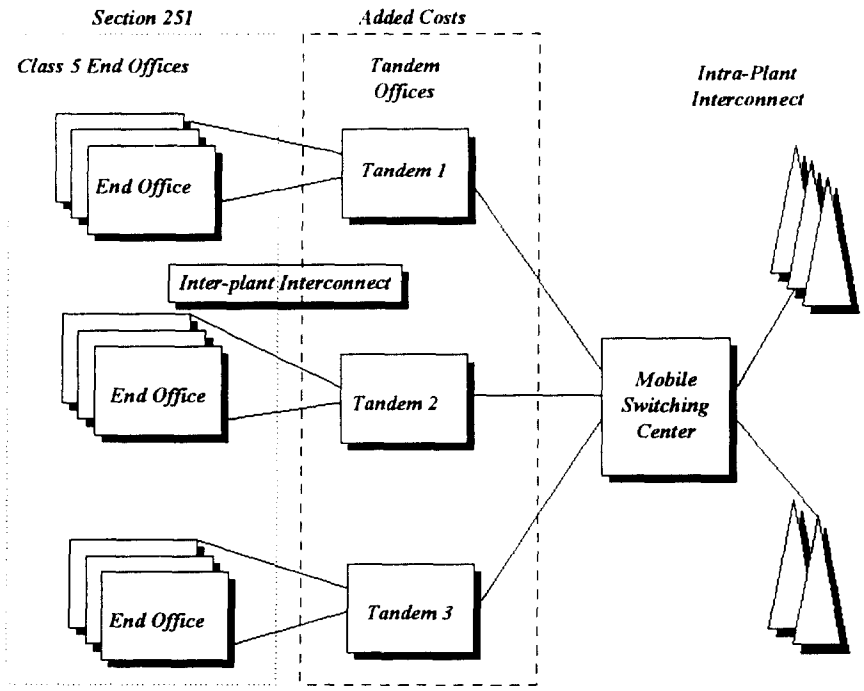
interconnect issue for a wireless carrier falls into two categories; intra-plant and inter-plant.[18] The intra-plant issue is that between cell sites and the carriers own switch and the inter is between the carrier's switching facilities and the I-LEC's facilities. The intra was discussed in Telmarc Report TR-96-008. The overview of these issues is shown below.



This Figure depicts three issues: first is that the intra-plant facilities are generally under the total control of the carrier. Second, that the end office I-LEC interconnect is clearly under the control of the Section 251 reciprocal compensation rule. Namely, such agreements as those between WinStar and NYNEX allow for termination of traffic here on a mutual compensation basis. Third, the real problem is how does one get from a single MSC, to several access tandems and then ultimately to dozens of end offices. This report addresses those issues.

The overall goal of this report is twofold. First to address the technical issues related to the interconnection, especially what options are available to tandem interconnection. Second, what are the resultant regulatory options that may be available to the carrier.

Any new carrier must be aware of these options before they interconnect since these interconnection options present significant fixed costs to the carrier and there may be ways to move these monthly fixed costs into some variable form or to move them into a form of carrier owned facilities.

6.1 C-LEC versus CMRS

In this section we develop a detailed review of the new regulatory structure as applied to interconnect. There is a difference between a C-LEC, a competitive LEC, and a CMRS, commercial mobile radio services provider. These are the two classes of players interconnecting under Section 251 of the Act.

[18]See the papers by McGarty in Interconnect and access. These discuss the detailed economics and the costs models. Also see the paper by McGarty, Federal Communications Law Journal. This latter paper presents a detailed antitrust analysis of the interconnection issue.

A C-LEC is a non-incumbent LEC. An incumbent LEC is generally a RBOC. A LEC is defined by the Act as:

"LOCAL EXCHANGE CARRIER- The term "local exchange carrier" means any person that is engaged in the provision of telephone exchange service or exchange access. Such term does not include a person insofar as such person is engaged in the provision of a commercial mobile service under section 332(c), except to the extent that the Commission finds that such service should be included in the definition of such term."

The definition of telephone exchange services and exchange access services is as follows:

"EXCHANGE ACCESS- As per the Act, Sec.3(b)(2), the term Exchange Access means the offering of access to telephone exchange services or facilities for the purpose of the origination or termination of telephone toll services."

and,

"TELEPHONE EXCHANGE SERVICE - Telephone Exchange Service is defined in 47 U.S.C. Sec. 153 (r)means service within a telephone exchange, or within a connected system of telephone exchanges within the same exchange area operated to furnish to Subscribers intercommunicating service of the character ordinarily furnished by a single exchange, and which is covered by the exchange service charge."

Exchange Services is generally the provision of toll telephone services whereas telephone exchange services is local services directly to the end user or customer.

In contrast a CMRS is defined as:

"(i) CMRS: *A Commercial Mobile Radio Service ("CMRS") as defined by 47 U.S.C. Section 332 and from the Code, Section 153 (n). Specifically, Commercial Mobile Radio Service means any mobile service (as defined in section 47 U.S.C Section 153(n)) that is provided for profit and makes interconnected service available (A) to the public or (B) to such classes of eligible Users as to be effectively available to a substantial portion of the public, as specified by regulation by the Federal Communications Commission."*

"(ii) MOBILE SERVICE *: As defined in section 47 U.S.C Section 153(n), Mobile Service means a radio communication service carried on between mobile stations or receivers and land stations, and by mobile stations communicating among themselves,* ***and includes*** *(1)* ***both one-way and two-way*** *radio communication services, (2) a mobile service which* ***provides a regularly interacting group of base, mobile, portable****, and associated control and relay stations (whether licensed on an individual, cooperative, or multiple basis) for private one-way or two-way land mobile radio communications by eligible Users over designated areas of operation,* ***and*** *(3) any service* ***for which a license is required*** *in a personal communications service established pursuant to the proceeding entitled "Amendment to the Commission's Rules to Establish New Personal Communications Services" (GEN Docket No. 90-314; ET Docket No. 92-100), or any successor proceeding."*

The mobile service definition requires three elements; two way communications, over a an infrastructure and that the operator is in possession of an FCC license to provide such services. There is an exception as stated by the FCC for a CMRS, namely as relates to a reseller of CMRS services. Specifically, the FCC has ruled:[19]

[19]See FCC GN Docket No. 93-252, February 3, 1994, FCC 94-31; ¶ 37.

