CHAPTER 3

TECHNOLOGY

3.1 INTRODUCTION

Cellular technology employs a grid of hexagons, or cells, that cover specific geographic areas. Each cell contains a low-powered radio transmitter and control equipment located in a building called a *cell site*. (Outside the United States, cell sites are often referred to as *base stations*.) The cell site is connected by wireline, microwave, or satellite facilities to a mobile telephone switching office (MTSO), which is typically then connected to the regular landline network through the local telephone company's central office. (Direct connections from the MTSO to long-distance carriers can also be made, bypassing the local telephone company's central office.) With its electronic switching capability, the MTSO monitors the signal strength of the mobile units used by customers and automatically *hands off* conversations in progress to the next cell site as the customer moves from one cell to another. Each cell has a set of radio frequencies, allowing reuse of every channel for many different simultaneous conversations in a given service area. As demand for the service grows, dividing cells into smaller cells allows greater numbers of customers to be served.

Thus, cellular is a wireless technology in the sense that the piece of equipment used by the customer (the phone) communicates with the network through radio waves rather than through a wired connection. This fact is significant with respect to technology for at least two important reasons. First, there are numerous transmission standards that define the air interface, or the link between the customer's equipment and the cell-site portion of the network. To analogize, the phone and the cell site must speak the same language to understand the signals they send to each other.

Because there are a number of air interface standards in use throughout the world, either the government or the marketplace must elect which one(s) to adopt. Second, the wireless aspect of cellular means that it can accommodate both mobile and fixed uses. Depending on whether a country wishes its network to serve one or both types of these functions, different network equipment and configurations are available, at different costs.

3.2 AIR INTERFACE TECHNOLOGIES

The choice of a particular air interface is important for several reasons. Any country that is considering issuing a cellular franchise will want to use a technology that will be reliable and have sufficient capacity to serve its citizens well, while not being unduly expensive to implement. But the choice is significant for another reason: there is an advantage to making it as easy as possible for customers visiting from other countries to use cellular service—for example, by allowing them to bring their phones with them [1]. It is from these customers, referred to as *roamers*, that a substantial amount of the revenue of a cellular business may be derived. Typically, roamers are charged higher rates than *home* customers. Roaming charges may include a daily fee as well as a higher per minute rate. Therefore, a country would want a technology that serves not only its own citizens, but its foreign visitors as well. Conversely, its choice might also be affected by the desire for its citizens to be able to use their phones when they are abroad. (Even given the portability of phones and the identity of the air interface standard, however, a customer may not be able to use the same phone she uses in her home system in a foreign country, because the foreign system may operate at a different frequency; that is, on a different part of the radio spectrum.)

The first distinction to be made between different types of transmission technologies is the one between analog and digital [2]. Originally, all cellular systems used analog radio signals, which mimic the wave pattern of the human voice to convey conversations and data. However, digital technologies, which can fit more transmissions into the same amount of spectrum, have since been developed. Digital radio signals transmit by converting the speech or data being sent to the 0's and 1's of computer language [3]. The increased capacity of a digital system may be of particular interest in developing countries, which often have very crowded urban areas and thus a high concentration of phone users in a small area. However, even digital technologies may not provide sufficient capacity to solve this problem in some countries [4]. In addition to using the airwaves more efficiently, digital technology may make it more difficult for eavesdroppers to intercept telephone calls [5].

Analog is not without its advantages, however. It may be deployed more rapidly than digital, it is cheaper, it can potentially provide a greater coverage area from a given cell site, and it is subject to fewer export restrictions [6]. One other advantage to a developing country of using an analog standard is that used analog equip-

ment may be available through service providers who are switching to digital and who might be able to resell their equipment in other countries.

The major analog standards in place are Advanced Mobile Phone System (AMPS), Nordic Mobile Telephone (NMT), and Total Access Communications System (TACS) [7]. AMPS is dominant in the Americas, but has spread to other parts of the world. A more advanced form of AMPS technology, Narrowband AMPS (N-AMPS), allows for increased system capacity by splitting each 30-kHz AMPS channel into three 10-kHz channels [8].

NMT, as the name implies, originated in Scandinavia but is also in use in many other European countries (particularly eastern Europe), some states of the CIS (the former Soviet Union), and African countries such as Algeria, Morocco, and Tunisia. NMT-450 refers to equipment that operates in the 450-MHz frequency range of the spectrum, and NMT-900 to that which operates in the 900-MHz range. A system that begins on the 450-MHz range can later be expanded to include the 900-MHz range [9].

TACS originated in the United Kingdom, but is now used as well in other parts of Europe and in Asia. Two more advanced versions of TACS are ETACS and TACS 2. ETACS incorporates modifications that increase the spectrum allocation (and hence the number of channels) and TACS 2 includes improvements that enhance the signaling and reduce fraud. NTACS expands the original capacity of a TACS system by narrowing channel separation. JTACS, which is based on the U.K.'s TACS system, was put into service in Japan in 1989 [10].

