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COMPETITION AND INTERCONNECTION: THE CASE OF PERSONAL COMMUNICATIONS SERVICES

Vivian Witkind Davis, Ph.D.
Senior Research Specialist

Hans Kruse, Ph.D.
Assistant Professor
Ohio University

William Pollard
Institute Engineering Economist

Catherine E. Reed
Graduate Research Associate

THE NATIONAL REGULATORY RESEARCH INSTITUTE
The Ohio State University
1080 Carmack Road
Columbus, Ohio 43210-1002
(614) 292-9404

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EXECUTIVE SUMMARY

Wireless technologies are one piece in the complex puzzle of emerging competition in the telecommunications industry. The advent of a market for new, personal communications services, or "PCS," is of concern to state regulatory commissions because it will relate to the wireline, public switched network in new ways. In this research report the NRRI analyzes the policy implications of PCS to help state regulatory commissions understand and adapt to PCS as it is marketed in their jurisdictions.

Demand studies show that many people want what radio can give that other technologies cannot—portability, and with it a new kind of freedom. Even the most conservative studies of demand show many millions of Americans using PCS within a few years of its introduction.

Potential providers of PCS want another kind of freedom—the freedom to compete fairly as they develop the exciting market for advanced wireless communications. A healthy market for new, wireless communications technologies will answer the question of just how many people want what type of wireless service at what price. But providers of wireless telecommunications cannot operate completely autonomously because their services must for the foreseeable future be interconnected with the wireline network. The regulated local exchange companies (LECs) will be both competitors and providers of PCS. As wireline competitors to wireless networks, they may not be inclined to subscribe wholeheartedly to principles of open network architecture and expanded interconnection when that will lead to reduced revenues. And insofar as the public switched network is bypassed, consumers of basic service must shoulder the load of landline costs. As providers of PCS themselves, the LECs are even less likely to want to be congenial hosts to PCS calls initiated or completed on their systems. Yet access to the databases and the intelligence of LEC networks is essential to the survival of PCS providers.

A modeling of the likely architecture of PCS shows the battleground on which economic efficiency and engineering efficiency must come to terms. No one player will be able to build the entire network, and by far the largest cost of a PCS network is the landline links to base stations. We can predict which players will have an advantage for which network segments. The LECs have a clear edge with their installed base of wireline switches and lines. The cost structure of PCS suggests that *de novo* entrants will be at a significant disadvantage. Our analysis suggests that even established cable and cellular companies will need the resources of the landline network. Business alliances of various kinds are likely. Interconnection arrangements will be crucial. Yet the history of interconnection between LECs and long distance companies has demonstrated that interconnection delays can have deleterious effects on competition and the survival of entrants. Compared to other components of a once seamless system that were separated out, like customer premises equipment and long distance, wireless in the local loop may be much more difficult to untangle from the public network. If access is all that is needed for PCS to thrive, principles of open network architecture and expanded interconnection will apply. Achieving "true" PCS, however, requires a degree of transparency and seamlessness that will simulate a unified network.

The FCC is attempting to establish an initial regulatory framework within which competition can develop. PCS and other wireless will be considered common carriage, which helps to assure fairness. But at its very best the market for PCS will be an oligopoly, and one in which one of the major players has an edge over the others. Half a dozen PCS providers, a cable company, and a telephone company would be many more providers of local telephone service than exist now but probably not enough for the market to be called fully competitive. Such a market is most likely to look like a "dominant/nondominant" one. At the beginning, the LECs and other existing cellular providers are likely to dominate. Perhaps that will lessen over time. It could also get worse, with PCS provisioning effectively consolidating among one or two providers. In some rural areas there might never be a PCS provider, or one at best, and that one an offspring of the telephone company.

What states can do to enable wireless communications technologies is limited but important. The federal regulatory framework cuts the states out of direct oversight of PCS. States still, however, have oversight of interconnection rates. State regulators should create an environment for investment and deployment of PCS networks that is stable and facilitates competition. We believe that successful state regulatory policies are likely to include (1) review of local rate structures, (2) monitoring, (3) judicious supervision of the terms and rates of interconnection with the public switched network, and (4) restraint.

Review of the pricing of local exchange, including rate groups and deaveraging, is called for by the advent of PCS as well as other types of local competition. This is not always politically palatable and needs to be juxtaposed against requirements of universal service policy, but would aid in giving accurate price signals to customers comparing PCS and landline service.

One of the most important things the states can do is monitor the development of PCS. This can be accomplished through the authority to regulate "other terms and conditions" of PCS, as allowed by Congress, as long as the requirements are not onerous. Monitoring will help to spot antitrust difficulties and barriers that are raised to competition. The FCC has established a large number of service areas and potential competitors. The service areas overlap state boundaries, making oversight more difficult. Regional sharing of information may be a good idea. The public service commission has unique expertise in dealing with telephone pricing issues and the oversight role is a natural use of its powers. In order to fulfill commission responsibility to prevent cross subsidization of unregulated affiliates by the regulated landline network, commissions will need to review LEC tariffs providing interconnection with PCS providers for congruence with open network architecture principles. State regulators must pay careful attention to the interconnection arrangements developed for PCS providers and assure that all parties are treated fairly and that diffusion of PCS is not artificially inhibited.

Regulators should not become the arbiters of competitive disputes unless there are clear grounds for action. They should refrain from micromanagement of telephone companies in an era when *minimal*, carefully targeted regulation that will not inhibit competition is expected and, indeed, all that is allowed in many states.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

LIST OF TABLES

FOREWORD

The telecommunications industry is being transformed in a number of ways. One of them is through the advent of advanced wireless devices that promise to offer user mobility at a price low enough to reach a mass market. This study analyzes the implications of these "personal communications services" for interconnection with the public switched network.

Douglas N. Jones
Director
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CHAPTER 1

TELEPHONY UNTETHERED: THE IDEA OF PERSONAL COMMUNICATIONS SERVICES

Economic competition requires interconnection. Competition takes place in a social context, nurtured and protected by such systems as banking, transportation, and courts. When competition is called for in an endeavor that is itself essential for binding together other markets, as it is today in telecommunications, public interest concerns are raised. The advent of a market for new, wireless personal communications services, or "PCS," calls for investigation of how competition will work with existing networks, especially the communications network itself.

In the abstract, PCS is a simple concept—that of being able to talk to anyone, anyplace, anytime while on the move. PCS is usually conceived of as wireless communications through a small, light-weight telephone, perhaps carried in a briefcase, handbag, or pocket, or worn as a functional necklace or watch. You could send or receive calls via radio waves worldwide whether in the office, at home, on the street, or in a moving vehicle. The idea of tetherless communications begs for a reorientation towards conversation and exchange of data. Today location anchors identity for senders and receivers. With PCS, people will provide that anchor, just as they do face to face, and people, rather than places, will be assigned a phone number.

PCS may be an idea whose time is about to come, but today the vision is neither actual nor simple. Technical, economic, and marketing problems remain to be solved. And the idea includes more than the straightforward notion of a pocket telephone. Wireless offices, wireless replacement of the copper-wired local loop, and existing cellular service all fit under the umbrella term of PCS. The Federal Communications Commission (FCC) defines PCS as "a family of mobile or portable radio communications services which could provide services to individuals and business, and be integrated with a variety of competing networks."[1] Similarly, but capturing more of the ill-defined, opportunistic, imaginative character of PCS, George Calhoun sums up PCS today as "a motley covey of wireless applications... which trades on the charisma of portable handsets and in general transcends 'cellular' as a model."[2]

In this research report the NRRI analyzes the policy implications of PCS to help state regulatory commissions understand and adapt as the new wireless services are marketed in their jurisdictions. The prospect of rapid deployment of communications systems that relate to the public switched telephone network in new, poorly understood ways must be of concern to commissions. Even as many commissions deregulate telephone services that are becoming competitive, they continue to protect consumers of monopoly basic services supplied by the local exchange carriers (LECs). Commissions must attempt to assure that the ordinary ratepaying citizen, who still uses the telephone for the simplest purposes—calling home, calling in sick, chatting with friends—can do that at reasonable rates. Among other things, this means that ratepayers must not be unduly burdened with paying for the LECs' risky ventures or paying more for basic service because of communications systems that may avoid the public switched network entirely.

Problems of cross-subsidies and bypass are familiar. Others are not so well examined. The FCC has decided to allow LECs to be PCS providers. Yet every PCS scenario for the near term requires wireless communications services to link up with the backbone landline network: The LECs must provide critical connections for their PCS competitors. The incentives of landline network providers, including both LECs and interexchange carriers, work against allowing PCS to develop into a fully competitive, universally available partner. This is especially true to the extent that development of PCS requires not only access, but integration. That is, to reify the idea of PCS ultimately

[1] FCC, *Notice of Proposed Rulemaking*, GEN Docket 90-314 and ET Docket 92-100, 7 FCC Rcd. 5676 (August 1992) 13. Referred to hereinafter as the *Notice*.

[2] George Calhoun, *Wireless Access and the Local Telephone Network*, (Boston: Artech House, 1992) 201.

might call not only for a loosely connected network of networks but a seamless, transparent whole, rather like the old AT&T. Whether consumers demand services that require merely access or those that need a unified network, commissions must take appropriate responsibility for assuring that LEC tariffs and interconnection agreements do not artificially give an advantage to any one PCS provider.

PCS in the Context of the Telecommunications Revolution

In ancient times—that is, slightly over a decade ago—state regulators had to begin to deal with the institutional consequences of a convergence of communications and information technologies. The modified final judgment severed interexchange services from local telephone service, allowing AT&T to branch out into the computer business. The word "bypass" entered regulatory language as commissions became concerned with the potential for alternative access providers to siphon off lucrative traffic from the local telephone company, leading to declining revenues and higher rates for captive customers. Today the telephone companies and others warn that two-way voice communications over a wireline network, the natural monopoly that commissions were called on to regulate, will in a few short years be overwhelmed and absorbed by new players and a convergence of voice communications, information and, not least in terms of consumer demand, entertainment. Ken Auletta summed up the situation in a recent article in *The New Yorker*:

> No one knew or knows what will happen as the cable box mates with the computer; the phone with the cable wire; the networks with the studios; the studios with cable; the computer with the studios or with telephone, publishing or electronics companies. To do any of this... require[s] a convergence of three distinct forces: the emergence of 'enabling technologies'; alliances among business adversaries; and government approval.[3]

[3] Ken Auletta, "Barry Diller's Search for the Future," *The New Yorker,* Feb. 22, 1993, 49-61.

Radio is conspicuously missing from Auletta's list of complementary couplings. To the extent that consumers want switched video on demand there must still be landline networks. But radio has a large role to play in the information age because it offers something besides high-quality video communications that consumers appear to want—portability for two-way voice and data communications.

The technologies that could enable plain old wireless telephony will build on three factors: the principles of cellular service, new means of adding to the amount of traffic that can be handled in limited radio spectrum, and advances in the ability of the network to find handsets that move with their owners. For a while the business pages of major newspapers looked like the wedding pages in June, announcing a steady stream of cooperative ventures that crossed the old technological boundaries. The merger boom had largely collapsed by the summer of 1994. But one of the boldest and most surprising of these innovative business alliances was alive: AT&T was still hoping to consummate a proposed $1.6 billion purchase of McCaw Cellular.[4] Such a merger would link long distance and local wireless service in a nationwide network.

The burgeoning of technologies and business ventures is testing the adaptability of regulatory mechanisms. The FCC finished establishing an initial regulatory framework for PCS in the spring of 1994. State commissions have been largely marginalized on this issue, at least for the time being. The Congress, in the budget reconciliation bill passed in August 1993, voted to limit state oversight of PCS providers even as it was recognizing PCS as a new form of common carriage and thus bearing special public responsibilities. It seems fair to say that many of the players in the telecommunications revolution, if they think about the states at all, consider state regulation interfering, costly, and anachronistic. Yet through their oversight of the LECs, states hold an important key to the development of a robust, stable market for PCS services.

[4] "Allen Tells Shareowners McCaw Deal Will Go Forward," *Telecommunications Reports,* April 25, 1994, 24-25.

Relationship to Other Research

A 1992 NRRI research report by professors Phyllis Bernt, Hans Kruse and David Landsbergen aimed to inform the regulatory community about some of the regulatory implications of new technologies, including PCS.[5] They described the technical capabilities, current deployment, and current regulatory treatment of the existing copper loop and the technologies that have allowed cellular, cable, fiber optics and PCS to emerge as potential competitors. The report discussed policy issues concerning universal service and competition as they relate to the local loop and local services.

This research report builds on the 1992 analysis, focusing on one alternative technology and emphasizing policies related to the efficiency consequences of competition more than the consequences for social equity. The reader should refer to the earlier work to gain a broader perspective on the evolutionary thrust towards greater competition in local telephone service.

This report also owes a debt to early research by the New York Department of Public Service, which outlined regulatory concerns about PCS two years before the FCC established the initial regulatory framework.[6]

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[5] *The Impact of Alternative Technologies on Universal Service and Competition in the Local Loop* (Columbus, Ohio: NRRI, 1992). Two earlier NRRI reports deal with issues of technological change and the attendant allocation of risks. The first is *Telecommunications Modernization: Issues and Approaches for Regulators* by Raymond W. Lawton (Columbus, Ohio: NRRI, 1988). The second is *Telecommunications Modernization: Who Pays?* by Nancy J. Wheatley, Lee L. Selwyn and Patricia D. Kravtin, (Columbus, Ohio: NRRI, 1988).

[6] New York Department of Public Service, *Personal Communications Services,* (New York: Department of Public Service, 1991).

Preview of Report

To become familiar with PCS, the reader should first have an overview of the several technologies it encompasses, the fundamental architecture, and an introduction to the players and their comparative advantages. At least initially, much PCS will look similar to cellular service. The LECs and cellular companies are not the only potential providers, however. Cable companies, interexchange carriers, independent companies, and providers of service by low-earth-orbiting satellites are also likely to be involved. Chapter 2 introduces the technology of PCS and reviews the status of experimentation and market trials.

The conditions of interconnection—how, at what price, and with what obligations—can make the difference between success or failure of PCS. This is particularly true insofar as the potential of PCS can only be achieved with full integration of wireline and wireless networks. Interconnection issues are discussed in Chapter 3.

Estimates of how many Americans will be using mobile telephone services in the next ten years or so are in the tens of millions.[7] How likely is it that such markets will develop and that PCS will be competitively viable? And what sort of pattern is the growth of competition likely to take? Chapter 4 discusses the economics of PCS, including a review of demand studies, and particularly emphasizes projections of market development. Several regulatory changes are suggested to aid the development of competition, including rate restructuring to send clearer price signals to consumers. Most of all, we caution commissions against injudiciously entering or reentering the fray, even when competition appears to be cutthroat and destructive.

The federal regulatory framework and some state responses to PCS are reviewed in Chapter 5. Despite setbacks and some rethinking of the framework initially proposed, the FCC and Congress have put in place the broad outlines of the field of competition

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[7] FCC, "En Banc Hearing on PCS Issues," GEN Docket 90-314, April 11, 1994, pp. 1-50.

for new wireless services. The states have been preempted from direct intervention in PCS, although a state may regulate in the future if it can show the FCC that the market is not protecting ratepayers, or that the market has not developed adequately and PCS has developed into a basic service.

The thrust of this report is that commissions have a legitimate interest in the development of PCS yet must refrain from intervention that would inhibit competition. As discussed in the final chapter, monitoring of the evolution of PCS, judicious oversight of the LECs' role, review of pricing policies, and restraint even in the face of seemingly destructive competition are likely to be hallmarks of successful state commission policies towards PCS.

PCS policies were evolving as the report was written, so that events will undoubtedly quickly overtake some of the facts and assertions. We hope, however, that for several years to come much of the report will provide a baseline reference to the commissions and guidance on the crucial regulatory questions raised by the advent of PCS.

CHAPTER 2

PCS TECHNOLOGIES, ARCHITECTURES, AND POTENTIAL PROVIDERS

Personal communications services are the subject of widespread interest and development efforts but exactly what they will look like, how they will work, and who will provide them is far from decided. Cordless and cellular telephones are following separate streams of evolution that could lead to PCS. But progenitors are also Dick Tracy's two-way wrist radio and *Star Trek*'s "communicators," lapel pins that at a touch of a finger allow conversation over vast distances. PCS today is as much an idea as a product. The idea is of communication anywhere and anytime and more attached to an individual than a location.

What makes PCS different from the stuff of science fiction is that unlike other visionary ideas, like time travel or vehicleless transport, to many observers we seem to be on the cusp of technical feasibility and mass affordability. In this chapter we will discuss the definition and origins of PCS, offer a generic architecture to serve as the basis of discussion of interconnection issues, and suggest the roles that various industries may play as PCS develops.

Avenues to PCS

The FCC's definition of PCS as "a family of mobile services" recognizes the amorphous nature of the final product or products. PCS is not one technology or application but a group of them that share the characteristic that they are usable by people on the move. The FCC's very general definition requires only that the communications device be wireless and movable. It could include a hodgepodge of instruments and applications related only by these two essential characteristics. The FCC offered as examples wireless private branch exchanges; smaller, lighter, cellular phones; portable fax machines; multichannel cordless telephones; and services that facilitate contacting an individual instead of a particular station.[1]

In this report the term "wireless" includes all kinds of existing and proposed mobile radio communications services, including existing cellular and paging. "PCS" follows the FCC definition, and includes advanced cellular, advanced telepoint and advanced cordless and wireless business applications (see Table 4-2). "True" PCS means anywhere, anytime communications using pocket telephones, or "personal telecommunications services" in the Telocator definition (see Table 4-2). "Wireline," landline," and "terrestrial" networks are synonymous. The "public switched network" is the existing landline network owned and operated by LECs and interexchange carriers.

One way of looking at PCS is by the expectations it will meet. PCS visionaries see PCS as the embodiment of a revolution in telecommunications in which a telephone is no longer associated with a location but with an individual human being. Buyers would not be an elite of especially peripatetic, well-heeled gadget lovers but the same sort of people who own and use personal computers and video cassette recorders. In order to get to this visionary definition of PCS, a number of requirements would have to be met. Most of these are driven by expectations about demand. The path of technological development is being directed toward achieving wireless communications that consumers want and can afford. The requirements include:

1. Portability: A PCS device would be highly portable, small enough to fit in a shirt pocket or purse, attached to a belt, or hung around the neck.

2. Reliability: Consumers do not want to reach for the pocket phone and find the battery has run down.

3. Ubiquity: PCS must be, if not ubiquitous, widely enough available that the customer can expect to be able to use it when he or she needs it. This implies that calls could be both originated and received wherever the user might be.

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[1] *Notice*, 12.

4. Convenience: The customer should be able to use the same phone from location to location, rather than having to switch from a home-based instrument to one in the car to one in the office or on the street.

5. Quality: Dimensions of quality include voice reception, blocking out of other calls, and an absence of ineffective attempts to dial.[2] Industry observers expect customers to demand the same quality from wireless as from wireline equipment. Another aspect of quality is transparency, which makes the actions of the network invisible to the telephone user.

6. Security: Current cordless telephones do not provide protection from eavesdropping; lack of privacy would inhibit diffusion of PCS.

7. Safety: Consumers would need to believe that pocket telephones would not cause cancer or other disease.

8. Price: Finally, the price of PCS would have to be low enough to attract large numbers of users.

The technology likely to result in portable, reliable, convenient, versatile, high-quality, and affordable PCS is high frequency, digital radio. Low-power handsets would allow batteries to be small and lightweight and permit plenty of use between charges. Frequencies would be reused as the customer passed through numerous small, contiguous areas, each containing a base station. This technology is essentially the same as for current cellular service but with many more cells and base stations. Cell sites in buildings would allow the user to move from home to car to downtown street to office without a lapse in service. This would occur with the evolution of the wireless office. Digital radio would also provide quality and security that is missing in analog service.

In fact, perhaps the clearest definition of PCS is given by the portion of the broadcast spectrum which it will use. The FCC has reallocated frequencies in the 2 gigahertz (GHz) range to broadband personal communication technologies and approved allocation of frequencies in the 900 megahertz (MHz) range for narrowband PCS. PCS is thus anything that uses these portions of the spectrum, as shown in Figure 2-1.

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[2] Rick Goldberg and Gary Brush, "Getting Ready for PCS," *Telephony,* February 10, 1992, 24-28.

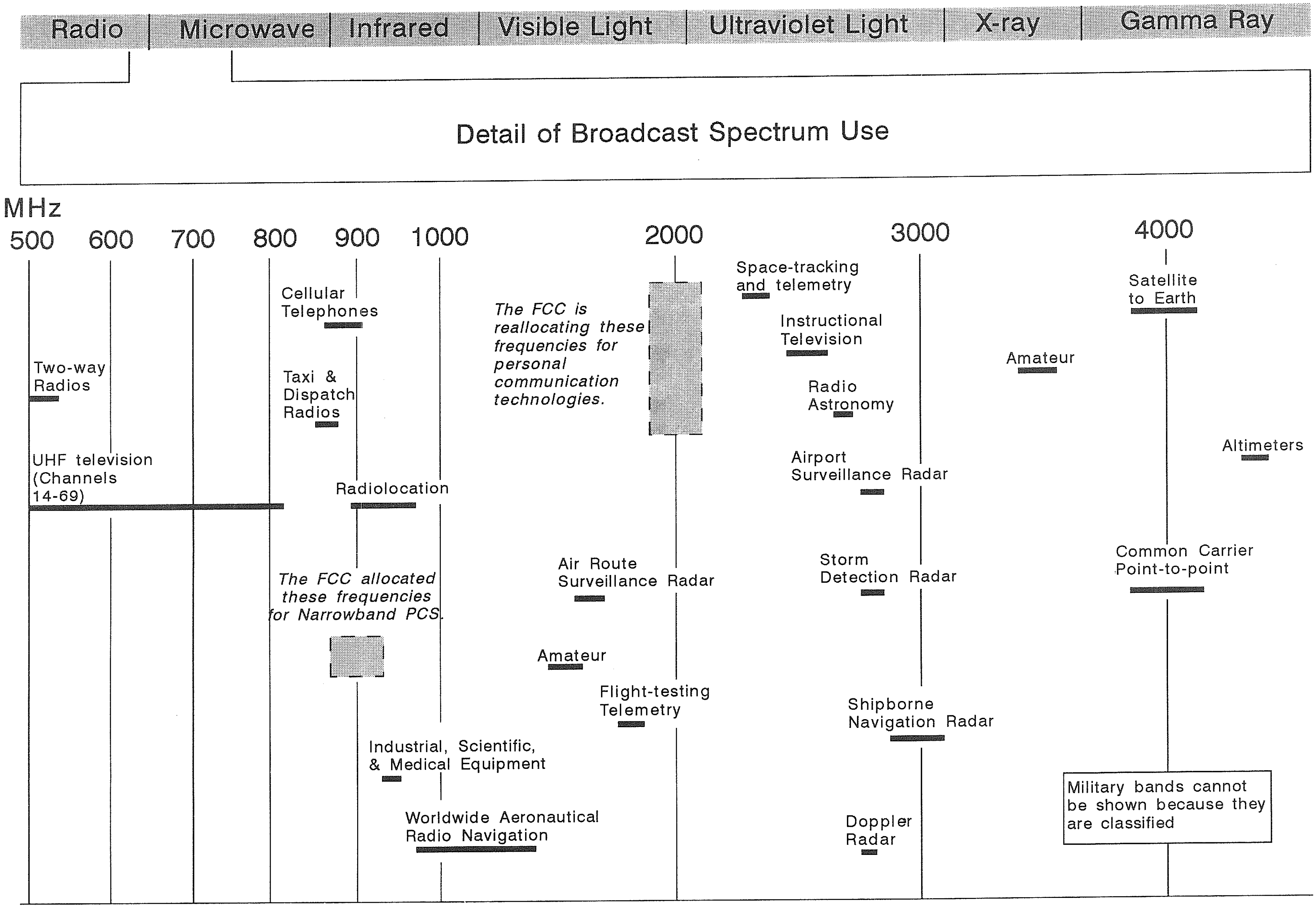

Figure 2-1. Communications and the Broadcast Spectrum.

Source: Edmund L. Andrews, "Radio Rights: A Move to Auction Licenses That Sell," *The New York Times*, March 21, 1993. Changes to table by Authors are italicized.

Both current cellular telephone service and advanced cordless telephones can be the basis for evolution to personal communications, but neither one today can truly be labeled PCS.

Cellular

Contrary to the above, representatives of the cellular industry believe they are already supplying PCS, using spectrum allocated to them. "Cellular *is* PCS," the cellular industry likes to claim.[3] And it is true that cellular service is widespread and has been branching out into handheld and portable units. Most of the cellular phones in the United States today are used by some nine million vehicular customers. Handheld portable cellular phones are currently 10-15 percent of total cellular sales. The democratization of cellular has been predicted by industry pundits. By 1993 one out of three cellular phones was expected to be sold for nonbusiness communications. By 1994 the installed base of personal and consumer cellular was predicted to be four million out of a total subscriber base of nearly 16 million cellular users.[4] Whether or not this is overly optimistic, it is certainly what the cellular companies would like to see. Sales of cellular to business is quickly becoming a mature market. If new business sales will be flat or declining, it is no wonder they are hoping to stimulate residential use.

Yet cellular is not quite PCS (see Table 2-1). Cellular phones use relatively large cells that the users can traverse at high speeds. Cellular service today is comparatively expensive. A recent article in the *Wall Street Journal* reported some representative prices. The average cellular rate was 60 cents per minute at peak time. Prices around New York City ranged from 59 cents to 65 cents per minute, compared to 41 cents to 45 cents per minute in Los Angeles. The lowest average cellular rate has decreased by

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[3] Charles F. Mason and Steve Titch, "PCS: What Is It? What Will It Do? What Will It Change?" *Telephony*, October 5, 1992, 15.

[4] Gautam Naik, "Cellular Rates Spark Static From Users," *Wall Street Journal*, 5 May, 1994, B1.

9 percent in eight years while long distance rates have decreased by 40 percent in a decade.[5] A monthly bill of $100 or more is easy for a user to run up, although reserving the cellular phone for emergencies can keep the cost well below that. A recent sampling of cellular charges for regional salespersons of a company based in Boston showed monthly total bills, including fixed costs and usage, as high as $300. Fixed charges for cellular service for that company are shown in Table 2-1. Of course, fixed charges tell only part of the story. A high fixed charge may be counterbalanced by relatively low rates for usage.

Handheld portables have been made smaller, lighter and better able to perform, although the time you can talk before the battery runs down is still limited and quality of reception is poor within many buildings. Motorola's 5.9 ounce MicroTac telephone was the lightest cellular telephone available at the time this report was being prepared.[6] Table 2-2 shows critical differences between cellular and true PCS.

Telepoint

Telepoint, or cordless telephony, is a possible route to PCS.[7] Twenty-five percent of American households now have analog cordless telephones (CT-1). More than ten million cordless telephones are sold every year.[8] Cordless telephones have a range of about three hundred feet and are hampered by susceptibility to interference and lack of

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[5] Ibid.

[6] "Motorola Again Packs Smallest Cellular Punch", *Telephony,* September 28, 1992, 22.

[7] See Victor J. Toth, "FCC Should Move Cautiously on Wireless Personal Communications Networks," for a discussion of CT-1, Ct-2 and CT-3, *Business Communications Review* (February 1990): 68-70.

[8] Ron W. Grawert, "Cellular Technology Role," National Communications Forum, Chicago, Ill., October 12, 1992.

TABLE 2-1

CELLULAR AND PERSONAL COMMUNICATIONS SERVICES COMPARED

	Cellular	PCS
Power requirement	High	Low
Cell size	Macrocells: up to several miles	Microcells: 200-1,000 feet
Battery size	Large	Small
Poor performance locations	Enclosed spaces	Automobiles
Price	High	Low

Source: Authors' construct.

TABLE 2-2

AN ILLUSTRATIVE SAMPLE OF FIXED CHARGES FOR CELLULAR SERVICE (Winter 1994)

State	City	Company	Fixed Charge
California	Los Angeles area	National Cellular	$45.00
North Carolina	Greensboro	Sprint Cellular	24.95
New Jersey	New York City area	Bell Atlantic Mobile Systems	39.99
Massachusetts	Boston area	Cellular One	21.00

Source: Authors' construct.

security, as well as by their limited range. Further, they are heavier than a "true" PCS unit would be.

CT-2, or cordless payphone service, is being used in Great Britain, where payphones have been less common and less reliable than in the United States. One-way (outbound) service is provided for the pedestrian user in a contiguous area outfitted with radio receivers. The next generation of cordless phones, or CT-3, would allow the cordless phone to originate calls in public. This is expected to evolve to a phone that notifies the customer of incoming calls through a pager and allows them to respond by placing an outgoing call from near a wireless public terminal.[9]

Sophisticated wireless payphones are being deployed and experimented with worldwide. Motorola recently announced the launching in Singapore of CT2 telepoint service for computer assisted instruction. The company reported attracting eighteen thousand users in two months. Other Motorola telepoint systems are operating in Bangkok, Thailand and Hong Kong.

Low Earth-Orbiting Satellites

A discussion of emerging personal communications services would not be complete without mentioning low earth-orbiting satellites. Governments from 160 nations agreed in March of 1992 to allocate a band of radio frequencies for "low earth orbit" satellite systems that would ring the globe with wireless service. Several proposals are being considered for how to array a satellite system. All but one would use the wireline network as well as wireless communications. Motorola's Iridium plan would set up a celestial telephone network that would route calls anywhere in the world without tying into the landline network. In this design, base stations are replaced by sixty-six low earth-orbiting satellites.

In satellite-based PCS, orbiting combinations of base stations and switches are interconnected using wireless links. The connection between the satellite base stations

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[9] Goldberg and Brush, "Getting Ready for PCS," 24-28.

and switches on the ground is also wireless. This type of PCS coverage is technically world-wide and does not use landline networks, although transmissions may be "blacked out" in countries which do not issue permits to the satellite-based PCS provider.

A Generic Architecture for PCS

In order to lay the groundwork for discussion later in this report about interconnection issues, here we will develop and present a model encompassing all currently foreseen PCS architectures. This will allow for a common nomenclature and clarification of all possible points at which PCS and the public switched network may need to connect.

Figure 2-2 shows the structure of proposed PCS systems. The figure is somewhat simplified to clarify the most important features of the network architecture which will be used by all PCS providers. The same structure is also currently in use by cellular mobile telephone services. Later in this section we will examine how each of the proposed PCS networks fit this structure. The descriptions are designed to provide an overview of proposed PCS structures. The reader should refer to the large body of technical articles on the subject for further details.[10] It should also be noted that details of any PCS implementation will depend on the services the provider intends to offer, for example, basic voice, low-to-medium speed data, high-speed data, or full multimedia (video) capability (although in general PCS will not be able to provide video service).

