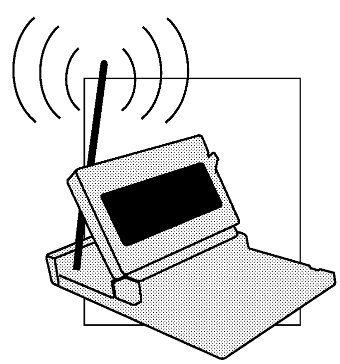
Wireless Data 4

The term *wireless data* describes a wide array of radio-based systems and services centered around pagers, portable computers, personal digital assistants (PDAs), and specialized applications for business. These wireless technologies enable users, who range from mobile professionals, to delivery drivers, and to factory and office workers to exchange electronic mail, send and retrieve documents, and query databases—all without plugging into a wire-based network. To date, however, growth in wireless data services has been low. Applications have been slow to develop, current speeds and capabilities cannot match those of wired services, and prices have been high. Like developments in other wireless technologies, there is great uncertainty regarding what applications the mass market wants, what it is willing to pay for, and what types of devices will match user needs.[1] Before the potential for wireless data services can be realized, service providers and manufacturers will have to overcome a number of technical, economic, and consumer-knowledge obstacles.



FINDINGS

- **The wireless data industry is at a nascent stage. Wireless data applications and systems will continue to grow, but at a slower pace than most analysts predict.** The acceptance

[1]Ken Dulaney, "Mobile Computing—Mobilizing the Organization," materials provided at Gartner Group presentation at the World Bank, Washington, DC, Feb. 10, 1994. Dulaney cites the example of Apple's Newton as a product that did not have a clear market or purpose, hence its low sales. He also notes that questions surrounding the ergonomics of portable computing devices—keypad and screen size, interface technologies, and capabilities—will only become clearer as users actually start to buy machines.

of wireless data by consumers and the general business market may be much lower than expected, especially in the short term. To date, use of wireless data technologies and systems remains concentrated in a small subset of business users—primarily in the fields of trucking, public safety, field service, and (taxi and courier) dispatch services. Current estimates of the total number of mobile data users range from 275,000 to 600,000.[2] Residential consumers, however, make little use of most wireless data communication technologies, and the prospects for significant growth in the consumer market are highly speculative and long term. Users have just begun to see the benefits wireless data can offer.

Despite this slow start, most industry analysts still expect wireless data to be one of the fastest growing sectors of the wireless industry. Applications and services are improving, and a host of new wireless data systems are expected to be introduced within the next five years. Some analysts predict the use of wireless data will grow as much as 30 percent per year, and many expect this growth to accelerate over the next decade.[3] OTA believes, however, that actual growth rates will be lower due to uncertain demand and technical difficulties in integrating wireless and wireline data networks and applications.

- **Technical challenges will continue to slow industry growth, but most analysts believe the problems will be solved as the technologies and the industry naturally mature**. Wireless data services lag those offered on wire-based networks, including the public telephone network and public/private computer networks, in many respects. Current speeds offered over wireless networks, for example, are usually substantially less than those available using wireline technologies, and it is unclear how advanced networking applications and protocols, such as Asynchronous Transfer Mode (ATM), will be adapted for use in a wireless environment.

Interoperability between wireline and wireless networks and services is a continuing problem. Services and applications designed for wired media work less well (and sometimes not at all) using the often-noisy and congested airwaves. Interoperability problems also result from wireline data communication standards and protocols that generally have not incorporated wireless features and requirements. Finally, the multitude of new wireless data companies that has sprung up has also led to many companies selling proprietary products and services that do not work together. Companies have been started that integrate wireless services, and software is being developed that attempts to mask as many of the differences as possible.

Fundamentally, these problems exist because the development of wireless data technology is still in its early stages, but they also reflect frequency allocations that were made based on past applications—when needs and spectrum requirements were lower. The federal government has recently allocated more spectrum to wireless data services, and private companies are working to improve their products by making them easier to use and more interoperable with existing wireline networks and services.

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[2] For individual services, estimates of subscribership vary, and, in most cases, are closely guarded. Some analysts suggest, for example, that RadioMail has only 1,000 paying customers, Ram Mobile Data between 3,000 and 15,000, and Ardis some 50,000, but with flat growth. "RadioMail Slashes Mobidems to $199," *Mobile Data Report*, vol. 6, No. 7, Apr. 11, 1994, p. 4. David Strom, consultant, presentation to OTA, Oct. 10, 1994.

[3] BellSouth, for example, predicts that 33 percent of its wireless revenues will be from data and that 25 million Americans will use wireless data services. BIS Strategic Decisions predicts wireless data revenues will be $10 billion/year by 2000. Andrew Kupfer, "Look, Ma! No Wires!" *Fortune*, Dec. 13, 1993, p. 147. Datacomm Research predicts the value of mobile hardware, software, and services will grow from $450 million in 1992 to $3.7 billion by the year 2002. Datacomm Research, *Portable Computers and Wireless Communications* (Wilmette, Illinois, 1993).

WIRELESS DATA SERVICES

Applications

Wireless data services use a mix of terrestrial and satellite-based technologies to meet a wide variety of local (in-building or campus settings), metropolitan, regional, national, and international communication needs. Most often, wireless data systems are designed to serve user needs for mobility or portability—*mobile data* is a widely used term—but many mobile systems and applications can also serve the data communication needs of users who do not move about (*fixed* users).[4] A number of wireless data applications, in fact, are being designed with fixed users in mind.

Traditionally, wireless data applications and services have been concentrated primarily in a few narrowly defined, *vertical*, business markets, including:

- *Field service* (dispatch, sales, repair, parts ordering, work order processing). Field technicians rely on wireless communication systems to get their next assignment, order parts, and check customer histories and accounts.
- *Fleet management* (dispatch, parcel tracking, vehicle location, and security). Wireless services are heavily targeted to trucking and other transportation industries. Wireless systems allow companies to dispatch trucks faster and more efficiently, track cargo, locate trucks, plan routes, and find stolen vehicles and merchandise.
- *Messaging* (paging, e-mail, short messages). Wireless systems also allow remote workers to stay in touch. A regional manager can be contacted at any store, sales personnel can be sent updated product information, and doctors can be paged for emergencies.

For the past decade, the use of these services has been limited to a small group of business users with high mobility and connectivity needs—those who could afford the high prices of equipment and service. Package delivery companies such as UPS and Federal Express, for example, rely on wireless data to keep up-to-the-minute track of parcels and for dispatch services (see box 4-1).

Today, however, the kinds of people and companies who use wireless data products are changing and expanding. As the United States has moved into a more competitive international environment and a more service- and information-based economy, the use of computers in the workplace has increased. In addition, more workers are getting out of the office—but even within the office or factory setting, the value of being mobile (but in touch) is being recognized (see box 4-2). These changes are beginning to affect the consumer mass market and the more general, *horizontal*, business market for wireless data products and services.

Moving from specific (and specialized) applications to products designed for the general user, however, is proving difficult. Services designed for one company often do not translate well to another with different needs and expectations. However, some general applications have been identified, including computer network extension, Internet access, wireline replacement (point-of-sale terminals, alarm monitoring), personal services (computer services, online services, and other information services), and other data applications, such as medical monitoring equip-

[4] As noted in chapter 1, fixed use can be thought of as a subset of mobile use. Cellular phones, for example, work just as well (sometimes better) when one is standing still as when one is driving or walking. Intuitively, if a system can serve mobile users it can usually serve fixed users as well. Although some engineering concerns (power level, building penetration) may be different, in many cases the same system can serve both types of users.

BOX 4-1: United Parcel Service's Use of Cellular Technology

In 1992 United Parcel Service (UPS) began developing a nationwide, real-time, package tracking system, combining UPSnet—UPS's existing wire-based network-with cellular technology. To provide this service, UPS had to stitch together a network of over 70 large and small cellular carriers, including GTE Mobile Communications, AirTouch (formerly PacTel Cellular), McCaw Cellular, and SouthWestern Bell Mobile Systems. These companies also arranged to provide UPS with a single point of billing for air time. The project involved technical as well as logistical challenges for UPS, the cellular industry, and equipment manufacturers, In February 1993 UPS initiated the new service it calls TotalTrack.

When delivering a package, UPS drivers use a device called a DIAD (Delivery Information Acquisition Device) to scan the bar codes on the package's label. When the driver returns to the truck, he inserts the DIAD into the DIAD Vehicle Adapter (DVA). The DVA transfers the package information from the DIAD and transmits it to a cellular telephone tower via an in-vehicle cellular modem. The data are then routed through the cellular system to the wireline UPSnet, and on to the UPS Data Center in New Jersey. Here, package information is stored in a database where it can be accessed by a UPS customer service representative.

By implementing the TotalTrack system using the U.S. cellular infrastructure, UPS has been able to keep pace with Federal Express, which in the 1970s and 1980s built their own private wireless data network to provide real-time package tracking. On an average day, UPS will track roughly 6.3 million packages with TotalTrack, moving about 290 million bytes of data over the cellular network. This utilization of the current U.S. wireless infrastructure enabled UPS to meet the growing demands of its clients.

SOURCE: Office of Technology Assessment, 1995.

ment. At the leading edge, videoconferencing and video telephony products are being developed for laptop computers.[5]

Finally, an increasing number of wireless data applications will not involve people at all. Systems are being developed to locate stolen cars, track individual pieces of cargo on trucks and trains, and remotely monitor environmental conditions (tides, wind, snowfall) and industrial operations such as natural gas/oil wells or pipelines. These systems give companies more immediate information and closer control over their operations in locations where wireline technologies either will not work or are impractical.

As the needs of wireless data users become better defined, new technologies and applications will be deployed. Service providers and equipment manufacturers have entered a period of innovation and uncertainty as they seek to (re)design products and applications to appeal to a wider audience. The next several years are likely to be characterized by rapid product turnover, slim margins, and consumer confusion. The technologies and services that succeed and those that do not will only be determined as users buy, and the market reacts.

▮ Factors Driving Demand

The most important factors fueling the demand for wireless, especially mobile, data communications services are: 1) the dramatic increase in sales of portable computers; 2) a growing familiarity and use of computer networks; and 3) a rising expectation of being able to access information anywhere,

[5] Current systems use telephone lines and V.34 (28.8 kbps) modems to deliver video at 7 to 10 frames per second (normal video runs at 30 fps), and cost from $1,000 to $1,500. The Personal Conferencing Specification now being developed will offer a standard for videoconferencing.

BOX 4-2: Wireless Technology in Restaurants

To speed order processing and improve customer service, some restaurants are implementing wireless technologies that allow wait staff to send customer orders directly from the table to the kitchen or the bar. One such system, the Squirrel Restaurant Management System, uses Fujitsu palmtop computers with PC card radio modems, and allows wait staff to transmit orders, call up drink and menu inventory, and process credit cards—all from the customer's table.

This system uses frequencies in the unlicensed 902 to 928 Mhz band to transmit signals from the hand-held unit to a system base station. The system achieves a burst data rate of up to 242 kilobits per second and has a range of 300 feet indoors and 800 feet outdoors. The Fujitsu PoqetPad sells for $2,285, including the radio modem. Additional costs include the Squirrel Restaurant Management software package and the restaurant base stations, each of which can accommodate five hand-held units.

In addition to speeding the delivery of the customer's order, such systems have enhanced accounting processes in many restaurants. Prior to implementing such a system, restaurant management would have to go through every order slip to track the number of salads, bottles of wine, etc. they had sold in a day/week/year. With the automated system, restaurants can have the wireless device send one copy of the order to a printer in the kitchen, and one to a main computer which keeps records of the sales. This makes tracking inventory and checking employee theft much simpler for restaurant accounting offices.

Although increasingly popular, these systems have encountered some problems. For example, one restaurant which implemented a wireless ordering system found that, without extensive training, wait staff spent too much time looking at the hand-held device while at the customer's table, and not enough time talking with the customer.