There are two basic types of digital technologies currently contending in the cellular arena: time division multiple access (TDMA) and code division multiple access (CDMA). Analog technology sends one conversation over one channel. For this reason the technology used by analog systems is called frequency division multiple access (FDMA). The FDMA approach can also be used with digital, but that would entail forgoing the spectral efficiency gains associated with digital [11]. In contrast, TDMA breaks a number of conversations into fragments that it transmits over one channel at precisely timed intervals [12]. CDMA also fragments conversations, but does not rely on timing to determine how to reassemble the pieces at the receiving end. Rather, it attaches a unique identifier, or code, to each piece. TDMA is expected to at least triple capacity compared to analog. The developer of CDMA at one time claimed improvements in capacity on the order of 18 times analog. The estimate of capacity expansion for CDMA has since been reduced to 10 times that of analog [13].

TDMA technology is used in two important digital standards: GSM (originally derived from Groupe Speciale Mobile, [14] but now modestly called Global System for Mobile) and Interim Standard (IS)-54 [15]. GSM has been adopted by the European Union as a mandatory standard for member states and is spreading throughout much of the world [16]. However, the United States and other countries that have significant investments in their existing analog AMPS cellular systems (or another analog technology) have chosen to transition the networks they have in place to digital over time: some channels will use analog technology and some will use digital.

The proportion of digital to analog channels in the network will increase over time. This means that the large number of customers who already have analog phones will not have to replace them immediately and simultaneously. Dual-mode phones, that use both analog and digital technology, will also be available [17]. At the same time, this solution allows the carriers to resolve their capacity problems. To accomplish these goals, the digital technology these countries use must be capable of being overlaid on the existing analog network. IS-54 TDMA technology was developed for this purpose. CDMA technology was also developed to address this problem. When GSM was designed, no attempt was made to make it compatible with the various analog networks already in place in Europe, the Americas, or any other part of the world [18].

Even though cellular licensees in the United States are not using GSM, some of the new operators of personal communications networks that received licenses beginning in 1995 will be [19]. (The new licenses for personal communications networks are discussed in more detail in Chapter 7.) Because these companies are building new networks and do not have an embedded base of customers with analog phones, they can begin with GSM technology.

The proliferation of GSM systems worldwide can make it attractive to developing nations [20]. A traveler may take his or her phone to another country that uses a system that is like the one used at home. Additional flexibility is provided by the fact that the GSM system operates by allowing any user to have a subscriber identification module (SIM) card. The user inserts the SIM card into the phone's handset in order to activate the phone and verify the customer's identity and authorization to use the network [21]; the customer may also be required to enter a personal identification number [22]. The SIM card allows a customer to use a phone that she or he does not own, such as a rental phone or borrowed phone, and still have the charges billed to her or him directly. Even when a roaming customer cannot use the cellular phone that she or he uses on her or his home system in a foreign country (because, for example, the phone is not portable but is installed in the car), she or he can borrow or rent a phone in the foreign country and make calls if it operates on a GSM system that will allow the use of a SIM card. This is likely to be less expensive than buying the service from a middleman (such as the lessor of the phone). Some cellular carriers that provide service on AMPS systems in the United States have made it easier for their customers to obtain GSM service while they are traveling in Europe, and in some cases vice versa [23]. The operators of the home and visited networks must have entered into a roaming agreement allowing them to bill each other for usage by each other's customers. (This is true even when the systems use the same air interface technology.)

Another advantage of the wide development of GSM digital cellular systems is that it has led to large-scale production of phone sets at reduced prices. Although the end user rather than the government bears this expense, high-priced handsets would certainly pose an obstacle to the government's goal of deriving social benefit from increased access to telecommunications [24].

In addition to achieving widespread acceptance in Europe and a measure of success in Asia, GSM is also being adopted by some African and Middle Eastern countries as the standard for one or more of their cellular franchises. These include Egypt, Algeria, Morocco, Tunisia, Cameroon, and South Africa [25].

However, GSM has been criticized on the ground that coverage area per cell site is too small in comparison with CDMA. This can increase the cost to such a degree that GSM may not be viable for some developing countries [26].

3.3 MOBILE, FIXED, AND INTEGRATED USES

3.3.1 Introduction

In most parts of the industrialized countries, cellular technology was initially developed to serve mobile users traveling in automobiles. In rural parts of these countries, and in developing or transition countries that lack a strong landline infrastructure, wireless technology—including but not limited to cellular technology—has been used as a way to serve homes and offices [27]. This is a trend often referred to as *wireless in the local loop*. Over time, however, mobile and fixed uses have converged so that one system can serve both classes of customers [28]. The convergence of fixed and mobile aspects of a network is sometimes referred to as personal communications services (PCS) or the personal communications network (PCN). This section will discuss wireless in the local loop and PCS/PCN.

