Introduction and Policy Issues

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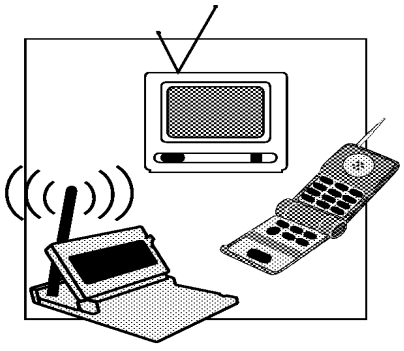
Wireless communications technologies are poised to bring dramatic changes to the nation's telecommunications and information infrastructure, reshaping how people communicate, access information, and are entertained. These technologies, which use radio waves instead of wires to transmit information, already play an important part in the daily lives of almost all Americans. For more than 70 years, radio and television broadcasters have entertained and informed millions of people each day. Satellites connect the countries of the world, allowing people to converse, share information, and transact business. Most recently, cellular telephones have extended the reach of the public telephone system to people who are on the move or beyond the reach of traditional telephones.

Over the next several years, use of wireless technologies is expected to grow dramatically as a wide range of new radio-based communication, information, and entertainment services and applications is introduced, and the prices of both equipment and services fall. Some of the wireless systems now being developed include: 1) terrestrial and satellite-based telephone systems that will allow people to make and receive calls from almost any point on Earth, 2) digital television that promises clearer images and better sound, 3) digital radio broadcasting that will offer crystal clear sound as well as a range of information services, and 4) a wide range of data communications systems that expand the reach of computer and information services. These emerging wireless technologies, along with existing wireless services, will become an integral part of the nation's evolving telecommunications and information infrastructure—more formally known as the National Information Infrastructure (NII).



Wireless systems offer many benefits for individuals and businesses, but a number of challenges must be overcome before wireless technologies can be effectively integrated into the NII. Residential and business users, for example, will have a wider range of communication, information, and entertainment services to choose from, but systems may not work together and switching between service providers could be difficult. Wireless companies will offer a range of technologies and services, but competition is likely to be intense in many markets and the long-term outcome of current policy initiatives—on interconnection of networks, universal service, and industry structure—remains uncertain. Some wireless technologies will complement existing services and networks, but many will also compete with the traditional communications and information providers—telephone companies, computer networks, broadcasters, and cable television companies. The economics of wireless systems are not yet well understood. In this uncertain and rapidly changing environment, policymakers and regulators will have to be vigilant in monitoring the effects of policies and rules already put in place.

Finally, the deeper implications of the widespread use of wireless technologies and services are not well understood. With the exception of television and radio broadcasting (and perhaps cellular telephony), radio-based systems have not yet penetrated deeply into the social and organizational fabric of American society and business. This is expected to change rapidly as technologies come into more widespread use as true mass-market products. Once large-scale use begins, the hidden impacts—both positive and negative—of wireless access and mobility will become clearer. While the benefits of ubiquitous communications and a wider range of services are important, potential problems remain regarding security, privacy, health effects, and social/organizational upheaval—including widening the gap between information and communication "haves" and "have-nots." Technical, regulatory, and economic policy decisions will be required to ensure that the benefits of wireless are realized to the fullest extent possible, while minimizing the potential disadvantages for individuals, business, and society as a whole.

REQUEST FOR THE STUDY

The initial focus of NII initiatives was primarily on wireline technologies. Some visions of the NII seemed to ignore wireless technologies completely, failing to recognize the unique benefits that wireless systems offer. Other views of the NII—declared "technology neutral"—addressed wireless technologies as just another delivery method, but generally failed to take into account the special challenges that wireless solutions will pose for a national communications infrastructure. Most NII plans concentrated on developing the necessary infrastructure primarily through the expansion of the existing telephone network, cable television systems, and national computer networks (such as the Internet and the National Research and Education Network). Even today, most observers and telecommunications analysts believe that the backbone of the NII—the high-capacity links that will bind together the disparate networks that will make up the NII—will be primarily based on fiberoptic technology.[1]

The role of wireless technologies in the NII, however, has never been fully developed by either the Administration or Congress. Wireless proponents, especially in the broadcasting and satellite communities, have attempted to have their systems more directly included in NII discussions, and their efforts have been somewhat successful. Wireless technologies are generally recognized by most policymakers as an important way to access the NII, but the general bias toward wire-based NII systems remains. To broaden understanding of these issues, the Committee on Science, Space, and Technology (now the Committee on Science)

[1] Joseph N. Pelton, "CEO Survey on the National Information Infrastructure," *Telecommunications*, vol. 28, No. 11, November 1994.

BOX 1-1: Scenario—Wireless Technologies in Health Care

Scenarios scattered throughout this chapter sketch some possible visions of what wireless technologies and systems can and cannot do, discuss some of the implications of their widespread use, and provide some of the potential downsides. These scenarios are set in the not-too-distant future, and, in fact, many of the applications described below are already being tested or deployed.

Ellen, a nurse in a big city hospital, does her rounds with an electronic clipboard. After checking her patient's temperature, pulse, glucose levels, and breathing, she enters the data directly on her clipboard. The information is immediately transmitted to the hospital's patient data network via a wireless link between her clipboard and the hospital's computer network,

A doctor wanting to talk to Ellen about dosages for a patient undergoing chemotherapy reaches her on her handheld phone. She is reminded how much easier the phone makes it to stay in touch. Only last year she had to listen for pages on the building loudspeaker, and often had to wait to get to a phone to call back. She calculate once that she spent two hours per week, on average, just waiting to be called back or trying to get in contact with the doctors on duty.

As she is checking on another patient, Ellen's pager signals that a staff meeting is beginning. Work schedules and patient loads are going to be reorganized and Ellen is opposed to one of the changes being proposed. She wants to canvas her colleagues and mobilize the opposition, but prefers to do this face to face, because it is a delicate matter. She calls up the personnel locator program on her electronic clipboard, which indicates that three of the 14 day shift staff are in the nurses' lounge One of them is new—she can't recall the face, so she asks the hospital's computer for a photo.

Midway through the meeting, Ellen's pager signals that she is wanted in the emergency room receiving area :a gunshot victim and multiple automobile accident victims are being brought in simultaneously. Preliminary information on the patients is being sent in from the ambulance, so Ellen calls the emergency room receiving program. As she is running to the receiving area, she is informed that the gunshot victim is a white male, 23 to 26 years old, his blood pressure is dropping rapidly, his blood type is B negative, he is likely to be a diabetic, and he has been taking antidepressant medication, Quickly, she grabs the appropriate IV units on the way down the hall, and is not surprised to see the other medical staff who will attend to this patient already there. In the emergency room, instant communication is crucial—a quick response and good information saves lives,

SOURCE: Office of Technology Assessment, 1995.

of the House of Representatives and Representative Michael Oxley asked the Office of Technology Assessment (OTA) to study the role of wireless technologies in the emerging NH.

SCOPE OF THE STUDY

This report considers how wireless systems and services can contribute to the development of a national information infrastructure and what specific impacts the NII, as presently conceived, may have on the development and deployment of new and existing radio services. Because of the breadth of the subject, not all technologies and issues can be analyzed in detail. Rather, this report is designed to serve as a general introduction to wireless technologies and services and the opportunities and problems they may give rise to in the context of the NII. It surveys most of the major wireless applications now being developed and identifies the most important issues arising from their implementation and use. Issues needing further study are identified. Some policy options for Congress are identified, but are limited primarily to broad issues that could affect the evolution or impacts of wireless technologies.

The study does not discuss generic NII issues--copyright, investment, or information content, for example—nor does it address several

aspects of wireless communication that, while critical, are outside the scope of present work. First, the report does not address the special needs and contributions of private radio systems—including those systems used for public safety. Only those systems available for use by the general public or businesses are included. Private radio systems, while often used to meet important public safety and emergency preparedness needs, cannot be used by the public. However, during the course of this study, OTA has noted the challenges facing the public safety community in the use of radio communications to fulfill its various missions, including severe shortages of capacity, incompatible radio systems that hamper cooperation in emergency relief efforts, and rising communication needs in a period of budget cutbacks. These problems deserve much greater attention than they could be given in this report, and should be the focus of a separate inquiry.

The report also does not directly address the international aspects of wireless technologies or the NII. Prior OTA reports on the international aspects of both wireline and wireless communications found that domestic and international telecommunications policy need to be more closely coordinated.[2] OTA continues to believe in the importance of viewing domestic telecommunications policy in an international context, but chose to limit the scope of the present report to domestic issues for purposes of clarity and length. The report uses examples from other countries to illustrate technology advances or policy choices where appropriate. Likewise, OTA recognizes the importance of foreign markets for U.S. wireless equipment manufacturers and service providers. Promoting the competitiveness of U.S. firms in international wireless products and services should be an integral part of domestic policymaking.[3]

BACKGROUND: THE NII

The U.S. telecommunications infrastructure is already among the best in the world, providing high-quality communication, information, and entertainment services to over 90 percent of the population:[4]

- telephone service is available to 93.8 percent of American households;
- cable television service is available to almost 95 percent of U.S. households, 63 percent of whom subscribe;
- 94 percent of U.S. households can receive at least five broadcast television stations;
- radio broadcasting is ubiquitous, with 99 percent of American homes having an average of five radios;
- cellular telephone service is available to about 95 percent of the population, covering 50 percent of the geographic area of the United States (including Alaska, which has large unserved areas);

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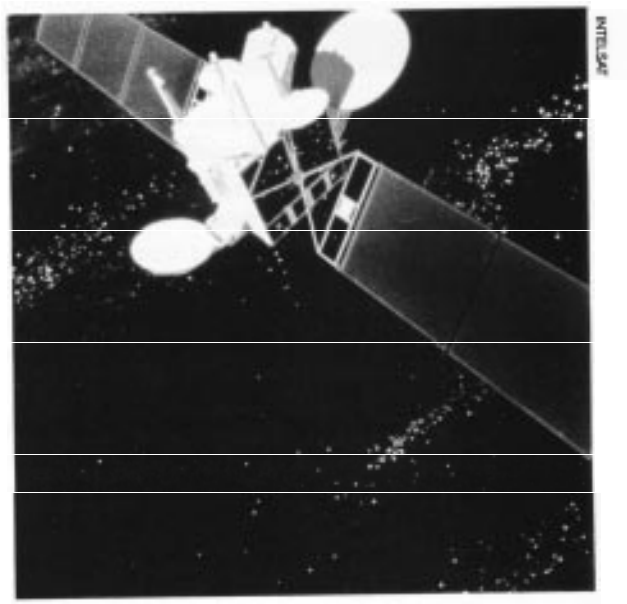
[2] U.S. Congress, Office of Technology Assessment, *The 1992 World Administrative Radio Conference: Issues for U.S. International Spectrum Policy,* OTA-BP-TCT-76 (Washington, DC: U.S. Government Printing Office, November 1991); U.S. Congress, Office of Technology Assessment, *The 1992 World Administrative Radio Conference: Technology and Policy Implications,* OTA-TCT-549 (Washington, DC: U.S. Government Printing Office, May 1993); U.S. Congress, Office of Technology Assessment, *U.S. Telecommunications Services in European Markets,* OTA-TCT-548 (Washington, DC: U.S. Government Printing Office, August 1993); U.S. Congress, Office of Technology Assessment, *Global Communications* (in progress).

[3] Office of Technology Assessment, *Global Communications,* ibid.

[4] Telephone statistics are from A. Bellinfonte, Federal Communications Commission, *Telephone Subscribership in the United States,* April 1995; cable figures from National Cable Television Association, *Cable Television Developments,* spring 1995, and U.S. Bureau of the Census, *Current Population Survey,* March 1994; television broadcast figure from Federal Communications Commission, *Broadcast Television in a Multichannel Marketplace,* June 1991; radio broadcasting figures from Radio Advertising Bureau, *Radio Marketing Guide and Fact Book for Advertisers,* 1994; cellular figures from Tim Rich, Cellular Telecommunications Industry Association, personal communication, May 4, 1995; and computer figures from Times Mirror Center for the People and the Press, *Technology in the American Household: The Role of Technology in American Life,* May 1994.

- 31 percent of American households have a personal computer, 12 percent have a computer with a modem, and about 50 percent of all workers use computers on the job.

It is this base of technology-the existing communications infrastructure---from which the NII will evolve. Technology advances are already improving these systems, especially in terms of capacity, quality, and flexibility. New wireless technologies will extend and expand the use of existing networks, and will create new links to information, allow more flexible communication, and provide connections to new sources of entertainment.



satellites carry voice, data, and video communications all around the world, linking far-flung business locations, allowing researchers to keep in touch, and bringing television images of far off events to millions of American living rooms.

History and Purpose of the NII

The concept of a national information infrastructure originally focused on the development of a national computer network, the NREN, that the federal government played a key role in financing and developing.[5] The idea of the information infrastructure broadened, however, as telephone and cable companies--driven by advances in fiberoptic, digital signal processing, and data compression-began to promote their ability to provide a more diverse range of services using their networks.

To make the most of the existing information and telecommunication infrastructure, and to bring *the* benefits of advanced telecommunications, information, and entertainment services to all U.S. consumers and businesses, government policymakers formally advanced the idea of the NIL In September 1993, the Clinton Administration released its *Agenda for Action.*[6] That report established, in broad outline, goals for the development of telecommunications and information resources in the United States, and identified a concept of how the U.S. communications and information infrastructure should evolve. The purpose of the NII, as described by the Administration, is to enable all Americans to access the information they need; when they want it, where they want it—at an affordable price.[7]

To serve this purpose, the Administration has stated that many different technologies and systems will be used where appropriate.[8] In fact,

[5] High-Perf ormance Computing Act of 1991 (HPCA), Public Law 102-194.

[6] Department of Commerce, Information InfrastructureTask Force, *The National Information Infrastructure: Agenda for Action,* Sept. 15, *1993.*

[7] See, for example, co mments of Mike Nelson, Office of Science and Technology Policy, at theWorkshop on Advanced Digital Video in the National Information Infrastructure, Georgetown University, Washington, DC, May l0-11, 1994.

[8] As explained in the *Agenda for Action,* the NII is really more than just an interconnected series of telecommunications or computer networks. It encompasses:l) a wide and ever-expanding range of equiprnent; 2)the information itself, which may be in the form of video programming, scientific or business databases, images, sound recordings, library archives, and other media; 3) applications and software that allow users to access, manipulate, organize and digest [information]; 4)the network standards and transmission codes that facilitate interconnection and interoperation between network; and 5) the people--largely in the private sector—who create the information, develop applications and services, construct facilities, and train others to tap its potential. Department of Commerce, op. cit., footnote 6, pp. 5-6.