"Finally, we conclude that mobile resale service is included within the general category of mobile services, as defined in Section 3(n) and for purposes of regulation under Section 332, since resale of mobile service can only exist if there is an underlying licensed service. There is no indication in the statute or the legislative history that resellers are not "mobile service" providers or exempt from the Section 332 regulatory classification, and we see no reason to establish such an exemption."

This simply states that even reseller are CMRS and thus also must be concerned with this issue.

6.2 Rates for Interconnection

The rates for interconnection have been established in the FCC First R&O. However this has been set aside by the Eight Federal District Court until it is reviewed. However, many f the RBOCs have already entered into interconnect agreements or are currently negotiating them. This section presents a comparison between several players in the market and presents the current pricing schedules.

The following Table compares the LEC status to that of a CMRS. This report focuses on the CMRS advantages

Carrier Comparisons

Characteristic	*I-LEC*	*C-LEC*	*CMRS*
Coverage	IntraState	IntraState	MTA[20]
Jurisdiction	State PUC	State PUC	FCC
Interconnection	Section 251	Section 251	Section 251
Reciprocal Compensation	Mandated CFR §51.717		Allowable CFR §51.717
Bill and Keep	Optional	Optional	Optional
Resale	Mandated	Mandated	NA
Reciprocal Compensation	Mandated	Mandated	NA
Dialing Parity	Mandated	Mandated	NA
Access to Rights of Way	Mandated	Mandated	NA
Duty to Negotiate	Required	NA	NA
Unbundling	Required	NA	NA
Co-Location	Required	NA	NA
Interconnection	Required	NA	NA

The requirement by the new CFR is related to local termination traffic. This is defined as:

*"**Local Telecommunications Traffic** means: (1) telecommunications traffic between a LEC and a telecommunications carrier other than a CMRS provider that originates and terminates within a local service area established by the state commission; or (2) telecommunications **traffic between a LEC and a CMRS provider** that, at the beginning of the call, originates and terminates within the same Major Trading Area"*

The latter statement is of significant import to a CMRS carrier. It covers all of an MTA and since the New York MTA covers eastern New York, New Jersey, Vermont, and eastern Pennsylvania, it is a

[20]See Title 47 C.F.R. §51.701(b)(2)

significant advantage over any LEC. The default tariffs applied by the FCC in the new CFR are as follows:

CFR Pricing Schedule

Connection	*Rate*	*Reference*
Symmetrical Reciprocal	Yes	CFR §51.711
Termination of Local Traffic	No less than $0.002 per minute and no more than $0.004 per minute	CFR 51.707(b)(1)
Transport of local traffic	Same as in Termination and in Tandem	CFR §51.707(b)(1), and §51.513(d)(3),(4),(5)
Tandem Switching	$0.0015 per minute of use.	CFR §51.715(b)(3)

The actual interconnect agreement negotiated between NYNEX and WinStar reflects the following rates. It should be remembered that although WinStar is a wireless carrier it is not a CMRS, it is a LEC. It is a C-LEC and thus there are certain distinctions. Also, all three are common carriers, namely the I-LEC, the C-LEC and a CMRS.

New England Telephone & WinStar Agreement[21]

Connection/Service	*Fixed*	*Variable*
Termination of Local Traffic		$0.0080 per minute
Transit Service		$0.0035 per min
Number portability	$1 per month residential $2 per month business $20 per ported number	
Unbundled ports	$8 per month	
911 Connections	$252 per month per DS1 plus $100 per month per voice grade trunk activation.	
Directory Assistance	$0.32 per message; branded $0.57 with DAC	
Reciprocal Rule Rate per minute Peak Rate = $0.009 per min OffPeak Rate = $0.0065 per min OPM=originated peak min OOPM orig. OffPeak min	[(Carrier OPM+ILEC OPM)* Peak Rate]+[(Carrier OOPM+ILEC OOPM)*OffPeak Rate]/ [Total Carrier Min+Total ILEC Min}	

The remainder of this paper presents the detail regarding the regulatory, technical and operating issues of inter carrier interconnection.

7. CONCLUSIONS

This paper has presented a detailed analysis of the costs of two wireless schemes; PCS and LMDS. The similarities are greatest as are the difference. PCS is a bandwidth limited system, 30 MHz of bandwidth,

[21]Filed with Massachusetts DPU on August 22, 1996.

at 1.9 GHz center frequency. LMDS is 1 GHz of bandwidth at 28 GHz center frequency. One is longer range, although not really that great, and the other is greater bandwidth, but the issue is for what purpose. The underlying question is; is there a sustainable business in wireless or has a glut been created? Also the second question is, if universal service is a socially acceptable and required goal, then which of these technologies is the most resource effective in deployment.

We argue that any single service, if there is a market, can be competitive. We further argue that wireless may not be the most efficient service for large areas, especially when the population density falls below 200 PoPs/Sq mi. This is especially true in rural areas. Possibly point to point may work but even this is debatable.

The major concern is the generai assumption that bandwidth is a scarce resource. This is true if can not been efficiently used. In the current models we see that with PCS alone we can service the entire US telephone network several times over. This may actually mean that the total capital deployed in PCS may be a poor use of capital resources on a national scale. On the other hand this excess capacity in a free market will drive prices down and drive for newer and more creative applications. The missing element has always been the load that data may apply on the system. This may be the savior for PCS.

As for Universal Service, the FCC seems to be focusing on the use of a fund type approach, taking the "taxation" control from the RBOCs. This may be the most effective mechanism. The issue that may academic policy analysts have tried to raise is that a wireless provider, in return for the right given them by the government, have a corresponding right to "play fair" with the monopolists and be required to provide universal wireless service. This bizarre set of reasoning goes beyond the wildest dreams of Schumpeter. First, the PCS entrants have risked billions to buy PCS spectrum, which is more than can be said for the monopolist RBOCs, who in may cases usurped their properties at the turn of the nineteenth century. Secondly, if economic efficiencies are of any importance, why not let the market determine who is the most efficient provider. Thirdly, why must the monopolist be protected. In fact if telecommunications is truly commodicized with wireless, then as we have seen in long distance, the market is very efficient without any governmental strictures such as compulsory universal service.