The use of wireless in the local loop has increased as the cost associated with it has decreased more quickly than the cost of a landline system over the years [29]. Cellular as a substitute for landline, or wired, service has the particular advantage of being *modular*. That is, the initial investment to erect cell sites can be made and additional equipment can be purchased as more customers sign up for service. In this way, expenditures for equipment beyond the initial build-out can be made out of the revenues of the system. (And the initial build-out itself may be financed by the vendor of the network equipment [30].) Building a landline system cannot follow this pattern; one does not want to redig trenches to lay a second cable [31]. A cellular network built to accommodate both fixed and mobile uses may well be more expensive than other types of wireless networks that are designed solely to serve fixed uses (such as fixed point-to-multipoint radio systems). Employing a system that serves only fixed uses eliminates the need for a considerable amount of switching and software associated with mobile service [32]. However, a cellular system designed to serve both fixed and mobile uses presents a unique opportunity not available with less expensive systems engineered solely for fixed uses: the chance to subsidize service to fixed subscribers who are not well off with revenues from affluent mobile users [33].

PCS/PCN is a term that has been used in several ways and that can cause much confusion if the speaker's intent is not clear. This chapter will discuss three mean-

ings. The first is the evolution of existing cellular systems from systems that were intended to serve mobile users in vehicles to systems that will deliver voice and data communications to anyone, anytime, anywhere. The second is a cordless voice telephone system that may not be able to receive incoming calls and that is not suitable for people traveling in cars, because it lacks full ability to hand off calls from cell to cell. The third is a system that may look much like what the existing cellular system is evolving into, but that will be provided at a higher frequency than existing cellular.

3.3.2 Evolution of Cellular Technology

Cellular technology was originally developed for use in cars [34]. Therefore, cells were designed to cover areas where people travel in cars. Radio waves from these *macrocells* may not penetrate deeply into buildings and may be blocked on a street surrounded by skyscrapers. Through the use of *microcells* and *picocells* [35] to fill in the coverage gaps, cellular is evolving into a system that can also be used by callers who either do not move or who walk rather than drive. (The main purpose of microcells and picocells is to allow coverage indoors. However, they may also be used as temporary outdoor cell sites in emergency situations, such as natural disasters.) Moreover, by utilizing advanced intelligent network capabilities built into the landline network, calls can be delivered to an individual whether he or she is in the car, office, home, or is walking down the street. The hope is that eventually the intelligent network function will be built into the customer's cellular equipment. At home or office, the handset can be plugged into a base station and used like a cordless phone.

The United States Federal Communications Commission has recently proposed that broadband commercial mobile radio service providers (a category that includes cellular carriers) be explicitly authorized to provide fixed wireless local loop services. The Commission stated that it was taking this step to foster competitive local exchange service by allowing wireless carriers to provide the equivalent of local exchange service [36].

Cellular technology was also originally developed for voice communications [37]. However, technological evolution has led to cellular networks being used for data as well. For example, cellular carriers are developing and using cellular digital packet data (CDPD) technology for both mobile (e.g., cellular fax, e-mail, and vehicle location) and fixed (e.g., cellular alarm systems and utility monitoring) data applications. CDPD is designed to be a frequency-agile technology that breaks data transmissions into bursts, or packets, that can be inserted into the blank spaces in conversations on different channels and then reassembled at the receiving end. Data can also be provided on a circuit-switched basis, in which one channel is dedicated to the transmission (as it would be for a conversation), but CDPD will be more efficient because it will not tie up channels that could otherwise be used for voice transmissions. Even when a single channel is devoted to CDPD, more than one transmission

can be carried on it. However, circuit-switched technology is better suited to certain applications that involve long, continuous transmissions (e.g., file transfer of a word processing document) than is packet data technology [38].

3.3.3 Cordless Telephony

A second form of PCS/PCN developed along a path that split off early in the process of cellular evolution. For this reason, as well as its relative lack of success in some areas, it might be referred to as the Neanderthal family of PCS/PCN. It is called CT-2 and represents the second generation of cordless telephones. Like the first generation of cordless phones, the subscriber equipment comprises two parts: a base station and a handset. However, the CT-2 handset is lighter and smaller and thus portable.

CT-2 has certain technical characteristics that make it less expensive than traditional cellular. Capability for handoff of ongoing conversations when the caller moves from the coverage area of one cell to the next is limited. Part of the problem is that the network does not have the intelligence to hand off calls and another part is that cell-site coverage is rather small and thus a large number of cells must be built to obtain overlapping coverage [39]. In addition, when the phone is out of range of its home base station, calls can only be made, not received. This inconvenience can be ameliorated if the individual carries a pager or uses voice mail and can thereby retrieve messages to call someone. Moreover, in Japan and France, systems are available with some incoming call capability outside the range of the home base station. However, the French system does not hand off in moving cars and the Japanese network hands off only when the car is traveling at speeds of less than thirty kilometers per hour [40].