BOX 1-2: OTA's Definition of the National Information Infrastructure

in discussing the integration of wireless technologies into the emerging communications infrastructure, OTA adopts a broad definition of the National Information Infrastructure (Nil). It includes all the systems and applications necessary for the public to communicate with whomever they want and access the information they desire. The Nll will be one-way and two-way, point-to-point and broadcast, and narrowband and broadband. It will be an amalgam of existing systems and services and completely new technologies and applications, Different parts of the Nll will serve different functions depending on technology and need, and some systems may serve a multitude of needs, The Nll will include satellite systems, fiberoptic cable, terrestrial radio systems, broadcasting, and the telephone and cable television networks, among others.

What will the Nil not be? Despite the singular way in which the term is used—the "NII" is not, and will not be, one "thing, " Rather, it will be more accurate to think of the Nil as a unifying concept or overarching idea that brings together all the different systems, technologies, and applications that are necessary for people to communicate, access information, and be entertained. Just as the transportation infrastructure of this country is more than just the interstate highway system—it consists of roads, railroads, aircraft, passenger cars, trucks, and ships—so, too, will the Nll consist of more than just an "information superhighway. " It will also include all the different, lower speed "on and off ramps''—the many local connections that provide access to the network.

Nor will the Nll be, as some have suggested, a huge collection of completely interconnected networks capable of transmitting interactive voice, data, and video among all businesses and citizens. Rather, the Nll will be a collection of many different kinds of systems. Some general-purpose systems may indeed be capable of carrying two-way, high-bandwidth, multimedia communications, but many other systems will carry only certain kinds of information (voice/data, but not video) or will carry it only one-way (broadcasters),

In addition, not all of these different subsystems will be completely or directly interconnected. Rather, the interconnections will be based on practical and/or economic considerations. It may not make sense, for example, to connect a phone system to a television broadcast station. The existing public switched telephone network may serve as a "core" network that serves as a common point of interconnection for many smaller networks, Finally, the Nll will not evolve out of the Internet—the name given to a worldwide network of interconnected computers. The Internet will be only one of the many parts comprising the larger concept that is the NII.

SOURCE: Office of Technology Assessment, 1995,

most analysts today think of the NII not as a single system, but as a "system of systems" or "network of networks" that will carry voice, data, and video communications to homes, businesses, schools—to people wherever they are. It is unclear, however, just what the public thinks the NII is. In the popular press, it is often referred to as the "information superhighway." This may connote, incorrectly, a *separate* system that is to be built in addition to existing cable, telephone, and computer networks. For purposes of this report, OTA defines the NII quite broadly (box 1-2).

To bring the NII into being, the Administration has identified five overarching policy guidelines

that will serve as the framework for developing not only wireline NII services, but wireless systems and applications as well.[9]

1. *Competition* is seen as the engine that will drive private sector investment in the NII, allowing companies to compete on fair and equal terms, while stimulating efficiency and innovation. Competition is also believed to lower costs for consumers, increase choices and diversity in information sources and entertainment, and protect quality and reliability.
2. A commitment to *universal service* seeks to ensure that NII services will be available to all who want them, regardless of income, location, or ethnicity. This commitment has been the foundation of the telephone system for more than 90 years; as a result, almost everyone in the country is able to have a telephone.
3. *Private investment* will be the source of almost all funding for the NII; the government will not build or operate the systems that comprise the NII. Government agencies, however, will operate publicly accessible databases and their own telecommunications and information networks.
4. *Open access* means the networks that will carry the information and entertainment will be open to all users—distributors of programming as well as residential and business consumers.
5. *Flexible government regulation* is recognized as vital to promoting the goals outlined above. Regulations must seek to promote fair competition and private investment in rapidly changing technology and market conditions; they must also protect consumers' interests by ensuring low-cost services, high reliability, and personal privacy and security.

Information Infrastructure Task Force

To guide its development of policies for the NII, the Administration formed the Information Infrastructure Task Force (IITF) in 1993. It is composed of high-level representatives of the federal agencies that play a major role in the development and application of communication and information technologies and those that rely on communication and information technologies to deliver their services. To gather private sector input and assist the IITF, President Clinton established an Advisory Council on the NII.[10] The IITF operates under the aegis of the Office of Science and Technology Policy and the National Economic Council, but is chaired by the Secretary of Commerce. Much of the staff work and administrative support for the IITF is done through the National Telecommunications and Information Administration (NTIA) of the Department of Commerce.

Functionally, IITF's work is divided among three main committees: telecommunications policy, information policy, and applications. These committees have delegated specific tasks or responsibilities for certain issue areas, such as privacy, reliability, universal service, health, etc., to individual working groups.[11] Although several of the working groups may cover wireless technologies in the context of their broader work, none deals specifically with wireless as a separate area. Given this lack of focus, it is unclear to what extent wireless technologies play a role in the com-

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[9] The *Agenda for Action* originally identified nine principles that would guide the NII initiative: 1) promote private sector investment; 2) extend universal service—ensure that information is available to all at affordable prices; 3) promote technological innovation and new applications; 4) promote seamless, interactive, user-driven operation; 5) ensure information security and network reliability; 6) improve management of spectrum; 7) protect intellectual property rights; 8) coordinate with other levels of government and other nations; and 9) provide access to government information and improve procurement. These nine principles were collapsed into five over time. See, for example, remarks by Vice President Gore at the Federal-State-Local Telecomm Summit, Washington, DC, Jan. 9, 1995.

[10] Clinton, W. J., President, United States, "Executive Order 12864—United States Advisory Council on the National Information Infrastructure," *Weekly Compilation of Presidential Documents* vol. 29, No. 37, Sept. 20, 1993, p. 1771.

[11] For more indepth information on the structure and accomplishments of the Information Infrastructure Task Force, see U.S. Department of Commerce, N*ational Information Infrastructure: Progress Report September 1993-1994*, September 1994, especially appendix B.

mittees' deliberations, and how well the specific benefits and problems associated with wireless are being considered. Another IITF working group, the Technology Policy Working Group has addressed wireless technology in some of its discussions as part of its mandate to examine cross-cutting technology issues. Government activities and policy initiatives relating to the NII and wireless systems are discussed in more detail in appendix B.

Industry Initiatives

Industry, as the primary builder and operator of the evolving NII, has been an active participant in the policy development process since before the moniker, "NII," was attached to the effort. Innumerable industry groups and consortia have produced vision statements and proposals, lobbied Congress, and testified at federal, state, and local hearings on all aspects of the NII. At the same time, all segments of the telecommunications industry, wireline and wireless, have been moving ahead to build their systems. A complete overview of industry activities regarding the NII would be impossible, given the scope and depth of their work and the fact that almost everything industries do could be considered NII-related in one way or another. Such a review is beyond the scope of this report.

The NII Today

The main challenge in building the NII will not be technical—the basic technologies that will form its foundation are already in place or being developed, and standards are being written that will permit different devices and networks to interoperate. The biggest obstacle to moving the NII forward is the lack of consensus on what it should encompass and, as a result, what policies, administrative procedures, and regulations are needed to deploy it. Beyond the broad concepts outlined by the Administration, the vision of the NII has remained vague and somewhat ill-defined. Different interest groups, government leaders, and industry observers have offered their own visions of what it should be and what needs it should serve. However, no real agreement has been reached, and, in many cases, it has even been difficult to agree on common terms of reference. Some have pointed out that the NII is all things to all people—that definitions are as varied as those who create them.

In the past eight months, the concept of "the NII" has become even more amorphous, eclipsed by broader efforts to overhaul regulation of the nation's telecommunications industries. Some even call the NII "quaint." A subtle shift has occurred that places competition at the center of the telecommunications policy framework rather than the NII. As a result, the NII now seems to be defined as whatever a competitive marketplace creates as a result of deregulated telecommunications and media competition—it has been reduced to a byproduct rather than the result of a specific vision or plan. Policy efforts seem directed more toward meeting NII *goals*—access, diversity, low prices, and interconnection—through the engine of competition as opposed to creating "an NII." Wireless and wireline policies are still rarely linked explicitly, but they are being developed under the same set of unifying principles—a dedication to competition. Despite this coalescence, however, no long-term vision of how wireless systems will fit into the NII exists or is being developed, and the marketplace is being relied on to sort out the details.

Despite the continued vagueness of the overall NII concept, however, intensive research, experimentation, and other development work is being done on its various parts. Technology vendors and service providers continue to develop and refine technologies and applications they believe will become part of the NII. The federal government has sponsored or organized many discussions—with both public and private sector input—on the issues of universal service, interconnection, and privacy, among others. Many people—in both government and the private sector—have invested considerable time and effort to advance the ideas of the NII, but questions still remain about what it

is, what it will do, how much it will cost to develop, and when its benefits will be available.[12]

Some analysts and citizens question the wisdom of pushing ahead with such a massive undertaking while fundamental questions-about the real need for the NII, what its functions will be, and what negative effects it might have-remain unanswered.[13] Many of these same questions also apply to the deployment of wireless in the NH. OTA has argued that deploying technology solutions before assessing the needs of the users is not likely to lead to the best solutions.[14] While such questions are important and valid-and should be carefully considered-events appear to have overtaken this type of carefully planned approach. The NII is already being built, and it would be virtually impossible to stop it. Further, even if one could start over, the rapid pace of technology development has made the concept of "needs' 'highly individualistic and subject to rapid change-making them difficult to rationally identify and plan for on abroad system level. This report examines some of the important issues surrounding the deployment of wireless systems in the NII, while acknowledging that some of the most fundamental questions about the NII have become moot.

The NII concept has served to focus more attention on telecommunications in general. It has also given added impetus to wireless development efforts, but industry analysts and stakeholders believe that wireless would be just about where it is today even without the NII. Perhaps more importantly, there is a widespread belief that development and use of radio-based systems and technologies will continue to expand dramatically---with or without the NII---as users become more familiar with them and as applications that meet real needs are developed.

WHY WIRELESS?

While estimates of demand and future subscriber rates vary considerably, most analysts believe that wireless telecommunications will become widely available over the next decade. Demand for mobile access to telecommunications networks and services is growing, and many companies--old and new—are rushing to get into the wireless business. But what is driving the trend toward wireless technologies?

Portable computing devices allow users to send and receive electronic mail, access online services and exchange files with other users. The combination of portability and connectivity is driving many new applications of wireless technology

[12]Pelton, op. cit., footnote l,pp. 27-34. Despite a wealth of conferences, papers, and public hearings, for example, the debate over universal service continues. Different segments of the service provider community remain split over how best to deliver an evolving "universal service" "Universal Service Consensus Eludes NTIA..." *Telecommunications Reports,* vol. 60, No. 52, Dec. 26, 1994.

[13]In comnents on this report, one reviewer noted: "In essence,what we are doing is that we are building a system's structure without knowing what its function is or ought to be.When one would design most other systems or for that matter, e.g., a building, one typically would first start with function from which structure follows. With the NII, and with wireless infrastructures as well, I believe we ignore this thinking and we start first with structure....shouldwe not raise the basic question as itwill probably be inevitable that many dysfunctions are the result of building a structure, i.e., happily paving the NII?" Rolf T. Wigand, personal communication, Apr. 28, 1995.

[14]U.S. Congress, Office of Technology Assessment, *Linking for Learning:A New Course for Education,* OTA-SET-430 (Washington,DC: U.S. Government Printing Office, November 1989).

TABLE 1-1: U.S. Wireless Telecommunications Service Subscribers and Growth Rates, 1984-94

	Cellular telephone subscribers (millions)	Cellular telephone growth rate (percent)	Pagers in use (millions)	Pager growth rate (percent)
1984	0.09			
1985	0.34	278	4.5	
1986	0.68	100	5.4	20
1987	1,23	81	6.5	20
1988	2.07	68	7.8	20
1989	3.51	70	9.4	21
1990	5.28	50	11.2	19
1991	7,56	43	13.4	20
1992	11.03	46	15.3	14
1993	16,01	45	19.3	26
1994	19,28*	20		

● Through June 1994. All others at year end.

SOURCES: Cellular Telecommunications Industry Association, Personal Communications Industry Association, Telephone Industry Association, and National Cable Television Association, 1995.

To understand the role radio-based technologies will play in the NII, it is necessary to understand the factors driving the demand for wireless services, as well as the technological capabilities and advances that are making new applications possible. Each of these factors—technology *push* and demand *pull—is* working independently to fuel the rush to wireless, but they also sustain and reinforce each other. This section describes the technical and sociological context in which wireless technologies and services are evolving and that simultaneously underlies the transition to the NII.

▮ Wireless Growth Estimates

Much of the excitement that surrounds wireless communications is based on assumptions analysts and companies make about what people and businesses want, but there is little agreement on how big the potential market for wireless might be. Most analysts base their estimates of future wireless growth on the diffusion of cellular telephone service and, to a lesser extent, on sales of portable computers. The growth rate of cellular telephone service is high, running about 45 percent per year in the United States until 1994, with comparable rates in other developed countries. 15 Paging, another widely used service, has experienced growth rates of about 20 percent per year for nearly a decade (table l-l). In another measure of potential demand, NTIA recently completed a study of future spectrum requirements that indicated that more than 400 MHz of additional spectrum was needed to support a growing range of wireless services.[16]

As a result of such findings, there is growing consensus that the demand for some kinds of wireless services is likely to be very high. Some analysts believe that as many as 100 million people will use some type of wireless telecommunications device by the year 2010. The following table of projected demand demonstrates both the trends and the variations in demand, but do not necessarily reflect OTA's assessment of the extent of the market (table 1-2).

All data or forecasts relating to future demand for wireless services must be regarded cautiously. Projections vary widely, reflecting different in-

[15] Compound annual growth rates (1990-92) in other countries range from 16 percent in the United Kingdom to 54 percent in Australia to 115 percent in Taiwan. Statistics cited in "ITU Deems Cellular Telephone Growth 'Truly Explosive,'" *Mobile Phone News,* June 20, 1994

[16] U.S. Department of Commerce, National Telecommunications and Information Administration, *U.S. National Spectrum Requirements: Projections and Trends,* Special Publication 94-31 (Washington, DC: U.S. Government Printing Office, March 1995).

TABLE 1–2: Wireless Technologies Subscription Forecast, 1993–2003

Service	1994 Subscribers (millions)	1994 Penetration (percent)	2000 Subscribers (millions)	2000 Penetration (percent)	2005 Subscribers (millions)	2005 Penetration (percent)
New PCS			14.8	5.4	39.4	13.1
Satellite	0.1	0.0	1.3	0.5	4,1	1.4
Narrowband/Paging	24.5	9.6	56.2	20.4	92.2	30.7
Dedicated data	0.5	0.2	3.4	1.2	5.7	1.9
Cellular	23.0	9.0	46,9	17.0	65.4	21.8
SMR/ESMR*	1.5	0.6	5.2	1.9	9.0	3.0
Total	34.1	13.4	79.7	28.9	136.3	45.4
Total voice services	14,6	5.7	48.2	17.5	96.5	32.1

Note: The following U.S. population figures were used: 1994-255 million, 2000--275.8 million, 2005-300.3 million.
Note: Total subscriptions include individuals with multiple subscriptions across services (i.e., there are more subscriptions than subscribers).
*SMR/ESMR = Specialized Mobile Radio/ Enhanced Specialized Mobile Radio

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

dustry definitions, assumptions, and biases. The data are highly uncertain and projection methods themselves crude and imprecise. Great uncertainty underlies all these numbers.

