Up in the Air — New Wireless Communications

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Executive Summary

- Recent developments in radio technology, such as digital encoding schemes and microcellular architecture, enable new wireless communication services. Personal communications networks (PCNs), similar to cellular telephony but with more features, promise mobile or personal communications for the public. Wireless local drops essentially replace the present wire-based local telephone networks. Both PCNs and wireless local drops have yet to be implemented.

- Along with developments in wireless technology, a new type of communication — personal communications services, or PCS — is emerging. PCS have yet to be defined by regulators or industry. They are not directly related to new wireless communications: PCN may facilitate the provision of PCS, but other telecommunications means may evolve to offer similar services.

- A central issue of the new wireless communications is spectrum allocation. Without frequency allocation, only existing holders of the spectrum can employ the unused portion of their frequencies to provide the new wireless services. Spectrum allocation is needed to introduce competition into the market, but most suitable frequencies are already occupied. The FCC intends to reallocate microwave frequencies to the new services, but relocating current users to different bands will be difficult.

- Many regulatory issues remain to be resolved, including licensing qualifications and criteria, the number of providers allowed in each geographical region, common or private carrier status, regional or national licensing, cost allocation methods, and future telephone numbering plan to accommodate new wireless services.

- The cost of setting up a PCN system is not yet known but will probably be high. Few enterprises may have the resources to go it alone. Industry alliance or unbundling the ownership and provision of a new wireless operation is likely.

- If new wireless communications are established, in the short term wireline and nonwireline cellular carriers would feel the greatest impact, and in the future local telephone companies could face direct competition. These two groups have little incentive to help create a successful new wireless business, but, if it is inevitable, they want to take part in the action. They are also developing capabilities to offer PCS with existing systems.

- Cable television companies regard new wireless communications as their entry point to local telephone service business. Their financial strength and network reach make them competitive. They will probably form alliances with radio communications companies to provide PCN.

- Although the new wireless communications systems have yet to be set up, many forms of competition to them have emerged from the private radio industry, the paging industry, the satellite industry, and even the computer industry.

- In spite of optimistic forecasts, the market for the new wireless communications is unknown. Cost, quality, and compatibility of future systems have yet to be studied thoroughly. The market may also be greatly affected by competition, possibly unexpected, enabled by innovations in other telecommunications technologies.

- As cellular telephones and local telephone networks evolve with advances in technology, the key to the many ways to offer PCS and compete in the wireless communications market is a license to use a portion of the spectrum to provide the service.

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Preface

All telecommunications can be classified according to two types transmission media: wire-based and wireless. "Wire" has become a generic term that includes metallic (copper) wire, coaxial cable, glass fiber, and so on. Every medium that does not require a wire is referred to as "wireless." In function, each type more or less serves the same fundamental purpose, which is communication between people or machines, but differ in architecture, in some of the features they offer, and perhaps in the way people use or perceive them.

The local telephone system of the United States at the turn of the 1990s was mostly wire-based. Although wireless communications have been in commercial use for many years, recently new wireless technologies have received considerable attention. Wireless has started to expand, owing to technological innovations, into mainstream telecommunications networks formerly almost exclusively wire-based. New wireless communications have the potential to become a serious form of alternative telecommunications.

This paper explores how new wireless voice communications on a short-haul basis may be established in the U.S. and how the new services may transform and modify the way telecommunications networks, services, markets, and industries are structured and perceived. Chapter One gives an overview of the new wireless communications, including the meanings of commonly used terms, the technological innovations that induced new wireless communications, and the various types of wireless systems proposed. Chapter Two summarizes the stakeholders and their positions and presents several cases used for discussion in the paper. Chapter Three describes government intervention in new wireless communications. Because telecommunications service industries are regulated, government intervention is likely to play an important role in shaping the future industry and market of new wireless communications. Such aspects of government action as spectrum allocation and industry regulation are discussed. This chapter also examines controversial topics related to government intervention in new wireless communications, taking into account the positions of various stakeholders.

Chapters Four and Five analyze two major aspects of the business: industry and the market. No effort is made to forecast the future; rather, the various forces and interactions that might shape the industry and market are described, as well as their potential and probable consequences.

This paper reflects information current as of June 1992.

CHAPTER ONE
NEW WIRELESS COMMUNICATIONS: MEANINGS, TECHNOLOGIES, AND SERVICES

"Wireless" is an umbrella term that covers many kinds of communications. Wireless communications can be classified according to two attributes, distance of communication and mobility (see **Figure 1-1**), and each class has a different role in a telecommunications network, as in the telephone system shown in **Figure 1-2**. For example, long-haul, fixed wireless communications means such as point-to-point microwaves and satellite links can be used as transmission media for long-distance telephones, while cellular telephony can be used for short-haul, mobile communications. **Table 1-1** gives examples of short-haul mobile wireless communications, identifying the three attributes — service, technology, and function — of each. Other wireless communications means also can perform various functions in a telecommunications network.

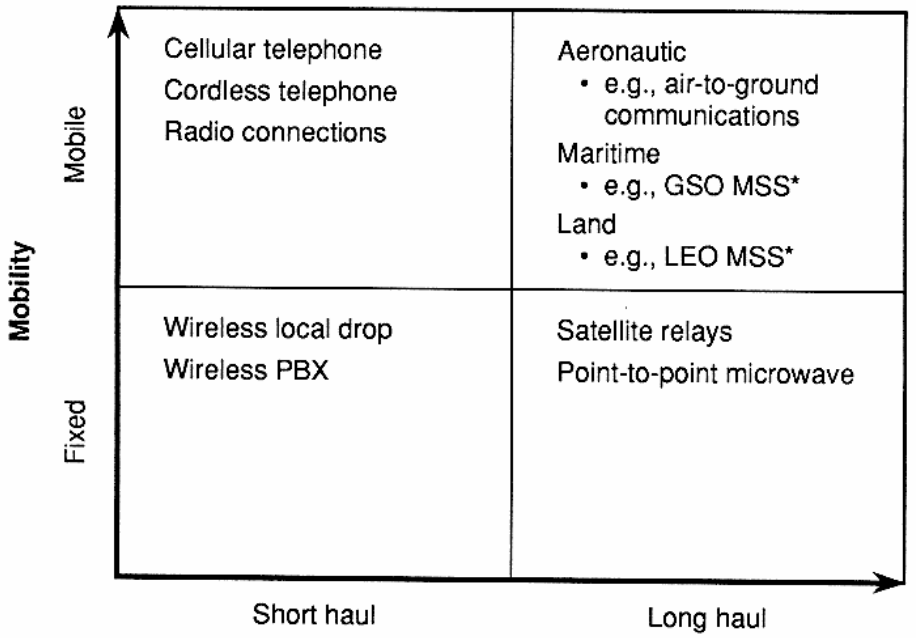
Recently, short-haul mobile wireless services have received much attention, partly driven by the nature of wireless communications — which frees users from mechanical connections to communications devices via wires — and the technological innovations that make this service cheaper and better. According to George Calhoun, Vice President of International Mobile Machines Corporation, in his book *Digital Cellular Radio*:

> It is often said that we are on the verge of a "revolution" in mobile communications, a revolution that will ultimately liberate us as communication users from being tied down to a particular fixed location in the telephone network, and will provide us with an advanced voice and data communication capability in a highly portable package ... at a reasonable price.[1]

This chapter provides an overview of new wireless communications, establishing common grounds for the discussions in later chapters by explaining and clarifying the meanings of terms usually associated with wireless communications. Developments in

Figure 1-1

Classification of Wireless Communications



*GSO: Geo-stationary orbit (satellite)
MSS: Mobile satellite service
LEO: Low-earth orbit (satellite)

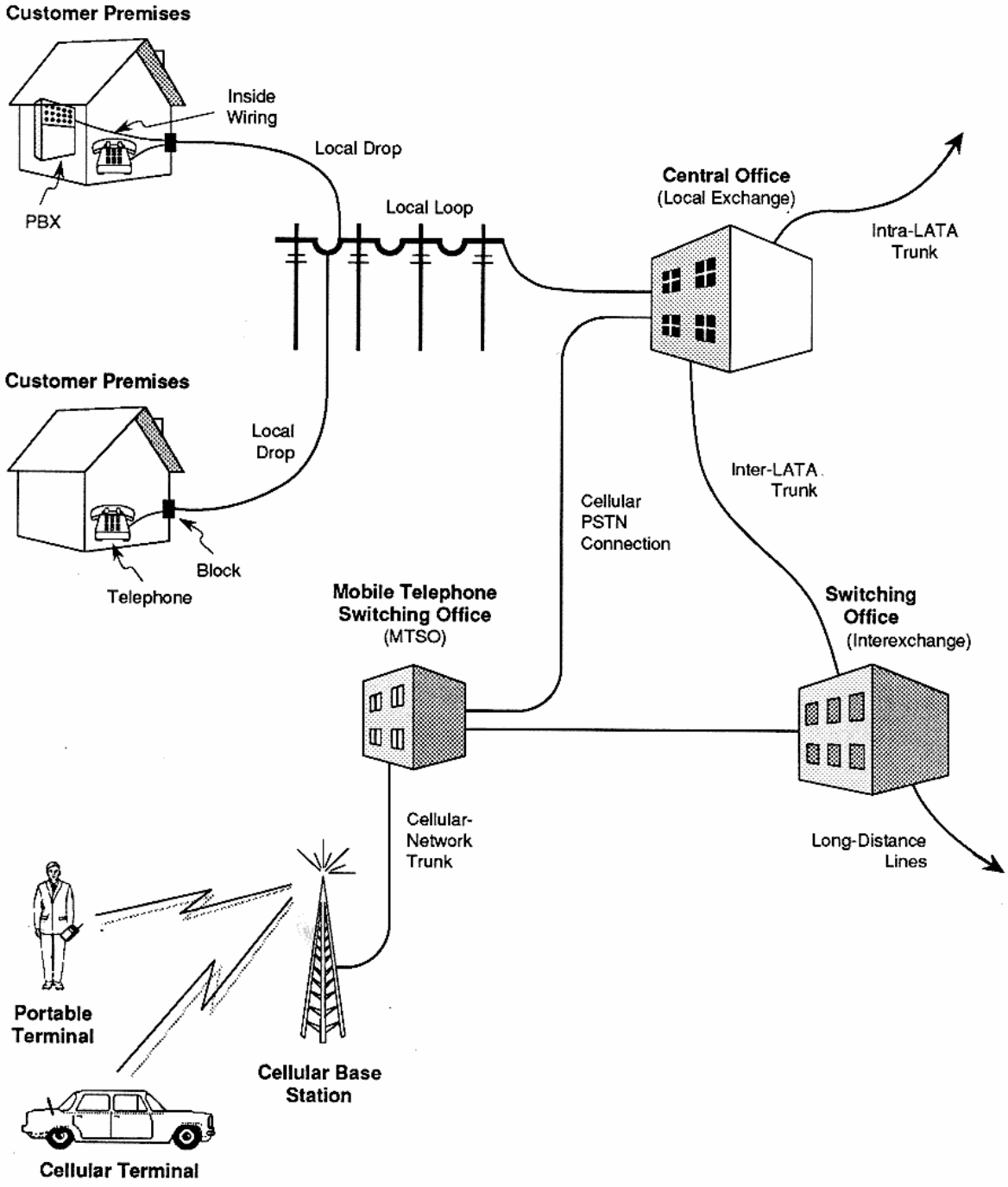
wireless technology, and in the types of services these make possible, are described in detail.

1.1. Commonly Used Terms

In the public discussion of wireless communications, many terms, such as wireless, portable, mobile, and cellular, are used as if they were interchangeable, but actually they often mean different things to different stakeholders and belong to different categories.

Figure 1-2

A Telephone System



Source: Adapted from Carol L. Weinhaus and Mark Jamison, *Alternative Costing Methods Project—Update on Modeling Process and Key Components of Technology Deployment*, Program on Information Resources Policy, Harvard University, 1991; and Michael Noll, *Introduction to Telephones and Telephone Systems* (Norwood, Mass.: Artech House, Inc., 1988), Figure 10-1, p. 146.

Table 1-1

Examples of Mobile Wireless Communications

Service	Technology	Function
Cellular telephone	Cellular radio • analog • digital	Primarily vehicular, increasingly portable
Land mobile radio • specialized mobile • private radio	Single base station radio	Vehicular, portable
Cordless telephone	Radio connection • CT–1 • CT–2	Portable
Personal communications network (PCN)	Microcellular architecture, digital radio	Personal*

*As described in Section 1.1.

- **Wireless** "Wireless" describes the format of communications. Wireless communications use the radio spectrum for transmission and are the "over-the-air" counterpart of land-line-based communications, in which signals and messages are transmitted through wires, optical fibers, or other waveguides. Generally, wireless communications include all means for transmitting messages without a wire, including satellite, point-to-point microwave, and cellular radio.

- **Cordless** In the telephone industry, "cordless" usually refers to telephone equipment used in homes or offices (customer premises equipment, or CPE) that requires no cord to connect the handset to a base unit connected to the local exchange network (which can be either land-line-based or wireless). These devices

are called "cordless telephones," and in this context the term "cordless" exclusively denotes a specific wireless technology.

- **Portable and Vehicular** "Portable" and "vehicular" describe functions of telecommunications. Portable telecommunications devices allow handsets to be moved from place to place while phone calls are made. Vehicular devices allow use of a telephone in a vehicle, such as a car, even when the vehicle is in motion.

- **Cellular** "Cellular," confusingly, has two meanings. As a technology term, it designates the kind of wireless radio communications that require a cellular structure of base stations. In this usage, the underlying transmission medium is radio, and the underlying technology can be analog or digital. In the U.S., all cellular radio systems in commercial operation in mid-1992 are analog systems: the telephone conversations carried by the networks are transmitted over the air in analog format. The current trend worldwide is to move from analog to digital.

  "Cellular" also denotes the type of service provided by cellular telecommunications carriers. The cellular service, which was once mostly vehicular, is increasingly becoming portable. In the U.S., there are two cellular carriers in a region, and each is assigned 25 MHz of the radio spectrum to operate its system.[2]

- **Mobile** This is a function term: mobile communications enable communication during motion. Although mobility is usually easier to achieve with wireless than with wire-based devices, mobility is not exclusively associated with wireless. Telephones with long cords provide limited mobility; some wireless communications, on the other hand, are essentially fixed, as between microwave towers. Mobility and cellular are not directly related either: telephones used in airplanes (such as "Airphones" operated by the carrier GTE in the U.S.) provide the function of mobile communications, but they are not cellular devices.

- **Personal** This also is a function term. "Personal" can describe a collection of functions or features of communications services, such as small, light-weight terminals, ability to communicate from a variety of places, and reachability at all times and locations.[3] A communications service could be designated mainly for "personal use" if it has those features. However, "personal communications" are still a vague concept with different meanings (which may or may not include these features) in different contexts.

1.2. Wireless Technology: Innovations and Implications

Over several decades, a variety of wireless communications technologies have been developed and implemented. In the 1990s, satellite communications are part of everyday life, and cellular telephony has been a fast-growing sector of the telecommunications services industries since its establishment in 1983. But wireless communications still occupy a separate, often complementary, segment of the telecommunications services market; the mainstream telecommunications, especially the local portion, have always been wire-based. Recent developments in wireless communications technologies — digital encoding schemes and microcellular network architecture — have the potential to change the role of wireless devices in telecommunications.

1.2.1. Digital Modulation Techniques

Although historically the only choice, analog format seems a reasonable one for telephone systems, whether wireless or wire-based, because everyday, face-to-face conversations are intrinsically analog. In the case of wireless communications, each radio communications carrier in a region operates in a certain frequency range; multiple access methods are used to accommodate several telephone channels in one frequency range.[4] Analog systems use the frequency-division multiple access (FDMA) method, which divides a large bandwidth into small channels. For example, the existing analog cellular network (the Advanced Mobile Phone Service, or AMPS, system in the U.S.) supports

more than 300 channels in the 25 MHz assigned to each carrier. A telephone conversation is frequency-modulated (FM) and carried in an assigned channel.[5] In FDMA systems, each channel supports one telephone conversation at a time.

The major thrust of digital modulation technology is more efficient use of the spectrum,[6] because with this technology an operator can use a range of frequency to carry more telephone calls. Two major classes of digital modulation techniques have been proposed, although these are only crude categories: many different technologies or technical standards in each class have been proposed or developed, which may or may not be compatible with one another.

- **Time-division multiple access (TDMA) method** In TDMA systems, the whole frequency range, as in analog FDMA systems, is divided into several channels, but conversations are converted into digital format. Several conversations, say N, are simultaneously assigned to one frequency channel. For a certain length of time, N handsets take turns transmitting and receiving the digital signals. When one handset is transmitting or receiving, each of the other N-1 handsets uses the signals that they received during the time-slots assigned to them to recreate the original conversations (by a digital-to-analog conversion). As long as the time-slots are frequent enough, human ears cannot detect that a complicated sampling and synthesis process has occurred. Current TDMA technology promises a threefold increase of capacity over the analog systems[7]; subsequent improvement and variations may lead to as high as fifteenfold increase.[8]

- **Code-division multiple access (CDMA) method** In CDMA systems, the whole frequency range is used as a single channel rather than divided into a number of channels. A telephone conversation is digitized, modulated by a fixed-length code (called the "spread function"), then transmitted. The transmitted signal is spread out over the whole frequency range — hence, this method is sometimes referred to as a "spread spectrum modulation" method. Many coded signals, each modulated with a different spread function, can be simultaneously transmitted by air in the

same frequency range. The handset or base station that picks up the modulated signals uses a particular assigned spread function to decode them, in a process called "autocorrelation." Because the spread functions are all different, one handset can decode only one coded signal and recover its original "audible" format. Thus, although many conversations are transmitted in the same frequency range, one handset can still pick up only the coded conversation signal designated to it. This is similar to the way a person in a crowded party *hears* many different voices in the room but *listens* only to one. CDMA technology could increase the capacity by tenfold or more over the analog systems.[9]

Another feature of CDMA technology is the so-called "graceful degradation." When the number of simultaneous users reaches the capacity of a traditional telephone system, no one can make more phone calls. Those who try simply will not get a dial tone. But in a system employing the CDMA modulation technique, new users might still be able to place calls. As a result, the noise level will rise with the increasing number of simultaneous users, with no strict cut-off limit on the number of phone calls that can be placed simultaneously. Returning to the analogy of people at a party, when the number talking exceeds certain limits, a listener might still be able to pick up a particular conversation, but this would become more and more difficult as the number of conversations increases.

Digital modulation techniques can increase the channel capacity of a wireless system. Digital radio systems provide essentially the same telephone services as analog systems, although the customers also benefit from a potentially lower noise level and fancy manipulation of the transmitted signals, such as signal encryption for security purposes, possible, or much easier to accomplish, only with digital systems.[10] The major motivation for providers to change analog systems to digital is that the new systems can serve more customers.

1.2.2. Microcellular Architecture

Many radio communications systems use only one base station (as the transmitting and receiving antenna) to cover a whole service area. In a cellular system, the service area is divided into cells, each with its own transmitter, receiver, and antenna. The radio equipment in a cell site constitutes a base station. The cellular structure allows a particular cell to use frequency channels currently used in cells not adjacent to itself.[11] In cellular systems today, most cells are between three and ten miles in diameter, although some cells, especially in urban areas, may be smaller.

In a system that would use the proposed microcellular architecture, the size of a cell can be as small as 2,000 feet in diameter.[12] A system with smaller cell size requires lower transmission power because of the shorter distance between handsets and base stations. Lower power transmission allows the use of smaller and cheaper handsets as well as base stations. Smaller cell size also implies more cells to cover a given service area. When the number of cells in one system is large, the frequency reuse in any one cell can be greater, thus more channels are available in a given cell at any one time. One consequence of this efficient use of frequencies is that the capacity of systems with microcellular architecture will be much larger than those of current cellular networks, maybe even rivaling that of the traditional (wire-based) public switched telephone network (PSTN).

Microcellular architecture is not without disadvantages. Because the cell size is smaller, a user in motion is more likely to cross the cell boundary so that signals would need to be handed off from one base station to another more often. Too many hand-offs may make systems with microcellular architecture unsuitable for vehicular applications. Owing to the large number of cells, the investment necessary to set up this kind of network will be high. Thus, from an economic point of view, microcellular architecture is not suitable for areas with a low population density.

1.2.3. Implications

Innovations in wireless communications technology could affect the telecommunications services industries and their customers in at least three ways. First, new technologies allow companies to provide new services or existing services more cheaply or effectively. The provision of common carrier cellular service, established in 1983 as a new service,[13] allows many people in moving vehicles to use telephones at the same time. Improvements in handset technology enable portable use of cellular telephones. Now, technological developments may create a higher capacity for cellular systems, so more people can enjoy cellular-type services, and may make handsets smaller and cheaper. The possibility of the emergence of "personal" communications, described in Section 1.1, seems plausible.

Second, new wireless technologies might have a direct impact on the competitive structure of the telecommunications services industries. The existing wireless service providers, including private radio companies, paging operators, and cellular carriers, would face increased competition, because technology developments create opportunities for new entrants. Wireless communications systems with both high capacity and good quality could even compete directly with wireline networks. These competitive threats could reshape the telecommunications services industries and trigger regulatory reforms, which in turn would affect the industries and the market structure of the future.

Third, new technologies may blur the boundaries between different types of services. For example, cellular carriers in the U.S. plan to implement the technological developments in wireless communications. If a company were to establish a service using only new wireless technologies (digital encoding and microcellular architecture), the system and the service might not look different from those of the cellular carriers. For legal purpose, however, seemingly identical services can always be identified by the regulator as different.

1.3. Personal Communications Services

With the developments in wireless technology, a new class of service, personal communications services, or PCS, is emerging as a type of communications service suitable for "personal use" (see Section 1.1).

In 1990, in GEN Docket 90-314, the Federal Communications Commission (FCC) issued a *Notice of Inquiry* on personal communications services to solicit comments on the development of new wireless technologies and the establishment of new services based on them.[14] Although the FCC officially used the term "personal communications services" in this *Notice of Inquiry*, it offered no legal definition. Various parties in the industry have proposed definitions and descriptions of PCS either in their comments or at the FCC's "en banc" hearing on December 5, 1991. For example, the Telecommunications Industry Association suggests the following definition:

> A mobile radio voice and data service for the provision of unit-to-unit communications, which can have the capability of PSTN access, and which is based on microcell or other technologies that enhance spectrum capacity to the point where it will offer the potential of essentially ubiquitous and unlimited, untethered communications.[15]

Craig McCaw, Chairman and Chief Executive Officer (CEO) of McCaw Cellular Communications, Inc., said that PCS implies "integrated handsets that provide [one] with an electronic gateway to a communications network [one] can tailor to match [one's] own personal needs, desires, and habits."[16] John DeFeo, President and CEO of U S West NewVector Group, envisioned PCS as "a continuum of [telecommunications] goods and services which offers a wide range of choice and will provide new services that will bring ease of use to the customer at home, at work, and at play."[17] According to these different views, PCS could encompass a fairly broad range of services, but so far no specific, industry-wide definition of PCS has been established.

As described, PCS is a class of service and is not directly tied to any particular system or network. It may be provided by new communications systems, existing systems (with some modifications), or a combination of networks. Although new wireless communications technologies, with such features as capacity, portability, and mobility, may facilitate the provision of this service, the association of PCS with new wireless communications is not exclusive.

1.3.1. Personal Number Calling

The vagueness of the meaning of PCS and its confusing association with new wireless communications are further illustrated by the example of the highly publicized "personal number calling" (PNC) function. PNC is the ability to attach telephone numbers to service subscribers, rather than to locations where subscribers use their telephones. A telephone system with PNC would allow subscribers to make and receive phone calls wherever they are. PNC has become a major subject in new wireless communications: some equipment vendors and service providers see it as an important part of personal communications services and regard new wireless communications as the way to achieve inexpensive PNC for the public.[18]

But personal number calling is not exclusively associated with the establishment of new wireless communications. For one thing, this service already exists, although the degree of implementation may vary. Call forwarding, a service offered by most local telephone companies, allows incoming calls to be transferred to another number (in the same local calling area) where a subscriber can be reached. Bell Atlantic, a regional Bell operating company, has announced that it would combine its fixed telephone, cellular telephone, paging, and voice mail services to offer a "one-number" service in its region, although at first this service is likely to be limited in geography and in function.[19] In April 1992, American Telephone and Telegraph Company (AT&T) introduced EasyReach 700 Service, which "offers a glimpse of where telephone service is headed."[20] For $7 a month, subscribers can register a personal long-distance number with AT&T; when they travel, they inform the network of where they are, and calls to the personal number can

be routed to them.[21] The "roaming agreement" between cellular carriers in different regions allows subscribers to use the same cellular service to make and receive phone calls beyond its usual locations, although the users usually need to inform the carriers when they move to another region in order to be reached there.[22] And McCaw Cellular Communications attempts to set up a national cellular network that may offer PNC to its fullest extent.[23]

The relation of new wireless communications to PNC can be explained by unbundling the offering of the services into two parts: network coverage wide enough to allow users to communicate in a large area and network switches intelligent enough to know that a telephone number is associated with a particular user no matter where that user is. As proposed, new wireless communications networks, with their mobility and coverage, can offer telephone services to users in a wide area. To allow users to use one telephone number, the appropriate database and network intelligence must be built into the telecommunications networks that interconnect local telephone systems. Therefore, PNC service in a wide area can be provided by new wireless communications systems operated on either a regional or a national scale (or by cooperation and coordination of wireless carriers in different regions) with intelligent networks (INs).