A CT-2 handset can be used in the home or office or as a substitute for a public phone, wherever a base station has been built. As the United States Federal Communications Commission (FCC) described it: "The latter [public phone] aspect of CT-2 is referred to as 'telepoint service.'…[P]roviders set up base stations in public places, such as airports, shopping centers, restaurants, etc. Subscribers to the service access it with their personal CT-2 handsets when they are within range of a base station" [41].

CT-2 has been implemented in several countries, including the United Kingdom, Hong Kong, and Singapore. Its introduction in European countries has been less than fully successful. Reasons given for this are that customers expect a similar level of coverage to cellular and that cellular is already so inexpensive in some countries that there is no market for CT-2 [42].

3.3.4 Next-Generation Systems

The third kind of system to which PCS/PCN refers is one that is being drawn on a blank slate rather than evolving from a vehicle-based, voice transmission arrange-

ment like cellular. However, when it is completed, it is expected to look, at least to the end user, much like the system that cellular operators are now creating by filling in the gaps in their coverage systems and expanding their range of applications. In the United States, PCS/PCN will use the 1,850- to 1,990-MHz portion of the radio spectrum [43]; in Europe, 1,710 to 1,880 MHz [44]. The FCC began auctioning blocks of PCS spectrum in December 1994. The precise technology to be used to provide services over this spectrum in the United States will be left to the market [45]. In Europe, PCS/PCN is referred to as DCS 1800. DCS 1800 licenses have been issued in the United Kingdom, Germany, and France [46]. Other than stating that the system is expected to compete with existing cellular systems, the French invitation to tender did not specify services required to be provided over this spectrum [47].

A projected standard for integration of various communications systems is the Universal Mobile Telecommunication System (UMTS) currently being developed in Europe. The goal of UMTS is to integrate the four principal types of mobile communications—cellular, wireless, paging, and private mobile radio—into one system with the pocket telephone as the principal customer equipment [48].

Much of this technology may be more advanced (and thus more expensive) than that needed to meet the needs of a developing country. However, some experts, cognizant of the way in which voice communications, data communications, and video communications (including entertainment) are converging [49] have envisioned a way that developing countries can take advantage of this convergence by using wireless communications. They propose that rural telecommunications systems can become self-supporting through establishment of community information centers composed of a computer, a printer, and a packet radio, all tied into a cellular system [50]. Local enterprises and individuals would pay for time-sharing of this equipment [51].

Even if cellular is used by a developing country only for basic voice communications rather than these more advanced services, it is helpful to understand the way in which wireless and landline systems are converging. Although some may still see wireless and landline as two separate beasts, from both a technical and business point of view, a more flexible approach will allow consideration of more options. The end result will be a more informed choice.

3.4 WHO CHOOSES?

Who should decide whether analog or digital technology is to be used in a country's system and which analog or digital air interface is appropriate? Who should determine whether the cellular system should be engineered to serve only mobile or fixed users, or both? What about which services are authorized over the frequencies allocated? In many countries, government has made these decisions; in others, they have

to some degree been left to industry. The answers will depend in some part on circumstances endemic to the country involved.

As was noted, the U.S. FCC has not specified which technologies must be used over the portion of the spectrum allocated to PCS. Nor has it required existing analog cellular operations to be converted to digital or mandated the digital format that must be adopted [52]. Rather, it has left this to the industry on the theory that the market will make the right decisions.

This was not the case, however, when cellular was first introduced in the United States. The FCC, over the course of several decades, reviewed the evolving state of mobile radio technology until AMPS was fully developed and the FCC was persuaded that it would be worthwhile to allocate sufficient spectrum for cellular to become widely available [53]. Moreover, because the FCC divided the United States into hundreds of markets—some geographically quite small—which were to be served by many different operators, it wanted to ensure that a customer of one operator could use his or her phone in other systems [54].

Today, however, cellular standards are often effectively set by industry groups such as the Telecommunications Industry Association (TIA). TIA committees are composed of representatives from carriers and equipment vendors. These committees write specifications that manufacturers of cellular equipment, while not bound to do so, generally follow when designing how their equipment should be able to perform [55].

Although cellular technology is far more advanced now than when the United States first issued licenses for cellular service, there are still reasons why a government might want to specify which technology must be used by cellular licensees in its country. One reason is the need to have a technology that is compatible with those in nearby countries for the benefit of the entire region. This has been the driving force in the European Community's specification of a GSM standard [56]. Similarly, members of the Southern Africa Development Community (SADC) [57] have met to attempt to agree on a common standard [58].