The PCS terminal is usually a hand-held unit. In contrast to cellular service, PCS networks do not provide reliable service in moving vehicles. Early PCS networks may require a subscriber to remain stationary during a conversation. However, all PCS designs will eventually function well at walking speed. Cellular service—with its larger

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[10] See, for example, Cox, D.C., Wireless Network Access for Personal Communications, *IEEE Communications Magazine* 30 (1992), 96-115, as well as references cited in that article.

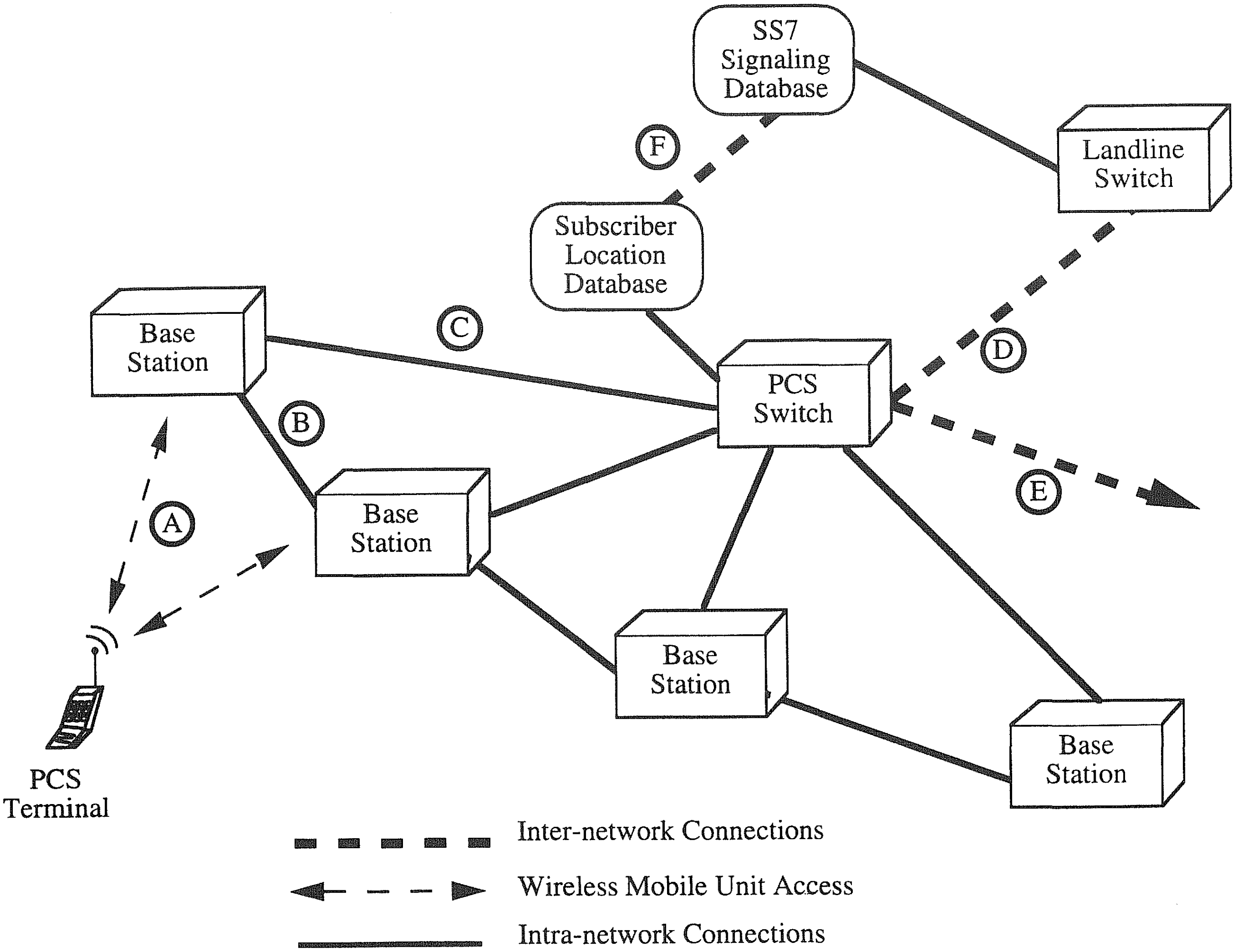

Figure 2-2. A generic architecture for PCS.

Source: Authors' construct.

cell sizes—will continue to be required to provide service to moving vehicles, and some PCS units will be designed to switch between vehicular and pedestrian service. Once a subscriber activates the handset, a low-speed signaling link (A) is established with one or more base stations. These base stations are the ones which receive a strong enough signal from the PCS terminal to provide service to the terminal when requested. When a call is originated or terminated at the PCS terminal, the link to the base station is expanded in bandwidth to accommodate the voice traffic.

In some PCS designs, a subscriber may have a small base set at home or in the office. This will be connected to the landline network and function just like the base of a cordless phone. When this base set can serve the PCS terminal, calls will be handled via the landline. Even in this case the signaling link is required, since the PCS network must be instructed to route incoming calls to the subscriber via the landline connection. Even if no call is in progress, the signaling link (or links) remain in effect, and the subscriber location database is updated as the subscriber position changes with respect to the base stations. One base station is needed to serve each cell. In terrestrial PCS, cells are expected to be about a thousand feet in diameter. Proposed low satellite-orbit systems—such as Motorola's Iridium—will provide PCS using much larger cells. Traditional cellular systems use cell sites which are several miles wide. Each cell's base station must be connected to the PCS switch, typically using wirelines (C). The PCS switch makes routing decisions on each call and handles database updates. Base stations may also be connected to each other via wirelines (B). These links facilitate call routing and handing calls off between cells. It is important to note that every PCS provider will need to provide these interconnections among base stations and between base stations and the PCS switch. A report on a study by A. D. Little suggests that these wireline links represent about 30 percent of the cost of providing PCS service.[11] This makes the wireline links the largest single cost of service.

Some future PCS providers are better positioned than others to put these connections in place at the time of their market entry. These differences will have an impact on the level and equity of competition between the providers. At a minimum, every PCS provider needs an interconnection to the terrestrial switched network (D). We expect early PCS providers to achieve this interconnection through the LEC network. This landline interface is needed whenever a PCS user places a call to a subscriber who is not a user of the local PCS system. This "remote" called party may be a landline

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[11] Barry E. Goodstadt, "Personal Communications Services in the United States: A Survey of User Interest," *Spectrum* (Burlington, Mass.: Decision Resources, Inc., July 17, 1991): 27-2.

subscriber or a user of another PCS or cellular system. The landline interface is also used any time a "remote" subscriber places a call to the PCS user.

The first PCS systems are expected to use the same interconnection methods as present cellular providers.[12] Each PCS provider will obtain a block of access trunks and associated telephone numbers from the LEC. Each subscriber is identified by the North American Numbering Plan number assigned to him or her as part of subscribing to the service.

The reader must consider the implications of this architecture to understand the demands PCS will make on the national public switched network. PCS as a philosophy is designed to change the basic addressing method, that is, the way in which we locate a subscriber. In PCS, we are supposed to cease routing calls to specific subscriber lines, and instead locate the subscriber regardless of his or her location. Since no PCS provider can afford to replace the public network, we will see a hybrid in which calls continue to be routed to subscriber lines as always. However, instead of connecting the subscriber line directly to a telephone (or data) instrument, we now connect this line to an add-on system (the PCS network), which is then given the task of locating the subscriber.

The use of a single landline interface to the LEC simplifies the operation of the PCS switch, since the only routing decision that must be made within the PCS system is to determine if a called number is inside or outside the system. In addition, the required technical and regulatory mechanisms for call hand-off are already worked out. In particular, this implementation requires no knowledge by the public switched network of the existence or properties of the PCS network.

However, several factors will drive PCS providers to use other landline interface methods. The public switched landline network consists of a "network of networks." Multiple interexchange carrier networks are in place. These networks are connected to one or more local access networks in each market area. While the LECs have by far the

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[12] Bernt, Kruse, and Landsbergen, *The Impact of Alternative Technologies*, and references therein.

largest market share for local access networks, multiple networks will increasingly be available in most areas. The non-LEC local access network providers are among the anticipated PCS applicants, including competitive access providers and cable TV providers.

PCS providers will therefore look at the cost of access service, as well as existing or desirable partnerships with a landline carrier (such as the alliance of McCaw and AT&T), and decide on this basis where to interconnect to the landline network. These considerations may well require more than one landline interface ((E) in Figure 2-1). If this is the case, the PCS provider will need to implement somewhat more sophisticated routing controls.

PCS providers operating in more than one service area may implement "private" networks to connect these service areas. In this way the PCS provider can economically provide enhanced services to subscribers who "roam" into multiple service areas.

The discussion of network interconnection so far does not answer the question of how to provide true PCS service, defined as reaching subscribers using a single number regardless of location, and doing so in an economical fashion.

Two approaches to addressing can be taken. In Chapter 3 we will discuss the detailed technical aspects of these network interconnection options. Here we want to outline the impact on the service delivered to the customer and the cost of the service. The landline interface (D) in Figure 2-2 includes an implicit, port-based addressing scheme. The landline switch is "aware" of the numbering plan addresses (that is, the telephone numbers) associated with the PCS region that it is interconnected to. Subscribers are identified by PCS-specific codes. Dialing patterns, however, are based on the address assigned to the subscribers from the pool of numbers associated with the PCS region.

In the interconnection scheme discussed up to this point, networks outside the PCS region route calls to a PCS subscriber to the PCS switch that "owns" the address of the PCS subscriber. This routing choice is independent of the actual location of the subscriber. It is the responsibility of the PCS switch, upon receipt of the call from the landline switch, to find the PCS subscriber and to complete the call. We will refer to this arrangement as "interconnected networks."

The interconnected networks approach has disadvantages which we will point out in the next chapter. This approach does, however, have the advantages of simplicity and separability. The trunk interface is simple and presents few problems in operation and troubleshooting. Separability refers to the billing implications of locating a mobile subscriber. The caller is used to being able to roughly predict the cost of a call based on the dialed number—we are accustomed to associating fixed locations with phone numbers. In the interconnected network approach this feature is preserved. The caller pays any charges associated with reaching the PCS switch (as opposed to reaching the called party). The called party is billed for the path from the PCS switch to the mobile unit. This usually includes a charge for the use of the wireless link (referred to as "air time"), and any terrestrial links which may be needed to establish this path.

In a typical example shown in Figure 2-3, a caller (Station A), dials what he or she perceives as a local number. The caller pays the message unit charges, if any, for the call shown as connection 1 in the figure—a charge he or she expected. The PCS switch queries its database and finds that the called party is actually in the service area of another mobile telecommunications switching office (MTSO). A long distance connection to the PCS region in which the called party currently resides is established (connection 2 in the figure), and charged to the *called* user. This PCS switch then locates the mobile unit, completes the call (connection 3 in the figure), and bills the called party for use of the wireless connection. While this example seems very reasonable, it leads to so-called "hair-pin connections." Figure 2-4 shows an example.

The network operation in this case is identical to the one shown in Figure 2-3. The only difference is that stations A and B are both located in the same local calling area. However, the landline network which A is using associates the address for B as belonging to B's home switching office. Station A must therefore place a long distance call on his network to access the PCS switch. The PCS switch, in turn, must use a long distance connection to the remote switching office to reach B. Had both networks been able to access a shared database, they would have been able to complete the connection

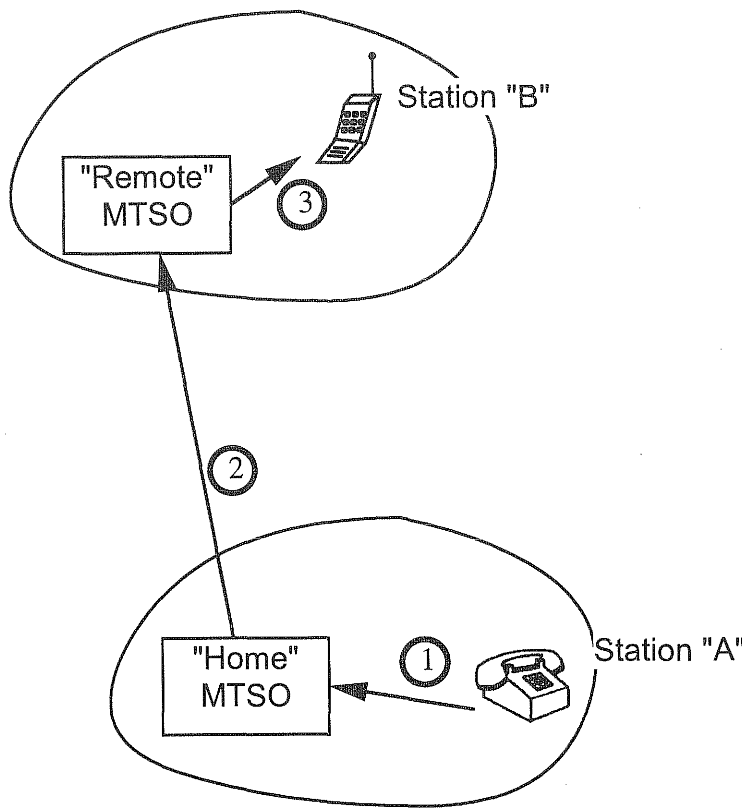

Figure 2-3. Typical long distance wireless connection.
Source: Authors' construct.

using only a local connection from A to the switching office which is currently serving B. A and B would save the cost of both long distance calls.

It is possible to go beyond interconnection of networks to fully integrated networks. Figure 2-2 shows a connection, labeled F, between the subscriber database for PCS and Signaling System Seven (SS7) implemented in the landline network. SS7 represents a significant advance in the "intelligence" of telephone networks. It can carry more signaling and routing information than has been possible. With full integration, the call shown in Figure 2-3 can be completed much more economically. Station A still dials the address associated with station B and its home mobile telecommunications switching office. Prior to routing the call, however, the landline network queries the appropriate PCS databases to locate B. This process will identify the switching office which is able to reach B. The landline call will be placed and charged based on this "optimal" connection. In Figure 2-4, this connection would be much less costly than the two long distance calls required in the interconnected network scheme.

A Profile of Potential Players and Their Relative Strengths

Cellular companies may see PCS as a natural progression of their core service. But a potentially lucrative market or set of markets and the fear of being beaten to the punch have energized other potential players to move forward aggressively on PCS research and development. Telephone companies consider PCS an extension of their own natural business. Cable companies see PCS as another means of gaining entry into the local loop, beyond their wired connections. Competitive access providers may be in a good position to move into PCS: suburban residential service would complement their downtown infrastructure. Independent PCS providers have sprung up or spun off from other companies to develop prototype equipment and services. Several consortia are preparing to deploy systems of low earth-orbiting satellites to provide PCS service world-wide. And interexchange carriers are very much in the game. AT&T has purchased a third of the stock in McCaw Cellular, which gives it the potential to tie long distance to local service once again.

The FCC order that allocates spectrum places very few restrictions on who may be eligible to bid on portions of the PCS spectrum (see Chapter 5). Total spectrum allocation for current cellular carriers is limited to 10 MHz in their current service area, and unlimited outside. There is a prohibition against bidding by companies which are controlled by foreign interests or in which foreign governments have a financial interest. LECs are permitted to bid for PCS spectrum except insofar as they are also cellular carriers.

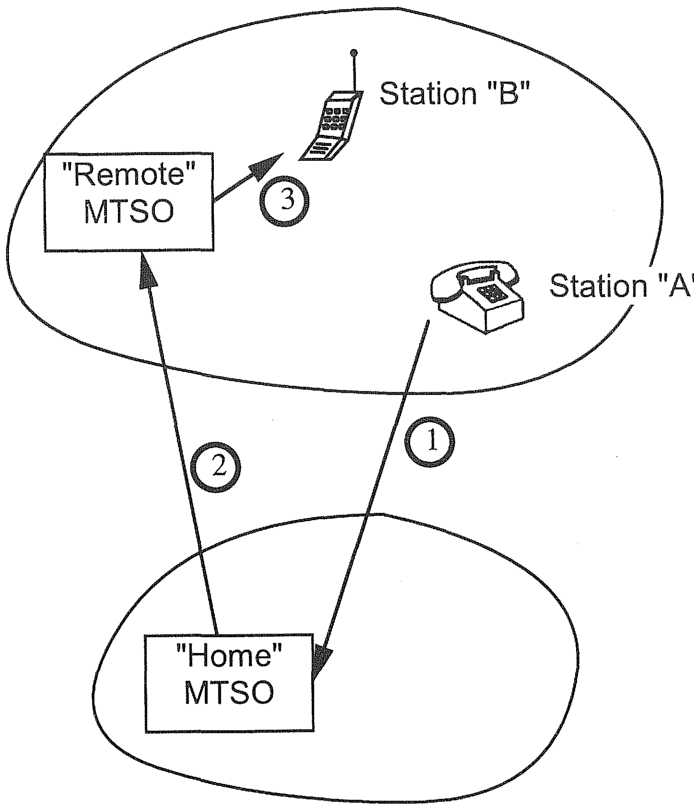

Figure 2-4. Potential hairpin connections in PCS.
Source: Authors' construct.

Tests of the market for various forms of PCS are underway throughout the United States. The FCC has approved 204 applications for PCS trials, of which 130 are for market tests. The appendix to this report shows the FCC-approved market tests by state. Forty-two states and Puerto Rico are represented. Many of the tests are being conducted in more than one state. The largest number of tests are in California, Florida, and Texas. Many are in major metropolitan areas. As of the end of 1993, twenty-one tests were completed with eighty-four more scheduled to be finished in 1994.

The number of active tests may be somewhat lower than 130, however. One mid-western applicant on the FCC list disclosed to the NRRI that an incentive for doing a market test was the hope of elevated status in the upcoming FCC auctions. Upon the realization that no special consideration was going to be made for companies who had conducted market tests, this company chose not to do one.

In the following section we examine the positioning of each of the potential entrants into the PCS market. It should be noted that every entrant faces the same investment in PCS base stations and related wireless components. The PCS frequency range and the much smaller cell sizes will force every PCS provider to deploy these network components "from scratch," regardless of their current product offerings. There are, however, many differences in the supporting architecture which some of the future PCS providers may already have in place.

The cost of establishing PCS service will be extremely high. Recent estimates[13] suggest that a network serving the New York City area would cost over $6 billion. Of that sum, only about $700 million would be spent on the wireless portion (licenses and radio transceivers), while switching equipment and marketing costs are the top two expense items. All potential entrants into the market are therefore planning to reduce their costs by utilizing their existing networks and marketing presence. Table 2-3 summarizes the roles of potential providers of PCS.

Local Exchange Carriers

PCS is a logical extension of services currently being provided by the LECs. Voice communications is still the line of business with which LECs are most comfortable. The sales force of the LEC is in place to reach the residential and small business user who is expected to be an early PCS adopter.

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[13] J.J. Keller and G. Naik, "New Wireless Phone Networks Take First Step Towards Reality," *The Wall Street Journal*, 23 September 1993, p. B1, B10.

TABLE 2-3

ROLES OF POTENTIAL PROVIDERS IN BUILDING PCS NETWORKS

	A	B	C	D	E	F	Switching Equipment
Local exchange carriers	New	Ex	Ex	Ex	Ex	Ex	Ex
Long distance carriers	New	Ls	Ls	Ls	Ex	Ex	Ex
Cellular carriers	New	Ls	Ex	Ls	Ls	Ls	Ex
Cable TV	New	Ex	Ex	Ls	Ls	Ls	New
New entrants	New	Ls	Ls	Ls	Ls	Ls	New
Low earth-orbiting satellites	New	New	New	Ls	n/a	Ls	New

Source: Authors' construct.

Key: New — This portion of the PCS network will be constructed as part of the provider's deployment of its PCS implementation.

Ex — The provider has this network component in place already.

Ls — The provider is likely to lease this network component, or to form alliances with other carriers who have this component available.

A-F — See Figure 2-2 and accompanying discussion.

LECs will have a number of advantages over their PCS competitors. The local loop owned by the LEC is well suited to provide the wireline connections between base stations and the PCS switch without new construction. The billing system operated by the LEC can be adapted easily to accommodate PCS. The LECs also have in place connections to the long distance carriers in the form of the intraLATA network.

In addition, the LECs are now in the process of deploying SS7 and connecting SS7 to the interexchange carriers' signaling systems. After an initial deployment of PCS services, the LECs should be in a very good position to begin full network integration between their PCS service and the landline network.

One test that includes pricing, a critical element in determining PCS marketability, is being conducted by Bell Atlantic Mobile. That company claims to have had the first test in the nation for a cellular-based "single number, single phone" communications service. The trial was a two-way test for people at home or in the office. The five hundred customers ranged from large corporate users to individual entrepreneurs, as well as a number of faculty, staff, and graduate students from Carnegie Mellon University. The expectation was to find out how customers responded to expanded communication opportunities including accessibility, call screening, and other features. Because the customers were paying for the service the company expected to learn much about demand for these types of services. Service pricing for the nine-month trial was:

Equipment leasing	$24.95
Personal line servicing	15.95
Advanced network functions	5.95
Total	$46.85

Bell Atlantic Mobile was not able to provide information regarding usage charges but specified that the usage charges were determined by the point of contact. For example, if the call went through the base station, then landline charges were incurred; if the call used cellular technology, cellular rates were charged.

Some of the findings of the initial nine-month test "demonstrate that personal and business life *can* and *will* remain separate—by user choice," reported the company.[14] There are also certain consumers and businesses who wanted instant reachability. The ease of use and the ability to "selectively control communication access" were key

[14] Bell Atlantic Mobile, "Individual Communications 'Future' Now in Test: 'Single Number, Single Phone' Service Being Tested in Pittsburgh," News Release, Bedminister, N.J., January 14, 1993; and Bell Atlantic Mobile, "Carnegie Mellon University Today Unveil Findings of Ground-Breaking Instant Accessibility Study," News Release, Bedminister, N.J., November 16, 1993.

features of the test. It was reported that due to the brief time they would have the phones, many of the customers were not willing to give out their numbers. Therefore the use of incoming calls was lower than it might have been. Bell Atlantic Mobile extended the test for an additional twelve months ending September of 1994.

Ameritech is undertaking a large public market trial in metropolitan Chicago. PCS base stations are directly connected to the landline network. The objectives of the trial are to understand the market for public PCS, including the relationship between price and service levels, to evaluate technical attributes of PCS, assess the role of the public switched network and determine conditions for successful spectrum sharing. A cross-section of the population was selected for participation in the trial. Contiguous areas of coverage were arranged to simulate ubiquity.[15]

Long Distance Carriers

The proposed merger of McCaw and AT&T has demonstrated most dramatically that a wireless "local loop" can be an attractive addition to an existing long distance network. We expect therefore to see the interexchange carriers bidding for PCS spectrum. As in the case of the LECs, the long distance carriers have the marketing, sales, and billing systems in place that are needed to approach the PCS market. The integration between interexchange networks and PCS cells provides a nationwide seamless infrastructure. Since the integration will involve a specific interexchange carrier, it is not as universal as a LEC could offer.

Interesting competitive situations will arise from the fact that the interexchange carrier will be carrying long distance traffic from all PCS providers and will possibly be asked to participate in the creation of fully integrated SS7 databases with other PCS providers.

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[15] Kenneth B. Hallman, "The Ameritech PCS Trial," National Communications Forum, Chicago, Ill., October 13, 1992.

It should also be noted that the interexchange carriers do not typically have access to a local landline infrastructure. In order to connect base stations, and to connect interexchange carrier "points of presence" to PCS switches and PCS switches to base stations, the interexchange carrier will probably need to lease lines from a local loop provider. While the local loop will not necessarily be controlled by a near-monopoly provider (that is, the LEC), *every* local loop provider is also a potential PCS competitor of the interexchange carrier. The potential for anticompetitive behavior by the local loop provider exists, as does the possibility of various strategic alliances.

Cellular Carriers

Of all potential PCS entrants, cellular carriers have the most experience with the wireless component of the new service. While they will need to install new transmitter sites like every other competitor, the cellular carriers have the expertise and engineering staff to handle the substantial problems encountered in providing high-quality wireless coverage.

Cellular carriers also have in place the billing systems needed to operate wireless services and have a sales force which is specialized in marketing wireless service. These carriers also have been able to accumulate experience with the modified central office switches, which are used to equip a mobile telecommunications switching office.

Cellular carriers will only be allowed to obtain a small spectrum allocation in their current service areas. They are, however, able to obtain the maximum spectrum allocation allowed by the FCC (40 MHz) in all other areas. Manufacturers have announced the development of dual-mode telephone sets which could function on both cellular and PCS frequencies. These mobile units would give the customer access to a network which, through a mixture of cellular and PCS networks operated by the same provider, would seem to be seamless over a large geographical area.

Like interexchange carriers, cellular carriers do not normally have a landline network in place to tie together PCS cells. This problem is much less severe in cellular service since current cell sites are so much larger and less numerous than PCS cells.

Consequently, the cellular carrier faces the same issues related to obtaining the landline connections from a local loop provider as were outlined above.

Many cellular carriers currently have an interconnected network architecture in place to provide roaming services. These same networks will initially support interconnection of PCS service areas. The cellular carriers have not made any significant advances towards integrated networks yet and will need to develop their strategies as competitive pressures require the deployment of network integration.

Centel Cellular Corporation and Motorola were conducting a test to assess the feasibility of replacing the final mile of copper to the home with a spectrally efficient high-speed, digital-backbone radio network that can provide voice, high-speed data, and interactive video service. The test was being conducted in Las Vegas as an alternative to fiber to the home or digitized copper. The long-term objective of Centel's research is tetherless communications in and out of buildings. The target cost is less than $1,000 per equivalent local loop. The focus was both residential and commercial and included data as well as voice communications.[16]

Cable TV

Cable TV companies are aggressively pursuing opportunities in the communications field. Next to the LECs, cable companies have installed the most ubiquitous local loop facilities. Planned upgrades to these facilities will make them capable of carrying two-way voice and data traffic of considerable volume. While some cable TV companies will focus on the delivery of video-on-demand, others will clearly begin to compete with the LECs in the local loop. Providing PCS services would be a good entré into this market.

Cable companies will face several challenges in providing PCS services. Their billing systems are not designed to provide the type of bills expected by residential or

[16] C. Fred Wright, "Centel Wireless in the Last Mile," Paper presented at National Communications Forum, Chicago, Ill., October 13, 1992.

business communications users. Their sales and service organizations are structured to sell and support entertainment rather than communications systems. The cable TV technical staff is not yet experienced in the areas of telephony, switching, or transmission systems. On the other hand, the existing infrastructure of the cable companies can be used to interconnect PCS base stations.

Cox Enterprises, Omnipoint, and Scientific Atlanta teamed together to demonstrate on February 12, 1992, that PCS, cable TV distribution plant, and the public switched network can be linked together. On that day a call was placed from a PCS phone in San Diego that went over the cable system to the public network and to the FCC offices in Washington, D.C. Cox has been granted a "pioneers preference" to explore the use of cable to tie together PCS microcells into a network. The FCC's pioneer preference rules permit preferential treatment in licensing for parties that develop significant communications services or technologies. The company's market tests have been in residential and light industrial zones of the San Diego area and have focused on cordless phone replacement, slow mobility, and high mobility.[17]

New Entrants

The reader will note that each segment of potential PCS providers introduced so far has at least some component of the PCS system in place. It would therefore seem that any completely new group entering the PCS arena will be at an initial disadvantage. Nevertheless, some openings will exist for these types of market entries. Circumstances which might promote a new entry include:

1. FCC regulatory steps: The most immediate example of regulatory intervention which will promote new entrants is the minority set-aside in the frequency auction, if the FCC decides to keep it.

[17] Rick Kimsey, Cox Cable, telephone conversation, May 9, 1994.

2. Failure of incumbents to act: If the embedded LEC and cable TV providers are slow to respond, openings will exist for independent entrants.

3. Technical expertise: The design and placement of PCS cells, especially the antenna systems, will be a very complex and technically demanding task. Since the spectrum auction order permits a fairly large number of market entries, it is possible that a new entrant into the market can compete on superior coverage, quality, and service.

4. Existing "right-of-way": While PCS does not, of course, require traditional right of way, groups which control large public gathering places may be successful in building small PCS "islands" as a starting point for broader coverage. Examples may be large shopping malls, railway stations, and airports.[18]

An independent PCS provider, American Personal Communications, in which the Washington Post Company owns a majority interest, received a temporary grant of a pioneer's preference from the FCC to explore the feasibility of telepoint service. They conducted a market trial of CT-2 using some 100 public base stations and 225 users in the Washington, D.C. area. Problems of radio frequency propagation and interference were explored in the trial. Further work was planned, including working with Bell Atlantic and interexchange carriers, to incorporate features of the advanced intelligent network into PCS tests.[19]

Low Earth-Orbiting Satellite Systems

Universal coverage will be the primary marketing feature promoted by the satellite PCS provider. Based on current projections, the cost of the user equipment and the per-minute cost for the service will be higher in a low earth-orbiting satellite system than in terrestrial PCS. In exchange for this surcharge, subscribers are assured that they can be reached anywhere and place calls from anywhere (except for the international

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[18] The NRRI is expected to publish a research report in 1995 on *Rights of Way Granted to Utilities: Who Owns Them? Who Can Use Them?*

[19] Albert Grimes, National Communications Forum, October 13, 1992.

issues of country by country operating permits), without being concerned about the operation or availability of local landline or PCS resources.

Conclusion

We have laid out some basic definitions and a generic architecture of PCS and discussed some of the contributions and leverage that might be exercised by potential players in the PCS game. Despite the widespread excitement over PCS, critical barriers stand in the way of widespread PCS deployment. Technical questions exist, such as what kinds of interference digital radio is likely to have if widely deployed or where to locate the radio receivers. How to create a seamless network, transparent to the user, needs to be worked out. These questions, as well as many about spectrum allocation and other radio-related issues, will not be dealt with in this report. But it is important to note, as we turn in the next chapter to interconnection issues, that much of the experimentation in PCS is still quite basic. Potential major participants in the development of PCS abound and their roles can be predicted, but the systems themselves, as well as the necessary business relationships, have yet to be put together.

CHAPTER 3

INTERCONNECTION ISSUES AND IMPLICATIONS FOR REGULATORS

Even though state regulators are not responsible for entry and rates of PCS providers, their role as regulators of the LECs means that they must pay careful attention to the interconnection arrangements that are developed for PCS providers. They should attempt to ensure that the terms of interconnection are fair to all parties and do not artificially inhibit the diffusion of PCS. Interconnection agreements can substantially affect the penetration rates of PCS over the next decade.

In this chapter we explore some of the implications for regulators of alternative evolutionary tracks that PCS might take. One central issue is access to and use of subscriber data. Integration of PCS databases and SS7 may be just as important to PCS as equal access provisions were for the "other common carriers" in the 1980s, or access to LEC central offices is now to alternative service providers. Another crucial issue is telephone numbers, a rapidly depleting resource. The chapter concludes with a brief discussion of two issues related to interconnection that should be noted—privacy and access to emergency services.