1.4. Modes of New Wireless Communications

Of the many new and existing types of wireless communications, shown in **Figure 1-1** and **Table 1-1**, this paper focuses on two: the so-called "personal communications network" and wireless local drop. Both of these potential applications are made possible by developments in wireless technologies that are not yet commercially available or proven in practice. Both are similar in being controversial. As wireless services, both need a portion of the spectrum to operate in, thus requiring a new allocation or reallocation for them. Both are new services using wireless technologies and have the potential to become direct competition to existing businesses, including existing wireless services and traditional land-line-based telephone networks. The regulation of these new

services presents challenges to the policymakers, because how they are introduced and regulated would shape the structure of the telecommunications services industries in the future and change how "public interests" are served. Both may or may not provide services unavailable in existing telecommunications. There is no clear dividing line, whether market-based or technology-based, between these new systems and existing ones.

1.4.1. Personal Communications Network

A personal communications network, or PCN, is the term used in this paper to specify the new wireless *system*, enabled by new technologies, that supports the (yet to be defined) personal communications *services*.[24] Generally speaking, the terms "PCS" and "PCN" are used loosely and sometimes even interchangeably. Although new wireless communications systems such as PCN are a means to achieve PCS, they are not the only way. As discussed in Section 1.3, the functions of PCS may be offered by other systems and thus are not directly linked to new wireless communications.

This paper does not attempt a general definition of PCN. For the discussion here, a "personal communications network" is used to mean, operationally, the type of wireless communications that implement new digital microcellular technologies and provide services to the public with features classified as "personal" (see Section 1.1). With this operational description, the criteria for whether a system can be classified as PCN are the technology the system uses ("digital microcell applications"), the functions or features it offers ("personal"), and the market it serves (the general public).

One major difficulty with the operational description is that it does not make a fundamental distinction between PCN and cellular systems.[25] Because cellular operators are implementing digital encoding and reducing cell size, when PCN starts operation in the future, there may be no real distinction between cellular and PCN — some parties, notably the cellular carriers,[26] argue that to distinguish between cellular telephony and PCN is very difficult.[27] Other parties claim that there are key differences.[28] For the purpose of this paper, the overlapping nature of PCN with cellular, and with other

telecommunications systems, does not hinder the discussion of the creation of a new service; instead, this ambiguity reflects one of the sources of controversies analyzed here.

Partly because of the vagueness of the meaning of PCN, two types of systems have been proposed. One is (technologically) enhanced cordless telephones, which provide expanded geographic coverage and capability: for example, the technology of CT-2, or the second generation cordless telephone, is what its name implies; the Telepoint service, introduced in mid-1989 in the U.K., is a CT-2-based personal communications service. The other is a migration from cellular telephone, employing digital encoding and microcellular technologies. In the U.K., three PCN licenses have been issued to construct this type of system (see Section 3.4).

The industry's awareness and interest in this type of new wireless communications are obvious. Since the FCC issued its *Notice of Inquiry* on personal communications services, more than a hundred parties submitted comments in October 1990, and more than ninety reply comments were filed in January 1991.[29] Opinions on how to implement PCN, allocate spectrum, and regulate the new business varied widely. Companies in different sectors of the telecommunications services industries have filed for and obtained experimental licenses from the FCC to operate PCN, but no conclusions have been reached regarding those controversial issues.

1.4.2. Wireless Local Drop

Another type of new wireless communications is the wireless local drop,[30] envisaged as an alternative to the wireline local drop used in telephone networks today.[31] Local drops are connections between local loops and customer premises, as illustrated in **Figure 1-2**. The wireless local drop does not create new types of service; it is a new way to realize an existing service.

Wireless communications might be preferable for local exchanges for several reasons. The first is cost. The maintenance cost of wire-based local drops is high,

especially in urban areas, where exposed wires are often cut or tangled. Wireless links can provide alternative connections between the local loop and home telephone equipment, reducing the maintenance cost of that portion. This is one of the main reasons that local exchange carriers (LECs) are exploring the possibility of using wireless local drops in their networks.

Second, because of the high cost of laying underground telephone lines, wireless communications could serve as a quick fix in areas that lack reliable telecommunications means. Instead of constructing a land-line infrastructure to provide services in under-served areas, wireless devices can substitute as the main means of communications. This is already the case in some rural areas in the U.S., where the LECs are obligated to provide phone services to remote homes where wire connection is uneconomical. On the national level, wireless technology is less likely to be used as primary communications means in developed countries, where well-established land-line telecommunications infrastructures are in place. Countries with less developed telephone networks are much more likely to exploit the wireless option. For example, Germany has already started to provide "basic" telephone services, using wireless rather than traditional wire-based technology, to the former East Germany.[32]

Among other benefits of implementing wireless local drops, they can be used not to replace existing wire-based local drops but as a secondary communications means. The redundancy of a second network ensures the proper functioning of communications at almost all times, even if the primary network should fail. Wireless local drops are also a better means for emergency recovery because, in case of fire, for instance, radio communications are less likely to be cut off.

Although initially intended as a "fixed" wireless connection to a customer's premise, networks with wireless local drops may be developed into a system more like PCN, which allows use of the telephone outside the customers' premises (see Section 4.2.1.2). In the future, wireless local drop, personal communications network, and cellular telephony all may provide similar services and compete with one another.

Wireless local drops can become an alternative to the land-line networks in the local exchange market. New business opportunities are being created for non-LEC companies to use wireless local drop technology to introduce their own local telephone services and compete against the LECs. So long as the regulations and the economics of deployment permit, wireless local drops could emerge as a serious form of direct competition to the LECs. This possible competition in the local exchange market has become one of the major controversies in the new wireless communications debate.

CHAPTER TWO
STAKEHOLDERS:
OVERVIEW AND CASES

2.1. Summary of Stakeholders and Their Interests

The parties and stakes involved in the debate over new wireless communications fall into three categories: private industries, public and governmental concerns, and users. This section briefly summarizes their positions and interests. To aid discussion, **Table 2-1** presents the current allocation of the radio spectrum — an important stake to many stakeholders in the establishment of new wireless communications — as well as proposals for its reallocation, covering the frequency range between 420 and 2,500 MHz.

2.1.1. Private Industries

The stake for private industries is financial. Companies, if they are newcomers, are interested in setting up new businesses and becoming competitive or, if incumbents, in protecting existing businesses from new entrants.

- **Holding companies of local telephone operations** The "holding companies of local telephone operations" are the parent companies of local exchange carriers (LECs), such as the seven regional holding companies (RHCs). They could own both local exchange operations (such as the twenty-two Bell Operating Companies, or BOCs, owned by the RHCs) and other businesses (such as telephone directory publications). In most areas, the holding companies have subsidiaries, called "wireline cellular carriers," which provide cellular services in their franchised regions. Some holding companies own cellular operations outside their local telephone service territories, which are classified as "nonwireline" (see Section 4.2.2.1).

Table 2-1

Spectrum Allocations and Proposals for Reallocations: 420-2,500 MHz

MHz	Allocations: Type of Service	Direct Users or Service Providers	Customers or Revenue Sources	Dollar Values	Comments	Reallocation Proposals and Displacement Controversies
420.0	Amateur	Radio amateurs	N/A	N/A		
	Radio location					
450.0	Public and private land mobile	Paging carriers Private industries	Service subscribers Self	$1,350 mi.		
460.0	*Meteorological*		Government budget			
	Private land mobile	Private industries Local governments	Self Government budget		Police; fire; special emergency.	
470.0	UHF TV: ch. 14-20 (1 of 3)	Independent TV stations	Advertisers/consumers	$16,254 mi.	UHF TV is intended to provide opportunities for minorities and small community development.	
	Public and private land mobile	Local governments Private industries	Government budget Self		Public safety concerns.	
512.0	UHF TV: ch. 21-36 (2 of 3)	Independent TV stations	Advertisers/consumers	$16,254 mi.	UHF TV is intended to provide opportunities for minorities and small community development.	
608.0	Radio astronomy	Researchers	Government and school research budget			
614.0	UHF TV: ch. 38-69 (3 of 3)	Independent TV stations	Advertisers/consumers	$16,254 mi.	UHF TV is intended to provide opportunities for minorities and small community development.	
806.0						

	Private land mobile	Specialized mobile radios (SMRs) Private industries	Service subscribers Self	$250 mi.	Service paired with 851-866 MHz.	
821.0						
	Private land mobile	Local governments	Government budget		Public safety; paired with 866-869 MHz.	
824.0						
	Cellular telephone (1 of 2)	Cellular carriers	Service subscribers	$5,642 mi.	Mobile terminals to cell cites. Wireline carriers: 835-845; 846.5-849 MHz. Nonwireline carriers: 824-835; 845-846.5 MHz.	
849.0						
	Air-to-ground telephone	Service carriers (e.g., GTE Airfone)	Service users		Service paired with 894-896 MHz.	To PCS (proposed by, e.g., Advanced Wireless Communications).
851.0						
	Private land mobile	Specialized mobile radios (SMRs) Private industries	Service subscribers Self	$250 mi.	Service paired with 806-821 MHz.	
866.0						
	Private land mobile	Local governments	Government budget		Public safety; paired with 821-824 MHz.	To PCS (e.g., experimental license of BellSouth).
869.0						
	Cellular telephone (2 of 2)	Cellular carriers	Service subscribers	$5,642 mi.	Cell sites to mobile terminals. Wireline carriers: 880-890; 891.5-894 MHz. Nonwireline carriers: 869-880; 890-891.5 MHz.	
894.0						
	Air-to-ground telephone	Service carriers (e.g., GTE Airfone)	Service users		Service paired with 849-851 MHz.	To PCS (proposed by, e.g., Advanced Wireless Communications).
896.0						
	Private land mobile	Specialized mobile radios (SMRs) Private industries	Service subscribers Self	$10 mi.	Service paired with 935-940 MHz.	
901.0						
	Mobile (general purpose)				Paired with 940-941 MHz.	To PCS (proposed by, e.g., Northern Telecom).
902.0						

	Radio location		Government budget			
	Amateur	Radio amateurs	N/A	N/A	FCC designates as ISM frequencies.	To PCS (e.g., experiemental licenses of BellSouth & Advanced MobileComm).
928.0						
	Private fixed microwave	Private industries	Self			
929.0						
	Paging	Service carriers	Service subscribers	$1,350 mi.		
932.0						
	Fixed				Service paired with 941-944 MHz.	
935.0						
	Private land mobile	Specialized mobile radios (SMRs) Private industries	Service subscribers Self	$10 mi.	Service paired with 896-901 MHz.	
940.0						
	Mobile (general purpose)			N/A	Paired with 901-902 MHz.	To PCS (proposed by, e.g., Northern Telecom).
941.0						
	Fixed				Service paired with 932-935 MHz.	
944.0						
	Auxiliary broadcasting					*<944-948 MHz> Canadian allocation for digital cordless telephones.*
952.0						
	Fixed microwave	International public				
960.0						
	Aeronautical radio navigation					
1215.0						
	Radio navigation satellite		Government budget		Global position satellite (GPS).	
	Radio location		Government budget			
1240.0						
	Radio location	Military	Government budget			
	Amateur	Radio amateurs	N/A	N/A		
1300.0						
	Aeronautical radio navigation					

1350.0						
	Radio location		Government budget			
1400.0						
	Radio astronomy	Researchers	Government and school research budget			
1427.0						
	Space operation **Fixed and mobile telemetering**					
1429.0						
	Fixed and mobile telemetering					
1435.0						
	Mobile aeronautical telemetering	Aerospace industry	Self		Aircraft flight testing.	*<1452-1492 MHz> WARC '92 worldwide primary allocation to DAB.*
1530.0						
	Maritime mobile satellite **Mobile aeronautical telemetering**	Maritime satellite carriers (e.g., Inmarsat)	Service subscribers		Service paired with 1625.5-1645.5 MHz (downlink).	
1544.0						
	General mobile satellite				Service paired with 1645.5-1646.5 MHz (downlink).	
1545.0						
	Aeronautical mobile satellite				Service paired with 1646.5-1660.5 MHz (downlink).	
1559.0						
	Aeronautical radio navigation					*<1610-1626.5 MHz> WARC '92 worldwide primary allocation to LEO MSS (uplink).*
1626.5						
	Maritime mobile satellite	Maritime satellite carriers (e.g., Inmarsat)	Service subscribers		Service paired with 1530-1544 MHz (uplink).	
1645.5						
	General mobile satellite				Service paired with 1544-1545 MHz (uplink).	
1646.5						
	Aeronautical mobile				Service paired with 1545-	

	satellite				1559 MHz (uplink).	
1660.5						
	Radio astronomy	Researchers	Government and school research budget			
1670.0						
	Meteorological					
1710.0						
	Fixed; Mobile		Government budget			Possibly be given to private sector because of the "Emerging Telecommunications Technology ACT"; proposed, e.g., by Motorola, for PCS.
1850.0						
	Fixed point-to-point microwave	Private industries Local governments	Self Government budget			FCC 2/7/92 NPRM (ET 92-9) to emerging technologies.
1990.0						
	Auxiliary broadcasting	Broadcasting networks; service providers	Self		Studio transmission; electronic news gathering (ENG).	
2110.0						
	Point-to-point microwave	Telecommunications common carriers	Self		Landline and cellular point-to-point connections.	FCC 2/7/92 NPRM (ET 92-9) to emerging technologies.
2130.0						
	Point-to-point microwave	Private industries Local governments	Self Government budget			FCC 2/7/92 NPRM (ET 92-9) to emerging technologies.
2150.0						
	Point-to-multipoint microwave	Wireless cable multipoint distributors				
2160.0						
	Point-to-point microwave	Telecommunications common carriers			Landline and cellular point-to-point connections.	FCC 2/7/92 NPRM (ET 92-9) to emerging technologies.
2180.0						
	Point-to-point microwave	Private industries Local governments	Self Government budget			FCC 2/7/92 NPRM (ET 92-9) to emerging technologies.
2200.0						
	Fixed; Mobile		Government budget		For line-of-sight propagation only, including aeronautical telemetering.	To PCS (proposed by, e.g., Northern Telecom, for 1,710-2,290 MHz).
	Space research	Researchers	Government and school research budget			
2300.0						

	Radio location					
	Amateur	Radio amateurs	Government budget N/A	N/A		
2310.0						
	Mobile					
	Radio location					
2390.0						
	Radio location		Government budget			To PCS (e.g., experimental license of LiTel Telecommunications).
	Amateur	Radio amateurs	N/A	N/A	<2,450±50 MHz> FCC designates as ISM frequencies.	
2450.0						
	Fixed; Mobile	Private industries	Self		More than 500 assignments, mostly to petroleum and auxiliary broadcast.	To PCS (e.g., experimental license of LiTel Telecommunications).
		Radio location service providers	Service subscribers			
2483.5						
	Radio-determination satellite				Approximately 150 assignments, mostly to oil and petroleum industry services.	*WARC '92 worldwide primary allocation LEO MSS (downlink).*
2500.0						

NOTES:

1. Meaning of formats in the "Allocations: Type of Service" column:
   Shading-bold-italic : Government exclusive allocation.
   Shading-bold : Government and private sector shared allocation.
   Normal : Private sector exclusive allocation.
2. An "N/A" in the "$ Values" column: not appropriate for a dollar value.
3. The dollar values for UHF TV are the total advertising expenditures on syndicated and spot (national and local) TVs in 1989, from *Statistical Abstract of the United States 1991*, Table No.939.
4. The dollar values for cellular telephone are the total cellular service revenues for the year ending in June 1991. Source: Cellular Telecommunications Industry Association.
5. The dollar values for paging are the total paging service revenues in 1991, estimated by Frost & Sullivan, in *RCR*, September 23, 1991.
6. The two sets of dollar values for SMRs are from Doron Fertig, *Specialized Mobile Radio*, FCC, February 1991. Data are service revenues for 800 MHz

($250 million) and 900 MHz ($10 million) operations.

7. The FCC Proposed to reallocate 220 MHz to "emerging technologies" in its NPRM, FCC 92-20, ET Docket 92-9, February 1992.
8. ISM frequencies: Industrial, Scientific, and Medical frequency bands. Designated by the FCC as bands for unlicensed radios (Part 15.247).
9. Italicized items in the "Reallocation Proposals and Displacement Controversies" column denote foreign or international reallocations that may nevertheless affect decisions made in the U.S.
10. Acronyms:
    DAB: Digital audio broadcasting.
    LEO: Low-earth-orbit (satellite).
    MSS: Mobile satellite service.
    WARC: World Administrative Radio Conference.

Because of this diversity of businesses, the attitudes of the holding companies of local telephone operations toward new wireless communications are mixed. They want to be allowed to provide new wireless communications services, including PCNs and wireless local drops, if and when these services are established. They also want to protect their existing telecommunications businesses, which are traditional wireline-based telecommunications and cellular telephones. New wireless communications could compete with cellular telephones in the short term and could also challenge the local wire-based telephone business in the long run.

- **Nonwireline cellular carriers** They are the cellular carriers that do not operate local telephone services in the same areas. They have incentives for defending their existing business, because new wireless communications could become direct competition. Like the holding companies of local telephone operations, they, too, are implementing new wireless technologies and starting to provide services usually classified as PCS. If and when new wireless communications services are established, they do not want to find themselves excluded from eligibility for providing the new services.

- **Interexchange carriers (IXCs)** The deployment of new wireless communications on a short-haul basis may affect IXCs in three ways. First, the implementation could generate greater use of the IXCs' networks. Second, the IXCs could choose between wire-based and wireless carriers, which might provide an alternative connection between customer premises and IXCs, for a cheaper route to access customers (see Section 3.2.4). Third, until restrictions are imposed on the ownership of new wireless networks, IXCs might themselves become providers.

On the other hand, some IXCs, such as MCI Communications, who operate fixed microwave equipment in the frequency ranges mainly of 2,100–2,200 MHz (for use by common carriers, as shown in **Table 2-1**), oppose spectrum reallocation for new wireless communications.[33]

- **Equipment manufacturers** The implementation of new wireless communications means new business opportunities and a brand new market for equipment manufacturers. Both major manufacturers (such as AT&T, Northern Telecom, Motorola, Ericsson, and Siemens) and new players (such as Qualcomm and Digital Spread Spectrum Technologies), whose products fill small "niches" in the new business, advocate the deployment of new wireless communications.

- **Specialized mobile radio operators (and other private radio carriers)** Specialized mobile radio (SMR) is a class of service created by the FCC in 1974 to provide land mobile communications on a commercial (for-profit) basis to users who could themselves have been licensed in the private land mobile services. SMR is classified as a private land mobile radio service: the end user who wants to use the facilities of an SMR operator needs to apply to the FCC for a radio license (see Section 4.2.5.1). In contrast, a public land mobile operator, such as a cellular carrier, can sell its service freely.

  A number of SMR operators, such as Advanced MobileComm and Fleet Call, want to expand their mobile radio business by entering the new wireless communications. Some oppose the reallocation of spectrum in the 800 and 900 MHz frequency ranges, in which they operate, to the new services. See **Table 2-1** for the details of the allocations in those frequency ranges.

- **Other potential operators (cable TV companies, start-up companies, etc.)** Among other interested private enterprises, cable TV companies hope to use the spare capacity of their fiber optic or coaxial cable networks as the distribution backbone for PCN.[34]

2.1.2. Public and Governmental Concerns

Parties with regulatory concerns, parties that use the spectrum to perform public or governmental functions, and international organizations or foreign governments might be affected by decisions made in the U.S. on new wireless communications.

- **Parties with regulatory concerns** New wireless communications concern parties, such as the FCC, state public utility commissions (PUCs), and the National Association of Regulatory Utility Commissioners (NARUC), all with regulatory responsibilities for telecommunications services (to see that the "public interest" is served). State regulators will be involved only if the new wireless communications are classified as common carrier service; the FCC has the sole regulatory responsibility for private radio services.

  Frequency allocation is an important issue of new wireless communications. In the U.S., allocation of the radio spectrum is administered by the National Telecommunications and Information Administration (NTIA), which handles government spectrum allocations, and the FCC, which is in charge of private sector activities.

- **Parties that use the spectrum to perform public or governmental functions** On the federal level, government departments that use the spectrum heavily, such as the departments of State and Defense, would be concerned because their frequencies might be taken away from them and given to the new services.[35] Other federal agencies, such as the National Aeronautics and Space Administration (NASA), oppose spectrum reallocation because of their heavy investments in equipment operating in specific frequencies. These agencies also fear air-wave interference and other technical problems if their frequencies are shared by new wireless communications carriers.[36]

State and local governments have similar concerns. Police departments and public safety commissions do not want their frequencies taken away and regard radio interference due to spectrum sharing as a problem of public safety.[37]

- **International organizations and foreign governments** The major concerns worldwide regarding new wireless communications are frequency allocation and the possibility of services on a regional or global scale. International spectrum allocations are coordinated and made in the World Administrative Radio Conferences (WARC) of the International Telecommunications Union (ITU), such as the one held in Spain in February 1992 (WARC '92); and the use of the spectrum is monitored by the International Frequency Registration Board (IFRB) of the ITU. Frequency allocation for new wireless communications — referred to as future public land mobile telecommunications systems, or FPLMTS, by many countries other than the U.S. — made in WARC '92 may help create a worldwide or regional (most likely European) mobile service.[38] The FCC "intend[s] to consider the results of the WARC ['92] in developing our domestic PCS allocations."[39] Allocations to and the provision of other services, such as low-earth orbit (LEO) mobile satellite service, may have an impact on the establishment of new wireless services.

Among regional concerns, the governments of adjacent countries, Canada, for example, generally have to take into account the U.S. spectrum allocation carefully because of possible interference from radio operations in the U.S.

2.1.3. Users

Current users of telecommunications, who are also potential customers of new wireless communications, and existing users of the spectrum for private purposes, whether personal or commercial, are both concerned with the establishment of new wireless communications.

- **Telecommunications users** This group, roughly classified as business users and consumers, wants inexpensive high-quality services, if and when new wireless communications are implemented. Large business customers, who would benefit from various modes of new wireless communications, such as in-building wireless links, especially favor the new services.

  As envisaged by many potential providers, new wireless communications such as PCN are supposedly for the general public, rather than for a special market sector. But because of lack of organization, consensus, and major impacts, the voice of the potential customers (i.e., the consumers) is usually not heard directly by the regulators and policy makers. Another reason for their lack of participation is that many of the controversies, such as spectrum allocation and industry structure, are transparent to them.

- **Private Spectrum Users** This group extends across industries — utilities (such as power companies), transportation (such as railroad companies), broadcasting (such as TV networks),[40] and others (such as petroleum). They oppose reallocation to the new services of the frequencies where their existing use is threatened, because the relocation of their operations to a new frequency is costly.[41]

2.2. Industry Players — Case Study

The companies discussed here — Advanced MobileComm, Inc., a specialized mobile radio operator; NYNEX Mobile Communications Company, the cellular subsidiary of the NYNEX Corporation; and Northern Telecom Limited, a telecommunications equipment manufacturer — are not meant to represent their respective industries, because positions and actions in the same industry may differ, but are used to explore such actions and positions regarding new wireless communications.

2.2.1. Advanced MobileComm, Inc.

2.2.1.1. Company Background

Advanced MobileComm, Inc. (AMI), based in Boston, Massachusetts, is an SMR company. It currently holds or manages licenses for more than 450 channels and more than 12,000 two-way radio units in major metropolitan areas in the U.S.[42] AMI opened a European office in the U.K. in 1989 as its first attempt to participate in the international market. The FMR Corporation, whose subsidiaries in Massachusetts are collectively recognized as "Fidelity Investments," is the parent company of AMI. AMI was formed in 1987 after Fidelity Capital, the business development arm of Fidelity Investments, acquired Anticom, an SMR operator company in Waltham (Massachusetts) and established an SMR business in New England. Because AMI is a wholly owned subsidiary of a privately held company, its operating revenues and incomes are not public.

Hal Davis, AMI's chief operating officer, explains the company's strategy:

> Our research indicated that demand for radio communications is growing at approximately 20 percent annually. Spectrum space is finite and limited. That combination of supply and demand suggests that, properly financed and managed, the business ought to be an excellent opportunity in the long term.[43]

In the U.S., AMI now competes mainly in five regional SMR markets: New England, Texas, Georgia, North Carolina, and Minnesota-Wisconsin.

2.2.1.2. Participation in New Wireless Communications

As an SMR operator, AMI is attempting to expand into public land mobile operation, using new wireless communications as an entry. It is, and has been, active in

applying for trial licenses and testing new technologies, as well as in responding to the FCC's *Notice of Inquiry* on PCS.

AMI currently (through December 1992) holds two experimental licenses from the FCC to test its digital wireless communications systems, one for the Boston area, the other for the Miami-Fort Lauderdale-West Palm Beach, Florida, area.[44] The spread-spectrum systems employed in both test sites use the 900 MHz range of the spectrum (see **Table 2-1**).

In November 1991, Mobile Radio New England (MRNE), a partnership controlled by AMI, requested the FCC to allow it to install a digital radio system in the New England area, similar to the Enhanced SMR network proposed by Fleet Call, Inc. (see Section 3.2.1.1).[45]

2.2.1.3. Positions

AMI advocates efficient use of the spectrum through "interference-tolerant" spread-spectrum technology and considers the digital microcellular technology under development by Digital Spread Spectrum Technologies, Inc. (DSST) encouraging.[46]

AMI "believe[s] that PCS will provide the public at large with significantly more opportunities to have easy and convenient access to a wide range of resources."[47] The market it is inspecting consists of more than business-related users. AMI cites the result of a study by the Opinion Research Corporation, that the potential market for PCN will be 50 percent of the U.S. households, while 68 percent will be interested if personal number calling is made available.[48]

AMI strongly advocates the open-entry regulatory model, intended to allow as many players as possible into the marketplace. Its essential points, as proposed by AMI, are the following:

- The FCC would reserve a frequency range for personal communications services that would be divided into as many slots as possible, each awarded to one PCN provider.

- Applicants would not be restricted by kinds of business — the LECs, cellular carriers, and so on, all would be allowed to bid for slots on the spectrum.

- Selection criteria (for example, financial and technical requirements) would be established by the FCC for admitting new players.

- After a firm acquires a PCN license from the FCC, it would be free to construct base stations; its PCN system would have to be up and running within a time limit imposed by the FCC. Access and interconnection to the public switched network would be guaranteed.