Developing countries might be concerned about compatibility of their system with that of an adjoining country for another reason. It may be that the profit to be made from a cellular license to be issued in a developing country would be so small that it would fail to attract many bidders. However, if the developing country is adjacent to a larger country that is planning to build or has already constructed a cellular system, the operator of the cellular system in the larger country might be able to extend its network into the developing country at a lower cost than an entirely separate operator. It could do this by using cell sites in the adjoining country to beam into the developing country, or by switching cell sites in the developing country off switches in the adjoining country. Alternatively, an independent operator in the developing country might be able to lease switch capacity from an operator in a larger, adjacent country.

A desire to foster competition is another reason why a government might want to specify the technology to be used. For example, if a country decides to authorize

two nationwide cellular systems, it might want them to utilize the same technology. This would allow a customer to switch from one system to the other—in case of dissatisfaction with service quality or pricing, for example—without incurring the cost of new terminal equipment [59].

A middle of the road option might be to ask interested bidders to propose the technology that they would like to provide and then to pick from among the submissions. This seems to have been the approach taken by Ghana, which ultimately granted six cellular licenses, although only two are operating [60]. It was also used in the issuance of the second Israeli license [61]. The disadvantage of this method is the possibility that none, or not enough of the bids would be acceptable to the government.

The government of a developing country may want to be more specific on the question of whether the cellular system(s) licensed by the country will be for mobile or fixed uses, or some combination of the two. The need for wireless to substitute for landline service in such countries would drive such specificity. Yet, to date many countries have not done so. This may be due to the perception of wireless as a "yuppie toy," [62] to a concern about alienating potential investors by making too many demands, or to a lack of knowledge about how to make such specifications [63]. Chapters 10 and 11 will discuss the ways in which a country might make such specifications.

3.5 CONCLUSION

A number of types of analog and digital technologies are available for the country contemplating the implementation of a cellular system to meet its telecommunications needs. Moreover, recent years have seen an integration of fixed and mobile applications in cellular systems that may be of particular benefit to a developing country. The choices a government makes among these options may depend in large part on the particular geographic and demographic characteristics of its country, as well as the financial resources available to it. And if the country decides to allow private interests to build and/or operate its cellular system(s)—the decision addressed in the next chapter—the choices can be limited by what private business is willing to provide.

Notes

[1] The trend in phones has been a movement from strictly mobile phones, which are installed in and cannot be removed from a vehicle, to portable phones, which can be carried in a pocket or purse. See, *e.g.,* Krister Raith, Erik Lissaker, Jan Uddenfeldt, and Jan Swerup, "Cellular for Personal Communications 2," in *Wireless Personal Communications*, Feuerstein (ed.), 1993; Calvin Sims, "A Gadget That May Soon Become the Latest Necessity," *N.Y. Times*, Jan. 28, 1990, Business Section, p. 10.