Access and Integration: Two Roads to Network Evolution

To achieve the promise of anywhere, anytime, truly personal communications would ultimately require a highly integrated, even "unified" network, not simply access to one or more landline networks from various wireless ones. Whether such a network arises of course depends on what customers demand but also on the incentives of the various players. From a systems engineering perspective, the landline network providers (LECs and interexchange carriers), have no real incentive to provide full network integration. There are costs involved in upgrading SS7 to support full integration of mobile systems. At the same time, the integrated network will always minimize the landline call costs of a given connection. Everything being equal the integrated network will select a "shorter" path to the mobile user than an interconnected network routing model. This is true because the integrated network can recognize "hairpin" connections, whereas the interconnected network cannot. In cases where superfluous connections are not present, the resulting routes will be identical in most cases, but the integrated network (which knows from the outset where the called party actually is) cannot create a "longer" path.

The actual cost for the call is also affected by the charges for database lookups, which are only present in the integrated network. From that perspective one might argue that these charges could in some cases outweigh the savings from selecting a "shorter" path.

Therefore, the implementation of an integrated network will reduce revenue for landline carriers. Unless compensatory arrangements are made, only PCS providers and subscribers have a desire to achieve network integration. They will see network integration as a competitive advantage. Since the LEC and one or more interexchange companies may also be PCS providers, other things being equal, network integration can become a tool for these carriers to obtain an advantage over other PCS providers. A conflict of interest is created in this situation.

Should a PCS provider be successful in achieving full integration with a landline network, while preventing other PCS competitors from doing the same, customers will perceive a significantly higher level of PCS service being provided by virtue of the tie-in with the integrated network. The ability of nonintegrated networks to compete will be severely degraded.

With appropriate interconnection and pricing policies, all parties might be winners in providing PCS. With a huge market to be tapped, nonLEC entrants to the wireless market could be successful and LEC revenues could grow, albeit at a slower rate than if they were able to use the full leverage of an integrated network. And since LECs are also allowed to provide PCS, revenue loss to a LEC on the landline side may be palatable if it is balanced by higher market penetration on the PCS side due to improved service provided by the integrated network. Under properly constructed rules, PCS competition should be a nonzero sum game.

To understand the evolutionary forces and choices at work in the development of PCS requires a more detailed description of the interfaces between PCS and the public switched network than was presented in Chapter 2. We mentioned there that the initial implementation of PCS will probably use a "minimal" approach towards network integration. The costs of building a PCS network are so high that each provider will attempt to start a useful system as quickly and inexpensively as possible, while still providing attractive services to the consumer. We therefore expect that each of the interfaces in Figure 2-2 will develop over time, starting from a simple interconnection design to a complex system of integrated networks.

It needs to be emphasized that the development of PCS and integration with the public switched network could prove to be a very involved process. Current cellular telephony systems, both in the United States and abroad, are *not* useful as models for PCS development in the area of network integration. The market penetration of cellular service is so small that they should be regarded as specialty, or "add-on," networks. Network integration in this case requires relatively modest resources when compared to the scale of the public switched (that is, landline) network.

Initially, PCS networks will clearly fall into the same category. However, if the goals of PCS providers—and the predictions of analysts—come true, the number of PCS users will eventually far exceed that of cellular users. Integration of PCS and the landline network will then no longer be a small addition to the requirements of the public switched network, but rather place a large additional demand on the public switched network systems.

If the development of PCS does indeed lead to an effort to integrate a large PCS network with the public switched network, it will be an undertaking without precedence. Recall that while the current public switched network consists of several very large integrated networks, it developed from a *single* network, rather than being created from independent ones. Even in this environment, which is much more conducive to cooperative designs and practices, complex network integration has been difficult to achieve, as witnessed by the deployment of SS7 and of integrated services digital networks (ISDN).

We now turn to a more detailed description of the interfaces between PCS and the public switched network in order to provide a deeper understanding of interconnection issues.

"Outbound" Calling from PCS Stations to Stations on Another System

The most basic interface required for all PCS systems is that which permits PCS subscribers to reach called parties outside the PCS system. This includes local calls to landline stations (or to subscribers of competing wireless systems), and all types of long distance calls (that is, to landline and to distant mobile subscribers). To fulfill these requirements, we expect PCS networks in their early phases to use trunk connections to the LEC class 4 and class 5 offices, similar to Type 1 and Type 2 cellular interconnections. In this way, the LEC switch can be used for those services the PCS provider is not yet able or willing to supply. Calls can be handed off with a minimum of routing decisions on the part of the PCS switch. A very small amount of signaling is required. As was the case with early cellular systems, long distance calls will be charged by the PCS provider who acts in effect as a reseller. This design further simplifies the signaling interface between the PCS and the public switched network, since the latter does not require any knowledge about the individual PCS users, nor does any billing information need to be passed from PCS to the landline network. This arrangement is illustrated in Figure 3-1. Once PCS passes beyond the initial deployment phase, however, decisions must be made as to how this interconnection should evolve. These choices will ultimately be made by the consumer and by the actions taken by regulators. Several possible models can be examined.

If PCS is considered an access service by the consumer, enhancements to network integration will be needed to give the user more control over the use of services outside PCS. For example, PCS users will wish to enter into their own agreements with long distance carriers, voice messaging providers, and electronic mail services. This

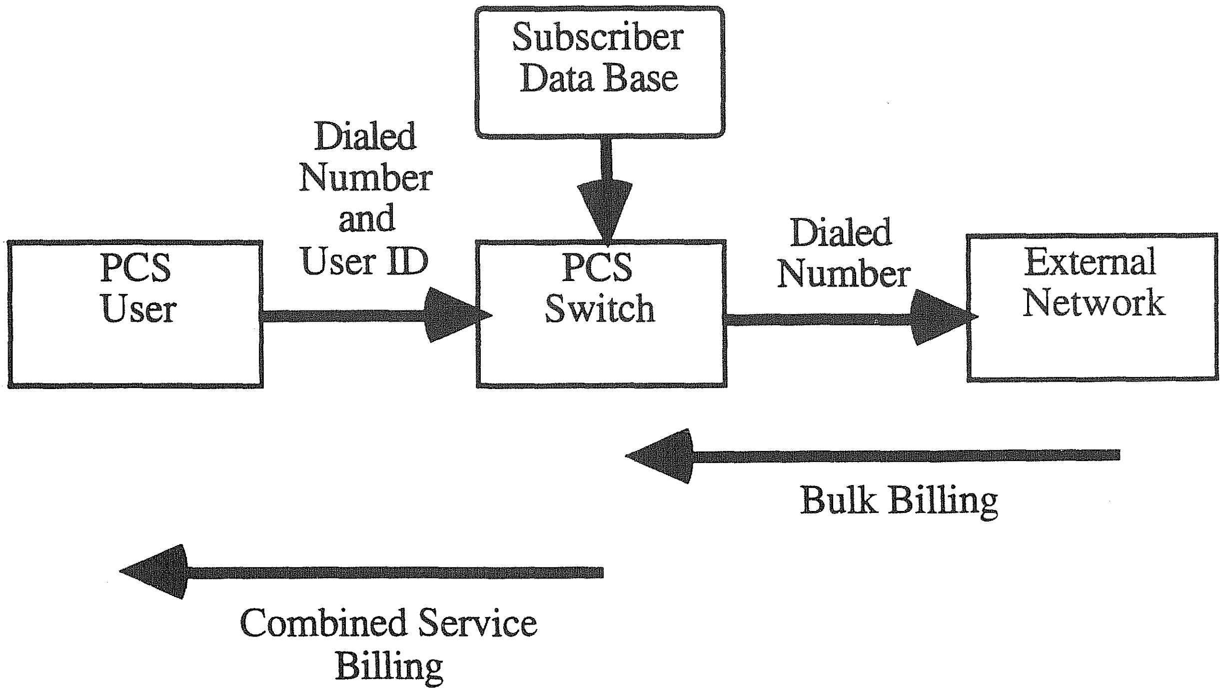

Figure 3-1. Early PCS interface with public switched network.
Source: Authors' construct.

development is somewhat analogous to the case of payphones or hotel telephone service. In each case, customers perceived these as access services and demanded full control over the way calls were handled once leaving the access system. This control was achieved through regulatory intervention. Figure 3-2 summarizes this arrangement.

The scenario we just described is of course at odds with the description of PCS as a "philosophy." PCS is envisioned by many as a way to reduce complexity, and to allow any two users to communicate while giving a minimum of thought to the facilities and contract arrangements required to do so. In some sense, this thinking mirrors the situation prior to divestiture, without the wireless component, of course. Figure 3-3 shows this configuration.

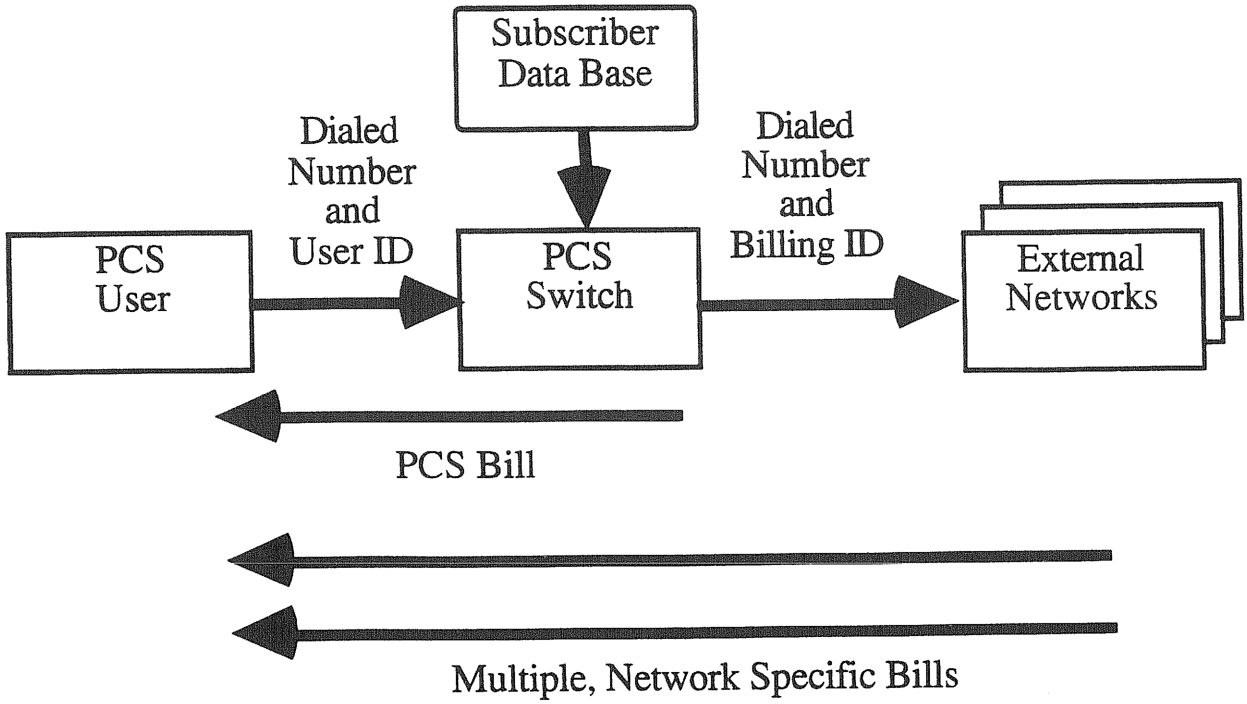

Figure 3-2. PCS as an access service.

Source: Authors' construct.

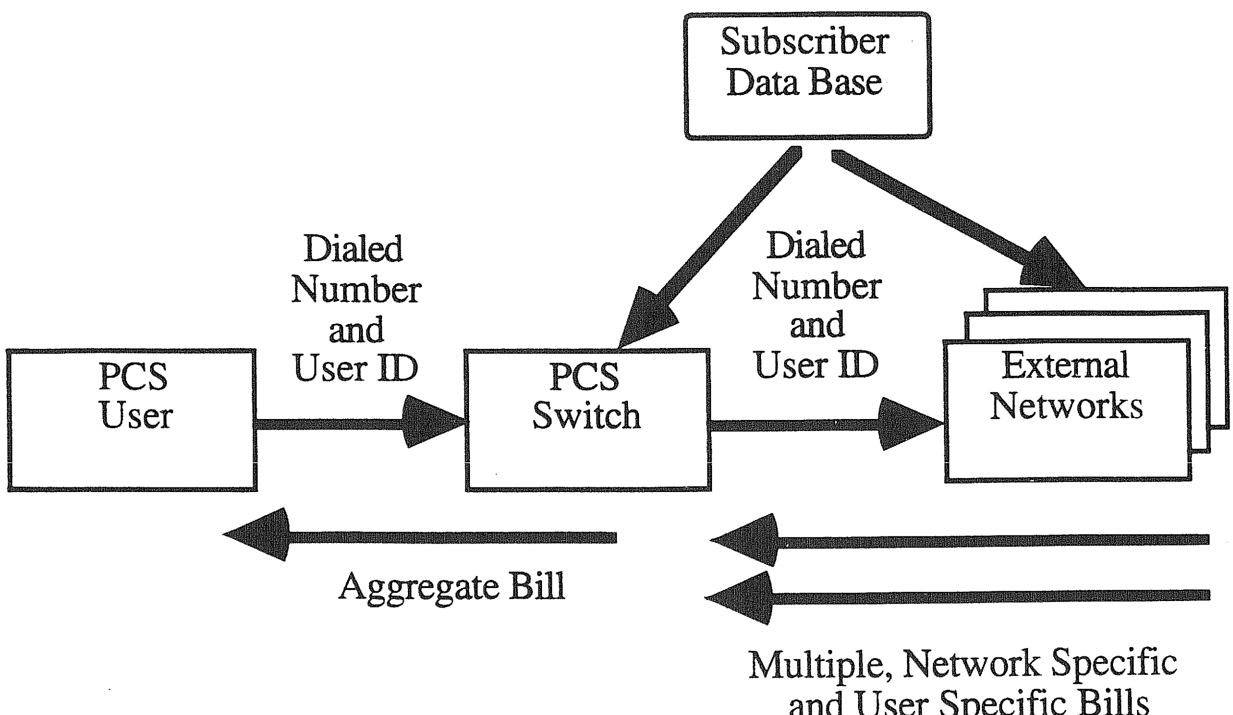

Figure 3-3. PCS as a service of a unified network.

Source: Authors' construct.

Should customers embrace this view of a unified network, the development of the interface between PCS and the public switched network will proceed in a somewhat different direction. Instead of passing billing and signaling information on to the secondary provider chosen by the user (by presubscription or on a call-by-call basis), the PCS system interprets the call placed by the user and any feature requests, and accesses the necessary services on behalf of the user. All billing to the user would appear to the user to originate from the PCS provider.

The differences in the two scenarios are profound in that they shape PCS into two very different services. Technical differences between the scenarios are not nearly as fundamental. The access service requires less "intelligence" on the part of the PCS switch than the unified network one, since service request interpretations will be made outside the PCS network.

Both scenarios require sophisticated signaling interfaces. The access service must pass on user and billing identifications to the next provider. In the unified network, specific service requests must be transmitted, even though the request does not need to identify the specific user for billing purposes. User identification may still need to be passed on if PCS is to participate in the advanced intelligent network (for example, to provider calling party identification). This is a feature a user would likely demand of a unified network.

In the two scenarios, user databases are located in different places. The access scenario requires that the PCS provider maintain a database for internal use, as well as information on the services to which the user has presubscribed. User information is also contained in user databases used by each service provider. Providing services associated with this scenario requires little coordination of the user databases, but their segregated design also makes any transition to a more integrated network difficult.

In order to provide unified network services, user data must be collected in a coordinated fashion. Each provider must maintain a portion of a collective database. (This database may be set up as a distributed system over many computer platforms, however.) In this way, the initial network provider, whether LEC, PCS, cellular, or other provider, has full access to all service parameters and can manage the call setup and billing in a transparent fashion.

Transport Between Cells or Switches Controlled by the PCS Provider

Figure 3-1 describes the equipment and connections within a contiguous area controlled by a single PCS provider. The same provider may control other sites not located near this one, or the provider may have cooperative agreements with other providers. To take advantage of this setup and provide the service demanded by customers, an additional interface is required. This interface takes care of conveying PCS database information between the PCS areas. Unless this link exists, PCS customers could not use their phones outside their own service area. In cellular service this is referred to as "roaming."

From the discussion in the previous section one can conclude that the intra-PCS interfaces are put in place to provide a portion of the functionality of the unified network. In particular, they provide collaborative database access across multiple PCS domains. Since networks outside the group of connected PCS systems have no awareness of the PCS database, "hairpin" connections like the ones discussed in Chapter 2 can occur whenever a non-PCS network is involved in completing the call. The PCS to PCS connection can, however, prevent the hairpin connection for calls among mobile stations.

To the extent that the access scenario develops, the PCS to PCS interconnections will be a necessity. If PCS moves towards the unified network scenario, these interconnections will be absorbed into the general database exchange mechanism.

"Inbound" Calling to a PCS Mobile Station

Unless a unified network is implemented, calls from a non-PCS to a PCS phone must be addressed using the routing known to the public switched network. One purpose for the North American Numbering Plan number assigned to each PCS user is to allow the public switched network to route calls for that user to the home PCS switch which "owns" the number. The other advantage of assigning numbering plan numbers is to maintain familiar dialing plans for all users, PCS or otherwise. The routing and billing algorithms within the PCS use an internal identification number associated with the PCS terminal or the "smart card" inserted by the user into the telephone instrument.

The interface between the landline network and the PCS network is a simple trunk group connection. While some additional features could be made available to the PCS user through additional signaling (such as calling party identification conducted by the advanced intelligent network), any real improvements in this area require network integration between the landline network and PCS. This integration would allow consistent feature sets for landline and PCS phones, such as call forwarding, and prevent the "hairpin" connections described earlier.

Two Models for Routing Calls Towards a Mobile Station

Our discussions of PCS architecture in Chapter 2 point to the routing model for calls towards mobile stations as a key element in determining the service levels provided to the PCS user. Figure 3-4 illustrates the existence of two distinct user databases in the current implementation of cellular systems and in the expected early stages of PCS deployment. Each PCS provider maintains a database of its subscribers. This contains billing information and is designed to maintain a record about the current location of the subscriber. The PCS database is designed around the concept of a location-independent personal identification number (PIN). The landline network maintains a database designed around port addresses (subscriber lines and trunks).[1] SS7 and the advanced intelligent network use this database to provide call handling and advanced services.

[1] This diagram does not show the fact that the public switched network is made up of multiple LEC and interexchange carrier networks. These networks do, however, use a common database mechanism through the definitions of billing systems and SS7 designed by Bellcore.

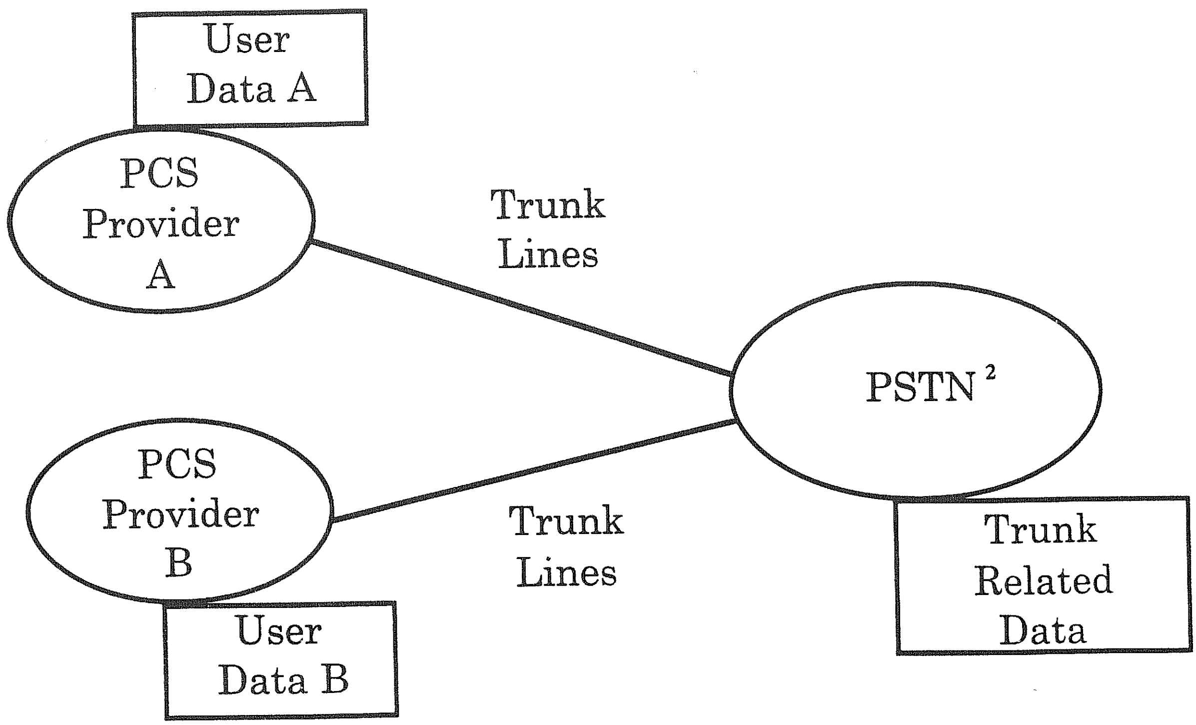

Figure 3-4. User databases in early PCS deployment.
Source: Authors' construct.

The current cellular system in the United States, like the European Global System for Mobile Communications, addresses the routing issue by connecting the various cellular providers' databases using leased landline facilities. A similar scheme has been advocated for PCS.[3] In other words, no integration of PCS and the public switched network databases is attempted in this approach. The services provided under this scheme are seamless, location-independent access to a PCS subscriber within the domain

[2] Public switched network or public switched telephone network.

[3] Homa, J. and S. Harris, "Intelligent Network Requirements for Personal Communications Services," *IEEE Communications Magazine* (1992): 70-76.

created by the connected PCS providers. The landline network is invoked to provide routing to trunk ports as needed, with the difficulties discussed above.

A second model provides a more complete approach that would integrate both the PCS and the landline (SS7) databases to provide full network integration.[4] In this approach, SS7 would be used to handle both its current tasks and updates of and access to the PCS user location database. The concept of PCS clearly assumes this level of integration, at least in the long run. On the other hand, a significant impact on the entire public switched telephone network will result from full PCS integration.

The technical discussions of SS7-based integration of wired and wireless networks tend to ignore one of the realities of the upcoming PCS deployment. The network providers who have to cooperate in the establishment of the integrated network will also be direct PCS competitors. Neither the SS7 deployment between LECs and interexchange carriers, nor the implementation of 800 number portability, had this feature. From a technical perspective, 800 number portability provides a good analogy to the integration of PCS. A central database provider must consolidate and update user information, and provide efficient access to the information during call setup.

The main difficulties anticipated in PCS integration would be the rate of database updates and the charges associated with access to databases. The content of the PCS subscriber database changes dynamically as the user enters and leaves cells. Since the PCS cells are small, each user can potentially create location data changes every few minutes. The amount of information to be processed in SS7 as a result of the movement of a large number of PCS users will be very large indeed. Further technical studies are needed before this integration can be attempted.

Given the frequency of database updates, the question of how to charge for the database service arises. Clearly, a charge for database lookup during call setup can be established. However, who pays for the database updates for a moving user who does not initiate a call? The framework for these database charges must be worked out very

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[4] Kripalani, A.T., "A Seamless and Smart Network is the Key to Great PCS," *Telephony* (1993): 24-29.

carefully, a process which is likely to be made much more complex by the competitive status of the negotiating parties.

Implications of the Two Models for Competition

If PCS evolves according to the access model, the concerns for regulators are clearcut and principles have already been articulated to deal with those concerns. The concepts of open network architecture and expanded interconnection can be applied to PCS just as to any other competitor of the LECs.

Open network architecture is a requirement of the FCC imposed on the regional Bell operating companies. The companies must unbundle their network so that competitors who must use the public switched network receive and pay for only those services which they want. Open network architecture and its applications have been addressed in several NRRI research reports.[5] Whether mandated unbundling is providing what competitors want is yet to be seen. A recent article in *Telecommunications Reports* stated that the Bell operating companies said they received few requests from enhanced service providers seeking open network architecture offerings. And progress was slow on making available services that had been considered infeasible or in need of further evaluation.[6] The lack of progress and continued Bell operating company control over critical services are cause for concern. If the overall paradigm of open network architecture is not working well, PCS providers may have difficulty purchasing packages of services tailored to their needs.

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[5] See most recently Bernt, Kruse, and Landsbergen, *The Impact of Alternative Technologies*, 102-105. See also Robert J. Graniere, *Implementation of Open Network Architecture: Development, Tensions, and Strategies* (Columbus, Ohio: NRRI, 1989); and John D. Borrows and Robert J. Graniere, *An Open Network Architecture Primer for State Regulators* (Columbus, Ohio: NRRI, 1991).

[6] "BOCs Sketch Plans in ONA Annual Reports for Services Based on Advanced Technologies," *Telecommunications Reports*, April 25, 1994.

Expanded interconnection gives LEC customers the opportunity to interconnect with the public switched network using their own equipment.[7] Both federal and state commissions have been exploring ways to do this and thus break up the LEC monopoly of facilities in the class 5 office that provides the means for connecting subscribers to each other. At the federal level the FCC has required the largest LECs to provide expanded interconnection for interstate special access services and switched transport services. The FCC attempted to open the LECs' central offices to physical colocation. This would have meant that a customer could lease space within a LEC's office, provide its own equipment, and connect to the network within the office, paying a connection charge to the LEC. The LECs challenged the FCC decisions in court, maintaining that physical colocation is an unconstitutional taking of property. A federal district court ruled June 10, 1994, for the LECs.[8] Among the states, the New York Public Service Commission moved aggressively to allow both trunkside and loopside interconnection to the class 5 office. The movement towards expanded interconnection opens the door to local competitors, such as PCS providers, who must connect to the landline network but will benefit from having choices in how to do so.

Interconnection issues for PCS all center around the routing databases (that is, SS7). Some of these issues have been addressed in enabling 800 portability:

1. Who maintains the database?
2. Who charges for and who pays for database changes?
3. Who charges for and who pays for database lookups?
4. Who regulates the charges being levied?

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[7] For discussion of expanded interconnection, see Bernt et al, *The Impact of Alternative Technologies*, 105-114.

[8] *Bell Atlantic Telephone Companies, et al.* v. *Federal Communications Commission, et al.* No. 92-1619, 1994 U.S. App. LEXIS 14191, at *15 (D.C. Cir. June 10, 1994).

The main difference for PCS is the fact that routing will change continuously as subscribers move about. This is a little like having subscribers change 800 number providers a few times per day. Also, PCS will require a database lookup to complete every call, which is similar to having to pay a database access charge for any time you make *any* call (not just 800). Questions regarding proper regulation of database access charges are therefore more central in this case.

Finally, the "best" structure for network interconnection is a distributed model where every provider (whether PCS, cellular, LEC, interexchange carrier, or other) maintains their portion of the database. In this case everyone will be charging everyone else for database access. The performance levels of the worst participant will define the performance of the entire public network. Clearly these issues will be of concern to regulators.

If PCS is to evolve towards an integrated network model, however, the guiding concepts do not yet exist. The conceptual and regulatory effort in recent years has gone into unbundling and opening up the network. The demands of an integrated network model for PCS suggest reengineering a seamless Humpty Dumpty while assuring that the gains in fairness of costing and access are not lost in the process. The communications industry is largely attempting to pursue the goals of transparency and seamlessness in a network of networks by themselves, with minimal government intervention. Whether they can succeed in this mammoth endeavor without appealing to authoritative outside decisions from the FCC or state regulators remains to be seen.

Number Availability and Distribution

The deployment of fax machines, pagers, and cellular phones has significantly increased the demand for telephone numbers. The deployment of PCS raises the issues of number availability and of fairness in the distribution of numbers. (Another numbering problem is portability, or the ability to carry a telephone number with you from one service provider to another. That issue will be discussed in Chapter 4.)

At present, the capacity of the North American Numbering Plan system is almost completely used. Pressure on the public switched network has been building for some time to expand the pool of available numbers. Table 3-1 below shows the effect of various technical changes to the pattern of numbers.

PCS will have two possible effects on number availability. On one hand, the PCS concept attempts to implement a "personal" addressing philosophy. In this approach, each network user has one unique address within the network. By comparison, currently four numbers on average are allocated per inhabitant of the United States. One might argue, therefore, that PCS has the potential to reduce the number of addresses needed. This would occur by eliminating the need to assign separate home, office, mobile, fax, and pager numbers to the typical office worker.

On the other hand, consumers are likely to view PCS as an "add-on" service. At least initially, few PCS users will be willing to give up their landline numbers unless pricing, coverage, quality, and convenience is equal to the landline network. Most families are likely to keep their landline telephone and add pocket telephones, just as is true for cellular now. Only some singles and the unusually footloose will totally give up wired service. If this analysis holds true, PCS users will demand additional numbers as they subscribe to PCS and significantly increase the stress on the numbering plan.

No data are available to make quantitative predictions regarding these competing trends. Speculation can be based on the experience gained with cellular networks and the way in which the FCC has decided to license PCS.

The PCS spectrum will be licensed using a large number of frequency blocks and market areas. The intent of the licensing rules is to allow a sufficient number of entrants into the PCS market so that a competitive environment can develop. This approach is likely to create an initial saturation of markets with multiple providers in urban areas and "niche" PCS services in rural areas. At this early stage, PCS will be offered as a "low-cost cellular" service to potential users who want mobility but do not require the ability to communicate from moving vehicles. Some users may be willing to give up cellular service or pagers at that time.

TABLE 3-1

AVAILABILITY OF TELEPHONE NUMBERS IN NORTH AMERICA

	Numbering Plan Areas (NPAs)	Number of NXXs	Stations	Total (Millions)	Numbers Per person (U.S. and Canada)
Maximum possible	1,000	1,000	10,000	10,000	33.7
Original plan (NPA-NNX[9])	128	640	10,000	819	2.8
Currently active numbers	144	800	10,000	1,152	3.9
As of Jan. 1, 1995 (Any digit in the second position of the NPA)	800	800	10,000	6,400	21.5

Source: Authors' construct.

Only after initial market penetration has been achieved will consolidation take place. Alliances and mergers will reduce the number of PCS providers and create large, interconnected or integrated service areas. This process must be well advanced before a significant number of users will switch to PCS as their primary telephone service.

It would be prudent to assume that appreciable market penetration by PCS will occur without any decrease in the demand for landline telephone numbers. And any decrease in the number of cellular phones and pagers will be minimal.

