are less regulated than the wireline local exchange carriers because the local exchange carriers have a near-monopoly, while the wireless industry is competitive. There are two cellular carriers in every market, with the prospect of additional competition from SMR and PCS providers. In developing the new CMRS regulatory regime, Congress and the FCC determined that competition would, inmost cases, be sufficient to protect consumers and keep prices reasonable. Although CMRS providers will be regulated as common carriers, subject to Title II of the Communications Act, Congress allowed the FCC to "forbear" from regulating interstate rates and requiring the filing of tariffs.[27]

More importantly, Congress preempted state regulation of intrastate rates.[28] While many states had already concluded that the cellular industry was sufficiently competitive that rate regulation was unnecessary, a few states still regulated cellular. Under the new law, states will only be able to regulate the price of cellular or any other CMRS service if they can demonstrate to the FCC that market conditions have failed to guarantee just and reasonable rates.[29] Eight states petitioned the FCC for the right to continue regulating cellular service, arguing that the industry would not become truly competitive until the PCS and ESMR providers were operational.[30] However, the FCC rejected these petitions in May 1995, freeing all wireless carriers of rate regulation by states.[31]

Issues and Implications

By allocating a large amount of additional spectrum for wireless telephony and creating the new CMRS framework, Congress and the FCC have established the foundations for a successful industry. Given the growth rates in cellular subscribership and the continuing development of low-cost wireless technology, the future of the wireless industry appears bright. However, there are several issues that will have an impact on the cost, utility, and availability of wireless services.

Spectrum Allocation for Commercial Services

The recent allocation of 120 MHz to PCS more than triples the amount of spectrum allocated to terrestrial commercial mobile telephone services. Combined with new, more efficient digital technologies, the current spectrum allocation should be sufficient to meet the demand for the next several years, even if subscribership continues to grow at a high rate.[32] However, if data, image, or video applications become important components of the service mix of commercial mobile radio services, additional spectrum may have to be found sooner than expected.

Mobile satellite systems may have more pressing spectrum needs. Currently, the five proposed U.S. LEO systems are required to share 33 MHz in the 1610 to 1626.5 MHz and 2483.5 to 2500 MHz frequency bands. If demand for mobile satellite service matches the expectations of its proponents, this allocation will be insufficient. The National Telecommunications and Information Administration (NTIA) has estimated that an additional 60 MHz of spectrum may be required for mobile satellite services over the next decade.[33] However, it is particularly hard to judge how much spectrum should be allocated to mobile satellite services. As yet, no mobile satellite services are operating on a wide scale, and demand remains unproven. Because these systems will generally not compete in the same markets as terrestrial services, demand estimates for these in-

[27] FCC, op. cit., footnote 15, pp. 68-70.

[28] Public Law 103-66, section 6002(c)(2)(A).

[29] Communications Act of 1934, 47 U.S.C., Section 332(c)(3)(B).

[30] Arizona, California, Connecticut, Hawaii, Louisiana, New York, Ohio, and Wyoming. Wyoming subsequently withdrew its petition.

[31] Each state's petition was handled in a separate proceeding. See, for example, Federal Communications Commission, *Report and Order, Petition of the Connecticut Department Public Utility Control to Retain Regulatory Control of the Rates of Wholesale Cellular Service Providers in the State of Connecticut,* PR Docket 94-106, May 19, 1995.

[32] NTIA has forecast that only 33 MHz of additional spectrum will be required for two-way commercial mobile radio services over the next decade. National Telecommunications and Information Administration, *U.S. National Spectrum Requirements* (Washington, DC: 1995), p. 33.

[33] Ibid., p. 57.

dustries provide only a rough guide to the potential for satellite-delivered services.

With current technology, the most desirable frequency bands for most mobile services are those below 3 GHz. At higher frequencies, radio waves are more subject to scattering by buildings, trees, and other obstructions. In addition, radios that operate above 3 GHz are more expensive to build. Unfortunately, there is very little unused spectrum below 3 GHz. Any future expansion in mobile services will require either technological advances that permit the economical use of higher frequency bands, or the reallocation of spectrum from other services.