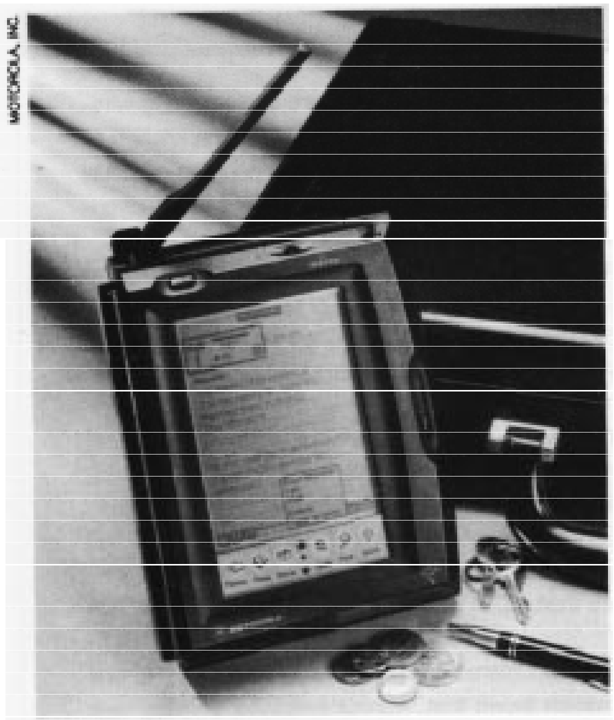
SOURCE: Jeff Tingley, "Wireless Pen Computing Serves Restaurant Industry," *Wireless for the Corporate* User, vol. 3 No. 1, 1994, p. 52.

anytime.[6] Today, worldwide notebook computer sales total almost 8 million units, accounting for 17 percent of the market for personal computers (see figure 4-1).[7] By 1998, at least one company predicts that sales of notebook computers will capture 22 percent of the total market. These figures suggest that workers in many jobs and who exhibit varying levels of mobility are using portable computers—no longer will they be confined to traveling professionals and executives. Most industry observers believe that the latent demand for mobile/portable computing is enormous, and that the development of mobile computing applications and software will lead to a corresponding increase in the demand for wireless connectivity (see box 4-3). This may be a reflection of the same trend that is fueling increasing cellular phone subscriptions by small businesses and even mass market consumers—the increasing desire and/or need to be connected to family, friends, the office, customers, or suppliers.

At the broadest level, wireless data applications are being driven by the increasing demands for mobility and by a need to access information immediately from any location. Almost 50 million workers have jobs that can be classified as mobile in some way (see chapter 2). For some, mobility is an inherent part of the job---a supervisor on a fac-

[6] Decision Resources, "Wireless Data Communications: Scenarios for Success," written by Clifford Bean of Arthur D. Little, Inc., cited in *Mobile Sate/life News, vol. 5, No. 18,* Sept. 15,1993, p. 4. For a discussion of the trends affecting the mobile computing industry, see Dulaney, op. cit., footnote 1.

[7] Paul Taylor, "Small, Light—and Powerful," *Financial Times, May 3.1995,* p. 5.



Personal digital assistants (PDAs) allow users to take many of the functions of their office with them when they travel. This unit combines pen based computing with wireless electronic mail and fax capabilities.

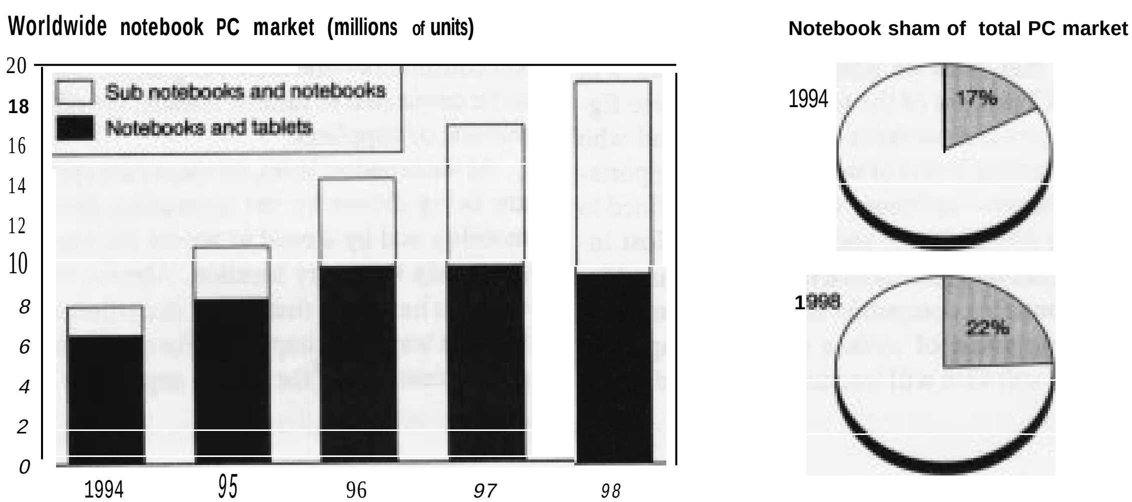
tory floor, a sales representative with a large multistate territory, or a repair technician working in a metropolitan area. These people need to be in touch with colleagues, customers, and suppliers; access company files; and transmit status reports and updated information. Wired networks may not always be easily accessible or convenient.

For other workers, mobility is only an occasional part of the job. Professionals and white-collar workers often use computers and computer networks in their offices, but when they travel-to visit clients, attend a conference, or take a vacation-these resources stay behind. Increasingly, however, users are demanding access to the same capabilities when they travel as they have in their offices, including electronic mail (one of the most common uses of mobile data services), remote file access, and fax.

WIRELESS DATA SYSTEMS

The following sections describe the various wireless data systems according to the character of the information sent (one-way or two-way) as well as the distinctions created by past regulatory and

FIGURE 4-1: Worldwide Notebook PC M



SOURCE: Ostaquest.

BOX 4-3: Wireless Data Devices and Products

Persona/ Digital Assistants. In the last two years, products have been introduced that combine many of the functions of a personal computer with wireless communication capabilities, including e-mail, paging, faxing, and remote data access. Some also enable users to place and receive phone calls. These personal digital assistants, PDAs, include Apple's Newton, Tandy's Zoomer, Motorola's Envoy, and IBM/BellSouth's Simon. Prices range from $200 to 1,500, depending on features. Some of these devices now use cellular or private data networks to allow users to communicate.

By most estimates, the introduction of PDAs has been a disappointment. Although experts disagree on which factor was most important in their low sales (poor handwriting recognition, slow processing speeds, etc.), nearly all agree that lack (and/or the high price) of communications software was an important contributing factor. Apple's Newton, for example, could communicate with other Newtons, but adding the capability to communicate with the "outside world" cost more. The fact that communications is viewed as so important in their demise, however, may mean that future PDAs (now sometimes called personal communicators) with standardized (and affordable) communications capabilities for messaging, faxing, e-mail, and perhaps even voice will be more successful.

Other factors contributing to the slow start of PDAs include unreliable (due to poor quality of links) transmission, and high prices both for the units themselves and transmission and data services. The machines also use competing operating systems: Apple and Sharp use Newton, Tandy/Casio use Zoomer (software by Geoworks), Microsoft (with Compaq) has developed Winpad , and General Magic, whose backers include Sony, Motorola, ATT and Apple, and Phillips, has developed software called Magic Cap,

Pen-based computing. In contrast to the disappointing sales of PDAs, pen-based computers serving specific business uses—field technicians, delivery personnel, insurance caseworkers—have been relatively successful. Each of these vertical applications, however, usually will not work with the others, Special software is customized for each user; with different capabilities and ways of entering information. Many applications require the individual user to fill an electronic "form" that is designed to capture specific kinds of information---census data for example—that would not transfer to other businesses.

PCMCIA cads. Personal Computer Memory Card International Association (PCMCIA) cards, also known as PC cards, are credit card-size devices that plug into a special slot in a (laptop) computer and perform a range of functions—modem, LAN access, hard drive, even GPS capabilities. In modem and LAN access applications, PC cards can use cables to connector radio waves. PC cards have had their share of problems—software incompatibilities, excessive memory and power requirements, and hardware connectivity-, but these problems seem to be subsiding as manufacturers and developers refine their designs and products.[1] However, wireless PC card adapters are still expensive; costing from $600 to $800 each.

SOURCE: Office of Technology Assessment, 1995.

[1] For an overview, see *PC Magazine,* Jan. 24, 1995, which has a series of articles on PCMCIA cards.

technological differences. Many of these systems can or will offer essentially the same service(s), but at different costs and with slightly different features and coverage areas.[8] Six types of systems are discussed: broadcast, two-way messaging, cellular data, wireless computing, unlicensed services, and satellite data services.

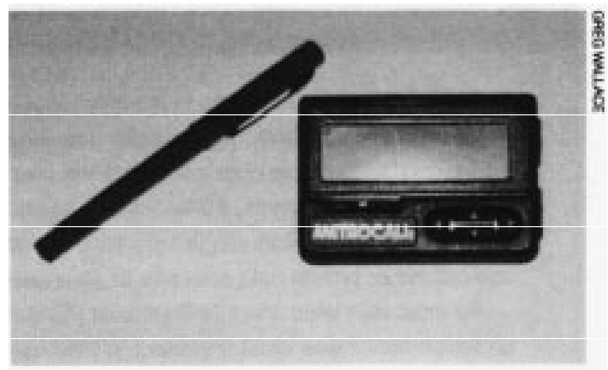
Broadcast Systems

Broadcast technologies are well suited to distributing data from one central location to many users (point-to-multipoint) in a given area, or to reach a user whose location is unknown or who is moving about. Although these technologies are one-way only, they often provide the lowest cost alternative for keeping in touch with family, business associates, and employees, and are increasingly being used by residential consumers as well as businesses.

Paging

Paging services represent the most basic form of w&l&s data delivery. Use of pagers has boomed in the past five years as prices have dropped 50 percent-to below $100 for basic models.[9] About 600 paging companies operate in the United States today, providing services to over 19 million people--making paging one of the most widely used wireless services. Paging systems provide service at all levels-local, regional, and national, and equipment and usage are usually quite inexpensive. Customers pay between $50 and $500 for a pager and between $15 and $100 per month for service.[10]

Paging companies provide a range of services. With tone-only pagers, the paging company transmits a signal to the user's pager, alerting them to call in for a message. With more advanced tone/voice or numeric pagers, the user receives a voice message or phone number on their pager. The most advanced units, alphanumeric pagers, can receive short text messages, e-mail (even from the Internet), voice mail notification, and information services such as traffic alerts or stock quotes. In 1993, numeric pagers accounted for 87 percent of the pagers in use, alphanumeric 7 percent, tone-only 4 percent, and tone/voice 2 percent (see figure 4-2).[11]



Pagers, such as this alphanumeric unit, have become one of the most popular means for people to stay in touch via wireless.

Paging companies are expanding their services to provide more sophisticated communication services. MobilComm, the country's second largest paging company, began sending messages to Newtons and other PDAs using a receiver that costs $200. Mtel is building a $150 million network that will allow users to acknowledge received pages beginning in 1995, and its Skytel service has already begun testing two-way communications. Recent Federal Communications Commission (FCC) auctions of narrowband personal communications service (narrowband PCS-see below) frequencies made additional spectrum available for advanced digital and two-way paging services. This new spectrum will en-

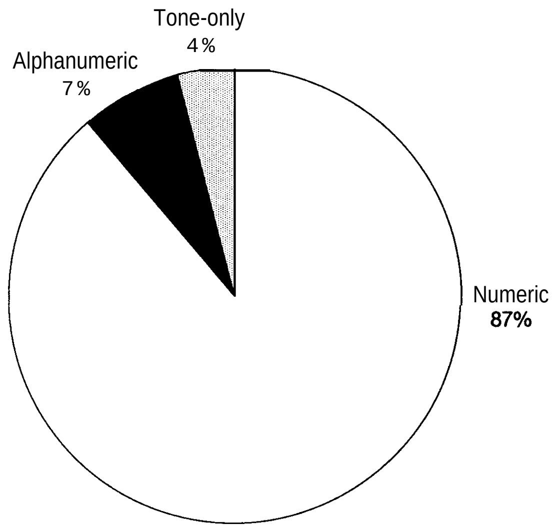
[8] For an overview of current products and services, see various articles in *Data Communications,* vol. 24, No. 4, Mar. 21, 1995.

[9] Lois Therrien, "Pagers Start to Deliver More than Phone Numbers," *Business Week,* Nov. 15,1993.

[10] David Strom,"Reality Check on Wireless Data Services," *Business Communications Review,* May 1994, pp. 62-66. See also Data Communications, op. cit., footnote *8.*

[11] EMCI, Inc., based on EMCI paging survey, January 1994.

FIGURE 4-2: Pagers in Use by Type, 1993



SOURCE: Office of Technology Assessment, 1995, based on data from EMCI, Inc.

able paging companies to offer a wide array of new information services, continuing the trend toward higher functionality.