It appears from the analysis of the technical changes currently underway that there will be ample numbers available to satisfy the deployment of PCS. (Table 3-1

[9] N equals any of the eight numerical values two through nine. X equals any of the ten numerical values zero through nine.

indicates an over five-fold increase in available numbers, there will be over twenty numbers per person available.) Problems may still arise in both privately owned and carrier-owned equipment, since the deployment of PCS will increase the rate at which new area codes need to be introduced. This more rapid increase in the total number of active network addresses will require a commensurate upgrade of the capacity and performance of the routing databases in all switching equipment.

The prospect remains that very extensive and costly upgrades to the nation's telephone system will be required to allow PCS to develop to its full potential, only to have successful PCS reduce the number of addresses needed after the expansion of the numbering plan is complete.

Possible Side-Effects of PCS Deployment

The transition to PCS from an entirely landline based system creates a number of side effects. Pierce points out that enhanced 911 services are based on locating the origin of emergency calls through the use of automatic number identification, an approach which is useless for PCS numbers.[10] Enhanced 911 databases and procedures assume that the location of each number remains unchanged. Further, PCS has serious implications for individual privacy. Not only is PCS at least in principle vulnerable to interception of conversations, but the size of the microcells creates a new category of information about a user. The PCS provider will be able to determine the location of a user within a fairly small area even with the currently envisioned technology. Fairly simple upgrades could possibly allow locating a phone user to within a few meters. Use and abuse of that information can create issues of a scope not unlike caller identification.

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[10] Pierce, G.J., "Calling for a PCN Emergency Services Standard," in *Telephony* (1992): 22, 24.

Enhanced 911 Systems

While PCS offers a future where emergency calls can be placed much more readily (based on the assumption that an increasing number of people will be carrying PCS phones), it also puts emergency dispatchers back into the position of having to rely solely on the caller for information needed to locate the site of the emergency. The situation is further complicated by the fact that callers are most likely to use their PCS phones while they are away from familiar areas like the home or workplace and often may be unable to provide good information on where they are.

A possible improvement of the situation would be the addition of a cell site identifier in the information automatically identifying a number that is passed to the enhanced 911 system. There is currently no provision for doing that; indeed, many cellular systems do not provide automatic number identification. For example, in high-density areas like malls and airports, each cell is small (50 to 150 feet in diameter) and the cell identifier alone can sufficiently localize the caller. In other areas cells can be much larger, and further localization of callers may be desirable. The same technologies used to control cell-to-cell handoff could be used to accomplish this goal. By measuring the signal strength at several cell base sites (which is needed to decide when and how a handoff should take place), a "triangulation" process could be used to determine the location of the caller with sufficient precision for the 911 application, as well as other services like dispatching and tracking of vehicles in commercial fleets.

Privacy Issues

We have discussed the need to provide automatic number identification information, including accurate location information, for PCS emergency calls. The technology to obtain this information exists. It seems unlikely, however, that PCS providers would invest in the additional equipment and software solely for the purpose of improving 911 services. Indeed, Pierce points out in his article that commercial applications exist for the PCS locator function.[11]

Tracking the location of a PCS mobile unit is possible as long as the unit is at least in "standby" mode, that is, ready to receive a call. It is not necessary that a call be in progress. That means that a user, by preparing to place or receive a call, will reveal his or her physical location. In the absence of legal barriers, this information could be provided to interested parties for their use.

For example, in theory a store in a mall covered by PCS cells could obtain information on the presence and location of potential customers by tracking all active PCS phones (and their owners) in the mall. Retailers could place telemarketing calls specifically to customers in the vicinity of their stores.

As with the caller identification option in the LEC networks, substantial privacy issues need to be explored in this context. The caller identification controversy centers around the question of whether a caller, by placing a call, gives up the right to keep his or her phone number private. With a "PCS locator" function, a similar question is raised. By turning on the phone (in order either to place or receive calls), is the PCS user compelled to reveal their physical whereabouts to any interested party?

Lawmakers and regulators will need to decide how far commercial use of this capability will be allowed to go. In this context we want to reiterate that the provision of Enhanced 911 and the commercial use of the same technical capability are connected. PCS providers will expect compensation for implementing a locator function, either through direct fees for enhanced 911, or by being permitted to use the technology for commercial services.

As was the case with caller identification, regulation could take a "middle ground." It could permit a PCS locator function but also allow a user to block the transmission of this information beyond the PCS mobile service office (except in the case of 911). Clearly, these safeguards will place additional demands on the content of the SS7

[11] Pierce, "Calling for a PCN Emergency Services Standard."

databases, since information regarding "location blocking" would now have to be stored for each PCS subscriber.

Even a cursory look at the privacy issues raised by PCS introduces far more questions than can be answered in this report. Here is a group of technologies that generates more information about users than wireline service or existing cellular. Yet customers may not be aware of the implications of the information-intensive nature of PCS. "Far from the tetherless image presented by the industry,... PCS can act as a virtual leash that each customer will constantly wear around his/her wrist or neck."[12]

A recent NRRI research report dealt with some of the issues raised by the commercial value of information that utilities can generate about customers. Thirty-seven public utility commissions had dealt with privacy implications in the context of caller identification, according to that report. Caller identification is only the first round in grappling with privacy issues for new telecommunications services.[13] That the states are ahead of the federal government in this area suggests the importance of state-level action for consumer protection despite pressures to preempt much state authority for PCS.

The most insidious, pervasive and complete destruction of privacy, however, derives not from what telecommunications providers do to wireless customers but what people do to themselves. A recent *New York Times* editorial presented "a glimpse at the end of solitude, of the time in the not-so-distant future when portable phones, pagers, and data transmission devices of every sort keep us terminally in touch, permanently patched into the grid... Why the rush to put every man, woman, and child on an electronic leash?"[14]

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[12] Charlotte F. TerKeurst and Roopali Mukherjee, "Review of Draft Report *Competition and Interconnection: The Case of Personal Communications Services*," unpublished memorandum, June 7, 1994.

[13] Robert E. Burns, Rohan Samarajiva, and Roopali Mukherjee, *Utility Customer Information: Privacy and Competitive Implications*, (Columbus, Ohio: NRRI, 1992), iv.

[14] "The End of Solitude: Thoreau Says 'No' to Beeper Bondage," *New York Times*, June 14, 1994, A14.

The simplest way to avoid being even more constantly at the mercy of the telephone than you already are is to stifle the urge to buy a wireless one, or, if you have one, to turn it off except when you really must be in touch. But PCS holds the promise of becoming a basic service, or at least the only telephone service of choice for a significant portion of the population. With a communications infrastructure evolving in this direction it would be a poor public policy choice to allow nonparticipation to be the primary means to assure privacy. Instead, policy makers should address protection of customer privacy early in the deployment of PCS.

Conclusion

Exactly how PCS develops remains to be seen and depends in large part on its appeal to potential customers. State regulatory commissions have a responsibility to assure that interconnection agreements do not stand in the way of the evolution of PCS, either through an access model of interconnection or an integrated network model that requires sacrifice of control and revenues by the existing landline providers. We have explored the implications of these two quite different models and, in addition, outlined possible enhanced features and the potential barriers that can be created by those who control the databases of the advanced intelligent network.

How a unified network might emerge and the implications for regulators is a question worth asking. An integrated, national PCS network would confer enormous advantages in the marketplace for a provider who was able to put it together. But such a provider may be deterred from creating the system in a regulatory climate that requires full reciprocity: Immediately after the provider had spent the money to build such a unified network, all other providers would be demanding access. And there might go the market advantage for the originator. We can envision a scenario where all providers hang back, jockeying for position on interconnection arrangements, then suddenly one party sprints for the unified network, quickly followed by others. The provider that breaks rank could be the LEC, although this would be in part a defensive move. Or it could be the result of an alliance between a cellular company and an interexchange carrier, like AT&T and McCaw. Or it could be a combination not yet thought of. Even a brief attempt to imagine one scenario for evolution of PCS points up the challenge faced by the FCC in crafting an initial regulatory framework that both aggressively promotes the development of viable competition for PCS and paves the way for achievement of the tremendous public benefits that a unified PCS network can offer.

CHAPTER 4

THE ECONOMICS OF PCS

How much interest regulators need to take of PCS is largely driven by how big the PCS market proves to be, how fast it develops, and whether regulatory commissions need to take any steps to remove barriers to competition. Major realignments of capital resources are occurring. Telephone companies are entering the cable television industry either through acquisition or separate subsidiaries. Cellular companies have been acquired by interexchange carriers. Cable companies are experimenting in the telecommunications business as alternative access providers. Such strategic realignments of major players in telecommunications and digital carriage suggests that sufficient capital may be available to deploy networks to provide integrated telephone, video, and information services. PCS is just one piece in this complex puzzle. What regulatory and technical changes may be needed to make PCS fit in as a viable piece? A careful review of existing studies of PCS suggests that the market will be sizable but the timing of development is in doubt. As PCS evolves, regulators will need to consider tariff mechanisms that send correct signals on the price of PCS compared to landline services. But speculation based on the normal sales pattern of a new product over time suggests that regulators would do well to refrain from premature intervention in the face of what will probably be a period of unsettling competition in the PCS market that may affect basic services of the regulated LECs.

In this chapter we analyze supply and demand for PCS and identify regulatory factors that may facilitate the development of a competitive market for PCS and local exchange services in general. First, we summarize two demand studies to investigate the potential market for PCS offerings. Second, we critique a cost study that estimates the first cost of deploying a PCS network. Third, we discuss the viability of a competitive PCS market and suggest several changes that would give a fairer chance at successful entry.

Demand for PCS

Two studies about the demand for PCS were available to the NRRI. One was conducted by A. D. Little; the other, by Telocator.[1] The two studies provide different perspectives on the market potential for PCS. The A. D. Little study focused on the demographic profile of the potential residential market. The Telocator study employed a broader definition of PCS and focused on the service offerings that may constitute the business and residential market. The NRRI did not have sufficient information to critique the methods and execution of the two studies, so the discussion here is primarily descriptive.

The A. D. Little Study

A. D. Little conducted a national survey in 1990 and followed up with a series of focus groups and research sessions in 1990 and 1991 to assess consumer interest in PCS. The study has been widely cited, perhaps largely because of its large market projection for PCS. The technique used was discrete-choice analysis. The hypothetical PCS offering was described as a cordless telephone service with a handset the size of a pocket calculator that would place and receive calls anywhere in the United States so long as the user was moving at less than twenty miles per hour. This service was described as priced lower than cellular service. The A. D. Little survey concluded that:

> ... the addressable market for PCS will be approximately half (about 47 million) of all U.S. households during the first ten years of *full availability*[2] and that 15 percent (14 million) of U.S. households would purchase such service if offered in the first three to five years.[3]

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[1] Telocator has since been renamed the Personal Communications Industry Association.

[2] Emphasis added.

[3] Barry E. Goodstadt, "Personal Communications Service in the United States," July 17, 1991, 27-2.

The report on the survey by Barry E. Goodstadt says that the results may be, if anything, understated because multiple purchases by single households are not considered and business purchases were not included in the sample. The estimated annual revenue potential from the PCS market is $30 to $40 billion once basic wireless communications is available in all U.S. geographic areas. This estimated revenue is approximately half of the current revenues of all LECs combined.[4]

Thus, the A. D. Little study anticipates a lucrative market for vendors of PCS equipment and PCS licensees. However, the estimates assume PCS signals are ubiquitous, and the projection of 47 million households within ten years of ubiquity is dependent on this assumption. How such an assumption and rate of diffusion for PCS are formulated is not explained in the information available to the NRRI, except that the figure on revenues assumes one subscriber per household. This information is not without importance. The time it takes to deploy PCS networks and the rate of diffusion are going to drive pricing and competitive issues confronting public utility commissions and company decision makers.

Although the A. D. Little study does not directly address business's demand for PCS applications, some observations concerning the market potential are offered. Goodstadt notes:

> ... unlike the market for cellular service, the market for off-site PCS is largely residential, although approximately 21 percent of all employees who work in critical job functions (executives, sales, technical/professional) and who spend eight hours or more per week away from the office will form a separate business market. This segment will constitute 20-25 percent of the PCS market.[5]

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[4] Goodstadt, "Survey of User Interest," 27-1.

[5] Ibid. 27-2.

This demand coupled with other business applications may drive the initial introduction of PCS. One might imagine PCS providers initially offering services such as private-office based systems and wireless PBXs. This market may identify prime areas for residential service that PCS providers may target for initial construction of facilities. The Telocator demand study, discussed below, gives more insight into the initial market for business applications.

The unique contribution of the A. D. Little study is the demographic profile of the potential residential market. First, interest in PCS offerings is "heavily correlated with the number of times per month respondents received calls rather than with the number of calls made."[6] Second, the information collected by A. D. Little allowed Goodstadt to create a profile of potential users by age, occupation, and income. Goodstadt characterizes "likely PCS buyers as having a typical new, high-tech product adopter profile."[7] That is, they would tend to be young, single, high income, and have attended some college. Men would be more likely to buy PCS than women. The age distribution data are presented in Table 4-1. This initial snapshot of the long-run penetration that is possible by age group may be expected to change as buyers and possible buyers gain experience, imitators move from the possible buyers category to the buyers category, and nonbuyers migrate to the buyers and possible buyers categories. This initial view, however, suggests target markets for PCS providers.

Unlike the information on age, the information on possible penetration by income does not lend itself readily to tabular form. Not surprisingly, penetration for people with incomes of $40,000 or over exceeds the penetration for people with incomes under $40,000 in the buyer and possible buyers categories. Goodstadt says that the survey results suggest people with incomes of $35,000 and over are more likely to buy PCS offerings.[8]

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[6] Goodstadt, "Survey of User Interest," 27-3.

[7] Ibid. 27-2.

[8] Ibid. 27-3.

TABLE 4-1

AGE DISTRIBUTION OF POSSIBLE PCS PENETRATION

Age Group	Buyers (percentage)	Possible Buyers (percentage)	Nonbuyers (percentage)
Under 35 years	19	43	38
34 to 44 years	16	39	45
45 to 54 years	12	32	56
Over 55 years	9	28	63

Source: Goodstadt, "Survey of User Interest," 27-4. The rows add to 100 percent.

The information on occupation presents the percentage of penetration for cellular, paging, and by occupation. The occupational groups are executive/manager, professional/technical, sales, administrative, protective, craft, and transportation. While exact numbers cannot be inferred from the graphical summation of the information in Goodstadt's report, paging is the most popular option for all occupational groups except administrative. For administrative, cellular is the most popular product option followed by PCS. As for the ranking of cellular and PCS for the other occupational groups, the demand for cellular exceeds that for PCS for the sales and transportation groups. PCS penetration is estimated to exceed that for cellular for the executive/manager, professional/technical, protective, and craft groups. Goodstadt suggests that PCS will appeal to a broader range of buyers than cellular which has depended on white-collar subscribers with annual incomes in excess of $50,000.

While the A. D. Little study provides a broad demographic profile of a PCS market of the future, timeframes seem to be mixed in the study. The forecasts of high penetration rates assume penetration occurs after *full availability* of PCS facilities. The demographic information, however, captures consumers' inclination to buy PCS offerings given their mind set in 1990 and 1991. What effect this has on the actual take rates as

PCS becomes available and finally achieves full availability will require close market monitoring by PCS providers in the future in order to match facilities to demand.

The Telocator study has a shorter timeframe and focuses on the service offerings that will constitute the business and residential market for PCS. This study may provide better insight into the initial phase of PCS introduction.

The Telocator Study

The Telocator study was conducted by the Customer Requirements Subcommittee of Telocator's Marketing and Consumer Affairs Committee, and the results were published in May 1992. The Telocator definition of PCS service offerings seems to be broader than that of the A. D. Little study. They define PCS as a broad range of individualized telecommunications services that enable people or devices to communicate independent of location.[9] Their definition encompasses both private and public systems. Private systems may or may not be interconnected with the public switched network. We will exclude from our discussion of the Telocator demand estimates those services that are clearly private and would not interconnect with the public switched network. This means there are six actual or potential offerings for which the Telocator study provides demand estimates.

Each of the six services is viewed by Telocator as existing or emerging. Existing services are paging, cordless phone, and cellular. The remaining services are considered emerging. Emerging PCS services are not offered today but are expected to provide new combinations of capabilities. Each of these emerging services requires some description, which is provided in Table 4-2. Of the four definitions, "personal telecommunications service" is closest to the A.D. Little definition of PCS and the idea of the "anywhere, anytime" pocket telephone.

[9] Telocator Service Description Subcommittee, Marketing and Consumer Affairs Committee, "PCS Service Descriptions," September 22, 1992.

TABLE 4-2
TELOCATOR DESCRIPTION OF EMERGING PCS SERVICES

Service	Description
Telepoint	A relatively low-functionality PCS. Telepoint would provide medium-to-high quality voice and low-speed data communications, similar to today's landline network. It would provide call origination only from a personal device to other devices or locations. System-specific enhanced services would be limited. The coverage provided by the telepoint system would be limited to discrete locations. Hand-off between base stations would not be provided. When placing a call, user mobility would be restricted to the coverage area provided by a single base station. Handsets are expected to be relatively small, light-weight (less than seven ounces), and low cost.
Advanced Telepoint	A medium-functionality PCS. Similar to telepoint, advanced telepoint would provide high-quality voice and low-speed data communications (but probably faster than telepoint). Unlike telepoint, advanced telepoint would provide call origination and termination from and to a personal device to other devices or locations. Network-specific enhanced services would be offered. Although the coverage provided by the advanced telepoint system would also be limited to discrete locations, it is expected to be deployed more broadly than telepoint. Hand-off between base stations would be provided. When offered to closed user groups (for example, residences or private businesses), such a service would be described as advanced cordless/wireless business (in some applications this could be referred to as a "wireless loop"). Hand-off between a private network and a public network would be possible, but not required. User mobility would be greater than telepoint, but would not be as ubiquitous or mobile as enhanced cellular, or personal telecommunications service. Handsets are expected to be similar in size and weight to telepoint.

TABLE 4-2
TELECATOR DESCRIPTION OF EMERGING PCS SERVICES (Continued)

Service	Description
Personal Telecommunications Service	A high-functionality PCS. Personal telecommunications service would provide high-quality voice. Unlike advanced telepoint, it would provide medium-speed data communications. Personal telecommunications service would provide call origination and termination from a personal device to other devices or locations. Network-specific enhanced services would be offered. The coverage provided by the personal telecommunications service network would be ubiquitous within a defined service area—local, wide-area, regional, and national. Hand-off between base stations would be provided. When offered to closed user groups (for example, residence or private businesses), such a service would be described as another type of advanced cordless/wireless business service. Hand-off between a private network and a public network would be possible but not required. User mobility would be greater than advanced telepoint and similar to enhanced cellular. Handsets are expected to be similar in size and weight to telepoint and enhanced cellular.
Advanced Cordless/Wireless Business	A medium-functionality PCS that will be offered to closed user groups or used as part of an internal communications system. Advanced cordless/wireless business would provide high-quality voice and medium-speed data communications. Advanced cordless/wireless business would provide call origination and termination from a personal or shared device to other devices or locations. Enhanced services provided as part of the internal communications would be available. Coverage would be limited to defined service areas, typically within buildings or on campuses or neighborhoods. In addition, coverage might be extended or integrated with a public network such as advanced telepoint, enhanced cellular, or personal telecommunications service. Hand-off between base stations would be provided. Hand-off between a private network and a public network would be possible, but not required. User mobility would be greater than landline or cordless. Handsets are expected to be similar in size and weight to telepoint, advanced telepoint, enhanced cellular, and personal telecommunications service.

Source: Telocator, "PCS Service Descriptions." (Shaded area is what is referred to in this report as "true PCS.")

Demand was estimated through the Delphi technique,[10] and the subjects were Telocator's PCS Section membership. Respondents to their survey were network providers and manufacturers of customer premises equipment, LECs, and cellular carriers, research organizations, and entrepreneurs. Telocator said, "In many cases, members provided results of internal primary research conducted by their respective companies as a basis for their response, in other cases, internal estimates were offered."[11]

The respondents were asked to estimate penetration of the services for 1997 and 2002 considering both price and cross-elasticity between and among services. They were further instructed to provide separate estimates for two possible periods of FCC licensing—1994 and 1997. The results for these two time periods are presented in Tables 4-3 and 4-4, respectively. These two tables contain estimates of penetration and price-range estimates for customer premises equipment and monthly service charges.

The projections are eight-year estimates of the PCS markets. The estimated penetration for PCS is 3.55 percent in three years and 8.75 percent in eight years. The customer premises equipment and service charge price estimates underlying these PCS penetration rates are relatively stable. The price estimates for 2002 have a larger range than for 1997, reflecting the greater uncertainty that far in the future. What is clear is that the upper part of the range is unlikely to increase, but price reductions are possible if not necessary.

When one compares the information in Table 4-4 to that in Table 4-3, the effects of licensing delays are apparent. The penetration rates for existing services are higher and for emerging service somewhat lower. What is interesting is that a three-year delay in licensing reduces personal telecommunications services penetration in year 2002 by only .79 percent on average. The real impact of delay would be in terms of prices of customer premises equipment and service charges. Telocator's PCS members are

[10] The Delphi technique reports the average response from a panel of experts after deleting the highest and lowest estimates.

[11] Telocator PCS Demand Forecast, 3.

TABLE 4-3

TELOCATOR PCS MARKET FORECAST ASSUMING LICENSING IN 1994

PCS Offering	1991 Existing Size Estimate	Year 1997 Market Forecast			Year 2002 Market Forecast		
		Penetration Percentage	CPE Price Range	Monthly Service Charge Range	Penetration Percentage	CPE Price Range	Monthly Service Charge Range
Paging	4.5	6.3	$75-$100	$8-$15	8.13	$45-$79	$7-$15
Cordless Phone	14.3	17.83	$75-$100	NA	20.83	$50-$75	NA
Telepoint/Advanced Telepoint	NA	2.14	$159-$250	$20-$29	5.43	$75-$150	$15-$28
Cellular/Advanced Cellular	2.5	8.31	$200-$600	$62-$85	12.43	$150-$300	$50-$7
Personal Telecommunications Services	NA	3.55	$175-$300	$35-$65	8.75	$100-$300	$30-$65
Advanced Cordless/Wireless Business	NA	3.11	$150-$450	$0-$55	5.71	$99-$400	$0-$50

Source: Telocator PCS Demand Forecast.

TABLE 4-4

TELOCATOR PCS MARKET FORECAST ASSUMING LICENSING IN 1997

PCS Offering	1991 Existing Market Size	Year 1997 Market Forecast			Year 2002 Market Forecast		
		Penetration Percentage	CPE Price Range	Monthly Service Charge Range	Penetration Percentage	CPE Price Range	Monthly Service Charge Range
Paging	4.5	6.85	$65-$109	$8-$15	9.04	$40-$79	$6-$15
Cordless Phone	14.3	20.00	$75-$85	NA	23.67	$50-$75	NA
Telepoint/Advanced Telepoint	NA	.56	$200-$249	$25-$30	2.64	$99-$200	$20-$25
Cellular/Advanced Cellular	2.5	9.06	$200-$600	$60-$85	13.26	$150-$400	$40-$75
Personal Telecommunications Services	NA	.17	$250-$500	$20-$42	7.96	$125-$350	$35-$65
Advanced Cordless/ Wireless Business	NA	.56	$100-$500	$0-$50	5.67	$100-$400	$0-$50

Source: Telocator PCS Demand Forecast.

projecting that both the average and range for price and service charges for customer-owned equipment would increase. The range increase is most likely due to increased uncertainty, while the average increases are due to the delay in bringing products to the market.

The concern about a delay in the FCC licensing of PCS service offerings is a practical one. As discussed further in Chapter 5, the FCC faces a complex and massive competitive bidding procedure. As of mid-1994 auctions before early 1995 seemed unlikely. When the difficulties in initial auctioning are coupled with delays caused by petitions for reconsideration, licensing may well be incomplete by 1997.

Summary: Demand Studies

The two demand studies differed in focus and methods, making direct comparison difficult. A few general observations are, however, possible. First, the A. D. Little study information may be contained in the Telocator study as a data point since the company is a member of Telocator's PCS section. Second, it is not clear from the information available how to reconcile Telocator's definitions of service offerings with those of A. D. Little. The A. D. Little study estimates a 15 percent penetration rate in three to five years, while Telocator estimates 8 percent to 8.75 percent penetration in five to eight years. These magnitudes of difference are significant. The differences may lie in the service definitions and service offerings described in the A. D. Little study. Furthermore, it is not clear what role is played by the handset price and service charge variables in the A. D. Little study. Both demand studies do demonstrate a potentially viable market for PCS service and equipment. It should be noted that neither of these studies seem to address the mature market level for PCS services. It should also be noted that, given the timing of the demand studies, they may not have accurately accounted for the effect of health concerns that consumers may have about cellular telephones and their PCS cousins. Fears that heavy cellular phone use might contribute to some cases of brain cancer surfaced early in 1993. Existing research does not support those concerns but that research is inconclusive.[12]

The Costs of Providing PCS

Putting It All Together: The Cost Structure of Personal Communications Services,[13] is a seminal study by David P. Reed of the Office of Plans and Policy at the FCC. Reed's main conclusions are:

1. The capital costs of a PCS network, including the handset, in a new residential area would be $703 per subscriber, assuming a base case of 25 MHz allocation size and 10 percent household rate of penetration.

2. The total annualized costs of operating this PCS network would be $546 per subscriber for these base case assumptions, with infrastructure costs accounting for 25 percent of the total.[14]

In Chapter 2 we sketched out a generic architecture for PCS and the probable form of participation for different PCS providers in various portions of the network. Reed's model computes actual costs for construction of pieces of a PCS network. Reed uses an engineering-process model to generate data in support of his conclusions and addresses issues of economies of scope and scale. The scope issues are pertinent to state regulatory authorities as participation by local exchange, cellular, and cable companies becomes a reality and may affect the viability of future potential competition in the local loop. At the outset, however, it should be recognized that economists do not generally

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[12] Natalie Angier, "Cellular Phone Scare Discounted," *New York Times*, February 2, 1993, B5.

[13] David P. Reed, *Putting It All Together: The Cost Structure of Personal Communications Services* (Washington, DC: FCC, 1993). The reader interested in the details of the study should request OPP Working Paper No. 28. A detailed presentation of the model and complete results of the study goes beyond the scope of this report.

[14] Ibid. vi.

accept the use of engineering-process models to assess issues of economies of scope and scale. The primary reason for this is that engineering process models assume a fixed technology when investigating scope and scale. In reality, however, a variety of approaches to the technology of PCS will be tried. Consequently, Reed's results should be viewed as suggestive of the general trend of economies of scope but not in any sense the absolute magnitude. The purpose of this section is to present his general results with regard to economies of scope and to critique those results in light of the increased network externalities that wireless communications foster.

Results for Economies of Scope

Reed's model computes the costs of providing PCS to 25,600 subscribers with 10 percent penetration (a total of 2,560 subscribers) located in a 13.5 square-mile area of 160 homes on each side of the square. Four primary cost estimates are computed to assess economies of scope. First is a stand-alone cost for a *de novo* entrant who must construct the entire network, according to Reed's assumptions. The remaining three cost estimates examine the costs of adding PCS to an existing network owned by a LEC, a cellular company, or a cable company. Each of these three potential entrants into PCS has different infrastructure advantages already integrated into their respective networks that are not available to a *de novo* entrant.

The results of Reed's scope calculations are shown in Table 4-5. They are presented in terms of total cost advantage, switching cost advantage, wireline advantage, handset advantage, and advantages in other operating costs. The total annual savings per subscriber over a *de novo* entrant range from $65 to $83 with LECs the winner. However, advantages for LECs, cellular providers, and cable companies lie in different infrastructure areas. A LEC has an advantage in every area except handsets. Only cellular companies have a cost advantage in handsets. Cellular companies, however, have no advantage in the wireline area. Cable companies lose in the switching area. While an $18 spread in cost advantage among local exchange, cellular, and cable

TABLE 4-5

ESTIMATED ANNUAL SAVING FOR PCS USING EXISTING INFRASTRUCTURE

Existing Infrastructure	Switching	Wireline	Handset	Other Operating Costs	Total Savings over de novo entrant
Telephone Network	$14	$41	$ 0	$28	$83
Cable Television Network	0	46	0	28	74
Cellular Network	14	0	24	27	65

Source: Reed, OPP Working Paper No. 28, 43.

companies is not significant, the $65 to $83 cost advantage over an entrant without an existing infrastructure is. In evaluating these results, Reed states:

> ... an independent firm—an entrepreneur or small company that obtains a PCS license but does not own any existing infrastructure in the subscriber loop—probably would not choose to construct a stand-alone PCS network... Instead, the independent provider is likely to pursue a strategy of negotiating alliances or commercial relationships among the infrastructure alternatives to deliver PCS.[15]

The infrastructure alternatives outlined by Reed are the lease of facilities or joint ventures with a LEC, a cellular company, a cable company, an interexchange carrier, a competitive access provider, an electric utility, or a gas utility. Reed's intuition seems likely to be on target with regard to this conclusion. As pointed out in Chapter 2 of this report, just to raise the capital required to enter the PCS business when confronted with enormous entrenched infrastructures requires some kind of partnership arrangements. One must, however, question the assumption Reed makes with regard to the scale of entry by the four potential players. The scale is large and summary costs may be misleading.

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[15] Reed, *Putting It All Together,* 44.

The accuracy of Reed's results may suffer from the use of an engineering-process model and the lack of inclusion of a significant increase in externalities in a PCS network when compared to a landline network. These two shortcomings are discussed in this section and the implications addressed.

Engineering-process models are typically used to study the least-cost design and configuration of plant and equipment used to produce a product, while meeting certain constraints. In Reed's study, the product is telephone service delivered over a network of switching and wire with a wireless loop and CPE. The configuration was relatively fixed, varying only with spectrum allocation, cell size, grade of service, offered load per customer, and spectrum efficiency. Sensitivity analysis was used to investigate economies of scale with respect to each one of these variables. The basic technology of service delivery and the size of the geographic area assumed for the entrant were fixed. There are two salient problems with this type of approach and its restrictive assumptions.

One of the main problems is that Reed's model does not attempt to optimize an entrant's investment strategy with regard to the geographic scope of operation or technology. In Reed's defense, it should be noted that such a model may not be easily formulated and implemented. He, in fact, recognizes this in his suggestion that a *de novo* entrant may seek to form various kinds of partnership alliances. However, the fact remains that a *de novo* entrant may seek out technological alternatives and pursue a strategy of niche markets to gain a foothold in the PCS business. These same comments also apply to his cost estimates of local exchange, cellular, and cable companies. For instance, a cellular company might pursue a strategy of a partially wireless network to implement his PCS offering. Cable companies may integrate their PCS offering with switched video and information service delivery, thereby spreading the costs. The problem with Reed's approach is that it is static, rather than dynamic, and fails to optimize the costs of providing PCS service. One may question his findings with regard to economies of scope on this basis alone.