Reallocating spectrum can be time-consuming and costly. Potential new users need frequencies for their proposed services, but incumbent users usually resist being forced to move to other frequency bands. Policymakers and regulators often have a hard time balancing the two competing sets of interests. Much of the spectrum now allocated to terrestrial mobile services—PCS, cellular, and SMR, for example—was once used for other purposes. PCS will operate in a band that is now being used by fixed microwave services (who will have to move their operations to higher frequencies), while the cellular and SMR services were allocated spectrum that had been previously been used for broadcast television's channels 70 to 83. To meet potential future needs for even more mobile spectrum, one plan being considered is reallocation of television frequencies as part of the transition to Advanced Television (ATV). In the case of mobile satellite services, a complicating factor is that they require global coordination and approval. At the WARC-92 conference, for example, additional spectrum was allocated to mobile satellite service in the 1970 to 2010 Mhz and 2160 to 2200 MHz frequency bands. However, in the United States, part of this spectrum is allocated to broadcast auxiliary services, and in the rest of the world it will not be available until 2005.[34]

Spectrum Allocation for Public Safety

Federal, state, and local public safety agencies, such as police and fire departments, may also have significant near-term spectrum needs. In the Budget Reconciliation Act of 1993, Congress mandated that the FCC submit to Congress a study of current and future needs of state and local government public safety agencies through the year 2010, and develop a plan to ensure that adequate frequencies are made available to public safety licensees. In its report, the Commission declined to allocate additional spectrum, but outlined the steps it would take to gather additional information and procedures to respond to emergency needs.[35] The report has been criticized by the public safety community for underestimating the urgency of their needs.[36]

The demand for public safety wireless communications has grown considerably in recent years. Part of the growth in demand is due to an increase in the number of public safety personnel. But a more significant factor is that future public safety communications systems will not only be used for voice communications, but will also have to accommodate increased use of imaging for mobile transmission of fingerprints, warrants, and mug shots. Image communications requires much more spectrum than ordinary voice communications. In comments submitted to the FCC, the Association of Public Safety Communications Officials (APCO) estimated that between 6 and 18 MHz of additional spectrum would be needed for public safety voice communications by 2010, but that 75 MHz would be needed for the new "wideband" applications.[37]

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[34] OTA, op. cit., footnote 2.

[35] Federal Communications Commission, *Meeting State and Local Government Public Safety Agency Spectrum Needs Through the Year 2010*, Feb. 9, 1995.

[36] "Public Safety Officials Pan FCC's Spectrum Report," *Telecommunications Reports,* vol. 61, No. 7, Feb. 20, 1995.

[37] FCC, op. cit., footnote 35.

In allocating spectrum for public safety, several other issues have to be considered. First, public safety users are concerned that the use of auctions to assign commercial licenses will cause regulators to allocate any available spectrum to commercial services because an allocation to public safety would not provide revenues for the Treasury. Second, even if more spectrum is made available, there will be a continuing need for greater coordination of the radio systems operated by different public safety agencies. Currently, different public safety agencies use different frequency bands, preventing them from talking to each other in an emergency. A single frequency band, or a limited number of bands, could improve coordination of public safety activities.

The Development of Competition

Congress and the FCC are relying on competition, not regulation, to ensure that the price of mobile telephone service will be reasonable. The new PCS allocation will provide three to six new competitors to the cellular carriers, and the deployment of ESMR technology will provide additional competition. In the larger cities, there is the potential for robust competition on the basis of price and coverage. Most observers foresee four or five major competitors in the larger markets, with some niche players as well. However, many analysts believe that smaller cities and rural areas, where customers are fewer, will not be able to support as many competitors.

It should also be emphasized that most of the new PCS competitors will not have operational networks before the end of 1996. They will have to acquire hundreds of sites for base stations in each market and build their networks a time-consuming and expensive process. More importantly, they are unable to use some of the spectrum they have acquired at the auctions until its current occupants, fixed microwave users, are relocated to another band. Under the procedures established by the FCC, the PCS licensees will have to negotiate with the microwave licensees and pay the cost of their relocation. However, microwave licensees are not required to negotiate until 1997, and PCS licensees will not be able to request that the FCC involuntarily relocate a microwave user until 1998.