▮ Technology Trends and Drivers

Rapid advances in technology are the most visible, and one of the most important, drivers in the development of the NII and wireless services. Over the past five years, advances in information and communications technology have greatly expanded the capabilities and flexibility of existing services, while also making possible a whole range of new services, including wireless. Cellular, PCS, and Enhanced Specialized Mobile Radio (ESMR) services, for example, are the result of improvements in computer processing, battery technology, miniaturization, and new digital signal processing and transmission techniques (box 1-3). New satellite services are the result of advances in digital compression technologies and improved computer processing-in both the provider's network and in consumer equipment. Current development efforts promise to bring users even more features and advantages in the future.

Technology advances have a two-fold, somewhat paradoxical, impact on the development of wireless technologies. First, as noted above, advances make new applications and services possible. As new services are introduced and existing services are improved, however, more people use them, sometimes resulting in congestion and "crowding" of the most popular frequency bands. Cellular telephones are now so popular that, in some areas, it can be difficult to place a call during rush hour because the cellular system is full. Technology advances, however, can also help solve these capacity and congestion problems. New technologies enable more efficient use of the spectrum by squeezing more users into existing bands, and by allowing radio frequencies to be shared more easily among different kinds of services.[17] Cellular service providers are now installing digital technology to add capacity to their systems and provide clearer calls.

[17] For a discussion of the range of solutions to spectrum crowding, see U.S. Department of Commerce, National Telecommunications and Information Administration, *U.S. Spectrum Management Policy: Agenda for the Future,* NTIA Special Publication91 -23 (Washington, DC: U.S. Government Printing Office, February 1991), p. 13; and Richard Gould, "Allocation of the Radio Frequency Spectrum," contractor report prepared for the Office of Technology Assessment, Aug. 10, 1990.

BOX 1-3: Wireless Technology Trends

Miniaturization

A key technical factor pushing the development of wireless technologies is the rapidly shrinking size of radio components. Advanced technology has enabled increasing numbers of functions to be performed by a single chip and at higher speeds. This allows manufacturers to produce telephones, pagers, and computers that are smaller, lighter, and consume less power. The limiting factor to the size of some of today's products is no longer the chips needed to make them operate, but the physical characteristics of the people who use them—keys that are too small to easily type on or dial are not very useful,

Battery Technology

The problems associated with powering today's portable devices continue to frustrate and annoy many wireless users. The batteries required to run portable cellular phones and computers are usually heavy and/or provide limited hours of operation, and they can be expensive. A number of developments in battery technology may remedy this situation. Some involve new technologies, such as nickel metal hydride (NiMH) and lithium ion (Lion) batteries. Another solution being developed is a zinc-air battery that draws oxygen from the atmosphere to extend its life to 15 continuous hours. Power-saving solutions that make smarter use of battery power by the devices themselves hold promise for extending battery life further. More power-efficient displays and more efficient sleep modes are examples of ways in which small improvements could yield significant benefits in battery life.[1]

Frequency Reuse

Capacity is a major problem with many mobile communication systems. In any given area, when a specific frequency is in use it cannot be used for other purposes or by other users.[2] Radio waves, however, travel limited distances (see appendix A) before they fade out; beyond that point, a specific frequency can be reused without interfering with the other signal. This is the principle that underlies cellular telephony. Within a geographic area encompassing many cells, the same frequencies might be used up to six times. Shrinking cell sizes and lower transmitter powers, however, are not a permanent solution for increasing capacity. There are limits on how small a cell can be and how low power can go while still maintaining adequate quality.

Use of Higher Frequencies

As the lower frequency bands have become increasingly crowded, engineers have begun to develop technologies that would use higher, less crowded frequencies.[3] As was the case in extending terrestrial frontiers, developing higher frequencies is difficult and expensive. In addition to the cost of developing new devices that will operate at the higher frequencies, transmission problems typically worsen at higher frequencies. Some of those problems, such as increased attenuation due to rain, appear to be surmountable only by brute force-by increasing transmitter power. In satellite systems, power must be increased at both the original transmission (uplink) site on Earth and on the satellite itself. Increased satellite power greatly increases costs.

(continued)

[1]Clive Cookson, "Battery Technology: Still an Achilles Heel, " *Financial Times Review, Information Technology,* May 3, 1995, p.7.

[2]This is, of course, an oversimplification. Different radio services can be designed in many ways to share spectrum

[3]For a recent discussion of the upward expansion of usable radio frequencies, see Edmund L. Andrew "Seeking To Use More of the Radio Spectrum, " New *York Times,* Sept. 11, 1991, p. D7.

BOX 1-3: Wireless Technology Trends (Cont'd.)

Satellite Antennas

Advanced satellite antennas permit the use of smaller, less expensive Earth stations by making more efficient use of available satellite power. Such antennas direct the signal toward, and concentrate it in, areas where the intended users are located. Systems with such antennas, called spot beams, also make more efficient use of spectrum than those with large, circular beams which waste satellite power by transmitting beyond the limits of the desired service area. The reduction of signal levels outside the service area permits the same frequencies to be reused by other systems serving nearby areas, in the same way that cellular technology operates. The National Aeronautics and Space Administration's (NASA) Advanced Communications Technology Satellite (ACTS) system uses spot beam techniques, and Motorola's Iridium and the Teledesic system also plan to use them.

Spread Spectrum

Spread spectrum is a modulation technique first developed to hide military communications amid natural noise and other signals. More recently, spread spectrum has been used to permit low-power signals to share spectrum with other services. As the name implies, the original modulating signal is spread over a wide range of frequencies (bandwidth) for transmission. Interference from conventional signals or other spread spectrum signals appear as noise to the system, and can be eliminated.

There are several types of spread spectrum systems. One type, known as direct-sequence spread spectrum, divides a radio signal's energy over a wide range of frequencies so that a little part of the signal appears on each frequency in the band. Frequency-hopping spread spectrum techniques spread a signal out over many frequencies by hopping from frequency to frequency in a sequence synchronized with the receiver. One frequency is not dedicated to one user, and all frequencies can be used more efficiently. As more user/signals are added, however, the noise may eventually become too great for good communications. New adaptations of spread spectrum techniques, including advanced forms of CDMA may help solve some of these problems.[4]

Advanced radio transmission technologies that spread radio signals over extremely wide bandwidths may also provide solutions to transmission and capacity problems. Several companies are working on radios that send and receive over an extremely wide range (up to several GHz) of frequencies, providing greater capacity than today's channel-oriented approach, However, little is known about the operational aspects of these devices, especially the potential interference they could cause to other systems—and spectrum managers believe that implementing such radios, especially in already-assigned bands, could be extremely difficult.

[4]Synchronous CDMA, e.g., is being developed for use in future personal communications systems. Jack Taylor, Cylink, personal communication, Mar. 14, 1991.

SOURCE: Office of Technology Assessment, 1995.

Digital Technology

Many recent communications technology improvements are the result of the rapid diffusion and deployment of digital technologies in all aspects of communications and information processing. Digital information is easier to compress, transmit, manipulate, and store; and digitized voice, data, and video are much easier to combine into a wide range of multimedia applications. These advances are fundamentally altering the relationships between previously separate systems and services.

For wireless communication systems, digitally encoded and transmitted information offers sev-

With just a personal computer, a radio scanner, and some software, criminals can reprogram cellular phones to steal service from unsuspecting consumers.

eral advantages over analog systems. The greatest benefit of digitizing radio communications is the ability to compress and combine multiple signals. This allows more information to be transmitted in a given time and more users to share a given amount of spectrum, thereby increasing speed and capacity.[18] Applications using digital compression techniques are spreading rapidly in many radiocommunication services. In cellular telephony, for example, digital signal processing and transmission techniques promise capacity up to 10 times that of existing analog cellular systems. Satellite companies are reportedly working on technologies that will combine up to 16 video signals on a single transponder.

Combined with compression, digital transmission techniques allow wireless system operators to exploit the spectrum more efficiently and deploy a wider range of applications serving more users. Digital transmission technologies, including spread spectrum, are a crucial piece of the solution to the spectrum congestion some radio frequency bands are now experiencing. Time Division Multiple Access (TDMA) and Code Division Multiple Access (CDMA), for example, are digital transmission schemes that allow more telephone conversations to be transmitted over a given bandwidth than analog technology allows (see chapter 3). Such schemes will allow Commercial Mobile Radio Service (CMRS) providers to dramatically increase the capacity of their systems and offer a wider range of services. Broadcasters believe that digital compression and transmission technologies will allow them to use their existing spectrum-which currently can carry only one analog channel-to transmit six or more channels of digital television programming (at today's quality), one high-definition television (HDTV) channel, or new information services.[19] Digitized information can also be more easily and effectively encrypted, making conversations and other communications more private, and preventing unauthorized pirating of pay services.

Uncertainty

Despite the benefits that new technologies bring, rapid technology advances also cause a great deal of uncertainty among users, manufacturers, service providers, and policymakers. Which technology is best? What is coming next? With technology life spans now measured in months not years, it has become harder for consumers and businesses to decide what services and equipment to buy and when.[20] For policymakers and regulators, rapid change makes policymaking and standards-setting more complex. Several factors underlie the uncertainty that now characterizes wireless technology development.

Much of the uncertainty can be traced to the fact that, despite significant research and development, and a great deal of industry "hype," few of

[18] Digital compression works by removing redundant or unnecessary information from the signal. In video transmission, for example, individual elements of the picture that do not change from frame to frame (when the background of a scene remains the same, for example) are not resent for each frame--just a code that tells the receiver/decoder that no change has taken place. This allows less information to be sent, requires less bandwidth, and allows more channels to be transmitted.

[19] Advanced Television (ATV) or Digital Television (DTV) increasingly are being used in place of high-definition television (HDTV).

[20] The recent delay in Bell Atlantic's planned system upgrade is evidence of the uncertainties facing today's service providers.

the new wireless systems are widely available. PCS frequencies have just been auctioned, and services are not expected to be available until late 1995 or 1996; ESMR technology has been plagued by technical problems; only one of the LEOs systems has launched satellites[21] (although experimental satellites have been used for some little LEO-like services), and many of the data services being developed are hampered by slow transmission speeds, incompatible systems and protocols, and a limited selection of applications. As a result, potential users do not know what the new systems will really offer, and technical details remain to be finalized. Lack of real-world operational experience also makes it hard to realistically determine the most efficient wireless access system—and thus to identify potential winners and losers.

In addition, the pace of technology deployment is also uncertain. Although, strictly speaking, the development of core radio-based technologies will not be a barrier to the development of new wireless systems and services, the pace of development and implementation is likely to be slower than most analysts predict, and, in combination with slow standards-setting processes and regulatory change, could slow the deployment of many new systems by at least months and possibly years. Finally, in some newly reallocated bands—the PCS bands, for example—new users are being required to pay to move incumbent users to other frequencies. This process will also be time-consuming and slow the deployment of wireless services.

Demand: Why Do Users Want Wireless?

In addition to the *push* provided by rapidly advancing technologies, users—consumers, businesses, and government—have an expanding set of needs and demands that are *pulling* the development of wireless applications. Although each user group has its own specific needs, there are also general factors that are increasing demand. These include the need for mobility and/or portability, easy access, ubiquity, and low cost.

Advantages of Wireless Technology

Wireless technologies have several unique characteristics that make them valuable to both individual users and companies wishing to distribute information. First, radio-based systems can be used to *broadcast* voice, data, and video programming and information to large groups of people over wide areas at relatively low cost. Broadcasting is point-to-multipoint and generally one-way. Radio and television broadcasters have served the American people for decades with news, entertainment, sports, public interest, and emergency programming. Satellite broadcasting promises to extend the reach of local audio and video programming to national, or even international audiences.

Second, wireless systems can serve needs that are not practically or efficiently served by wire-based networks. Both satellite and terrestrial technology, for example, can be used to create a *wireless local loop* to serve extremely remote telephone customers (see chapter 3).[22] Radio technologies can also be used to deliver communications services faster and less expensively than building or extending a wire-based network. Cellular technologies, for example, are being used in many developed and developing countries to bring telephone service to areas that have been unserved. Wireless Local Area Networks (LANs) connect computers where it is too expensive or impractical to install a wire—for example, in a building where asbestos creates construction hazards or an historic site. Many of the nation's schools reportedly have this problem. Wireless systems also allow flexible deployment of people and devices quickly and easily—e.g., to reconfigure a computer net-

[21] Orbcomm launched two satellites in March 1995. Both developed technical problems, but were later reported to be operational.

[22] Basic Exchange Telecommunications Radio Service, or BETRS, has been in use for many years to provide telephone service to remote rural residents. US West has also been testing the use of satellites to provide telephone service to remote areas of Wyoming.

BOX 1-4: Scenario—Wireless Technologies in Small Business

Sandra has operated her own plumbing business for the past three years in sprawling Phoenix, Arizona. It is a demanding business—lots of competition, small margins, and customers who can't wait long for service.

Sandra decided early on to minimize her overhead and run her business entirely out of her van, so she bought a portable telephone, a pager, and a laptop computer with a wireless modem. Sandra figures she can be on the job and be able to respond to calls for service, thus keeping business flowing in. Her response time is often very rapid, which customers appreciate. She handles all the estimates, ordering, invoices, and accounts on her laptop, including ordering parts for delivery either to her house, or directly to the jobsite. This means she doesn't have to hire a secretary or maintain an office, keeping her costs down.

Setting all this up was quite a chore for Sandra. She tried to do it on her own, but assembling the right hardware, software, service providers, and actual services proved too difficult. She ended up using a systems integrator, a national franchise operation that could get better deals on components than she could, and even handles the various telecommunications service billings for her. Even though she pays a premium for the service, she figures she will come out ahead because the technologies are just changing too fast for her to keep up.

Because the city is so big and growing so rapidly, Sandra also decided to invest in satellite navigation and route-planning equipment. Traffic can be difficult and time spent on the road is time lost on the job, so the payoff is obvious. She also hopes to expand her business to two vans, and hire her friend Wayne. The navigation gear she has will allow her to keep tabs on him, and coordinate their responses to emergency calls.

Sandra is also the mother of two young school-age children. Because she needs to spend so much time on the road, she stays in touch with them via pocket telephones and pagers. She likes the sense of security it gives them all because she can locate them whenever she needs to, and they can call her (and have twice) or911 if they feel in any way in danger. But she also worries that they will never know the feeling of really being free and independent, like she was at their age, when the whole neighborhood was her playground.

SOURCE: Office of Technology Assessment, 1995.

work without having to move wires, or deploy emergency personnel in times of natural or man-made disasters.