Another issue that should be dealt with in considering PCS costs is the existence of externalities. Wireless technologies significantly increase the external benefits associated with access. Externalities arise from ill-defined property rights. In the case of an external benefit, the use of a resource cannot be limited to the owner, or, in this case, a subscriber. External benefits have always been present in the landline telephone network because the use of a subscriber's loop cannot be limited to the subscriber alone. Instead, incoming calls from any other subscriber could congest a subscriber's loop. With PCS and wireless access, use is not simply limited to subscribers in a geographic area, cell site, or even to subscribers for a single company. Instead, any PCS subscriber may use any cell site to originate or terminate a call when roaming. Simply put, PCS is more of a public good than the landline network.

The immediate implication for the Reed study is that summarizing costs in terms of the annual cost per subscriber is misleading. The global implication concerns the optimal pricing of PCS. Without explicit recognition of external benefit, access costs would be overstated and usage costs understated since some usage costs are contained in the access portion. This result suggests that access would be underused and lower penetration rates realized, but subscribers on the system would tend to overuse it. Explicit recognition of the externality would require that some access costs be rolled into the usage price to internalize it.

Summary of PCS Costs

This review of Reed's study has raised questions concerning the validity of his estimates of the costs of *de novo* entry and economies of scope. The critical problem is that the engineering model fails to optimize the network design which is something a *de novo* entrant would do. Instead, it is *ad hoc* and the conclusions are only as good as the assumptions regarding network design. Lack of recognition of increased network externalities is also a problem because of how he chooses to summarize his cost estimates. Reed's cost estimates do tend to confirm one's intuition regarding the relative advantages expected from potential players with existing infrastructure. The magnitude of the results, however, should be viewed with a good deal of caution because there are many possible strategies available to potential providers of PCS that are not considered in his study.

Is PCS Competitively Viable?

Demand can be high and costs relatively low yet PCS might still not fulfill its potential if there are artificial barriers to diffusion. Removal of several important barriers could improve the competitive viability of PCS. Design of regulatory processes that assure fair and workable competition is a broad subject that will be discussed in the following chapter as well as here. We will focus on three regulatory barriers and one technical one. In the regulatory arena, the pricing of local exchange services for the landline network may need to be restructured. The second regulatory change is to adopt a posture of forbearance in competitive struggles. Third, the use of rate groups and rate averaging needs to be reviewed. In the technical area, the numbering plan needs to be changed to allow number portability among local exchange providers. None of the changes advocated here are easily accomplished.

The Pricing of Local Exchange Service

The pricing of local exchange service is the outcome of the complex interplay of many economic, engineering, market, and regulatory factors. Since the mid-1980s a number of pricing reforms have been analyzed or implemented by state and federal regulatory commissions that directly and indirectly affect the pricing of local exchange service. It would be beyond the scope of this report to examine all of these and to assess the impact of each pricing decision on the emerging PCS providers. Instead, one aspect of pricing, the use of two-part tariffs, is examined as an illustration of how existing pricing practices may affect PCS.

A deductive argument from neoclassical economics suggests that the flat-rate pricing of local exchange service is economically inefficient because it sends the wrong price signals to subscribers about the long-run opportunity costs of calling. All that is required is a positive marginal cost that is unrelated to usage (access) and a positive marginal cost that is related to usage (usage). In this circumstance, advocates of this argument would recommend an optimal two-part tariff that recovers the cost of the access portion of the network through a flat monthly fee and recovers the costs of usage (or calling) through a minutes-of-use charge based on time of day. This type of rate structure is just the form that PCS providers would likely charge if cellular provides a role model. However, with flat-rate pricing for the landline local exchange service, PCS offerings based on a two-part tariff may not compare as favorably as they could to the landline network. The reason is not any inherent technical superiority of landline over PCS but the practice of promoting flat-rate service for local calling. The effect on the potential for competition in local exchange services could under certain circumstances retard entry and expansion of PCS offerings.

By saying that flat-rate pricing is economically inefficient, the argument is pointing to its effect on the allocation of resources for telecommunication services, in particular, the LEC's investments in plant and equipment. From the standpoint of the local exchange provider, the lack of a usage charge suggests that subscribers perceive the cost of additional usage as zero whether on-peak or off-peak. As a result, incremental usage is treated as a free good. Telephone companies, with an obligation to serve and quality-of-service standards to meet, must expand capacity in the public switched network to meet subscribers' demands. Thus, one could argue that there is too much investment in capacity and the pattern of investment may not be economically efficient. In fact, one might argue that there is too much investment in the usage portion of the network and too little in the access portion, if existing prices are assumed to be based on costs. The economist's deductive analysis of flat-rate pricing suggests telephone companies with landline networks may be facing a competitive future saddled with too much capacity.

From the standpoint of an entrant wishing to provide PCS offerings, one must ask what would induce a subscriber to switch from landline service to wireless service. The A. D. Little demand study pointed to mobility and convenience features of PCS that subscribers desired. However, when the price comparisons are made, the take rate for PCS may be lower than would occur if the landline telephone company also had a two-part tariff. In effect, the growth rate of penetration for PCS may be lowered. High-usage customers may decline PCS services or simply view it as a complementary good to their landline phone rather than a substitute. To the extent that potential PCS customers view the price comparisons in this manner, potential and actual entrants may perceive that gaining a foothold in the local exchange market is complicated by flat-rate local exchange service. Consequently, entry is discouraged and the extent of the potential PCS market may be dampened.

The adoption of a two-part tariff for toll services was exactly the response of the FCC and many state commissions with the breakup of AT&T. When AT&T was a single entity providing end-to-end toll service, the toll rate charged was based on usage alone. The same basic argument given above to suggest that flat-rate pricing of local exchange services is inefficient applies to the old toll rate structure. In the case of toll, including access costs in usage rates distorts economic decisions regarding use of the toll network and the expansion of the network. As before, all that is required is a positive marginal cost of usage and access. Once these marginal costs are established a two-part tariff is indicated for efficient consumer and producer choices to be made. The two-part tariff has a flat-rate fee for access that is paid on a monthly basis and a usage rate for use of the public switched network computed as calls are sent and received from a toll carrier's point of presence. At the time the FCC was formulating access prices for LECs, their actions were controversial and subject to extended debate.

The above argument has been framed from an economic perspective and does not include offsetting factors that commissions have considered when selecting flat rates. These include universal service goals, the financial health of the utility, and the preference of many residential consumers for flat rates. Some commissions have approved measured rate-type designs. Some commissions have undertaken comprehensive reviews to bring local rates in line with costs. This issue becomes further complicated in price-cap states because a two-part tariff may not be fully under the control of a commission. Further, many states have allowed their utilities to use flexible pricing or have detariffed many services and may find it a problem to introduce a two-part tariff constraint.

Redressing the flat-rate pricing for local exchange would not be a politically easy process. The expectation of telephone subscribers for flat-rate service is well-entrenched. The purpose of this analysis is simply to point to the effects of flat-rate price structures as an economically inefficient form of pricing and as a potential factor affecting the future of competitive local services. The authors of this report do not have any easy policy solutions to this potential problem.

Rate Groups, Rate Averaging, and PCS Entry

The practice of using rate groups and rate averaging might have detrimental effects on the entry of PCS providers in smaller towns and rural areas, while encouraging possibly inefficient entry in large metropolitan areas. Rate groups are typically designed on value-of-service concepts rather than cost of service. Consequently, in large metropolitan areas where subscribers can call a larger number of people, the flat rates for local service are set higher than the statewide average cost. In small rural areas where few people can be called at the local calling rate, flat rates for local service are set below the average cost. By severing the relationship between costs and rates, inefficient price signals are sent both to potential PCS suppliers and their customers. Such price signals can lead to both allocative and productive inefficiencies. State utility commissions may want to redress their long-standing practice of using rate groups as a basis for designing local rates in the face of competitive entry by PCS providers.

Again a deductive argument from neoclassical economics would suggest that efficient price signals are sent to customers and potential entrants when prices are based on marginal or incremental costs. Typically, pricing telephone services at marginal costs will not recover the revenue requirement and make the company whole. Consequently prices must deviate from marginal costs to recover joint and common costs of providing service. The potential entry of PCS providers into local exchange services will have two positive effects when rates for local services are based on marginal costs. First, the entry that does occur will be by firms that can provide services at a price comparable to the landline provider, given value references by consumers. Thus inefficient firms are not encouraged to enter the market. Second, the pressure exerted by the potential entrants will encourage productive efficiency by the incumbent landline telephone company and cellular companies. Entrants consequently will also have to be productively efficient.

All of this flows from the fact that prices for the landline system are based on marginal costs rather than value-of-service concepts.

In the absence of rate restructuring along the lines that an economist would recommend, both inefficient entry and productive inefficiencies would follow. Rate groups in the larger cities and towns would experience the pressure of entry by PCS providers. However, the above-average-cost prices charged to customers in these rate groups would encourage entry by PCS providers who are not necessarily productively efficient and would most likely encourage the deployment of too many PCS resources (allocative inefficiency). The real losers in this scenario would be potential PCS customers in the small towns and rural areas. Rate group pricing by keeping flat rates artificially low would discourage entry by PCS providers. Decisions on universal service concerns that commissions made when designing rate groups may have unintended consequences when local services become competitive by the application of new technologies such as PCS. Thus commissions should address the likelihood of entry in markets based on current rate structures and consider carefully the full implications of rate restructuring.

Number Portability

Number portability is another problem potentially inhibiting the extent of the market for PCS service offerings and competition for local exchange services in general. Number portability means that a customer can retain the same telephone number regardless of the carrier that provides the service. Presently, it is no more than a desirable concept. Under the existing regime with Bellcore administering the North American Numbering Plan and cellular companies obtaining blocks of numbers by area code and NNX from LECs, the transaction costs of changing local carriers is borne by the consumer. These transaction costs inhibit consumer choice and impart a degree of market power to a customer's existing carrier. Solving the number portability problem means developing procedures and processes that relieve the consumer of these transaction costs. To understand this issue, one must only examine what competition from PCS carriers might look like without number portability.

Under present arrangements, a PCS carrier would have to obtain a block of telephone numbers by NNX from the existing landline telephone company in order to have telephone numbers the existing public switched network could recognize and use to route calls. As the carrier gained subscribers it would assign these numbers. Any subscriber wishing to drop his or her subscription to the landline public switched network would have to disseminate his or her PCS number to potential callers. Existing telephone directories publish only the landline numbers for the landline network. As one can see, the subscriber to a PCS carrier is at a considerable disadvantage. Even requiring publication of PCS numbers in the directory may not solve the problem if there are to be several PCS carriers per market region, because each PCS carrier would have its own block of NNXs. The subscriber changing PCS carriers would also have to change telephone numbers and disseminate that number by word of mouth and other nonpublic methods. In essence, PCS and existing cellular services are not as convenient as the landline public switched network from the standpoint of receiving incoming calls. Number portability solves the problem by assigning the property rights to the number to the subscriber rather than the carrier.

This solution, however, creates a number of institutional and technical problems. On the institutional side, finding or creating an entity to administer the North American Numbering Plan and funding the entity are the chief problems to be solved. The technical problems center on development of routines for routing calls to numbers that do not identify switching centers by NNX within an area code. The solution to this technical problem suggests that the memory capacity and processing capabilities of switches may have to be expanded. These changes are not costless; nor should the costs be borne by the competitive carriers alone. Instead, they could be viewed as costs associated with changing from a monopoly carrier to local exchange services in a competitive regime. These are social costs that are likely to impart social benefits to the population at large and could be recovered through interconnection arrangements.

Product Life-Cycle Analysis and Regulation

A standard vehicle for economic analysis of new products such as PCS is the product life-cycle curve.[16] This curve depicts a relationship between time and market penetration (or number of customers) for product or service over its lifetime. Since PCS is a service that is embedded in plant and equipment, the product life-cycle curve permits the investigation of estimated demands, investments, and costs over a hypothetical lifetime for PCS services and the interrelationship of PCS with landline telephone services. Technological advances may have a disruptive influence on both plant and equipment used to provide PCS and landline telephone services. The product life-cycle curve can be used to investigate likely scenarios for technological advances. When placed in a regulatory context, these analyses point to specific epochs in the evolution of PCS that should concern regulators, whether or not PCS is regulated at the state level.

A hypothetical product life-cycle curve for PCS is depicted in Figure 4-1.[17] The product life-cycle curve can be divided into six distinct epochs: product development, market development, rapid growth, competitive turbulence, saturation, and decline. Each of the epochs is defined below. Once the epochs of the product life-cycle curve are defined, we discuss the activities one could expect to see companies and possibly regulators involved in at each stage.

The *product-development stage* begins prior to time t_0, the time of PCS introduction and marketing. PCS was in this stage early in 1994. In licensing spectrum for PCS, the FCC will decide many market characteristics. One in particular is the number of potential entrants to a geographical market. Under the FCC rules there

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[16] See, for example, Sharon M. Oster, *Modern Competitive Analysis* (New York: Oxford University Press, 1990), 165.

[17] In thinking about the product life-cycle curve, the maximum penetration rate represented by the vertical axis is not 100 percent but could be quite low such as less than one percent. The timeframe is also not specified in the diagram and is uncertain for any given product.

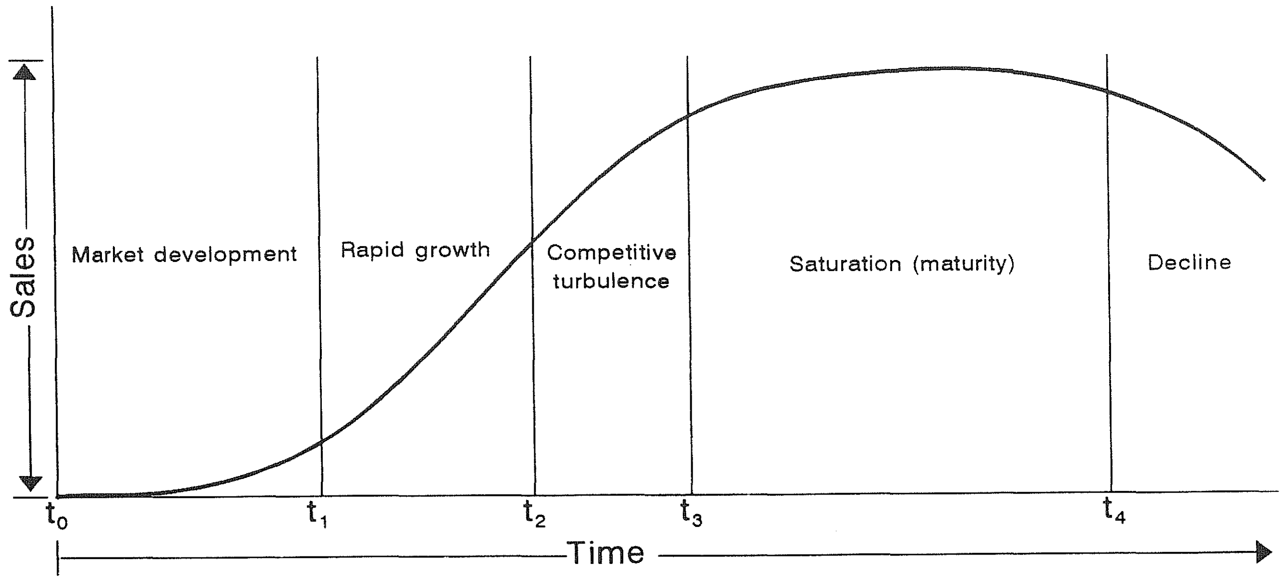

Figure 4-1. Stages of hypothetical product life-cycle curve for PCS.

Source: Robert H. Hayes and Steven C. Wheelwright, *Restoring Our Competitive Edge: Competing Through Manufacturing* (New York: John Wiley & Sons, 1984), 202, and authors' construct.

could be several providers of PCS services within any geographical area. This situation implies that an oligopoly model may be appropriate for analyzing competitive behavior in the future. However, PCS providers will not only compete with other PCS providers but with the landline public switched network, cellular telephone providers, paging operations, and coin-telephone services. The extent to which these services emerge as substitutes or complementary services for PCS will dictate to a large extent the competitiveness of the market and potential pricing behaviors for fixed local communication services versus portable ones. Throughout the remainder of this analysis and discussion, it is explicitly assumed that there will be several PCS providers in a local market area and entry to the market is uniquely controlled by the allocation of spectrum at the federal level by the FCC.

Beginning at time zero, t_0, demand for PCS services grows slowly at an increasing rate up to time t_1. This epoch (t_1 - t_0) is usually referred to as the *market-development or start-up stage* of the product-life cycle curve. This is the introductory period for PCS on the horizon in mid-1994. The strategic objectives of PCS providers in this stage are to minimize the learning requirements for personnel and locate and remedy service deficiencies quickly. From the standpoint of marketing, providers should seek to develop a widespread awareness of the potential benefits of adopting PCS and gain experience from early adopters. Typically, the most valuable media mix for promotions is publicity, personal sales, and mass communications. Pricing objectives during this period should focus on matching price to the value-reference perception of the early adopters and using discounts. Service-design objectives should focus on limited geographical areas where the most receptive segments of the population live and work so that the highest penetration for a given investment may be achieved. This aggregate planning for facilities and service offerings should be based on techniques such as consumer surveys and market tests.

The next epoch of the product life-cycle curve is the *rapid-growth stage* spanning the time horizon from t_1 to t_2. During this epoch (t_2 - t_1), demand is increasing at an increasing rate up to time t_2. At time t_2, demand growth begins increasing at a decreasing rate. This change in demand growth can have profound and substantive effects on the industry as a whole and regulators. This epoch beginning at t_2 and ending at t_3 is typically known as the *competitive-turbulence stage* because of the price squeezes and investment patterns that may occur. These two stages taken together constitute the formative period of PCS in the future. These two stages are analyzed in some detail below. It is sufficient for now to note that they are characterized by increasing standardization and volume. Consequently, economies of scale in the PCS networks for each provider are potentially being realized and there is likely to be an industry shake-out and consolidation. Competition is likely to focus on service quality and availability. Pricing objectives will diversify and focus on promotional opportunities.

The next epoch (t_4 - t_3) is the *saturation or maturity stage* of the product-life cycle curve. The market in this stage is deeply penetrated and the service is viewed as a commodity and, in fact, a necessity for modern living. Landline telephone systems are currently in this stage because of the high penetration and the commodity-like nature of long distance and plain old telephone service.

The final epoch, beginning at t_4, is the *decline stage*. Market penetration begins to decline, usually because of technological advances that displace the function provided by the service. The time when PCS will enter the maturity stage is well into the future given the current technological frame of reference. Consequently, little attention is given here to these stages for PCS. However, as noted earlier, the landline public switched network is in its maturity stage. The possible implications for the impact of PCS on the existing public switched network entails some analysis using this stage. In the maturity stage, the strategic objectives of a company are to defend brand position against other potentially competing services and pay constant attention to service improvement opportunities and fresh promotional approaches. These strategic objectives are likely to play out to some extent in the regulatory arena.

The life-cycle pattern of costs suggests that cost per unit would decline over the life-cycle of a product or service as penetration increases, as depicted in Figure 4-2. Beginning at t_0, costs first decline at an increasing rate and then at a decreasing rate somewhere during the *competitive-turbulence* stage, which begins at t_2. The primary reasons for this cost behavior lie in the fact that as market acceptance grows, economies of scale are realized through increased standardization, and product-development costs are recouped. These life-cycle costs are the important ones to consider when contemplating the competitiveness of PCS offerings relative to the landline public switched network. The model suggests that cost and price advantages that may be attributed to the landline network may dissipate as PCS gains market acceptance. However, the absolute level of the costs depends on a number of factors that facilitate market acceptance such as price realignment for local service, number portability, and the efficiency of the pattern of investment in PCS facilities.

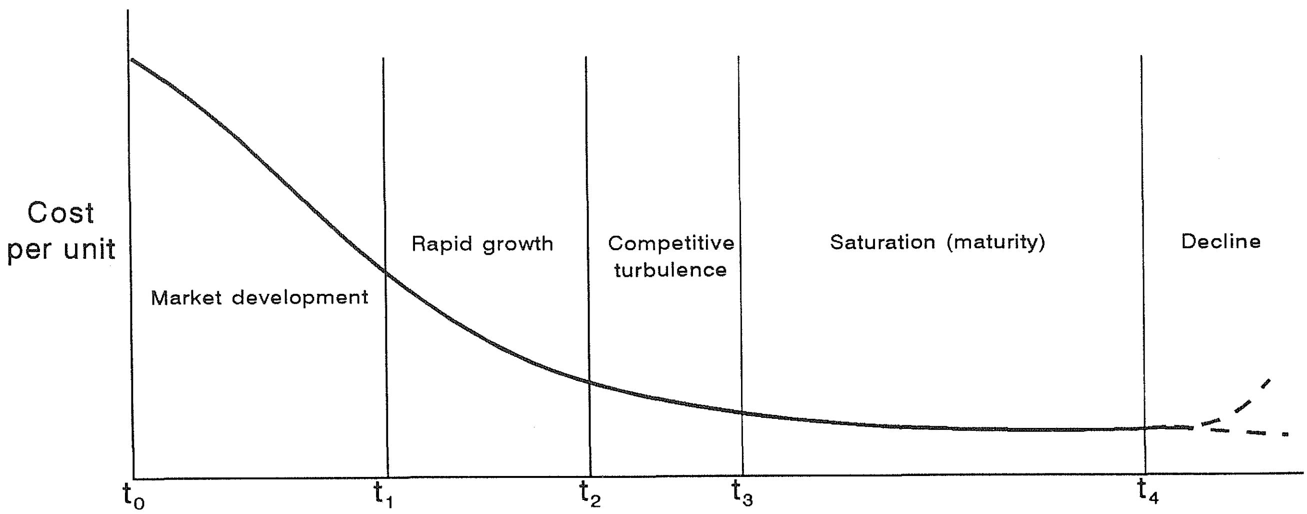

Figure 4-2. Hypothetical behavior of the costs of PCS over the stages of product life cycle.

Source: Authors' construct.

Investment in PCS over the life cycle must precede demand because the service cannot be provided to customers if facilities are not in place. Consequently, PCS providers must estimate the demand for facilities and the geographic markets in which demand will materialize in advance of providing service. In the context of the product life-cycle curve, the growth in investment over time must exceed the realized demand by the lead time needed to construct the facilities. Referring to Figure 4-3, the product life-cycle curve is labelled D_0, while the investment curve to meet the demand is labelled I_0. The horizontal difference between the two curves at t_2 is the lead time needed to construct the facilities.

Using this framework, one can understand the root causes of the *competitive-turbulence* stage. At the beginning of this stage, t_2 , demand changes from increasing at an increasing rate to increasing at a decreasing rate. If the industry members fail to correctly predict the timing of this change, there will be a period of overbuilding and

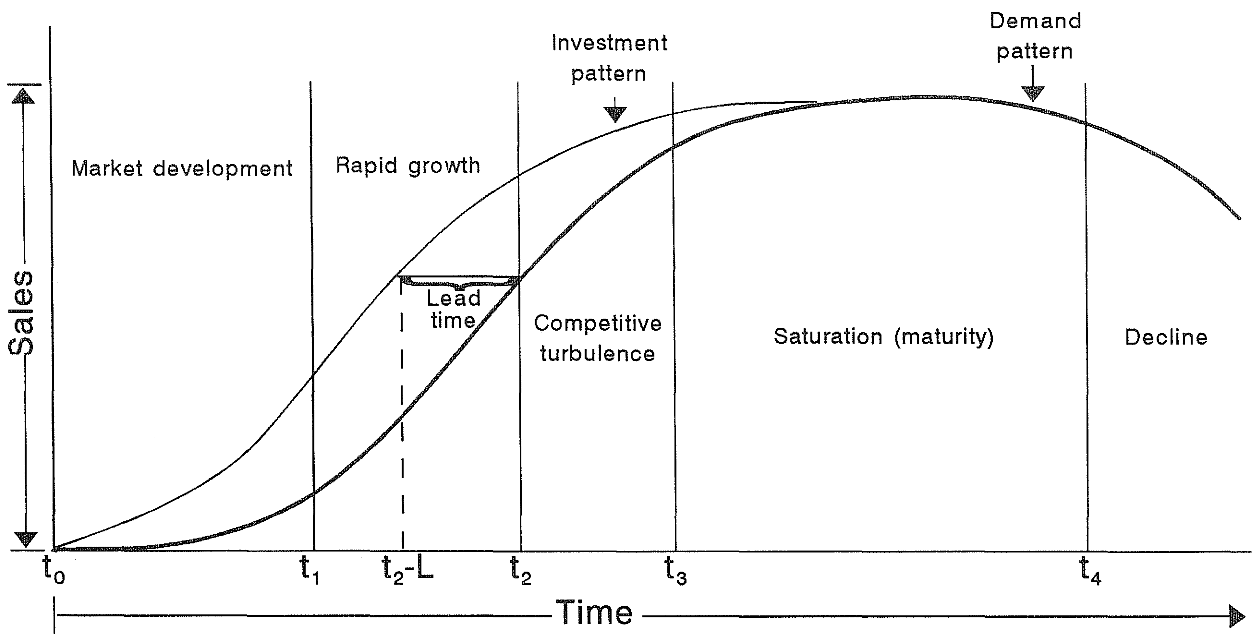

Figure 4-3. Hypothetical investment pattern for PCS and relationship of pattern to the product life cycle.

Source: Authors' construct.

excess capacity in the PCS industry in a geographic location. This has two consequences. First, some or all of the PCS providers will have excess capacity and will incur the carrying charges on this excess investment. Thus, costs increase above the optimal levels. The increased costs by themselves will create a profit squeeze. Second, the excess capacity coupled with the slowing growth in demand will set off price and other forms of competition for customers. This intensified competition will squeeze profits further and increase costs to the extent that nonprice competition is prevalent. In this context, one might expect to see some business failures of carriers and some industry reorganization. This phenomena is just an expected normal industry shakeout and is the direct result of imperfect information concerning market forces. In these circumstances, it is best that regulators, whether federal or state, refrain from intervention. The problem lies in recognizing the forces at work. There is no simple formula to do this during the period of competitive turbulence. Even industry participants will find it difficult. Thus, a competitive environment in the local market would require regulatory forbearance.

Conclusion

Regulators can seek to create an environment for investment and deployment of PCS networks that is stable and facilitates competition. Realignment of local exchange rates from flat-rate service to a two-part tariff would be a partial aid to the development of competition, as would elimination of the use of rate groups and rate averaging. Number portability to facilitate consumer choice among carriers would also help. These changes would increase the growth rate of demand and total demand along the product life-cycle curve. As noted above, being able to predict the rate of demand increase within reasonable tolerances drives investment strategies for PCS offerings. In a competitive environment, landline LECs would also depend heavily on predicting demand to guide their investment strategies. Regulatory actions that greatly affect the growth rate of demand are best avoided because they could create competitive turbulence within the industry. The essential reason for this recommendation is that capacity decisions must be made in advance of demand and if regulators were to make a decision that slowed the growth rate of demand, PCS providers could find themselves saddled with excess capacity that might set off cut-throat competition. So should regulatory actions that affect the costs of service because of the potential price squeezes they may entail. Finally, regulatory commissions should not become the arbitrators of competitive disputes unless there are clear grounds for antitrust action.

CHAPTER 5

TOWARDS A REGULATORY FRAMEWORK FOR PCS

Congress, the FCC, and those state commissions that have addressed PCS have for the most part adopted a hands-off approach. The emphasis has been on regulating only as much as necessary to allow the new radio-based communications to get started and ensure that potential players all have a fair chance to compete. By the summer of 1994 the initial regulatory framework for PCS was in place. States are by and large precluded from direct intervention in the development of PCS. But they still have oversight of interconnection rates for cellular service, and the FCC has not preempted such oversight of PCS. This chapter reviews federal and state actions affecting PCS and some of the associated regulatory issues, including common carriage, universal service, and preemption. Table 5-1 summarizes FCC decisions on regulation of PCS through June 1994.

Overview of Federal Actions

The FCC began in 1990 to establish a regulatory framework for PCS. By 1993 it was well on the way towards comprehensive rules when Congress substituted its judgment for important decisions in the FCC regulatory process. Congress enacted legislation to treat both cellular and PCS as common carriage and preempt state regulation unless it could be proven necessary. For most states preemption has little impact for the time being, since they were not regulating cellular service. California is a major exception. That state fully regulated cellular companies and had to decide whether to make a case to the FCC to continue to do so.

TABLE 5-1

SUMMARY OF FEDERAL ACTION ON PCS THROUGH JUNE 1994

Market Framework	
Broadband spectrum allocation	120 MHz for licensed devises. 40 MHz for unlicensed devises.
License term	Ten years.
Number of providers per service territory	Six established through auction.
Technical standards	Significant flexibility in the design and implementation of PCS systems.
Service territories	Two 30-MHz blocks to each metropolitan trading area. Three 10-MHz blocks to each basic trading area. One 30-MHz block to each basic trading area.
Regulatory Framework	
Regulation of entry and rates	States preempted from entry and rate regulation except on successful petition to FCC. States permitted to regulate "other terms and conditions."
Interconnection	Federally protected right to interconnection. State regulation of interconnection rates. Type of interconnection that is reasonable for the particular PCS system and no less favorable then that offered by the LEC to any other customer or carrier.
Common or private carrier	Common carrier presumption.

Source: FCC documents.

The FCC enunciated the goals of regulation of PCS in an August 1992 *Notice of Proposed Rulemaking*. Table 5-2 gives the chronology of FCC actions. The Commission said, "We intend to ensure that all mobile services are provided with the highest quality at low-cost, reasonable rates to the greatest number of consumers, consistent with the goals of the Communications Act."[1] The Commission identified four values to "optimize and balance" in providing a spectrum and regulatory structure for PCS: (1) universality, (2) speed of deployment, (3) diversity of services, and (4) competitive delivery.[2]

In the *Notice*, the FCC said there was a steadily increasing consumer and business interest in new mobile services and technologies. Noting that the establishment of PCS would introduce additional competition to current mobile radio services, and asserting that consumer requirements for PCS increasingly are international, the FCC said it intended to allocate sufficient spectrum for PCS and establish rules that would allow the widest possible range of such services.[3]

In two brief pages, the FCC outlined its proposal for a regulatory framework for PCS. The thrust of the Commission's proposals was towards minimal regulation unimpeded by state intervention. The FCC said PCS was likely to be a highly competitive service, with "no captive customers who must take the service from a monopoly" provider.[4] In the spirit of making certain that the nascent technology could flourish without undue government intervention, the FCC broached the idea of treating PCS as private carriage, which would, among other consequences, serve to preempt state regulation. If PCS was classified as common carriage, the FCC tentatively concluded that PCS providers should be treated as nondominant carriers and thus not subject to

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[1] FCC, *Notice of Proposed Rulemaking*, August 1992, 4. Further references to this document in text and footnotes will be to the *Notice*.