- The operators would be allowed to operate freely without regulatory oversight. The market would decide the winner(s).

According to AMI's proposals, if the FCC were to allocate the spectrum range of 1850–1990 MHz (see **Table 2-1**), a total of 140 MHz, for new wireless communications, then fourteen operators would be accommodated, if each were given a bandwidth of 10 MHz, thus providing plenty of competition. To scare off speculators and spectrum hoarders, AMI argues, the FCC should require each licensee to provide PCN services for a minimum period.[49]

Besides open entry, AMI expressed strong concerns about interconnectivity and access to telephone poles. "Mandatory interconnection between LECs and PCS providers should be implemented from the start in order for the LECs to be allowed to share in the benefits of open entry."[50] And "FMR Corp.'s first-hand experience with LEC interconnection arrangements indicates that there must be appropriate regulatory remedies

in this area that are available in the event that agreements are not produced, or are not followed once signed."[51]

2.2.2. NYNEX Mobile Communications Company

2.2.2.1. Company Background

The NYNEX Mobile Communications Company (NMCC) is a subsidiary of the NYNEX Corporation, the parent company of New York Telephone and New England Telephone. (The NYNEX Mobile Communications Company has no formal business ties with either New York Telephone or New England Telephone, although all three are wholly owned subsidiaries of the NYNEX Corporation.) NMCC is a wireline cellular operating company in the northeast,[52] with licenses in several metropolitan statistical areas (MSAs), such as New York City, Buffalo, Albany, Syracuse, and Orange County in New York; Boston, Worcester, and New Bedford in Massachusetts; and Providence, Rhode Island. In 1991 it expanded its cellular networks to new areas such as Watertown and Kingston in New York State. NMCC added 51 new cell sites in 1991, for a total of 265, and expects to add another 130 in 1992.[53]

For 1991, the operating income of NYNEX Mobile Communications was $48.5 million on revenues of $324 million, and it has a customer base of more than 300,000.

2.2.2.2. Participation in New Wireless Communications

In 1991, NMCC and NYNEX Science and Technology conducted several trials of new wireless communications systems and digital cellular networks in Boston, New York City, and White Plains (N.Y.) and participated in a multicompany trial in San Diego, California. The systems use the spectrum range 1850–1990 MHz (see **Table 2-1**.)

NMCC, like other cellular carriers, plans to upgrade its cellular systems to digital networks. The Cellular Telephone Industry Association (CTIA) endorsed the TDMA

method as the industry standard for future digital cellular systems in the U.S.,[54] but NYNEX, along with several other RHCs, announced its intent to support new CDMA digital cellular methods. (The two technologies, TDMA and CDMA, and therefore systems based on them, are not compatible.) In July 1991, NMCC announced that, because of delays in the development of CDMA equipment, it would postpone the implementation of CDMA technology and reserved the option to use TDMA method.[55]

In 1990 NMCC announced that it intended to launch "the nation's first commercial personal communications network service,"[56] called Personal Telephone Service (PTS), in New York City and then other areas. This system would use one-fifth of the spectrum (5 MHz) assigned to NMCC for cellular operation. With PTS, several different types of services could be available, such as full two-way communication, one-way communication coupled with paging, one-way outgoing service, and wireless data communications.[57] The applications were scheduled to be fully tested in 1992,[58] but, depending on the availability of equipment and the feasibility of new technology, the launch date could be delayed.

2.2.2.3. Positions

With no formal business ties to other NYNEX companies, NMCC's position on new wireless communications might not necessarily coincide with those of the other subsidiaries, but, as the policy-setting parent for its subsidiaries, the NYNEX Corporation has stated its position regarding new wireless communications in its comment and reply comment to the FCC's *Notice of Inquiry* on PCS. These comments may also represent NMCC's position:

- NYNEX does not want to be excluded because it is a local exchange carrier or a cellular provider: "[A]n exclusion of LECs or their cellular affiliates from utilizing wireless technologies within the public network infrastructure would be blatantly anticompetitive."[59] Also, "[t]he [Federal Communications C]ommission must view with great skepticism proposals to exclude any class of potential competitors from providing wireless services."[60]

- NYNEX asserts that personal communications services are ill-defined. "PCS, as reflected in the commission's discussion, could include almost anything that utilizes mobile radio frequencies."[61] And "[a]ny distinction the Commission might attempt to draw between 'cellular' and 'PCS' would be highly artificial."[62]

- NYNEX suggests that new wireless systems should take advantage of existing network infrastructure and that the features, functions, and performance of the wireline network will be used by the customers as a basis to judge wireless services.

- NYNEX expressed concerns about the proposed worldwide spectrum allocation for "personal, portable wireless technology" at WARC '92.[63] It opposes this proposal, claiming that "[t]elecommunications users and providers in the U.S. should not be limited by, or required to develop, systems and applications that might be effective for other countries."[64]

2.2.3. Northern Telecom Limited

2.2.3.1. Company Background

Northern Telecom Limited, a telecommunications equipment manufacturer based in Canada with manufacturing facilities and operations worldwide, is one of the leading suppliers of telecommunications equipment, with $460.2 million in earnings on $6.77 billion in sales in 1990. Its products include telephone terminals, transmission products, and central office switches.

In February 1991 Northern Telecom underwent a major reorganization. The company now has separate arms for production and marketing. On the marketing side, its operations are grouped according to geographical areas: North America, Europe, and Asia-Pacific. In the product division, separate companies were formed to handle three types of products: public network equipment (such as central office switching and

transmission), private network equipment (such as private branch exchanges [PBXs] and terminals), and wireless system equipment.

2.2.3.2. Participation in New Wireless Communications

Before 1990, Northern Telecom was not a very strong player in wireless communications, in comparison with such large equipment manufacturers as Motorola, Ericsson, and AT&T. One of its more important wireless markets is Mexico, where in 1990 it supplied five of the nine cellular regions.[65] It made significant gains in the U.S. in 1990, becoming the third largest cellular equipment supplier with nearly 100 systems.[66]

The formation of a separate department for wireless systems in 1991 signaled the company's commitment to the new technology and product group. Simultaneous with reorganization, Northern Telecom announced an agreement with Motorola, details not disclosed, jointly to develop and implement major enhancements to their existing cellular products for global markets, to be based on new open-system standards the companies will establish. The standards will be a combination of existing international switching and cellular standards, such as SS-7,[67] GSM,[68] ISO,[69] and ISDN.[70] According to John Roth, President of Northern Telecom's Wireless Systems Products, the agreement will "give cellular network operators a greater choice of equipment and more control over the evolution of their network."[71] To further the cooperation, in February 1992 the companies announced a joint venture to manufacture and market integrated cellular systems, called Motorola-Nortel Communications Company, which will produce mobile systems combining Motorola's radio equipment with Northern Telecom's switching and transmission network technologies.[72]

Northern Telecom demonstrated its first wireless business communications system at the Geneva Telecom '91 show in October 1991. Scheduled for launch in 1992 in the U.K. and Hong Kong, the system is intended for use in offices to allow workers to use their telephones while moving around the workplace.[73]

2.2.3.3. Positions

Northern Telecom proposes a common radio standard for personal communications interface (PCI), built on the CT-2 Common Air Interface (CAI) standard.[74] Northern Telecom claims that PCI is technologically suitable to new wireless communications services.

Northern Telecom sees a need for spectrum allocation for new wireless communications[75] and proposed the immediate exclusive allocation of the 930–931 MHz and 940–941 MHz bands for low-power PCN, the allocation of 930–960 MHz in the short term on co-primary basis, and another 120 MHz in the long term (see **Table 2-1**).

Northern Telecom has also taken the following positions:[76]

- Encouragement of open standards for new wireless communications
- Adoption of technology that promotes American exports[77]
- Internetworking and interoperability among different networks
- Encouragement of the development of a personal communications numbering plan in the future.

CHAPTER THREE
GOVERNMENT INTERVENTION

In the U.S., telecommunications services industries are regulated; the government's actions and oversight strongly influence how business is conducted. This paper does not deal with justifications and rationales of government intervention in the telecommunications services industries[78]; it takes as a given that the U.S. telecommunications services industries are, and are likely to continue to be, regulated, although the extent and degree of regulation may vary. For new wireless communications, as a form of telecommunications, the potential and the pattern of government intervention cannot be disregarded. Government intervention may include, but not be limited to, policies and regulations addressing spectrum allocation, type(s) of wireless services offered, types of technologies employed, extent of competition, structure of the industry, technical standards, and user protection. Government intervention (or its absence) in the new wireless communications is of concern to potential service providers as well as to firms in other sectors of the telecommunications services industries.

3.1. Spectrum Allocation

New wireless communications such as PCN and the wireless local drop, like all other radio communications systems, operate in the radio spectrum. Spectrum allocation for their operations has become a focus of debate mainly for two reasons.

First, almost all frequencies suitable to new wireless communications are already occupied by existing services.[79] The incumbents have invested in the equipment operating in those frequencies and, if relocated, would need to reinvest. Whether reallocation to the new services is desirable needs to be judged on economic, political, social, and technological grounds by those with responsibility for managing the spectrum.[80]

Second, the allocation of spectrum will directly affect the competitive structure of the industry. It is the precursor of any radio communication: those who get frequencies are in the market, and those who do not, even if they can offer the best service at the lowest price, are out. In other words, the spectrum is the ultimate barrier to entry into the market. Thus, the outcome of controversies over the industry structure and market definition of new wireless communications can be determined by the decision about spectrum allocation.

From the regulators' point of view, along with the issues of reallocation and the competitive structure of the industry, consideration of spectrum allocation for new wireless communications involves the following questions:

- Is the allocation necessary? (The answer determines whether newcomers are allowed into the market.)
- Which frequency bands will be allocated? (The answer may hurt some incumbents while leaving others alone and may benefit some equipment vendors and damage others.)
- How much spectrum should be allocated? (The answer can determine the degree of competition.)

Table 3-1 summarizes the issues concerning options for spectrum allocation for the new services.

3.1.1. Reasons for and Against Frequency Allocation

Whether frequencies should be allocated at all has been at the center of the debate about the new wireless communications. Parties agreed that this issue is important, but opinions differ on whether an exclusive allocation to the new services is desirable. Northern Telecom, for example, requests an immediate allocation of 30 MHz and a long-term allocation of 120 MHz for PCS.[81] Current spectrum users, such as the American Petroleum Institute, whose spectrum might be taken away, are against spectrum allocation for PCN.[82] The Cellular Telecommunications Industry Association (CTIA) claims that the

Table 3-1

Spectrum Allocation for New Wireless Communications: Merits and Demerits of Options

	Without Spectrum Allocation	With Spectrum Allocation		
		Allocation of Unused Frequencies	Spectrum Shared with Other Services	Reallocation of Frequencies
MERITS	New services can be provided by current spectrum users No relocation of existing services needed	No relocation of existing services needed	No relocation of existing services needed Expansion of provision of new wireless services relatively easy	Interference not a problem Regulatory rule-making based on exclusive allocation less complicated
DEMERITS	No competition from new entrants Limited expansion of services	Little unused spectrum available for new wireless services Difficult for service providers to reach economy of scale	Difficult to overcome interference problems	Relocating existing users a major problem

difference between PCN and existing systems, namely cellular telephones, is too small to justify a new frequency allocation.[83]

But offering PCS to the public is not directly associated with the exclusive allocation for new wireless systems: actions by parties with unused or underused frequency bands

demonstrate that those bands can be used for other purposes, including PCN. In July 1991, AT&T applied for an experimental license to operate a PCN in the 6 GHz range, the microwave band for common carriers. The company is currently using less than 10 percent of the licensed three bands, each 5 MHz wide, between 5.9 and 6.4 GHz, so there is ample capacity to conduct the PCN experiment.[84] AT&T claims that more channels in that band, currently in use, would be available for PCN when analog microwave facilities are replaced with digital ones.[85]

Part of the cellular bands can also be used to offer PCS, thus avoiding exclusive frequency reallocation. The FCC already allows cellular frequency licensees to offer advanced cellular technologies or auxiliary communications services in the assigned bands.[86] The new digital cellular technologies could increase the capacity of cellular systems several times in the same spectrum range. If digital systems are used and the predicted capacity increase is realized, the 25 MHz spectrum assigned to cellular carriers may meet the demand for mobile communications in the future.[87] On the assumption that these (technology and market) predictions are correct, cellular carriers wishing to operate PCNs have two options: they can use part of the cellular spectrum for the new service — as NYNEX Mobile Communications Company intended with its announcement of Personal Telephone Services (see Section 2.2.2.2) — or they can implement new wireless technologies on top or in place of their existing cellular networks and transform themselves into PCN carriers.[88] Either way, PCS would be offered without new spectrum allocation.

These arguments sound like those used by parties, in particular cellular carriers, to oppose allocation to new PCN carriers, but also they show that, if the main objective of the regulators is to make new wireless services available to the public, regulators need not go through the difficult process of reallocating frequencies. The provision of new wireless communications services does not directly depend on exclusive spectrum allocations.

But new frequencies are crucial when the regulators' objectives are not only to facilitate the provision of new wireless services but also to introduce competition into the telecommunications services industries. If no new spectrum is allocated nor currently used spectrum reallocated, eligible new wireless providers would be limited to those already in possession of frequency bands. According to Janice Obuchowski, former Assistant Secretary for Communications and Information in the Department of Commerce and Administrator of the NTIA, even if, for instance, cellular operators do not need to use the full 25 MHz assigned to them, it is practically impossible for the spectrum administration to reclaim and reallocate unused portions to new entrants for new wireless services.[89] Whether and how the spectrum will be allocated for new wireless communications will shape the pattern of competition in the wireless communications industry, as well as in the telecommunications services industries as a whole.

The decision to allocate or reallocate spectrum for new wireless communications or not is thus unlikely to be based on market demand for the new services alone. Policy goals of the regulators would be the major consideration.

3.1.2. Controversial Frequencies

Vendors make equipment for different frequencies, and operators in various locations prefer different spectrum bands because of the availability of spectrum, propagation characteristics of radio waves, interference problems, and so on. According to comments by various parties in response to the FCC's *Notice of Inquiry* on PCS in GEN Docket 90-314 and the experimental licenses companies filed with the FCC to test new wireless communications systems,[90] potential carriers prefer particular frequency bands (see **Table 2-1**):

- **800–900 MHz** This band is densely occupied by such land mobile services as private radio, SMR, and cellular telephone. Only two small portions, 849–851 MHz and 894–896 MHz, are possible candidates for new wireless communications.

- **900–1,000 MHz** This band also is mostly allocated. The focus is on three unused bands: 901–902 MHz, 930–931 MHZ, and 940–941 MHz. Some firms, such as BellSouth, also test new wireless communications systems in 902–928 MHz band, which is allocated to the federal government for radio location.

- **1,710–2,500 MHz** This band is the center of the focus, with more than 80 trial proposals as of July 1991.[91] Bands 1,710–1,850 MHz and 2,200–2,300 MHz are government frequencies. Others, including 1,850–1,990 MHz, 2,100–2,200 MHz, and 2,450–2,483.5 MHz, are currently used for point-to-point microwave communications by various industries — petroleum, utility, railroad, broadcasting, and common carriers — that strongly oppose reallocation of these frequencies.

3.1.3. Options for Spectrum Allocation for New Wireless Communications

If regulators decide to allocate spectrum to the new wireless services, three principles may guide them finding suitable frequencies and making allocations:[92]

- **Allocation of unused spectrum** This is, of course, the easiest way to accomplish the goal, but only three one-MHz slots are free — 901–902 MHz, 930–931 MHz, and 940–941 MHz (see **Table 2-1**) — in the preferred frequency ranges. For providers to offer services using only these slots would be difficult, because the slots do not allow enough channels for them to reach the economy of scale.

- **Reallocation of spectrum** Companies are advocating freeing ranges of spectrum for new wireless communications, particularly 1,850–1,990 MHz, currently used by point-to-point microwave (See **Table 2-1**). Incumbents are expected to offer strong opposition, and questions such as where they can be moved and who will bear the displacement costs are hard to answer.

In spite of the difficulties, the FCC favors reallocating spectrum. At a meeting on October 24, 1991, it disclosed its intention to allocate a portion of the

spectrum for PCN, probably, according to Thomas Stanley, the Chief Engineer, in the 1,850–2,200 MHz band.[93] This band was recommended "because of the likely availability of equipment, relatively low cost, and international consultations that indicate an interest" in this range.[94] In February 1992, the FCC released a *Notice of Proposed Rule Making* in ET Docket 92-2 proposing the reallocation of 220 MHz (specifically the 1.85–1.99, 2.11–2.15, and 2.16–2.20 GHz bands), currently used for fixed point-to-point microwave operations, to "emerging technologies," including new wireless communications.[95]

At the same time, it also recognized the difficulty of relocating the incumbents. Commissioner Ervin Duggan noted that the final policy statement regarding PCN should include a provision that "the FCC is sensitive to existing users of the 1.8–2.2 GHz band,"[96] and this position is shown by the many relocation proposals in that *Notice of Proposed Rule Making*. The existing users, however, still strongly oppose the reallocation plan, and a tough political battle is being fought.[97]

- **Sharing spectrum with existing users** Spectrum sharing is a highly desirable solution which minimizes the economic and political impacts on both new service providers and incumbents, but it also imposes strong technical requirements to prevent interference. Motorola, a major manufacturer of radio equipment, claims that spectrum sharing techniques are not viable for providing services in a wide area.[98] Although several experimental systems are being tested for sharing spectrum with existing services, its technical feasibility is not yet certain.

In addition to the initiatives and actions that the FCC could take regarding allocation, private companies might obtain frequencies to provide new wireless services by taking advantage of the flexibility of the FCC's regulations. In April 1991 the FCC established rules and procedures to adopt the "pioneer's preference" proposal for spectrum allocation.[99] Its key element is recognition that "new services" and "new technologies used to improve an existing service" should receive preferential treatment in

spectrum licensing.[100] Several potential PCN carriers, such as Advanced Wireless Communications, Inc.,[101] and U S West Communications, Inc.,[102] have requested that the FCC award them "pioneer's preference." As of June 1992, the FCC has rejected some "pioneer's preference" applications for PCN and left other undecided.[103]

3.2. Industry Regulation

The policy objectives and regulatory actions of the telecommunications services industries, which will evolve in response to technological, economic, political, or social changes, will affect the pattern of competition and the structure of the industry. According to Eugene B. Lotochinski, Vice President of Northern Telecom, the previous objectives of the regulation were universal service and economic efficiency; now that these have been achieved, technological innovation and responsiveness to customers may become the next focus.[104] New wireless communications, with their potential to compete directly against current wireless as well as wire-based services, stir up issues related to the effects of regulatory objectives and government intervention on the structure of telecommunications services industries.

3.2.1. Regulatory Trends

According to its recent remarks and actions, the FCC appears to have adopted a liberal attitude toward new technologies and services and to promote competition in telecommunications industries. In 1989, Chairman Alfred Sikes told a *Financial Times* World Communications Conference that the first objective is "to sustain and ... strengthen our competitive system."[105] In September 1990, FCC General Counsel Robert L. Pettit remarked:

> The Chairman has thus led the Commission in an effort both to streamline its approval requirements [of new communications technologies and services] and to examine the underlying incentive structure facing

> telecommunications entrepreneurs. The ultimate goal of this effort is to get government out of the way of entrepreneurs and get competitive communications innovations to the public as quickly as possible.[106]

Recent events help track this regulatory objective. The adoption of the "pioneer's preference" proposal (discussed in Section 3.1.3) for spectrum allocation encourages companies providing new services with technological innovations. On May 9, 1991, the FCC proposed a rule to require tier-1 telephone companies (those with revenues greater than $100 million a year) to let competitive access providers (CAPs) of special access networks set up switching equipment on or near the LECs' premises.[107] It also issued a *Notice of Inquiry* in CC Docket 91-141 to solicit comments on extending this expanded interconnection ruling to switched networks.[108] The Fleet Call case, discussed next, demonstrates the FCC's intention of promoting competition in mobile communications services.

3.2.1.1. Fleet Call, Inc. — A Case Study

In 1990, Fleet Call, Inc., of Bloomfield, New Jersey, one of the largest specialized mobile radio companies in the U.S., asked the FCC for a waiver to combine its existing 800 MHz systems and to construct enhanced specialized mobile radio (ESMR) systems with multiple base stations in six cities with congested frequencies — Chicago, Dallas, Houston, Los Angeles, New York, and San Francisco. This multiple base station structure is unusual for SMR systems.[109] In February 1991, the FCC granted most of these requests: Fleet Call will be allowed to construct the ESMR systems in five years[110] but will still need to apply for a license for each individual base station[111]; in constructing these systems, however, Fleet Call will remain a private radio provider, exempt from state regulation, rather than become a common carrier. In the news release, the FCC said that "[t]he public interest ... favors a regulatory approach that encourages such endeavors when they lead to the development and implementation of unique and spectrum efficient communications systems."[112]

Fleet Call's application and the FCC's ruling received considerable attention. Before the FCC decision, more than twenty law firms, representing companies opposed to Fleet Call's proposal, lobbied to seek delay.[113] After the favorable ruling, Fleet Call's ability to provide services in direct competition with cellular operators, who are common carriers and thus subject to stricter regulations, while remaining a private land-mobile operator drew opposition from both the private and public sectors.[114] The National Association of Regulatory Utility Commissioners (NARUC) asked the FCC to reconsider, because the states are preempted from regulating Fleet Call's proposed services, which are similar to the common carrier service of cellular telephony.[115] Fleet Call's proposal also met strong opposition from competitors. In California, Fresno Mobile Radio Inc., another SMR operator, claimed that the proposed ESMR systems would harm its ability to compete and to expand its business and filed a petition with the FCC on June 5, 1991, to deny the application of Fleet Call.[116]

In defending the FCC's decision, Ralph Haller, its Chief of the Private Radio Bureau, asserted that the differences between Fleet Call's proposed services and cellular telephony are sufficiently large for the two to be regulated differently. Fleet Call's systems would not have nearly the spectrum capacity in its markets as cellular carriers; subscribers to its systems would need to obtain individual licenses; and subscribers to its services would not be able to roam across regions.[117] In spite of these differences, the overlap between ESMR and cellular telephones cannot be overlooked, and competition between these services and between ESMR and other wireless communications services can be expected in the future.

3.2.1.2. Trends in Regulating New Wireless Communications

In October 1991, the FCC issued a *Policy Statement and Order* in GEN Docket 90-314 on PCS. It asserted its desire in "the rapid development of this [personal communications] service and ... in promoting competition in PCS and in telecommunications generally," and "intends to make available an adequate amount of spectrum to foster the development of innovative and competitive markets for [personal

communications] services."[118] In a separate statement, Commissioner Andrew Barrett emphasized his interest "in reviewing comments that address the various ways we can ensure that PCS gives new entrants and small businesses new opportunities to get into the mobile service business."[119] The Commission solicited comments on general questions such as spectrum allocation, definition of PCS, and regulatory issues in an "en banc" hearing on December 5, 1991, and announced that later in 1992 it might release a *Notice of Proposed Rule Making* regarding PCS (in GEN Docket 90-314).

In another effort, the FCC seeks to reallocate 220 MHz of the spectrum, currently used by common carriers, private industries, and local governments for fixed microwave communications, to "emerging technologies," new wireless communications such as PCN being among them. Taking into account the difficulty in relocating existing users, it proposed rules such as a fifteen-year relocation period (to cover the average ten-year life-span of microwave equipment) and private negotiation for relocation costs to smooth the transition.[120]

The establishment of new wireless communications received attention at the state level as well. In September 1991, the Department of Public Service of New York State issued a study of PCS that supported the development of new wireless communications, raised questions, and made recommendations of concern to the Public Utility Commission.[121]

3.2.2. Basis for Regulations

Should new wireless communications be regulated differently from other modes of telecommunications? On what basis would regulations differ? If the regulations for various sectors are different, the regulators need to distinguish sectors of telecommunications services industries. The following criteria may provide a basis for different regulations:

- **Communications media or systems** One basis might be different types of transmission or system. For example, cellular telephony, a wireless communications means, is regulated differently from wire-based telecommunications. Should this criterion be adopted, operators providing new wireless communications services over radio waves might be regulated differently from those using optical fiber, copper wire, microwave, or satellite.

- **Types of operators** Grouping carriers into different categories could also provide a basis for different regulations. Although CAPs offer basically the same interstate access service, using similar technologies, like the LECs, they face more flexible regulations.[122] Thus, different types of companies, such as LECs, IXCs, cellular companies, cable television companies, and entrepreneurs, may be regulated differently even when they provide, or are contemplating providing, the same type of wireless services.

- **Types of services** The legal definition of a service or market could be the basis for different regulations. Although SMR operators and cellular carriers offer similar wireless mobile communications services,[123] as "private carriers" and "common carriers," respectively, they are regulated differently. PCN, which offers a service dedicated to "personal" use that is yet to be defined by the FCC, may be regulated differently from cellular telephony, which is mainly for vehicular use (both historically and currently). A crucial first step for adopting "types of services" as the criterion for different regulations is the establishment of definitions that distinguish the various services.[124]

3.2.3. Issues in Regulatory Rule-Making

Since the FCC issued its *Notice of Inquiry* on PCS in 1990, comments and reply comments have been filed, arguing the method, extent, and process by which PCS can be established in the U.S. Opinions on regulatory issues the FCC would need to address

when making the rules for the establishment of new wireless communications services vary widely (see **Table 3-2**).

3.2.3.1. Number of Carriers

Most stakeholders agree that there should be competition in the new wireless services market but not on how the FCC would promote it, nor on how to measure the degree of competition. The FCC could regulate this industry segment as a monopoly, duopoly, oligopoly, or open competition,[125] and its decision on the number of providers allowed in each region will affect the pattern of competition.[126]

The number of carriers allowed is limited by the amount of allocated spectrum. The economy of scale is associated with the spectrum: the width of the frequency band a carrier has (along with the technology used and the size of the cells) determines the capacity of a new wireless system, which in turn limits the number of users the carrier can serve. A fixed portion of the spectrum can only accommodate certain number of carriers if each is to reach the economy of scale. Thus, a higher level of competition (that is, more carriers) in new wireless communications translates into a greater need for the spectrum.