By combining a computer or a PDA with a paging unit, users can receive data files, short messages, and other more advanced features. Some analysts expect that alphanumeric paging will become an integral part of portable computers before the end of the century, and that computer-based services will represent an increasing portion of the paging business.[12] In the future, paging devices may be reduced to a single computer chip and integrated into a wide range of computing and information devices. One idea now being developed would have the paging chip **be** unprogrammed when purchased, allowing the purchaser to call their preferred service provider that would then program the chip over the phone.[13]

Regardless of the type of service provided, all paging systems use similar technologies and architectures to deliver service (see figure 4-3).[14] When a caller wishes to send a message to a paging customer, he calls the paging company, which then encodes the message with the paging customer's "address," called a cap code, and broadcasts it.[15] The subscriber's pager receives the WUISIIIk-sion and alerts the user. To achieve the best possible coverage of an area, paging companies use a technique called ***simulcasting*** that transmits the same message from multiple transmitters at the same time. To extend the coverage of services, many companies establish agreements with other paging companies that allows their customers to use paging systems outside their home system. A few service providers have assembled nationwide networks using this approach. National paging services also use satellites to relay messages between local systems.[16] Because pagers are generally tuned to specific service providers, users cannot easily change carriers-unlike cellular phones, which can be easily reprogrammed.

Radio Broadcast

Traditional AM and FM radio broadcasters are exploring ways to deliver information services using their broadcasting facilities. Some are experimenting with Radio Data System (RDS) technology that will transmit additional information—such as song title and artist, the station's call letters, and music format information-along with

[12] The Gartner Group, for example, predicts that 50 percent of all palmtop computers will have paging capabilities built in by 1998. See also T. Garber, "Special Report,' 'Radio *Communications Report,* vol. 13, No. 10, May 23, 1994.

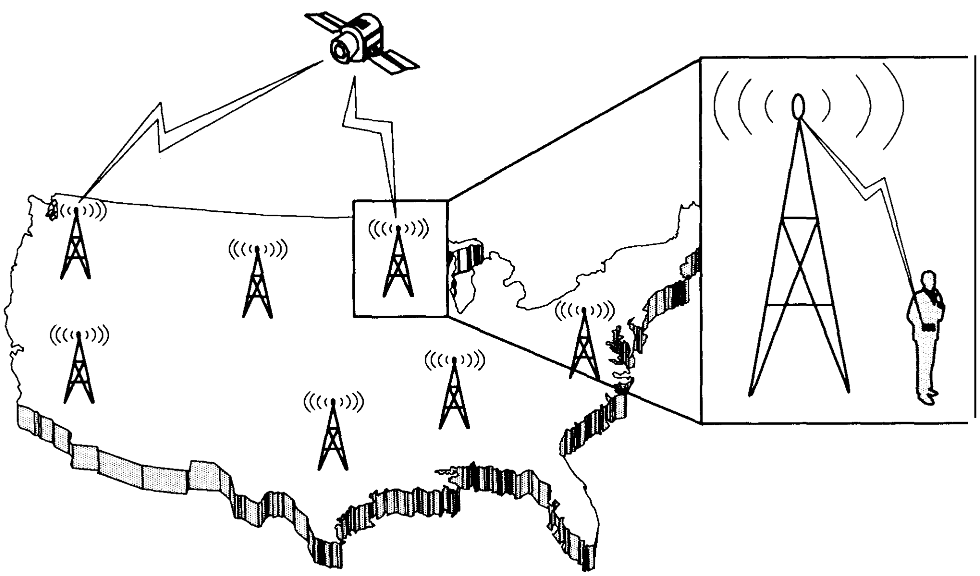
[13] Andrew M. Seybold, *Using Wireless Communications in Business (New* York, NY: Van Nostrand Reinhold, 1994).

[14] Paging companies are licensed in 25 kHz channels in four bands: Lowband, Highband, UHF, and 900 MHz. The recent Fcc Narrowband PCS auction made available 1,300 KHz of additional spectrum in three bands between 900 and 941 MHz.

[15] Alphanumeric pagers are an exception. A Computer with paging software and a modem, rather than just a telephone, is required to initiate an alphanumeric message. Telephone answering services (TAS) are available so that anyone with a telephone can call the TAS and leave a voice message with a representative, who then inputs the message through a computer to the paging company's encoding and controller station.

[16] D. Baker (ed.), *Comprehensive Guide to Paging* (Washington, DC: BIA Publications, Inc., 1992).

FIGURE 4-3: Generic Paging Syster



SOURCE: Office of Technology Assessment, 1995.

the regular programming.[17] Such systems have been used in Europe for many years, but the U.S. Radio Broadcast Data Service (RBDS) was only established in early 1993, and deployment of the technology has been extremely slow. By early 1994, some 100 stations were said to be using RBDS, but few RBDS-compatible radios are in use.[18]

Other radio data services being considered include travel advisories, local restaurant/hotel information, and advertising supplements. In FM radio, for example, broadcasters would like to use the FM subcarrier to transmit supplementary advertising information-school closings, stock quotes, and other information services--directly to personal computers.[19] Such systems have been tested, but most efforts are only in the conceptual stage. Standardized (receiving and processing) technology for consumers has not been developed, and systems are not expected to be ready for widespread deployment until late 1995 or 1996. Speeds up to 19.2 kilobits per second (kbps) are expected to be available, and, like other broadcasting applications, these types of services are expected to serve both mobile and fixed users.

Television Broadcast

Using their existing equipment, television broadcast systems are capable of transmitting data in several ways. Over the years, a number of at-

[17]The system uses a *subcarrier* that is broadcast alongside the main radio signal and allows data to be sent at about 1.2 kbps. It does not interfere with the main radio programming. Reportedly, a higher data-rate standard is being developed by the National Radio Systems Committee of the National Association of Broadcasters-perhaps ready by 1995— that would carry information at speeds up *to* 20 times the existing standard. Bennett Z. Kobb, *Spectrum Guide* (Falls Church, VA: New Signals Press, 1994), p. 29.

[18]John Gatski, "RDS/RBDS Slowly Gains Acceptance," *Radio World,* vol. 18, No. 4, Feb. 23, 1994.

[19]Paul Farhi, "EZ Communications Forms Unit to Develop Radio Technology," *The Washington Post,* Dec. 4, 1994, p. D4.

tempts have been made to develop *videotext* services that send data—including stock quotes, newspapers, and other local information—in the vertical blanking interval (VBI), the black stripe at the top/bottom of a television picture. To decode the data, users had to have a set-top box that would capture the information, store it, and display it. None of these experiments were commercially successful. The VBI can also, theoretically, be used for applications such as paging and updating retail information (stolen credit card lists, for example), but there has been little demand for these services from businesses and most broadcasters are not providing them.

Other methods for transmitting data are also being developed. Recently, one company has developed a proprietary system that transmits high-speed data using the whole broadcast signal without interfering with the regular programming.[20] Similar to the sideband broadcasting applications being developed for radio broadcasting, other applications are being developed that use television secondary audio (SA) channels.[21] One system currently being tested uses audio channels transmitted via satellite to deliver current weather information and emergency weather and environmental alerts to personal computers located around the country.

The industry is also working with new companies to provide Interactive Video Data Services (IVDS). These systems would allow viewers to respond to polls, order merchandise, and play along with game shows by using a remote control and a set-top box connected, via special IVDS frequencies, to a local control center. Frequencies for IVDS were auctioned by the FCC in 1994, but services have not yet been deployed because of problems with the technology and availability of equipment. In addition, a number of the IVDS auction winners defaulted on their bidding commitments.

Two factors will seriously limit the implementation of data systems by broadcasters in the short run. First, most of the services developed so far are fairly low bandwidth, and demand has historically been low. Second, these systems are based on the existing analog technology currently used by television broadcasters. They will most likely not work with the digital broadcasting systems now being developed (see chapter 5). Once digital broadcasting technologies are implemented, broadcasters hope to use at least some of their spectrum to provide various information services. The terms under which such uses will be allowed have been a contentious issue for policymakers. Legislation now being debated in Congress generally allows broadcasters to provide "ancillary or supplementary services," subject to various licensing restrictions and payment of fees.[22] The definition of an "ancillary or supplementary" service remains unclear, however, and what services will be allowed remains uncertain.

Two-Way Messaging

Two-way messaging services provide a variety of interactive low-speed data applications, and can serve fixed, portable, or mobile users. Many individuals use two-way services to send and receive electronic mail and access company data networks. Other services include remote meter reading, point-of-sale and credit card verification, and alarm monitoring. Some of these applications could be provided by wire-based systems, but the

[20]Presentation of Wave-Phore at the National Association of Broadcasters convention, Las Vegas, NV, April 1994.

[21]These channels are currently used to provide second-language translations for television programming, or, on some PBS stations, weather reports.

[22]U.S. Congress, Senate, *S. 652, Telecommunications Competition and Deregulation Act of 1995* (Washington, DC: U.S. Government Printing Office, 1995); U.S. Congress, House of Representatives, *H.R. 1555, Communications Act of 1995* (Washington, DC: U.S. Government Printing Office, 1995).

high cost of laying wire would likely be prohibitive, and, in many cases, it is easier to install a wireless system.

Packet Radio

The two-way data messaging industry is dominated by Ardis (backed by Motorola) and Ram Mobile Data (a joint venture of Ram Broadcasting and BellSouth Enterprises). These two providers offer specialized communication services primarily to companies, but are now trying to expand into more general markets (e.g., mobile professionals). Some analysts doubt that such a strategy will work, citing potential competition from both cellular carriers deploying cellular digital packet data (CDPD) and future narrowband PCS companies (see below).

Commercial messaging services are provided through terrestrial towers in each metropolitan area. Digital packet technology is used to send information over channels in the 800 MHz SMR frequency band. The Ram service is currently available in more than 250 metropolitan areas, while Ardis serves the nation's 400 largest metropolitan areas—coverage is not quite national. Both services are designed to deliver short (200 to 300 bytes) text messages, generally using specialized equipment. Ram operates at 8 kbps and Ardis is upgrading its network to offer speeds up to 19.2 kbps, but actual data throughput is usually about half these speeds. Each offers a range of pricing plans based on peak and off-peak times and different levels of use. Ram's prices range from $25 to $135 per month, and are based on the amount of data sent, while Ardis's range from $39 to $299 per month, and are based on the number of messages sent.[23]

Narrowband Personal Communications Service

In 1993 the FCC established a new category of wireless data services, narrowband PCS; allocated spectrum for it; and established the rules that would govern the systems' operations.[24] Following congressional mandates, in 1994 the FCC began auctioning narrowband PCS licenses. To date, 10 national and 30 regional licenses have been awarded; bringing in just over $1.1 billion.[25] A total of 3,554 licenses will be issued to companies that plan to offer new services as well as expand and augment existing networks and services. The first systems are expected to begin operation sometime in 1995.

The FCC defines narrowband PCS as a family of mobile and portable radio services that will provide a variety of advanced paging and messaging applications to individuals and businesses.[26] It promises low-cost, two-way data communication services that are expected to appeal initially to the traditional mobile data markets, such as field sales or (repair) service and fleet and courier dispatch.[27] Narrowband PCS licensees plan services that include: credit-card verification, locator services (for vehicle dispatch and tracking), voice paging, acknowledgment paging, and two-way exchange of short messages. These services will be delivered to user devices such as alphanumeric pagers,

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[23]Joseph Palenchar, "Will Cellular Packets Lead the Way in Wireless?" *Mobile Office*, July 1994; *Data Communications*, op. cit., footnote 8.

[24]The service was allocated 3 MHz of spectrum at 901 to 902 MHz, 930 to 931 MHz, and 940 to 941 MHz, of which 1 MHz was held for future uses. Federal Communications Commission, *Amendment of the Commission's Rules to Establish New Narrowband Personal Communications Services*, First Report and Order, Gen. Docket 90-314, 8 FCC Rcd 7162 (1993).

[25]Licenses were divided among four types of service areas: 492 Basic Trading Areas and 51 Major Trading Areas (as defined by Rand McNally), five regional licenses, and 11 national licenses. Six companies paid $617,006,674 for 10 national licenses: Airtouch Communications Inc., Bellsouth Wireless, Inc., Destineer Corp (MTel), McCaw Cellular Communications, Inc., Pagenet, and Pagemart. Six licenses were auctioned for each of the five regions, with bids totaling $488,772,800. Robin Gareiss, "PCS: Making Sense of the New Services," *Data Communications*, October 1994, p. 49.

[26]Federal Communication Commission, op. cit., footnote 24.

[27]Gareiss, op. cit., footnote 25.

computers equipped with radio modems, portable fax machines, and portable computers.

Like other new wireless systems and services, the costs of building the systems and the prices that will be charged are closely guarded by the companies involved. One company, Pagemart, estimates the cost of building their system is about $200 per subscriber—more than a traditional paging system, but significantly less than the $750 that cellular companies say they spend on building their systems.[28] Prices are still being determined, but are expected to be higher than traditional paging services, but less than other wireless data services such as Ardis/Ram, CDPD, or cellular.