Finally, it is unclear how many competitors can be supported in the long term. The major players in the industry will have to spend billions of dollars to build out the new PCS networks. While the pioneers of cellular service had the luxury of building out their networks one cell site at a time, the PCS-band networks will have to enter the market with broad coverage and compete against established providers. The new PCS carriers, especially the licensees who qualified as small businesses or businesses headed by women or minorities, face a difficult challenge. Even the deep-pocketed cellular carriers, long distance carriers, and cable companies that are acquiring PCS licenses are risking large amounts of money on the assumption that demand will continue to grow and that they will survive potential price wars.

E-911 from Mobile Telephones

Emergency assistance available through 911 has been a significant driver of recent cellular telephone sales, and the industry promotes this with advertisements touting the benefits of mobile communications for personal safety and security. As a result, demand for 911 services from wireless users is growing with the rise in cellular subscribership. It has been estimated that 10 percent of 911 calls are from mobile users. The California Highway patrol reported that in January 1993 it fielded 80,000 emergency calls, of which 25,076 were from cellular telephones.[38]

However, while many wireless users can get access to 911 operators, they may not be able to fully

[38] Federal Communications Commission, *Notice of Proposed Rule Making, in the Matter of Revision of the Commission's Rule to Ensure Compatibility with Enhanced 911 Emergency Calling Systems,* FCC No. 94-237, CC Docket No. 94-102, RM- 8143, proposed rules, Sept. 19, 1994, para 9.

benefit from the Enhanced 911 or E-911 services available to wireline users. Systems equipped with special equipment providing E-911 services identify the location of the caller, even if he or she cannot speak. An Automatic Number Information database together with an Automatic Location Information database provide precise location information to the 911 public safety answering point (PSAP), from which the appropriate emergency service (police, fire, medical) is dispatched. About 90 percent of all wireline telephones have 911 services available, and of these about 76 percent also have E-911 capabilities.

The location of a cellular telephone user, however, currently cannot be automatically determined because cellular phones—unlike their wireline counterparts—are not linked to a specific location; they are designed to move around. As a result, unless the caller can provide clear and exact information or directions—which is often not the case—emergency assistance workers often do not know where to go when receiving a call from a mobile handset. It is unclear how many people understand that mobile phones do not offer the exact same services available from a wireline telephone. Some public safety officials believe that failing to integrate wireless systems into the E-911 framework undermines the $2 to $3 billion invested in 911 service since it was established as a nationwide goal 30 years ago.

To address this problem, the FCC has initiated a rulemaking to guide development of E-911 services and to ensure that location information will be available from all phones.[39] There are a number of technologies that may be useful in providing better location information, such as use of triangulation; Global Positioning Satellite (GPS) or LORAN systems; signal strength, angle and/or time delay measurements; antenna and cell site sectorization; and time synchronization.[40] Each system has its strengths and weaknesses, and the FCC has invited comments on the technical, performance, and cost considerations of each of the candidate technologies, but appears inclined to set performance rather than technology standards for achieving accurate location identification. This proceeding has resulted in substantial debate about the importance of accurate location information technologies for wireless systems.

Other Issues

In addition to the issues discussed above, there are a number of critical issues that will affect how new and existing wireless voice technologies will be integrated into the NII and what effects and implications ubiquitous mobile services may have for individuals and businesses. These issues are only briefly discussed here, but are analyzed in more detail in later chapters.

Standards

For the first generation of cellular technology, the FCC specified a standard technology (AMPS) that had to be used by all carriers. This guaranteed that every cellular phone would work anywhere in the nation. But for digital cellular and PCS, the FCC has refrained from picking a standard. Industry standards committees have been unable to agree on a single standard, in part because manufacturers have an incentive to promote their own technology as a standard. Because there is no standard, each network operator will have to choose from among the contending digital technologies. There is considerable concern that different technologies will be deployed, making roaming impossible. These issues are discussed in detail in chapter 6.

Interconnection to local exchange carriers

The interconnection of wireless and wireline networks allows their users to call each other. FCC

[39] Ibid.