3.2.3.2. Eligibility

The FCC may decide on the eligibility for market entry. Should eligibility to provide new wireless communications services be restricted? The LECs favor no restrictions and even a "wireline set-aside"[127]; nonwireline cellular carriers want the LECs excluded; and many potential providers and entrepreneurs suggest that neither LECs nor cellular operators should be eligible to compete in new wireless communications.

Among those favoring restrictions on eligibility for the LECs and cellular operators, the MCI Communications Corporation argues that, because each cellular licensee already has exclusive access to 25 MHz of the spectrum, it should not be granted a PCN license

Table 3-2

Issues in Regulatory Actions on the Establishment of New Wireless Communications

Number of Providers
- Degree of competition is related to number of carriers in each geographic region
- Limited spectrum available for new wireless services will restrict number of operators allowed

Eligibility for Licenses
- Reserving licenses for LECs may not result in faster implementation of new services
- LECs and cellular carriers may be excluded because their current businesses compete with new wireless services

Licensing Restrictions
- Qualifications for applications and resale restrictions may deter speculators
- Strict requirements for qualification may favor both large and incumbent organizations

Coverage of Systems
- Regional licensing can make investment low enough to encourage entry, but wide area coverage of personal communications services may be difficult
- National licensing can create a national system for personal number calling, but investment is high

Common or Private Carriers
- If new wireless services are ruled common, regulators' power to serve the "public interest" will increase
- If new wireless services are ruled private land mobile, state regulators' control will be preempted

to use additional spectrum.[128] Cox Enterprises, Inc., argues that if providers of competing services (such as the LECs) are allowed to participate, they would have no incentive to develop new wireless communications to a degree that might threaten their original businesses.[129]

Those favoring restriction express concern for anticompetitive behavior by wireline and nonwireline cellular operators, such as the cross-subsidy from existing businesses and the use of the current customer base to manipulate the market.[130] Nonwireline operators also are worried about anticompetitive behavior by the LECs if the latter are allowed to provide new wireless services. The concerns most widely discussed are inferior interconnections to public switched telephone networks and discriminatory treatment of telephone pole attachment.[131]

The LECs, however, want the FCC to reserve a part of the spectrum allocated to the new wireless services "for the use of local exchange carriers within their local exchange areas"[132]; failure to do so would "deter the full development and ubiquitous availability of portable access and personal communications services."[133] In the early 1980s, the FCC adopted the "wireline set-aside" for cellular regulation as a way to introduce cellular telephone services to the public promptly, because the LECs (at that time, mostly subsidiaries of AT&T) were in a better technical and economic position to offer cellular services than other companies.[134] This argument in favor of large and technically advanced companies may still be valid in the establishment of new wireless communications, especially when the experience of the U.K. in setting up the PCN market is taken into account.[135] However, the financial strength and technical expertise demonstrated by some holders of experimental PCN licenses, such as cable TV companies, may render this consideration invalid.

3.2.3.3. Licensing Restrictions

There are two main types of licensing restriction: qualification for application for a license and license resale rules after the award of a license. Both are designed to guarantee the provision of service and to keep out speculators.

The FCC can require applicants, in order to qualify for licenses for new wireless communications, to show detailed information of the companies and their business plans. Historically, in issuing cellular licenses for the ninety-first metropolitan statistical area

(MSA) and beyond, the FCC adopted an open lottery — a random selection process — to determine the licensees. The applicants were not required to show detailed information to qualify for the drawing. The result was a massive number of applications; the cellular license became a financial asset, because speculators could apply without restriction, were chosen randomly to receive the license, and would later trade it to another party for a profit. Such speculative behavior tends to deter enterprises that want to become service providers.[136]

The proposed requirements for qualification include financial qualifications, such as proof of financial ability and commitment to offer the services, and technical qualifications, such as thorough description of implementation plans and features of the networks to be constructed.[137] Some parties responding to the FCC's *Notice of Inquiry* on PCS claimed that these requirements may be used to keep speculators out of the licensing process.[138] The qualifications have drawbacks. The preparation of the application may incur considerable cost.[139] The requirement to demonstrate financial commitment may have a negative impact on small entrepreneurs, and the requirement of a detailed technical plan would favor incumbents with demonstrated experience.

Another way to prevent new wireless licenses from becoming a financial asset is resale restrictions. A licensee may be required to construct the network and start the service within a certain period before it can transfer the license to another party. To limit eligibility for new wireless communications (as discussed in Section 3.2.3.2), parties trading licenses may be restricted — for example, the LECs may not be allowed to buy PCN licenses. This rule could be regarded as a form of "cross-ownership ban." However, because the FCC is moving toward flexible treatment of spectrum license issuance and transfer, restrictions, even though needed for regulatory purpose, seem to be against this trend of liberalization.

3.2.3.4. Coverage of Systems

In the U.S., most local communications means are licensed or franchised on a regional basis. Cellular telephone licenses, for example, are issued for one market at a time, while in other countries wireless communications carriers often receive national licenses. In certain very rural areas, the service may be provided as an "isolated island." The coverage of future PCN licenses can be based on either scheme.

To the regulators, regional PCN licensing has greater appeal than national: the cost of investment is limited, so systems may be brought on-line more quickly, and the choice of carriers is more flexible. But the regional scheme may undermine the idea of providing "personal" communications services, especially the "personal number" feature: although interoperability, interconnectivity, and compatibility among systems of different operators in different areas can in theory enable the provision of personal number calling, experience in cellular telephony shows that this is a difficult goal to accomplish — "Roaming" across different systems, after several years of implementation, still cannot approach the level of proposed "personal number calling." A national PCN license would create a system that would offer most PCS functions, but the huge investment requirement means that only a few, if any, "giant" companies could qualify (see Section 4.1.1). The FCC may issue both regional and national licenses at the same time, but then the competition between these two types of carriers would be hard to evaluate — one type of carriers may hold strong competitive advantage over the other in offering PCS.

3.2.3.5. Regulatory Authority

If the new wireless communications operators were classified as common carriers, they would be subject to federal jurisdiction (by the FCC) as well as state regulations, such as state certifications, tariff requirements, discriminatory pricing prohibitions, interconnection requirements, technical standards, and so on, in a regulatory structure similar to that covering cellular carriers.[140] If the services were classified as private land mobile, such as SMR, the states would not be able to regulate the new business.

Classification as a private land mobile service, however, may require individual base-station licensing and user (subscriber) licensing.[141] Preempting the states from regulating new wireless communications may complicate the regulatory and competitive structure of the telecommunications services industries, because such competing services as cellular telephony and local exchange are regulated by the states. The state regulators and existing common carriers advocate common carrier classification, while some potential entrants prefer classification as private land mobile operators, because it would involve fewer regulatory oversights.

3.2.4. Methods of Pricing and Cost Allocation

Another issue regarding regulatory action is methods of pricing and cost allocation. The local telecommunications services market, although not strictly a monopoly because there is (limited) competition, is still served predominantly by large-scale carriers. Pricing regulation of local telephone services, characterized by complicated accounting rules and political discretion on the part of the regulators, is an important means to regulate them.[142] One major aspect of the price-setting regulation is the access charge, which consists of payments by the IXCs to the LECs for the use of local exchange facilities. The structure of the access charge depends on, among other discretionary factors, how and where the dividing line is drawn between exchange and interexchange services and the method of cost allocation employed in the telephone industry,[143] a method justified under the umbrella of "universal service" provision.[144] The amount can be significant: in 1989, the total access charge paid to all LECs was more than $25 billion, which is more than one-quarter of their total $82.7 billion telephone operating revenues and more than half the total toll service revenues of $50.9 billion received by long-distance carriers.[145]

Currently, the access charge paid to the LECs — the twenty-two BOCs, owned by the RHCs, and the Independents — is traffic-sensitive; the access charge paid by the IXCs was higher for serving business users than residential users, because it depends on the volume of traffic and business users tend to use telephone services more often than

residential users. Others, such as the CAPs and other alternative carriers, who provide local communications and interconnections with long-distance carriers, are allowed to adopt flexible pricing methods, such as structuring the access charge without reference to the volume of traffic. The difference in the structure of the access charge implies interesting competitive patterns in sectors of the local telecommunications services market. In competing for large business customers, the LECs would be at a disadvantage vis-à-vis alternative operators, who, with their flexibility in pricing, could provide less expensive interconnections between business users and long-distance carriers by charging the IXCs lower access charges.[146] In the consumer market, however, the price of the LECs' local services would be artificially lower than that of the alternative operators, who would not receive as much an access charge to cover their costs as the LECs do from the IXCs.[147]

If the regulators promote competition, the current cost allocation scheme effectively limits the ability of the LECs to compete on price in one market sector and creates a barrier to entry in another. If the regulators reregulate the industry to make it more competitive, should the method of cost allocation be revoked, changed, or extended to competing providers? The FCC did not address this issue when in May 1991 it proposed rules for expanded interconnection,[148] but the structure of the access charge, as well as regulations on pricing policies by telecommunications operators, will need to be considered when the competition in the local exchange market becomes significant.

3.2.5. Telephone Numbering Plan

Because potential PCN providers intend to go beyond the "roaming agreement" in cellular networks to offer personal number calling (see Section 1.3.3), a new telephone numbering plan may be needed. Currently in the U.S., Canada, and the Caribbean, the North American Numbering Plan Administration, an agency of Bell Communications Research (Bellcore) with government mandate, administers the telephone numbering plan, called the North American Numbering Plan (NANP). The NANP is "geographic": telephone numbers are attached to the locations of the equipment. Because existing networks are designed to use this scheme — network operators rely on a caller's dialing

sequence to identify the type of call and billing arrangements[149] — considerable adaptation in the networks will be needed to let a user make and receive phone calls from anywhere with a personalized, rather than location-specific, number. Who should be responsible for a new (or adjusted) numbering plan is also under debate, because new wireless communications operators will probably compete with the BOCs, which own Bellcore, in providing local telephone services.

The LECs assert that "PCS activities can be supported within the current numbering plan"[150] and do not want the NANP abolished. Companies such as Northern Telecom advocate the design of a new "personal telecommunications number scheme which will facilitate rapid deployment of PCS,"[151] but the users should not be forced to change their current dialing habit, and a smooth transition from the NANP to the new plan should be provided.[152] AT&T argues that "a neutral administrator" other than Bellcore should be chosen for the new personal numbering plan.[153] "It's clearly a case of having the fox guarding the hen house," said Royce Holland, President and CEO of Metropolitan Fiber Systems, of Bellcore's administrative power over the numbering plan.[154]

3.3. Standards Setting

3.3.1. Types of Standards

Standards in telecommunications services industries can be classified into three types:

- **Performance standards**, such as standards specifying the signal-to-noise ratio imposed on television transmission equipment used by broadcasters, define levels of quality or performance by service providers.

- **Technical standards** are imposed on service providers for compatibility. Standards for television broadcasting services allow consumers to use the same television set to

receive signals from different stations; standards for cellular radio systems allow users to "roam" across regions; standards for telecommunications networks in general enable interconnections between different systems; and, to avoid interference, users of the spectrum often need to comply with standards for transmission power and distance.

- **Service standards** can be employed for legal purpose. For example, in the case of new wireless communications, regulators may define different types of services by specifying technical and functional elements for each. The FCC could then issue licenses only for Telepoint-type services (one-way communication using CT-2, or cordless telephone-second generation, technology) to certain applicants while allowing others to provide two-way communication services using different technologies. Ericsson, in its comments on the FCC's *Notice of Inquiry* on PCS, maintained that the FCC should "make reasoned decisions on the ultimate types of PCS services to be provided."[155] Service standards, though important, are really part of regulation rather than standard setting and will not be discussed further in this paper.

3.3.2. Standard Setting: Authorities and Processes

Many forms of standard setting exist. National governments can select technical standards for industries to follow, as in many developing countries. Standards can be promulgated by domestic trade or industry associations. For instance, the American National Standards Institute (ANSI), the Electronic Industry Association (EIA), the Telecommunications Industry Association (TIA), and the Institute for Electrical and Electronic Engineers, Inc. (IEEE), all publish standards for use by industries. The digital cellular technology endorsed by the CTIA is likely to become the standard for all cellular carriers in the U.S. Instead of industry-wide actions, a group of companies can select their own standards. Bellcore, for example, tests equipment and establishes "generic requirements" for the twenty-two BOCs and participating independent local telephone

companies, and these requirements are often adopted by manufacturers as part of the network equipment standards.

Standards can be established not only nationally but also internationally. Many international forums, both governmental and private sector, promulgate or recommend technical standards. The Consultative Committee of International Telephone and Telegraph (CCITT), for instance, recommends global standards for telecommunications networks. Organizations such as the European Telecommunications Standards Institute (ETSI) are formed to address regional standards. Unlike international forums, however, regional caucuses tend to take prescriptive actions, imposing rather than recommending regional standards.

Finally, standards can be chosen by market force: the technical specifications that survive in the marketplace can become industry standards without intervention by government or industry associations. UNIX and MS-DOS, two *de facto* standard computer operating systems, are good examples.

In the U.S., standard setting is often nongovernmental, although promoting standards of compatibility is an important task for telecommunications policy, because "regulator[s] cannot assume *a priori* that voluntary, unregulated markets will or will not compel firms universally to adopt efficient compatibility standards when these are available."[156] Usually, the government aids the process only when international negotiations are involved. There is also an point of view that the government should promote a standard for the new wireless communications to be adopted internationally to help domestic manufacturers compete in the worldwide equipment market.[157] However, the effect of standards on the competitiveness of domestic manufacturers is unclear, because a uniform standard might also help foreign suppliers compete in the U.S. market.[158]

3.3.3. Merits and Demerits of Technical Standards

Standards for new wireless communications are desirable for two reasons. First, technical standards are an important element to insure connectivity and compatibility of systems. Compatibility is commonly believed to benefit the users. According to Thomas Krattenmaker, Associate Dean and Professor at Georgetown University Law Center, "[c]ompatibility standards underlie every telecommunications system and market."[159] The "subscribership externality" argument asserts that because the main purpose of any communications system is to enable communication among people or machines, the more people and machines reached by a communications means, the more valuable this means is to an individual user. Although islands of communication may satisfy all of a user's requirements,[160] users may also want to be connected to other parts of the world by compatible communications means. U S West, for example, claims that "the most important role of technical standards is to allow for efficient interconnection of networks...."[161] One main reason given for the failure of the Telepoint service in the U.K. is incompatibility of equipment.[162]

Second, uniform technical standards are a step toward interoperability.[163] Interoperability of new wireless communications systems means that when several networks operate in the same or different locations, subscribers to one system can use the services of the others. Ideally, the carriers and systems would be transparent, so users could roam through areas each carrier serves without needing to know anything about the systems and operators. The NTIA's comments give one U.S. government agency's view on interoperability:

> As a fundamental policy objective, it is important that public networks be able to interconnect and interoperate smoothly.... An important related activity is the translation of standards that commonly provide numerous technical options into specifications that ensure interoperability in a multi-vendor environment.[164]

Interoperability is crucial to the proposed offering of personal number calling.

Setting standards also has disadvantages. Both the timing and the process are crucial, because technologies improve so quickly that choosing the right one at any given moment is difficult. As Digital Spread Spectrum Technology, Inc., argued, "The major lesson of the last two years is that explicit technical standards ... are a waste of time.... [E]xplicit digital standards can become obsolete before they are in place."[165] Even worse, once a technical standard has been selected, future innovations may be hampered by the need to make all systems comply with it.

3.4. The U.K. Experience — An International Case Study

The U.S. is not the only country implementing new wireless communications services, nor has it taken the lead in establishing regulations governing these services. The U.K. has been very active in introducing new telecommunications technologies and services, including PCN, and provides an interesting example of regulation of new wireless communications and its consequences.

The British approach to introducing new wireless communications services reflects the government's effort to promote competition in the local telephone services.[166] Already the second largest cellular market in the world, with 1.2 million subscribers as of November 1990,[167] the U.K. managed to establish two new wireless services, Telepoint and Personal Communications Network (PCN-UK).[168] Launched in 1989, Telepoint, using the CT-2 technology, provides one-way telephone service: subscribers can make but not receive calls. The government has issued licenses to three other companies or consortiums to offer PCN-UK, a two-way communication service, which would implement new wireless communications technologies, such as digital modulation and microcellular architecture. The PCN-UK systems are expected to be introduced in 1992.[169]

Telepoint and PCN-UK are established on a national basis: the licensees are allowed to construct national networks for their systems. Only limited regulatory oversight is

imposed, and the operators are free to compete against one another and against other communications providers without pricing or other business restrictions. Transfers of licenses and mergers are generally unrestricted. The government set two loose guidelines for PCN-UK licensing: (i) the service should compete with cellular services and traditional local telephone services, and (ii) the technology should be based on existing European standards.[170]

Of the two services, the PCN-UK project is the more ambitious in its attempt to promote competition in the telecommunications services market. Major LECs or cellular carriers were kept out of the PCN-UK business. The major local telephone company is British Telecom (Mercury, one of the PCN-UK licensees, has a very small share of the local exchange business). The two cellular carriers are Racal-Vodafone and Cellnet (60 percent owned by British Telecom). With the exception of Mercury, PCN-UK operators represent new competitors to British Telecom and cellular carriers.

The result and development of the implementation of new wireless communications are interesting. The introduction of Telepoint service has proved a monumental failure — as of August 1991, fewer than 10,000 users subscribed to Telepoint service, and the combined losses of the four providers were near £100 million (roughly $185 million [U.S.]).[171] The operators have already started to exit the market.

The three original licensees of PCN-UK are Mercury Personal Communications (owned by Cable and Wireless, Plc., and Motorola), Microtel Communications Ltd. (a consortium that includes British Aerospace, Pacific Telesis Group, Millicom, and Matra of France), and Unitel Ltd. (a consortium that includes STC Northern Telecom, U S West, Thorn EMI, and the Deutsche Bundespost Telekom).[172] Since 1991, shifts in ownership in these three groups have taken place so often that it is hard to keep track of who owns what. Motorola sold its stakes to Cable and Wireless in July 1991. In the same month, British Aerospace, having acquired shares of Pacific Telesis and Matra, sold Microtel to Hutchison Whampoa Group of Hong Kong.[173] Still in that month, Unitel and Mercury disclosed plans to establish, own, and operate one PCN network together while

also offering separate services. And, finally, these two groups announced an agreement to merge operations, with initially 50-50 ownership, and planned to start service by mid-1993.[174] The PCN-UK business, even before coming into existence, is reduced to a duopoly.

CHAPTER FOUR
INDUSTRY ANALYSIS

The decisions the telecommunications industries will make regarding new wireless communications depend on the answers to the following questions:

- What will the construction costs and magnitude of investment be?
- What are the economic, technological, social, and political impediments to entry? How can incumbents use them and newcomers overcome them?
- Should industry alliances be formed to provide the services, and, if so, how to form them?
- How would new wireless communications compete with existing businesses?
- How would the incumbents respond to the new competition?
- Will the new business be profitable immediately and in the future?

This chapter analyzes the forces at play in the industries and provides insights useful in addressing these questions.

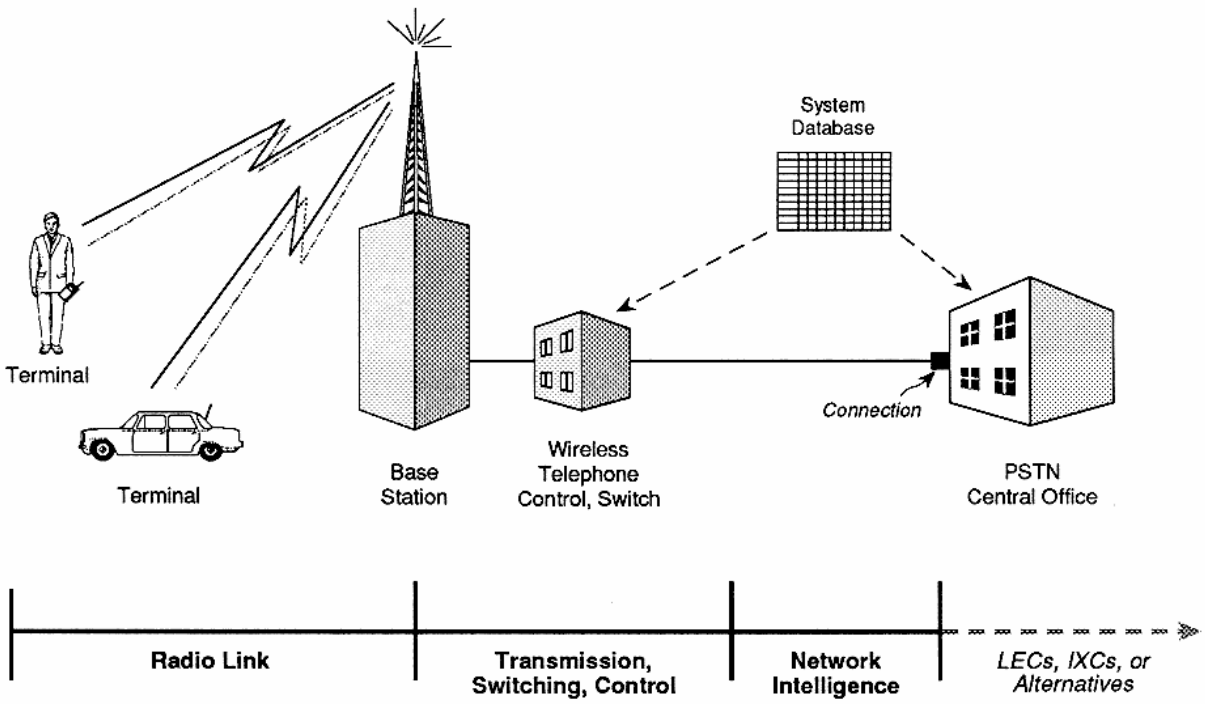
4.1. Architecture of the New Wireless Communications

The network structure of new wireless communications is not totally new. For example, to construct wireless local drops, wires in the local drop portion need to be replaced by radio waves (**Figure 1-2**); the resulting wireless system is essentially a fixed wireless device that performs the same function as a wire-based local drop.

Figure 4-1 shows the structure (the local portion) of a PCN network, consisting of five main components: terminals installed in cars or carried by pedestrians, base stations (cellular-structured) that relay signals, wireless switching offices for switching and routing wireless telephone calls, databases of customer and other network information, and connections to the central offices of public switched telephone network (PSTN). The

Figure 4-1

Structure of a PCN System (Local Portion)



Source: Adapted from Michael Noll, *Introduction to Telephones and Telephone Systems* (Norwood, Mass.: Artech House, Inc., 1988), Figure 7-2, p. 122.

overall architecture of this system essentially replicates a traditional cellular network, with one difference: the PCN network has a microcellular architecture, so the cells are smaller and the number of base stations larger than in existing cellular systems.

The strategic implications of the difference and the similarity of PCN systems and cellular telephony complicate the potential establishment of a PCN business.

4.1.1. Strategic Implication — Setting up the Networks

The microcellular structure complicates the implementation of PCN systems. With the large number of cell sites, network management becomes difficult — because calls must be routed to the many base stations in the system and numerous handoffs between cells are possible when callers are in motion — and the switches in the system require high processing power.

The microcellular architecture implies a large investment to set up the system. Although each PCN base station might cost less than one cellular base station because of the lower power requirement for radio transmission, the cost of a whole system might be large because of the many base stations a PCN network requires. The transmission facilities, most likely wire- or microwave-based, between the base stations and the wireless telephone switching offices would be another costly investment, because of the need for many connections. The combination of powerful switches, the construction of the many base stations, and the transmission facilities between them and the switches could impose a considerable investment.

Figure 4-1 shows only part of the story — it covers only the local portion of a PCN system. If the coverage of a PCN system is wide — such as the kind of national PCN license that the FCC may issue (discussed in Section 3.2.3.4) — a large portion of its network would not be radio-based, and a considerable investment in nonradio facilities would be needed. An intelligent network (IN) ability and the establishment of and access to an extensive database are needed to route calls to persons as they travel to different regions.

The issue of investment and costs has yet to be addressed realistically in the PCS debate.[175] Although the construction costs of PCN systems in the U.S. are still unknown, experience in other markets may be used as an indicator. In the U.K., an estimated £4 billion (roughly $7.4 billion [U.S.]) would be needed to set up a digital PCN network.[176] If the investment required for a PCN system in the U.S. were similar in scale, few

enterprises might have the financial strength to afford it alone.[177] In the cellular industry, a carrier usually constructs and owns all major components of its network(s). The unknown but probably high network investment requirement may create new patterns of industry competition.

One possibility is that carriers might share facilities. In the U.K., two of the three PCN-UK licensees, Mercury Personal Communications and Unitel Ltd., first agreed to share a large part of their infrastructure to reduce set-up costs by as much as £400 million (roughly $740 million [U.S.]) and then finally announced a plan to merge into one PCN-UK system (see Section 3.4). This type of alliance (or merger) among competitors may emerge in the U.S.

Another possibility is unbundling the ownership and provision of PCN systems and services, or the emergence of the question of "who provides what." Unbundling PCN systems and services implies the potential vertical disintegration of the services as well as opportunities for strategic alliances. Rather than one company alone constructing, owning, and operating a PCN network, several can form a consortium in which each is in charge of a portion of the network and provides part of the service. By dividing the network, allied companies, each selecting the portion of the network that best matches its own strengths, can share the costs of setting up a whole PCN system.