Cellular Data

Cellular telephone systems can also be used to send data, and represent an alternative to packet radio networks and future narrowband PCS. Cellular data transmission allows users to do everything they can do with a regular wireline modem— connect to office LANs, send and receive electronic mail or text files, access online services, and browse the Internet. Speeds remain slow; and operation is not as reliable as a wired modem, but cellular systems are rolling out new digital data services that should improve performance.

Circuit-Switched Cellular Data

The traditional method for sending data over a cellular system is much the same as sending data from a computer using the telephone lines. A computer is connected to a radio modem that dials the phone number and makes the connection using regular cellular channels. Radio modems add features to compensate for the different transmission characteristics of the airwaves, which are more prone to noise and interference than the wireline network.[29]

Alternatively, using a regular wireline modem, a user can connect his or her computer directly to a cellular phone through a data connection (RJ-11 jack) built into the phone (not all phones have such connections). This method is often less reliable, however, because wireline modems are designed for landline use and may not be able handle the differences in cellular phone networks and calling procedures; the phone may disconnect during cellular hand-offs, for example.[30] Such problems, combined with the interference and noise common in cellular voice calls, make cellular data calls less reliable than those made through the public telephone network.[31] Maximum speed is theoretically 9.6 kbps, but actual speeds are usually lower—2.4 or 4.8 kbps.

Current circuit-switched analog data applications, which currently account for about 3 percent of total cellular traffic, may grow in the next several years, but in the longer term, they will be discontinued.[32] Cellular providers are now deploying digital data technologies that use their existing networks (CDPD-see below), and eventually, they will completely replace their analog service with new digital services (see chapter 3).

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[28]Ibid.

[29]Specially designed cellular modems offer advantages over regular landline modems for cellular use, but they generally require the same type of modem on both ends to work (a mobile worker with a cellular modem cannot just connect with anyone with a regular modem). To overcome this compatibility problem, some carriers have instituted modem *pools* that allow users with cellular modems to dial in to the pool and the carrier will serve as a go-between, translating the cellular modem signals into signals the modem being called can understand.

[30]Common cellular-network impairments include frequent cellular base-station hand-offs, dropouts, call interference,

fading, echo, and other types of signal distortions. These problems require signal conditioning techniques not implemented in traditional landline modems.

[31]Datacomm Research reports that "even with special 'cellular modems,' one can expect call attempts to fail anywhere from 20 to 50 percent of the time," op. cit, footnote 3, p. 23.

[32]Palenchar, op. cit., footnote 23.

Cellular Digital Packet Data

To overcome the limitations and high cost of circuit-switched cellular data, a group of cellular carriers began to develop an alternative data transmission system called cellular digital packet data (CDPD) in 1992. Standards were agreed to in mid-1993. CDPD radio modems transmit data by breaking the information into digital "packets" and sending them over vacant channels on existing analog cellular systems—no one channel is dedicated to one data "conversation" as in circuit-switched service.[33] Although CDPD was originally envisioned as a dynamic system in which vacant channels would be identified "on the fly," in practice, system operators have set aside a certain number of channels dedicated to CDPD use in order to improve performance. CDPD systems can transmit at speeds up to 19.2 kbps, but actual throughput is closer to 9.6 kbps because of error-correction features added to increase reliability.

CDPD services are being designed to support a wide range of data applications. In addition to the mobile services used by professionals and field technicians, CDPD is also being developed for some fixed location applications, such as vending machines and remote utility installations like natural gas wellheads. CDPD can be used like a regular wireline modem to remotely connect to LANs, access databases, and exchange files, but it is especially useful for applications characterized by short "bursty" data. CDPD systems have been designed to favor shorter transmissions (less than 600 words) and have been optimized for users who send and receive many short messages (500 characters, or 50 to 75 words)—credit-card verification, real estate transactions, emergency services, dispatch, fleet management, package delivery and tracking, telemetry, two-way paging, Internet access, and electronic mail.[34]

Service packages currently range from $11 to $139 per month, and, like Ram and Ardis, are usually based on varying levels of usage that allow users to match their usage to their budgets. Following the technology, pricing structures favor shorter communications. Messages of up to 1,000 characters, for example, may cost as little as $0.17.[35] CDPD is expected to be more cost-effective than circuit-switched data services for short communications, while circuit-switched may be preferred for larger file transfers.

For cellular system operators, CDPD offers an important benefit; it allows them to upgrade their data capabilities without replacing their existing analog cellular infrastructure (antennas, transmitters, frequencies), and with the addition of very little additional equipment. This "overlay" approach may allow CDPD services to be rolled out faster and at less cost than competing services that have to be built from scratch like some of the new narrowband PCS services.[36] CDPD also offers performance advantages over circuit-switched cellular data applications, including better error correction; improved reliability; faster speeds; more flexible functions, including multicasting; and potentially lower costs.

One important advantage that CDPD has over most other wireless data technologies (except satellite services) is coverage. The potentially wide availability of CDPD—cellular services are currently available to about 95 percent of the population—would give it a distinct edge over existing wireless services such as Ardis and Ram, which

[33]Data are NOT sent in between pauses in conversations, but in the time between different conversations. When a voice conversation is assigned to a channel currently being used for data, the system will automatically find another vacant channel and switch the data communication so that no interference occurs. This is called "channel hopping." Research indicates that an average channel is unused as much as 30 percent of the time. John Gallant, "The CDPD Network," *EDN*, Oct. 13, 1994.

[34]Ibid.

[35] "Sending the same message via circuit-switched cellular could cost more than four times that amount because carriers bill for air time in one-minute increments, even if a transmission takes only a few seconds." Palenchar, op. cit., footnote 23.

[36]Chris Pawlowski and Peter McConnell, "CDPD Air Interface Basics," *Telephony*, Dec. 5, 1994.

typically provide coverage only in metropolitan areas. The relatively small number of potential users outside those coverage areas, however, may mean that this advantage is important only for users who need very broad coverage, such as trucking or package delivery companies. The interoperability of CDPD, however, has not yet been proven. Only a few carriers have struck CDPD roaming agreements, and the technical ability to connect different CDPD systems is only now being tested—true nationwide roaming may be years away.

There is still a great deal of uncertainty over CDPD's role in data transmission and how successful it is likely to be. CDPD standards were set in 1993, but deployment of CDPD capabilities has fallen well behind initial expectations due to technical difficulties. By mid-1995, only 19 systems were offering service, and another 22 were planning to begin operation by the end of the year.[37] Some analysts see CDPD as little more than an interim service that few people or businesses will use. Others, including the consortium of cellular companies that developed CDPD, believe it is the answer to publicly accessible wireless data services.[38] At least one forecast estimates that there will be 1.6 million CDPD users by 1998.[39] Given the slow deployment of CDPD, it is still unclear how successful it will be, or whether it will be quickly superseded by advanced digital cellular data applications.

Digital Cellular Data

Once cellular carriers switch to digital formats—time division multiple access (TDMA) and code division multiple access (CDMA)—new data formats will also become available. The data portions of these overall standards are being developed, but have not yet been finished, and no commercial data services are being offered. Cellular digital data applications will be deployed after the voice applications, which are already starting to appear. In the first implementations of TDMA, for example, existing analog channels continue to be set aside for analog and CDPD modem communications.

By contrast, more than two dozen Global System for Mobile communications (GSM—see chapter 3) systems around the world have already begun to offer data services.[40] However, only a few vendors are making GSM data equipment, and services are usually limited to the home system—roaming is not yet possible due to the lack of roaming agreements for data applications. Individual networks also must be upgraded to provide data services. Finally, compared to other wireless services, such as the international affiliates of Ram Mobile, GSM data communications can be more expensive. Vendors and analysts expect these initial problems to be solved quickly as more GSM systems are deployed and more users subscribe.

Wireless Computing

The use of wireless technologies by computer users is one of the areas projected for the strongest growth over the next several years, and a good number of companies have targeted mobile or wireless computing as a potential market for various kinds of wireless information services. This section will concentrate on the use of portable computers for general computer tasks—word

[37]Robin Gareiss, "Wireless Data: More Than Wishful Thinking," *Data Communications*, op. cit., footnote 8.

[38]Consortium members include: Ameritech Mobile Communications, Inc., Bell Atlantic Mobile Systems, Inc., GTE Mobilenet, Inc., Contel Cellular, Inc., McCaw Cellular Communications, Inc., Nynex Mobile Communications, Pactel Cellular, and Southwestern Bell Mobile Systems. CDPD service and product providers have also formed the CDPD Forum, Inc., a trade association composed of more than 80 companies involved in CDPD that will continue work on stardardization and interoperability.

[39]Report by BIS Strategic Decisions, cited in Pat Blake, "Wireless Data: The Silent Revolution," *Telephony*, Dec. 5, 1994.

[40]The following material comes from Elke Gronert and Peter Heywood, "GSM: A Wireless Cure for Cross-Border Data Chaos," *Data Communications*, op. cit., footnote 8.

processing, file transfer, and remote connection to computer local area networks (LANs).

Device Connectivity

At the simplest end, products are being developed that allow users to link tirelessly with their desktop computers while they are near, but not in, their offices. These products respond to studies of mobility on the job that indicate that most of the time people are out of their offices, they are still close by. The machines have varying levels of intelligence and storage built in, but allow users to remotely access their desktop computer-to read electronic mail or use any applications. The systems require modems at both ends and have a range of about 500 feet. Remote devices cost about $1,400, while radio modems for the desktop range from $600 to $700.

In addition to these products, infrared technologies-like those used in television remote controls and other consumer electronics devices—are also being developed that would allow portable computers, printers, and PDAs to communicate directly with one another. Infrared technology allows the ad hoc creation of low-speed networks (maximum data rate is currently 115 kbps, but speeds up to 10 Mbps are being developed)---at a meeting, for example-and direct device-to-device communication. Most PDAs, for example, already have infrared technology built in so they can communicate with each other, and one analyst estimates that 90 percent of all personal computers will have this capability by 1997.[41] In the future, proponents expect many kinds of devices to incorporate infrared communications capabilities, including public phones, computer printers, cash registers, and fax machines.

The advantages to infrared technology is that it is inexpensive (around $3 to $5 to equip a computer with infrared, and $50 to $100 for an adapter, with prices expected to fall with increased volume), and potentially ubiquitous-companies from many countries have agreed to an international standard that will allow products to work around the world.[42] Computer hardware and software companies have already begun to build infrared communications capabilities into their products, and adapters that will connect to existing computers, printers, and telephones are expected to be on the market by mid 1995.[43] In the future, proponents expect infrared technologies to provide an inexpensive way to provide high-bandwidth communications over short distances---another way to access the resources of the NII.

Portable personal computer makers are beginning to integrate wireless data communications capabilities, including remote local area networking, into their products. Users will soon be able to wirelessly connect to their office LAN from almost any where.

Wireless Local Area Networks

LANs connect computers in a small area (in an office, for example) and allow them to share

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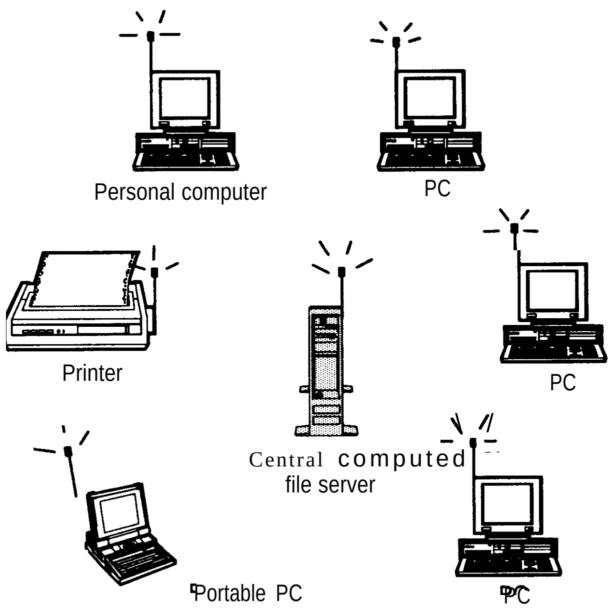
[41] Dulaney, op. cit., footnote 1.

[42] The Infrared Data Association, which is composed of over 70 companies in the field, announced a set of infrared data standards in early 1994. John Romano, "Infrared Boosts the 'Personal Area Network,'" *CeBIT News*, Mar. 21/22, 1994.

[43] Materials provided in a briefing to the Office of Technology Assessment by the Infrared Data Association, no date.