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The Economics of the Wireless Local Loop

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Economics of Wireless Communications Systems

4.0 Wireless technology in the *National Information Infrastructure* (NII)
Wireless telecommunications is receiving a lot of attention these days. Some would say an inordinate amount. Why? After all, wireless telecommunications has been around for a very long time, and by now nearly everyone knows about the convenience of cordless and mobile telephones. The key to what is going on lies in the fact that, for the first time ever, wireless technology is progressing to the point that it will not only be convenient to use, but will be affordable for the mass market of American consumers.

Due to the obvious advantage of portability, it is a given that wireless telecommunications will be very successful with consumers. However, any meaningful discussion of the role that wireless communications might play in the grand scheme of things cannot occur in a vacuum. While it is a foregone conclusion that the convenience inherent to portable wireless telecommunications assures that it will always be an integral part of the telecommunications business, the real public policy issue for governments around the world is whether or not wireless technology will be an important part of the public network infrastructure for the 21st century. This raises some obvious questions: 1) can wireless technology meet the service demands placed on a modern network infrastructure?; 2) can this be done at a cost lower than those for wired alternatives?; and 3) if the answer to questions 1 and 2 are yes, then what could (or should) the government do to stimulate investment in a public wireless network infrastructure?

One critical roadblock to obtaining a market based answer to these questions has been the governmentÕs historical policy of compartmentalizing wireless network operators by restricting the use of their particular slice of spectrum to one specific type of service(s) and expressly prohibiting entry into the market for traditional telephone services. Finally, however, the *Federal Communications Commission* (FCC) has adopted a new Òflexible useÓ philosophy, and is considering allowing wireless network operators into the market for tradtional telephone services. This is a huge step in the right direction, but is only a beginning. As of this writing the FCC has not removed this barrier to entry, but they are considering it.[1] This chapter begins an investigation of the potential for wireless technology to augment or even replace the traditional wired telecommunications network infrastructure.

The Clinton Administration's characterization of the NII provides the context for the discussion of wireless technology herein. But the Administration has said very little

about what the form or substance of that infrastructure would be. For example, will the NII use wireline or wireless technology, or some combination of the two? Will it be digital, analog or both? Will it be capable of "narrowband" voice and data services applications, or will it support multimedia and "broadband" services such as TV or even video telephony? The answers to these questions are simply not addressed in the current version of the Administration's vision of the NII. Therefore, each of these possibilities will have to be considered.

There are some aspects of the future NII which are clearer. There are three basic pillars of the Administration's vision of the NII as an advanced network infrastructure: 1) investment for infrastructure will be privately funded; 2) services will be widely available and accessible to the public (i.e., "affordable"); and 3) the various networks comprising the NII will be compatible or standardized.

Given these principals, what current or future wireless network systems are likely candidates for the NII? Since virtually every household in America already has affordable access to analog broadcast radio, television and cordless telephone service, the NII must represent more. Maybe the NII is best described in terms of new digital television, interactive television, new digital voice and data mobile telephone systems, satellite radio paging and messaging systems?

Such questions must be answered before any meaningful progress can be made in deciding what characteristics make wireless systems candidates for use in the NII. The key is to narrow the field of likely candidates without eliminating the possibility of novel systems that may not even be on the drawing board yet? The way to do this is to focus on the generic role and capabilities of the technology itself, rather than analyzing specific wireless network systems or trying to guess the uses to which the technology will ultimately be put.

For analytical convenience it is useful to view wireless technology as potentially playing a role in three major aspects of the physical NII: 1) consumer terminal devices or cordless "handsets"; 2) the over-the-air transmission network; and 3) the interconnection, or*wireless access*, arrangement connecting a consumer terminal or private network to the nationwide public network infrastructure.

Wireless access, the focus of this chapter, implies the use of a handset and is, therefore, the term that best captures the essence of the role of wireless technology in the NII; it represents the wireless counterpart of the all important on/off ramps to the information superhighway. Of much less importance for the NII is the role of wireless transmission for internodal transport--the "open road" part of the information superhighway. Besides representing only a small fraction of the total cost of an

advanced network infrastructure, experts agree that there will be many private industry players and much investment flowing into this segment of the NII using a mix of routing and transmission technologies.

The great potential for wireless telecommunications in the NII is obvious once one considers the basic economics of supply and demand. On the demand side, the raw convenience offered by truly portable, personal and private telecommunications in the everyday activities of all Americans makes it an unambiguous winner in the market place. On the supply side, wireless telecommunications technology is progressing to the point where it meets or exceeds the cost performance and quality characteristics of wireline alternatives for traditional telecommunication services.

4.1 What exactly is "wireless" telecommunications?
The answer to this question is invariably a matter of scope and context. Broadly speaking, the term "wireless" simply refers to telecommunications which does not involve a tether. But this definition is too broad to be meaningful in the context of the NII which places certain minimum requirements on infrastructure network technology (e.g., that it feature capacity and cost characteristics that make it publicly accessible to, and affordable for, most Americans).

Many popular forms of electronic communication already rely on wireless technology but would not be suitable for the NII. Mass market demand for wireless communications has been rapidly expanding for decades, but has generally been limited to use in the immediate household area (e.g., broadcast and satellite TV, radio, and cordless phones). In most cases, non-interactive wireless "networks" using truly portable wireless media have been featured (e.g., PCs and diskettes, video tapes and VCRs, and compact discs and CD players).

Wireless telecommunications in the context of the NII is different. The technology must support two-way real time (i.e., interactive) digital telecommunications. In common parlance, it simply means a *phone without wires*; but, technically, that's what a cordless phone is. So, to be more precise, the wireless phone of the future would be connected via a digital wireless interface to the *public switched telephone network* (PSTN). Just where that point of interconnection would be is one of the most critical, yet fluid, issues being considered by would-be wireless network operators.