The segmentation of the network into the working portions depends on the views of the participants. One possibility is shown in **Figure 4-1**, where the local portion is distributed into three segments: radio links; transmission, switching, and control; and network intelligence.[178] Each can be constructed, owned, and operated by separate enterprises, and different types of companies may be competitive in operating different parts. For example, a PCN system may be owned by three companies: company A can operate the base stations and the radio links between them and the user terminals; company B can provide connections from base stations to PCN switching offices; and company C can interconnect those switching offices to PSTN, as well as run processing

facilities to provide database and billing services, etc. These companies are likely to belong to different sectors of the telecommunications industries.

4.1.2. Strategic Implication — Nature of Competition

In the PCN structure shown in **Figure 4-1**, the basic architecture is not too different from that of existing cellular networks, and its operation would depend (rather heavily) on nonradio technologies and network elements (such as the intelligent network, or IN). Cellular carriers have already started to reduce cell size, switch to digital systems, and integrate their networks in various regions in different ways; when PCN actually goes on-line, cellular and PCN systems may even appear identical.

In system architecture, PCN is more of a "marketing innovation" than a technological one. The distinction between the idea of a *service* like PCS and a *system* like PCN is important to understand the future telecommunications services market: PCN was designed to provide PCS, but as long as companies can obtain licenses to use certain frequencies to provide the *service*, no matter what their *systems* are called — PCN, cellular, mobile radio, or whatever — they are competing in the same market for the same customers. With technological advances, boundaries between systems and services are fading: the perception of "one system, one service" is no longer valid.

To offer PCS, potential carriers would not have to have the status of a "PCN operator"; they would only need a license to use the spectrum. Newcomers would encourage the FCC to make allocation so that they can obtain frequencies to provide PCS. And existing spectrum users may already be in the PCS market, as long as proper systems (such as the one in **Figure 4-1**) can be built to offer the proper services, without being called "PCN operators" (see Section 3.1.1).

How PCN is interpreted or perceived by various parties, then, is often a matter of self-interest.[179] With their well-established PSTN and built-in network processing power to operate the IN segment of the system, the LECs argue that the PCN is a natural

extension of their existing wire-based networks.[180] As owners and operators of both the radio link and the transmission, switching, and control portions of the (cellular) network, cellular carriers claim that PCN is only an evolution of cellular telephone and should not be treated differently.[181] Start-ups, radio carriers, and new wireless market entrants all concentrate on the features provided by the radio link portion and advocate that PCN should be established as different from other communications means.[182]

These arguments are technological and economic. Regulation and legal definition (such as the association of a type of service with a particular type of system by law or regulation), which are designed to accomplish certain political purposes, may create a totally different situation for industry players in the different sectors.

4.2. Industry Players

The stakeholders and their stakes and interests were discussed briefly in Section 2.1; this section focuses on industry stakeholders, their views and actions, and their competitiveness in new wireless communications. **Table 4-1** summarizes their positions on issues of the new wireless services.

4.2.1. Local Exchange Carriers

The LECs are an interesting group in the new wireless communications competition, partly because of the complexity in the organization of their companies. They are usually owned by a holding company — the twenty-two BOCs are subsidiaries of the seven RHCs (sometimes called regional Bell Operating Companies, or RBOCs). The LECs provide traditional wire-based telephone services to homes and businesses. The holding companies run cellular networks through separate subsidiaries within, and sometimes outside, regions that their telephone companies cover. Technically, within a holding company, the local telephone operations have no formal business tie to the cellular systems and other (unregulated) businesses. The discussion here is limited to local

Table 4-1

Summary of Positions of Industry Players on New Wireless Communications

Players	Establishment of New Services	Spectrum Allocation for New Services	Major Regulatory Concerns	Competitive Actions
Local Exchange Carriers (LECs)	Want new services established as extension of local telephone networks	Generally favor allocation	Do not want to be excluded	Experimenting with wireless local drops and PCN
Cellular Carriers	Strongly oppose establishment of new wireless as a separate business	Mostly oppose allocation	Do not want to be excluded	Increasing cellular system capacities and upgrading functions to match potential PCN offering
Equipment Manufac-turers	Strongly favor new services	Strongly favor allocation	Want high level of competition	TDMA equipment available; CDMA equipment under development
Cable TV Companies	Strongly favor new services	Strongly favor allocation	Want LECs and cellular carriers excluded	Experimenting with PCN both independently and with firms in other sectors
Specialized Mobile Radio Operators (SMRs)	Generally favor new services	Generally favor allocation but not reallocation of SMR frequencies	Want PCN ruled private carrier service	Experimenting with PCN; upgrading SMR to match potential PCN offering
Interexchange Carriers (IXCs)	Generally favor new services	Generally favor allocation but not reallocation of IXC microwave frequencies	Want LECs and cellular carriers excluded	Experimenting with PCN; testing PCN in unused IXC frequencies
Paging Operators	No clear position	No clear position	No clear position	Incorporating technology innovations to offer advanced mobile communications
Start-up Companies	Strongly favor new services	Strongly favor allocation	Want LECs and cellular carriers excluded	Experimenting with PCN

telephone companies that run local exchange telephone services, excluding other subsidiaries of the holding companies.

4.2.1.1. Views and Actions

The local exchange business is large and profitable. In 1989, the twenty-two telephone companies owned by the seven RHCs reported a combined net income of $8.1 billion out of total revenues of $66.2 billion. For all LECs, net incomes are $10.4 billion on total operating revenues of $82.7 billion in the same year.[183] These numbers translate into a return on sales of more than 12.5 percent for the LECs.

In spite of the numbers, the market condition for the LECs is not very optimistic. The local exchange business has been growing slowly, with less than a 1.1 percent average rate of increase in revenues from 1986 to 1989.[184] In contrast, from 1987 to 1988 and from 1988 to 1989, the growth rates of the gross national product (GNP) of the U.S. in current dollars were 7.9 percent and 6.7 percent, respectively.[185] Competition in the local telephone market is emerging. A new breed of CAPs[186] that took shape in the late 1980s interconnect subscribers, usually large business users, with the central offices of the LECs or facilities of the IXCs by optical fibers or microwaves, offering mostly interstate access services. The number of CAPs (Metropolitan Fiber Systems, Inc. [MFS], Teleport Communications Group, Inc. [TCG], among others) has grown from fewer than five in 1986 to approximately thirty by early 1991. During this period, the number of cities covered by CAPs' operations expanded to more than forty. The pattern is to start in large cities and then follow the large end-users to smaller urban areas.[187] The collocation rule proposed by the FCC will further facilitate the interconnections of CAPs' networks with those of the LECs.[188]

The current condition of the local exchange market suggests two reasons the LECs are interested in new wireless communications. One is diversification and expansion: the LECs could provide new wireless communications on top of or in conjunction with their basic phone services and thus expand their telephone operations as a whole. The other is

a turf battle: new wireless communications could threaten the LECs' wire-based local telephone business, and they do not want to be excluded from the action. The BOCs and many large independent LECs want the FCC either to reserve a PCN license for the LECs or at least allow them to compete, should new wireless services be established.[189]

Not unrelated is the LECs' view of new wireless communications as an extension of the public switched network.[190] The Cincinnati Bell Telephone Company, for example, argued that "the most efficient role of wireless technology is one of direct access to the wireline network."[191] Many LECs, in their response to the FCC's *Notice of Inquiry* on PCS, indicated that one license should be reserved for the LECs if new wireless communications services are to be established.[192]

Small independent telephone companies also expressed their concern for new wireless communications. The Alliance of Rural Local Exchange Carriers claimed that the public interest would be best served if the LECs are allowed to provide PCS.[193] The Organization for the Protection and Advancement of Small Telephone Companies also urged granting rural LECs the opportunity to operate PCN and asserted that the licensing of new wireless communications should be tied to the development and benefits of rural communities.[194]

4.2.1.2. Competitive Positions

The LECs have a strong competitive edge over others in new wireless communications because of the vast reach of their facilities. If and when they operate PCN, their use of their own telephone poles to attach antennas and their in-place underground wires for connecting base stations and switching facilities will greatly reduce their initial investments and construction costs. Further cost reduction can be achieved in the integration of billing systems and collocation or shared use of switching facilities. On the basis of cost alone, the LECs could prove very competitive in a PCN business.

They have a major advantage over others also in wireless local drops. Unlike other would-be operators who want to enter the local telephone service market using wireless local drop technology, the LECs already have 93.3 percent of U.S. households as potential customers.[195] These customers are more likely to switch to the new wireless equipment provided by the same companies (the LECs) rather than to new carriers, because choosing a new provider for the similar telephone services might cause confusion and inconvenience. As long as the regulation allows, if the LECs find it advantageous to replace wire-based local drops with wireless, the entry barrier against others wishing to implement wireless local drops would be quite high.

Focusing on wireless local drops rather than on PCN may be a smart strategy for the LECs. They have argued that wireless local drops operated by local telephone companies are in the public interest,[196] while their potential entry into PCN is strongly opposed by many parties (see Section 3.2.3.2). Even if they were to implement only wireless local drops now, the future evolution of the systems is hard to predict. Consider the following scenario: Company XYZ, the LEC in certain urban area, is given a piece of the spectrum to construct wireless local drops as a replacement of and enhancement to the traditional wire-based local drops. After a year or two, when a good portion of its local drops have become wireless, XYZ announces that customers can now bring their wireless handsets to the airport or train stations in the city, turn them on, and make phone calls just as they do at home. This is not hard for XYZ, with some technical enhancements to its base stations and switches. But now XYZ is offering PCS and competes directly with PCN operators! The point of this scenario is that today's wireless local drops, considered a "fixed" wireless application, may with a little modification become tomorrow's PCN.

The LECs' financial clout and the broad coverage of telephone networks are strengths for competing in new wireless communications, but politically these strengths also create adversarial conditions against their entry into wireless business. Potential PCN providers are trying to convince the FCC not to allow the LECs to enter this business. One reason given is conflict of interest: Cox Enterprise claimed that if the

LECs are allowed to participate, they will not have incentives to develop new wireless communications fully enough to become competitive with their own fixed local telephone network.[197] Possible cross-subsidy from the regulated business by the LECs is another concern.[198] Companies are afraid that if the LECs, especially the BOCs, were permitted to compete in the PCS market, they would deter competition by allowing discriminatory access by competitors to public switched network facilities.[199] The LECs, denying the allegations, want the FCC to set aside PCN licenses for them. The outcome of this political battle was unclear as of mid-1992.

4.2.2. Cellular Operators

The cellular industry[200] may experience the most direct impact from the establishment of personal communications services. On the pressure on the cellular industry created by new wireless technologies, FCC Commissioner Ervin S. Duggan commented:

> I am convinced that the challenges ahead for the cellular industry will primarily be business challenges, not regulatory ones. New technologies will intensify the "pressure of entry," and new providers will clamor to compete with you [the cellular carriers] in offering consumers ubiquitous service at reasonable prices. We regulators do not create those pressures, and there is little we can be expected to do to block them.[201]

He concluded that "[f]or [cellular carriers], in short, PCS is not so much a competitive threat as it is a business opportunity."[202] Whether PCN is a threat or an opportunity and how cellular carriers would respond remain to be seen.

4.2.2.1. Regulations and the Industry

The cellular telephone industry is less than ten years old: it was established by the FCC in 1983. According to the regulation for cellular telephony, regions in the U.S. are classified as either metropolitan statistical areas (MSAs) or rural statistical areas (RSAs).

Two operators, one wireline and one nonwireline, are licensed for each MSA or RSA. Each licensee is given 25 MHz in the 800–900 MHz band to run its system, as shown in **Table 2-1**. The wireline company is a subsidiary of the holding company of the LEC in that region. The nonwireline operator is either an independent radio company providing cellular services or a cellular subsidiary of the holding company of an LEC outside its service area and is selected using either comparative hearings (each applicant files documents stating its plans for establishing, and later offering, cellular telephone service. Hearings on those plans of different parties may follow. The FCC then picks the company whose plan it considers most appealing) or random lottery (each applicant files a streamlined plan. The FCC chooses the licensee by lottery from applicants whose plan meet a minimal technical and economic standard). Both operators are classified as common carriers and are subject to both federal and state regulations, although the regulatory oversight is less restrictive on cellular companies than that on wireline telephone common carriers.

Cellular telephony has grown tremendously. According to the Cellular Telecommunications Industry Association (CTIA), as of June 1991 the number of subscribers reached 6.4 million, the cumulative capital investment approached $7.5 billion, and more than 6,500 cell sites had been established in the nation.[203] The industry had total revenues of almost $3 billion in the first half of 1991, while collectively employing 25,500 people.[204] In the same year signs of slowdown appeared.[205] The revenue growth rate had dropped from 71 percent in 1989 to 36 percent in 1990. As of May 1991, subscribers were disconnecting the service at a rate of 36 percent per year, up from 24 percent in 1990, and customers were using less mobile telephone service: in PacTel Cellular's west coast region, for example, monthly use fell to $91 in the first three months in 1991, from $104 the year before.[206]

The cellular telephone industry has an interesting attribute: only one large player in this industry — McCaw Cellular Communications, Inc. — lists cellular telephone as its primary revenue source. Among the nine largest cellular operators, eight are wireline common carriers — GTE and the seven RBOCs.[207] Some cable TV companies, such as

Comcast Corporation, also have financial interests in cellular telephone. If one wants to invest in cellular business by buying companies' common stock (publicly traded), the only choice is McCaw and probably fewer than a handful of small companies such as United States Cellular and Vanguard Cellular Systems.[208] The strategic decisions companies make regarding their cellular operations have to fit into their overall strategy, because cellular telephony usually is not the major business of companies that own cellular franchises. In case of internal conflict of interest, companies are likely to run their cellular services according to the business plan for the whole company rather than to benefit the cellular operation alone.

4.2.2.2. Competitive Positions

The overlapping nature of PCN and cellular telephony (see Section 1.4.1) explains why cellular carriers strongly oppose the establishment of PCN as a separate business in the U.S. They argue repeatedly that PCN cannot be distinguished from cellular telephone.[209] The CTIA, in response to a statement made by a proponent of PCN, emphasized that "it is simply wrong" that cellular telephone services cannot match the attributes of PCS.[210] McCaw Cellular Communications argues that cellular services offer a growing list of features usually ascribed to PCN, and technological innovations such as digitization and microcellular architecture are being implemented in cellular networks, or are about to be.[211]

One of the first and best defenses by cellular carriers against potential PCN systems is to increase the capacity of the systems to accommodate more customers. There are three ways to do so: get more spectrum, split the cells (i.e., reduce the size of the cells and increase the number of them), and go digital. The first option does not seem practical: the cellular spectrum for each carrier (25 MHz) is not likely to be expanded by the FCC. Reducing the cell size has been a continuing effort: cellular carriers are already installing more cells, each covering smaller areas, in congested areas such as large cities. Digitization is their final important resort to increase network capacity and to facilitate improvements, such as voice quality and privacy, in cellular systems.

To switch to a digital standard, which is not compatible with existing analog systems, is not a trivial matter for cellular carriers. Their first question, given the slowdown in the growth of demand in 1991, is whether a digital system is still needed to accommodate growth. Because of incompatibility, digitization renders analog radio devices useless. How would digitization be carried out by the service providers? To smooth the transition, dual-use — analog and digital — cellular phones may be produced to allow customers to continue to receive services during the changeover.[212] As of mid-1992, whether the carriers or the customers would bear the extra cost of the analog capability, destined to become obsolete, of the dual-use phone is unknown.[213]

Another concern for cellular companies is the choice of digital standard. The two competing technologies — TDMA and CDMA — are incompatible (see Section 1.2.1). The CTIA supports TDMA, which is immediately available[214]; the CDMA technology is not yet commercialized and may take months or years to reach the market. In theory, however, CDMA could be the more efficient and thus the long-term solution. If the TDMA technology proves transitional and a further move to CDMA is unavoidable, cellular carriers would experience difficulties similar to those encountered in moving from analog to digital. Some TDMA vendors, such as Hughes Network Systems, claimed that TDMA systems can increase the capacity of the existing analog systems up to ten times, an improvement approaching that of proposed and tested CDMA systems.[215] Uncertainty about the choice between these competing technologies creates confusion in the cellular industry: carriers such as McCaw stated a commitment to TDMA[216]; Pacific Telesis is the only carrier to commit to CDMA[217]; and most carriers are reluctant to commit themselves to either technology; they are still waiting for the dust to settle — for instance, NYNEX Mobile Communications announced support for CDMA but reserved an option to use TDMA (see Section 2.2.2.2).

Another upgrade path is available. Motorola is offering an enhanced analog system, called N-AMPS,[218] based on existing analog cellular technology which could increase the system capacity threefold.[219] Current analog cellular systems could be transformed into N-AMPS systems without major alteration, buying time for cellular carriers to evaluate

the two digital standards. Centel has announced that it will test the N-AMPS technology in its Las Vegas market.[220] And N-AMPS got a major boost in March 1992 when the U S West NewVector Group announced that beginning in the fall it will deploy this Motorola technology in Seattle, Denver, and Minneapolis.

The last, but certainly not least, difficulty in going digital is creating incentives for customers to switch. The price of analog cellular devices, especially the handsets, has been dropping rapidly, and in the initial stage of implementation new digital devices would probably cost more than their analog counterparts. Earle Mauldin, President of the BellSouth Enterprises' Mobile Systems Group, said on the shift to digital: "Digital handsets will be bigger, heavier, uglier, and more expensive. Other than that, we don't see a marketing problem."[221] For the customers, aside from such benefits as the higher probability of getting a dial tone because of the higher capacity,[222] digital systems provide essentially the same services as analog systems. Marketing innovations will probably be needed to convince customers to switch to the more expensive digital devices without receiving many extra benefits.

Another defensive measure of cellular carriers is to match the potential PCN systems by offering the same (promised) features in their own cellular networks. Developments in VLSI[223] technology have made cellular telephones more portable — the handsets are becoming smaller and lighter. McCaw Cellular Communications is making an effort to match the "personal number calling" feature proposed by potential PCN providers.[224] The company intends to link its regional cellular networks into one national network in three phases, so that subscribers can use and be reached by cellular telephone anywhere across the country. Although McCaw owns operations in more than 100 cities, the success of this project requires participation by other cellular carriers as well.[225]

Offensively, cellular carriers can themselves start to provide PCS, without being called PCN providers, because they already own a portion of the spectrum. The FCC already permits flexible use of cellular frequencies, stating that "cellular licensees at their option [are allowed] to use portion of their spectrum to implement advanced cellular

technologies or auxiliary common carrier services,"[226] provided several conditions, such as the continuous offering of cellular services and noninterference requirement, are satisfied. The NYNEX Mobile Communications Company is one of the first to plan to use part of its cellular spectrum to provide a PCN-like service, which NYNEX calls Personal Telephone Services, or PTS (see Section 2.2.2.2). If the trend toward downsizing cells and digitization continues, by the time PCN operators receive their licenses and then construct their networks, existing cellular carriers may have already started to offer the same type of PCS that the PCN operators promise to offer. Cellular carriers, in taking this strategic route, would have a considerable advantage both in cost-saving and time-to-market over potential PCN providers.

Beyond competition with new wireless communications, cellular carriers may become PCN providers by obtaining PCN licenses. This is equivalent to cellular carriers obtaining another piece of the spectrum on top of their cellular bands. The idea that cellular carriers might receive PCN licenses and more spectrum has met considerable opposition (see Section 3.2.3.2).

4.2.3. Equipment Manufacturers

If new wireless communications systems, such as PCN, are established, equipment manufacturers seem the most likely ones to benefit. Although new wireless communications represent a technological evolution, rather than a revolution, of cellular radios, a fair-sized new market for equipment manufacturers will probably be generated.

The biggest battle among equipment manufacturers is over technical standards, and at its center are the two digital encoding schemes, TDMA and CDMA (see Sections 1.2.1 and 4.2.2.2).[227] Some large telecommunications equipment manufacturers, such as Ericsson and Northern Telecom, and some technology firms, such as Hughes Network Systems, support TDMA technology exclusively. Qualcomm, a small San Diego firm, is betting heavily on the success of CDMA. Companies like Motorola and AT&T are testing both methods, hoping to capture the market no matter which becomes the

standard. The winners and losers in this battle will probably be decided by the support of the service providers.

The potential equipment suppliers of new wireless communications can be roughly classified into three types according to position and competitiveness. The major telecommunications manufacturers with well-established cellular equipment businesses — Motorola and Ericsson are the two largest — clearly intend to continue to be major suppliers of the new wireless communications equipment. Motorola has been very active in supplying new wireless equipment,[228] and AT&T came out with Series II cell site equipment, designed as a platform for both analog and digital cellular and microcellular technologies.[229] The large telecommunications manufacturers that have not been major players in the cellular telephone market want to establish themselves in new wireless communications business. In February 1991, Northern Telecom formed a wireless communications product group (see Section 2.2.3.2), which has already had some success.[230] Finally, small entrepreneurial companies also are trying to capitalize on technological innovations in new wireless communications. Qualcomm, Inc., the champion in developing CDMA technology applications for digital cellular systems,[231] stands to benefit if CDMA becomes the industry standard.

4.2.4. Cable Television Companies

The cable TV industry has stated its interest in new wireless communications, as well as the telephone business as a whole. Examples abound: Comcast Corporation bought a Philadelphia cellular franchise from Metromedia for $1.1 billion, or about $193 per potential customer[232]; many major cable companies have applied to the FCC and obtained experimental licenses for PCN, including Cox Enterprises, Inc., and CableVision Systems[233]; Cable Television Laboratories, the industry's technology research consortium, is studying the PCN technology[234]; Tele-Communications, Inc. (TCI), the largest cable TV operator in the U.S., teamed up with McCaw Cellular Communications to test a version of PCN systems in Medford, Oregon[235]; and on May 20, 1991, Time Warner announced the creation of Time Warner Telecommunications to develop new mobile radio

technology applications and enlisted Dennis Patrick, former Chairman of the FCC, as the chief executive.[236]

4.2.4.1. The Industry

The potential entry of cable TV companies as serious contenders has drawn considerable attention. The cable industry is financially large, with $16.85 billion total revenues in 1989,[237] and their infrastructure reaches the majority of potential customers: 52 million, or 56.4 percent of the total, U.S. households subscribed to cable television in 1989.[238] Some even argue that cable TV companies should be the only candidates to offer potential PCN services.[239]

The cable TV industry encounters troubles in its own backyard. Criticisms of poor service and dramatic increase in subscription rates in recent years have mounted, and the industry is facing the possibility of regulatory measures.[240] The local telephone companies are threatening to enter cable TV business, in spite of the ban on owning cable operations in the areas they serve by the provision of the Cable Act of 1984.[241] In October 1991, the FCC decided to encourage telephone companies to introduce a new video technology, called video dial tone, which can carry video programming to homes. Cable TV companies' interest in PCN has also been seen as defensive tactics against this threat.[242]

4.2.4.2. Competitive Positions

The transmission, switching, and control portion of a PCN system is a major bottleneck because of the potentially high cost of transmission facilities (see Section 4.1.1). Cable companies, the vast reach of their cable wires rivaled (and actually surpassed) only by local telephone companies, hold a distinct competitive advantage. They offer an almost ready-to-use interconnection link between cell sites and switching facilities for a PCN network. The use of their cable networks as distribution systems for new wireless communications can also be viewed as a cost-recovery plan.[243] They are

laying optical fiber networks in major metropolitan areas, "getting much closer to the end-user premises than they need to be for cable TV."[244] The PCN test in Medford, Oregon, mentioned above, by TCI and McCaw Cellular Communications will use TCI's fiber and coaxial cable system to interconnect McCaw's Cellular One system, with additional new microcells.[245] In Canada, British Columbia-Rogers Cantel Inc. is testing the use of Rogers Cable Systems' coaxial cable TV network to bring PCN to the market more quickly and cheaply and thereby "change the economics of [PCN]."[246]

Cable TV companies have various options for entering new wireless communications. By adopting wireless local drops technology, they could provide local telephone services to homes using their own networks as the local loop portion of a telephone system. This prospect would enable them to compete directly with the LECs in the local telephone service market, if the cable companies have access to or own local switches that would provide sizable telephone services.[247] Cable companies can also construct full-fledged PCN systems, using their cable wires as the distribution backbone. Another option is to form alliances with radio companies such as cellular carriers or SMR operators to provide PCN networks. The radio companies could operate the radio link portion of the PCN system, and their base stations could be interconnected by the cable TV networks.

Cable TV companies have experienced little opposition to their entry as potentially important players in new wireless communications, compared with responses to the LECs and cellular carriers. However, their overall intention in entering telecommunications, not just new wireless communications, has received considerable attention. Cox Enterprises announced in March 1992 that it would increase its ownership of Teleport Communications Group to a majority (50.1 percent); the balance of the share is owned by TCI. TCG, previously owned by Merrill Lynch, is a leading CAP in the local exchange market.[248] Active in both PCN and CAP businesses, cable TV companies may emerge as major players in the local telephone business, a prospect that may raise concern because of the cross-ownership ban in the Cable Act of 1984.[249]

Technological developments, in this case in wireless communications and fiber optics, are a driving force that breaks down the traditional distinction between the telephone industry and the cable TV industry.