Finally, wireless can serve quite well when communication needs are unpredictable or transitory. Radio-based technologies are ideally suited to providing ubiquitous access in a specific geographic area where a user will be traveling.[23] A mobile repair person, for example, may not know in advance where his or her services will be needed, and will likely need to stay on-site for only a short period of time. This capability allows people to be connected wherever they are, and serves the need to get information or communicate *immediately.* Different types of systems will serve different areas-a building or mall, an office park or

[23] In reality, many of the benefits of radio technologies for access and mobility are based on the concept of broadcasting. Broadcasting> in fact, is the mode of communication that allows mobility to take place—no matter where one travels within the range of the signal, the signal is always present. Cellular telephony, although not a broadcasting service like radio or television, uses a broadcast signal to contact the desired person. Similarly, in cases where many users in an area need access or where users will be at different locations-some known, some not—the broadcast radio signal, because it blankets a given area, is what makes ubiquitous access possible.

BOX 1-5: Scenario—Wireless Technologies in the Migrant Community

Jose is a migrant farmworker in West Virginia with strong ties to Miami where his family lives. His job is tough—he spends many hours in the orchards battling poison ivy, insects, and the residue of pesticides sprayed on the trees. He worries about his wife and children—particularly how his eldest daughter is doing in school—and his sister, who has had a series of medical difficulties that have left her unable to work. Jose has always been the responsible family member. Because he speaks English, he often negotiates appointments, visits to the health clinic, and so on for family members. Being able to contact and be contacted by them is essential for his family's survival. Jose gets little time off during his workday; even when he does, he is unable to find a payphone because he is often miles from the nearest town.

But recently, Jose bought a pocket telephone that he takes into the fields with him. Several years ago, this would have been too expensive, but a price war among the mobile telephone companies has put both telephone handset and service charges within his grasp. He uses the phone to call his family in Florida nearly every day. Occasionally he even contacts his widowed mother back home in Mexico, despite the very high international telephone charges (he typically pays about $40 for a four- to five-minute call), Jose also finds it convenient to make appointments for himself and his coworkers at the local clinic in rural West Virginia, to contact the school his daughter attends in Miami, and to call the hospital where his sister's doctors work. It used to be difficult to get a return call because he was not near a telephone, the payphone was busy, it was after business hours, or he had followed the migrant work stream to a different community. Now he feels much more connected to the people and services he needs to live a better life.

SOURCE: Office of Technology Assessment, 1995.

downtown area, a metropolitan area, a region of the country, the whole country, and even the whole world. Users will be able to pick and choose the technologies that best meet their needs.

Mobility anti Access

The unique advantage that wireless technologies bring to the NII is mobility. Increasingly, users want to communicate wherever they are-while walking, driving, or traveling on a plane, train, or ship.

> [E]very human, even the most committed landlubber, is a sailor of sorts, or else a driver, or a flyer, or at least a pedestrian. After almost a full century of development, the telephone still had a very fundamental shortcoming: telephone wires don't move. People do.[24]

All wire-based services are inherently limited in one important way: they can go only as far as the wire extends. For applications that require mobility, wireless is the only way communications services can be provided, and thus mobility is the most important characteristic and benefit that wireless technologies bring to the NII. Most radio-based services in the NH will function as tetherless, mobile, portable extensions of the wire-based network.

Clearly, mobility is an integral aspect of human activity, but telecommunications services that enable or accommodate mobility are still in their infancy. Strong demand for such services has existed in the past, and business interest in new wireless technologies suggest that future demand is anticipated by many others. However, little is

[24] Peter W. Huber, Michael K. Kellogg, and John Thome, *The Geodesic Network II: 1993 Report on Competition in the Telephone Industry,* (Washington, DC: The Geodesic Co., 1992), p. 1.5.

"Who can we call?"

known about the scope or scale of that demand. Few data are available to predict how people will actually use mobile systems, and thus which wireless services are most needed. Better data about mobility and its characteristics would help anticipate the future direction of these technologies as they are brought into the marketplace and the society in greater numbers. Chapter 2 discusses mobility in greater detail.

Wireless technologies can provide more than just mobile services, however. Radio-based systems can provide information, entertainment, and communication services to homes and businesses as well. In this context, wireless technologies are expected to make their greatest contribution as an access point to the resources of the NII, either extending services where wires cannot go-to remote customers, for example-or competing with wireline networks in the provision of traditional communications and entertainment services such as telephone, data communications, and video programming. Satellite systems, for example, can provide end-to-end voice, data, and video services that bypass, and could compete with, the wireline infrastructure entirely.[25] Cellular, PCS, and direct broadcast satellite (DBS) services will compete with wireline alternatives such as the telephone and cable television networks to provide the *last mile* connection to the resources of the NII. *Unlicensed* wireless technologies (see chapter 4)

[25] Satellite systems are technically capable of offering two-way broadband services, but the limited capacity of satellites has meant that such services were largely restricted to large business or government users who could pay for the equipment and satellite time. Such services have not been intended for general commercial (public) use. This may change with the advent of such satellite-based systems as Spaceway and Teledesic (see ch. 5). In combination with the existing telephone network, satellite systems also can deliver interactive services to the home, but with only limited return channel capabilities,

BOX 1-6: Scenario—Wireless Technologies in the Drug Trade

Mike is a major drug distributor in southeast Los Angeles. He moves thousands of kilograms of cocaine worth millions of dollars through his neighborhoods every year. He knows the Drug Enforcement Administration and the police are investigating him. Though Mike is 24 years old, he has never been caught, mostly, he thinks, because he is smart, protects himself, and stays ahead of the cops. He keeps his records (encrypted) on a laptop. He keeps in touch with his information and distribution networks through pagers and stolen and cloned cellular phones. Associates tell him what the cops and other dealers are up to through frequent calls, and he makes each call short so that even if they find him they won't be able to tap him as he moves from cell to cell.

Mike is always on the move in his car because he believes that this makes it harder for the cops to find him and listen in. He has his car searched daily for vehicle location devices, which he thinks might be planted by the police to keep tabs on his movements. He hears that new phone encryption devices cannot be broken even by the government, but he still needs to think about getting one. So far, it's easier just to clone a phone and change the number,

SOURCE: Office of Technology Assessment, 1995.

will allow users to create spontaneous, direct connections between their computers or PDAs—allowing them to share data or communicate in limited areas such as a classroom or office---all without connecting to a wired network.

Productivity and Efficiency

For businesses, the bottom line on wireless technology is its contribution to productivity. Although research on the productivity impacts of wireless communication technologies is limited and largely anecdotal, some analyses attribute large productivity gains to the use of wireless, mobile technologies. One analysis estimates the economic contribution of mobile services at five to eight times the cost of ownership.[26]

Another study assessed employees' ability to "recapture" time spent away from the office by using cellular telephones.[27] Table 1-3 shows the annual productivity gains for broad job categories, and assumes conservatively that at least 14 minutes or 10 percent of time away from the office per day is recaptured using cellular telephones.[28] If a sales representative recaptured 20 percent of time away from the office, the productivity gain

TABLE 1–3: Annual Productivity Gains Using Cellular Phones

Occupation	Annual productivity gains
President or chief executive officer	$2,200
Sales or other revenue-generating employee	1,200
Middle management/director/ supervisor	780
Field service person/technician	680

SOURCE: Pactel Cellular, "Cellular Use and Cost Management in Business, " study prepared for Pactel Cellular by Yankelovich Partners, Newport Beach, CA, 1993.

[26] "Mobile Commmications Europe Lags Behind America," *Intug News,* October 1994, p. 20.

[27] PacTel Cellular, "Cellular Use and Cost Management in Business," study prepared for PacTel Cellular by Yankelovich Partners, Newport Beach, CA, 1993.

[28] Senior executives in the survey reported they were away from their offices 149 minutes per day, and that they used cellular telephones about 10 percent of this time. The study then calculated the annual productivity gain by multiplying time recaptured by the average wage rates for various job classifications.

study also notes that increased accessibility and faster customer response time play an important role in decisions about providing cellular telephone service to employees.

These figures should be viewed with caution. Employees may do many productive things during the time they spend away from the office while not on the telephone. On the other hand, time spent talking on the phone is not necessarily productive. Alternatives to having a cellular telephone, such as using pay phones, are not addressed in the study. Calling the home office too often may reduce an employee's autonomy and incur increased coordination costs for the whole firm, and could reduce productivity overall. Variations in job structure and performance may occur as well; as a result, measuring recaptured time away from the office may not accurately describe the benefits and disadvantages of cellular phones. For example, in addition to improvements in productivity, the increased sense of company control over employees' activities is often a significant element in decisions to adopt wireless technologies.

Evaluating the contributions of wireless technologies to national productivity is even more difficult. Extrapolating from figures like those presented above to make estimates of national productivity enhancements is problematic because the job classifications given are too aggregated to know what they actually contain and how different groups actually use wireless telecommunications. As a result, attributing and separating direct and indirect contributions of wireless and mobile systems and services to gross domestic product are difficult.[29]

Likewise, the contribution of wireless telecommunications to employment levels is likely to be positive, but its magnitude is unclear. Rough estimates by the Cellular Telecommunications Industry Association based on the U.S. experience with cellular telephony suggest that the introduction of PCS and the extension of cellular telephony, SMR, and paging will result in the creation of 280,000 new jobs in these industries over the next decade and approximately 700,000 in related industries, such as manufacturing, retailing, and ancillary services.[30] Estimates of the contribution of wireless telecommunications to economic growth have not been made.

Uncertainty

Beyond the basic characteristics of demand, the fundamental question surrounding the evolution of the NII and new wireless services is: What do users really want? What will they be willing to pay for? Many companies have done marketing studies and some have conducted field trials to determine the answers to these questions. So far, no "killer applications" have emerged. In communications services, quality, reliability, coverage, and low price seems to be most important. In entertainment and data services, there is little consensus about consumer and business demands beyond, possibly, electronic mail. Interactive services have continued to disappoint both users and providers. Nevertheless, proponents point to the success of cellular telephony as evidence of widespread demand for wireless, especially mobile, products and continue to develop services and equipment based on the belief that eventually they will discover what customers really want.

The uncertainties of demand are some of the most important considerations underlying many of the NII policy debates now taking place. Specifying NII services, setting minimum service

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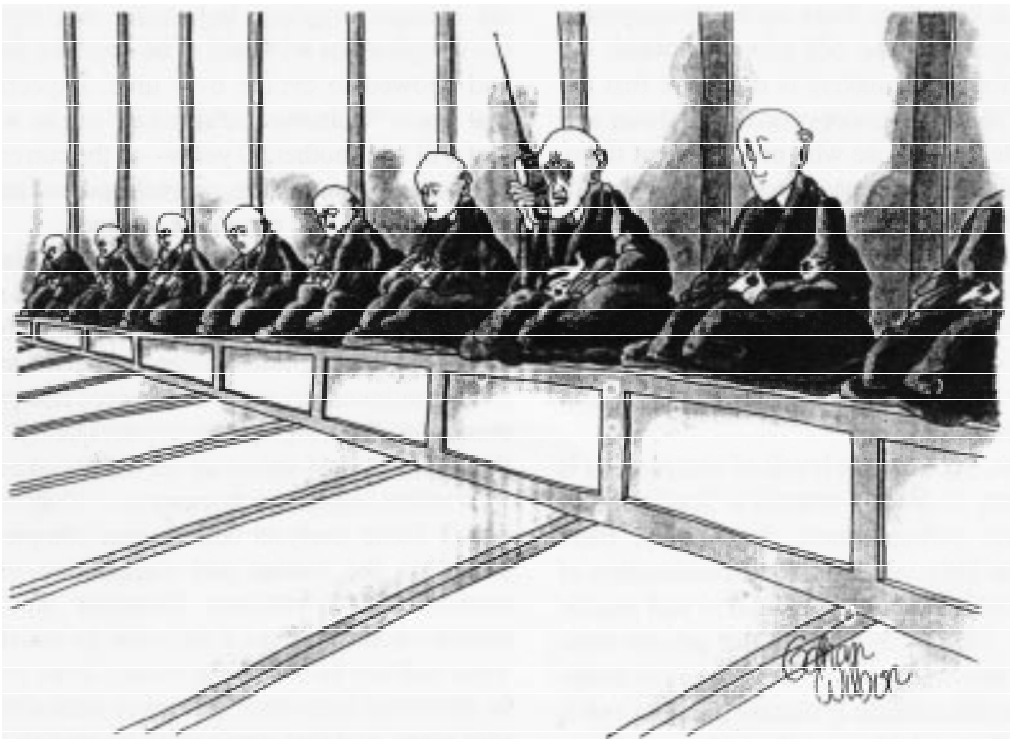
[29] Estimates range from 2 to 3 percent of GDP to 33 percent, according to a study conducted by MITI (Japan) and reported in "Mobile Communications," op. cit., footnote 26.

[30] These are rough estimates based on proprietary information from firms in the industry, projections of wireless service subscriber rates, extrapolations from the growth and penetration rates of cellular telephony, and estimates of the ratio of direct jobs in cellular service provider companies to indirect jobs in manufacturing, retailing, etc. No effort was made to determine the number of jobs lost, if any, due to substitution of wireless communications for other communications services. These estimates should be considered very tentative; further research is needed.



"None of this seems to be doing me any good at all"

standards, and defining universal service all hinge on an implicit understanding of what people want and need. Without this understanding, setting specific, long-term policies for NII services is likely to be premature. Because most policymakers and industry representatives believe it would be inappropriate for the federal government to pick technology "winners and losers," regulators also must avoid enacting policies that inadvertently have the same effect. At this early and uncertain stage of wireless development, putting constraints on the industry could stifle valuable development efforts. Open entry and competition-subject to some safeguards for basic consumer protection—may be the best solution, at least in the near term. As the market matures, new regulations and safeguards may be needed based on the experiences of the industry and the users.

POLICY ENVIRONMENT

Over the past several years, technology advances have fundamentally changed the nature of communication, information, and entertainment services and the industries associated with them. These changes have put increasing pressure on lawmakers to reform telecommunications regulation, a process in which they are now deeply engaged. The ideological concepts dominating the current public policy debate about telecommunications reform will significantly affect how wireless systems will fit into the NII, determining how and where they can compete with wireline carriers and what rights and responsibilities they will have. Considered together, these two elements, technology and ideology, constitute the policy context for wireless technologies in the NII.

■ Concepts Guiding Policy

Competion

The many networks and systems that make up the current U.S. communications and information infrastructure are widely deployed and access to services is usually physically available even if the

services are not taken. Thus, as the development and deployment of the NII moves forward, the challenge for policymakers is to ensure that the benefits of the new services and applications will be available to all those who need or want them, including those who cannot access them now. To accomplish these goals, most policymakers have come to view competition in an open and deregulated (as far as possible) market as the most socially and economically efficient solution for promoting diversity in information sources, keeping quality high and innovation moving, and controlling prices.