[2] *Notice*, 4.

[3] *Notice*, 13.

[4] *Notice*, 37.

TABLE 5-2
CHRONOLOGY OF FCC ACTION ON PCS
(As of June 1994)

Date	Title	Docket Number	Action
June 1994	Memorandum Opinion and Order	GEN Docket 90-314, FCC 94-144	Revises rules for broadband PCS
April 1994	Second Report and Order	PP Docket 93-253	Established auction rules for narrowband PCS
March 1994	Second Report and Order*	GEN Docket 93-252	Implemented 1993 amendments to the Communications Act on regulatory treatment of mobile services
October 1993	Second Report and Order*	GEN Docket 90-314	Established comprehensive regulatory framework for PCS
November 1992	Putting It All Together: The Cost Structure of Personal Communications Services*	OPP Working Paper 28 David P. Reed	Analysis of PCS issues and suggested directions
June 1993	First Report and Order	GEN Docket 90-314 and ET Docket 92-100, 8 FCC Rcd 7162	Allocated spectrum and adopted rules for narrowband PCS
October 1992	Tentative Decision and Memorandum Opinion and Order	GEN Docket 90-314, 7 FCC Rcd 7794	Companies awarded pioneer preferences for PCS experiments

TABLE 5-2
CHRONOLOGY OF FCC ACTION ON PCS (Continued)
(As of June 1994)

Date	**Title**	**Docket Number**	**Action**
September 1992	First Report and Order and Third Notice of Proposed Rulemaking	ET Docket 92-9, 7 FCC Rcd 6886	Allocated spectrum to emerging technologies
August 1992	Notice of Proposed Rulemaking and Tentative Decisions*	GEN Docket 90-314 and ET Docket 92-100, 7 FCC Rcd 5676	Proposed possible spectrum allocation, regulation and licensing for PCS and how to make it available to the public
January 1992	Notice of Proposed Rulemaking and Tentative Decisions	ET Docket 92-9, 7 FCC Rcd 1542	Proposed to allocate 220 MHz of spectrum for innovative new services like PCS
December 1991	En Banc Hearing	GEN Docket No. 90-314, 6 FCC Rcd 6601	Developed the record on PCS issues
October 1991	Policy Statement and Order	GEN Docket 90-314, 6 FCC Rcd 6601	Stated goals of development of PCS
June 1990	Notice of Inquiry	GEN Docket 90-314, 5 FCC Rcd 3994	Solicited comments on issues related to making PCS available

Source: FCC Documents
* Major documents referred to in text of this report.

tariff regulation at the federal level. Whether PCS were considered private or common carriage, the FCC in essence warned that state regulation of intrastate rates for interconnection to the public switched telephone network would be preempted if it got in the way of commercial development of PCS.

The 1992 *Notice* also addressed issues of the optimum number of licensees, the configuration of service areas, and who would be authorized to provide PCS. A major issue of interest to the state commissions was whether the LECs would be authorized to be PCS licensees.

Before final FCC rules could be issued, Congress passed and the President signed the Omnibus Budget Reconciliation Act of 1993. The budget act included amendments to Section 332 of the Communications Act of 1934.[5] The law considerably broadened the definition of "commercial mobile service," which is treated as common carriage but preempted the states from regulating rates and entry for commercial mobile service. A state that wanted to continue regulation of commercial mobile service had to petition the FCC by August 1994. The budget legislation authorized the FCC to use competitive bidding to choose licensees for PCS spectrum and set a strict timetable for the FCC to finish establishing regulations.

The FCC adopted regulations on spectrum allocation, licensing, and technical standards for broadband PCS in October 1993.[6] In separate proceedings the agency addressed remaining issues on regulatory status and selection procedures for licensees. Those issues were resolved and regulations issued in March and April of 1994, respectively. Further revisions were issued in June 1994. Broadband PCS was defined along the broad lines of the *Notice*: "Radio communications that encompass mobile and ancillary fixed communication services that provide services to individuals and business and can be integrated with a variety of competing networks."[7]

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[5] 47 U.S.C. 332 (1993).

[6] FCC, *Second Report and Order*, GEN Docket No. 90-314, October 22, 1993. Further reference will cite the *Rules*.

[7] FCC, *Rules*, 14.

Use of PCS spectrum for broadcast service was prohibited and fixed use of the PCS spectrum allowed only as an ancillary of the mobile service.[8]

Laying Out the Playing Field: Spectrum Allocation, Number and Type of Providers, and Service Territories

In opening up the market to PCS, the FCC appears to have tried to avoid the mistakes made in establishing cellular duopolies and strive for a minimum of government control and a maximum opportunity for healthy competition. The Commission aimed to provide an allocation of spectrum that "allows for the provision of the widest range of PCS services at the lowest cost to consumers."[9] The Commission allocated a total of 160 MHz for licensed and unlicensed PCS providers (120 MHz for licensed PCS and 40 MHz for unlicensed devices). Unlicensed devices include data links between computers, cordless telephones and wireless PBXs.[10] The Commission left for future consideration the allocation of spectrum for PCS services using satellites.[11] The spectrum allocated for licensed PCS providers is more than twice that provided for cellular services. A total of as many as six licensees could use this spectrum, decided the Commission. Three 10 MHz blocks, one 20 MHz block, and three 30 MHz blocks would be auctioned. Most licensees will be permitted to aggregate spectrum up to a total of 40 MHz in any given geographical area.[12] The Commission originally authorized four 10 MHz blocks. This decision was widely criticized, and the FCC backed away from allowing seven users.

The Commission's approach to designating service areas was a compromise that attempted to avoid having areas that were too small to be efficient but still to promote

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[8] *Rules*, 12.

[9] *Notice*, 15.

[10] *Rules*, 35.

[11] *Ibid.*, 30.

[12] *Ibid.*, 25-29.

competition. Noting that the initial 734 service areas delineated for cellular providers were consolidated into much larger ones, the Commission in the Notice suggested the same economies might exist in PCS.[13] But smaller service areas might permit broader participation by firms of all sizes, they suggested. The Commission concluded that PCS service areas should be larger than those initially licensed in cellular and gave four options:

1. The 487 "basic trading areas" defined in the Rand McNally *Commercial Atlas and Marketing Guide*, plus Puerto Rico.

2. The 47 "major trading areas" defined in the Rand McNally guide, plus Alaska and Puerto Rico.

3. The 194 telephone LATAs, an option which the Commission suggested might facilitate integration of PCS into the local telephone infrastructure.

4. Nationwide.

Although a majority of the commenters in the rulemaking proceeding supported using existing cellular service areas, rather than any of the proposed areas, to delineate PCS boundaries, the FCC decided on a combination of basic and major trading areas. The trading area boundaries are drawn along county lines based on "such factors as physiography, population distribution, newspaper circulation, economic activities, highway facilities, railroad service, suburban transportation, and field reports."[14] A basic trading area is composed of one or more counties for which a particular city serves as the focal point for transportation, communication (especially newspaper), and economic activity. As people need goods and services not available in their immediate locality, they have to travel to the trading areas to get them. A major trading area consists of two or more trading areas for which a major metropolitan area serves as the dominant trading center.

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[13] *Notice*, 25.

[14] *Rules*, 33; quoting Rand McNally, *1992 Rand McNally Commercial Atlas and Marketing Guide* (Chicago: Rand McNally & Co.), 39.

The dominant trading center is a place with a greater variety of economic activity than found within any basic trading area within the region.[15]

Two 30 MHz blocks of spectrum will be licensed to the major trading areas. Licensees will be allowed to aggregate service areas, and the Commission opened the door to the possibility that nationwide service areas might be available through that process. Figure 5-1 is a U.S. map showing the Rand McNally major trading areas, which cross state lines. The basic trading areas, which are much smaller, tend to stay within state lines.

In deciding who should be eligible for PCS licenses, one of the Commission's main considerations was the impact on competitiveness if cellular operators were allowed to vie with newcomers in their own service areas. This could be an invitation to anticompetitive behavior, the Commission noted, but also might lead to greater production efficiencies.[16] The *Rules* allow cellular companies to have PCS licenses outside of their territories but restrict PCS provision within them. When there is significant overlap of a PCS service area and a cellular service area, the cellular licensee is allowed only one 10 MHz frequency block license.

As for telephone companies, the FCC suggested that PCS would complement LEC-provided wire loops initially, while over time it could become a full-fledged competitor. The Commission noted the importance of fostering PCS growth by efficient connection to the public switched network. It expressed concern that, if LECs were permitted to supply PCS within their service areas, they might have incentives to discriminate against competitors requesting interconnection and to cross-subsidize provision of PCS from customers using the wireline network. But, said the Commission, allowing LECs to provide PCS service within their current service areas would allow

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[15] Dean Westmeyer, Rand McNally. Telephone conversation, April 4, 1994. Descriptions of the major and basic trading areas are available for $25 by calling Rand McNally at 1-800-333-0136.

[16] *Notice*, 27.

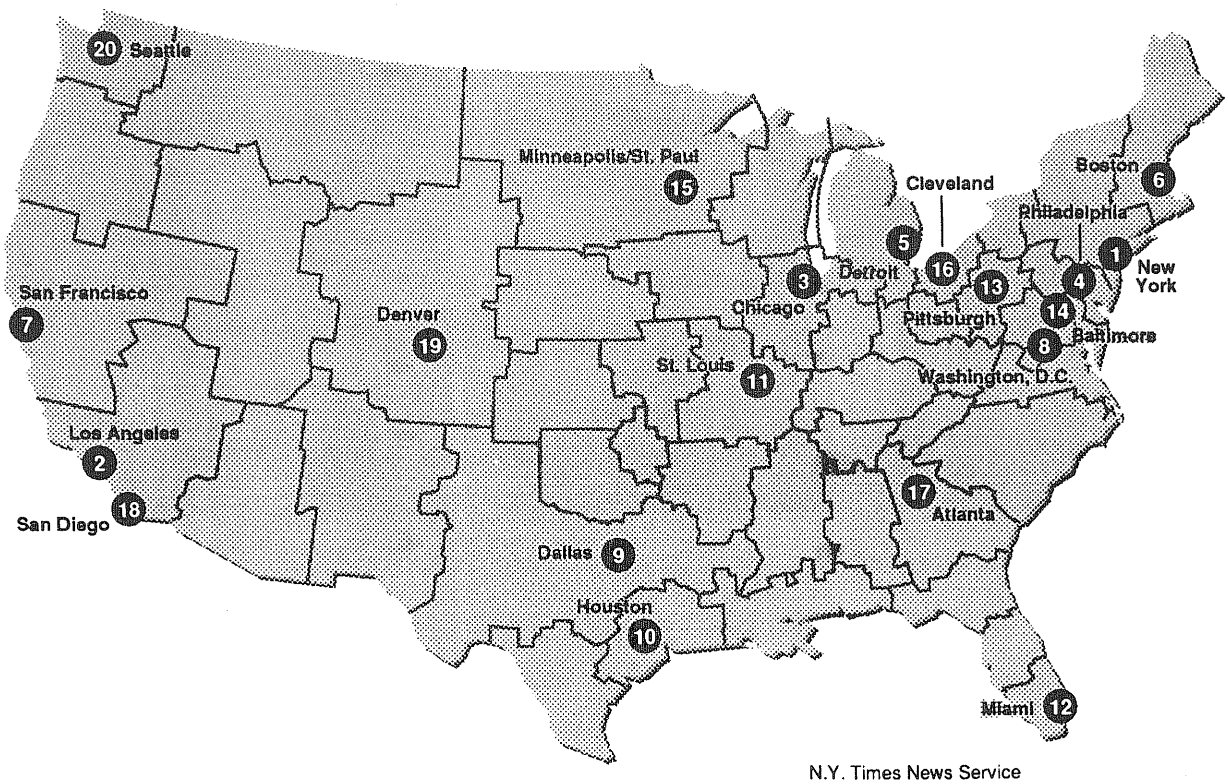

Figure 5-1. Boundaries of major trading areas. The circled numbers show the largest metropolitan markets, by population; some areas contain more than one of these cities.

Source: *New York Times*, September 24, 1993, C15. Courtesy of New York Times News Service.

realization of economies of scope and encourage them to develop their wireline architectures in a PCS-friendly way, and nonstructural safeguards against discrimination and cross-subsidy might be adequate.[17] Despite the concerns of many commenters to the proposed rules, the Commission found that allowing LEC participation might produce significant economies of scope between wireline and PCS networks. The

[17] *Notice*, 30.

Commission suggested that this would lead to more rapid development of PCS, would yield more PCS services at lower prices, and would encourage the LECs to develop their wireline architectures to better accommodate all PCS services. However, in areas where a LEC has cellular interests, the LEC will be eligible only for the same frequency blocks available for PCS licensing to cellular carriers.[18]

The FCC imposed no new requirements for LEC subsidiaries, reasoning that they could provide PCS through existing cellular subsidiaries and that the organizational requirements already existing were sufficient to protect against cross-subsidization and undue use of market power.[19]

As will be discussed below, most states have been preempted from direct regulation of PCS for the time being. The potentially complex web of numerous providers over varying geographical areas would inhibit state oversight of the development of the market for PCS, even if the states were allowed to and were so inclined. Even monitoring the situation will be difficult, particularly since territories cut across state lines. Some form of regional sharing of information may be desirable for some commissions to be able to assure that regulated telephone companies are not taking advantage of captive ratepayers in their ventures into PCS.[20]

Preemption of State Regulation of Entry and Rates

In the 1992 *Notice* the Commission broached the notion that PCS might best be categorized as private land mobile radio service, which would automatically have taken the nascent family of radio services out of the purview of state commissions. State commissions were preempted from regulation of private radio service but not from

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[18] *Rules*, 52-3.

[19] *Rules*, 52.

[20] For a discussion of what state commissions can do on a regional basis to exercise oversight, see Douglas N. Jones *et al*, *Regional Regulation of Public Utilities: Opportunities and Obstacles* (Columbus, Ohio: NRRI, 1992).

cellular, which is and has been treated as common carriage. The distinction between common and private carriage had become increasingly arcane and its applicability blurred over time. A major purpose of the hairsplitting was apparently to prevent the states from regulating new entities in radio-based communications.

Rather than waiting for an FCC ruling on whether PCS is common or private carriage, and if it was common carriage, whether it should be preempted, Congress in 1993 cut the Gordian knot and approved legislation that broadened the application of the common carriage doctrine. At the same time Congress made it much more difficult for states to regulate mobile radio communications.

The new legislation amended the Communications Act to treat anyone engaged in provision of commercial mobile service as a common carrier. Commercial mobile service was defined as "any mobile service provided for profit and that makes interconnected service available to the public or to such broad classes of eligible users as to be effectively available to a substantial portion of the public."[21] This would include cellular, PCS, and specialized mobile services like Fleet Call.

The Budget Act preempted state regulation of entry into the PCS business and conditioned continued state regulation of rates on a successful petition to the FCC. States currently regulating could continue to do so while the petition was being heard. At the same time, other entities, like cellular companies, could petition the FCC in opposition to state regulation. Petitions were due by August 10, 1994. To be successful in petitioning for rate regulation, a state must demonstrate that (1) the service is a substitute for landline telephone exchange service for a substantial portion of the communications within the state, or that (2) market conditions do not protect subscribers adequately from unjust and unreasonable rates or rates that are unjustly or unreasonably discriminatory. The FCC has nine months in which to grant or deny a petition.

States not regulating commercial mobile services may also petition the FCC. This can be done at any time. The grounds for such a petition are that market conditions "fail to protect subscribers adequately from unjust or discriminating rates," or the

[21] 47 *U.S.C.* 332 (1993).

commercial mobile service replaces a "substantial portion" of the telephone landline service in the state. If mobile service is a substitute for landline networks, states can impose conditions to ensure universal availability and affordable rates.[22]

In the meantime states are allowed to regulate other terms and conditions of commercial mobile service. What those other terms and conditions are is not specified in the legislation or the conference report on the Budget Act, but the House report listed several illustratively and NARUC Assistant General Counsel J. Bradford Ramsay has suggested others (see Table 5-3).

Since most states did not regulate cellular service at the time of the federal legislation, they did not need to decide immediately whether to petition the FCC. If regulation appears to be called for later, under the terms of the Budget Act they can still petition. A survey in 1992 concluded that "the states continue to exert a relatively light hand on the existing analog cellular car phone and pocket phone services."[23] The survey found that twenty-six states had completely deregulated cellular. As of 1992 only five states required certification and tariff filings for retail resellers of cellular service—California, Louisiana, Massachusetts, New York, and West Virginia. Another dozen or so regulated wholesale providers of cellular (see Figure 5-2).

North Carolina is among the states that decided to end *direct* regulation of cellular before Congress began considering action to preempt the states. In a 1992 proceeding the North Carolina Utilities Commission found that provision of cellular service in the state was competitive and that cellular was a nonessential, discretionary service not warranting continuing regulation.[24] The Commission cited evidence that cellular prices were lower in unregulated states than in fully regulated states and

[22] 47 U.S.C. 332(c)(3) (1993).

[23] Herb Kirchoff, *State Regulation of Wireless Communications*. (Alexandria, Va.: TPG Briefings, 1992), 1.

[24] *Order Exempting Domestic Public Cellular Radio Telecommunications Service Providers from Regulation*, Docket No. P-100, Sub 114 (North Carolina Utilities Commission: February 14, 1992), 8, 10.

TABLE 5-3

"TERMS AND CONDITIONS" OF PCS THAT STATES MAY REGULATE

Terms and conditions identified by House Report 103-111:

- Customer billing information and practices and billing disputes
- Other consumer protection matters
- Facilities siting issues (that is, zoning)
- Transfers of control
- The bundling of services and equipment
- The requirement that carriers make capacity available on a wholesale basis.

Terms and conditions tentatively identified by J. Bradford Ramsay:

- Pro forma certification or registration of all commercial mobile radio services
- Financial and market share reports
- Informational tariffs
- Quality-of-service standards
- Intrastate telecommunications relay services obligations based upon a "reasonable allocation"
- Emergency operational procedures
- Operator services regulation
- Other consumer protection matters

Source: J. Bradford Ramsay, "Special Mobile Radio Services—State Response," Memorandum, April 12, 1994.

suggested that this held out the promise that deregulation would result in lower prices. The Commission decided to continue regulating rates and conditions of *interconnection* between cellular carriers and LECs and other regulated providers. In an order issued March 21, 1994, the North Carolina Utilities Commission determined that it would not petition the FCC for an extension of rate authority for commercial mobile radio service.

California has been a leader among states regulating cellular service. The Commission will be petitioning to continue to regulate cellular. The California Public Utilities Commission opened an investigation in 1993 to propose a regulatory framework

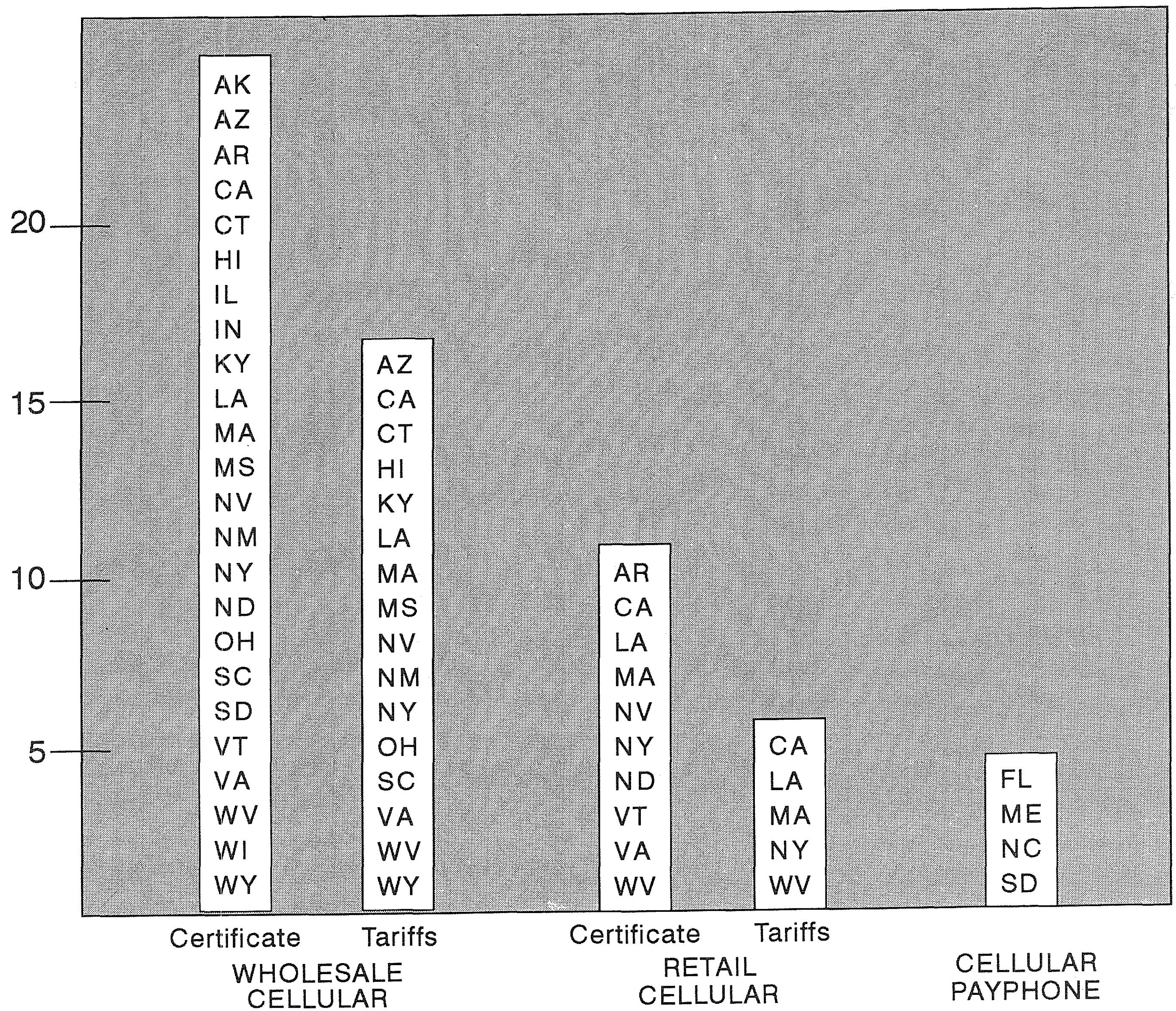

Figure 5-2. Cellular regulation by state.

Source: Herb Kirchhoff, *State Regulation of Wireless Communication*, 1992 ed. (Va.: Telecom Publishing Group, 1992), 4-6.

for all forms of mobile telephone service in the state. The investigation was intended to provide information and a policy approach to back up an expected petition to the FCC to continue rate regulation of mobile services. The Commission said, "We envision that in the not too distant future that the market forces of competition will police the mobile market and allow for an orderly withdrawal of government oversight."[25] In the meantime the Commission goal was government oversight appropriate to the degree of power over consumers or suppliers held by firms in the mobile market. The proposed regulatory framework would classify firms as dominant if they possessed significant market power, with duopoly cellular licensees classified as dominant. The Commission suggested a price cap approach to rate regulation of dominant providers. Prices would either be capped at current rates or on the basis of costs. Relaxed regulation was another alternative proposed by the Commission.

The West Virginia Public Service Commission conducted a general investigation to decide whether to petition the FCC to continue to regulate cellular providers and decided not to. The Commission found that the cellular market in West Virginia was competitive enough to protect consumers. The Consumer Advocate Division argued that cellular providers are not subject to vigorous competition in the state but thought that a petition to continue state rate regulation would be likely to fail. The Commission decided against petitioning the FCC but is requiring cellular companies to continue filing schedules of rates and charges for informational purposes. The Commission noted that it would not be precluded from petitioning the FCC later to regulate market entry and rates.[26]

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[25] *Investigation on the Commission's Own Motion into Mobile Telephone Service and Wireless Communications*, I.93-12-007 (California Public Utilities Commission, December 17, 1993), 2.

[26] *Commission Order*, General Investigation into State Regulation of Cellular/wireless Telecommunications Rates, Case No. 93-1167-C-GI (West Virginia Public Service Commission, March 21, 1994).

Interconnection Rights and Jurisdiction

The Budget Act and federal regulations issued in March 1994 delineate interconnection rights for commercial and private mobile service providers. The federal government has preempted state regulation of the right to intrastate interconnection and the right to specify the type of interconnection but allowed state regulation of interconnection rates. The Budget Act required the FCC to order a common carrier to interconnect with a commercial mobile service provider upon reasonable request. The Act did not change the FCC's authority to order interconnection.[27] In the March *Order* and the 1993 *Rules* setting the general framework for PCS, the Commission addressed interconnection rights to be afforded commercial mobile service providers and matters of jurisdiction.

The Federally Protected Right to Interconnection

The federal assertion of primary jurisdiction over the physical conditions of interconnection with the public switched network continues a policy that goes back to the pathbreaking *Carterfone* decision. Interestingly, this seminal decision in unbundling and competition dealt with the connection of radio equipment to AT&T's unified network.[28] State regulatory commissions in the early 1970s attempted to forbid interconnection with local exchanges of terminal equipment not supplied by the monopoly carrier except where used exclusively for interstate communication. But the FCC issued a declaratory ruling on the extent to which it asserted primary authority over interconnection of customer-provided equipment to the subscriber's telephone terminal. The Commission

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[27] FCC, *Implementation of Sections 3(n) and 332 of the Communications Act: Regulatory Treatment of Mobile Services Notice of Proposed Rulemaking*, GEN Docket No. 93-352, October 8, 1993, 25.

[28] For a discussion of the *Carterfone* decision, see Peter Temin, "Did Regulation Keep Pace with Technology?" in Harvey M. Sapolsky, et al, *The Telecommunications Revolution* (London: Routledge, 1992), 19.

said that state commissions could not regulate in conflict with FCC regulations governing the same equipment. Affirming the FCC action, the Court of Appeals agreed that separation of terminal equipment used exclusively for local communications is a practical and economic impossibility: "Usually it is not feasible, as a matter of economics and practicality of operation, to limit the use of such equipment to either interstate or intrastate transmission."[29]

The Court quoted Judge Warren Burger, later a Supreme Court justice, who said that the Communications Act "must be construed in light of the needs for comprehensive regulation and the practical difficulties inhering in state by state regulation of parts of an organic whole."[30] However, said the Court, "The FCC is deprived of regulatory power over local services, facilities, and disputes concerning telephone service which, in their nature and effect, are separable from and do not substantially affect the conduct or development of interstate communications."[31]

Extending the federally backed right of interconnection to PCS will help to prevent discrimination by the LECs and to promote the fulfillment of obligations to provide open network architecture.

Type of Interconnection

The FCC *Notice* said that PCS providers should be entitled to obtain a type of interconnection that is reasonable for the particular PCS system and no less favorable than that offered by the LEC to any other customer or carrier. The Commission remarked that such a policy would further the federal goal of ensuring the development of PCS service. If the LEC were already providing interconnected service to another

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[29] *North Carolina Utilities Commission v. FCC*, 537 F.2d 787 (1976), 791.

[30] Ibid., 796; quotation from *General Telephone Co. of California v. FCC*, 1969, 134 U.S. App.D.C. Cir. 116, 413 F.2d, 390, 398.

[31] Ibid.

customer or carrier, the Commission said it would be technically feasible for the LEC to provide such interconnection to a PCS provider.[32]

The reactions of commenters to the *Notice* provide both a list of concerns on interconnection and a sense of where the various players fall on their own assessment of how they stand to gain from PCS. Regional holding companies and LECs endorsed enthusiastically the goal of assuring fair terms of interconnection. Other participants were more likely to point out barriers to achievement of the goal. The comments of the various types of potential providers are interesting because of these veiled worries, as well as for what was explicitly stated. The relative coolness of the non-LEC players to an affirmation of the right to equitable terms of interconnection suggests an underlying concern that some players are more equal than others. Commission commenters to the FCC *Notice* were among those espousing fair interconnection. The New York Public Service Commission said PCS providers should be entitled to obtain a type of interconnection that is reasonable for their particular system and no less favorable than that offered by the LEC to an affiliate, customer, or any other carrier."[33]

Regional holding companies and LECs were supportive of interconnection equal in quality and price for PCS providers. Bell South noted that interconnection standards would be needed for both the communications path between the caller and called party and for the internal links connecting components of a PCS network, including the microcell sites, switches, controllers, computers, and databases.[34] Several regional holding companies agreed with the FCC that particular types of interconnection should

[32] *Notice*, 40.

[33] FCC, *Comments of the New York State Department of Public Service on the Notice of Proposed Rulemaking*, GEN Docket 90-314, November 6, 1992, 3.

[34] Wiley, Rein & Fielding, *Summary of Opening Comments: Notice of Proposed Rulemaking on Personal Communications Services*, GEN Docket 90-314, ET Docket 29-100; *Comments of BellSouth*, 27.

not be mandated for the time being, since there might be many appropriate forms of interconnection.[35]

A number of telephone companies expressed approval of the concept that interconnection should be equal for all PCS providers.[36] Interconnection standards should be based on standards of technical and economic feasibility and reciprocity, said Rochester Telephone.[37] The U.S. Telephone Association said, "The Commission has long required exchange carriers to define appropriate interconnection upon reasonable demand and on terms no less favorable than provided to telephone affiliates."[38] GTE and Telephone and Data Systems also cited existing commission rules on nondiscriminatory interconnection, suggesting that they would be adequate for PCS.[39]

Cincinnati Bell pointed out that interconnection equal in quality and price was a two-way street: "CBT anticipates that full interconnection among all PCS providers will be required by the Commission and that PCS providers will be required to provide, in turn, the same level of access to the LECs."[40] Interconnection assumes interoperability, said Cincinnati Bell, and that is the key to universal deployment.

Few cellular companies commented on interconnection types and parity. SNET Cellular remarked that the LECs had the opportunity to provide advanced network

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[35] Ibid., *Comments of U S West,* 188; *Comments of Pacific Telesis Group,* 121; *Comments of PacTel Paging,* 287.

[36] Ibid., *Comments of Centel,* 42; *Comments of Concord Telephone,* 57; *Comments of GTE,* 75; *Comments of Roseville,* 152.

[37] Ibid., *Comments of Rochester Telephone,* 148.

[38] FCC, *Comments of the United States Telephone Association,* GEN Docket 90-314, ET Docket No. 92-100, November 9, 1992, 33-5.

[39] Wiley, Rein & Fielding, *Comments of GTE,* 75; *Comments of TDS,* 170.