[2] For a rather technical description of the various analog and digital standards, see the ITU's "Reports of the CCIR (International Radio Consultative Committee)," 1990, p. 232, Report 742-3.
[3] Keith Bradsher, "Can Cellular Phone Companies Agree on a New Standard for Transmission?" *N.Y. Times*, Sept. 16, 1990, Business Section, p. 9.
[4] Discussion with Gerald A. V. Buttex, Telecommunications Consultant, Africa, Middle East, and Europe Regions, The World Bank, Sept. 28, 1994.
[5] But see Milo Geyelin, "Cellular Phones May Betray Client Confidences," *Wall St. J.,* Sept. 1, 1994, p. B1, col. 3 ("snoopers are already finding ways around the new [digital] technology.") Moreover, analog signals can be encrypted with special equipment.
[6] Megumi Komiya, "Fixed Wireless Local-Loop System: A New Recipe for Success?," *in Pacific Telecommunications Council Sixteenth Annual Conference Proceedings*, 1994, pp. 481, 484.
[7] For a complete list of abbreviations and the names of the technologies they represent, see Barry L. Leff, "Making Sense of Wireless Standards and System Designs," *Microwaves & RF*, Feb. 1994, p. 113.
[8] Balston & Macario, *supra* Ch. 1, note 1, at 65.
[9] *Id.* at 73–74 ("The ability to combine the 450- and 900 MHz systems using the same exchange and cell sites has been introduced by most manufacturers.")
[10] *Id.* at 114–15, 118, 137, 143.
[11] *Id.* at 31.
[12] Anthony Ramirez, "Next for the Cellular Phone," *N.Y. Times*, March 15, 1992, Business section, p. 7.
[13] Balston & Macario, *supra* Ch. 1, note 1, at 228, 334; Steven Titch, Charles F. Mason, "Digital cellular: What now?," *Telephony*, Feb. 10, 1992. (TDMA subdivides the digitized radio signal into three bit streams, or time slots, and expanded TDMA (E-TDMA) subdivides it into six.) A major personal communications services consortium in the United States has chosen CDMA as its standard. See Julie Chao, "Qualcomm's Prospects Suddenly Become Very Good," *Wall St. J.*, June 7, 1995, p. B3, col. 1. Use of CDMA technology has been mandated in South Korea. See *Telecommunications Rep'ts*, May 3, 1993, p. 48.
[14] Taken from the name of the committee of representatives from the European PTTs that was charged with selecting a pan-European standard. Balston & Macario, *supra* Ch. 1, note 1, at 154.
[15] Roger Newell, "Commentary: U.S., Foreign Battles over Standards for PCS: The Worldwide Race for TDMA, CDMA, GSM," *TR Wireless News*, Jan. 13, 1994, p. 11.
[16] "Japan, Korea and the Americas are the only GSM black spots," *FinTech Mobile Communications*, Nov. 4, 1993.
[17] Some cellular systems that are being constructed now are starting with a mix of digital and analog technology with plans to convert entirely to digital later. "BellSouth/IDB/Safra Group Gets Israel Cellular License," *Telecommunications Rep'ts*, May 16, 1994, p. 32. Digital FDMA, IS-54 TDMA, and CDMA are sometimes collectively referred to as "D-AMPS" or digital AMPS.
[18] Newell, *supra* note 15, at 13.
[19] "PCS Providers in U.S. Form North American Interest Group to Promote 'GSM' Wireless Technology," *Business Wire*, Nov. 20, 1995; "BellSouth Unit To Launch GSM Wireless Network," *Dow Jones News*, Nov. 14, 1995.
[20] *E.g.,* Nirmal Ghosh, "Globe Telecom launches $599 handphone in Manila," *Straits Times* (Singapore), Sept. 14, 1994, p. 34 (GSM subscribers may use their phones in some 50 countries under international roaming arrangement); "GSM Standard's Influence Spreads Worldwide," *Mobile Phone News*, March 1, 1993.
[21] Safeguards that prevent confidential subscriber information from being picked up by bandits with equipment that monitors the airwaves are built into the GSM network. Guy Daniels, "The European Market for Digital Cellular Communications," *Microwave Journal*, Jan. 1993, pp. 66–71. There has been some concern that the GSM encryption algorithm is so sensitive that it should not be made available to some countries. John Williamson, "GSM bids for global recognition in a

crowded cellular world," *Telephony*, April 6, 1992, pp. 37–38. A semipermanent SIM card can be plugged inside the equipment, so that a subscriber need not always remember to carry her SIM card with her. Balston & Macario, *supra* Ch. 1, note 1, at 171.

[22] Personal identification numbers are becoming more common with AMPS systems as well, as a way to deter fraud.

[23] "AT&T Corp., Cellular-Phone Coverage Expands to 35 Countries," *Wall St. J.*, Nov. 8, 1995, p. B9 (reporting on SIM cards issued to U.S. cellular subscribers for use in foreign countries); Douglas Lavin, "Deutsche Telekom, GTE Will Develop New Phone Service," *Wall St. J.*, March 8, 1995, p. B7, col. 5 (reporting on reciprocal system); "Ameritech Cellular Customers Can Use GSM Phones," *Telecommunications Rep'ts*, June 20, 1994, p. 40 (reporting on SIM cards issued to U.S. cellular subscribers).

[24] "Hungary Awards Two Digital Cellular Licenses," *Telecommunications Rep'ts*, Aug. 30, 1993.

[25] A more complete listing of countries adopting the GSM standard is contained in Appendix C, Review of Worldwide Developments, to Commission of the European Communities, Towards the Personal Communications Environment: Green Paper On a Common Approach in the Field of Mobile and Personal Communications in the European Union, COM94, 45 final, Brussels, 27.04.1994) [hereinafter, "Mobile Green Paper"].

[26] Telephone conversation with Ed Resor, Consultant, Jan. 3, 1995.

[27] See, *e.g.,* Quentin Hardy, "Motorola Wins $100 Million Contract To Provide Wireless Phones in Hungary," *Wall St. J.*, June 8, 1995, p. B12, col. 3; "Ericsson Wins $450 Million Contract for Fixed Cellular in Malaysia," *Edge*, Sept. 19, 1994.

[28] For example, a system is being installed in the Republic of Tatar that will serve primarily as a substitute for a basic wireline network, with fixed terminals in homes and businesses, and fewer than one in ten terminals dedicated to mobile use. *Telecommunications Rep'ts*, Sept. 6, 1993, p. 42.

[29] ITU, World Telecommunication Development Report 38 (1994). This ITU report was issued to participants in the first ITU World Telecommunications Development Conference in Buenos Aires in March 1994. "Vice President's Role Seen as Signal of Administration's Interest in Telecom as Catalyst for Global Development," *Telecommunications Rep'ts*, March 21, 1994, p. 12.

[30] John J. Keller, "Sprint Ready To Tap AT&T For PCS Pact," *Wall St. J.*, Dec. 8, 1995, p. A3, col. 4.