FIGURE 4-4: Generic Wireless LAN



SOURCE: Office of Technology Assessment, 1995.

memory, use a common printer, and exchange files and electronic mail (see figure 4-4). Wireless LANs substitute radio waves for the fiberoptic or coaxial cables that connect most wire-based LANs. A computer equipped with a radio modem links to a central computer, called a server, which is also equipped with a modem or modems. Most wireless LAN radio modems also support direct device-to-device communication separate from the server.

Wireless LANs were originally designed to substitute for wireline LANs; to be used where wires were either too costly to install or where added flexibility (to move computers easily and/ or quickly) was needed. For example, many older buildings are difficult to wire for computers (or even phone lines) because of their construction or the presence of hazardous materials such as asbestos. In these cases, wireless LANs may provide a cheaper solution. Box 4-4 compares wired and wireless LANs in school applications.

However, the market for such applications has not developed as expected. The primary problem, most analysts agree, is that wireless networks are significantly slower than wired LANs—1 to 2 Mbps on wireless versus 10 Mbps on most wired LANs. Wireless speeds are adequate for some applications---electronic mail and database queries, for example-but not for the higher-speed applications, such as image and graphics transfer, that are becoming increasingly popular. In addition, wireless LANs are often more expensive than their wired counterparts, with wireless modems costing up to $800 and access point equipment (that allows multiple computers to connect to the LAN remotely) costing up to $2,500 each.[44] As a result, wireless LANs have not proven popular simply as a replacement for wireline systems.

Currently, the wireless LAN industry is undergoing a transformation as vendors refine their products and marketing. Some see the concept of LAN extension—in-building mobility-or remote access to wired LANs as a more lucrative market. In fact, the market for wireless LANs has recently begun to improve. Commenters in a recent FCC proceeding provided sales figures demonstrating a rapidly expanding market for wireless LAN equipment—sales of $200 million for 1994 and expected sales as high as $2.5 billion by 1998.[45]

[44] By comparison, wired products cost from $150 to $500 for an adaptor and $500 to $1,500 for a multiple access hub. For a discussion of the speeds and prices of select systems, see David Newman and Kevin Tony, "Wireless LANs: How Far? How Fast?" *Data Communications,* op. cit., footnote 8.

[45] Federal Communications Commission, *Allocation of Spectrum Below 5 GHz Transferred from Federal Use,* First Report and Order and Second Notice of Proposed Rulemaking, ET Docket 94-32, released Feb. 17, 1995, para 33.

BOX 4-4—School Networking and Wireless Technologies

Schools and school districts nationwide have been struggling for years to upgrade their communication and computer networks to keep pace with the rest of society. Facing tight budgets, many have found it difficult to afford the major capital investment of wiring classrooms, installing local area networks (LANs), and buying computers, let alone training teachers and administrators on the new technology.[1] Nevertheless, some schools and school districts have made computer networking a priority.

Although wireless LANs have been considered for many school applications, these systems have generally not been selected due to some combination of cost, reliability, and data-rate concerns.[2] As a result, wireless LANs are generally perceived as a second choice solution that is most appropriate for buildings that are hard to wire- historic buildings, those with asbestos, and buildings with insufficient room in the walls or ceilings for additional wiring---or for temporary school-building settings.[3]

As technology develops, however, wireless LANs may become a more competitive alternative to traditional wire-based LANs for school applications. In recent years, for example, wireless LANs have become more popular for business applications because of their enhanced security, higher throughput, and more competitive pricing relative to first generation wireless LANs.[4] However, as wireless technologies advance, so too do wire-based technologies. Some believe that 100 megabit/second wire-based LANs will soon become standard, dwarfing the throughput of even the fastest wireless alternatives.

School officials may wish to complement their existing wire-based LAN with wireless LAN technology. Many wireless LANs offer the flexibility to have numerous interconnected computers in a classroom one day and none the next. In addition, many wireless networks allow students to carry a portable PC or other device from classroom to classroom without sacrificing connectivity to the network. Other characteristics of wireless networks include: 1) implementation can be gradual (a school can purchase five transceivers for five computers, and increase the number as slowly or as quickly as demand warrants and the budget allows); 2) changes to the school are unnecessary (e.g., no asbestos removal or rewiring); and 3) installation takes days or weeks instead of the months required for a wire-based IAN. The table below provides a rough comparison of three wire-based LAN configurations for schools with three wireless alternatives. Because the installation cost of any IAN is dependent on the specific needs and circumstances of each user-which will vary greatly by site-the numbers presented below should only be considered as a crude illustration of the relative costs and merits of each system.

(continued)

[1] For an in-depth treatment of this subject, see U.S. Congress, Office of Technology Assessment, *Teachers and Technology: Making the Connection,* OTA-EHR-616 (Washington, DC: U.S. Government Printing Office, April 1995.

[2] Charles Orocter, Florida Department of Education, Bureau of Educational Technology, personal communication , Mar. 9, 1995.

[3] Marty Heavey, Windata, Inc., personal communication, Mar. 28, 1995.

[4] Susan D. Carlson, "Wireless LANs Take on New Tasks, " *Business Communications Review,* February 1995, PP. 36-41.

BOX 4-4—School Networking and Wireless Technologies (Cont'd.)

Comparison of Wire-based Local Area Network Costs and Capabilities With Wireless Alternatives

	LAN Speed					
Wire-based LANs	**Internal**	**Internet Connection**	**Expansion Potential**	**LAN Cost**	**Drops**	**Per Drop cost**
MIT Model						
Low cost estimate	10 mbps	**56** kbps	low	$37,100	67	$554
High cost estimate	<10 mbps	56 kbps	low	102,000	67	1,522
Central Kitsap, WA						
Low cost estimate	<10 mbps	512 kbps	high	357,500	350	650
High cost estimate	<10 mbps	512 kbps	high	412,500	350	750
Acton-Boxborough, MA	<10 Mbps	56 kbps	medium	25,393	82	310
Wireless Alternatives[1]						
Windata FreePort[2]						
High Mobility	<5.7 mbps	56 kbps	medium	136,495	67	2,037
Low Mobility	<5.7 mbps	56 kbps	medium	50,295	67	750
Proxim	<1.6 mbps	56 kbps	medium	52,385	67	782
Metricom[3]	10-40 kbps	28.8 kbps	high	13,400	67	200

NOTES: **LAN Cost** represents the one-time cost of installing the network (hardware costs and facility upgrades, including significant electrical upgrades with the wire-based LANs), but excludes computers and ongoing costs such as maintenance, usage fees, and personnel training. The wide discrepancy in the total LAN costs shown here represents different technology choices and also different-sized schools. For this reason, a better comparison can be drawn between the per-drop costs for the different LANs.

Per-Drop Cost is the cost of the IAN divided by the potential/intended number of users. This needs some qualifying in the case of the wireless alternatives because there are no "drops" per se, but rather wireless transceivers.

Expansion Potential refers to the ease (both financial and physical) with which additional users can be added to the various LAN architectures.

SOURCE: Russell I. Rothstein and Lee McKnight, MIT Research Program on Communications Policy, *Technology and Cost Models of K-72 Schools on the National Information Infrastructure,* Feb. 10, 1995; Kent Quirk, Chairman, Citizen's Technology Advisory Committee, Acton, MA, personal communication, Mar. 29, 1995; Gordon Mooers, Coordinator Information Systems, Central Kitsap School District, Silverdale, WA, personal communication, Mar. 29, 1995; George Flammer, Metricom, personal communication, May **4,** 1995; Windata, Inc.; Max Sullivan, Proxim, personal communication, May 16, 1995.

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[5]The Windata and the Proxim systems are intended to complement an existing wireline IAN, thus, in addition to the wireless LAN components, a minimal wireline infrastructure is required, including a server ($4,000) and cabling to each wireless node ($520), These cost figures are taken from the MIT model and the Acton-Boxborough model, respectively.

[6]The Windata FreePort transceivers (the transmitters that provide communication from the PC to the rest Of the wireless LAN) can support up to eight PCS. In the low mobility model, it is assumed that every computer will share the transceiver with seven others, thus reducing the amount of mobility realized for each user, and also reducing the cost dramatically. In the high mobility model, each computer has its own transceiver, thus increasing each user's mobility and the cost. We assume a total of four wireless hubs, at a cost of $7,450 per hub. Schools may require fewer, for example if all users are on one floor, then only one hub is needed.

[7]The Metricom Ricochet Network uses pole-top radios to relay wireless data from sender to receiver. These radios, which cost about $700 each, are owned and maintained by Metricom. Therefore, the only cost to the school is the $200 for the Metricom modem for each computer,

SOURCE: Office of Technology Assessment, 1995.

Several different kinds of wireless LANs are used today, which can be divided into three categories: infrared, narrowband, and unlicensed spread spectrum.[46]

Infrared

LANs using infrared signals are capable of transmitting data in fixed or portable LAN applications, although true mobility is hard to achieve. Infrared systems transmit information using both lasers (generally for point-to-point) and light-emitting diodes (LEDs—primarily for indoors).[47] These systems can operate at speeds of up to 10 Mbps, although throughput is much lower, and range is limited (60 to 150 feet). The technology works best with a direct line of sight between sender and receiver, but can also work by reflecting the signal off walls and ceilings—although not very well. Infrared signals, however, will not pass through walls or office partitions, limiting its usefulness for larger scale applications. Infrared data systems do not require licensing by the FCC and can be relatively inexpensive because they take advantage of production economies for other consumer electronic uses. The Institute of Electrical and Electronics Engineers (IEEE) is now developing standards for infrared LANs.

Licensed

A few companies have experimented with licensed spectrum to provide wireless LAN services. Motorola's Altair, for example, first introduced in 1992, operates at frequencies in the 18 GHz range and offers throughput at about 5.7 Mbps. One problem with licensed systems is that they are limited in the amount of spectrum they can use—only five channels in a 35-mile diameter area—and licensing is required.[48] In the case of Altair, Motorola controls the licenses. To avoid licensing and coordination problems and delays, most vendors have developed wireless LANs using unlicensed frequencies.

Unlicensed (Spread Spectrum)

Wireless LANs operate in the 900 MHz, 2.4 GHz, and 5.7 GHz bands (see discussion below on unlicensed data services). They offer speeds up to 5.3 Mbps, although actual throughput is usually 1 to 2 Mbps.[49] They use either direct sequence or frequency-hopping, spread spectrum transmission techniques (see appendix A). A number of wireless LAN products operate in the unlicensed bands, and the IEEE is currently developing industry standards for LANs as well as standards that will allow users' computers to communicate with each other directly—"ad hoc" or "peer-to-

[46]For further discussion of these systems, see Datacomm Research, op. cit., footnote 3.

[47]These systems currently do not work like most other radio systems—by modulating a radio wave. Instead, they simply turn the LED or laser on/off at high speeds to send digital streams of information—in the same fashion as digital fiber optic technology. Some companies, however, have begun to develop amplitude and frequency modulated systems. These systems could reduce interference and increase the range of infrared systems. High costs make the timeline for deploying such systems uncertain.

[48]Seybold, op. cit., footnote 13.

[49]Nathan Silberman, presentation to OTA staff, Sept. 16, 1994. Because these bands have been designated for "unlicensed" use by the FCC, neither manufacturers nor end users have to obtain a radio license from the FCC. The manufacturer is responsible only for ensuring that the product conforms to FCC technical rules and regulations, to prevent interference to other products.

peer" networking.[50] Development of products for the 2.4 GHz band has reportedly accelerated in anticipation of the IEEE standard for wireless LANs, the increasing congestion (see below) of the 902 to 928 MHz band, and the greater amount of bandwidth available compared to the 900 MHz band.

Unlicensed Data Services

One of the most rapidly developing and hotly contested areas of wireless data involves the use of spectrum that does not require the user to be licensed.[51] In 1985, the FCC opened up three bands for unlicensed uses (data and other types of communications) based on a set of regulations designed to minimize interference and encourage the development of new services.[52] Since then 130 companies have developed more than 200 systems and products for use in these bands—the 900 MHz band being the most popular—and more than 3 million devices are now in use by consumers and businesses.[53]

Unlicensed systems and devices are widely known as *Part 15* services because they operate according to Part 15 of the FCC's rules. Some of the services that operate under Part 15 include: automated utility readers, wireless LANs (see above), cordless phones, wireless audio speakers, home security systems, and some medical monitoring devices. In addition to these services, which are mostly self-contained or private, developers are also looking at the bands to provide more public services similar to those that now require a license—advanced paging and two-way messaging, for example—in order to avoid the expense (possibly exacerbated by auctions) and time (months or years) required to obtain a license. Zenith, for example, recently announced CruisePad, essentially a portable computer with a range of communication options, including remote LAN access operating in the 2.4 GHz band. Metricom uses a series of small (toaster-size) radios mounted on telephone or utility poles to create a microcellular, mesh network that provides metropolitan area coverage, and allows computers with appropriate modems to communicate with remote servers, send and receive e-mail, or access the Internet.[54] It serves utility monitoring, credit card verification, and personal communications functions.