4.2.5. Specialized Mobile Radio Operators

The specialized mobile radio (SMR) is used here as an example of the private mobile radio industry. The SMR services were created in 1974 by the FCC to provide private commercial land mobile communications. The FCC defines SMR as

> A radio system in which licensees provide land mobile communications services (other than radiolocation services) in the 800 MHz and 900 MHz bands[250] on a commercial basis to entities eligible to be licensed under [the regulation], Federal Government entities, and individuals.[251]

4.2.5.1. Regulations

To start an SMR operation, an enterprise first needs to identify available frequencies in the desired region. An available frequency is one in which no other licensed systems operates within seventy miles of the proposed site. The enterprise must next file an application with the FCC for the service, demonstrating that implementation of its system will not cause interference. The FCC would grant the license on the basis of noninterference and the serviceability of the proposed system. It imposes no standards for compatibility or interoperability; the enterprise can choose the radio equipment that best meets its own requirements. Once the FCC approves the application and issues a license (one for each base station an operator wants to construct), the operator will have one year to construct its system and start the proposed services. Another way for a company to become an SMR operator is to acquire an existing (licensed) system, but the FCC does not permit the transfer of an SMR license unless the licensed system is fully constructed and operational.[252]

Specialized mobile radio services are classified as private land mobile services. Unlike common carriers, such as local telephone companies or cellular operators, SMR operators are not subject to state regulation. They are regulated only by the FCC, whose rules have become increasingly flexible. SMR pricing practices are not subject to either state or federal regulations.[253] Each end user needs to have an individual land mobile radio license in order to use the facilities and services of an SMR operator, although this regulatory burden would be lifted by the FCC's proposal in 1992 to eliminate end-user licensing requirement for the SMR operators, making SMR services appear more like cellular telephony to end users.[254]

SMR operators are allowed to interconnect with the public switched telephone network and to offer this interconnection to their customers, but they cannot resell that service for profit. They are required to pass along all costs incurred by the interconnection with the telephone network to their customers without additional charges. In effect, their ability to interconnect with public telephone networks lets the SMR systems function as mobile telephone networks providing value-added telephone services.

4.2.5.2. The Industry

As of February 1991, there were more than 5,000 licenses to trunked SMR systems[255] on about 32,750 channels in the 800 MHz band.[256] About one million mobile radios were using these systems, and the total service revenues of trunked 800 MHz SMR operators were estimated at $250 million[257]; 900 MHz SMR operations are on a much smaller scale because of the unavailability of frequencies in that band. The recent growth of the SMR business has been significant.

Major services offered by SMR operators include dispatch and mobile telephone services. SMR systems now operate in most parts of the country and, unlike cellular, mostly from single base stations only.[258] As of February 1991, 5,460 SMR base stations were in operation at about 3,800 sites, and only 370 of them were secondary.[259]

Partly because of its growth, coverage, and flexibility, SMR emerges as a competitor to such "common carrier" radio services as cellular telephone. In comparison with cellular networks, SMR systems generally are smaller and less expensive to set up, and the industry is less regulated. On the other hand, users of cellular telephones do not need individual licenses as SMR users do, and each of the two cellular operators in any one market has more spectrum (25 MHz) than all the SMR operators in the region combined. On average, for SMR services interconnected with local telephone networks, the typical revenues are $45 to $100 per mobile radio per month, compared with approximately $100 per radio per month for cellular operators.[260] In September 1991, Motorola unveiled its SMR system, the Motorola Integrated Radio System, which uses the TDMA method to create a sixfold increase of spectrum use over existing analog systems.[261] Such increased capacity is likely to raise the level of competition between SMR and cellular telephony.

The coverage of SMR services is moving from narrow to regional to national. Fleet Call has obtained waivers from the FCC to combine its systems in six regions into multiple base station digital systems (see Section 3.2.1.1). Both RAM Mobile Data Communications and Millicom won approval from the FCC to construct national mobile voice and data SMR systems in the 900 MHz band. Motorola is implementing its "Coverage Plus," an 800 MHz SMR system, to provide nationwide operations.[262]

4.2.5.3. Competitive Positions

SMR companies have shown interest in new wireless communications. PCN, a potential competitor to the SMR business, could also be a reasonable extension of single base station SMR systems,[263] allowing SMR operators to maximize their use of the SMR portion of the spectrum. Some of the larger SMR operators — Motorola,[264] Fleet Call, and Advanced MobileComm — as well as the American SMR Network Association, filed comments in response to the FCC's *Notice of Inquiry* on PCS. Because the key to provide SMR services is identification of unused or under-used frequencies in the 800

MHz and 900 MHz bands, SMR operators strongly oppose allocation for PCN in those bands.[265]

Unlike LECs or cellular providers, SMR operators will probably be ruled eligible potential PCN providers by the FCC, on the basis of smaller size and fewer conflicts in interests with other industries. Fleet Call argues that the trunked SMRs should already have been classified as PCN and that a future PCN license should be reserved for existing mobile communications providers such as SMR.[266] Some proposed SMR systems resemble new wireless communications networks. Fleet Call's new Enhanced SMR systems, approved by the FCC to operate in six cities (see Section 3.2.1.1), and Advanced MobileComm's proposed digital radio system operating in the New England area[267] both might be viewed as a type of PCN but under different regulations. SMR operators acknowledged the merits of remaining private radio service providers rather than common carriers — private carriers receive looser regulatory oversight — and emphasized that PCN should be provided by both common and private carriers.[268]

Although SMR carriers may not be strong enough financially to construct and operate a whole system in a wide region, they might be competitive as niche players in a small market and as providers of the radio link portion of the PCN network (see **Figure 4-1**). They have technical experience in radio communications and, like cellular carriers, already have spectrum. Another advantage is their ability to use existing SMR antenna sites as PCN base stations (the cost of acquiring one is significant).[269]

4.2.6. Interexchange Carriers

The IXCs are another interesting group of stakeholders in new wireless communications who may benefit from the provision of PCN and wireless local drops by other operators: IXCs would be glad to see alternatives to traditional telephone services created which would offer them more options for reaching customers. MCI Communications Corporation, for example, encourages the FCC to allocate spectrum and to ban cellular operators and wireline carriers from providing the new wireless services.[270]

The IXCs can themselves become PCN providers, and they have some competitive advantage in the race for PCN. First, they already own frequencies, allocated for point-to-point microwave operations (see **Table 2-1**), that may be used for PCN purpose. AT&T has applied to conduct PCN tests in its 6 GHz microwave frequencies (see Section 3.1.1). The FCC has proposed reallocation of bands in the 2 GHz range for "emerging technologies," including PCN, and the incumbents would be encouraged to negotiate with new service providers regarding the terms of relocation.[271] The IXCs, themselves users in the microwave bands, can take advantage of this proposal to use these bands for PCN while relocating their microwave operations to other frequencies.

With extensive (and, in many cases, national) networks already in place, the IXCs may already be able to provide functions of PCS, such as personal number calling (PNC) — AT&T is offering EasyReach 700 services, a less complicated form of PNC, using its long-distance network (see Section 1.3.1). They are thus in a unique economic and technological position to become national PCN carriers, either by constructing their own PCN networks or by teaming up with other companies to operate at the local level, and hold a competitive edge over other potential PCN operators intending to offer PCS in a wide area, who would need to build (expensive) IN systems from scratch.

An IXC-operated national PCN system may diminish IXCs' reliance on the LECs to access companies and households — the local access service currently generates considerable access charge for the LECs. The prospect of the LECs' loss of revenues because of IXCs' PCNs would create tension between these groups as well as a dispute in telecommunications regulation. Since divesture, long-distance telephony and local exchange business have been separated by regulations. New technologies such as new wireless communications may change this balance and put the IXCs in direct competition with the LECs in the local telephone market.

4.2.7. Other Potential Providers

Not only are firms with established telecommunications businesses expressing interest in the new wireless communications business, but many start-up companies also have been formed to become PCN providers. For example, PCN America, Inc., a newly-established subsidiary of Millicom, Inc., is an active proponent of PCN and the first applicant for a full-market test, although the FCC rejected its application on the ground that more technical results are needed before an extensive experiment should be held.[272]

With competition in mind, in issuing PCN licenses the FCC may prefer start-up companies and entrepreneurs to established telecommunications companies — some commissioners have shown particular interest in the way PCN creates opportunities for small businesses.[273] But the experience in the U.K. with PCN may have an adverse effect on American start-up companies. In the U.K., the mergers and the frequent shifts in ownership among the PCN licensees (see Section 3.4) show that the economy of scale can be significant in new wireless communications and that financial strength and stability are important in establishing PCN business. In choosing PCN licensees and to ensure that the networks can be constructed and run successfully, the FCC may prefer large firms such as cable TV companies to start-up firms and entrepreneurs.

PCN may also create opportunities for noncommunications companies to enter the telecommunications services industries. The possibility that the local utility companies might enter the PCN market cannot be ruled out — their vast reach to homes and real estate, such as underground conduit and poles, may be the basis for the transmission, switching, and control segment of a local PCN system (see **Figure 4-1**), and many of them own microwave frequencies in the 2 GHz range, which may be used for providing PCN. (Some activities of utility companies may resemble, or may be regarded as a step toward, personal communications: the Boston Gas Company started a program to replace residential meters with radio-operated ones, so that meter readers can drive down a street and, without stopping the vehicle, read the home meters.)

Other companies trying out PCN may have a different objective. In August 1991, Metropolitan Fiber Systems, Inc., a major CAP, filed applications for experimental licenses for PCN trials in Baltimore, Boston, Chicago, and San Francisco. The company is interested in new wireless communications services as a vehicle in its strategy to become a full competitor to the LECs.[274]

4.2.8. Other Potential Competitors

Even before the new wireless communications have been established, strong competitors are emerging. One example is paging, a large and dynamic industry, with combined service revenues estimated at $1.5 billion and more than 10 million subscribers in 1991.[275] By some forecasts, by 1996 the industry could have 23 million subscribers with total revenues of $2.1 billion.[276] Similar to cellular carriers, nonprivate paging operators are classified by the FCC as radio common carriers (RCCs).

Paging is becoming a serious form of personal communications. People used to think of a pager as the "beeper" that sounds when a call is placed to reach a subscriber, who then contacts a service bureau to get information on that call. This kind of paging is limited to locations with easily accessible payphones. Not any more. New alpha-numeric-display pagers allow subscribers to receive names, phone numbers, and actual messages, in effect providing a complete means for one-way — incoming, but not outgoing — communication. Companies are incorporating new display pagers into CT-2, Telepoint-type telephones (one-way outgoing only) to implement two-way mobile communication.[277] Even before PCN begins operation, paging, combined with the convenience of national coverage established by carriers such as MobileComm of BellSouth,[278] has emerged as serious competition.

Thanks to rapid advances in technology, competition may also appear in related but unexpected areas. Companies such as Motorola and AT&T are designing mobile modems and pagers to be used with the increasingly popular "notebook" and "palmtop" computers. Pagers connected to these computers allow traveling users to receive

messages up to several hundred characters long,[279] offering the same function as voice mail. Wherever payphones are available, this function offers competition to mobile voice communications like PCN. Technological developments blur the distinction between the industries of voice telecommunications and data communications.

Another potential threat is the mobile satellite services (MSSs). In 1990, Motorola proposed the $2 billion-plus Iridium project, which would use seventy-seven low earth-orbit (LEO) satellites to offer global mobile telephone services. This system was particularly aimed at developing and newly-industrialized countries, and was expect to start service in 1997.[280] Since 1990, several other companies have come up with proposals for similar services, including Constellation Communications' Aries, TRW's Odyssey, and Inmarsat's Project 21.[281] These proposed systems, sometimes called "big LEOs," promised that subscribers in different countries could make or receive phone calls with hand-held terminals or fixed telephone stations.

At the WARC '92, the big LEOs received a worldwide, primary frequency allocation at 1,610–1,626.5 MHz and 2,483.5–2,500 MHz (see **Table 2-1**). With this allocation, Iridium, for example, was estimated to accommodate 6,960 full two-way channels across the contiguous U.S.[282] The operation of the big LEOs may threaten the post, telephone, and telegraph authorities (PTTs) and other carriers in host countries: part of the local exchange and cellular telephone revenues may be lost to the big LEOs, and the governments of the host countries will not be able to control international communications traffic. To alleviate these worries, companies have tried to keep a low profile for their big LEOs. Motorola claimed that Iridium would be complementary to existing communications services, rather than a competitive threat.[283] And Ahmad Ghais, Director–Engineering and Operations of Inmarsat, said of Project 21: "You can't compete with cellular terrestrial technology, but you can augment it."[284]

In the U.S., the American Mobile Satellite Corporation (AMSC) has been licensed by the FCC to provide mobile telephone and data services, using three satellites.[285] AMSC expects to work with cellular companies to build a national mobile

communications network, claiming that its "system will complement [cellular carriers'] existing service by offering [their] customers seamless cellular coverage anywhere in the U.S. with roaming into Canada."[286] If successfully built, this network could provide the same personal communications services that potential PCN operators promised to deliver.

CHAPTER FIVE
MARKET FACTORS

Factors that might affect the shape of the future market of new wireless communications can be examined according to three themes:

Theme 1. A customer choosing a provider values the price and the quality, functions, and features of a telecommunications service.

Theme 2. Current and past data cannot predict the future market for new wireless communications.

Theme 3. In spite of the unpredictability of the future market, lessons can be learned from the history of other modes of telecommunications, such as cellular telephony.

5.1. Market Unpredictability

New wireless communications have drawn considerable attention from potential providers, such as radio communications companies and cable TV companies, as well as potential competitors, such as cellular carriers, who take very seriously the possibility that PCN will become important and successful. Why all the fuss about new wireless communications? Will a sizable market exist, and, if so, how would one know this in advance?

Among the numerous market studies of PCN by various firms, a 1990 Bellcore study, one of the most publicized, asserts that more than 20 percent of residential users will subscribe to the new service if the monthly fee is 1.25 times of the monthly telephone bill and price of handsets around $250 per unit.[287] That study also predicts that

"a [PCN] service that is fully integrated with mobile cellular and other wireless communications services could achieve penetration rates of 40–50%."[288] A similar study by Arthur D. Little, Inc., claims that PCN penetration would reach almost 40 percent of the households when the premium is $10 above the monthly telephone bill and a handset costs $250.[289] A January 1990 nationwide telephone survey by Opinion Research Corporation of Princeton, New Jersey, cited by the FMR Corporation in its comments on the FCC's *Notice of Inquiry* on PCS, asserts that the potential U.S. market for PCN is 48 million households, with a near-term latent demand of 12 million.[290]

Even though most market forecasts have concluded that the potential market for new wireless communications such as PCN is promising, they may all be wrong for the reasons given below. Contemporary history has repeatedly shown that market studies, based on past data or current user surveys, of a product or service, especially if nonexistent or revolutionary, tend to be off the target. Any strategic decision based on these error-prone forecasts risks being flawed, as the experiences in cellular telephony in the U.S. and the Telepoint service in the U.K. demonstrate.

Telepoint presents a classic example of how differently a market can behave from the original professional forecasts. Heralded as the first personal communications services to provide cheap pocket telephones for the mass market, Telepoint was closely observed by regulators and private companies worldwide since it began operation in mid-1989. Early forecasts of the market were extremely optimistic, including such numbers as 2.5 million subscribers by 1998 and 3.2 million by the year 2000 estimated by such respectable research firms as BIS Mackintosh and Booz-Allen and Hamilton, respectively.[291] The industry also had high expectations. BYPS Communications Group, one of the four Telepoint licensees, predicted 3.5 million subscribers in the mid-1990s generating more than £1 billion (approximately $1.85 billion [U.S.]) revenues per year.[292] In spite of all the rosy forecasts, after two years of operation, Telepoint did not take off. As of mid-1991, there were fewer than 10,000 subscribers,[293] and the service providers started to exit the market. Since signs of Telepoint's demise began to surface, many discussions and studies have taken place, often by the same firms that had made the

original rosy forecasts, about why Telepoint was such a flop and why the market envisioned when it began never materialized. The reasons included system noncompatibility, high price, inferior quality of service, and incomplete features,[294] but the number of factors cited only indicates the difficulty of predicting the future market behavior of a new telecommunications service.

In contrast to the example of Telepoint, the history of cellular telephony shows that a market can be underestimated by almost everyone. Early forecasts of the cellular market placed the number of subscribers at around one or two million in early 1990s. In 1984, MCI Communications predicted that the mobile telephone market in the U.S. would grow from less than 200,000 (conventional, noncellular) users to more than one million by the end of the century.[295] More optimistically, AT&T predicted that the number of subscribers would reach 1.5 million by 1992.[296] Forecasts by Frost and Sullivan and Herschel Shosteck showed similar figures and predicted that the market would begin to saturate in the sixth or seventh year of operation.[297] According to the Cellular Telecommunications Industry Association, in June 1991 the number of subscribers actually reached 6.4 million, and the growth rate since June 1990 was around 20 percent.[298] The cellular telephone market has considerably outperformed any forecasts.

These examples, both directly related to new wireless communications, indicate that market forecasts of yet-to-be-offered services can often be grossly off the mark. They do not address other important factors that could reduce the accuracy and feasibility of market forecasts, such as the effects of competitive products and services due to the fast pace of technological development.[299] The purpose of the arguments presented here is not to show how wrong analysts can be: totally "unexpected" market behavior may be due to the execution by the carriers rather than the intrinsic demand conditions forecast by the analysts. The examples demonstrate that actual market behavior depends on many more factors than can be taken into account in a market forecast. The numbers do not mean much if the underlying forces and trends are not studied thoroughly.

It would certainly be unwise to ignore these forecasts when no other studies exist, but in view of the problems of market forecasts, policy decisions on the government side, or strategic moves on the private company side, based mainly on the numeric results of those studies of future markets, would have a large chance of failure. Focusing on the factors, forces, and trends of the market, which often hide behind the numbers, rather the numeric values themselves, can help decision makers understand the market better.

5.2. New Wireless Communications Market: Factors and Forces

Wireless communications have experienced tremendous growth in the 1980s. U S West, for instance, estimated that approximately 22 percent of all the homes in its operating area have some form of wireless telecommunications equipment in 1989.[300] The high demand for mobile wireless communications, however, does not mean that just any new type of wireless services can automatically become a success. The case of Telepoint service in the U.K. clearly suggests the opposite.

This section examines what affected the outcome of the offering of various wireless communications services up to now, focusing on two factors, the quality, functions, and features and the price, as suggested by **Theme 1**. The factors and forces explored in this section shed light on the future market of new wireless communications (**Theme 3**).

5.2.1. Quality, Functions, and Features

5.2.1.1. Communication Quality

The quality of wireless communications is not on par with that of wire-based telephone systems. Although among the highest quality wireless communications, cellular telephone still has problems, such as sudden cut-off, no dial tone, and a high level of noise, according to users' complaints.[301] The lack of privacy in cellular networks is another serious concern.[302] If new wireless communications are to compete with

traditional wire-based networks, quality could be an important factor. Should wireless local drops be offered, for example, providers may have difficulty convincing customers to switch to the wireless system if its quality is inferior.

The communications quality of the new wireless systems can be expected to improve in two ways, both attributable to digitization. First, encrypting and compressing the digitized conversation, a relatively easy process in digital systems, can ensure privacy in new wireless networks. Second, voice clarity may be better in digital systems, because high-frequency noise is "filtered" when conversations are digitized.[303] In contrast to existing cellular networks, wireless local drops can offer a service with fewer cut-offs and constantly available dial tone, because it is essentially a fixed service with no competition for frequency channels like in a cellular system.

When the new wireless communications, such as PCN, are implemented, they may not be of higher quality than cellular telephony because the latter is undergoing digitization. No evidence suggests that the quality of PCN and the wireless local drop may be at the same level as traditional wire-based telephone systems.

5.2.1.2. Coverage of Service

Compatibility, connectivity, and interoperability, the buzz words in today's communication world, are crucial for services extended beyond a local region. The "subscribership externality" (discussed in Section 3.3.2) argues for compatibility and connectivity of network equipment. Interoperability is important for users to continue to use a service in locations served by different providers.

Providing compatible or extensive-coverage services has been a trend in mobile wireless communications. The SMR systems, originally operated only in metropolitan areas, are expanding to become regional, even national (see Section 4.2.5.2). At least one cellular carrier, McCaw Cellular Communications, plans to set up a national network

(see Section 4.2.2.2). The failure of Telepoint was partially attributed to the noncompatibility between the systems operated by the four providers.[304]

Despite being primarily a local service, the new wireless communications operated by various providers in different regions must be compatible and interoperable with one another in order to offer PCS features, such as personal number calling, promised by potential providers. Compatibility, connectivity, and interoperability of the new wireless communications systems in a wide region can be effected in many ways, such as by uniform technical standards, intersystem agreements, or a multiregional or nationwide network. Regulators and service providers are likely to select a combination of these means to achieve the functions promised by personal communications services.

5.2.1.3. Rapid Technological Development

The fast pace of technological development creates implications for the market behavior of new services. Many, perhaps most, products and services based on new technologies could become "transitional" over time, that is, they could eventually be replaced by better and cheaper products and services employing newer technologies. This argument may explain why Telepoint was such a flop: with PCN-UK due to begin operation in the near future (in 1992, according to original plan), people are willing to wait for this better service and forego Telepoint, which provides only outgoing communication.

A service or technology of "transitional" nature may still be successful. According to the digitization schedule of cellular carriers, analog cellular telephone could become extinct, giving way to new digital technology in fewer than five years. If so, its brief existence, a little more than a decade, could be regarded as transitional. But analog cellular telephone has certainly been a market success and set the tone for future land mobile communications, probably because it was the exclusive choice at a time when people wanted public mobile telephone service and stabilized (or had the prospect of stabilizing) long enough and early enough so that users were willing to rely on it. Being

transitional is fine as long as the timing to market is good. Whether PCN might become a transitional service in the near future cannot be known, but, if so, it is questionable whether it would meet an unsatisfied demand, as analog cellular telephony did, so that it could still thrive during its existence.

Another implication is that fast change in technologies creates diversity — an increasing number of ways to accomplish the same purpose. As a result, although PCN is lauded as the only real means for personal communications because of its potentially low price, light-weight handsets, and vast coverage, in the near future it might face unexpected competition made possible by new technologies. Developments in paging technologies, for instance, could make paging serious competition to the future PCN. The "big LEO" mobile satellite services also may become a threat (see Section 4.2.8). New digital cellular telephones and the SMR networks also could evolve into systems comparable in function and feature to PCN,[305] and many more unidentified areas of technologies may be useful in creating services that would offer services promised by PCN. The future of the market for new wireless communications is difficult to portray, because, unlike the beginning of cellular telephony in the 1980s, the market for PCN will probably be affected by various forms of competition, many of which are yet unknown. PCN is not likely to become the only system that offers personal communications services by the time that it is established.

5.2.1.4. Product Differentiation

The enormous growth of wireless services indicated a market for mobile wireless communications, given which, how PCN providers would define and position themselves is a difficult question. When cellular telephony was launched in 1983, mobile wireless common carrier service was new to the public, and the unsatisfied or potentially unsatisfied demand for mobile wireless communications was filled by cellular telephones. PCN, however, is not likely to be introduced as a totally new service, because most of its promised features will be neither new nor exclusive: as discussed in Section 1.4.1, the distinction between PCN and cellular telephony is difficult. Proponents of PCN argue

that PCS can be performed in a smaller, faster, cheaper, and better way by these systems than by any other currently available means, including cellular telephones. But as cellular, paging, private radio, satellite, and other wireless mobile communications all move toward "personal" services and become cheaper, more portable, and provide more universal coverage, differentiating them from PCN becomes increasingly difficult. Even if the underlying technologies of PCN — microcellular architecture and digital encoding — leapfrog those of the existing wireless services, the other systems may gradually evolve to match the capability of PCN.

Market segmentation also can achieve product differentiation. According to a recent survey by Smith, Barney, Harris, Upham & Co., the typical cellular subscriber is between thirty-one and fifty years old, with an annual income of more than $35,000.[306] Cellular telephones are still mainly used for business: more than 80 percent of the respondents claimed they used cellular telephones exclusively or partly for business. As envisioned by many potential players, PCN will offer a consumer rather than a business service.[307] The consumer market, which is still relatively untapped by the mobile wireless communications, is huge — 93 million households as of March 1989.[308] Targeting PCN systems to this market could be a reasonable strategy, the success of which depends on such factors as quality of service and pricing.

5.2.2. Pricing and Costing

Pricing will be important in reaching the consumer market many potential PCN providers are targeting. The customer cost to use a wireless communications service consists of the start-up cost and the monthly bill. The start-up cost includes the purchase price of the handset (customer premise equipment, or CPE) and possibly a charge for activation of the service. The price of CPE has been dropping, primarily because of rapid technological developments in microelectronics. The initial price of the appropriate digital handsets for PCN may or may not be lower than the analog handsets used in cellular systems — handsets for PCN may cost less because they will require batteries with smaller power, but digital handsets may cost more than analog ones because the

technology of the latter has become more mature. The monthly bill will be tied to the use of the service and paid to the PCN carrier. The bill will be partly determined by the expenses incurred at the service provider's level, including initial investment, equipment maintenance costs, and other operating costs (such as billing and marketing). These expenses, as discussed in Section 4.1.1, could be quite high.

The pricing objective of PCN, in order to generate sales in the mass market at which many would-be providers are aiming, is to offer services at a low enough price to attract users with incomes lower than that of a typical cellular subscriber (see Section 5.2.1.4). The customer cost, discussed above, suggests that lowering the initial price of the PCN services below that of cellular telephones will probably be difficult. This was what happened in the Telepoint case, where pricing turned out to be one of the key reasons for the failure of the new service.[309]

Epilogue

This paper is mostly concerned with wireless communications services for voice, with very little mention of data services. These services are related and not mutually exclusive, and some of the issues around them are even intertwined. For example, digital data services may be a driving force for the conversion of analog cellular networks to digital. Other issues, such as market segmentation — data systems are more likely to be aimed at specific industry sectors rather than the mass market — are unique to wireless data services and would require a separate study.

The paper offers no conclusion about if, when, or how new wireless communications services will be established in the U.S. As of mid-1992, too many issues remain unresolved, and further conversation, debate, and compromise among the various stakeholders are expected. How the forces and trends discussed here will shape the new wireless communications as well as existing services remains to be seen.

Notes

1. George Calhoun, *Digital Cellular Radio* (Norwood, Mass.: Artech House, Inc., 1988), p. 3 (hereafter, *Digital Cellular Radio*).

2. The frequency bands for cellular telephone are in the 800–900 MHz range. See **Table 2-1** for details.

3. These are among the "personal" features of a telecommunications means mentioned by witnesses in the FCC's "en banc" hearing on personal communications services on December 5, 1991. See "FCC's 'En Banc' Hearing Reveals Emerging Consensus on Broad Definition of PCS, But Many Issues Remain Unresolved; Spectrum, Licensing, Regulation Continue to Haunt Proceeding," *Telecommunications Report,* December 9, 1991, p. 6.