Thus, wireless refers to the ability to engage in real time, private, two-way voice and data communications at a distance without the use of wires.

Note that the issue of whether or not wireless systems may support only narrrowband voice and data services or include multimedia and broadband services (e.g., video

telephony) is not pre-supposed, nor should it be at this early stage. Any requirement that the future NII include broadband service will depend partly on the government's public policy objective and partly on the costs of achieving it--the latter being the focus of the discussion which follows.

4.2 Portability aspects of wireless access

On the demand side of the wireless market, the convenience aspect of portability poses a substantial inherent advantage over wireline service. Holding constant the quality and price of wireless transmissions, the combination of portability and reliability will be paramount in determining winners and losers in the market place. However, supply side considerations dictate that portability itself is a matter of degree and is directly related to wireless system cost. From a wireless network operator's perspective, meeting consumer demand for a wide range of service capabilities and portability features is potentially very costly.

It is one thing to say that a given consumer application of wireless telecommunications is "portable," but quite another to claim that it is possible to use a portable phone *anywhere*, *anytime*, to call *anyone*. These are the all important three "A"s of portability. The availability of portability anytime is a given, the ability to call anyone is not and will depend on the connectivity of wireless and wireline networks. Portability anywhere is yet another matter.

Anywhere means that a telephone handset will work at home or in the office, or while walking or driving. More formally, there are three possible modes associated with calling anywhere: 1) using wireless access while at the home base station location; 2) moving about (e.g., walking) at a distance from the home base station in a given home base station area; and 3) roaming (e.g., driving) at a distance from the home base station area. The economics of wireless access systems critically depends on the relative costs and demand for each of the three modes of portability. The overall cost of building wireless access systems varies dramatically as portability is expanded from modes 1 thru 3.

These "modes" of portability should not be confused with popular lingo in the cellular phone business today which characterizes as "multi-modeÓ those "smart" handsets which are capable of changing frequencies. In the lingo of wireless marketing, so-called "dual-mode" handsets are contemplated for switching between paging and cellular service, home area and roaming, or for switching between different types of new digital cellular systems. For example, Nextel is introducing a triple-mode phone capable of performing dispatch, paging, and cellular functions.

To place the three portability modes in context, the stationary or "fixed" wireless mode is akin to using a cordless telephone in the home, office (including wireless *local area networks* (LANs), and wireless *private branch exchanges* (PBXs)), or at another base station location (e.g., shopping mall, airport, bus and train terminal). This mode of operation is the least expensive to provide.

The second portable mode for wireless access, moving about in a given geographic area at a limited distance from the "home" base unit (e.g., walking, driving in town), requires that base station unit(s) provide continuous coverage throughout the local geographic area. Personal/portable phones, pagers, two-way radios, and car phones will work in such situations, whether using radio, cellular, broadcast, or satellite technology. This mode of operation is considerably more expensive to provide than the fixed location mode above, but much less expensive to provide than complete portability.

The third portable mode works even when driving fast in a car potentially far away from home base. Mobile cellular systems are one example of this at work, but satellite-based systems would work as well. This mode of operation is the most costly, so would-be wireless system operators must carefully evaluate the value to consumers of this type of system relative to other more limited systems to assure that the substantially increased costs associated with offering "fast hand-off" mobile capability and "roaming" service capability is worth it.

A single multi-mode handset may potentially function on one or more wireless systems simultaneously for all three modes of portability, providing a full range of portable narrowband voice and digital data services. In addition, all three modes could support a host of other digital services including non-real time messaging (e.g., paging and locator services, data, computing, and fax services) and other transaction services (e.g., "smart-card" debit/credit financial services, electronic databases, information services). There are other more exotic portable applications as well, such as satellite "briefcase" phones (actually a portable earth station) for communicating from isolated and remote locations, air-to-ground phones, and ship-to-shore phones. However, none of these niche market applications is important for the mass market contemplated in the NII which connotes a publicly available infrastructure.

One of the most crucial decisions which prospective wireless network operators face is the tradeoff of consumer demand for the added convenience of multi-mode operation versus the additional cost of providing the sophisticated hybrid network hardware, electronics and handsets necessary to make it all work. Through the use of sophisticated network electronics, digital signal processors, and intelligent control software, any of the three modes of portability may be used in conjunction with one

another in hybrid wireless network systems via interconnection arrangements and so-called "overlay" networks used to combine features of different wireless systems.

The network design and cost structure of these systems will be examined in more detail later within this chapter. But first, a basic description of known wireless access alternatives and service capabilities will be discussed.

4.3 Wireless access alternatives

There are many wireless network alternatives. Four major categories of wireless systems which will be discussed below include cellular radio, non-cellular radio, broadcast, and satellite. Within each of these categories there are any number of alternative methods for network access, transmission and routing functions. The basic technical and economic aspects of the most popular wireless access systems, and their acronyms, are briefly described as follows:

1. Cellular--any given geographic market area is segmented into "cells", each with its own radio base station. This arrangement is often cost effective relative to non-cellular arrangements because it allows for the possibility that different users could share the same radio frequencies within a given cell, and allows for re-use of the same frequency spectrum in different cells across the entire geographic coverage area. Depending on network system design criteria, a network operator may utilize relatively large cells ("macrocell"), relatively smaller ones ("microcell"), or even smaller ones yet ("picocell"). All other things being equal, smaller individual cell areas allow for higher system traffic capacity, but the overall system cost is higher due to the larger number of network nodes (antennae sites) per total system coverage area.[2] Current generation mobile cellular systems use macrocells, and future ones will use microcells or picocells (e.g., *personal communication network or system* (PCN/PCS)).[3]

There are three primary modes of operation for cellular networks, *frequency division multiple access* (FDMA), *time division multiple access* (TDMA), and *code division multiple access* (CDMA), all of which refer to the method by which network operators provide, and individual users access, a particular communications channel. The relative costs and performance of these three access methods will be discussed in the next section. FDMA and TDMA are well known technologies that work. CDMA systems have yet to be deployed and that has given TDMA digital systems a huge head start in the market. However, some major industry players are betting that CDMA is imminent and could even become the predominant technological chioce for digital wireless access systems.[4]

Even within a given cell area, system capacity and unit cost performance may be improved through "sectorization" of the cell into smaller geographic coverage areas via

the use of directional antennae and variable powering schemes for handsets and/or base stations to reduce interference. Cell sectorization comes at a cost, but is usually a less expensive method of adding system capacity compared to adding entirely new cells or splitting the older, larger cells into newer, relatively smaller, cells.