[31] Conversation with Peter Smith, *supra* Ch. 2, note 17.

[32] Komiya, *supra* note 6, at 484–85. C. Billowes, "Some Background to and Experiences in Rural Telecommunications in the Third World," in *Second International Conference on Rural Telecommunications*, London: Institution of Electrical Engineers, 1990.

[33] Rudi Westerveld, "Cost Effective Rural Communications Using Fixed Cellular Radio Access," in B. A. Kiplagat & M.C.M. Werner, *Telecommunications and Development in Africa*, 1994, p. 199, 205. The Westerveld article describes how a mixed use—mobile and fixed—system can be engineered to serve rural areas.

[34] In the United States, the Federal Communications Commission (FCC), the agency that regulates cellular service, for years mandated that, with the exception of basic exchange telephone radio service ("BETRS"), fixed point-to-point services over cellular frequencies could only be offered on an "incidental" basis. Report and Order, 65 RR 2d 985, 995–6 (1988). BETRS is designed to serve as an extension of basic exchange service in areas where inadequate or no basic is offered by a landline carrier. For current policy on provision of fixed services over cellular frequencies, see 47 C.F.R. §§22.901, 24.5.

[35] Some do not distinguish between microcells and picocells, but simply refer to any cell with a coverage radius of less than one kilometer as a microcell. "Cellular for Personal Communications," *supra* note 1. Others refer to a picocell as one with a coverage radius of, for example, 30–250 meters. Hans van der Hoek, "The New DECT Standard for Cordless Communications," *Telecommunications*, April 1993, p. 37.

[36] Notice of Propose of Rulemaking, in the Matter of Amendment of the Commissions Rules to Permit Flexible Service Offerings in the Commercial Mobile Radio Services, FCC 96-17 (Released January 25, 1996).

[37] For years, U.S. cellular frequencies could be used for "auxiliary" services such as data (voice is considered "conventional") transmissions only on a secondary basis. Report and Order, *supra* note 34, at ¶ 2. For current policy, see 47 C.F.R. §§22.901, 24.5.

[38] Laurie Flynn, "The Executive Computer: 3 Ways to be Unplugged Right Now," *N.Y. Times*, Dec. 4, 1994, § 3, p. 11; "BAM to Deliver Cellular Digital Packet Data," *Bell Atlantic World*, Third Quarter 1993, p. 1. See Bruce Caldwell, "GTE Prepares CDPD Rollout—Announces successful interoperability test," *Informationweek*, Nov. 28, 1994; "Why Your Company Should Think Wireless," *Investor's Business Daily*, Nov. 16, 1994, p. A4; Jeffery Schwartz, "US West to Offer Wireless Data Services Via Voice Nets, Not CDPD," *Communicationsweek*, Oct. 31, 1994. As the *New York Times* article cited above describes, CDPD is not the only packet data technology available.

[39] John Williamson, "The wireless industry erupts worldwide," *Telephony*, Aug. 3, 1992, p. 26.

[40] Jenny Walker, "Tiger economies beat forecasts," *Fin'l Times*, Nov. 27, 1995, Special Section on Mobile Communications, p. 4., col. 1; David P. Hamilton, "Japan Rolls Out Entries in PCS Market Meant to Rival Bigger Cellular Phones," *Wall St. J.*, July 3, 1995, p. A3A, col. 2 (discussing Japanese "Personal Handy Phone"); "Romancing the Bi-Bop: the French and Their Phone," *N.Y. Times*, April 23, 1995, § 1, p. 49 (calls can be forwarded to the portable phone if the caller will be in one place for a long time); Michael Paetsch, *Mobile Communications in the U.S. and Europe: Regulation, Technology, and Markets*, Norwood, MA: Artech House, 1993, p. 327. (The French Bi-Bop system allows user to key in a code number on his or her handset, and incoming calls will be routed to the specific base station that received the code.)

[41] Notice of Inquiry, In the Matter of Amendment of the Commission's Rules to Establish New Personal Communications Services, at p. 3, n. 3, GEN Docket No. 90-314 (1990).

[42] MalarkyTaylor Associates/Economic and Management Consultants, Inc., Asian Cellular Markets, Vol. 1, 1993, p. 17; "Finnish closure leaves only two telepoint systems in Europe," *FinTech Mobile Communications*, June 16, 1994.

[43] Memorandum Opinion and Order, In the Matter of Amendment of the Commission's Rules to Establish New Personal Communications Services, 9 FCC Rcd. 4957 at ¶ 26 (1994).

[44] Daniels, *supra* note 21, at 76; Balston & Macario, *supra* Ch. 1, note 1, at 208.

[45] Memorandum Opinion and Order, *supra* note 43, at ¶ 3.