4. Multiple access methods are techniques to allow a number of channels of communications to "access," or use, one frequency range at the same time.

5. A brief introduction to the current analog cellular network structure can be found in A. Michael Noll, *Introduction to Telephones and Telephone Systems* (Norwood, Mass.: Artech House, Inc., 1986), Chapter 7 (hereafter, *Telephones and Telephone Systems*).

6. Digital radio technology can also make more efficient use of some wire-based systems, such as fiber optic transmission. Many (local) wireless communications use wire-based systems for transmission among base stations and switching offices, and a greater number of communication channels enabled by digital encoding technologies can make better use of the high traffic capacity allowed by those wire-based systems.

7. See "Can Cellular Phone Companies Agree on a New Standard for Transmission?" *The New York Times*, September 16, 1990.

8. "Mammoth Vendor Hughes Enters the Cellular Market," *Advanced Wireless Communications*, December 19, 1990, p. 5.

9. "Competitive Issues Forcing Cellular Industry to Digitize," *Advanced Wireless Communications*, December 11, 1991, p. 5. Theoretically, CDMA was touted as offering as much as twentyfold increase over the analog systems.

10. For example, even without any further manipulation, CDMA technology ensures the privacy of telephone conversations by the very nature of individual spread functions, because each conversation is coded by its own spread function. Thus, privacy is achieved, because anyone wanting to tap the network must know the spread function in order to decode the conversation.

11. Cells are grouped into clusters and only frequencies not used by other cells in the cluster can be reused. In most cellular systems, a cluster contains seven cells. See Noll, *Telephones and Telephone Systems*, pp. 117–121.

12. This is not to say that the diameter of a cell can either be three miles (in traditional cellular systems) or 2,000 feet (in proposed microcellular systems). Intermediate cells are possible. In fact, to increase the capacity, many cellular carriers are reducing the size of the cells in urban systems.

13. Vehicular mobile communications, such as the private land mobile service used by taxis and trucks, preceded cellular telephones, but with cellular systems the channels in one frequency band can be reused, allowing many simultaneous uses. Cellular was the first such service offered as a common carrier service.

14. Federal Communications Commission, *Notice of Inquiry in the Matter of the Amendment of the Commission's Rules to Establish New Personal Communications Services*, GEN Docket 90-314, 1990.

15. Ad Hoc Microcell Committee of the Telecommunications Industry Association, *Comments in the Matter of Amendment of the Commission's Rules to Establish New Personal Communications Services*, FCC's *Notice of Inquiry*, GEN Docket 90-314, October 1990, p. 2.

16. "FCC's 'En Banc' Hearing Reveals Emerging Consensus on Broad Definition of PCS, But Many Issues Remain Unresolved; Spectrum, Licensing, Regulation Continue to Haunt Proceeding," *Telecommunications Report*, December 9, 1991, p. 6.

17. Ibid.

18. For a provider's view of how new wireless communications might make personal number calling possible and affordable, see, for example, FMR Corp., *Comments in the Matter of Amendment of the Commission's Rules to Establish New Personal Communications Services*, FCC's *Notice of Inquiry*, GEN Docket 90-314, October 1990, pp. 9–11 (hereafter, *Comments of FMR Corp.*).

19. Anthony Ramirez, "Bell Atlantic Plans Service That Links Phone Numbers," *The New York Times*, March 17, 1992.

20. *AT&T News Release*, April 28, 1992.

21. See ibid. and "A Way of Life," *The Economist*, May 30, 1992, pp. 19–22.

22. Although intrinsically independent of specific locations because it is a mobile system, the current cellular network is region-dependent: a subscriber to a provider in one region cannot be reached in another region. The "roaming agreement" permits users to use systems provided by all parties in the agreement.

23. See John J. Keller, "McCaw Cellular Plans to Create National Service," *The Wall Street Journal*, October 15, 1991, as well as the discussion in Section 4.2.2.2.

24. In this paper, for the purpose of clear presentation, a distinction is made between PCS and PCN: PCS is the communications service for "personal use," and PCN the type of

systems enabled by new wireless technologies. In the literature, however, these terms are not always used this way.

25. One proposed way to distinguish PCN from cellular telephony is its microcellular architecture (cellular telephony employs macrocells); another is that PCN provides essentially a communications means for pedestrians (because of the frequent hand-offs produced by the microcellular architecture; see Section 1.2.2) (while cellular is more suitable for vehicular use). As cellular technology is evolving, these two distinctions may only be temporary.

26. See the Cellular Telecommunications Industry Association, *Comments in the Matter of Amendment of the Commission's Rules to Establish New Personal Communications Services*, FCC's *Notice of Inquiry*, GEN Docket 90-314, October 1990, p. 2 (hereafter, *Comments of CTIA*).

27. It is argued that PCN may be viewed as a next-generation system of analog cellular. Cellular offers a growing list of features sometimes exclusively ascribed to new wireless communications. In spite of all the promises, no evidence exists to show that PCN will have any special features not available from existing providers of cellular radio.

28. For a list of possible key differences between PCN and cellular telephones, see Victor Schnee, *Take Over — Taking Over Telephone Companies*, Probe Research, Inc., 1990, p. 217 (hereafter, *Take Over*).

29. Comments and reply comments are filed by federal, state, and local government bodies, as well as companies in industries besides telecommunications.

30. Sometimes termed "wireless local loop." Most proposals, however, are for using wireless connections in the "drop," rather than the "loop," portion, of the local exchange network. See **Figure 1-2** for details.

31. In **Figure 1-2**, the local drop is wire-based. With wireless technology, no wires connect the local loop to homes. Instead, radio waves connect a transceiver at home and the base station on the local loop. In general, users at home would not notice whether the local drop is radio-link or wire-link.

32. Peter Purton, "Germans Use Radio to End Line Crunch," *Telephony*, January 14, 1991, p. 23.

33. MCI Communications Corporation, *Comments in the Matter of Amendment of the Commission's Rules to Establish New Personal Communications Services*, FCC's *Notice of Inquiry*, GEN Docket 90-314, October 1990, p. 3 (hereafter, *Comments of MCI*).

34. Charles Mason, "Cable Industry Examines PCNs," *Telephony*, April 8, 1991, p. 12.

35. Government frequencies may be reallocated for commercial use. "The Emerging Telecommunications Technology Act of 1991," jointly introduced by Representatives Markey and Dingell on February 21, 1991, seeks to accomplish this purpose by

identifying 200 MHz of little-used government frequencies and giving them to private users.

36. NASA, *Comments in the Matter of Amendment of the Commission's Rules to Establish New Personal Communications Services*, FCC's *Notice of Inquiry*, GEN Docket 90-314, October 1990, p. 2.

37. See, for example, The Los Angeles County Sheriff's Department, *Comments in the Matter of Amendment of the Commission's Rules to Establish New Personal Communications Services*, FCC's *Notice of Inquiry*, GEN Docket 90-314, October 1990.

38. "U.S. 'Big, Little LEOs' Get Allocations at WARC Largely as Proposed, But Limits Aimed at Protecting Russian Glonass System Could Restrict Iridium; CEPT Nations Get 230 MHz, for Future Public Land Mobile Service; BSS-Sound Gains Worldwide Allocation at L-Band," *Telecommunications Report*, March 9, 1992, pp. 12–18.

39. Federal Communications Commission, *Policy Statement and Order in the Matter of Amendment of the Commission's Rules to Establish New Personal Communications Services*, GEN Docket 90-314, October 1991, p. 2 (hereafter, *FCC Policy Statement & Order, GEN 90-314*).

40. In the U.S., the broadcasters have not strongly opposed spectrum allocation for new wireless communications, because, although they hold a large block of civilian spectrum for TV broadcasting, the proposed allocations do not involve their frequencies (see **Table 2-1**). In other countries the situation may be different, because wireless communications may use a range of the spectrum that overlaps with broadcast frequencies.

    However, a possible reallocation of 1,990–2,100 MHz band is opposed by the National Association of Broadcasters (NAB), because it is used for electronic news-gathering activities (See **Table 2-1**). See "NAB Opposes Any Spectrum Reallocation from 2 GHz TV Auxiliary Band for PCS Systems," *Telecommunications Report*, December 2, 1991, pp. 28–29.

41. See Alabama Power Company, *Reply Comments in the Matter of Amendment of the Commission's Rules to Establish New Personal Communications Services*, FCC's *Notice of Inquiry*, GEN Docket 90-314, January 1991, pp. 1–2.

42. Advanced MobileComm company brochure.

43. Paul Phillips, "A New Power in SMR," *Business Radio*, April 1990.

44. *Advanced Wireless Communications*, November 7, 1990, p. 11.

45. "Regional SMR Operator Seeking Federal Approval to Develop Digital System," *Radio Communications Report*, November 18, 1991, p. 1.

46. FMR Corp., *Reply Comments in the Matter of Amendment of the Commission's Rules to Establish New Personal Communications Services*, FCC's *Notice of Inquiry*, GEN Docket 90-314, January 1991, p. 2 (hereafter, *Reply Comments of FMR Corp*).

47. Ibid., p. 1.

48. *Comments of FMR Corp.*, p. 14.

49. *Reply Comments of FMR Corp.*, pp. 14–23.

50. Ibid., p. 25.

51. Ibid., p. 32.

52. There are other wireline cellular carriers in the northeast: Southern New England Telecommunications Corporation, for instance, provides cellular services in Connecticut.

53. *NYNEX Annual Report 1991*, NYNEX Corporation, 1992, p. 14.

54. Thomas Lanning, "CTIA Backs Push for TDMA as Digital Cellular Standard," *Telephony*, January 21, 1991, p. 8.

55. "NYNEX Delays Implementation of CDMA Digital Cellular Standard," *BOC Week*, July 15, 1991.

56. Richard Karpinski, "NYNEX Sets PCN Goal," *Telephony*, August 6, 1990.

57. Interview with Alfred Boschulte, President, NYNEX Mobile Communications Company, March 26, 1991.

58. *Managing the Forces of Change: NYNEX Annual Report 1990*, NYNEX Corporation, 1991, p. 27.

59. NYNEX Corporation, *Reply Comments in the Matter of Amendment of the Commission's Rules to Establish New Personal Communications Services*, FCC's *Notice of Inquiry*, GEN Docket 90-314, January 1991, p. 3 (hereafter, *Reply Comments of NYNEX Corp*).

60. Ibid., p. 3.

61. Ibid., p. 1.

62. NYNEX Corporation, *Comments of NYNEX Corporation in the Matter of the Commission's Rules to Establish New Personal Communications Services*, FCC's *Notice of Inquiry*, GEN Docket 90-314, October 1990, p. 4.

63. NYNEX Corporation, *Comments in the Matter of an Inquiry Relating to the Preparation for the International Telecommunications Union World Administrative Radio Conference for Dealing with Frequency Allocations in Certain Parts of the Spectrum*, FCC's *Notice of Inquiry*, GEN Docket 89-554, February 1990, pp. 2–3.

64. Ibid., p. 4.

65. *Annual Report 1990*, Northern Telecom Limited, 1991, p. 19.

66. U.S. Department of Commerce, *1991 U.S. Industrial Outlook*, January 1991, p. 31-8 (hereafter, *1991 Industrial Outlook*).

67. Signaling System No.7 is a specific network control system that consists of network protocols established by Consultative Committee on International Telephone and Telegraph (CCITT).

68. Groupe Speciale Mobile (or Global Standard for Mobile), a digital cellular standard developed in Europe.

69. International Standardization Organization.

70. Integrated Services Digital Network, a networking standard developed by CCITT.

71. "Motorola, Northern Telecom to Develop Open Cellular System Standards," *Northern Telecom News Release*, February 20, 1991.

72. Steven Titch, "Public Network's Wireless Role Grows," *Telephony*, February 17, 1992, p. 9.

73. "Northern Telecom To Demonstrate First Wireless Business Telephone System in Geneva Next Month," *Northern Telecom News Release*, September 11, 1991.

74. Bell-Northern Research Limited, *PCI, A Common Radio Standard for Personal Communications Interface*, Annex to Northern Telecom Inc., *Comments in the Matter of Amendment of the Commission's Rules to Establish New Personal Communications Services*, FCC's *Notice of Inquiry*, GEN Docket 90-314, October 1990 (hereafter, *Comments of Northern Telecom*).

75. *Comments of Northern Telecom*, pp. 13–36.

76. Northern Telecom Inc., *Reply Comments in the Matter of Amendment of the Commission's Rules to Establish New Personal Communications Services*, FCC's *Notice of Inquiry*, GEN Docket 90-314, January 1991 (hereafter, *Reply Comments of Northern Telecom*).

77. Even though Northern Telecom is based in Canada.

78. For a historical perspective on the justifications and goals of regulations of the telecommunications services industries, see Jeffrey A. Masoner, *Alternatives to Rate Base/Rate of Return Regulation of Local Exchange Carriers: An Analysis of Stakeholder Positions* (Cambridge Mass.: Program on Information Resources Policy, Harvard University, May 1990), pp. 12–17.

79. "Suitable" frequency bands are discussed in Section 3.1.2.

80. The FCC is not the only agency in charge here; the NTIA, and even Congress, are involved, because the frequencies likely to be used by new wireless communications may come from the government sector.

81. *Comments of Northern Telecom.*

82. American Petroleum Institute, *Comments in the Matter of Amendment of the Commission's Rules to Establish New Personal Communications Services*, FCC's *Notice of Inquiry*, GEN Docket 90-314, October 1990.

83. *Comments of CTIA*, pp. 4–9.

84. "AT&T to Test 6 GHz Band for PCNs," *Microcell Report—The Journal of Microcell Telecommunications*, July 1991, p. 1.

85. "AT&T Proposes PCN Trial in 6 GHz Range, Using Auxiliary Common Carrier Analog Spectrum," *Telecommunications Report*, July 1, 1991, pp. 16–17.

86. Federal Communications Commission, *Report and Order in the Matter of Amendment of Parts 2 and 22 of the Commission's Rules to Permit Liberalization of Technology and Auxiliary Service Offerings in the Domestic Public Cellular Radio Telecommunications Service*, GEN Docket 87-390, December 12, 1988, p. 1 (hereafter, *FCC Report & Order, GEN 87-390*).

87. This idea is equivalent to relying on advances in technology to solve the problem of spectrum crowding currently in the U.S., as advocated by many people. See, for example, Calhoun, *Digital Cellular Radio*, p. 16.

88. These two options are not an "either/or" choice. Cellular carriers can choose to do one thing in one region and do the other in another.

89. The logic can be found in Janice Obuchowski's "Wireless Communications and Spectrum Conservation: Sending a Signal to Conserve," *IEEE Communications Magazine*, February 1991, p. 26; she does not specifically use cellular and PCN as examples.

90. For partial lists of the experimental licenses, see *Advanced Wireless Communications*, November 7, 1990, pp. 11–12; December 5, 1990, p. 8.

91. Counted by AT&T. See "AT&T Proposes PCN Trial in 6 GHz Range, Using Auxiliary Common Carrier Analog Spectrum," *Telecommunications Report*, July 1, 1991, p. 16.

92. The arguments closely follow that of Danny E. Adams, *Regulatory Options for the Establishment of Personal Communications Services in the United States*, Wiley, Rein & Fielding, 1990.

93. Margot Moody, "FCC Plans Microwave Raid for PCS Spectrum Allocation," *Radio Communications Report*, November 4, 1991, p. 1.

94. "FCC Adopts General Policy Statement on PCS, Calls for 'En Banc' Hearing on Dec. 5," *Telecommunications Reports*, October 28, 1991, p. 24.

95. Federal Communications Commission, *Notice of Proposal Rule Making in the Matter of Redevelopment of Spectrum to Encourage Innovation in the Use of New Telecommunications Technologies*, ET Docket No. 92-9, February 1992. (hereafter, *FCC NPRM, ET 92-9*).

96. Ibid.

97. See, for example, Charles Mason, "Congress Weighs in on PCS Spectrum," *Telephony*, April 20, 1992, p. 16.

98. Motorola, Inc., *Comments in the Matter of Amendment of the Commission's Rules to Establish New Personal Communications Services*, FCC's *Notice of Inquiry*, GEN Docket 90-314, October 1990, Appendix A, Paragraph 9.

99. "FCC to Grant 'Pioneer's Preference' for New Services and Technologies Requiring Spectrum Allocation Rule Changes," *Federal Communications Commission News Release*, Report No. DC-1838, April 9, 1991, p. 1.

100. "FCC Adopts 'Pioneer's Preference' for New Services, Technologies," *Telecommunications Report*, April 15, 1991, p. 12.

101. "Advanced Wireless Communications Asks FCC to Authorize Co-Primary Sharing of Spectrum in Air-to-Ground Channel for 'First-Generation' PCS, Also Seeks 'Pioneer's Preference,'" *Telecommunications Report*, May 6, 1991, p. 9.

102. "Two U S West Units File for FCC 'Pioneer's Preference' Award," *Telecommunications Report*, August 5, 1991, p. 30.

103. "FCC Rejects Remaining Pioneer's Preference Applications," *Advanced Wireless Communications*, June 10, 1992, p. 8.

104. Remarks of Eugene B. Lotochinski in S-483 Seminar, the Kennedy School of Government, Harvard University, April 18, 1991.

105. Remarks of Alfred C. Sikes, Chairman, Federal Communications Commission, before the *Financial Times* World Communications Conference, December 4, 1989, p. 3.

106. Remarks of FCC General Counsel Robert L. Pettit before the Federal Communications Bar Association, September 28, 1990, p. 10.

107. Edmund L. Andrews, "Bell Units' Rivals Gain at FCC," *The New York Times*, May 10, 1991.

108. Federal Communications Commission, *Notice of Proposed Rule-making and Notice of Inquiry in the Matter of Expanded Interconnection with Local Telephone Company Facilities*, CC Docket 91-141, June 6, 1991 (hereafter, *FCC NPRM & NOI, CC 91-141*).

109. As private radio carriers, SMR operators usually have only single-base-station systems Cellular providers use multiple-base-station systems to achieve greater coverage, lower power requirements, and better frequency use. For the regulation of SMR industry, see Section 4.2.5.

110. For SMR licensees, the required construction period is usually one year.

111. "FCC Acts on Fleet Call's Proposed Wide-Area SMR Systems," *Federal Communications Commission News Release*, Report No. PR-68, February 13, 1991.

112. Ibid.

113. Robert S. Foosaner, "Counterpoint: The Fleet Call Decision — Spectrum Efficiency and Improved Service for the Public," *Tele/Scope Fax Alert*, March 26, 1991, pp. 1–4.

114. Richard E. Wiley, "Opinion: The Fleet Call Decision — Policy in Search of a Principle," *Tele/Scope Fax Alert*, February 27, 1991, pp. 1–4. Wiley is a partner in the law firm of Wiley, Rein & Fielding, which represents parties opposed to the Fleet Call applications.

115. "NARUC Asks FCC to reconsider Fleet Call Order, Worries about Cellular-Like Services," *Telecommunications Report*, April 29, 1991, p. 33.

116. Margot Moody, "Fleet Call's ESMR Applications Meeting Resistance in California," *Radio Communications Report*, September 23, 1991, p. 26.

117. "FCC Approves Fleet Call Plan for Enhanced Mobile System," *Telecommunications Report International*, February 22, 1991, pp. 17–18.

118. *FCC Policy Statement & Order, GEN 90-314*, p. 3.

119. Separate Statement of Commissioner Andrew C. Barrett Re: Amendment of the Commission's Rules to Establish New Personal Communications Service, October 25, 1991.

120. *FCC NPRM, ET 92-9.*

121. State of New York, Department of Public Service, *Personal Communications Services*, September 1991.

122. The CAPs are providers who interconnect large business users with facilities of local telephone companies or interexchange carriers, using fiber optics or microwave. They usually offer only interstate access service. See Section 4.2.1.1 for a discussion of the CAPs.

123. Important differences, in terms of regulations, economics, and technologies, between specialized mobile radio and cellular radio exist, but the differences are diminishing especially with the proposed ESMR system by Fleet Call, Inc. For details, see Sections 3.2.1.1 and 4.2.5.

124. As argued in Section 1.2.3, these definitions do not have to be technologically or economically sound. There are always ways to devise legal definitions to suit the regulatory needs.

125. Even if the market were open to competition, it might still end up as a monopoly or oligopoly because of the economy of scale. For new wireless communications services, however, if and how the scale economy matters is not clear.

126. Some believe that the number of PCN licenses the FCC will issue would be three. The theory behind this belief is interesting, though not scientific: the FCC would not issue one to create a monopoly and may not want to repeat the duopoly case in cellular telephony. The number "three" becomes the logical choice, because it is the smallest number bigger than two.

127. "Wireline set-aside" means that the FCC reserves a license for the LEC in each region.

128. *Comments of MCI*, p. 5.

129. Cox Enterprises, Inc., *Comments in the Matter of Amendment of the Commission's Rules to Establish New Personal Communications Services*, FCC's *Inquiry of Notice*, GEN Docket 90-314, p. 7 (hereafter, *Comments of Cox Enterprises*). Cox argued in the context of the LECs only. According to this argument, cellular carriers should be excluded if new wireless communications are to compete with cellular telephony, and the LECs should not be allowed if new wireless systems are to provide alternative local telephone services.

130. Tandy Corporation, *Comments in the Matter of Amendment of the Commission's Rules to Establish New Personal Communications Services*, FCC's *Notice of Inquiry*, GEN Docket 90-314, p. 4.

131. See *Reply Comments of FMR Corp.*, pp. 27-35.

132. Southwestern Bell Corp., *Comments in the Matter of Amendment of the Commission's Rules to Establish New Personal Communications Services*, FCC's *Notice of Inquiry*, GEN Docket 90-314, October 1990, p. 12 (hereafter, *Comments of Southwestern Bell*).

133. Ibid., pp. 14–15.

134. See Calhoun, *Digital Cellular Radio*, pp. 54–61, 121–124.

135. The three PCN licensees in the U.K. have struggled with merger, acquisition, and shuffling of investors because of the potentially huge investment and an uncertain market for the service. See Section 3.4 for details.

136. See Calhoun, *Digital Cellular Radio*, (Section 4.4) for a vivid description of the lottery and its consequences.

137. See, for example, McCaw Cellular Communications, Inc., *Comments in the Matter of Amendment of the Commission's Rules to Establish New Personal Communications Services*, FCC's *Notice of Inquiry*, GEN Docket 90-314, October 1990, p. 65 (hereafter, *Comments of McCaw Cellular Communications*).

138. See, for example, *Reply Comments of FMR Corp.*, p. 18. This argument is similar to the "sunk cost" argument in economic theory: the more time and energy a company spends on the preparation to show financial and technical commitments, the less possible that it would apply for the license only due to speculation.

139. The estimated cost to prepare a cellular license application in 1983 ranged from $50,000 to $250,000. See Calhoun, *Digital Cellular Radio*, p. 122.

140. Few states in the U.S. currently exercise fully their regulatory power over cellular carriers. Operational matters in cellular telephony such as competition and pricing are practically unregulated.

141. The FCC proposed lifting the end-user licensing requirement for SMR; see Section 4.2.5.1.

142. Carol Weinhaus and Anthony G. Oettinger, *Behind the Telephone Debates* (Norwood, N.J.: Ablex Publishing Corp., 1988), describes the complex accounting schemes and their political justifications.

143. For a discussion of discretion in cost and price relationships and access charges, see Anthony G. Oettinger, *The Formula Is Everything: Costing and Pricing in the Telecommunications Industry* (Cambridge, Mass.: Program on Information Resources Policy, Harvard University, October 1988), pp. 3–11 (hereafter, *Formula Is Everything*).

144. Arguments that LECs charge high access charges because of universal service abound. See, for example, Edmund L. Andrews, "Bell Units' Rivals Gain at FCC," *The New York Times*, May 10, 1991.

145. Federal Communications Commission, *Statistics of Communications Common Carriers*, February 1991, pp. 33–34 (hereafter, *Statistics of Communications Common Carriers 1991*).

146. Mary Lu Carnevale, "To Open Up Phone Service," *Wall Street Journal*, May 10, 1991.

147. The access charge paid by the IXCs to the LECs, when serving the consumer market, is mandatory and fixed by regulation. But alternative providers need to negotiate the access charge with the IXCs, thus may not be able to receive as much as the LECs do.

148. F*CC NPRM & NOI, CC 91-141*, p. 3. Paragraph 4 clearly describes the FCC's intention not to change the access charge structure at this point even when the expanded interconnection could lead to direct competition to the LECs.

149. U.S. Department of Commerce, National Telecommunications and Information Administration, *The NTIA Infrastructure Report: Telecommunications in the Age of Information*, NTIA Special Publication 91-26, October 1991, p. 126 (hereafter, *NTIA Infrastructure Report*).

150. GTE Service Corporation, *Comments in the Matter of Amendment of the Commission's Rules to Establish New Personal Communications Services*, FCC's *Notice of Inquiry*, GEN Docket 90-314, October 1990, p. 26 (hereafter, *Comments of GTE*).

151. *Comments of Northern Telecom*, p. 39.

152. Ibid.

153. *Comments of AT&T*, p. 19.

154. Ann Lindstrom, "Bellcore Proposes 640 New North American Area Codes," *Telephony*, March 2, 1992, p. 8.

155. The Ericsson Corporation, *Comments in the Matter of Amendment of the Commission's Rules to Establish New Personal Communications Services*, FCC's *Notice of Inquiry*, GEN Docket 90-314, October 1990, p. i.

156. Thomas G. Krattenmaker, "Compatibility Standards and Telecommunications Policy," in Paula R. Newberg, ed., *New Directions in Telecommunications Policy, Volume 2: Information Policy and Economic Policy* (Durham, N.C.: Duke University Press, 1989), pp. 290–295 (hereafter, *Compatibility Standards*).