2. Non-cellular--this wireless access system is conceptually similar to traditional analog radio networks with a single radio station transmitter serving a given geographic area (e.g., mobile phones, taxi dispatch, emergency services). Such systems typically feature very limited capacity compared to cellular systems, but may be less expensive to develop and operate depending on the type of service being offered (e.g., dispatch and paging services). By using the same methods for frequency sharing as cellular systems (i.e., FDMA, TDMA, CDMA), and "sectorization" of the radio coverage area, it has become possible to dramatically improve system capacity and performance. The leading applications for this technology are called *specialized mobile radio* (SMR) and *enhanced SMR* (ESMR). It is possible to expand the capacity of these systems by migrating to a cellular or "cellular-type" network structure and setting up many relatively low power radio signal repeater sites that may re-use the same frequencies as other such sites within the same geographic coverage area.

From a network service perspective it is not yet clear whether the cost of migrating an existing SMR system toward a cellular structure is a less expensive proposition than building and operating a digital cellular network, even assuming that the service quality of the former could equal the latter.

3. Broadcast radio--traditionally used for one-way analog video and audio service, broadcast radio is being reborn using digital technology to expand system capacity and allow for two-way transmissions. Digital signal processing and compression of video signals have dramatically improved channel capacity and functionality of broadcast systems ultimately providing for two-way interactive communications including basic telephone services. The most popular systems being considered for the NII are two-way "wireless cable" systems called *multipoint and local multichannel distribution systems* (MMDS and LDMS). There are a number of other system designs featuring more limited capacity, geographic coverage, and functionality including some which are single-channel broadcast systems (e.g., *single master antenna television* (SMATV), *interactive television* (ITV), *low power television* (LPTV)).

The economics of migrating one-way broadcast networks toward two-way digital service capability is unclear as it is in the very early stages of development. To date, it appears that, for a relatively small incremental investment in network electronics, such systems will soon be able to support a digital narrowband upstream data channel for limited consumer interactivity for such services as Òpay per viewÓ video, Ònear video

on demandÓ, and, ultimately, "virtual VCR" video service. Most of the consumer cost of subscribing to interactive television services will be for sophisticated electronics to perform the required signal decoder and memory functions in the television "set top" boxes. Voice and video telephony are another matter, however, and the incremental network investments required to provide these services over traditional broadcast networks may be substantial. Whether or not it will prove to be cost effective to upgrade digital radio broadcasting systems to provide for interactive multimedia service, the FCC has at least started to remove a major regulatory barrier to entry into this market, but only for LMDS systems not MMDS. In July 1995 the FCC issued rules which allow LDMS operators to provide services that compete with the fixed wired local service of local telephone companies. The wording of the applicable provision effectively limits LMDS operators to providing basic voice services. It does not permit LMDS operators to provide other enhanced telecommunications services, but it is certainly an important step in that direction.

4. Satellite--these wireless systems rely on orbital satellite transmissions as opposed to terrestrial or "land-based" wireless alternatives. The most popular systems being considered for possible application in the NII are *low earth orbit* (LEOs), *medium earth orbit* (MEOs), and *geosynchronous earth orbit* (GEOs) satellites using high frequency (e.g., Ku and Ka band) radio frequency spectrum. So many new digital satellite systems have been announced that it is difficult to sort out the similarities and the differences.[5]

GEOs have historically dominated the scene for satellite telecommunications for both two-way telephone service and for one-way broadcasting services using C-band radio frequency spectrum. Because of their high orbital altitude (36,000 km), and correspondingly slow orbit period (24 hours), GEO telecommunication systems may achieve effective global coverage with only three satellites. Traditional GEO systems use relatively low frequencies, and therefore require lower operating power levels. Such low powered, low frequency systems required system users to install rather unwieldy (and unsightly) large signal receiver dishes. The first applications of this technology for telephony were made by the traditional C-band public satellite telecommunication network systems such as COMSAT, INTELSAT, and, more recently, PANAMSAT.

The newer GEO systems use higher power levels and frequency bands (Ku and Ka band) to provide one and two-way video and data communications. These satellite systems support popular data networks called *very small aperture terminal* (VSAT) telecommunications systems which use small, unobtrusive and relatively inexpensive signal receiver dishes.

Using the same high frequency bands, new digital GEO systems providing *direct broadcast satellite* (DBS) services are being deployed to provide digital video broadcasting direct to the home. As in the case of traditional land-based broadcasting systems, new digital signal processing techniques will continually expand the capacity and functionality of many types of satellite broadcast systems, ultimately allowing for two-way voice and data transmission. The FCC's flexible use spectrum policies may be extended to allow DBS networks of the future (or, for that matter, any other broadcast satellite networks) to provide two-way voice and data services. One persistent problem faced by GEO broadcast video and data systems wishing to migrate toward two-way voice service capability is the inherent transmission delay time associated with geosynchronous orbit "uplink" and "downlink" which causes annoying echo and cross-talk in voice telephone calls.[6] While such problems have always existed with traditional C-band long distance telephone systems, consumers will be less willing to tolerate it when good substitutes are available for global transmissions like trans-oceanic cables.