In the past two years, the FCC has taken three actions to allocate more spectrum for unlicensed uses. First, as part of its broadband PCS proceeding, the FCC allocated the 1910-1930 MHz band

[50] The current standard for wireless LANs is 802.11, which specifies 1 Mbps or 2 Mbps. The European Telecommunications Standards Institute (ETSI) is developing a wireless LAN standard (expected to be completed in 1995) called Hiperlan that many in the United States feel is superior to the U.S. 802.11 standard. It allows wireless LANs to operate at speeds up to 22 Mbps over a range of 50 meters, and is capable of transmitting voice, data, and video in a user-to-user or broadcast mode. It does not require a license to operate. Hiperlan, however, is likely to be expensive and quite power-hungry, making portable applications difficult initially. To support these applications, and minimize interference, European countries have allocated a total of 350 MHz of frequencies at 5.2 and 17.1 GHz that will be dedicated to wireless LANs. Japan has also established two standards for wireless LANs, one operating at speeds less than 2 Mbps in the 2.4 GHz band, and the other supporting higher (greater than 10 Mbps) speeds operating near 18 GHz.

[51] In this case, unlicensed refers to the fact that neither the service provider, equipment manufacturer, nor the user must have a license. Cellular phone service, for example, is considered a licensed service because even though end-users do not need to be licensed, the company providing service does.

[52] The bands are 902 to 928 MHz, 2400 to 2483.5 MHz, and 5.725 to 5.875 GHz. See generally 47 CFR 15.247.

[53] "Review Could Lead to Auctions for Licenses in 902-928 MHz Bands," *Land Mobile Radio News*, vol. 48, No. 49, Dec. 16, 1994.

[54] The system operates in the 902 to 928 MHz band at 100 kbps total for each radio, which can be shared by several users. Shared use, however, brings down the bit rate available for each user. The system provides connection to the public telephone network, but does not allow handoffs; therefore it supports portable, but not fully mobile, communications. Metricom presentation to OTA staff, Sept. 14, 1994.

to unlicensed PCS—for both fixed and "nomadic" uses.[55] This allocation was designed to support a range of new data services centering around portable phones and computers, including wireless LANs. To reduce the potential of interference among users, the FCC adopted a "spectrum etiquette" that defines the technical rules that unlicensed PCS devices must meet to operate in the band. Systems cannot begin operating until the existing users of the band are moved, although exceptions will be permitted in areas where the unlicensed PCS system or devices can be coordinated with existing microwave system operators. It is not known how long the spectrum will take to clear or when such systems and devices will begin operation. For these reasons, this band is seen by industry as inadequate to meet short-term needs.

Second, in February 1995, fulfilling an earlier pledge to find more spectrum for unlicensed uses, the FCC reallocated 50 MHz of spectrum transferred from government uses by the National Telecommunications and Information Administration (NTIA).[56] Of that amount, 10 MHz is designated specifically for use by unlicensed radio services such as portable computers and wireless networks, and will be governed by Part 15 rules and the rules that govern data PCS applications. Part 15 users were allowed to continue to operate in another 15 MHz of the band already used for digital cordless telephones, wireless LANs, and inventory control systems. The FCC specifically indicated the benefits of this allocation for serving the needs of the NII: "The potential for open access to the information infrastructure offered by unlicensed PCS devices will provide benefits, not only to commercial users, but also to individuals and private users."[57] This allocation will be available immediately for use by unlicensed wireless data devices.

Finally, the FCC recently opened a proceeding into the possible uses of various frequency bands above 40 GHz by unlicensed (and licensed) services.[58] These frequencies would allow high-bandwidth communications to be transmitted, but only over very short distances (several miles at most). The FCC believes that data rates between 50 Mbps and 5,000 Mbps or more are possible, enabling systems to deliver extremely high-bandwidth services including high-speed data, high-resolution video and image transfer, and vehicle radar systems. The possible uses of these frequencies to provide NII access for consumers and backbone communications services for NII providers was explicitly recognized by the FCC.

Satellite Data Systems and Services

All the of the systems previously described use land-based towers to transmit information. Some systems—paging networks, for example—use satellites to connect local systems to form regional or national coverage areas. Satellites, however, have also been used by themselves for many years to transmit data and other types of information, primarily to fixed locations. The primary advantage of satellites is their ubiquitous coverage—the beam of one satellite can cover the whole United

[55] Of these frequencies, the bottom 10 MHz are reserved for *data PCS*. Material in this paragraph comes from Federal Communications Commission, *Amendment of the Commission's Rules to Establish New Personal Communications Services*, Memorandum Opinion and Order, GEN Docket 90-314, RM-7140, 7175, and 7618, released June 13, 1994; Federal Communications Commission, *Amendment of the Commission's Rules to Establish New Personal Communications Services*, Second Report and Order, GEN Docket 90-314, RM-7140, 7175, and 7618, released Oct. 22, 1993.

[56] Specifically, the bands allocated were 2390 to 2400 MHz, 2402 to 2417 MHz, and 4660 to 4685 MHz. These bands were the first transferred as part of a more general reallocation of government spectrum to private sector use mandated by the Omnibus Budget Reconciliation Act of 1993, Public Law No. 103-66, Aug. 10, 1993.

[57] Federal Communications Commission, op. cit., footnote 45.

[58] All information in this paragraph comes from Federal Communications Commission, *Amendment of Parts 2 and 15 of the Commission's Rules to Permit Use of Radio Frequencies Above 40 GHz for New Radio Applications*, ET Docket 94-124, released Nov. 8, 1994.

States. This easy national coverage also makes satellites uniquely suited to transmitting information to many sites that are far apart, and for transmitting to extremely remote areas that wire-based or terrestrial radio services cannot reach.

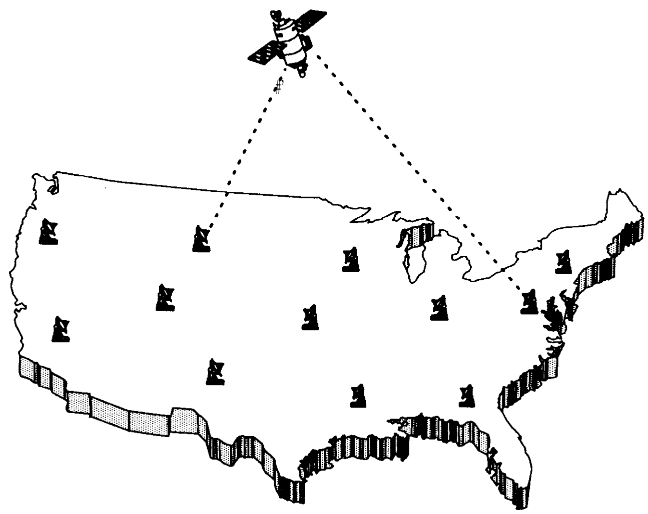
Several companies are now developing products and services that will take advantage of satellites' unique capabilities. Some of these systems are designed primarily to serve mobile users, while others will concentrate on fixed uses. In general, these systems can be divided into two types: geosynchronous and low-Earth orbiting (LEO).

Geosynchronous Satellites

Geosynchronous satellites orbit the Earth 22,300 miles directly above the equator. At this height and location, satellites move at the same speed the Earth is rotating. Thus, the satellite appears to be stationary in the sky. This is what enables geosynchronous satellite communications to work—they are always able to communicate with the satellite receivers on the ground.

Today, an increasing number of satellite data transmission systems use very small aperture terminals (VSATs). VSATs, introduced in the early 1980s, are small satellite dishes (approximately 1.8 meters in diameter) that are connected in a network through a central hub, which broadcasts information to the VSATs in the network and can connect individual VSATs directly (see figure 4-5). VSATs are capable of two-way voice, data, and video communication, but are usually used to send data to and from far-flung company locations. Networks of VSATs are commonly used to connect car dealerships, gas stations, and grocery stores, for example. Such a system enables a company headquarters to keep daily track of inventory and speed up shipments and deliveries. An increasing number of VSATs are being used to deliver video (live and recorded) training materials

FIGURE 4-5: Generic VSAT Network



SOURCE: Office of Technology Assessment, 1995

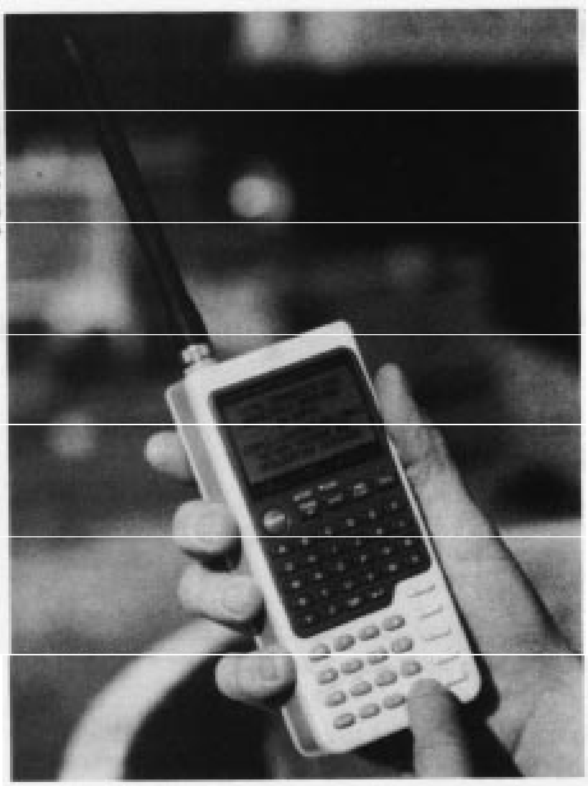
to remote sites, and to connect company LANs at different sites.[59]

Using geosynchronous satellites, several companies are planning new services that will deliver data to businesses and consumers. Hughes Communications has announced plans to construct a bandwidth-on-demand system, Spaceway, that would provide a range of communication services to end-users (see chapter 5). Hughes Network Systems plans to launch a service that would allow users to download large files, software, or images from the Internet. The system is expected to operate at speeds up to 400 kbps, use a 24-inch satellite receive dish, and cost $16 per month plus a $1,495 setup fee.[60]

In addition to these primarily fixed-location systems, satellites also promise to make mobile data more ubiquitous. Inmarsat currently offers service to small satellite terminals that can be packed in a suitcase, enabling them to be carried to any location. Such services are designed to

[59] Over 6,000 VSATs are now being used to connect LANs. Dennis Conti, "LANs & VSATs," *Satellite Communications,* August 1994.

[60] "Hughes Network To Offer Data Retrieval Via Satellite," *The Internet Letter,* vol. 2, No. 4, Jan. 1, 1995.



ORBITAL COMMUNICATIONS CORP.

Hand-held terminals will enable consumers and business users to send and receive short messages around the world and to determine their location anywhere on Earth within 100 meters.

support remote research locations and provide communications in times of disaster or emergency. Commercial satellite mobile data services, however, are very limited; only a few companies offer services, and these are primarily aimed at fleet management operations-messaging to truck drivers. In the future, however, new satellite systems promise to provide a full range of mobile data applications.

Low-Earth Orbiting Satellites (LEOs)

In addition to the geosynchronous satellite systems, several companies plan to use satellites orbiting the Earth at lower altitudes to deliver data services. There are three types of LEO services. The "big" LEOs (discussed in chapter 3) will focus primarily on voice services, but will also offer data services with capabilities similar to those offered by terrestrial PCS and cellular companies. Such systems will greatly exceed the coverage offered by terrestrial systems such as cellular or Ram/Ardis.

A second type of LEO satellite system has been proposed that would provide a wide range of services-bandwidth on demand-including voice and video telephony, interactive multimedia, as well as high-speed data communications. The Teledesic system, for example, will focus on providing high-bandwidth interactive applications to fixed locations in the United States, and to both mobile and freed users abroad (see chapter 5 for more discussion of these multipurpose systems).

A third group of companies is developing so-called "little" LEO satellite systems that will provide ubiquitous (and eventually global) data-only messaging, tracking, and monitoring services to individuals and businesses.[61] The first application for a LEO system was filed at the FCC in 1988, and currently eight companies have proposed to launch little LEO systems.[62] To date, only one of these, Orbcomm, has received an FCC license to launch and begin offering service. It launched the first two of 48 satellites in March 1995. VITA now expects to launch in June 1995, with service beginning by the end of the year.

[61] The term "little" referes to the fact that all little LEo systems will use frequencies below 1 GHz, and that the service will be non-voice. The satellites used for little LEO systems are also physically smaller than those used for "big" LEO operations (see below). The FCC refers to this class of satellite services as *non-voice, non-geostationary* (NVNG).