[40] FCC, *Comments of Cincinnati Bell Telephone Company,* GEN Docket 90-314, ET Docket 92-100, November 9, 1992, 3.

capabilities and functionalities for new services.[41] SNET recommended that the LECs work with industry bodies to develop useful, nationwide standard access arrangements, with the recognition that different arrangements might be necessary for various PCS carriers."[42] The company said interconnection of wireless and wireline networks would accommodate broader geographic coverage, customer "ease of use" and network functionality. Customers could be located and validated easily on a real time basis. SNET said it would be in the interest of the public to let service providers select, bundle and resell these network based services to efficiently and cost effectively meet customer needs.

Among the interexchange carriers, MCI called for full parity of PCS providers and the LECs:

> The Commission should declare that PCS carriers have cocarrier status with local exchange carriers, have a federally protected right of interconnect that includes the right to their own telephone numbers, the right to participate in the settlements processes with other telephone companies, and have the federally protected right of interconnect at the Class V level as equals.[43]

MCI called for the Commission to establish policies to foreclose anticompetitive pricing by the LECs. Citing a cost of interconnect for cellular carriers of $.05 to $.10 per minute, MCI said it would be impossible for a PCS carrier to offer low-rate services on that basis.[44] MCI suggested that equal access must include signaling and database access in addition to voice.

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[41] FCC, *Comments of the Southern New England Telecommunications Corporation,* GEN Docket 90-314, ET Docket 92-100, 4.

[42] Ibid., 8.

[43] FCC, MCI Telecommunications Corporation, *Comments,* GEN Docket 90-314, 20.

[44] Ibid., 21.

Two cable companies were openly wary of the potential for abuse of the bottleneck connection with the landline telephone networks: Cablevision predicted that without a right of interconnection, LECs might attempt to stifle competition to their own services by offering inferior interconnection and excessive access charges.[45]

Cox Cable, which holds a pioneer preference, gave an extended discussion of interconnection issues. The company called for interconnection that would be high quality, broadly available, unbundled, and cost-based:

> The Commission should use PCS as a means to open up local exchange competition through adoption of mandatory cost-based network unbundling, number portability, cocarrier compensation and equal access to LEC signalling systems and informational databases. Additionally, to the extent a PCS provider switches and terminates a call for a LEC, just as PCS providers will pay LECs for this service, reciprocal compensation must be required... It is a measure of the overwhelming control landline carriers have over cellular carriers that such an obviously fair requirement, adopted by the Commission in 1987, has never been successfully enforced.... The frustrating experiences of interexchange carriers, cellular service providers and alternative access providers in seeking fair, cost-based interconnection from the LECs should be instructive as the Commission attempts to fashion its PCS ground rules. The Commission must develop rules and policies that recognize the continuing LEC incentives to forestall true local competition.[46]

Cox suggested that compensation between LECs and PCS providers should be reciprocal and that the rules and principles established by the FCC in its expanded interconnection proceedings should be applied to PCS.[47]

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[45] Wiley, Rein & Fielding, *Comments of Cablevision*, 89.

[46] FCC, *Comments of Cox Enterprises, Inc.*, GEN Docket 90-314, ET Docket 92-100, November 9, 1993, 23-4.

[47] Ibid., 25.

In its reply comments, Cox was equally caustic:

> While... proposed PCS interconnection principles are a useful starting point for consideration, they fall far short as a mechanism to open up local exchange competition. Competition will begin only when the Commission requires that LECs provide mandatory cost-based network unbundling, number portability, cocarrier compensation, equal access to LEC signalling systems and informational databases, and reciprocal compensation for carrier-provided switching and termination functions. General statements supporting a PCS federal interconnection right... are insufficient to achieve the commission goal of developing PCS as a competitive alternative.[48]

LEC Intrastate Interconnection Rates

The FCC found in the March 1994 *Second Report and Order* that LEC costs in providing interconnection for interstate and intrastate cellular services could be segregated and did not preempt state regulation of LEC intrastate interconnection rates for cellular, paging, or PCS.[49] The Commission laid down some basic rules for LEC provision of interconnection but left some decisions to further proceedings.

FCC requirements are:

1. Mutual compensation: LECs must compensate commercial mobile radio service providers for the reasonable costs incurred by the providers in terminating traffic that originates on LEC facilities. The radio providers, in turn, must compensate LECs for costs incurred with traffic originating in their systems and terminating on LEC facilities.

2. Reasonable charges: LECs must establish reasonable charges for interstate interconnection.

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[48] FCC, *Cox Enterprises, Inc., Reply Comments,* GEN Docket 90-314, ET Docket 92-100, January 8, 1993, 28.

[49] FCC, *Regulatory Treatment of Mobile Services*, Second Report and Order, GEN Docket 93-252, March 7, 1994, 88.

3. Comparable interconnection arrangements: Unless technically infeasible or economically unreasonable, the type of interconnection a LEC makes available to one carrier must also be available to others.[50]

Several other issues remain to be clarified. Table 5-4 lists the new proceedings that will be coming up. Issues to be considered include contracting versus tariffing arrangements, equal access obligations, and whether to require commercial mobile radio service providers to provide interconnection to other carriers. The Commission said that experience with cellular interconnection issues and review of comments in the PCS proceedings convinced them that the current system of individually negotiated contracts between LECs and cellular providers needed review. The Commission intended to propose new rules on the question of whether to require LECs to tariff all interconnection rates. The new notice of proposed rulemaking might also request comment on whether the FCC should mandate specific tariff rate elements and, if so, how they should be structured. A decision on equal access obligations was to be addressed in the context of a pending petition by MCI.

Finally, the Commission said that the issue of radio providers providing interconnection to other carriers was too complex to be resolved in the current proceeding and would be explored in a notice of inquiry. Analysis of this interconnection issue must acknowledge that commercial mobile radio service providers do not have control over bottleneck facilities, said the Commission. The Commission remarked that it did not want to encourage a situation where most commercial traffic must go through a LEC for a subscriber to reach a subscriber to another mobile radio service. One example of an issue to be addressed through the new notice was whether the obligations of mobile radio providers included access to mobile location databases and routing information to interexchange carriers and others. If interconnection was required of all commercial mobile radio service providers, the statute would preempt state regulation of interconnection rates of those providers, said the Commission.

[50] Ibid., 89.

TABLE 5-4

FUTURE FCC PROCEEDINGS ON REGULATION OF MOBILE SERVICES
(As of June 1994)

- Notice of inquiry to determine whether commercial mobile radio service licensees should be required to provide interconnection to other carriers, define the scope of such obligations and explore requiring mobile radio providers to allow resale.
- Proceeding on whether to impose equal access obligations on all mobile service providers.
- Notice of proposed rulemaking on licensing requirements.
- Notice of proposed rulemaking on whether LECs should be required to file interconnection rate tariffs for radio providers.
- Notice of proposed rulemaking to establish monitoring provisions for cellular licensees.
- Proceeding on whether further Title II forbearance actions for specific mobile providers are warranted.
- Proceeding on whether prohibition of common carriers providing dispatch service should be removed.

Source: FCC, *Regulatory Treatment of Mobile Services, Second Report and Order*, GEN Docket 93-252, March 7, 1994.

Resale of commercial mobile service was another issue to be explored in this notice of inquiry.[51]

State regulatory commissions have an interest in the further federal efforts to pave the way for PCS because of the commissions' responsibility to prevent cross-subsidization of unregulated affiliates by the regulated landline network. Commenting on the FCC *Notice*, Pacific Telesis said PCS providers should have the option of

[51] Ibid., 89-90.

obtaining switching, database access, access management, radio controllers and/or ports in support of PCS services from the LECs.[52] U S West similarly provided a list of services the network might be able to provide: transport, switching, network intelligence, collection of billing data and customer validation.[53] States are likely to want to keep track of services being provided by the LECs, the extent to which services are unbundled, their prices, and the extent of reciprocity in the arrangements.

Common Carriage

In one fell swoop, Congress in the Budget Act disposed of an increasingly murky set of distinctions between common and private carriage. While settling some problems, however, they may have raised new ones.

Distinctions between Common and Private Carriage

A "common carrier" or "carrier" under the Communications Act "means any person engaged as a common carrier for hire, in interstate or foreign communication by wire or radio."[54] This definition is unhelpful, in fact, tautological. An understanding of the meaning of the term "common carriage" requires looking at case law. In general, "a 'common carrier' is one who holds himself out as furnishing transportation to any and all members of the public who desire such service insofar as his facilities enable him to perform the service."[55] Common carrier services involve a holding out to the public, in

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[52] Wiley, Rein & Fielding, *Comments of Pacific Telesis Group,* 45.

[53] Ibid., *Comments of U S West*.

[54] 47 *U.S.C.* 153 (h) (1993).

[55] *Mt. Tom Motor Lines v. McKesson & Robbins*, 325 Mass. 45 89 N.E.2d3 (1949); cited in *Words and Phrases*, 15.

contrast to private carriage, which involves individualized decisions regarding the terms and conditions of service offerings.[56]

Telephone companies were and are considered common carriers of communication, but for radio communications the applicability of the Communications Act definition of common carriage suffered erosion over the years. Cellular companies were designated as common carriers. But an increasingly broad array of radio service providers were designated as private land mobile radio service and not subject to the same requirements as common carriers.

By 1988 the FCC had expanded the pool of eligible users of private radio services to include individuals and the federal government, rendering foreign governments the only group barred from obtaining licenses. This pool of users was nearly identical to those served by common carriers.

In the *Fleet Call* case, the FCC expanded the effective definition of private land mobile radio service still further.[57] Fleet Call asked for a waiver to permit creation of digital, specialized mobile radio systems in six markets with congested frequencies. Commenters contended that Fleet Call's service would constitute common carriage, pointing to its concentration on interconnected service, combined with a multiple base station configuration. The commission said a multiple base station configuration and interconnected telephone-type services were allowed under current rules. NARUC argued bitterly against considering Fleet Call a private carrier but did not prevail and a NARUC petition for reconsideration was dismissed on procedural grounds. NARUC decided to pursue the matter in other FCC dockets.

Thus, when it came time to decide whether PCS should be considered common or private carriage, federal regulators were saddled with a bizarre categorization based on historical policy decisions rather than real distinctions in technology or customers. Commenters to the *Notice* had by and large objected to considering PCS private carriage.

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[56] *NARUC v. FCC* 525 F. 2d 630, (D.C. Cir. 1976).

[57] FCC, *Memorandum Opinion and Order* 6 FCC Rcd. 1533, February 15, 1991.

The objections were not based on explicit legal reasoning but seemed largely due to fears that private carriage designation would put LECs and cellular providers at a practical disadvantage.

The Congressional decision to broaden the applicability of the common carriage designation was interpreted by the FCC to require a new category of commercial mobile service providers. In its March 1994 *Order* on regulation of mobile services the FCC said such service must be provided for a profit, interconnected to the public switched network, and available to a substantial proportion of the public.[58] Existing services in this category would include cellular, paging, and specialized mobile radio, as well as others. PCS was classified presumptively as commercial mobile radio service. A PCS applicant or licensee would be regulated as a commercial carrier but could offer private PCS if it made a showing that it did not fall within the statutory definition of commercial service and was not the functional equivalent of a service that meets the three-part test.[59]

The FCC agreed in their March *Order* with a NARUC contention that the state and federal commissions should work together to develop methods to monitor mobile services to decide whether particular private services continue to deserve that classification. The FCC agreed that federal-state cooperation on monitoring was reasonable and expressed a commitment to meet informally with the NARUC Communications Committee to discuss monitoring.[60]

Is the Common Carriage Designation Correct?

Even under the old rules of distinguishing private from common carriage in radio communications, a strong case can be made that PCS is indeed best considered a

[58] FCC, *Second Report and Order*, March 1994, 99.

[59] Ibid., 100.

[60] FCC, *Second Report and Order*, March 1994, 97.

common carrier. Analysis of the service descriptions of PCS proposed by Telocator (see Chapter 4) against the pre-1993 definition of private land mobile radio service in the Communications Act suggests that for many services, and especially for the "anywhere, anytime pocket telephone" the designation as common carriage is appropriate. In assessing the degree of commonality or privateness of a service proposed under the PCS *Rules*, we suggest something like the set of tests shown in Figure 5-3. The criteria have to do with (1) the degree to which the service users form a discrete, limited group, (2) the extent to which the service is interconnected with the public switched telephone network, and (3) the use of the wireline network. Figure 5-4 shows how these criteria might be applied to a sample group of existing and emerging wireless services. The results suggest that many existing services constitute common carriage, whether or not they were so classified under the Communications Act before the 1993 amendments. Even more important, the trend is towards common rather than private services and a presumption that PCS is common carriage makes sense now and in the future.

The regularization of rules on common carriage improves the accuracy of the distinctions between private and public. At the same time it could impose burdens for PCS entrants. For example, ordinarily the designation of common carriage implies that a provider must live up to standards of service quality. It may be questioned whether new PCS providers can live up to the same standards as existing cellular providers, not to mention, of course, wireline providers. Interference with the signal is a hazard of radio transmission and not of the landline network. Standards appropriate to the new type of provider will need to be designed and are in fact being undertaken by the industry.

The common carriage designation also brings with it an obligation to build out the PCS network within a service territory. The federal rules establish strict deadlines for completion of PCS networks, a requirement in accordance with the obligation of being a common carrier. As common carriers, PCS providers will have to be generous in signing on customers who may be poor credit risks and lenient in terminating service for customers who have not paid their bills. This may be a somewhat onerous requirement for fledgling companies but is part of common carriage responsibility.

1. To what extent are the service users a discrete limited group?

highly discrete group	some "leakage" to wider group	users are not significantly differentiated by occupation or other affiliation

2. To what extent is the service interconnected with the public switched network?

no intercon-nection	interconnected for incoming or outgoing calls, but not both	interconnected for both incoming and outgoing calls

3. What is the use of the wireline network?

spectrum is used directly to generate profits in another line of business from switched tele-phone service	profits are generated by reselling the use of spectrum	profits are generated by the fact of interconnection with the public network

Figure 5-3. Criteria for deciding whether a wireless service is private or common carriage. (See Figure 5-4 for application.)

Source: Authors' construct.

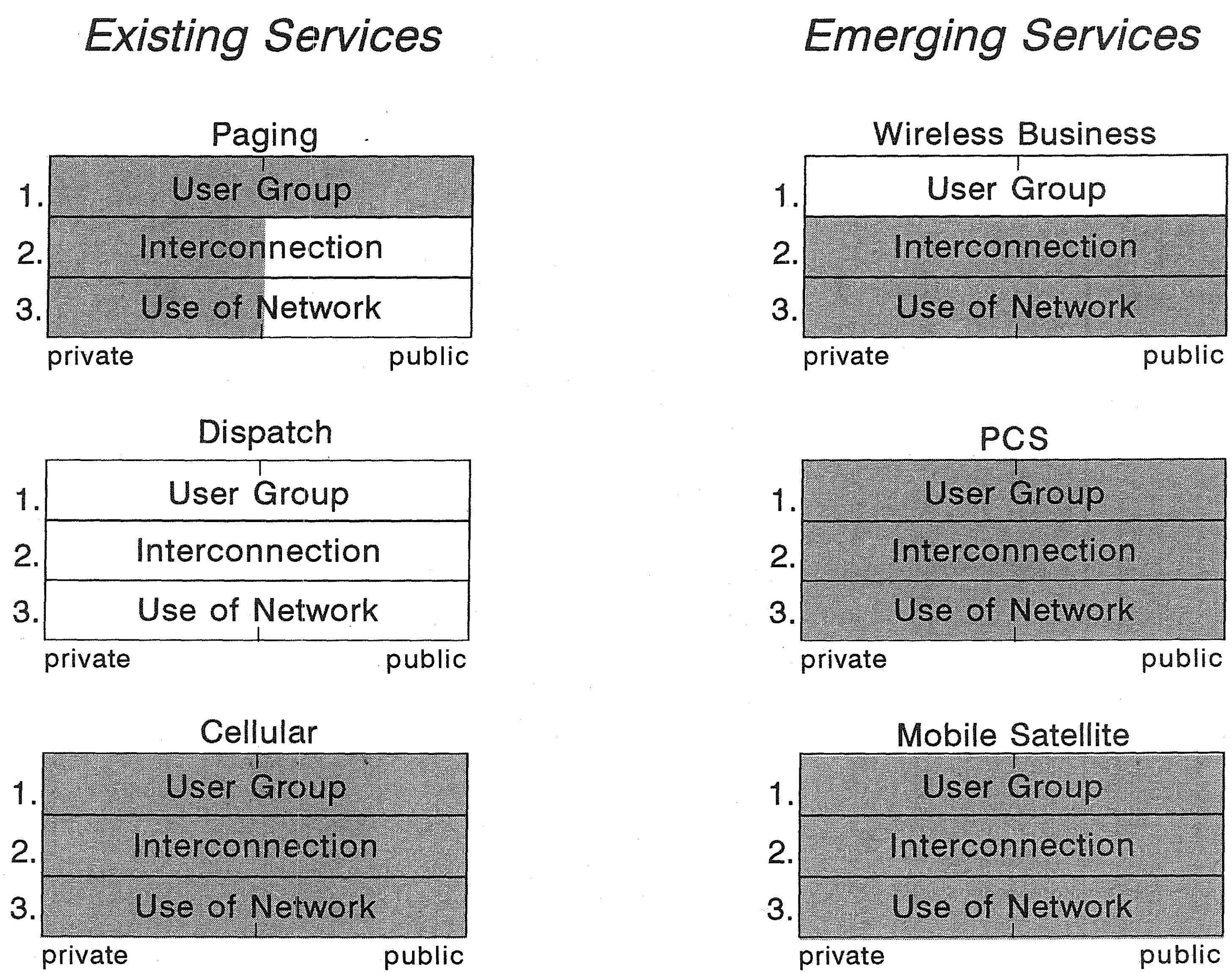

Figure 5-4. Application to selected services of criteria for deciding whether a wireless service is private or common carriage. (See Figure 5-3 for definitions of criteria.)

Source: Authors' construct.

Universal Service

"Universality" was one of the goals mentioned in the *Notice* to be maximized in setting the regulatory framework for PCS. Yet there is little mention of it thereafter. Presumably the FCC avoided explicit consideration of how to achieve universality because competition can be expected to bring PCS to everyone who wants it. But the federal framework for PCS has implications for universal service that have yet to be explored.

Given the market projections in Chapter 4 of this report, PCS is likely to be a premium service for at least a decade. If it becomes universally available and is widely regarded as something people cannot do without, commissions might eventually want to include PCS in basic service.

In the meantime there could be areas or particular subgroups for whom PCS would be considered basic service very quickly. Some rural areas or new developments may now be served better and cheaper by radio. The LECs are well positioned to bring PCS to more sparsely settled areas. And there already is potential for economies of scale when combining cellular vehicular service and local radio service in some parts of the country. The basic exchange telecommunications radio service program (BETRS) has helped bring the telephone to rural areas of the country that otherwise would have been extremely expensive to serve. However, radio can provide both voice and data, but not all the services of the infobahn. Rural dwellers may not be willing to settle for anything other than full interactive video. And the Clinton administration has promised that interactive video will be available at least to every school and hospital in the country, no matter where they are, if not to every home.

If universal service is still a national goal owed more than just lip service, then the country should not be satisfied with the existing overall 93 percent penetration rate for telephone service nationally and the much lower penetration rate for certain minorities and low-income people.[61] Affirmative programs to make PCS available to specific

[61] NARUC Universal Service Project: Staff White Paper, February 1994, 21.

groups would increase their access to employment, emergency services, and other functions of mainstream America.

Conclusion

The FCC and Congress have laid the groundwork for a PCS industry with many players and little government intervention. Whether competition develops remains to be seen as some 2,000 potential licenses are auctioned off for PCS beginning late in 1994. Multiple providers and overlapping service areas would make direct regulation of PCS messy and unnecessary in the eyes of most state regulatory commissions, even if the federal regulatory framework did not preclude them from rate and entry regulation of the budding industry.

If the healthy competition anticipated and planned for by the FCC develops in PCS services, most states may have little to regret in federal preemption of regulation of the nascent industry. If on the other hand competition does not develop and the organization of the mobile service industry takes bizarre and unforeseen turns, and yet consumers become more dependent on mobile communications, there may be states that wish they had taken a more proactive stance. Witness the airline industry after deregulation. The hub-and-spoke system of airline service, which has resulted in virtual territorial monopolies for some cities, was not anticipated. Where expansion of consumer choice was desired, consolidation that restricted choice was a result. States, which are closer to the consumer than the federal government, may be in a better position to monitor competition in new wireless services and be alert to the growth of situations and practices that are not in the public's best interest, such as the development of PCS fiefdoms.

If and when market conditions fail to protect consumers or PCS replaces a substantial portion of landline service, states can still petition the FCC to regulate rates and entry. In the meantime the authority to regulate other terms and conditions of PCS service and interconnection rates gives the states some leverage.

CHAPTER 6

ENABLING THE TECHNOLOGIES OF SAND, GLASS, AND AIR

The vision of AT&T's Theodore Vail in the 1930s was of a hierarchical, unified network. That vision came to pass. The unified system was not simple, as any regulator who has struggled with the separations process will tell you. But it was one system, an organic whole. The "technologies of sand and glass"—the computer chip and fiber optic cable—are bringing revolutionary services to consumers and creating new modes of organization to deliver them.[1] New uses of radio—technologies of the air—contribute to the fragmentation and opening up of old architectures and delivery systems. Demand studies show that many people want what radio can give and other technologies cannot—portability, and with it a new kind of freedom. Even the most conservative studies of demand show many millions of Americans using PCS within a few years of its introduction.

Potential providers of PCS want another kind of freedom—the freedom to compete fairly as they develop the exciting market for advanced wireless communications. A healthy market for new wireless technologies will answer the question of just how many people want what type of wireless service at what price. But providers of wireless telecommunications cannot be completely autonomous because their services must for the foreseeable future be interconnected with the wireline network—and not only with the physical aspects, which have their own history and quirks, but with the databases, the signalling systems, the operating systems, and the associated regulatory, legal and economic frameworks. Some of the most significant questions to be answered to enable the new technologies of the air have to do with establishing necessary terrestrial linkages. The regulated LECs will be both competitors and providers of PCS. As wireline competitors to wireless networks, they may not be

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[1] George Gilder, "Dark Fibers and Free Bandwidth: The Future of Telecommunications," *Regulation* 2 (1993): 24.

inclined to subscribe wholeheartedly to principles of open network architecture and expanded interconnection when that will lead to reduced revenues. And insofar as the public switched network is bypassed, consumers of basic service must shoulder the load of landline costs. As providers of PCS themselves, the LECs are even less likely to be congenial hosts to PCS calls initiated or completed on their systems. Yet access to the databases and the intelligence of LEC networks is essential to the survival of PCS providers.

A modeling of the likely architecture of PCS shows the battleground on which economic efficiency and engineering efficiency must come to terms. No one player will be able to build the entire network, and by far the largest cost of a PCS network is the landline links to base stations. We can predict which players will have an advantage for which network segments. The LECs have a clear edge with their installed base of wireline switches and lines. David Reed's cost study for the FCC, while having some flaws, agrees with the intuition of the authors of this report on relative advantages expected for potential players with existing infrastructure.

The cost structure of PCS suggests that *de novo* entrants will be at a significant disadvantage. Business alliances of various kinds are likely. It also suggests that even established cable and cellular companies will need the resources of the landline network. Interconnection arrangements will be crucial. Yet the history of interconnection between LECs and long distance companies has demonstrated that refusal of interconnection or discriminatory rates can have deleterious effects on competition and the survival of entrants. Compared to other components of a once seamless system that were separated out, like customer premises equipment and long distance, wireless in the local loop may be much more difficult to untangle from the public network. If access is all that is needed for PCS to evolve, principles of open network architecture and expanded interconnection will apply. Achieving "true" PCS, however, requires a degree of transparency and seamlessness that will simulate a unified network.

The FCC is attempting to establish an initial regulatory framework within which competition can thrive. PCS and other wireless will be considered common carriage, which helps to assure fairness. But at its very best, the market for PCS will be an oligopoly, and one in which one of the major players has an edge over the others. A half dozen PCS providers, a cable company, and a telephone company would be many more providers of local telephone service than exist now but probably not enough for the market to be called fully competitive. Such a market is most likely to look like a "dominant/nondominant" one. At the beginning, the LECs and other existing cellular providers are likely to dominate. Perhaps that will lessen over time. It could also get worse, with PCS provision effectively consolidating among one or two providers. In rural areas there might never be a PCS provider, or one at best, and that one an offspring of the telephone company.

What states can do to enable wireless communications technologies is limited but important. The federal regulatory framework cuts the states out of direct oversight of PCS. As mentioned in Chapter 5, few states are affected by preemption because they are not fully regulating cellular. States still, however, have oversight of interconnection rates. State regulators should create an environment for investment and deployment of PCS networks that is stable and facilitates competition. We believe that successful state regulatory policies are likely to include (1) review of local rate structures, (2) monitoring (3) judicious supervision of the terms and rates of interconnection with the public switched network, and (4) restraint.

Review of the pricing of local exchange, including rate groups and deaveraging, is called for by the advent of PCS, as well as other types of local competition. This needs to be juxtaposed against requirements of universal service policy but would aid in giving accurate price signals to customers comparing PCS and landline service.

One of the most important things the states can do is monitor the development of PCS. This can be accomplished through the authority to regulate "other terms and conditions" of PCS, as allowed by Congress, as long as the requirements are not onerous. Monitoring will help to spot antitrust difficulties and barriers that are raised to competition. The FCC has established a large number of service areas and potential competitors. The service areas overlap state boundaries, making oversight more difficult. Regional sharing of information may be a good idea. It is unlikely that a state Attorney General's office can provide the quality and intensity of oversight that a public service commission can. The public service commission has unique expertise in dealing with telephone pricing issues and the oversight role is a natural use of its powers. In order to fulfill commission responsibility to prevent cross subsidization of unregulated affiliates by the regulated landline network, commissions will need to review LEC tariffs providing interconnection with PCS providers for congruence with open network architecture principles. State regulators must pay careful attention to the interconnection arrangements developed for PCS providers and assure that all parties are treated fairly and that diffusion of PCS is not artificially inhibited. Commissions must be particularly alert to footdragging of the sort described at the end of Chapter 3, where providers maneuver for short-term advantages on interconnection while readying themselves to be first with a unified PCS network.

Regulators should not become the arbiters of competitive disputes unless there are clear grounds for action. They should refrain from micromanagement of telephone companies in an era when minimal, carefully targeted regulation that will not inhibit competition is expected and, indeed, all that is allowed in many states.

Anywhere, anytime pocket telephones are easy to imagine. It must be emphasized, however, that the future of personal communications services and local competition in general is uncertain. We do not know what the "killer applications" (as the telecommunications industry likes to call key, foot-in-the-door uses) are for the technologies of sand, glass, and air. What will be the relationship of tetherless communications to the notion of fiber to the home? Will it be the box on top of the TV set or the personal computer that brings the infobahn to America? How long will it take? What kind of service should be universal? Competition can answer many of these questions, but you cannot have competition in telecommunications without interconnection. And interconnection requires rules, which often must be backed by one or more levels of government. State commissions have the responsibility and the obligation to help assure the development and execution of fair interconnection policies.

APPENDIX

MARKET TESTS OF PERSONAL COMMUNICATIONS SERVICES BY STATE

State	City	Company	Test Specifications	Test Dates
AL	Birmingham	BellSouth Telecommunications (2)[1]	Tests of wireless access business systems; 60 bases, 800 portable units	2/6/91-1/1/95
	Baldwin, Clark, Conecuh, Escambia, Mobile, Monroe, and Washington Counties	Gulf Telephone Company	PCS test; 100 bases, 1,000 handunits	11/8/93-3/1/95
AK	Anchorage	Prime II Management (5)	Development of PCS equipment by cable company; 100 bases, 1,000 handunits	8/21/92-7/1/94
AZ	Phoenix	American Portable Telecommunications (4)	10 bases, 1,000 handunits	12/21/91-1/1/96
	Phoenix	Linkatel Communications, Incorporated (4)	PCN,[2] 10 bases, 100 handunits per city	2/27/92-5/1/94

[1] Numbers in parentheses are the total number of states with sites of the market test. For example, the BellSouth test is being conducted in Atlanta as well as Birmingham.

[2] Personal communications network.