LEOs and MEOs are low-flying satellites which reduce considerably the problems of signal delay in GEO systems, making them more acceptable for voice services.[7] Such systems require that more satellites be launched and maintained or replaced. Whereas GEO systems may achieve effective global coverage with only a few satellites, MEO systems require 10-15 satellites with an orbit altitude of 10,000 km and orbit period of 6-12 hours. LEO systems require more than 48 satellites at an altitude of only 700 km and orbit periods of about 1.5 hours.[8] One proposed LEO system, Teledesic, uses hundreds of satellites. In the near future (pending final approval from the FCC), new global and domestic *mobile satellite systems* (MSSs) using the higher frequency Ku and Ka bands will begin providing two-way voice and data services. These systems are being planned and financed by many major communications companies. Pending other FCC decisions regarding spectrum allocation, still other future satellite systems are targeting not only mobile but also otherwise fixed telecommunication service markets which could ultimately compete directly with traditional wired voice and data telephone networks.

Given the level of business activity that is already occurring, it is safe to say that all of the four categories of wireless services discussed above will be players in some portion of the NII. Some of them, perhaps even most of them, will be only very small players. The relative cost and service advantages of each will dictate which ones ultimately become viable for mass market deployment.

4.4 Functionality of wireless

There is considerable dispute within the telecommunications industry as to the service "functionality" of wireless access. In other words: what functionalities are possible using wireless access (e.g., analog/digital switching and transmission, narrowband and

broadband signal speeds, circuit and packet switching and transmission, routing, network control), over what types of networks (e.g., cellular, SMR, broadcast, satellite), to provide what range of services (voice, video, text, data), capable of satisfying what types of end user applications? The answer to this series of questions is: all of the above. It is simply a matter of network cost and the cost and availability of RF spectrum.

The functionality of wireless transmission is potentially universal, just as it is for wireline transmission, with one obvious benefit on both the supply and demand side of the market equation--it is portable ("untethered"), and does not require costly installation because there are no physical transmission cables or wires. The actual functionality of wireless access (as opposed to wireline access) is directly related to the government's willingness to provide sufficient usable frequency spectrum so as not to limit its capacity, and, in turn, its service capabilities. The more relevant questions then become: in light of what we know or can forecast about the government's spectrum allocation policies, what functionalities will various types of wireless access systems be able to provide, and what types could be cost effectively provided vis a vis wireline alternatives?

Among the technical improvements in digital telecommunications technology, advances in wireless signal processing techniques to enhance network functions such as, access, routing, transmission, control, message encoding and encryption, will continue to improve system functionality and performance. It is already known that any of the four types of wireless access either can now, or will soon be able to, utilize digital technology to perform both circuit and packet network functions capable of providing two-way voice and data telecommunications. However, some of the wireless network alternatives have a huge head start (for example cellular mobile service started back in 1984), while others have just begun to be developed or have yet to be conceived (for example local lightwave telecommunications using so-called "photonic phones" are on the horizon).

The following section on wireless access network cost structures and cost estimates includes underlying assumptions regarding the amount of frequency spectrum available to each individual network operator in a given stylized geographic area and will therefore indirectly address the issue of system functionality. Of course, it is very dangerous at this early stage of technology development and deployment to presuppose the functional uses to which wireless access systems will be put, especially in business markets with highly specialized applications and system requirements.

It remains to be seen whether or not portable wireless access systems will be capable of providing for two-way or interactive real-time video telephony. Some of the systems

could potentially do so, but only at a significant incremental cost above narrowband digital service. Most experts agree that such cost is at least high enough to preclude it from being universally available to the mass market of *plain old telephone service* (POTS) subscribers, making it ineligible for the NII. WhatÕs more, from a practical perspective, it is not likely that most people will be watching TV while on the move using digital wrist watches or pocket phones. It is most likely that people will be stationary when participating in activities involving broadband telecomunications.

Upgrading a two-way narrowband voice and data cellular telecommunication system for broadband telephony or "bandwidth-on-demand" service requires enormous capacity additions and financial investments to current, and even planned, systems. Expansion of capacity in wireless systems, especially those capable of handling both mobile and fixed services, implies additional expenses for support structure and scarce public rights-of-way (e.g., light poles and rooftops) for additional antennas, transceivers and associated electronics; whereas, for wireline systems, broadband capacity expansion can generally be accomplished by adding digital processing equipment within the existing support structure and rights of way.

Picture a fixed fiber optic or coaxial cable phone connection from a subscriber location to a network node which, in turn, is connected to a fiber-optic backbone network. Compare that to expanding capacity on wireless connections requiring "line of sight" connections in a mobile environment. Once the initial network system is constructed, it is generally less expensive to expand capacity on the fixed wireline network connections which do not require line of sight. Frequency spectrum limitations of wireless systems notwithstanding, the additional electronics and new cell sites required to significantly expand wireless network system capacity is relatively expensive compared to similar incremental capacity expansion of an existing wireline network system.

Unless there are 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.

Rather than thinking of integrated bandwidth-on-demand service as an extension of next-generation narrowband cellular systems, it is much more likely that wireless technology, should it become the vehicle for the information "super pipe" of the future, will develop as an extension of next generation digital broadcast and satellite systems, such as two-way MMDS, LMDS and DBS systems. Like wireline systems, these wireless systems are primarily designed to serve fixed service demand. Therefore, line of sight and support structures are only significant issues for the initial deployment of

the network, not for capacity additions to serve increased demand for bandwidth. Still, the additional costs associated with electronics for providing two-way bandwidth-on-demand service, combined with existing limitations on frequency allocations effectively make this scenario an unlikely alternative to the wireline solution.

While there is no doubt that the specific areas of the frequency spectrum which are, or will be, assigned to digital wireless access systems of all types will be nominally capable of providing multimedia and broadband telecommunications (including video telephony), the significant issue is the bandwidth of the particular slice of spectrum licensed to any one network operator, which may easily be less than that required to support mass market multimedia and broadband services featuring simultaneous (and random) access by network subscribers. Given the relatively small slice of spectrum which the FCC has licensed to individual wireless PCS network operators (no more than 40 MHz in a geographic market area), it is clear that these operators are not going to be in the multimedia or broadband business for the mass market.

This is not necessarily true, however, in the case of satellite and other broadcast radio network systems, which may be licensed with sufficient spectrum to provide for any type of digital multimedia service including broadband video telephony. While technological advances on these types of wireless access systems will eventually make it possible to provide an integrated bandwidth-on-demand service capability, it is not probable that scenario will ever be realized for the mass market unless the FCC allocates even more frequency spectrum to this industry segment.