[62] The eight are CTA Commercial Systems, Inc., E-Sat,Final Analysis Communication Services, Inc., GE American Communications, Inc., LEO One, Orbital Communications Corp. (Orbcomm), Starsys, and Volunteers in Technical Assistance (VITA), "Four New Applicants Join Leo One in Reposing 'little LEO' Systems for Second Processing Round," *Telecommunications Reports*, Nov.28, 1994.

BOX 4-5: Global Positioning System (GPS)

Initiated as a test program by the Department of Defense in the early 1970s, the Global Positioning System (GPS) has provided position location service for military and civilian applications since 1992, The system uses 24 satellites that orbit the Earth at an altitude of 10,900 nautical miles, Portable or vehicle-mounted GPS devices receive signals from the satellites and calculate the user's position to within 100 yards for civilian purposes and even closer for the military.[1] GPS operates 24 hours a day, can serve an unlimited number of users, and operates in all weather conditions.[2] The system may eventually replace many ground-based navigation systems, such as the current U.S. air traffic control system, helping to expand the capacity and improve the safety of the aviation system in the United States and the world.[3] Civilian GPS products are already used by boaters and trucking companies.

In the future, GPS services will form an integral part of many intelligent transportation system services, such as map and navigation programs for cars and portable computers. Many of the proposed satellite communication systems, including some of the Low-Earth Orbiting (LEO) satellite proposals and American Mobile Satellite Corp., plan to integrate the GPS location services into their service offerings.

SOURCE: Office of Technology Assessment, 1995.

[1] For security reasons, the Defense Department scrambles the civilian GPS signal to limit its accuracy to approximately 100 yards.

[2] Keith D. McDonald, "Course 101: Fundamentals of GPS, " presented at the Loews L'enfant Plaza Hotel, sponsored by Navtech Seminars, Inc., Washington, DC, July 11, 1994.

[3] U.S. Congress, Office of Technology Assessment, *Federal Research and Technology for Aviation,* OTA-ETI-610 (Washington, DC: U.S. Government Printing Office, September, 1994).

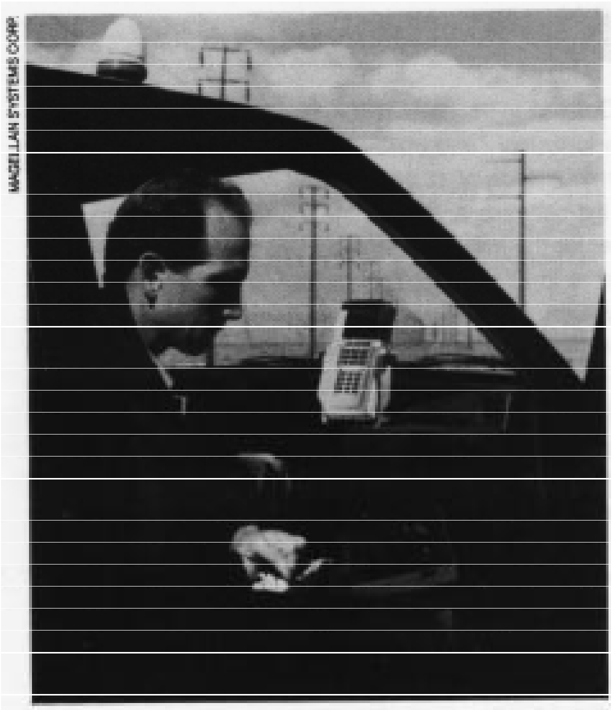
The little LEOs companies plan to offer ubiquitous, two-way messaging and data services, for either fixed or mobile users, potentially on a global basis.[63] Initially, service providers plan to target the transportation industry and remote monitoring applications (oil or gas pipelines or wells, for instance). In the longer term, proponents also perceive a market for emergency and personal communications; law enforcement, such as stolen vehicle location; environmental monitoring; fleet and cargo management for marine shipping companies and trucking companies; and other similar services. Most little LEOs will also couple data offerings with position location service, using the Global Positioning System (see box 4-5). To serve diverse customer needs, little LEO providers are designing a variety of consumer equipment expected to cost between $100 and $400. Message delivery is expected to cost about $0.25 per message.[64]

Although technical differences exist between the proposed little LEO systems, it is possible to describe a generic little LEO system (see figure 4-6).[65] Each system will consist of between 25 and 50 satellites in low-Earth orbit, about 1,000 kilometers above the Earth's surface. Each system

[63] VITA, for example, plans to offer e-mail and short file transfers between remote sites. Orbcomm, however, while offering services in a number of countries, will not transmit between countries. In addition, each little LEO system will have to obtain a license to provide service in every country in which it plans to operate. Negotiating these contracts could slow the deployment of worldwide services.

[64] "Orbcomm Gets First 'little LEO' License for Satellite Data Service," *Telecommunications Reports International,* Oct. 28, 1994.

[65] The exception is the VITA system, which will use only two satellites in fixed orbits serving about 1,000 stationary ground regional gateways. The system will be managed by a single control center near Washington, DC.



The U.S. Global Positioning System uses a network of satellites that allows users (in aircraft, on ships, in vehicles, or equipped with hand-held devices) to determine their location almost anywhere on Earth.

will also consist of at least one terrestrial control center, and sometimes secondary and tertiary "gateways" that will serve as the relay and control point between the customer units, the satellites, and public and private communications networks, including the Internet.[66]

Depending on complexity, the systems are expected to cost between $100 and $200 million each, with the exception of the VITA system, which will be significantly less expensive since it will use only two satellites.[67]

ISSUES AND IMPLICATIONS

Mobile data applications are quite promising and the industry has much potential. However, despite predictions for explosive growth, use of mobile data applications and services remains relatively low. In many ways, the use of wireless technologies to serve mobile/portable computing needs is a microcosm of the larger world of wireless communications. A wide range of technologies is being developed and deployed to meet the perceived needs of wireless data users—traditional paging, satellite, and cellular, as well as PCS, LEOs, and public and private wireless data networks. But applications vary in their technical characteristics (speed, throughput, etc.), ease of use, and capabilities, and it is still unclear which models of wireless data will be successful and when. For equipment vendors, this makes it difficult to decide what systems and services to include with their hardware, and for users, it may be difficult to determine which product/service(s) best meet their needs.[68] Several issues will have to be addressed before mobile data reaches the levels many analysts have predicted.

Technical Issues

Fundamentally, using radio waves to send information is more difficult than using a wire because the environment-the atmosphere-is much harsher. Noise, interference, and attenuation are much harder to anticipate and overcome in the open air than in the more protected environment of an insulated wire. To overcome these problems, radio engineers are working on a variety of improvements to radio technology, including better data compression, higher capacity transmission and spectrum-sharing methods, improved error correction, and greater resistance to natural and man-made interference.

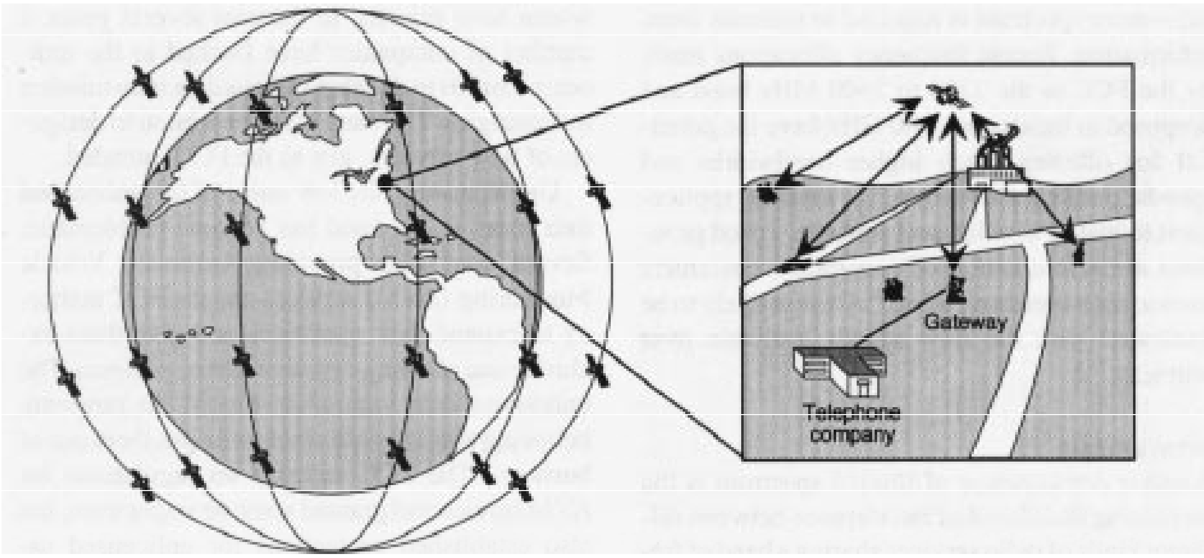
Despite the great strides made in the use of radio for sending information, the wireless data industry must still overcome several technical obstacles before wireless data applications become more widespread: 1) the speed and capacity

[66] All little LEG systems will use spectrum below 1 GHz.

[67] U.S. Congress, Office of Technology Assessment, *The 1992 World Administrative Radio Conference: Technology and Policy Implications,* OTA-TCI-549 (Washington, DC: U.S. Government Printing Office, May 1993).

[68] Seybold, op. cit., footnote 13.

[redacted]



SOURCE: Office of Technology Assessment, 1995.

of the radio link, 2) its susceptibility to environmental interference and signal loss, 3) interference from electronic devices and other radio services, and 4) interoperability problems with other wireless systems and wireline systems. Because of these factors, current wireless data communication technologies generally cannot offer the same level of performance (measured by speed, reliability, and/or capacity) as wireline technology, although some individual wireless systems may offer comparable service.

Spectrum Limitations

Many of the problems confronting the wireless data industry come down to a limited number of radio frequencies on which to operate systems. Limited spectrum constrains the numbers of users who can use or offer a service, limits the speed at which information can be sent, and often creates interference problems between users when they have to share the same frequencies-furtherlimiting performance and capacity. In recent years, the FCC has allocated more spectrum to wireless data services, and more is being considered.

Speed is limited

The most serious drawback to wireless data applications today is the limited speeds at which they operate. Winless LANs generally operate at between 1 and 2 Mbps, compared with 10 Mbps on most wired LANs. Most commercial two-way wireless data services (packet radio, circuit-switched cellular) now achieve effective throughput of 300 to 4,800 bps, compared to wireline modem speeds up to 28,800 bps. Commercial providers are working to upgrade speeds to 19,200 bps, and CDPD will operate at similar speeds, but these technologies are not yet widely deployed, and actual throughput is likely to be lower.

In part, slow speeds area function of technology, and in part they are due to the limited bandwidth that is currently available for wireless data applications. Radio waves are limited in the amount of information they can carry-often measured in the number of digital bits per Hertz transmitted. Current systems can transmit about 1 or 2 bits/Hertz, but researchers are working to expand this to 6 or even 10. Digital compression and transmission technologies will help increase the carrying capacity of radio waves, but physical limitations may continue to limit high speeds. As a result, adequate spectrum allocations are critical—more spectrum is required to transmit more information. Recent frequency allocations made by the FCC in the 2390 to 2400 MHz band and proposed in bands above 40 GHz have the potential for offering much higher bandwidths and speeds, perhaps allowing some wireless applications to match wireline performance. Speed problems are also a matter of perception; customers used to high speeds on wired LANs are likely to be frustrated with the slow speeds available over wireless.

Interference

Another consequence of limited spectrum is the increasing likelihood of interference between different kinds of radio services sharing a band of frequencies, as well as between different systems providing the same service. For example, manufacturers of medical telemetry devices—such as electrocardiogram monitors—have asked the FCC to allow them to expand their operations and increase their power on vacant VHF and UHF television channels in order to overcome severe congestion and interference from other radio users. Sometimes interference is only a minor annoyance—static or voices on your cordless phone, for example—but at other times, interference can be severe enough to prevent transmissions from being received at all. For data communication systems, which are sensitive to interference and which depend on reliable transmissions to communicate information accurately, interference in the wireless environment can be a significant issue.

Interference problems are experienced by many wireless data systems, but they are currently acute in the unlicensed bands, which are home to a wide variety of systems and radio devices. Data systems in the 902 to 928 MHz band must share the spectrum with a number of other users—most of whom have priority. In the past several years, a number of companies have flocked to the unlicensed bands to develop various data transmission technologies. The band has been a boon to designers of new services, just as the FCC intended.