However, the form (or level) of competition is being bitterly disputed—what is a "level playing field?" And perhaps more importantly, there seems to be little public policy consideration of the long-term effects of competition and market reliance.[31] There is little doubt that private companies and their consultants have done such analyses, but the information is closely guarded and is not generally available to policymakers and analysts. As a consequence, it is impossible to judge the extent to which these analyses consider long-term (10 years and longer) effects. Policies that promote competition now may ultimately lead to a market structure that consists of a small number of large corporations controlling end-to-end communications of all kinds. Again, little or no research has been done that bears directly on wireless economics and long-term industry structure.[32]

It is also unclear whether a one-shot approach to changing regulatory structures will work. The history of cable television regulation reflects the need to adapt rules to the different stages of industry growth and external (competitive) conditions. What is clear is that industries and technologies are changing rapidly, suggesting that any new laws/regulations will need to be similarly flexible and allowed to evolve over time. Expectations that a new "Communications Act" can be written that will last another 60 years—as the current one has—may be unrealistic, given the pace of technological, social, and economic change.

Finally, many analysts and public interest groups are concerned that social goals and needs may get lost in a competition-driven policy framework. What safeguards might be needed to promote continued diversity of services and protect consumers from high prices or poor quality? Does the imposition of universal service requirements on wireless businesses threaten their ability to operate? Some analysts believe that complete reliance on the market and competition—where economic and business decisions are paramount—could lead to a situation in which services will not be rolled out evenly, users will not be protected from poor service or confusing service plans, and that service will be available only to those who can afford it. On the other hand, overly aggressive requirements by the federal and state governments could threaten the vitality and even the existence of new competitive services. The private sector's research, development, and investment activities could be stifled if the federal, state, or local governments adopt rules and regulations that inhibit the flexibility to develop new products and services.

Competition, Diversity, and Interconnectivity

Diversity and competition are closely related. Competition is premised on many diverse companies producing goods and/or services. In the current technological climate, the wide range of new services being developed is largely due to the

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[31] See, for example, Eli Noam, "From the Network of Networks to the System of Systems," *Regulation*, No. 2, 1993. Some commenters argue this statement is too strong. In its policies regarding PCS licensing, the FCC did set limits on cellular participation to address concerns about competition and industry concentration.

[32] Some initial research has been completed. See, for example, Bruce L. Egan, "Economics of Wireless Communications Systems in the National Information Infrastructure (NII)," unpublished contractor report prepared for the Office of Technology Assessment, U.S. Congress, Washington, DC, November 1994; Glenn A. Woroch, "The Evolving Structure of the U.S. Wireless Communications Industry," unpublished contractor report prepared for the Office of Technology Assessment, U.S. Congress, Washington, DC, December 1994.

introduction of new digital technologies. These technologies make it easier to produce, transmit, and store information and data, allowing businesses to combine voice, data, and video on networks that were previously dedicated to only one type of service. This digital convergence has made it easier for companies to invade each other's turf. So, for example, telephone companies want to use their telephone lines to deliver information and video services, and cable companies want to provide telephone service. The rapid development of new technologies has also led new companies to enter the field—utility companies, for example, want to enter the telecommunications business—further increasing the diversity of companies involved. Wireless companies are an increasingly important part of this competitive mix.

The diversity of service providers and users reinforces the importance of connectivity and interconnection. The more different sources of information and entertainment there are, and the more users follow their individual tastes, the greater the need for interconnectivity. In the history of telephony, this is referred to as the externality of networks—the value of the network (to an individual or business) rises as more and more users are connected to it. Today, the value of interconnectivity is higher than ever. Computers, for example, started out primarily as stand-alone devices, but increasingly they are part of networks that allow them to access almost any type of information around the world. Allowing users to access rich and diverse forms of information from a variety of suppliers is at the heart of most views of the NII, and moves issues surrounding interconnection to the forefront of many current policy debates.

Technology's Impact on the Policy Environment

Technology and "Convergence"

As noted above, the U.S. communications infrastructure consists of many different technologies and systems. Over the past 100 years, each of these developed independently from the others, and different regulatory structures were developed to manage the distinct characteristics of each industry. For example, the telephone system, which was designed to provide two-way voice communications, has operated as a virtual monopoly for almost a century based on the principles of common carriage and universal service. The broadcasting industry, both radio and television, has concentrated on delivering one-way information and entertainment to a wide local audience, and has been regulated as a user of a scarce resource, the radiofrequency spectrum. Satellites have been providing national and international connections for voice, data, and television signals for many years. And finally, the cellular industry uses radio waves to extend the reach of the telephone network to mobile users. Each of these industries provided a different service based on different technologies, and consequently was subjected to different rules and regulations.

As a result of digitization and the increasing use of computer processing power in more and more telecommunications applications, however, systems and services that once were separate have now begun to overlap. This *convergence* is not merely the result of combining computers with communications, but of combining many services and applications that historically had been separate. Thus, convergence can be separated into three distinct phenomena:

1. *convergence of technology*, where computer power and communications technologies are integrated to improve functionality and offer new applications. For example, the marriage of computer power to radio technology was crucial in enabling cellular radio to be developed. Computers route calls to the correct cells and handle hand-offs as mobile users move from one cell to another. The networks that allow cellular users to *roam* are actually interconnected computer databases.
2. *convergence of applications*, where voice, data, and video services can be offered over the same network. Today, networks of all kinds—whether originally developed to transmit voice, data, or video—are being improved in order to

carry all kinds of information in many different combinations. By far the most common convergence is between voice and data services. The most obvious example is the use of the telephone network to send data by fax, using a modem, or via new digital transmission technologies such as integrated services digital network (ISDN). Cellular service providers have begun to offer a wider range of data services (see chapter 4), and some of the new LEO systems are designed to carry both voice and data. Because of its high bandwidth requirements, video is less often combined with other services; however, some cable companies offer data services, and satellites are capable of transmitting voice, data, and/or video signals.

3. *convergence of networks and companies* through mergers, acquisitions, and joint ventures. The most obvious example is the recent acquisition of McCaw Cellular by AT&T. This type of convergence is not between similar technologies and providers— a merger of cellular companies, for example—but a combination of systems: AT&T's long-distance (mostly fiberoptic) network with McCaw's local (cellular) systems. In addition to the economic rationale behind the merger—AT&T's desire to avoid paying access charges to local telephone companies—this type of merger indicates that there may be technical and economic efficiencies that make previously distinct communication systems interdependent.

Wireless technologies and companies are playing a central role in much of the convergence activity. In the past several years, wireline service providers of all types—cable, local telephone, and long-distance companies—have shown increasing interest in using wireless technologies to provide new services. The big winners in the recent PCS auctions, for example, were various groups of telephone and cable companies. Wireline companies are also investing in many different kinds of wireless companies and technologies. The Primestar DBS system is owned by a consortium of cable companies, and several telephone companies recently announced large investments in wireless cable companies. Most analysts expect such mergers to continue as the benefits of wireless become more apparent.

Convergence and Policy

The convergence of technologies and services has serious implications for U.S. policymakers at all levels of government who are already engaged in efforts to redefine how telecommunications is treated in this country. As the technological differences that have characterized different modes of communication disappear, new regulations and policies will be needed that are focused more on services and industry/market structure than on technology. This idea was explicitly recognized by Congress when it created CMRS based on the principle of "treating like services alike." Federal and state governments continue to struggle with how to update regulations in order to bring the benefits of new technologies to the widest range of people, while simultaneously promoting fair and open competition among the many different companies that want to provide services. Economic concerns are becoming more important as various segments of the wireless industry mature. Mergers and acquisitions have been going on for several years in the cellular, SMR, and paging industries, and horizontal concentration has already become a concern to regulators.[33] Over the longer term, the effects of market concentration and vertical integration of the sort promised by AT&T/McCaw are uncertain; economists have just begun to sort out the economics of wireless services and how they may interact with wireline services. Trying to anticipate the long-term competitive effects of current deregulatory policies will be difficult.

[33] Nextel, for example, was required by the Department of Justice to divest some of its radio licenses in specific cities before it completed acquisitions of its major competitors. This was due to a concern that Nextel would control too much of the SMR market.

FINDINGS AND POLICY OPTIONS

Overall, OTA found that—apart from current regulatory reform efforts—federal government action or assistance is currently needed in a relatively few, but important, areas regarding wireless technologies and their effective integration into the NII. Several factors led to this conclusion. First, the outcomes of current policy initiatives are unclear. The FCC is in the middle of a number of critical proceedings regarding wireless technologies, and Congress is in the midst of completely reshaping the nation's telecommunication industry. Before proceeding with even more far-reaching changes, it may be wise to evaluate the effectiveness of changes already put in motion.

Policy analysis is complicated by the dynamic nature of the industry itself. The structure of most segments of the overall wireless industry is about to change in fundamental and radical ways. Some services are only at a nascent stage. Services such as DBS, for example, have only just begun operating. For others, such as PCS or LEOs, initial regulations have been set, but the systems are still being built and are not yet operational. A final group of services, including Local Multipoint Distribution Service (LMDS) and some satellite services, does not even have final spectrum allocations or operating rules; widespread commercial service is years away.

In addition, even the wireless services that have been in existence for many years—radio and television broadcasting, cellular telephone, and satellite television—are facing radically new environments as digital technology and new competitors reshape their traditional ways of doing business. This fact—along with the uncertainties associated with technology development, the regulatory climate, and, most importantly, customer demand for wireless services—puts policymakers and analysts into the difficult position of waiting to see how consumers and markets will react to what has been done so far. Policies designed and implemented based on past assumptions and models of industry structure—monopoly-based or limited competition—are likely to be inadequate to address future models in which the structure will be quite fluid and unpredictable.

The second factor indicating a limited government role is the large amount of innovation and development now occurring in the wireless industry without benefit of direct government support. Over the last several years, hundreds of companies have begun developing wireless products and services, and most large telecommunications firms have initiated wireless projects as well. Few areas appear to need government financial assistance to develop new technologies or services—with some important exceptions noted below. This represents a change from several years ago, when financial markets were not eager to invest in wireless companies because of their often speculative nature and regulatory uncertainties. Money is now flowing to most segments of the industry, and, in fact, a number of analysts have commented that "wireless is hot" on Wall Street.

Finally, a political commitment to competition is the foundation of current economic and regulatory policy. Many policymakers view competition as a more effective "regulator" of industry than the government rules of the past, and are reluctant to put additional regulatory burdens, however well motivated, on industry. This approach, however, limits government involvement, and the development of the wireless industry needs to be closely monitored to ensure that the public interest is served.

Given these circumstances, determining the appropriate role and level of involvement of the federal government in the wireless industry is difficult. A strong government role could help promote industry growth, encourage diversity and innovation, and protect consumers. Low prices, quality, and security all are important concerns that may or may not be ensured by the market. Forward-looking policy also could anticipate and help diminish any potential future problems. However, a government approach that is too strong could overburden industry and reduce investment.

On the other hand, an approach that is too "hands off," relying too much on private sector

initiatives, could actually contribute to uncertainties (in this case primarily regulatory) that slow innovation and development. In the short term, companies may not invest if uncertainties are too great or development resources could be wasted on efforts that are later superseded by new technologies, regulations, or economic conditions. Benefits may take longer to appear. Given that the market has not even begun to operate in significant portions of the wireless industry, it is premature to identify market failures that could indicate policy problems. **In the future, government intervention-through changes in regulation or other incentives-may be needed if market failures develop.**

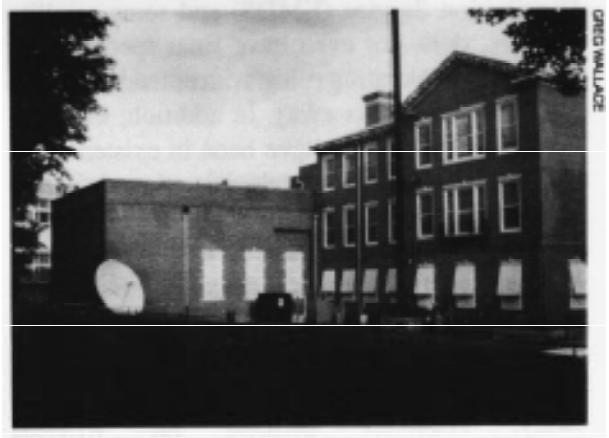
Despite the uncertainties, it is possible to indicate some specific social and public interest needs that competition and the market are not likely to address effectively, and for which some form of government intervention will be needed. Spectrum management, for example, is one important area requiring government action. Because public uses of the spectrum-public safety, national defense, amateur radio, and education, for example-are not subject to auction provisions (and do not operate as commercial or fee-producing services), there will continue to be an important federal government role in managing the spectrum to accommodate the largest number of services and users while avoiding interference and congestion.

Wireless technologies can also contribute to the achievement of other social and public policy goals where the market may not provide adequate incentives. Two specific examples are: 1) education, which may not have the resources to take advantage of wireless technologies where appropriate, and 2) underserved users and areas---the so-called "information poor," people whose economic status or remote locations may cause them to be underserved by profit-maximizing firms. Proposed legislation now under consideration by Congress addresses the need for connectivity through universal service requirements and provisions for educational institutions.[34] These issues are discussed throughout the report.

Given this environment, the federal government can perform three important functions over the next several years:

- monitor the growth of the industry and competition, and identify any potential market failures or social concerns that arise;
- continue to pursue policies that promote open access to all networks, including goal-setting and encouragement of industry standardization efforts; and
- promote development of new technologies, including ensuring the availability of adequate spectrum for existing and emerging wireless technologies.

The following sections discuss OTA's specific findings and identify several areas of interest and concern for policymakers. Although not every issue requires a policy response, the discussion will provide policymakers with a context for their deliberations and identify possible options for consideration as NII development advances.



Schools can use wireless technologies such as satellites to connect students and teachers to educational resources and *peers around the world.*

[34] See, for example, U.S. Congress, Senate 652, "The Telecommunications Competition and Deregulation Act of 1995," (Washington, DC: U.S. Government Printing Office, June 15, 1995) sections 103,104, and 310.

Uncertainty Pervades Wireless Technology Diffusion

Rapid technology advances, unfocused user needs, regulatory reorganization, and the nascent state of the wireless industry all combine to make predicting the future of wireless technologies and services highly speculative.[35] These same uncertainties make long-term social and economic implications even more difficult to forecast. **In the case of wireless and the NII, the level of uncertainty is much higher and more pervasive than usual; all aspects of the wireless industry—technologies, markets, and rules—are changing almost constantly.** Defining social and public policy goals in such an environment becomes quite a challenge as the current telecommunication debate in Congress attests. Consumer advocates believe that legislation currently proposed—S. 652 and H.R. 1555—will lead to concentration in various communications and media industries that will reduce diversity and raise prices. Industry proponents and many lawmakers, however, believe that allowing companies to compete and merge will produce lower prices and a wider range of programming. At this time, there is no way to determine conclusively what will happen. The issues will only become clearer once final legislation is passed and companies and consumers begin to react. Many issues are actively being addressed, but many more—some of the most difficult ones involving social and public policy—remain to be identified and resolved.