4.4.1 Frequency spectrum and wireless system functionality

Cost and service characteristics inherent to a given wireless access system notwithstanding, ali types of wireless access facilities require radio frequency spectrum to function. The potential for success depends on the FCCÕs procedures governing the allocation and licensing of spectrum. Allocation refers to the amount of spectrum and the specific uses to which it may be applied. Licensing refers to the FCC's assignment of the exclusive rights to use a portion of the allocated spectrum to a company in a particular geographic area. Usually this right to use the spectrum is granted subject to provisions specifying the types of services which may be provided, and stating that it is granted only for a temporary (but not always specified) time period. Thus, quite apart from the issue of technical cost and service advantages inherent to any particular technology or network design, the scales of competitive advantage may be tipped in favor of one type of wireless access system or another depending on FCC spectrum policy.

The FCC is in the process of implementing an entirely different regime of flexible spectrum allocations and market-based licensing procedures (i.e., auctions), while

"grandfathering" its past non-market-based decisions.[9] Beginning with the spectrum allocations and licenses for PCS services, the FCC has allowed licensees to provide whatever services they wish (except broadcast and point-to-point microwave services). This new flexible use policy, which the FCC has adopted as a pillar of its new market-based spectrum allocation policies for the future, should be expanded to include other portions of the radio frequency spectrum. For example, if broadcasters were allowed to use (or offer to others for use) their spectrum endowments under current and future licenses, then such spectrum could possibly serve as a platform for two-way digital telephony in the NII.[10]

Specifically, in the future environment, traditional analog broadcast video channels may be digitally compressed resulting in dramatic increases in spectrum efficiency to support many more channels per unit of radio bandwidth, including upstream voice and data channels. This would argue for the FCC to expand its flexible use policies so that broadcasters and wireless cable systems may become full players in the NII by providing two-way digital voice and data services.[11] Once the FCC's service restrictions are removed from current broadcast spectrum licenses, the playing field among competing wireless access alternatives is leveled to the point where the least-cost network systems could emerge to compete with the wireline systems of cablecos and telcos.

Expanding the FCC's flexible use policies puts a very complex twist into any analysis of potential winners and losers in the market for wireless access alternatives. But this is a market risk which must be accepted by the wireless players as they vie for market position. That is not to say that the FCC should be empowered to randomly, and without notice, be able to change its spectrum policies with the effect of devaluing existing, or future, licenses. This would create tremendous uncertainty among prospective wireless system network operators and could seriously dilute the value of (and the monetary bids for), new spectrum licenses. What it does mean is that the FCC must make clear its long term intentions regarding spectrum policy: that it will gradually and deliberately expand both the spectrum allocations and the flexible use rules.

In any event, the FCC's spectrum policies going forward must try to balance the business risk associated with investing in new communication networks with the interests of consumers seeking more market choices and lower costs. The FCC should generally opt for those policy options which favor the latter over the former. The old spectrum policies did as much to protect the business interests of competitors as it did to promote the interests of consumers. The new policies are pointed in the direction of reversing this situation and should be aggressively pursued.

For purposes of the technical analysis to follow, to the extent possible, the impact of FCC spectrum allocation policy *on any given* wireless access alternative will be considered neutral as among alternatives within the four categories of technologies listed above.

However, *between and among* wireless access alternatives this assumption is problematic for two reasons. First, the total bandwidth allocated within any geographic area between competing wireless access systems will potentially affect the per unit costs of providing service, and, in turn, could dictate winners and losers in the market place. Second, regardless of the absolute amount of spectrum associated with a given license, the old service restrictions, which were conditional with the granting of the license, severely limit the market opportunities available for any type of wireless system, and, in turn, may be enough to dictate winners and losers in the market place. If the FCC is serious about extending its new flexible use policies beyond those for the relatively narrow PCS bands, they should begin the process as soon as possible so as to allow all types of wireless access systems to achieve their full potential in the NII.

Invariably, spectrum allocation rules for a given technology/service type will, in practice, directly affect its relative cost performance. The primary reason is that the total amount of spectrum allocated to a wireless service, or that portion granted to one licensee, (e.g., 30 MHz out of 200 MHz total allocation), along with its corresponding underlying network/technology (e.g., PCS/TDMA), and exactly where in the range of electromagnetic spectrum (e.g., 1.8-2.0 GHz) that particular allocation lies, in large part determines the cost, performance, and market viability of a given wireless access system. A full discussion of such issues is beyond the scope of this analysis, but the implications of known spectrum licensing rules for wireless system economics will be evident in the cost and service evaluations to follow.

The implication of the FCC's current spectrum policy for new digital wireless access systems is that, while these systems can fare well in the NII (as a narrowband service platform in the case of PCS or as a one-way broadband service platform in the case of wireless cable), they will not fare well if the vision of the NII includes broadband telephony. The reason is that when the FCC licenses spectrum, it has traditionally done so with very strict spectrum usage limitations. For example, when the FCC allocated SMR spectrum, it issued licenses to individual applicants with a very strict proviso that it only be used for local radio dispatch services. Recently, that restriction has been relaxed to allow for provision of new two-way narrowband telephony.

The same practice is true, but somewhat less so, under the new flexible use rules that the FCC is applying to its recent spectrum allocations for PCS services. While a licensee is allowed to use the PCS spectrum for any service it wants (except broadcast

and point-to-point microwave service), it is assigned so little spectrum that there is still an implied or effective service limitation. By limiting any given service provider to 40 MHz of PCS spectrum in a given geographic area, the FCC is effectively precluding them from mass market broadband service applications like video telephony. In other words, if very many system subscribers chose at any point in time to access multimedia and broadband telephone services, the system capacity would quickly exhaust leaving no room for other users to sign on.