157. See, for example, Sam Ginn, "Personal Communications Services: Expanding the Freedom to Communicate," *IEEE Communications Magazine*, February 1991, p. 32.

158. Michael Skapinker, "HDTV Standard Is Overrated," *Financial Times*, April 30, 1991. Skapinker argued that as long as there is a standard, foreign suppliers (specifically mentioning the Japanese) would be better able to compete, because they do not have to produce many different types of products just to serve a single market.

159. Krattenmaker, *Compatibility Standards*.

160. For example, a local area network (LAN) connecting all the personal computers might be all that a company needs for data communications, if the company does not exchange data with other firms or individuals.

161. U S West, *Comments in the Matter of Amendment of the Commission's Rules to Establish New Personal Communications Services*, FCC's *Notice of Inquiry*, GEN Docket 90-314, October 1990, p. 26 (hereafter, *Comments of U S West*).

162. See, for example, Neil McCartney, "Telepoint Disappoints So Far," *Financial Times*, October 15, 1990, Mobile Communications Survey (hereafter, *Telepoint Disappointing So Far*).

163. See, for example, arguments in *Comments of GTE*, p. 26.

164. *NTIA Infrastructure Report*, p. 138.

165. Digital Spread Spectrum Technologies, Inc., *Comments in the Matter of Amendment of the Commission's Rules to Establish New Personal Communications Services*, FCC's *Notice of Inquiry*, GEN Docket 90-314, October 1990, p. 9.

166. Hugo Dixon, "Competition Comes Calling," *Financial Times*, September 26, 1990.

167. *FinTech Mobile Communications*, November 22, 1990, p. 1.

168. In this paper, PCN designates generic new wireless communications systems that serve personal communications services. In the U.K., PCN is legally defined as a class of system and service, as described in this section; for this use the term will be written as "PCN-UK" instead of PCN in this paper.

169. "Personal Communications Network: Facility Is a 'Gadget Person's Dream'," *Financial Times*, October 15, 1990, Mobile Communications Survey.

170. "Telephones That Get Up and Go," *The Economist*, September 16, 1989, p. 71.

171. Paul Abrahams, "Sink or Swim at the Deep End," *Financial Times*, August 5, 1991 (hereafter, *Sink or Swim*).

172. There have been considerable restructuring of the three consortia since the issue of licenses. See Abrahams, *Sink or Swim*.

173. "U.K. PCN Licensee Ownership Shifts Continue as Motorola Sells Stakes in Mercury Group to C&W; Mercury, Unitel Groups Plan to Construct Common Network for Separate Services," *Telecommunications Reports*, July 22, 1991, p. 29.

174. "U S West, C&W Announce Plans for Merger of Mercury, Unitel PCN Operations in U.K.," *Telecommunications Reports*, March 23, 1992.

175. For example, the Cellular Telecommunications Industry Association feels that none of the comments in response to the FCC's *Notice of Inquiry* on personal communications services provides a realistic view of the cost of various PCN systems. See Cellular Telecommunications Industry Association, *Reply Comments in the Matter of Amendment of the Commission's Rules to Establish New Personal Communications Services*, FCC's *Notice of Inquiry*, GEN Docket 90-314, February 1991, p. 6 (hereafter, *Reply Comments of CTIA*).

176. Abrahams, *Sink or Swim*. In the U.K., new wireless communications services are implemented in two forms, namely Telepoint and PCN. See Section 3.4 for details.

177. The cost depends on the coverage of the systems. A small investment may be enough for a very small PCN system, but a multiregion or even a nationwide network would require a tremendous initial investment.

178. This division of service provision is based on company's lines of business. For example, the enterprise operating the radio links portion of the network could own totally different facilities and technologies from those of the company who provides the network intelligence piece of the network.

179. See, for example, "New York Department of Public Service Supports PCS Development; Recommendations to State Commission Involve Regulatory Treatment of PCS Regarding Universal Service, Interconnection, Privacy, Number Portability; Maximum Entry Opportunities Urged," *Telecommunications Reports*, October 28, 1991, p. 22.

180. See, for example, Southern New England Telecommunications Corporation, *Comments in the Matter of Amendment of the Commission's Rules to Establish New Personal Communications Services*, FCC's *Notice of Inquiry*, GEN Docket 90-314, October 1990, p. 9 (hereafter, *Comments of SNET*).

181. See, for example, *Comments of CTIA*, p. 2.

182. See, for example, the arguments presented by Cox Enterprises, in *Comments of Cox Enterprises*, pp. 1–7.

183. *Statistics of Communications Common Carriers 1991*, pp. 36–39.

184. The average annual growth rate of local network service revenues, in current dollars, from 1986 to 1989 (*Statistics of Communications Common Carriers 1991*, p. 240).

185. Bureau of the Census, U.S. Department of Commerce, *Statistical Abstract of the United Stated 1990*, January 1991, Table 700, p. 433 (hereafter, *Statistical Abstract 1991*).

186. The CAPs are sometimes called alternative local transport providers, or ALTs.

187. Joseph S. Kraemer, *Competitive Assessment of the Market for Alternative Local Transport*, Deloitte & Touche Telecommunications Industry Program, 1991 Monograph Series, 1991.

188. "Expanded Interconnection Proposed for Interstate Special Access; Inquiry Begun Into Expanded Interconnection for Interstate Local Transport," *Federal Communications Commission News Release*, Report No. DC-1869, May 9, 1991.

189. *Comments of Southwestern Bell*, pp. 12–16.

190. This type of arguments appear repeatedly in many LECs' comments on the FCC's *Notice of Inquiry* on personal communications services. See, for example, *Comments of SNET*, pp. 6–7.

191. Cincinnati Bell Telephone Company, *Comments in the Matter of Amendment of the Commission's Rules to Establish New Personal Communications Services*, FCC's *Notice of Inquiry*, GEN Docket 90-314, October 1990, p. 3.

192. *Comments of Southwestern Bell*, pp. 12–16.

193. The Alliance of Rural Local Exchange Carriers, *Comments in the Matter of Amendment of the Commission's Rules to Establish New Personal Communications Services*, FCC's *Notice of Inquiry*, GEN Docket 90-314, October 1990,

194. The Organization for the Protection and Advancement of Small Telephone Companies, *Comments in the Matter of Amendment of the Commission's Rules to Establish New Personal Communications Services*, FCC's *Notice of Inquiry*, GEN Docket 90-314, October 1990,

195. *Statistical Abstract 1991*, Table 919, p. 556. This datum is for the year 1990.

196. *Reply Comments of NYNEX Corp.*, pp. 8–9.

197. *Comments of Cox Enterprises*, p. 7.

198. The cases of the LECs' cross-subsidy from regulated to diversified businesses are discussed in National Cable Television Association (NCTA), *The Never Ending Story: Telephone Company Anti-competitive Behavior Since the Breakup of AT&T*, April 1991, pp. 6–15 (hereafter, *Telcos' Anti-Competitive Behavior*).

199. The telcos' discrimination in access to facilities is discussed in NCTA, *Telcos' Anti-Competitive Behavior*, pp. 10–15, 31–35. Among the examples cited, some RBOCs allegedly refused technically efficient interconnections and charged higher interconnection fees to their cellular competitors.

200. In this section, "cellular operators" include both wireline and nonwireline carriers. For the classification and regulation of cellular industry, see Section 4.2.2.1.

201. "The Cellular Success Story Continues," Remarks of Commissioner Ervin S. Duggan Before the Cellular Telecommunications Industry Association, Washington, D.C., June 13, 1991, p. 4.

202. Ibid., p. 6.

203. *Cellular Trends CTIA Data — Industry Report*, Shearson Lehman Brothers, Inc., September 18, 1991 [NEXIS] (hereafter, *Cellular Trends CTIA Data*).

204. Ibid.

205. The recession is suspected to be the instigator of the slowdown.

206. "For Cellular, a Sudden Hang-Up," *Business Week*, May 6, 1991, p. 128.

207. See "Cellular Competition: Caller May Ring Up Rewards from BellSouth's Indiana Expansion," *Indianapolis Business Journal*, May 20, 1991, p. 1 [NEXIS]. The size of a cellular operator is measured by "pops," defined as the total population in the markets where it operates. According to this article, the largest carrier was McCaw Cellular Communications, Inc., with 61 million "pops." GTE was the second, with 54.5 million "pops."

208. These smaller companies do list cellular as their main line of business. Although their stocks are traded publicly, they are mostly controlled by individuals, families, or parent companies.

209. One example is the position taken by the NYNEX Mobile Communications Company. See Section 2.2.2.3.

210. *Reply Comments of CTIA*, p. 10. The claim was made in response to GEC Plessey Telecommunications' comments on the FCC's *Notice of Inquiry* on personal communications services, GEN Docket 90-314.

211. *Comments of McCaw Cellular Communications*, pp. 18–27.

212. Companies such as Qualcomm have announced plans to make dual-mode (analog and digital) terminals. See, for example, "NYNEX Delays Implementation of CDMA Digital Cellular Standard," *BOC Week*, July 15, 1991.

213. The first (commercial) dual-mode cellular handset (for analog and TDMA) was announced by Ericsson in December 1991, although its cost was not specified. See "First Pocket-Size Dual-Mode Cellular Phone Arrives," *Advanced Wireless Communications*, December 11, 1991, pp. 4–5.

214. Thomas Lanning, "CTIA Backs Push for TDMA as Digital Cellular Standard," *Telephony*, January 21, 1991, p. 8.

215. See Hughes Network Systems, Inc., *Cellular Facts*, 1992, [company brochure].

216. Charles Mason, "Cellular Carriers Ready Digital Rollout Plans," *Telephony*, February 24, 1992, p. 3.

217. Steven Titch, "Pacific Telesis Chooses CDMA Format; TIA to Develop Standard," *Telephony*, February 17, 1992, p. 8.

218. N-AMPS stands for narrow advanced mobile phone system. AMPS, or the advanced mobile phone system, is the analog cellular system currently used in the U.S. N-AMPS, while compatible with AMPS, uses narrower channels and has higher capacity.

219. N-AMPS uses the same specifications as today's normal analog cellular systems, except its channel width is 10 KHz (as opposed to 30 MHz in current systems), providing a threefold increase in capacity.

220. A. Humphries, *Cellular Telephone Review — Industry Report*, Hanifen, Inhoff, Inc., September 30, 1991 [NEXIS].

221. Ibid., Quote of the Month.

222. Other benefits such as higher quality and better security also are possible but not yet fully demonstrated.

223. VLSI (Very Large-Scale Integrated) circuits are the semiconductor technology that allows thousands or even millions of electronic circuit elements to be put on a small silicon wafer.

224. Anthony Ramirez, "Cellular Network's Big Step — McCaw to Announce Its Plan Tomorrow for National Linkup," *The New York Times*, October 15, 1991.

225. Nancy Kuehl, "McCaw Network Said to Make Roaming a Thing of the Past," *Radio Communications Report*, November 4, 1991, p. 11. McCaw plans to offer an opportunity for other *nonwireline* cellular operators to join the project.

226. This flexibility is furnished by the FCC's rule making in Docket 87-390. See *FCC Report & Order, GEN 87-390*, p. 1.

227. See "CTIA Backs Push for TDMA as Digital Cellular Standard," *Telephony*, January 21, 1991, p. 8. The development of CDMA technology has met some delays, and, as a result, some of its supporters do not want to commit themselves. See Section 2.2.2.2 for an example.

228. See Peter Purton, "Motorola Poised for CT-2 Lead," *Telephony*, February 11, 1991, p. 3.

229. Richard Karpinski, "Southwestern Bell Sees Integration of Digital Cellular and Microcell," *Telephony*, May 27, 1991, p. 8.

230. Northern Telecom was chosen by Microtel, one of the three PCN licensees in the U.K., as the suppliers for PCN switches. See "No. Telecom Wins PCN Contract," *Telephony*, May 20, 1991, p. 16.

231. "Cellular Breakthrough: San Diego Firm at Forefront of New Mobile Phone Technology," *Los Angeles Times*, April 16, 1991 [NEXIS].

232. Geraldine Fabrikant, "Comcast's $1.1 Billion Phone Deal," *The New York Times*, May 8, 1991. As Fabrikant pointed out, the purchase price of $193 per potential customer paid by Comcast is quite high, compared to recent sales which were valued at about $135 per potential customer.

233. *Advanced Wireless Communications*, November 1990, p. 12.

234. "Cable Industry Examines PCNs," *Telephony*, April 8, 1991, p. 12.

235. "Cellular, Cable TV Giants to Test New Wireless Service," *Los Angeles Times*, May 23, 1991 [NEXIS].

236. "TCI, Time Warner Stepping Up Development of PCS Businesses," *Cable World*, May 27, 1991.

237. *1991 Industrial Outlook*, p. 32-6.

238. *Statistical Abstract 1991*, Table 919, p. 556.

239. Jerry Lucas, "My Turn: What The FCC Should Do with PCS," *TeleStrategies Insight*, October 1991, p. 1 (hereafter, *My Turn*).

240. In W. Robert Tirman, *The Elephant and the Blind Men: The Phenomenon of HDTV and Its Would-Be Stakeholders* (Cambridge, Mass.: Program on Information Resources Policy, Harvard University, April 1991), Appendix C, cable TV industry's problems are discussed. See also *1991 Industrial Outlook*, pp. 32-6–32-7.

241. For a discussion of cable-telephone cross-ownership issues, see Naoyuki Koike, *Cable Television and Telephone Companies: Towards Residential Broadband Communications Services in the United States and Japan* (Cambridge, Mass.: Program on Information Resources Policy, Harvard University, December 1990), Section 1.2.

242. Lucas, *My Turn*.

243. Ibid.

244. Dominick Calicchio, "Turning into Telecoms," *Communications International*, June 10, 1991.

245. "TCI and McCaw Cellular to Test Market Personal Communications Service," *Business Wire*, May 22, 1991 [NEXIS].

246. Seth Malgieri, "Cantel Studying Cable As Way to Bring PCS to Neighborhoods," *Radio Communications Report*, November 4, 1991, p. 14.

247. Requirements for extensive fine-tuning cannot be overlooked. The cable TV companies have the real estate and the conduits (the transmission facilities), but a lot more work needs to be done and plenty of equipment has to be added and integrated into the existing networks, if those companies want to provide telephone services using networks they built to carry cable TV.

248. Rachel Thompson, "Cox Takes Majority Stake in Teleport Communications," *Multichannel News*, March 8, 1992, p. 5.

249. The "cross-ownership ban" forbids telephone companies from providing cable services in their telephone service areas (*The Cable Act of 1984*, Section 613[b][1]). In general, cable TV companies are not banned from providing two-way communications services. But when these companies started to provide "local telephone services," as the prospect of the development in CAP and PCN shows, their owning cable operations may be challenged. In fact, in May 1992, the U.S. Telephone Association, representing telephone companies, requested the FCC to deny Cox's acquisition of Teleport for the above reasons.

250. Refer to **Table 2-1** for details.

251. *Code of Federal Regulations*, The Office of Federal Register, National Archives and Records Administration, Volume 47, October 1990, Part 90, Subpart A, §90-7, p. 220.

252. Doron Fertig, *Specialized Mobile Radio*, Private Radio Bureau, Federal Communications Commission, February 1991, pp. 13–17 (hereafter, *Specialized Mobile Radio*).

253. For a summary of the evolution of SMR regulations, see Fertig, *Specialized Mobile Radio*, pp. 36–44.

254. Jeffrey Silva, "Proposal Could Eliminate End User Licensing Rules," *Radio Communications Report*, RCR Publications Inc., April 20, 1992, p. 1.

255. For the definition of "trunked" SMR system, see Fertig, *Specialized Mobile Radio*, pp. 6–7.

256. Ibid., p. 23.

257. Ibid., p. 33.

258. The base stations are used to retransmit the signals from and to mobile radios. SMR systems usually use only one base station in an operating area, while a cellular network has several to perform the same function in a single operating area.

259. Fertig, *Specialized Mobile Radio*, p. 23. Single-base-station systems have no secondary base stations.

260. Ibid., p. 32.

261. "Motorola Unveils 2 Technologies to Boost Radio Service Capacity," *Telecommunications Report International*, October 4, 1991.

262. Fertig, *Specialized Mobile Radio*, p. 24.

263. There are exceptions. For example, Fleet Call is granted a waiver by the FCC to construct multiple base-station systems in six major cities to provide SMR services. See Section 3.2.1.1.

264. Though the largest SMR operator in the U.S., in the PCS debates Motorola is more commonly classified as an equipment manufacturer.

265. Fleet Call, Inc., *Reply Comments in the Matter of Amendment of the Commission's Rules to Establish New Personal Communications Services*, FCC's *Notice of Inquiry*, GEN Docket 90-314, January 1991, pp. 8–9 (hereafter, *Reply Comments of Fleet Call*). U S West claimed that since Fleet Call is now able to construct multiple base stations in its systems, it should be able to use frequencies more efficiently and free up part of its spectrum for others to provide PCN services (*Comments of U S West*, pp. 18–19). Fleet Call retorted in its reply comments that it is the cellular operators that should give up the spared spectrum after they start employing the capacity-increasing digital cellular technology.

266. *Reply Comments of Fleet Call*, pp. 9–10.

267. "Regional SMR Operator Seeking Federal Approval to Develop Digital System," *Radio Communications Report*, November 18, 1991, p. 1.

268. See American SMR Network Association, Inc., *Reply Comments in the Matter of Amendment of the Commission's Rules to Establish New Personal Communications Services*, FCC's *Notice of Inquiry*, GEN Docket 90-314, January 1991, pp. 2–4.

269. Fertig, *Specialized Mobile Radio*, p. 31.

270. *Comments of MCI*, pp. 2–6.

271. *FCC NPRM, ET 92-9.*

272. Margot Moody, "FCC Modifies PCN America's License, Requests More Tests," *Radio Communications Report*, September 23, 1991, p. 15.

273. See remarks of Commissioner Andrew Barrett, quoted in Section 3.2.1.2.

274. The intention of MFS, as well as such competitive access providers as Teleport, to compete directly with the LECs and become an alternative carrier is evident from its recent moves in several large cities in the U.S. See, for example, Thomas Lanning, "MFS, Teleport Turn Competitive Screws," *Telephony*, December 3, 1991, p. 16, and Steven Titch, "MFS Unveils Services in New York; Teleport Tries in California," *Telephony*, May 13, 1991, p. 8.

275. Seth Malgieri, "New Technologies in Paging Industry Plus for Everyone," *Radio Communications Report*, September 23, 1991, p. 1, 28. The data are from a Frost & Sullivan report.

276. Ibid.

277. Ibid.

278. For details regarding its nationwide and regional paging services, see MobileComm company brochure.

279. See, for example, David Coursey, "AT&T Readies Safari Notebook; 25-MHz 386SL Safari Will Offer Credit Card-size Modem," *InfoWorld*, October 28, 1991, p. 12.

280. "Motorola, Lockheed Sign Letter of Intent to Develop International Team for LEO Iridium Satellite Construction; FCC Accepts Application; Motorola Says AMSC Objections Invalid," *Telecommunications Reports*, April 8, 1992, pp. 19–21 (hereafter, *Motorola, Lockheed to Develop LEO*).

281. For a detailed description of these systems, see Edward Reinhart, "Mobile Communications," *IEEE Spectrum*, February 1992, pp. 27–29.

282. *Motorola, Lockheed to Develop LEO.*

283. "Motorola Official Stresses PTT's Role As Local Gateway Operator for 'Iridium' System," *Telecommunications Reports*, September 24, 1990, p. 29.

284. "Inmarsat Planning PCS Service via Hand-held Voice Terminals," *Telecommunications Reports International*, September 20, 1991, pp. 1–3.

285. AMSC Company brochure.

286. Ibid.

287. Robert White and Veena Gupta, *Residential Market Analysis of Personal Communications Services in Support of BCC Regulatory Analysis* (Washington, D.C.: Bell Communications Research, August 1990), p. 11.

288. Ibid., p. 18.

289. Peter D. Shapiro, "Market Opportunities for Cable TV in Personal Communications Services," presentation in a TeleStrategies Conference on Cable TV and PCS, Washington, D.C., May 1991.

290. *Comments of FMR Corp.*, p. 14.

291. McCartney, *Telepoint Disappointing So Far.*

292. Ibid.

293. Abrahams, *Sink or Swim.*

294. McCartney, *Telepoint Disappoints So Far.*

295. Schnee, *Take Over*, p. 203.

296. Ibid., p. 204.

297. Calhoun, *Digital Cellular Radio*, pp. 63-68.

298. *Cellular Trends CTIA Data.*

299. For example, in the case of new wireless communications, paging can be regarded as a potential competition whose effect is very difficult to evaluate because of other fast technological advances. See Section 4.2.6; other examples are in Section 5.2.1.3.

300. *Comments of U S West*, p. 9.

301. S.M. Passoni, *1991 Cellular Industry Subscriber Survey — Industry Report*, Smith, Barney, Harris, Upham & Co., August 1991 [NEXIS] (hereafter, *1991 Cellular Industry Subscriber Survey*).

302. Keith Bradsher, "Users of Cellular Phones Put Privacy at Risk for Convenience," *The New York Times*, June 16, 1991.

303. Digitization is a sampling process that transforms analog voice signals into digital format. The number of bits transmitted per second limits the frequency range of the voice signals represented by the digital format. The usual digital transmission is about 8k bits per second, which corresponds to about a bandwidth of 4 kHz, good enough for speech. Noise, usually of high frequency, cannot be recreated using this limited bandwidth. For how digitization works, see Anthony Oettinger, "The Abundant and Versatile Digital Way," in Martin Ernst and Anthony Oettinger, ed., *Mastering the Changing Information World* (Norwood, N.J.: Ablex Publishing Corp., in press).

304. This is not a problem if a system that can satisfy the demand of every subscriber covers the whole region. But this is not the case with Telepoint. See "A Phone Booth in Every Pocket? Not Bloody Likely," *Business Week*, June 17, 1991.

305. Both cellular and SMR carriers have started to implement features usually attributed to PCS in their systems. See Sections 4.2.2.2 and 4.2.5.3 for details.

306. Passoni, *1991 Cellular Industry Subscriber Survey*. This survey may not reflect the actual market situation because of its relatively small sample size (only 218 respondents) in a large pool of users (over 5 million).

307. See, for example, *Comments of Cox Enterprises*, pp. 1–4.

308. *Statistical Abstract 1991*, Table 725, p. 451.

309. McCartney, *Telepoint Disappoints So Far*. The charge per minute of a call using Telepoint was comparable to that of a cellular telephone, and it was considered too expensive for the market.

Acronyms

ALT	Alternative Local Transport
AMI	Advanced MobileComm, Inc.
AMPS	Advanced Mobile Phone Service
AMSC	American Mobile Satellite Corporation
ANSI	American National Standards Institute
AT&T	American Telephone and Telegraph Company
BCC	Bell Communications Company
BOC	Bell Operating Company
BSS	Broadcasting Satellite Service
CAI	Common Air Interface
CAP	Competitive Access Provider
CCIR	Consultative Committee on International Radio
CCITT	Consultative Committee on International Telephone and Telegraph
CDMA	Code-Division Multiple Access
CEO	Chief Executive Officer
CEPT	Conference of European Postal and Telecommunications Administrations
CPE	Customer Premises Equipment
CT-1	Cordless Telephone, First Generation
CT-2	Cordless Telephone, Second Generation
CTIA	Cellular Telecommunications Industry Association
EIA	Electronic Industry Association
ESMR	Enhanced Specialized Mobile Radio
ETSI	European Telecommunications Standards Institute
FCC	Federal Communications Commission
FDMA	Frequency-Division Multiple Access
FM	Frequency Modulation
FPLMTS	Future Public Land Mobile Telecommunications System
GHz	Gigahertz
GNP	Gross National Product
GSM	Groupe Speciale Mobile/Global Standard for Mobile
GSO	Geo-Stationary Orbit (Satellite)
HDTV	High-Definition Television
Hz	Hertz
IEEE	Institute for Electrical and Electronics Engineers, Inc.

IFRB	International Frequency Registration Board
IN	Intelligent Network
ISDN	Integrated Services Digital Network
ISM	Industrial, Scientific, and Medical (Frequencies)
ISO	International Standard Organization
ITU	International Telecommunications Union
IXC	Interexchange Carrier
LAN	Local Area Network
LATA	Local Access and Transport Area
LEC	Local Exchange Carrier
LEO	Low Earth Orbit (Satellite)
MFS	Metropolitan Fiber Systems, Inc.
MHz	Megahertz
MSA	Metropolitan Statistical Area
MSS	Mobile Satellite Service
MTSO	Mobile Telephone Switching Office
NAB	National Association of Broadcasters
N-AMPS	Narrow Advanced Mobile Phone Service
NANP	North American Numbering Plan
NARUC	National Association of Regulatory Utility Commissioners
NASA	National Aeronautics and Space Administration
NCTA	National Cable Television Association
NMCC	NYNEX Mobile Communications Company
NOI	Notice of Inquiry
NPRM	Notice of Proposed Rule Making
NTIA	National Telecommunications and Information Administration
PBX	Private Branch Exchange
PCI	Personal Communications Interface
PCN	Personal Communications Network
PCS	Personal Communications System
PNC	Personal Number Calling
POTS	Plain Old Telephone Service
PSC	Public Service Commission
PSTN	Public-Switched Telephone Network
PTS	Personal Telephone Service
PTT	Post, Telephone, and Telegraph Administrations
PUC	Public Utility Commission
RBOC	Regional Bell Operating Company
RCC	Radio Common Carrier
RHC	Regional Holding Company
RSA	Rural Statistical Area

SMR	Specialized Mobile Radio
SNET	Southern New England Telecommunications Corporation
SS-7	Signaling System No.7
TCG	Teleport Communications Group, Inc.
TCI	Tele-Communications, Inc.
TDMA	Time-Division Multiple Access
TIA	Telecommunications Industry Association
UHF	Ultrahigh Frequency
VHF	Very High Frequency
WARC	World Administrative Radio Conference