The uncertainty of demand is particularly important for legislators and policymakers charged with the task of defining rules to regulate various competing services. Overestimating demand for new services, and making such a judgment part of a definition of universal service, could subject companies to higher costs for upgrades or system construction that may not be recoverable through revenues. In addition, the technological limitations of some wireless systems may mean that they cannot—using today's technology—deliver some of the most advanced services, potentially disqualifying them from receiving universal service funding. Conversely, underestimating demand and matching policies to lower expectations may lead to inequities as companies roll out advanced services only to certain users—based on where they live and what they can pay. This could widen the gap between information "haves" and "have nots."

Uncertainty is not unusual in the development and deployment of new technologies, nor is it necessarily a bad thing. Some uncertainty is always involved in developing and marketing new products as manufacturers and service providers struggle to discover what works, what customers will buy, and what they will not. Uncertainty is characteristic of the early stages of innovation as different approaches are tried to solve problems and meet ill-defined demand.

Wireless Technologies Extend and Compete in the NII

Wireless technologies will serve two critical functions as the NII develops: radio-based technologies will *extend* the reach of the NII to places that wire-based technologies do not reach, and wireless systems will provide valuable *competition* to emerging NII service providers. These two functions are not mutually exclusive; in many cases, wireless technologies will provide both. DBS systems, for example, compete locally with cable television suppliers, but they also provide services almost anywhere in the country to those who cannot get cable. Mobile (cellular and PCS) telephone systems extend the NII by providing communications services to people on the move, but are also expected to compete in the provision of telephone service to homes and businesses in the future.

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[35] This uncertainty is not limited just to wireless. Many aspects of the NII, such as the future of interactive and multimedia services, are similarly unclear. "Demand for Interactive, Multimedia Services Is Unclear..." *Telecommunications Reports*, vol. 60, No. 48, Nov. 28, 1994.

Wireless technologies can *extend* the NII in two important ways. First, they allow users to tap into communication and information networks as they move about. Mobility is a key driver for wireless (see chapter 2). Second, as noted earlier, wireless technologies can extend NII services to places where wire is too costly or difficult to install. This may prove to be especially important as links need upgrading. In this role, wireless systems will help ensure that future universal service goals are met (see chapter 9).

Wireless technologies and systems will also *compete* in the delivery of NII-related services, both among themselves and against wire-based services. Competition is a key principle underlying the NII, and different wireless services have advantages that will allow them to compete effectively in a number of markets. Wireless systems already compete with wire-based services on a small scale, but over the next five to 10 years, wireless technologies will emerge as significant competitors in most communication, information, and entertainment markets. The ultimate outcome of a more wide-open competitive marketplace—which technologies and companies will "win" and which will "lose" and what the structure of the various industries will be—cannot be determined at this time. The uncertainties that pervade the development and implementation of wireless technologies, including rapid changes in technology, unfocused consumer/business demand, and regulatory upheaval, all combine to make analysis exceedingly difficult. Some general observations about the competitive potential of wireless systems can be made, however.

Wireless systems—broadcast, DBS, and Multichannel Multipoint Distribution Service (MMDS)—already compete with cable television systems (and each other) across the country, and competition is expected to increase as companies convert to digital and new competitors enter the market for video services. Wireless technologies are also expected to make a substantial impact in the market for voice and data communications, especially where mobility is desired. A good deal of spectrum has recently been allocated for wireless voice and data services and companies have been working on systems for a number of years. Many analysts believe that wireless could become the voice communications technology of choice for many people—eventually becoming a substitute for existing telephone service—because it offers the added advantage of mobility.[36]

The one area in which wireless is not expected to become a significant competitor in the near future is in the provision *to the general public* of two-way, broadband, multimedia communications, including integrated voice, data, and video services.[37] These are the types of high-end applications often discussed as the ultimate objective of NII policymaking and technology development. Wireless technologies are technically capable of providing such services and there is nothing that inherently prevents it, but most existing systems are limited based on past technical and regulatory choices. Two-way voice and data systems, for example, operate with a limited amount of spectrum that was originally allocated before high-bandwidth applications were widely accepted. As a result, most of them cannot be economically upgraded to provide two-way broadband services including multimedia, video telephony, or any other applications requiring high-speed connections.[38] Broadcast and satellites services potentially have enough spectrum, but generally only work one-way—to the con-

[36] Egan, op. cit., footnote 32.

[37] This discussion is based on Egan, ibid.

[38] Some current and planned systems provide integrated broadband services, but their limited capacities will limit them primarily to business or high-end users in the near term. For example, a few systems currently provide such services, notably satellite systems based on very small aperture terminal (VSAT) technology. However, these systems are not designed for the mass market, and current system capacities could not support a consumer/mass market type of service that would accommodate millions of individual users.

sumer. Some of these systems have limited interactive capabilities—provided either with a small return radio channel or telephone lines—that may make them competitive with wire-based systems and could serve important market demand.

In general, however, to upgrade existing systems for interactive high-bandwidth services, either new spectrum will have to be allocated or new compression techniques developed, or both. New wireless systems that could provide these "bandwidth-on-demand" services on a mass-market level are now being conceived, but are not expected to be available in the near term (see chapter 5). As a result:

> [u]nless there is radical, and, as yet, unanticipated, advances in both wireless access technology and the FCC's spectrum allocations, the future vision of integrated broadband access offering end-user bandwidth-on-demand type service will likely be reserved to the province of wireline technology.[39]

Universal Service Definitions Could Disadvantage Wireless Systems

The debate over the future of universal service—what it should include, how much it should cost, how it will be paid for—exposes some of the most difficult questions facing NII policymakers, private sector developers, and public interest groups. Many analysts and consumer advocates strongly believe that interactive, broadband services should be a key component of any future definition of universal service. They maintain that such communications capabilities will be necessary if Americans of all socioeconomic levels are to participate in the social, economic, and political life of the country. However, if such a definition were immediately adopted, there is a potential for overbuilding the NII based on projected needs (broadband and interactive) that the majority of users currently do not have, and likely will not have for many years.

Depending on how universal service and the NII are defined in the short term—what functions and conditions policymakers impose—and how new requirements are implemented, wireless technologies could become an integral part of the NII or be seriously disadvantaged. The outcome of current universal service debates will affect the role wireless technologies and services can play in the NII in several important ways. According to one researcher:

> The important message for public policy is that, until the service requirements of the universal NII have been specified, the question as to which is preferred, wireline or wireless access service, cannot be answered. If, as many believe, the NII only contemplates socially efficient access to narrowband digital voice and data services, then digital wireless technology is preferred for dedicated subscriber connections to the wireline intercity PSTN. The fact that wireless access costs are lower notwithstanding, the real bonus for the consuming public from this scenario is portability.
>
> If, however, access to broadband service, especially bandwidth-on-demand type access service, must be added to the narrowband service mix for the NII, then wireline access technology is likely to be the winner in the race for preeminence in the NII.[40]

Wireless technologies offer several advantages over wire-based telecommunications systems, but wireline systems also have advantages in delivering some services. On an economic basis, the ability of wireless systems to deliver narrowband voice and data and one-way video (broadcast) services puts them at least on par with wire-based systems, and, in fact, will likely allow wireless to compete directly with wireline in the future.[41] In the delivery of two-way broadband data, video, or

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[39] Egan, op. cit., footnote 32, pp. 11-12.

[40] Ibid.

[41] Ibid.

multimedia applications, however, wire-based media are still the most cost-effective. In large part, this is a result of the amount of spectrum that has been allocated to radio services historically, the technical limitations of wireless systems, and the phenomenal advances in fiberoptic and digital technologies. Current technical and regulatory constraints simply do not allow two-way broadband wireless services to compete with wire-based systems in the general consumer market. Thus, ***at this time,*** **a minimum definition of universal service in the NII as interactive, two-way, and broadband could disqualify wireless systems where they would otherwise be most appropriate or efficient.**

In addition, if universal service expectations and definitions are set too high, simpler, lower cost solutions that might profitably stand by themselves may be lost. As a result, those businesses and consumers who have more basic needs could be forced to pay for more than they really want. It is not clear that all information and all communications need to be broadband, interactive, and/or multimedia—particularly in the presence of "cheaper non-integrated alternatives."[42] Some users may not want or need these advanced features. From an economic standpoint, mandating such a high level of service begs economic efficiency questions. Why should companies be forced to build to such a standard? Will customers have to pay for a level of service they do not need and may not use? Do the potential benefits justify the expense?

In the long term, there can be little doubt that advanced interactive broadband services will play a critical role in the NII, and probably will eventually be included as elements of a future definition of universal service. In the near- and medium-term (five to seven years), however, OTA believes that interactive, broadband capabilities are not likely to be needed by the majority of citizens and should be allowed to evolve as demand warrants. A flexible approach to NII universal service policy would allow the different parts of the NII—interconnected or not—to grow to meet varying levels of need, while simultaneously ensuring a smoother upgrade path. In fact, many policymakers favor defining universal service in an evolutionary fashion, updating it as services become more ubiquitous and necessary.[43]

Aside from these broader issues, the definition and implementation of new universal service requirements could have a substantial impact on wireless systems and services. The potentially lower cost structures of both terrestrial and satellite-based (and combinations of the two) wireless systems make them an efficient alternative to wire-based media for reaching unserved users in both rural and urban settings (see chapter 3).[44] The current move to deregulate pricing may encourage wireless alternatives because of the increasing emphasis on least-cost technology options, which allow a company to cut its costs through use of more efficient technologies and lower its prices to compete more effectively. However, current subsidy flows and rate-of-return regulations may actually serve as a disincentive to wireless technologies. In addition, "essential telecommunications" (carrier of last resort) obligations, which have been proposed to bring service to areas where no carrier is operating, could harm wireless start-ups that are unable to meet the requirements and, therefore, could not qualify for universal service funds.[45] A much closer examination of these issues is necessary.

Options

Congress has proposed legislation directing the FCC, in consultation with the states, to develop a new (evolving) definition of universal service.

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[42] Ibid.

[43] See, for example, S. 652, op. cit., footnote 34, sec. 103.

[44] Ibid.

[45] S. 652 would designate carriers as "essential telecommunications carriers" in specific service areas for purposes of providing universal service. Wireless companies are eligible for this designation. Ibid.

NTIA has held several hearings on universal service. Nothing has yet been decided. In order to protect business and enhance access to NII services for *all* Americans, Congress could:

- Enact proposed legislation directing the FCC and the states to work out a definition of universal service and enforce deadlines for this effort. Before such definition(s) are put in place, Congress may first wish to consider the business impacts and prospects for providing service to the unserved.
- Review proposed legislation to ensure that it is fair and competitively neutral. The structure, funding levels, and participation in a new universal service fund will need to be carefully considered to ensure that startup and/or wireless carriers are not unfairly disadvantaged.
- Develop its own policies or guidelines for NII development based on hearings held to determine: 1) what services should be available, and 2) what technical capabilities are needed to enable these services to develop. Alternatively, Congress could establish a working group or outside commission to develop recommendations.

Interconnection and Standards are Increasingly Important

As a consequence of the boom in wireless technologies and systems, the importance and complexity of interconnection arrangements, standards, and interoperability are about to grow dramatically.

> As the National Information Infrastructure develops, policymakers must recognize the importance of wireless access to information and communications services because wireless may become "the first mile on and the last mile off" the information superhighway. Interconnectivity and interoperability are important determinants of whether a product or service can be offered in such an environment. The adoption of standards that make it difficult for wireless technologies to connect with the superhighway will be detrimental to the now well-documented consumer demand for mobile, wireless service.[46]

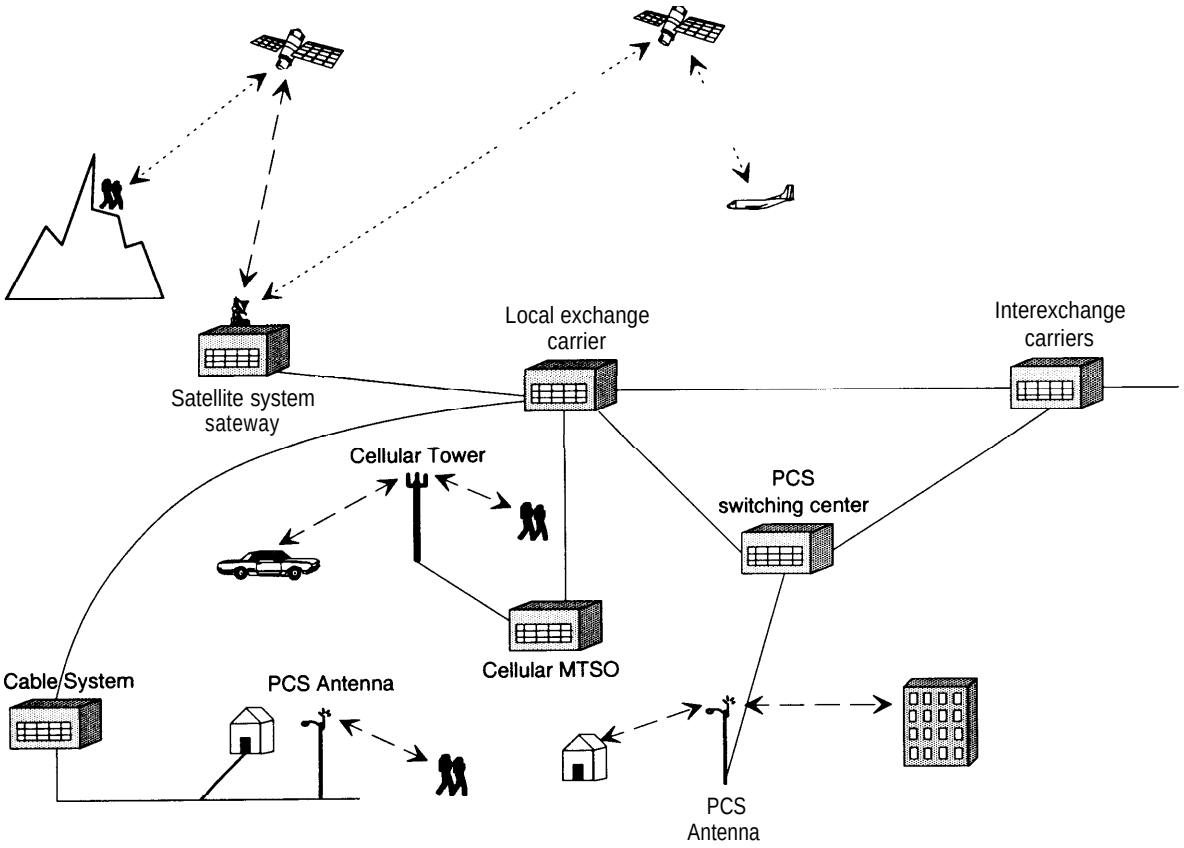
In thinking about the NII and wireless technologies' role in it, it is important to carefully define some of the major assumptions that underlie the vision. It will be necessary to specify exactly what the "network of networks" means and what implications it has for policies regarding interconnection. The notion of the NII as a seamlessly integrated network of networks is at best simplistic and at worst misleading. The NII initiative does not call for all networks to be directly connected to each other, which would be virtually impossible. Some companies and networks will connect directly, based on business needs. In many cases, however, different networks will interconnect *indirectly* through separate links to existing core networks—the public switched telephone network (PSTN), cable networks, and computer networks—and direct interconnection will not be necessary to enable different systems to interoperate (figure 1-1). The interconnection policies now being debated in Congress and at the FCC are vital in allowing all service providers to connect to other networks (see chapters 6 and 7). Determining which companies should be required to open their networks to interconnection by other carriers is already a hotly contested issue. As new wireless networks and services are deployed and usage increases, more direct interconnections may occur.[47]

Until recently, very few systems, services, or companies connected at all. Cellular telephony is the most visible exception. Over the next several years, however, as a multitude of PCS, ESMR,

[46] Center for Wireless Telecommunications, Virginia Polytechnic Institute and State University, "A Survey of Emerging Applications of Wireless Technology," unpublished contractor report prepared for the Office of Technology Assessment, Sept. 15, 1994, p. 4.