Unfortunately, the low status of the unlicensed data users in the band has become problematic. Several companies providing Automatic Vehicle Monitoring (AVM) services sought FCC authority to expand their operations and give them exclusive use of a major portion of the spectrum. The unlicensed data community fought this proposal, believing that it would essentially put them out of business. The FCC recently set regulations for AVM service and granted some new spectrum, but also established protections for unlicensed users.[69] A number of parties have filed petitions with the FCC to reconsider parts of its ruling, and it is still unclear how the issue will finally be resolved.

In addition to interference between different radio services sharing the same range of frequencies, there is concern that portable computing or other devices may interfere with or be affected by interference with the radio links. Electrical devices, like computers, often leak spurious radio energy produced as a by-product of their normal operation. This interference can affect nearby radio devices, including a radio modem/transmitter connected to (or inside of) the computer itself, causing serious performance problems for the radio device. Adequate shielding or redesigning the computer's internal layout can solve the problem.

Radio signals can also interfere with computers and other electronic devices. Because several ranges of frequencies are used for wireless data applications, computers must be designed to limit

[69] Federal Communications Commission, *Amendment of Part 90 of the Commission's Rules to Adopt Regulations for Automatic Vehicle Monitoring Systems*, Report and Order, PR Docket 93-61, released Feb. 6, 1995.

the effects of unwanted radio energy and shielded from devices using these frequencies.[70] There is, as yet, no group or process in place to determine if a portable computer is properly protected ("radio ready"). Chapter 12 discusses interference issues in greater detail.

Lack of Interoperability

One of the most serious problems facing wireless data users is the lack of interoperability—both between different wireless systems and between wireless systems and different wireline networks. Connecting users on different wireless networks and integrating an individual company's use of multiple wireless networks has been extremely difficult. Different companies have developed a variety of proprietary, incompatible wireless data technologies, such as those for the Ram and Ardis networks and CDPD, standards are almost nonexistent, and applications work differently on different systems (see below). Different wireless LAN manufacturers, for example, make equipment that is not compatible. And while the personal computer (PC) cards discussed in box 4-3 are standardized, there are reportedly so many different implementations of the standard that true interchangeability is not possible—a user cannot necessarily switch cards between different machines.[71] Overall, the use of radio-based technologies to support mobile data needs is often slow and tricky—users must be willing to endure complicated connections and poor quality to gain the advantage of mobility and portability.

The main problem with multiple technologies is that they complicate the development of applications software—word processing, electronic mail, and spread sheets, for example. Software developers do not want to incur the additional cost of writing a different version of their program for each type of wireless data system, especially when, as is the case today, the markets are small. As a result, there are few off-the-shelf applications designed for use with wireless data systems. Most wireless data applications have been one-of-a-kind, written for a particular job by companies that can afford to do their software development in-house. However, even these companies are concerned about the lack of standards because they will have to rewrite their software to change providers.

In addition to the problems of incompatible wireless systems, one of the most serious concerns facing wireless data users is the transfer of information—interoperability—between wireless and wireline networks. Standard interfaces do not yet exist for sending data between cellular and Integrated Services Digital Network and other public switched telephone network (PSTN) services, for example. Speed is an important part of the problem. Wireless networks, because of spectrum limitations and the current state-of-the-art technology, cannot operate at the speeds now common in wireline applications.

A similar incompatibility problem exists with applications software designed to work on wireline and wireless networks. Most existing computer/data applications were written based on the parameters and characteristics of wire-based systems, and developers have years of experience in writing software that uses wireline protocols. This software, however, often does not work well when used over a wireless network. Software developers are now modifying some of their products to work in a wireless environment; this would reduce the cost of developing and adopting wireless data services. However, this process is difficult for developers, who have to learn specialized protocols in order to develop wireless data applications. It is also unclear how extensive or difficult it is to redesign such programs, and how many applications will have to be retrofitted to work well in a wireless setting.

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[70] Data services are, or will be, offered on cellular frequencies, SMR systems, paging systems, PCS (licensed and unlicensed) frequencies, several satellite frequency bands, and general unlicensed (e.g., 902 to 928 MHz) frequencies. See Seybold, op. cit., footnote 13.

[71] Strom, op. cit., footnote 2.

Another solution is to develop a common interface for the software that could work in either a wireline or wireless environment. This would allow users to move between wireless and wireline networks more easily. For example, the same software could be used to access office computers from home via wireline and from the road via wireless.

Yet another solution to the problem of incompatible systems and standards is technological. More than a dozen companies are developing "middleware," an extra layer of software that translates information from the general application into the specialized wireless data protocol.[72] Middleware saves developers from having to learn the details of wireless data protocols: they write their applications to work with the middleware, which then handles the details of sending the data over any of a number of wireless networks. Middleware can also mask the differences in wireless data systems because it is usually able to translate into several different wireless data protocols. For example, middleware allows a user on the Ram network to communicate with a user on the Ardis network. Once an application has been written to work with the middleware, the user could switch to a different wireless data provider without having to make extensive modifications. In many cases, middleware mimics the behavior of a wireline network, allowing the large number of applications written for the wireline environment to be used over a wireless network.[73] Even middleware suffers from interoperability problems, however;

> Applications written to one vendor's middleware package don't necessarily work with middleware from a different vendor. The main reason for this interoperability gap is that most makers of wireless middleware products now use proprietary application program interfaces (APIs) to connect to network applications and services.[74]

It is possible that not all of today's wireless data services will survive in the marketplace. Software developers may write applications for some services, but not for others. Users would then tend to choose the wireless data service for which there is the widest choice of applications, enlarging that service's market share further and encouraging developers to write more software. Over time, the market may converge on only one or two of the systems available today. This is similar to personal computer operating systems, where a single operating system—DOS—came to dominate the market.

The wireless data industry is at an early stage in its development, and users and developers are only beginning to sort out the options. As various segments of the industry mature, better technology and increasing standardization is expected to alleviate many of the interconnection and interoperability problems that are now common. The speed with which this transition will take place, however, is still uncertain—most analysts believe it will take at least 3 to 5 years.

Demand Issues and Applications Development

> Mobile computing is a reality and will become a more dominant part of computing later in the decade. Vendors are investing billions of dollars into the creation of new types of devices, new communications links and new software applications. There is a real danger that all this technology will be developed and made available without the existence of any real demand. Vendors must understand the segmentation of the mobile market to build the right products.

[72]For additional discussion of middleware, see Johna Till Johnson, "Middleware Makes Wireless WAN Magic," *Data Communications,* op. cit. footnote 8.

[73]One example is the *Winsock* interface. See Mobeen Khan and John Kilpatrick, "MOBITEX and Mobile Data Standards," *IEEE Communications,* vol. 33, No. 3, March 1995, p. 96.

[74]Johna Till Johnson, "The Wireless API Standards Watch," *Data Communications,* op. cit., footnote 8, p. 72.

> Users have to understand the benefits, as well as the pitfalls, of mobile computing to get excited about using it.[75]

A substantial problem that has not yet been solved is how to move mobile data services more into the business and consumer mainstream. To develop applications for today's wireless data users: first, needs are identified; then, technology is produced or adapted to fit needs; and finally, pilot tests are conducted. Due to the nascent stage of technology and applications, customization is usually the first step. As a result, horizontal markets for mobile data applications may be difficult to develop because of the specific nature of the tasks vertical solutions are designed to serve.

Once concepts, products, and services have been validated across a number of business applications, a broadening of software can be expected. This is, in fact, what companies like Ardis and Ram are attempting to do—move from vertical to horizontal markets. Over the next few years, more general wireless data products and services are expected to come on the market. Developers are already writing more software and applications for the mobile environment,[76] and the expected explosion of mobile data users has prompted a flurry of alliances between software developers and wireless data companies. Microsoft and Mtel, for example, have teamed up to offer services on Mtel's Nationwide Wireless Network (NWN). GTE and IBM recently announced an agreement to allow GTE cellular customers to access IBM's data network. Analysts point to the availability of good applications as the key to the future growth of the market.[77]

As a result, the market for wireless data services is becoming increasingly crowded, but many analysts question whether the market can support all the different levels and kinds of competition. Traditional paging companies face competition from new PCS providers, as well as potential competition from little LEO systems. The original two-way data service providers, Ram and Ardis, will face increased competition from CDPD, narrowband PCS, and perhaps a range of satellite services. Some of these systems will provide competing services for some applications, but may also offer different combinations and levels of service. Some analysts believe that the systems currently serving vertical markets are unlikely to be able to broaden their customer base significantly. Ardis and Ram, for example, may be confined to vertical markets, while cellular data services will become the technology of choice for most business/mobile professional users due to the integration of cellular systems with the public telephone network.[78]

A final part of the problem of broadening the use of wireless data involves users themselves. Many businesses and consumers are less aware of the uses and benefits of mobile data than they are of a cellular phone or even a wireless LAN. As a result, demand has been unfocused, and applications developers have not had a clear direction to pursue. "If you think in terms of mobile data . . . it's far less obvious what the benefits of using mobile data are. It's a matter of education and awareness."[79]

[75]Dulaney, op. cit., footnote 1.

[76]Susan D. Carlson and Craig J. Mathias, "Big Guns Target Mobile Middleware," *Business Communications Review*, November 1994.

[77]Some analysts point to the development of mobile data in the United Kingdom as an example of the importance of developing good applications the market wants. There, five licenses were made available, and four were actually developed. Of these, the most successful, Cognito, has only 4,000 subscribers (compared to 3 million cellular users). Pat Blake, "Wireless Data: The Silent Revolution," *Telephony*, Dec. 5, 1994.

[78]Ibid.

[79]Ibid., p. 32.

In particular, the needs of residential consumers for such business-oriented services are likely to remain unclear for several more years. Most of the applications discussed in this chapter are designed to meet business needs. The benefits for individuals in their personal lives remain highly speculative. “Educating” mass market consumers about the benefits of new wireless data technologies has begun (e.g., Motorola pager television advertisements), but will continue to be one of the industry’s more difficult challenges. With the proliferation of portable computers and PDAs, this awareness is expected to grow, user needs should become clearer, and the use of wireless data services should grow.

Prices

One of the key issues of demand for wireless data solutions is cost. The price of wireless data equipment is still high. Radio modems can cost up to $800. Economies of scale and mass market economics have not yet driven the price of equipment down to a level that is affordable to most companies or consumers. This relatively high up-front cost, in addition to activation fees, per month charges, and usage fees, may prevent some users from signing up—especially residential consumers. As economies of scale are realized, equipment prices are expected to drop.

In addition to high initial equipment costs, the ongoing costs of service are also an issue. Some mobile data service providers offer flat-rate payment plans that allow users unlimited use for a set fee. Others will charge a combination of flat rate plus additional charges for use over a set limit. In the future, businesses will likely demand flat-rate pricing based on large volumes of traffic. Individuals and small businesses, however, are more likely to want per-call charges because they will not want to pay for anything they do not use. And like cellular and PCS services, the question of who pays any air time charges for calls to the user—the user or the caller—will continue to be studied.

Coverage

Another important issue for users is coverage—“where can I use it?” Users want ubiquitous coverage within the area in which they travel. This geographical range varies by user. Some businesses, such as real estate companies, need primarily local/metropolitan coverage. Salespeople may need a larger coverage area—statewide or even multistate regional coverage. Traveling executives may need an even wider coverage area—national or even global in scope. Different technologies can provide different levels of coverage. Paging networks are generally local/regional in scope, but, using satellite technology to connect local transmitters, some systems can offer nationwide or global coverage. Cellular circuit-switched or CDPD applications are also technically local, but, with roaming capabilities and their connection to the PSTN, can also achieve national or even international reach.

Defining “coverage” is not necessarily straightforward. Ram and Ardis, for example, are often referred to as “national” services; however, while they cover many metropolitan areas, they do not cover the whole country. In addition, a user’s specific location within a coverage area may determine whether or not service is available. Users tell stories of having to switch hotel rooms from the north to the south side of a building in order to use their service.[80] For some business users, these may be minor inconveniences, but many will not tolerate such performance.

Security Concerns

Some companies are afraid that moving data over the airwaves, especially sensitive data about clients or products, might make them vulnerable to potential eavesdroppers who could be listening in.

[80] While terrestrial data services are not technically line-of-sight, position within a building does matter. Often, users will congregate near a window on a specific side of a buildin—gwhere the coverage is best.

Users are also concerned about the possibility that saboteurs could somehow use the systems to destroy computer files. New spread spectrum systems are relatively secure because of the way they transmit information, but users are still wary. Encryption is thus an important issue for wireless data users. Many large corporate and government users will not send data without encrypting it, and most wireless LAN providers offer some type of encryption software. A more complete discussion of the security issues associated with cellular and PCS data applications is found in chapter 10.