MARKET TESTS OF PERSONAL COMMUNICATIONS SERVICES BY STATE (Continued)

State	City	Company	Test Specifications	Test Dates
AZ	Phoenix	Optimum Communications (7)	PCS test; 5 bases, 50 handunits per city	8/17/92-7/1/94
	Phoenix	Times Mirror Cable Television (5)	PCS test; 200 bases, 1,000 handunits	3/29/93-10/1/94
AR	None			
CA	Southern California	American Telezone	Telepoint service; 4,000 public bases; 1,000 home bases; 15,000 handunits	10/19/90-7/1/94
	Concord	Concord TV Cable	PCS test; 100 bases, 1,000 handunits	3/17/92-1/1/94
	Fullerton Sacramento San Jose	Kycom	PCS test; 1,000 handunits per location	9/18/92-5/1/94
	Hemet	Inland Valley Cablevision	PCS test; 100 bases, 1,000 handunits	3/17/92-5/1/94
	Irvine Los Angeles San Diego	Times Mirror Cable Television (3)	PCS test; 200 bases, 1,000 handunits	3/29/93-10/1/94
	Long Beach and Los Angeles	Research Resources International (5)	PCS test near large seaport terminals; 100 bases, 1,000 handunits	3/17/92-8/1/94

MARKET TESTS OF PERSONAL COMMUNICATIONS SERVICES BY STATE (Continued)

State	City	Company	Test Specifications	Test Dates
CA	Los Angeles County	Metrophone	PCS test, 500 bases, 1,000 handunits	4/6/93-6/1/95
	Los Angeles	Associated PCN	Spread spectrum; 25 bases, 2,000 handunits	1/7/91-12/1/94
	Los Angeles	Cellular Services	PCS test; 100 bases, 500 handunits	12/6//91-1/1/96
	Los Angeles and San Francisco	GTE Mobile (5)	Test for possible use of ATG frequencies for mobile services	3/24/92-3/1/94
	Los Angeles and San Diego	Local Area Telecommunications	Spread spectrum; 100 bases, 1,000 handunits	3/16/92-5/1/94
	Los Angeles and San Francisco	McCaw Cellular (8)	PCS test; 1,000 units	4/29/92-6/1/94
	Los Angeles	Pathfinder Ventures (7)	PCS test; 500 bases, 5,000 handunits	2/24/92-7/1/93
	Los Angeles	Providence Journal Company (6)	PCS test; 50 bases, 1,000 handunits per city	8/10/92-7/1/94
	Palm Springs	Providence Journal Company (2)	PCS test; 50 bases, 1,000 handunits	8/10/92-12/1/94
	Los Angeles, San Diego, San Francisco, and San Jose	Rim Com (3)	PCS test; 500 bases, 5,000 handunits	2/24/92-8/1/93

MARKET TESTS OF PERSONAL COMMUNICATIONS SERVICES BY STATE (Continued)

State	City	Company	Test Specifications	Test Dates
CA	Orange County	PCS Partners	PCS test, 100 bases, 500 handunits	3/1/93-7/1/94
	Monterey	Monterey Peninsula TV Cable	PCS test; 100 bases, 1,000 handunits	3/17/92-6/1/94
	San Diego and San Francisco	Linkatel Communications, Incorporated (3)	PCN, 10 bases, 100 handunits per city	2/27/92-5/1/94
	Sacramento	2001 Technology, Incorporated	PCS test, 100 bases, 1,000 handunits	9/21/92-10/1/94
	San Francisco	Advanced Wireless (2)	Test of various CT-2 & PCN; test possible sharing w/ATG; 2 bases, 10 residential bases, 40 handunits	4/5/91-12/1/92
	San Francisco and San Jose	Digital Spread Spectrum Technologies	PCN and part 15; 1,000 units per city	2/20/91-1/1/95
	San Francisco	Metropolitan Fiber Systems of San Francisco	PCN with fiber optic support; 100 bases, 1,000 handunits	3/16/92-6/1/94
	San Francisco	Viacom International (5)	Use of cable to tie cells together; 1,000 bases, 10,000 handunits	3/12/92-11/1/94
	San Francisco	Western TV Cable	PCS test; 100 bases, 1,000 handunits	3/17/92-12/1/93
	San Francisco	The ZN Group (6)	PCS test in convention areas; 100 bases, 1,000 handunits	3/17/92-8/1/94

MARKET TESTS OF PERSONAL COMMUNICATIONS SERVICES BY STATE (Continued)

State	City	Company	Test Specifications	Test Dates
CA	Stockton	Continental Cablevision of California	Use of cable to tie cells together; 100 bases, 500 handunits	2/22/91-1/1/93
	Ventura	Ventura County Cablevision	PCS test; 100 bases, 1,000 handunits	3/17/92-11/1/93
CO	Boulder	U S West Communications (2)	PCS test; 6 bases, 6 handunits	9/4/92-11/1/95
	Colorado Springs	McCaw Cellular (3)	High speed point to multipoint data broadcast service; 200 units per city	4/29/92-6/1/94
	Colorado Springs	Optimum Communications (7)	PCS test; 5 bases, 50 handunits per city	8/17/92-7/1/94
	Denver	LDH International (3)	Phase I technical test; phase II market test; 100 bases, 2,000 handunits	9/21/92-10/1/94
	Denver	Pathfinder Ventures (7)	PCS test; 500 bases, 5,000 handunits	2/24/92-7/1/93
	Denver	Quantum Communications Group (2)	PCS test; 25 bases, 250 handunits	6/4/93-2/4/95
CT	Fairfield	Columbia Cellular Corporation (4)	PCS test; 25 bases, 500 handunits	6/4/93-1/13/95
	Hartford	Essex Communications (3)	PCS test; 100 bases, 1,000 handunits	3/17/92-2/1/94

MARKET TESTS OF PERSONAL COMMUNICATIONS SERVICES BY STATE (Continued)

State	City	Company	Test Specifications	Test Dates
CT	Hartford and New Haven	Wireless Communications Services (5)	PCS test, 10 bases, 100 handunits	3/25/93-11/1/95
DC	Washington	American Personal Communications	PCS test	7/1/92-7/1/94
	Washington	American Portable Telecommunications (4)	10 bases, 1,000 handunits	12/21/91-8/1/96
	Washington	Associated PCN Corporation (3)	Spread spectrum, 25 bases, 1,000 units	3/16/92-12/1/93
	Washington	Hauser Communications (5)	PCS test, 10 bases, 100 handunits per location	3/1/93-3/1/95
	Washington	MCI Telecommunications (2)	PCS test and test of roaming equipment; 12 bases, 500 handunits	4/23/93-6/1/95
	Washington	The ZN Group	PCS test in convention areas; 100 bases, 1,000 handunits	3/17/92-8/1/94
DE	None			
FL	Broward, Dade, and Palm Beach Counties	High Seas Technology	Test CT-2 equipment aboard ships; 15 bases, 20 handunits	8/17/92-3/1/94
	Fort Lauderdale, Miami, and West Palm Beach	Advanced Mobilcom	Part 15 spread spectrum device	8/1/90-12/1/94

MARKET TESTS OF PERSONAL COMMUNICATIONS SERVICES BY STATE (Continued)

State	City	Company	Test Specifications	Test Dates
FL	Fort Lauderdale	Motorola	PCS test; 50 bases, 1,000 handunits	4/21/92-6/1/94
	Fort Myers	Providence Journal Company (2)	PCS test; 50 bases, 1,000 handunits	8/10/92-7/1/94
	Miami	Providence Journal Company (6)	PCS test; 50 bases, 1,000 handunits per city	8/10/92-7/1/94
	Gainesville	TRX Transportation Telephone Company	PCS test; 10 bases, 100 handunits	7/1/92-10/1/94
	Jacksonville	Continental Cablevision of Jacksonville	Use of cable to tie cells together; 100 bases, 500 handunits	2/22/91-1/1/93
	Jacksonville and Orlando	Hauser Communications (4)	PCS test, 10 bases, 100 handunits per location	3/1/93-3/1/95
	Miami	Alliance Telecom, Incorporated	PCS test, 10 bases, 100 handunits	6/4/93-12/1/95
	Miami and Tampa	American Portable Telecommunications	10 bases, 1,000 handunits	12/21/91-1/1/96
	Miami, Orlando, and West Palm Beach	McCaw Cellular (6)	PCS test; 1,000 units	4/29/92-6/1/94
	Miami	The ZN Group (6)	PCS test in convention areas; 100 bases, 1,000 handunits	3/17/92-8/1/94

MARKET TESTS OF PERSONAL COMMUNICATIONS SERVICES BY STATE (Continued)

State	City	Company	Test Specifications	Test Dates
FL	Orlando and Tampa	Intermedia Communications of Florida	Development of PCS equipment; 50 bases, 2,000 handunits	12/6/91-4/1/93
	Orlando	PCN America (Millocom) (2)	Spread spectrum digital system	5/8/90-5/1/92
	St. Petersburg and Tampa	Wireless Communications Services (2)	PCS test; 40 units	5/15/92-11/1/94
	Tampa	Teco Energy, Incorporated	PCS test; 1,200 units	10/8/92-10/1/94
GA	Athens	BellSouth	CT-2 service; cellular frequencies; 100 units	11/30/90-12/1/92
	Atlanta	BellSouth (2)	Tests of wireless access business; 60 bases, 800 portable	2/6/91-1/1/95
	Atlanta	GTE Mobile Communications	Test for possible use of ATG frequencies for mobile services; 20 bases, 100 handunits	3/24/92-1/1/94
	Atlanta	LDH International (3)	Phase I technical test; phase II market test; 100 bases, 2,000 handunits	3/15/91-5/1/93
	Atlanta	Motorola	Spread spectrum (2)	6/1/92-6/1/94
	Atlanta	Pathfinder Ventures (7)	PCS test; 500 bases, 5,000 handunits	8/17/92-6/1/94

MARKET TESTS OF PERSONAL COMMUNICATIONS SERVICES BY STATE (Continued)

State	City	Company	Test Specifications	Test Dates
GA	Atlanta	Prime II Management (5)	Development of PCS equipment by cable company; 100 bases, 1,00 handunits	8/21/92-7/1/94
	Atlanta	Telmarc Telecommunications (4)	PCS test; 10 bases, 100 handunits	6/4/93-10/1/95
	Macon	Middle Georgia Personal Communications	PCS test; 100 bases, 175 handunits	8/17/92-6/1/94
HI	Honolulu	Optimum Communications (7)	PCS test; 5 bases, 50 handunits per city	8/17/92-7/1/94
	Honolulu	Rim Com (7)	PCS test; 500 bases, 5,000 handunits	2/24/92-5/1/94
	Kahului	Chronicle Cablevision of Hawaii	PCS test; 100 bases, 1,000 handunits	3/17/92-5/1/94
ID	Boise	U S West Communications	PCS test; 1,500 bases, 1,500 handunits	1/18/94-11/1/94
IL	Chicago	Ameritech Direct	Spread spectrum (CDMA, TDMA); 100 bases, 1,000 handunits	2/22/91-12/1/95
	Chicago	Associated PCN Corporation (3)	Spread spectrum; 25 bases, 1,000 handunits	3/16/92-12/1/93

MARKET TESTS OF PERSONAL COMMUNICATIONS SERVICES BY STATE (Continued)

State	City	Company	Test Specifications	Test Dates
IL	Chicago	Cablevision (4)	PCN interfacing with existing cable system; possible sharing with CARS service at 13 GHz; 200 bases, 2,000 handunits	3/9/92-1/1/95
	Chicago	GTE Mobile (6)	Test for possible use of ATG frequencies for mobile services	3/24/91-3/1/94
	Chicago	Goeken Customer Communications (2)	28 GHz to tie microcells to switches; 5 bases, 50 handunits per city	10/30/91-4/1/95
	Chicago	Metropolitan Fiber Systems of Chicago	PCN with fiber optic support; 100 bases, 1,000 handunits	3/16/92-6/1/94
	Chicago	Motorola (2)	Spread spectrum	6/1/92-6/1/94
	Chicago	Pathfinder Ventures (7)	PCS test; 500 bases, 5,000 handunits	2/24/92-3/1/94
	Chicago	Prime II Management (5)	Development of PCS equipment by cable company; 100 bases, 1,000 handunits	8/21/92-7/1/94
	Chicago	SM TEX	PCS test; 5 bases, 50 handunits	9/24/92-9/1/94
	Chicago	Telmarc Telecommunications (4)	PCS test; 10 bases, 100 handunits	6/4/93-10/1/95

MARKET TESTS OF PERSONAL COMMUNICATIONS SERVICES BY STATE (Continued)

State	City	Company	Test Specifications	Test Dates
IL	Golden	Adams Telecom	PCS test; 10 bases, 250 handunits	8/10/92-12/1/94
IN	Indianapolis	USA Mobile Communications (3)	TDMA & TDD (time division multiplexing); 4,000 total units	10/1/92-10/1/94
	Indianapolis	Wireless Communications Services (6)	PCS test, 10 bases, 100 handunits	3/25/93-11/1/95
IA	Cedar Rapids, Davenport, Des Moines, Ft. Dodge, Mason City, Sioux City, and Spencer	Iowa Network Service, Incorporated	PCS test; 100 bases, 1,000 handunits	9/21/92-4/1/94
KS	None			
KY	Louisville	USA Mobile Communications (3)	TDMA & TDD; 4,000 total units	10/1/92-10/1/94
LA	Alexandria, Lafayette, Lake Charles, Monroe, and Shreveport	Paramount Wireless Limited Partnership	PCS test; 5 bases, 200 handunits per city	8/10/92-7/1/94
	Ascension, Iberville, and West Baton Rouge	East Ascension Telephone	PCS test; 4 bases, 100 handunits	8/3/92-2/1/96

MARKET TESTS OF PERSONAL COMMUNICATIONS SERVICES BY STATE (Continued)

State	City	Company	Test Specifications	Test Dates
LA	Assumption, Lafourche, St. Charles, St. James, St. John, and Terrebonne	Reserve Telephone	PCS test, 4 bases, 100 handunits	8/3/92-8/1/94
	Baton Rouge and New Orleans	Freeman Engineering	PCS test to investigate switching, interconnection, and trunking problems; 1,000 units	3/20/92-2/1/94
	East Baton Rouge	Advanced Telecom	PCS test; 2 bases, 200 handunits	8/17/92-12/1/94
	New Orleans	The ZN Group (6)	PCS test in convention areas; 100 bases, 1,000 handunits	3/17/92-8/1/94
ME	None			
MD	Baltimore	American Personal Communications	PCS test	7/1/92-7/1/94
	Baltimore	Hauser Communications (5)	PCS test, 10 bases, 100 handunits per location	3/1/93-3/1/95
	Baltimore	Metropolitan Fiber System of Baltimore	PCN with fiber optic support; 100 bases, 1,000 handunits	3/16/92-6/1/94
	Montgomery County	Hughes Network Systems, Incorporated	PCS test; 10 bases, 1,000 handunits	9/21/92-3/1/94

MARKET TESTS OF PERSONAL COMMUNICATIONS SERVICES BY STATE (Continued)

State	City	Company	Test Specifications	Test Dates
MA	Boston	Advanced Mobilecom	Part 15 spread spectrum device, PCS test	8/1/90-12/1/94
	Boston	Atlantic Cellular Company (3)	PCN; 50 bases, 1,000 units	3/5/92-1/1/94
	Boston	Cablevision (4)	PCN interfacing with existing cable system; possible sharing with CARS service at 13 GHz; 100 bases, 1,000 handunits	3/9/92-1/1/95
	Boston	Continental Cablevision of Massachusetts	Use of cable to tie cells together; 100 bases, 500 handunits	2/22/91-1/1/95
	Boston	GTE Mobile Communications (6)	Test for possible use of the ATG frequencies for mobile services	3/24/92-3/1/94
	Boston	Metropolitan Fiber Systems/McCourt	PCN with fiber optic support; 100 bases, 1,000 handunits	3/16/92-6/1/94
	Boston	NYNEX Science & Technology (3)	115 public base stations, 200 home bases, 400 handunits	5/20/92-7/1/94
	Boston	Telmarc Telecommunications Company	PCS test; 10 bases, 100 handunits	8/17/92-10/1/94
	Suffolk and Worcester Counties	PCS 21, Incorporated	PCS test; 100 bases, 1,000 handunits	11/8/93-7/1/95

MARKET TESTS OF PERSONAL COMMUNICATIONS SERVICES BY STATE (Continued)

State	City	Company	Test Specifications	Test Dates
MI	Ann Arbor	Optimum Communications, Incorporated (7)	PCS test; 5 bases, 50 handunits per city	8/17/92-7/1/94
	Detroit and Grand Rapids	City Signals	PCN test with fiber optic cable; 20 units	3/16/92-1/1/94
MN	Minneapolis	Essex Communications (3)	PCS test; 100 bases, 1,000 handunits	3/17/92-2/1/94
	Minneapolis	Hauser Communications (5)	PCS test, 10 bases, 100 handunits per location	3/1/93-3/1/95
	Minneapolis	Pathfinder Ventures (7)	PCS test; 500 bases, 5,000 handunits	2/24/92-7/1/93
	Minneapolis	Providence Journal Company (6)	PCS test; 50 bases, 1,000 handunits per city	8/10/92-7/1/94
	Minneapolis	Quantum Communications Group (2)	PCS test; 25 bases, 250 handunits	6/4/93-2/4/95
MO	St. Louis	Gateway Technology	PCS test; 100 bases, 500 handunits	8/17/92-8/1/94
MT	Missoula and Billings	Statcom (2)	Testing in rural areas; 5,000 units per area	9/1/92-9/1/94
NE	Grand Island, Hastings, Kearney, and Omaha	Cable USA	CT-2 and PCN; 10,000 units per area	3/15/91-1/1/95

MARKET TESTS OF PERSONAL COMMUNICATIONS SERVICES BY STATE (Continued)

State	City	Company	Test Specifications	Test Dates
NV	Las Vegas	Linkatel Communications (4)	PCN; 10 bases, 100 handunits per city	2/27/92-5/1/94
	Las Vegas	Optimum Communications (7)	PCS test; 5 bases, 50 handunits per city	8/17/92-7/1/94
	Las Vegas	Prime II Management (5)	Development of PCS equipment by cable company; 100 bases, 1,000 handunits	3/17/92-7/1/94
	Las Vegas	The ZN Group (6)	PCS test in convention areas; 100 bases, 1,000 handunits	3/17/92-7/1/94
NH	Manchester	Atlantic Cellular Company (3)	50 bases, 1,000 handunits PCN	3/5/92-1/1/94
NJ	Morristown and Princeton	Telmarc Telecommunications (3)	PCS test, 10 bases, 100 handunits	6/4/93-10/1/95
	Newark and Trenton	Bell Atlantic Network Services (4)	PCS test; 54 bases, 910 handunits	2/24/93-1/1/94
	Newark	PCN Services of New York (2)	Spread spectrum; 100 base stations, 10,000 handunits	12/26/90-5/1/94
	Union	Suburban Cablevision	PCS test; 20 bases, 500 handunits	3/18/92-9/1/94
NM	Las Cruces	Las Cruces TV Cable	PCS test; 100 bases, 1,000 handunits	3/17/92-5/1/94

MARKET TESTS OF PERSONAL COMMUNICATIONS SERVICES BY STATE (Continued)

State	City	Company	Test Specifications	Test Dates
NY	Buffalo and Rochester	Alliance Telecom, Incorporated	PCS test, 10 bases, 100 handunits	6/4/93-12/1/95
	New York	Associated PCS Corporation (3)	Spread spectrum; 25 bases, 1,000 handunits	3/16/92-12/1/93
	New York	Cablevision (4)	PCN interfacing with existing cable system; possible sharing with CARS services at 13 GHz; 200 bases, 20,000 handunits	3/9/92-1/1/95
	New York	GTE Mobile (6)	Test for possible use of ATG frequencies for mobile services	3/24/92-3/1/94
	New York	McCaw Cellular (3)	High-speed point to multipoint data broadcast service; 200 units per city	4/29/92-6/1/94
	New York	McCaw Cellular (9)	PCS test; 1,000 units	4/29/92-6/1/94
	New York	Pathfinder Ventures (7)	PCS test; 500 bases, 5,000 handunits	2/24/92-7/1/93
	New York	PCN Services of New York (2)	Spread spectrum; 100 base stations; 10,000 handunits	12/26/90-5/1/94
	New York	PCN Services of New York	CT-3 wireless PBX; 100 bases, 1,000 handunits	9/11/91-7/1/93

MARKET TESTS OF PERSONAL COMMUNICATIONS SERVICES BY STATE (Continued)

State	City	Company	Test Specifications	Test Dates
NY	New York	PCN Services of New York	Used for backbone PCN network between PCN base stations	3/17/92-5/1/94
	New York	Research Resources International (6)	PCS test near large seaport terminals; 100 bases, 1,000 handunits	3/17/92-5/1/94
	New York and White Plains	NYNEX Science & Technology	115 public base stations; 200 home bases, 400 handunits	5/20/92-7/1/94
NC	Charlotte	Providence Journal Company (6)	PCS test; 50 bases, 1,000 handunits per city	8/10/92-7/1/94
	Greensboro	Vanguard Cellular Systems (3)	PCS test; 60 bases, 500 handunits	2/24/92-11/1/93
	Greenville	LDH International (3)	Phase I technical test; phase II market test; 100 bases, 2,000 handunits	3/15/91-5/1/93
	Hickory	Prime II Management, Incorporated	PCS test; 50 bases, 1,000 handunits	9/28/92-7/1/94
	Raleigh	Fibercom, Incorporated	PCS test, 100 bases, 1,000 handunits	9/28/92-2/1/94
ND	None			

MARKET TESTS OF PERSONAL COMMUNICATIONS SERVICES BY STATE (Continued)

State	City	Company	Test Specifications	Test Dates
OH	Ashtabula	Alltel Service Corporation	Test of foreign equipment; 10 bases, 20 handunits	11/26/91-1/1/95
	Cincinnati	Advanced Wireless (2)	Test of various CT-2 & PCN; test possible sharing w/ATG; 2 bases, 10 residential bases, 40 handunits	4/5/91-12/1/92
	Cincinnati	Cincinnati Bell Telephone	CT-2 and PCN test; 22 bases, 63 handunits	7/29/92-1/1/95
	Cincinnati, Cleveland, and Toledo	USA Mobile Communications	TDMA & TDD; 4,000 total units	10/1/92-10/1/94
	Cincinnati, Cleveland, and Columbus	Wireless Communications Services (4)	PCS test, 10 bases, 100 handunits	3/25/93-11/1/95
	Cleveland	Cablevision (4)	PCN interfacing with existing cable system; possible sharing with CARS service at 13 GHz; 200 bases, 2,000 handunits	3/9/92-1/1/95
	Cleveland	Pertel (3)	Use of cable to tie cells together; 100 bases, 10,000 handunits	2/22/91-9/1/92

MARKET TESTS OF PERSONAL COMMUNICATIONS SERVICES BY STATE (Continued)

State	City	Company	Test Specifications	Test Dates
OH	Columbus	Litel Telecommunications	PCS test; 10 bases, 1,000 handunits	5/1/92-5/1/94
	Dayton	Viacom International (5)	Use of cable to tie cells together; 1,000 bases, 10,000 handunits	3/12/92-11/1/94
OK	Texas County and Williamette	Panhandle Telephone Cooperative	PCS test; 25 bases, 250 handunits	8/17/92-7/1/94
OR	Gervais	Gervais Cooperative Telephone	PCS test; 10 bases, 100 handunits	11/8/93-3/1/95
	Portland	Electric Lightwave (2)	PCS test; 20 bases, 100 handunits	3/24/92-7/1/94
	Portland	Rim Com (7)	PCS test; 500 bases, 5,000 handunits	2/24/92-8/1/93
	Portland	U S West Communications (2)	PCS test; 6 bases, 6 handunits	9/4/92-4/1/93
	Oregon City	Clear Creek Mutual Telephone Company	PCS test; 25 bases, 250 handunits	1/1/94-1/1/96
	Molalla	Molalla Telephone Company	PCS test; 25 bases, 250 handunits	3/1/93-6/1/94
	Woodburn	Monitor Cooperative Telephone Company	PCS test; 25 bases, 250 handunits	8/10/92-6/1/94

MARKET TESTS OF PERSONAL COMMUNICATIONS SERVICES BY STATE (Continued)

State	City	Company	Test Specifications	Test Dates
OR	Monroe	Monroe Telephone Company	PCS test; 25 bases, 250 handunits	8/10/92-6/1/94
	Mt. Angel	Mt. Angel Telecommunications	PCS test; 25 bases, 250 handunits	8/10/92-6/1/94
OK	Philomath and Williamette	Pioneer Telephone Coop	PCS test; 25 bases, 250 handunits	8/10/92-7/1/94
	Scio-Albany	Scio-Mutual Telephone Assoc.	PCS test; 25 bases, 250 handunits	8/10/92-9/1/94
	Stayton	Stayton Coop Telephone	PCS test; 25 bases, 250 handunits	8/10/92-9/1/94
	Tillamook	AKT Value Services, Incorporated (3)	PCS test; 5 bases, 500 handunits	11/8/93-12/1/94
PA	Allentown and Harrisburg	Vanguard Cellular Systems (2)	PCS test; 100 bases, 500 handunits	2/24/92-11/1/93
	Allentown and Philadelphia	The ZN Group (5)	PCS test in convention areas; 100 bases, 1,000 handunits	3/17/92-8/1/94
	Jamison, Lancaster, and Philadelphia	Micronet (6)	Test foreign equipment; 10 bases, 200 handunits	12/13/91-7/1/93
	Philadelphia	Bell Atlantic (5)	PCS test; 54 bases, 910 handunits	8/10/92-1/1/94

MARKET TESTS OF PERSONAL COMMUNICATIONS SERVICES BY STATE (Continued)

State	City	Company	Test Specifications	Test Dates
PA	Philadelphia and Pittsburgh	Pertel (2)	Use of cable to tie cells together; 100 bases, 10,000 handunits	2/22/91-9/1/92
	Pittsburgh	Tel/Logic (2)	CDMA 50 MHz spread; 75 bases, 1,000 handunits	10/1/92-10/1/94
RI	Providence	Atlantic Cellular Company (3)	PCN; 50 bases, 1,000 handunits	3/5/92-1/1/94
	Providence	Providence Journal Company (6)	PCS test; 50 bases, 1,000 handunits per city	8/10/92-7/1/94
	Providence	Times Mirror Cable Television (5)	PCS test; 200 bases, 1,000 handunits	3/29/93-10/1/94
SC	York and Chester Counties	Rock Hill Telephone	PCS test; 20 bases, 200 mobiles	7/1/92-8/1/94
SD	None			
TN	Nashville	Viacom International (5)	Use of cable to tie cells together; 1,000 bases, 10,000 handunits	3/12/92-11/1/94
TX	Eastern Texas	Nationone Telephone Company	Telepoint service; 2,000 public bases; 1,000 home bases, 15,000 handunits	10/19/90-7/1/94
	Austin	Century Telephone of San Marcos, Incorporated	PCS test; 20 bases, 1,000 handunits	3/20/92-9/1/94

MARKET TESTS OF PERSONAL COMMUNICATIONS SERVICES BY STATE (Continued)

State	City	Company	Test Specifications	Test Dates
TX	Austin and Houston	Globus Communications (2)	PCS test; 100 bases, 250 handunits	7/29/92-4/1/94
	Austin, Dallas, and Houston	Micronet (5)	Test foreign equipment; 10 bases, 200 handunits	12/13/91-7/1/93
	Austin	Sharecom-Austin	PCS test multistory office building; 50 bases, 1,000 handunits	8/21/92-9/1/94
	Brazoria	Columbia Wireless Limited Partnership	PCS test; 5 bases, 200 handunits	6/8/92-1/1/94
	Dallas	GTE Mobile (6)	Test for possible use of ATG frequencies for mobile services	3/24/92-3/1/94
	Dallas and Houston	McCaw Cellular (8)	PCS test; 1,000 units	4/29/92-6/1/94
	Dallas	MCI Telecommunications (2)	PCS test and test of roaming equipment; 12 bases, 500 handunits	4/23/93-6/1/95
	Dallas and Fort Worth	MTEL PCN	PCN; 10 nodes, 100 bases, 15,000 handunits	3/15/91-1/1/93
	Dallas	Pathfinder Ventures (7)	PCS test; 500 bases, 5,000 handunits	2/24/92-7/1/93
	Dallas	Tel/Logic (2)	CDMA 50 MHz spread; 300 bases, 4,000 handunits	10/1/92-10/1/94

MARKET TESTS OF PERSONAL COMMUNICATIONS SERVICES BY STATE (Continued)

State	City	Company	Test Specifications	Test Dates
TX	Del Rio	Optimum Communications (7)	PCS test; 5 bases, 50 handunits per city	8/17/92-7/1/94
	Houston	PCN America (Millicom) (2)	Spread spectrum digital system	5/8//90-5/1/92
	Houston	Prime II Management (5)	Development of PCS equipment by cable company; 100 bases, 1,000 handunits	8/21//92-7/1/94
	Houston	Research Resources International (6)	PCS test near large seaport terminals; 100 bases, 1,000 handunits	3/17/92-8/1/94
	Houston	Southwestern Bell Personal Communications	PCS test; 80 bases, 300 handunits	3/17/92-9/1/93
	San Marcos	Capital Network System	PCS test; 40 bases, 1,000 handunits	3/16/92-1/1/94
	Victoria	Wireless Communications Services (3)	PCS test; 40 units	5/15/92-11/1/94
UT	Salt Lake City	Snowcap Communications, Incorporated	PCS test; 100 bases, 1,000 handunits	9/24/92-9/1/94
VT	None			
VA	Norfolk, Richmond, and Williamsburg	Columbia Cellular Corporation (3)	PCS test; 25 bases, 500 handunits	6/4/93-1/13/95

MARKET TESTS OF PERSONAL COMMUNICATIONS SERVICES BY STATE (Continued)

State	City	Company	Test Specifications	Test Dates
VA	Richmond	Bell Atlantic Network Services, Incorporated (5)	PCS test; 54 bases, 910 handunits	2/24/93-1/1/94
	Richmond	Essex Communication (3)	PCS test; 100 bases, 1,000 handunits	3/17/92-2/1/94
WA	Ellensburg	Ellensburg Telephone Company	PCS test; 25 bases, 250 handunits	6/4/93-2/1/95
	Seattle	Electric Lightwave (2)	PCS test; 20 bases, 100 handunits	3/24/92-2/1/94
	Seattle	McCaw Cellular (3)	High speed point-to-multipoint data broadcast service; 200 units per city	4/29/92-6/1/94
	Seattle	McCaw Cellular (9)	PCS test; 1,000 units	4/29/92-6/1/94
	Seattle	Providence Journal Company (6)	PCS test; 50 bases, 1,000 handunits per city	8/10/92-7/1/94
	Seattle and Tacoma	Research Resources International (6)	PCS test near large seaport terminals; 100 bases, 1,000 handunits	3/17/92-8/1/94
	Seattle	Rim Com (7)	PCS test; 500 bases, 5,000 handunits	2/24/92-8/1/93
	Seattle	Viacom International (5)	Use of cable to tie cells together; 1,000 bases, 10,000 handunits	3/12/92-11/1/94

MARKET TESTS OF PERSONAL COMMUNICATIONS SERVICES BY STATE (Continued)

State	City	Company	Test Specifications	Test Dates
WA	Sequim and Woodland	AKT Value Services, Incorporated	PCS test; 5 bases, 500 handunits	11/8/93-12/1/94
	Spokane	Satcom (3)	Testing in rural areas; 5,000 units per area	9/1/92-9/1/94
	Yelm	Yelm Telephone Company	PCS test; 25 bases, 250 handunits	10/8/92-11/1/94
WV	Charleston	Bell Atlantic Network Services, Incorporated	PCS test; 54 bases, 910 handunits	2/24/93-1/1/94
WI	Appleton, Fond du Lac, and Green Bay, Stevens Point, and Wausau	Wisconsin Wireless Communications	PCN; 12 bases, 300 handunits	5/4/92-9/1/93
	Milwaukee	SM TEK	PCS test; 5 bases, 50 handunits	9/24/92-9/1/94
	Milwaukee	Goeken Custom Communications (2)	28 GHz to tie microcells to switches; 5 bases, 50 handunits per city	10/30/91-4/1/95
	Milwaukee	Viacom International (5)	Use of cable to tie cells together; 1,000 bases, 10,000 handunits	3/12/92-11/1/94
WY	None			

MARKET TESTS OF PERSONAL COMMUNICATIONS SERVICES BY STATE (Continued)

State	City	Company	Test Specifications	Test Dates
PR	San Juan	Local Area Telecommunications	PCN; 50 bases, 1,000 handunits	3/16/92-5/1/94
	San Juan	Optimum Communications (7)	PCS test; 5 bases, 50 handunits per city	8/17/92-7/1/94
PR	San Juan	TPI Communications International	PCS test; 25 bases, 250 handunits	6/4/93-10/1/95
National		ROLM Systems	PCS test; 1,200 units	3/20/92-7/1/94
		Northern Telecom	Demonstration of equipment at various locations	6/19/92-7/1/94
		Globus Communications (3)	PCS test; 100 bases, 250 handunits per location	7/29/92-4/1/94

Source: FCC list, reordered by state.