[47] For more discussion of changing interconnection arrangements and their implications, see Rob Frieden, "Universal Personal Communications in the New Telecommunications World Order," *Telecommunications Policy,* vol. 19, No. 1, January/February 1995, pp. 43-49.

FIGURE 1-1: The National Information Infrastructure



SOURCE: Office of Technology Assessment, 1995.

and satellite communication providers begin offering services, interconnection issues will become critical. In the past, wireless systems have been conceived primarily as adjuncts to the PSTN, and wireless technologies were employed only in special (mobile) circumstances.

In the future, wireless systems and technologies will become an integral part of the overall communications infrastructure, providing not only mobile communications and broadcasting, but a wide range of mobile and fixed services for both businesses and consumers. Interconnection and interoperability arrangements premised on older, asymmetrical relations—where cellular companies pay access charges to local telephone companies, but not vice versa—will give way to technical and contractual arrangements based on treating wireless carriers as equals. A number of factors will impact the ability of wireless companies to interconnect with the PSTN (and other wireline systems, such as cable television or computer networks), including the different cost structures of radio-based services, rising consumer demand for wireless services, increasing business demands for more integrated communications solutions, and technical advances that may help or hinder greater interconnection and interoperability.

Interconnection and interoperability are widely viewed as the keys to realizing the vision of the

NII—allowing users to easily send voice/data/video across many different types of networks. Today, system interconnection is usually accomplished through the PSTN for voice, and increasingly through the Internet for data. New systems and services are already putting a strain on this arrangement. Many wireline systems, especially data communication systems, operate according to protocols that often do not work well for wireless communication—which is affected by a number of factors not present in wireline systems, including interference from other radio services and propagation losses from rain or even trees. In addition, as new companies have entered the field, the number of proprietary applications and standards has grown. For individual users, sending information across different networks can be difficult, and using software on different systems can be almost impossible. It is unclear what will happen when additional services are developed and different kinds of companies begin to link up. **Developing new standards that accommodate the needs of wireless technologies and that operate across multiple systems will be critical to ensure that the benefits of an interconnected NII are realized. Most analysts expect that technical solutions will be developed, but OTA believes it will take longer than expected to work out many interoperability issues.**

Standards are the critical link that will allow different parts of the NII to work together. One kind of standard describes the connection between consumer devices—radios, televisions, and cellular telephones—and the networks that provide services. These standards benefit consumers by ensuring that their devices will work across different companies' networks. They also enable manufacturers to build one device rather than many different types of equipment for many incompatible systems. Standards also make it easier for the industry to plan and deploy upgrades, allowing consumers and businesses to revise, customize, and improve their systems as their needs dictate.

Other standards govern the connections between networks. While general rules are now well known, a whole range of new companies and interconnection agreements will have to be addressed in the near future, putting pressure on existing interconnection arrangements. For example, the rules that govern the transmission and reception of digital video services are only beginning to be considered. Multiple standards are being developed for transmission of video services in the broadcast, cable, and satellite industries, and there are a number of complex issues, and a range of vested interests, that will have to be addressed before such services are widely available and interoperable. The economic consequences of these decisions are enormous, and will have a vital affect on the broadcast and consumer electronics industries.

A lack of standards, or the proliferation of multiple standards, may undermine the NII goal of interconnectivity. For example, the current analog cellular telephone standard specifies how a cellular phone can "talk" to the cellular network. The fact that the United States settled on one standard for analog cellular telephones many years ago ensures that any phone will work with any cellular network. Today, however, two digital cellular standards are being deployed and up to seven standards are being considered for PCS systems. As a result, it is likely that all phones will not work with all networks (see chapter 6).

The current situation is different from the past because the process of setting standards has become very difficult. Historical standards-setting processes have undergone tremendous change since the breakup of AT&T in 1984. The FCC has largely backed away from aggressive standards-setting, preferring to let industry and/or the marketplace set standards; however, the intense competition that is expected to characterize NII services puts the process of cooperative standards-setting in question. The FCC approach to HDTV is an exception to current practice (see chapter 5). The federal government could play a stronger role in setting standards for interconnection and interoperability, but it is unclear what that role should be. Individual circumstances call for different government responses—there is no well-defined set of procedures that will work in all cases. Some companies prefer a "hands-off" approach by gov-

ernment, while others would like the government to at least set goals or even deadlines for standards. This idiosyncratic, flexible approach to standards-setting is likely to continue.

Options

The tension between fair competition and the NII goals for a widely interconnected series of networks is felt most acutely in relation to interconnection, standards, and deregulation issues. The FCC has established a number of different wireless license areas, which do not necessarily coincide, and that do not match the boundaries and regulations set up to govern local and long-distance communication services. To ensure the benefits of NII interconnections, while preserving competitive incentives, Congress could:

- review the regulatory and structural underpinnings of the long-distance industry. Possible congressional actions include: 1) eliminating the Local Access and Transport Area (LATA) boundaries that currently define long-distance service, and/or 2) harmonizing CMRS license areas. These options are not mutually exclusive, and could be pursued as part of a larger redefinition of local/long-distance communications.
- establish guidelines to direct the FCC's standards-setting activities or mandate the FCC to do so. Guidelines could help the FCC determine when to get involved in standards-setting and what its actions should be. In this way, the benefits of early standards-setting could be combined with the flexibility of industry or market-based solutions.
- explicitly allow the FCC greater latitude in preempting state regulations that may slow wireless startup interconnection to the public network and each other. Potential areas for congressional action include: 1) establishment of co-carrier status, rights and obligations; 2) mutual compensation for competing local communications companies; and 3) consistent interconnection arrangements ensured through tariffs or publicly-filed contracts.

Integration of Wireless and NII Policymaking is Improving, But...

Integrating NII and wireless communications has been and will continue to be a challenge. Early thinking and policy development regarding the NII focused primarily on wire-based technologies, especially fiberoptic networks. Policies for wireless technologies and systems, meanwhile, developed largely independently of NII initiatives. There has been little formal coordination between government NII efforts and wireless efforts—the two have proceeded along parallel, but seemingly separate, tracks. As a result, many of the issues surrounding wireless technologies, especially broadcasting and satellites, were delayed until long after NII planning efforts got under way, and no comprehensive vision exists for integrating the wide range of wireless technologies into the NII.

Wireless technologies were only lightly treated in early legislative and executive branch NII planning. The Administration's *Agenda for Action*, for example, mentions wireless technologies in its nine principles; however, the treatment of wireless is limited, concentrating on spectrum reallocation, use of market principles in assigning spectrum (auctions), and ensuring that small, rural, minority- and women-owned businesses can participate in the auctions—all concepts proposed or required by Congress in previous legislation. One specific effort to combine NII policy development with a wireless focus, the Untethered Networking Group, met with no success (see appendix B).

Several factors contributed to this situation. First, no common vision exists for the development and implementation of radio services in the United States. Wireless policy development is divided between the FCC, which manages private sector and state/local government spectrum use, the federal government. This division of responsibilities historically has hampered the development of a clearly defined, comprehensive

framework to guide U.S. radiocommunication policy development (see next section). The lack of a unified vision for wireless makes it correspondingly difficult to develop a more comprehensive strategy for the integrating wireless systems into the NII. At a practical level, wireless policy development has been more successful. See appendix B for a discussion of the efforts of the Federal Wireless User's Forum and The Federal Wireless Policy Committee.

The second factor making the integration of NII and wireless policies difficult is that policymaking regarding radio technologies and services has *historically* been separate from wireline policymaking. Radio and television broadcasting networks, amateur radio, and even early satellite systems were developed and operated largely as stand-alone systems, capable of communicating information separately from the wireline networks—there was little need to coordinate wireless and wireline policies.

In addition, the philosophy underlying radiocommunications policy was substantially different from the models applied to wireline services. Unlike the tightly controlled, monopoly-based regulation that characterized the telephone system, wireless systems of all kinds have been much less closely regulated on an economic basis. Companies have been able to set rates, merge, and compete much more freely than most wireline companies. Today, the federal government continues—as part of this long-standing practice—to let market forces play the primary role in deciding how radio frequencies should be used. As wireless technologies become a more integral part of the NII, however, a purely market-based approach to wireless policymaking may prove inadequate. As wireless and wireline systems increasingly connect and the services they offer overlap, the need for integrated policymaking will correspondingly increase.

Finally, the separation of wireless and wireline policymaking is a matter of timing and historical accident. The issues of cable/telephone competition have occupied center stage of the telecommunications debate in this country for almost a decade. It is, therefore, no surprise that the NII has centered around these industries. Additionally, some wireless supporters charge, policymakers were slow to recognize the potential of wireless systems. Others concede that some wireless industries entered the policy development process late, and their potential contributions were not recognized by government officials.

In the latter part of 1994, however, wireless technologies began to receive more attention as an important, even integral, part of the NII. Officials at the FCC, for example, now refer to wireless as one lane on the information superhighway. NTIA is in the process of reallocating at least 200 MHz of spectrum as mandated by the Omnibus Budget Reconciliation Act of 1993, and has recently completed a study of the nation's radio spectrum needs for the future. The FCC has proceedings under way in many areas of wireless communication, many of which overlap. It is still unclear, however, how all these initiatives will contribute to the establishment of an interconnected NII.

Options

To maximize the benefits of the NII and minimize inefficiencies and potential adverse effects, wireline and NII policymaking must explicitly recognize and address the unique capabilities and limitations of wireless technologies. Wireless and wireline policymaking need to be more closely coordinated by establishing goals for wireless technologies in the context of the NII, and needs must be prioritized. This does not imply that all NII and telecommunications-related planning—each individual decision—should be centralized and bound together in one master plan. It only suggests that a focused vision of the future could help guide private sector development and implementation efforts. To bring wireless technologies and policy development more directly into the mainstream of NII policymaking, Congress could:

- direct the FCC and NTIA to develop policies and plans—or justify/amend existing plans—for integrating the wide range of wireless systems into the NII. Specific plans could be developed for specific industry segments.

- hold hearings to determine if NII policies or FCC rules currently discourage wireless systems from playing a larger role in NII development. Hearings could also help determine how wireless technologies could more directly contribute to the goals of the NII—universal service, for example.
- mandate more direct coordination of NII and wireless policy development, both within the executive branch and with the FCC. Reporting requirements could be established.

Spectrum Policymaking Faces Significant Challenges

Government policymakers and regulators will face an increasingly difficult task in meeting expanding spectrum needs while accommodating existing users. No coordinated framework for making spectrum policy exists, although some long-range planning is taking place. Technology advances and increasing demand for mobile services have led to the development of a wide range of new and improved wireless services. As a result, however, many portions of the radio frequency spectrum are becoming increasingly congested, leading to what one analyst has called spectrum "pollution."[48] To alleviate overcrowding, and expand the number and variety of wireless applications even further, there has been a sharp increase in demand for radio frequencies.[49] The most valuable frequency bands, however, have already been allocated, and many are heavily used.

Several trends are pushing the increasing demand for spectrum: 1) existing wireless service providers—including broadcasters, satellite companies, and data communication companies—want additional spectrum to expand capacity and services; 2) new applications now being developed—including digital radio and television broadcasting, terrestrial- and satellite-based communications systems, and data and information messaging systems for mobile and fixed users—will need new frequencies; and 3) communication and entertainment applications will increasingly combine voice, data, and video, requiring large amounts of spectrum to meet the bandwidth-intensive nature of such applications. Complicating the situation is that portions of the spectrum have characteristics that make them particularly well suited for specific types of applications. The frequencies that most engineers consider ideal for mobile communications, for example, are located between about 0.5 and 3 GHz—frequencies that are rapidly becoming congested.

The radiofrequency spectrum is a finite, but reusable, resource (see appendix A). Technology advances are expanding usable capacity, but it is unclear if such advances will be able to keep up with rising demand for services in the longer term.[50] Unlike wireline systems, which can add capacity or serve more users by laying more wires, the capacity of the spectrum is limited by current technology. For any given set of frequencies, the spectrum can only serve a limited number of users and cannot be expanded. Technology advances such as more efficient modulation, cellular architectures, narrower channels, digital compression, and use of higher frequencies can reduce overcrowding—by extending the usable spectrum and increasing efficiency and capacity—but demand for radio frequencies has historically outstripped supply.

Faced with rapidly rising demands, Congress, the executive branch, and the FCC all have taken important steps to ensure that the wireless indus-

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

[49] For a more complete discussion of the spectrum needs of various radio services, see U.S. Department of Commerce, *U.S. National Spectrum Requirements*, op. cit., footnote 16.

[50] For a more optimistic assessment of the ability of technology advances to stay ahead of demand, see Robert J. Matheson, "Spectrum Stretching: Adjusting to an Age of Plenty," National Telecommunications and Information Administration, April 1995. The author argues that technologies such as digital compression and frequency reuse can increase spectrum efficiency—and capacity—dramatically.

try has access to adequate spectrum. In 1993, for example, Congress required NTIA to identify and transfer 200 MHz of spectrum to private use.[51] In response, NTIA released a preliminary report in February 1994 identifying 50 MHz that could be transferred immediately and a final report in March 1995 that identified an additional 185 MHz for transfer.[52] The FCC, in cooperation with NTIA, recently proposed making 18 GHz in 12 bands available for the development of new commercial technologies. These would include licensed and unlicensed applications such as vehicle radar systems and extremely high-bandwidth applications, including two-way video and multimedia computer communications.[53] The FCC has also recently began auctioning frequencies for new mobile telephone services (PCS—see chapter 3) and has completed or launched a number of proceedings specifically aimed at bringing more spectrum resources to wireless data applications (see chapter 4). Although sufficient for the short term, it is too soon to tell if more spectrum will be needed for these applications in the long term.