[40] These technologies were reviewed in C. J. Driscoll & Associates, "Survey of Location Technologies to Support Mobile 9-1-1," report prepared for California Department of General Services, Telecommunications Division and the Association of Public Safety Communications Officials, ed. 1.0, July 1994.

rules require that local exchange carriers (LECs) allow wireless carriers to interconnect with their network. But wireless carriers have to pay LECs a fee for every minute of traffic. In the past, state regulators have allowed these interconnection charges to be significantly above cost to provide additional revenues that support the LEC's low residential rates. The high cost of interconnection is becoming an increasingly important issue because it raises the price of wireless service. These issues are discussed in more detail in chapter 7.

Interconnection obligations of wireless carriers

Because LECs have a monopoly in their market, they are required to interconnect with wireless carriers, long distance carriers, and, increasingly, wireline local exchange competitors. Wireless carriers, on the other hand, do not control a bottleneck—there are at least two competitors in each market, with more to come. Therefore, they have not been required to interconnect with other wireless carriers or with all long distance carriers. For example, the FCC does not require wireless carriers to give their customers a choice of long distance carrier. An issue of growing importance is whether the interconnection obligations of wireless carriers should continue to be minimal, or if they should be modeled on those of the LECs. For further discussion, see chapter 7.

Local restrictions on antenna siting

A cell site consists of base station equipment and an antenna mounted on a building or tower. The cellular carriers have deployed about 18,000 cell sites to date, and it is expected that the wireless industry will have to deploy an additional 100,000 cell sites over the next decade. Some communities, however, are becoming concerned about possible health effects from electromagnetic radiation and the aesthetics of the towers. Increasingly, zoning regulations and other ordinances are being used to limit or halt the construction of new towers. The wireless industry contends that such restrictions will hamper their efforts to provide ubiquitous wireless service, and has petitioned the FCC to preempt all local restrictions on antenna siting. Zoning issues are discussed in more detail in chapter 8.

Privacy and security

The issues surrounding the confidentiality and security of wireless communications will become a more important issue as more consumers and businesses begin to use mobile/portable devices. Already, eavesdropping is a concern to many individuals and businesses who fear that important or sensitive personal or business information may fall into the wrong hands. Fraudulent use of wireless telephones is a particularly difficult problem, costing the industry and consumers an estimated $480 million a year. Finally, the use of wireless devices also raises questions related to the location of the user. Wireless technologies can be used to track people and things, but may also be used to hide ones' location. These issues are discussed in chapter 10.

Health effects

One of the most controversial issues surrounding the widespread use of wireless technologies involves any possible health effects caused by either the devices (cellular telephones, for example) or the transmitting antennas. Although research has been conducted, it has not been conclusive—it is not yet possible to say with certainty whether the devices/antennas do or do not pose a risk to human health or how serious any risk may be. In the face of this uncertainty, some researchers and members of the public believe that the safest course is to redesign, restrict, or even ban the use of wireless systems, while the industry believes it should be allowed to pursue its plans until there is convincing evidence that health problems are likely. This issue is intensely polarized and is already being played out in battles over cellular/PCS antenna siting and local zoning (see above). It is likely to become a more important political issue as citizens raise the issue with state and federal policymakers and regulators. This controversy is discussed in chapter 11.

Interference between devices

As the number of wireless devices used by consumers and businesses increases, there is a likelihood that interference will increase. Radio devices can cause interference to other wireless communication systems or to some electronic devices, giving rise to poor quality communications or malfunctions. Cellular phones, for example, may interfere with aircraft navigation systems and some medical equipment, including monitoring devices, pacemakers, and hearing aids. Electronic equipment, such as a computer, can also interfere with wireless communications unless it is properly shielded. These issues are discussed in chapter 12.

FIXED WIRELESS TECHNOLOGIES

In the United States, telephone service to houses and other fixed locations is generally provided over copper *loops* that run between the telephone company's *central office* and the customer's premises. But fixed service can also be provided with wireless technologies (see figure 3-2). Instead of being transmitted through copper wires, voice signals are transmitted from a radio tower or satellite to an antenna on the outside of the home. In the past, wireless was more expensive than copper, and would have required a prohibitive amount of spectrum to serve a large number of households. However, today's wireless technologies may be able to serve fixed users more efficiently. Spectrum allocations and current regulatory uncertainty, however, present obstacles to the widespread use of fixed wireless.