[46] Thomas Kamm, "Boygues Wins a Second Contract, Posts Profit Rise and Will Seek New Capital," *Wall St. J.*, Oct. 6, 1994, p. A14, col. 1; Balston & Macario, *supra* Ch. 1, note 1, at 207; Kavita Bowry, "A Review of European Communications," *Microwave Journal*, Oct. 1993, p. 64.

[47] Invitation to Tender, for setting up a public radiotelephone network, aiming to develop a personal communications service on French territory (Feb. 1994).

[48] Cengiz Evci and Vinod Kumar, "Pan-European Project for Third Generation Wireless Communications," in Jack M. Holtzman & David J. Goodman, *Wireless Communications: Future Directions*, 1993.

[49] *E.g.,* "Geoworks to Provide Ericsson with System for 'Smart Phones,'" *Wall St. J.*, Jan. 23, 1996, p. B7 (describing cellular phones that supplement voice communications with features like faxing, Internet connections, and electronic mail); Diane Mermigas, "Virtual Reality (Part 1 of 2): Moving Beyond the Dreams of the Communications Revolution," *Electronic Media*, Nov. 7, 1994, p. 38; "Multimedia: Sprint Unveils Multimedia Test Track in Silicon Valley," *Edge*, Oct. 224, 1994.

[50] For early uses of packet radio in developing countries, see Willem Zijp, "Improving the Transfer and Use of Agricultural Information," *World Bank Discussion Paper 247*, at 76–80 (1994).

[51] Telephone conversation with Ron Epstein, Volunteers in Technical Assistance, Nov. 23, 1994. Mr. Epstein suggests that the equipment for such an arrangement would cost about $1,500–$1,600 and that such a center could be self-sufficient if about twenty to thirty thousand people live within one-half hour of it. Countries that he indicates have attempted or are attempting to establish such centers are Uganda, Turkey, Madagascar, and India. Mr. Epstein is working with the World Bank to promulgate such centers in developing countries. He also indicated that the European Union is examining a proposal for such centers, referred to as Community Educational Utilities. Telephone conversation with Ron Epstein, Feb. 17, 1995. See Saunders, *supra* Ch. 2, note 1, at 354–55 (discussing similar concept of "telecottages" in Scandinavia).

[52] Balston & Macario, *supra* Ch. 1, note 1, at 226.

[53] Philip Palmer McGuigan, David M. Connors, and Kenneth L. Cannon II, "Cellular Mobile Radio Telecommunications: Regulating an Emerging Industry," 1983 *B.Y.U.L. Rev.* 305, 307–10, 1983; Report and Order, In the Matter of An Inquiry Into the Use of the Bands 825-845 MHz and 870-890 MHz for Cellular Communications Systems; and Amendment of Parts 2 and 22 of the Commission's Rules Relative to Cellular Communications Systems, 86 F.C.C.2d 469, 49 R.R.2d 809 (1981). It should be noted that certain aspects of the McGuigan article (such as the statement that the FCC would not use lotteries to award licenses) are out of date and contradicted by subsequent events.

[54] McGuigan, *supra* note 53, at 318.

[55] Comments of Jim Akerhielm, Director, Network Planning, Bell Atlantic Mobile Systems, Inc., Aug. 31, 1994.

[56] Directorate-General, Telecommunications, Information Market and Exploitation of Research, Overview of the Green Paper on Mobile and Personal Communications and Extract of the Positions Proposed, §§ II and III [hereinafter "Overview"].

[57] The SADC comprises Angola, Namibia, South Africa, Botswana, Zambia, Lesotho, Swaziland, Zimbabwe, Malawi, and Mozambique. Bill Keller, "Southern Africa's Old Front Line Ponders Its Future in Mainstream," *N.Y. Times*, Nov. 20, 1994, p. A1, col. 4.

[58] Although it was reported that the SADC decided to adopt AMPS because it was less expensive than GSM, with the hope of migrating to GSM, South Africa subsequently issued two GSM (rather than AMPS) licenses. "The Cellular Switch is On In South Africa," *Africa Communications*, July/Aug. 1994, p. 22; "Africa Works Toward a Common Cellular Standard," *Mobile Phone News*, March 8, 1993; *Mobile Phone News*, April 19, 1993. The issuance of the GSM licenses immediately may have occurred because GSM cannot be overlaid on AMPS.

[59] Balston & Macario, *supra* Ch. 1, note 1, at 114.

[60] Conversation with Jim Cowie, Senior Telecommunications Specialist, Industry and Energy Division, The World Bank, Sept. 28, 1994. Ghana also allowed bidders for the licenses to specify what coverage area they wished to serve. *Id.*

[61] Alan Stewart and Alan Pearce, "PCS: first, find your market," *Communications Int'l*, Oct. 1994, p. 78.

[62] Telephone conversation with Ed Resor, Consultant, Oct. 3, 1994.

[63] Conversation with Jim Cowie, *supra* note 60.