Thus, under the FCC's current spectrum policy, the market for two-way broadband services will be the province of wireline access alternatives, primarily fiber optic and coaxial cable, perhaps in conjunction with satellite and other land-based broadcast networks. The irony of this may be that the FCC, in the name of promoting digital wireless technology, has simply not allowed for wireless access to be the technology of choice in the race to develop a fully integrated broadband network system, leaving the winnerÕs circle to wireline access alternatives. However, this is not a criticism of the current Administration or the FCC, both of which favor changing the rules to liberalize spectrum usage restrictions. Indeed, the current policy has been constrained by historical practices which can only be gradually changed over time. The past restrictive spectrum use policies were not a serious problem in the days when digital radio services were non-existent or nascent and the public demand for spectrum was relatively low. Nevertheless, it remains important for the government to aggressively pursue the new policy direction toward flexible use so that the NII may develop unencumbered by obsolete spectrum policies.

In any event, it still remains to be seen if, in the very long run, the market for a wireline information "super pipe" to the home will ever become financially viable in the presence of cheaper, non-integrated alternatives, including digital wireless access and digital broadcasting systems.

4.4.2 The cost of frequency spectrum

Since 1993, the FCC has raised about $9 billion from auctions of radio frequency spectrum for new digital services. The first auctions were for relatively low valued spectrum for interactive television and regional and national paging services. Since then, interactive TV has gone nowhere as a service while paging has grown very rapidly. The early auctions only generated about $2 billion, compared to frequency spectrum auctions for PCS which concluded on March 19, 1995 and generated about $7 billion. The top bidders were established companies with deep pockets including, in the top three, the telco-cableco consortium called Wireless Co ($2.1B--Sprint, TCI, Cox, and Comcast), AT&T ($1.8B), and PCS Primeco ($1.1B--AirTouch, Bell Atlantic, NYNEX, USWest). In response to the future development of digital television broadcasting, the FCC is considering extending the auctions to new (or even existing)

broadcast frequency spectrum. If it does, it could bring in another $100 billion dollars in bid revenues.[12]

The up-front cost of purchasing the rights to use the radio frequency spectrum, either via FCC auction or by purchasing it from an incumbent, is substantial. This situation causes many bidders to complain that auctions, rather than posing a market opportunity, are actually a barrier to entry. However, bidding merely implies that there is a perceived financial payoff from owning the license, and that perceived benefit is at least as high as the bid price. Thus, the cost of the license for the rights to use a slice of RF spectrum is very straightforward for a prospective system operator to incorporate into a business case analysis. It simply represents a (potentially huge) start-up cost which is amortized over the system life or other planning horizon. Presumably, there is also a (potentially huge) salvage value of spectrum rights as well. The overall effect may be just like having money in the bank. Indeed, spectrum itself can be banked; just like oil in the ground and fallow land held for future use, there is latent value inherent to some types of stored assets and spectrum happens to be one of them.

As an up-front, fixed cost, once incurred, spectrum cost has little real impact on future competitive market outcomes. In a financial model, spectrum license fees are simply rents assigned at the outset to either the government or incumbent private interests, depending on which has the spectrum rights. Therefore, any would-be market entrant must offset this amount against the *net present value* (NPV) of cash flows from network operations.

This is not to say that the start-up costs of spectrum cannot be so substantial as to give a would-be wireless access operator serious pause to enter the market. Only that, no matter what the up-front cost of spectrum, an incumbent or entrant firm will make a bid for it unless there is simply no profit to be made by entering the wireless access business. In that case no one would come forward to bid for spectrum and the government would have to re-evaluate its spectrum allocation and licensing policies.

There is also the risk of overbidding for an FCC license, especially if the FCC does not guarantee that additional spectrum would not be allocated in the future, thereby diluting the value of a license purchased today. However, this is hardly a legitimate complaint against the government's auction. In a world of uncertainty, the risk of overbidding is always there.

This is a very important point because there are many who believe that the auctioning of spectrum would discourage market entry, or otherwise distort market outcomes, due to the apparent asymmetry of requiring new wireless access network operators to purchase spectrum when incumbent firms (or, for that matter, future entrants) may be

endowed with "free" spectrum. This would be true except that incumbents, too, have an opportunity cost and market value associated with their own spectrum endowments. Therefore, the spectrum auction fees are really just a one-time assignment of the rents associated with spectrum rights to the government instead of the private sector. The net effect on market entry and network operations of either the new wireless network operators or the incumbents should be neutral, with one important caveat -- that either is free to compete with the other if they choose to and are willing to pay for the privilege.[13]

This is a non-trivial caveat. If the government were to regulate and limit the uses to which spectrum could be put, then there is the possibility that competitive market outcomes would be precluded and that monopoly quasi-rents associated with spectrum rights would exist. In the case of wireless access for PCS services, the government has followed the advice of economists and has not restricted the uses to which the new spectrum allocated for wireless access could be put.[14] In turn, the government has not precluded incumbent cellular operators, previously endowed with spectrum via so-called "set asides" of half of the spectrum to PSTN operators and the other half, via lottery, allocated to non-PSTN operators, from using it for new wireless access services.

The FCC's flexible use policy for spectrum allocated to PCS is totally new and represents a true sea change in spectrum licensing policy.[15] However, the FCC still retains strict rules limiting how the vast majority of licensed RF spectrum is used. For example, broadcast spectrum cannot be used for non-broadcast services, and spectrum allocated to wireless telecommunications cannot be used for broadcast services or point-to-point microwave services.

Critical to business case analysis of wireless access operators is the uncertainty and risk associated with changing FCC spectrum allocation policies, and whether or not more total spectrum will be assigned to wireless telecommunications. For example, in the future, the FCC could, in further pursuit of its new flexible-use rules, allow UHF spectrum, which lies adjacent to cellular spectrum, to be used for wireless telecommunications. Or the FCC could allow wireless cable spectrum, which lies adjacent to PCS spectrum, to be used for telephony. This would represent a veritable flood of additional spectrum into a competitive wireless telecommunications market, diluting the value of the licenses of the early licensees.[16]

In pursuit of its objective to allocate spectrum for use by wireless service entrepreneurs and innovators, Congress has ordered that another 200 MHz of RF spectrum below 5 GHz be reassigned from government to private sector use. While the process of reallocation of all 200 MHz may take up to 15 years, the FCC has since requested that