Services and Users

One reason for the growing interest in "wireless local loops" is that they may now be comparable in cost to copper loops, due to the development of new spectrum-efficient technologies. In addition, wireless local loops allow telephone service to be rolled out quickly. Service can be provided to thousands of users as soon as the base stations are in place, without the need to install copper loops to each household. For this reason, wireless is now the technology of choice in developing countries that have little or no telephone service.[41]

Reducing the Cost of Telephone Service

In the United States, fixed wireless systems may be able to provide lower cost telephone service in some, especially rural, areas. One of the characteristics of wireline technology is that the cost to serve a household depends on its distance from the central office. It is much more expensive to provide telephone service in sparsely populated rural areas—where homes are typically far from the central office—than in cities. Wireless, on the other hand, has a cost structure that is largely distance-independent. The cost to serve a household is much the same whether it is close to the transmitter or far away.[42] In addition, radio waves can cross canyons or other difficult terrain that rule out wireline telephone service or make it extremely expensive.

Recognizing that wireless could reduce the cost of rural telephone service or provide it to unserved households, the FCC created a service called Basic Exchange Telecommunications Radio Service (BETRS) in 1988.[43] BETRS allows telephone companies to use a limited number of frequencies in the 450 MHz band to provide fixed wireless services in rural areas. Currently, no more than a few thousand households are served by wireless due to the small amount of available spectrum and the high cost of early BETRS equipment. However, with advances in technology, wireless may soon play a key role in delivering service to rural areas.

Wireless could also be used in suburban or urban areas. Carriers would like to take advantage of

[41] Terry Sweeney, "Lenders Backing Wireless Loops," *CommunicationsWeek International*, Dec. 12, 1994, p. 3.

[42] In the most extreme cases, even terrestrial wireless may be too expensive and satellite services may be used.

[43] Federal Communications Commission, *Report and Order, Basic Exchange Telecommunications Radio Service*, CC Docket No. 86-495, 3 FCC Rcd 215 (1988).

lower installation costs, reduced maintenance costs, and faster deployment of service in new housing developments.[44] In some cases, suburban areas are growing so quickly that the demands cannot be met with the existing network.[45] Even where wireline facilities exist, wireless may provide a less expensive solution if the copper loop is deteriorating and is affecting the reliability of telephone service. Furthermore, by using wireless loop technology, telephone companies would no longer have to dig up established yards and streets to replace facilities.

Local Exchange Competition

For many years, the expense of duplicating the incumbent's copper loop was seen as evidence that the local exchange market was a natural monopoly. Today, regulators who are trying to facilitate competitive entry have had to require the LEC to *unbundle* its network, allowing competitors to connect their switch to the existing loops. Only the cable companies, who already have a wire to many homes, can easily contemplate entering the local exchange market with wireline technologies.

Wireless technology may provide an alternative that will allow new local exchange competitors to enter the market. With wireless, a new entrant does not have to install a copper wire to each customer. Instead, it can deploy enough base stations to provide telephone service to every household in a city. This strategy would be especially attractive for long distance carriers, cellular carriers, and other companies that already have switches or other infrastructure in place. Cable companies, for example, could install base stations at various points on their network in order to provide local telephone service to a neighborhood. The cable network would be used to connect the base stations to a switch at the cable headend.

Technologies

In most of the world, the equipment used in wireless local loop applications is much the same as that used for mobile services. In some cases, mobile network operators use excess capacity to provide service to fixed users as well. In other cases, a modified version of mobile network equipment is deployed specifically for use in fixed applications. The major difference between fixed and mobile systems is that a fixed system does not require handoff capabilities. These modified cellular systems have been successfully deployed in local loop applications throughout Central Europe, in developing countries, and in other parts of the world where there is little or no wireline infrastructure.

In the United States, most of the wireless local loops are based on a technology specifically developed for use in the BETRS service in the 450 MHz band. However, newer wireless local loop technologies are being developed for use in the new 2 GHz PCS band. These "low-tier" wireless systems would provide service to fixed users, and would also allow limited mobility in the neighborhood around the user's home. Hand-offs between cells would be supported at walking speeds, but not at vehicular speeds. These low-mobility systems generally offer voice quality and data transmission capabilities that match or surpass those of a copper loop.