Such actions, however, treat only parts of the problem, and policymakers will continue to struggle to match the supply of spectrum with demand. The ways in which spectrum is allocated and managed in the United States may need to be changed to respond to a new, more mobile world. To plan for the future and avoid piecemeal, reactionary decisionmaking, a national vision for long-term spectrum use is needed. More coordinated and focused spectrum planning—combining the efforts of both NTIA and the FCC—has been legislated several times (most recently in the Omnibus Budget Reconciliation Act of 1993), but has never been accomplished. The FCC and NTIA have not worked cooperatively to build a comprehensive framework for radiocommunications policy, although the FCC does have a liaison who coordinates policy at the staff level with NTIA. **The lack of a unified vision of future spectrum use could undermine long-term planning efforts and development of spectrum policy (including priority-setting), and may hamper development of innovative wireless technologies.**

The federal government has not maintained an aggressive approach to long-range spectrum planning—for practical as well as ideological reasons. Practically, allocating spectrum for needs that have not been identified is difficult, and ideologically, such a planned approach was seen as too closely resembling "industrial policy," which past Administrations have tried to avoid. Furthermore, management of private sector spectrum in the United States has long relied on petitions by prospective users to determine uses rather than a priori planning. As a result, policymaking has tended to concentrate on specific portions of the radio spectrum without always addressing how individual decisions might interact. However, as the number and kind of wireless systems and users have grown and the technologies and services have begun to merge, the need for a more integrated policymaking framework has become necessary because multiple systems can now deliver essentially the same service.

Developing a practical and effective approach to long-term spectrum planning will be challenging. Planning for needs and technologies that do

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[51] "The Omnibus Budget Reconciliation Act of 1993," Public Law 103-66, Aug. 10, 1993. Title VI deals with telecommunications issues.

[52] U.S. Department of Commerce, National Telecommunications and Information Administration, *Preliminary Spectrum Reallocation Report*, NTIA Special Publication 94-27, February 1994; U.S. Department of Commerce, National Telecommunications and Information Administration, *Spectrum Reallocation Final Report*, NTIA Special Publication 95-32, February 1995.

[53] The bands are located between 47 and 153 Ghz. These frequencies historically have been limited primarily to military and scientific purposes, and are generally only lightly used. Sixteen of the 18 GHz specified will be shared with government users. General Motors, Ford, and Chrysler have submitted comments to the FCC on vehicle radar systems they have already begun to develop. "Notes on the FCC 40 GHz Plus Proposal," *Telcom Highlights International*, vol. 16, No. 47, Nov. 23, 1994. "FCC Identifies Spectrum Above 40 GHz for Commercial Use, New Technologies," *Telecommunications Reports Wireless News*, vol. 4, No. 22, Nov. 3, 1994.

not yet exist is nearly impossible, and would not necessarily lead to efficient use of the spectrum. The tradeoffs between encouraging efficiency and promoting development of new technologies must be carefully weighed as a part of determining future radiocommunication policy. It may be possible to craft policies and regulatory efforts that encourage both, but it will be necessary to carefully balance the needs for efficiency with the demand for new technologies and services.

In any case, even better spectrum planning will not guarantee that a market for the planned service will actually develop or that the services/systems planned will become economically viable. The 12-GHz band of frequencies, for example, was planned more than a decade ago to provide television programming services directly from satellites to homes. Initial efforts to launch a service failed, however, and DBS systems are only now beginning commercial service. The history of DBS shows both the difficulties and ultimate success of one government planning effort. DBS frequencies went unused for many years as proponents struggled to launch operating systems, but without that early allocation, companies might not have developed new technologies so quickly. In addition, without early government action, companies might still be fighting for spectrum and customers might still be waiting for service. This case clearly illustrates the inherent uncertainties in planning for future, undefined spectrum applications.

In 1991, NTIA issued a report on improving spectrum management, and implemented some of the recommendations. However, some of its most fundamental conclusions for improving U.S. spectrum allocation and assignment processes were never put into practice.[54] It may be time to revisit some of these options. NTIA recently completed a major study that identifies the spectrum requirements of most radio services for the next 10 years—an important first step in improving spectrum planning.[55]

The process of allocating spectrum, however, is only part of the problem. Until recently, spectrum was assigned to individual entities by the FCC on the basis of comparative hearings or lottery. In 1993, Congress authorized the FCC to use competitive bidding—auctions—to distribute some licenses.[56] Auctions are believed to be the most economically efficient way to assign licenses, while also raising money for the federal government. Given the financial success of the PCS auctions, which raised more than $7 billion, some analysts and policymakers have now begun to consider auctions as a way to assign spectrum for other services in the future. Despite their financial success, however, the longer term operational and economic effects of the auctions are still unknown.[57]

In any case, auctions may not be applicable to all radio service users. Federal, state, and local governments, for example, have a wide range of operations that support vital public interests such as national defense, air traffic control, public safety, and emergency preparedness functions. These types of services are not currently affected by auctions, and there would likely be a great deal of resistance to auctioning such spectrum. There are also a number of economic and public policy issues, in addition to administrative and practical questions, that would have to be addressed before such an approach could even be seriously considered.

Options

To ensure that adequate spectrum continues to be made available in the future, Congress could:

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[54] U.S. Department of Commerce, *U.S. National Spectrum Requirements*, op. cit., footnote 16.

[55] Ibid.

[56] Omnibus Budget Reconciliation Act, op. cit., footnote 51.

[57] Many of the winners in the Interactive Video Data Service auction, for example, defaulted on their bids. This will slow the development and deployment of the service.

- mandate the transfer of additional spectrum from the federal government to the private sector. This effort would build on already-conducted NTIA studies of spectrum needs and reallocation.
- build on existing efforts to determine spectrum needs and existing planning, and enforce previous mandates for the FCC and NTIA to engage in cooperative long-term spectrum planning.
- establish research funds for development of high frequency (40 GHz and up) radio communication service, through the federal government and/or private sector initiatives.
- evaluate new methods for allocating and assigning spectrum, including the recommendations in earlier NTIA reports and the possibility of auctioning all future radio licenses. This may entail developing new rules for auctions.

Research is Needed

Research on the social, economic, and public policy implications of widespread use of wireless technologies is very limited, and research on the longer term effects and implications of wireless devices and systems is only at the conceptual stage. This situation is directly tied to the nascent state of the various segments of the wireless industry as a whole. Many of the technologies that will make the biggest impacts are not yet operating, and evaluating their social and economic effects is impossible. Even in the more mature wireless industries, research is sparse.[58]

One of the most important, and underappreciated, aspects of the development of wireless technologies is the problem of scale. Problems that seem trivial with only a relatively small number of users become magnified as the number of users grows. Some have commented that "society is not ready" for the many changes that ubiquitous wireless communications will bring. One study estimates that 45 percent of the population will be using mobile communications devices (phones and/or laptop computers) by 2005.[59] And although some information and statistics have been collected on various aspects of mobility, there is little hard data that allow a good understanding of the characteristics of personal and professional mobility, and what implications they may have for the implementation and use of wireless services and for society. One example is 911 service. Despite the fact that only about 10 percent of urban customers have cellular phones, 911 operators receive, on average, eight reports for each traffic accident. As subscriber and penetration levels rise, 911 system administrators may be inundated with calls.

The most controversial area of research, and the one most in need of additional study, concerns the possible impacts radio communication systems could have on public health (see chapter 11). Some members of the public and a few scientists believe that radio waves can damage human cells. Research to date, however, has been inconclusive. No direct link has been found that radio waves are harmful, but it is still not possible to say with certainty whether the devices or antennas pose a risk to human health or how serious any risk may be. This issue is extremely emotional and polarized. Some people are convinced that wireless systems are dangerous and should be banned or severely limited. The wireless industry, however, believes that development of wireless technologies should continue because there is no conclusive evidence that either phones or antennas are harmful. Research is now being conducted, but much of it is sponsored by industry, either directly or indirectly, and it is unclear whether the public will be satisfied with the results. The federal government has played only a minor role in research on this

[58] The exception is broadcasting. There is a long history of economic, public policy, and social science research into all areas of radio and television broadcasting.

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

topic. Representatives from several government agencies, however, are involved in oversight and review of industry research.

Research on the economic structure of the various wireless industries and long-term outcomes of competition is even more limited.[60] In wireless voice and data services, for example, many new companies will enter the market over the next five years. Gathering accurate data on cost structures, revenues, and customer demand is only just beginning, and many companies will not divulge such information. Even industries that have been around for decades, such as broadcasting, will be affected. Both radio and television broadcasters are preparing for radical change as digital technologies replace analog, and as new competitors—some wireless (DBS, wireless cable, and cellular television) and some wireline (telephone companies)—enter the market for audio and video programming and services. The ultimate outcome of all these changes cannot yet be predicted, and the economic studies and modeling of such competition are just beginning.

Likewise, wireless telecommunications' contribution to productivity, economic growth, and employment is unclear. Industry studies indicate that wireless telecommunications account for significant productivity increases through better use of time, particularly for higher paid employees who spend time away from their offices. There are no credible data on additions to the gross domestic product or on future employment (either in the industry or in the economy generally) due to wireless telecommunications, though the cellular industry has experienced significant economic and job growth over the past decade.

Finally, the implications of wireless technologies for individuals, organizations, and society are only now emerging; they are likely to involve increased personal and business efficiency, but also increased stress and concern about health effects, monitoring, and privacy. Wireless technologies are likely to play a role in the continuing evolution of new organizational and social forms, including their geographic dispersion and functional disaggregation. The widespread deployment of mobile communication technologies also portends a change in the average wireless user—from mobile professional/field service representative to mass market consumer.[61] Again, the effects of this change are unknown.

Technical research and development is the exception to OTA's finding on the state of research. Research and development of new radio technologies and services is moving quickly. Some industry representatives, especially those representing larger companies, see no need for government support of technology research. Whether this position is shared by all technology developers is uncertain. The satellite industry has put together a list of topics they would like the federal government to help them in exploring.

Options

To increase understanding of the many economic, social, and regulatory issues surrounding the integration of wireless technologies into the NII, and establish a basis for informed policymaking, Congress could:

- monitor the development of various industry segments and social issues, including privacy, security, and especially health effects to determine if future congressional action may be necessary.
- establish funds to promote research into these issues. Congress already funds research in a

[60] OTA contracted for two studies—one to examine the basic economics and one to analyze the evolving structure—of the wireless industry. Both authors noted the lack of empirical data available on the various segments of the wireless industry, and the lack of appropriate models for studying wireless economics. Egan, for example, notes that "...based on publicly available data (including that from investment houses in their efforts to calculate prospective market penetration rates and net cash flows to establish valuation benchmarks for the investor community) indications are that the state of the art in engineering economics and financial modeling of network systems is not very far along." See Egan, op. cit., footnote 32, p. 43, and Woroch, op. cit., footnote 32.

[61] Frieden, op. cit., footnote 47.

number of related fields, such as transportation, labor statistics, and public health that could be expanded to cover wireless topics. Alternatively, a portion of the funds received from spectrum auctions could be designated for this purpose.

State and Local Government Roles are Unclear

States have a significant interest and role in protecting their residents from services that are priced too high or that offer poor quality. Municipalities have an important, historically-defined role in local zoning matters and protection of public rights-of-way. However, the federal government, primarily the FCC, also has a legal role to play in advancing the communications systems of the country. **Since the Communications Act of 1934 was passed, state, local, and federal authorities have been struggling among themselves and in court to define the boundaries of their rights and responsibilities.**

Current proposed legislation will not end the debate. Bills under consideration in Congress generally prohibit states from enacting laws that "may prohibit or have the effect of prohibiting the ability of any entity to provide any interstate or intrastate telecommunications services."[62] The bills, however, also permit states and local governments to impose requirements for universal service, protect the public safety, and manage public rights-of-way. Specific cases will no doubt arise where the two policies will clash. In the case of wireless technologies and systems, there are several potential areas of conflict between federal and local policy goals.

State and local governments currently regulate wireless services only lightly. Broadcasting is mostly free of local regulation. Half the states once regulated cellular in one form or another, and another 20 had laws stipulating that the state regulatory commission must forebear from regulation.[63] As a result of new regulations governing CMRS, however, no state will be allowed to regulate wireless rates or enact laws that stifle entry by new providers.[64] Satellite providers have been struggling against local ordinances and taxes for many years (see chapter 8).

In the future, however, state regulation of telecommunications services in general may have significant, if indirect, effects on new wireless services, especially those used as a substitute for local wired telephone service. Importantly, the states will retain regulatory jurisdiction over the terms and conditions regarding wireless companies interconnection with local telephone companies. States are also likely to have a significant role in helping to define universal service obligations and subsidy schemes, both of which could significantly affect new wireless carriers.

Currently, the most controversial battle between federal and local policies involves zoning and land use. Wireless companies need to erect antennas and towers to provide their services. Some municipalities, however, in response to citizen concerns about public health and property values, have enacted zoning laws or other prohibitions that can make it difficult to put up a tower. Such regulations have delayed or halted construction of radio towers already licensed by the FCC. More local governments are expected to enact similar prohibitions as the number of antennas and towers proliferates with the spread of cellular and the introduction of PCS and ESMR services (see chapter 8).[65] Industry associations have asked the FCC to preempt such regulations, maintaining

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[62] S. 652, op. cit., footnote 34.

[63] Woroch, op. cit. footnote 32.

[64] Eight states applied under the law to continue to regulate cellular/wireless rates, but the FCC denied all the petitions.

[65] Some rules set height limits, while others ban towers altogether in residential areas. See "City Zoning Rule Limits Radio Tower Height," *Telecommunications Reports*, vol. 61, No. 3, Jan. 23, 1995.

that new services will be slowed or even precluded.[66] The FCC has not yet ruled on this issue, and **the question of which should take precedence—federal laws that encourage the development of public communications systems or local control over land—remains unanswered.**

Options

Aside from specific issues relating to preemption, Congress may wish to establish an overarching framework to guide future policymaking. Establishing a cooperative relationship between federal and state regulators will be critical if the NII is to develop as quickly as possible. To determine the proper relationship between federal and state regulatory authority in a new competitive era, Congress could:

- make explicit its views on federal preemption regarding NII and wireless issues, indicating which authority should take precedence.
- hold a series of hearings in Washington and around the country or form a commission to gather input from all parties involved in federal-state telecommunications issues. As part of this broader effort, Congress could also establish more formal mechanisms for resolving federal/state/local disputes in telecommunications policymaking.

[66] The Electromagnetic Energy Association and the Cellular Telecommunications Industry Association have filed petitions for rulemaking on the issues. "FCC Asked To Preempt States' RF, Radio Tower Rules," *Telecommunications Reports*, vol. 61, No. 1, Jan. 9, 1995.