In suburban or urban areas, wireless local loop systems would consist of many "radio ports" or base stations mounted on telephone poles or street lights. Each radio port would serve an area with a radius of about 1,000 feet, which would allow each port to serve 35 to 40 homes.[46] Because it is difficult for radio waves to penetrate the walls of buildings, antennas would be mounted on the outside of customers' homes. The antennas are then connected by a wire to a phone inside the house. In

[44] See comments of Southwestern Bell (now SBC) in Federal Communications Commission, *First Report and Order, Allocation of Spectrum Below 5 GHz Transferred From Federal Government Use*, ET Docket 94-32 (1995).

[45] See comments of US West, ibid.

[46] Southwestern Bell comments, op. cit., footnote 44.

rural areas, where homes are further apart, more powerful transmitters are used and the antenna is mounted higher, allowing the signal to travel several miles to the customer's home.

Regulation

In most states, fixed wireless service can only be provided by the incumbent, monopoly, local exchange carrier. The reason is that most state regulators have only allowed the monopoly telephone company to provide local exchange service. When the FCC created the BETRS service, it was careful to state that only the incumbent LEC or another carrier that had been certified by state regulators would be permitted to provide BETRS. The FCC also does not allow cellular, SMR, and PCS licensees to provide service to fixed users, except on an "incidental" or "ancillary" basis. If the FCC's rules had permitted these licensees to provide fixed service, this might have been seen as sanctioning local exchange competition.

Issues and Implications

Limited Spectrum

Despite the promise of wireless local loops, almost no spectrum has been allocated for this application. The only spectrum used for fixed wireless is the 26 frequencies assigned to BETRS in the 450 MHz band. These are allocated on a co-primary basis, and are only available in rural areas. The FCC rules allow cellular spectrum to be used for BETRS, under certain circumstances, but, in practice, only the 450 MHz band has been used. LECs have been asking the FCC to allocate additional spectrum for fixed wireless, claiming that the small amount of spectrum available has limited wireless local loops to niche applications and prevented their use on a wider scale.[47]

Because of the limited amount of spectrum allocated specifically to fixed wireless applications, the FCC needs to clarify whether PCS or other mobile telephone spectrum can be used for wireless local loops. During the proceeding that created PCS, the FCC emphasized that the new spectrum was to be used for mobile services.[48] The FCC has since indicated that, in certain cases, it would be open to waiver requests from operators seeking to offer a fixed service with PCS spectrum.[49] However, this position was stated only in passing in an unrelated proceeding, and may only apply to rural areas.

Local Loop Competition

Many of the state rules limiting local exchange competition are gradually being dismantled. Moreover, legislation currently being debated in Congress would preempt state restrictions on entry by local exchange competitors. Many of these competitors are considering wireless as a vehicle to enter the market. However, because the FCC's rules on fixed PCS are unclear, it is uncertain whether a cable company could use a PCS license to compete with the LEC. This is another reason why FCC policies regarding the provision of fixed service by PCS, cellular, and SMR carriers need to be revisited.

Universal Service

Fixed wireless service may be able to advance the goal of universal service in the emerging NII. For many years, telephone penetration rates in rural areas lagged behind those in the cities. To promote universal service, regulators established a variety of mechanisms to direct billions of dollars in subsidies from low-cost urban users to high-cost rural users. This subsidy flow is now being threatened by the transition to a more competitive industry in

[47] United States Telephone Association comments, op. cit., footnote 44.

[48] "In ... allowing fixed use of PCS spectrum only on ancillary basis to the mobile service, we note that there is only a limited amount of spectrum available to meet the primary purpose of serving people on the move." FCC, op. cit., footnote 12, at 7712.

[49] FCC, op. cit., footnote 44, para. 20.

which prices are expected to move closer to cost. Wireless may provide a way to lower the cost of providing rural telephone service, making it affordable even if subsidies are reduced. The relationship between wireless and universal service is discussed further in chapter 9.