Pergamon

Telecommunications Policy, Vol. 21, No. 5, pp. 387–410, 1997

Printed in Great Britain
0308-5961/97 $17.00+0.00

PII: S0308-5961(97)00018-9

The economic viability of wireless local loop and its impact on universal service

Terrence P McGarty

This paper presents an overview of the economics of wireless transport focusing on Personal Communications Service (PCS) and Local Multipoint Distribution Service (LMDS) as compared with the existing incumbent local exchange carriers, namely the I-LECs. The paper also addresses the issues of universal service and presents an analysis of how wireless may be a viable player in that environment. The paper combines the approaches from several different fields and demonstrates that wireless has applications as a provider of universal services in certain niche areas but it is not a clear universal application. The paper also develops several policy issues as to how best to deal with the issue of universal services and also addresses the issue of how far that social demand should be extended. © 1997 Elsevier Science Ltd.

Terrence P McGarty is Chairman and CEO of the Telmarc Group, Inc, 24 Woodbine Road, Florham Park, NJ 07932, USA (Tel: +1 201 377 6269; fax: +1 201 377 2143; email: mcgarty@rpcp.mit.edu).

This paper was presented at the Columbia University CITI seminar on 'The Role of Wireless Communications in Delivering Universal Service'.

Introduction

Wireless Local Loop is a vision of how wireless technology may be deployed in the provisioning of local telephone service. Both the large existing entities such as AT&T and the entrepreneurial entrants such as NextWave and others have looked at taking the PCS spectrum and using the new technologies to allow for the provision of full local loop capabilities in a wireless fashion. This paper discusses the economic viability of such a plan.

There currently are several different strategies aimed at the presentation of local telecommunications. One is the strategy of attempting to go head-to-head with the existing Local Exchange Carrier (LEC) on a local loop only basis. The other is the bundling of this with other services, such as long distance and television delivery to attempt to obtain scale economies in the delivery of the services. The latter approach is clearly expressed by both AT&T and MCI.

The key issue is initially one of cost. Can wireless be delivered at a lowered cost per unit service than is the existing wire based local loop. Previous analyses have shown that wire based systems have capital per subscriber as high as $1800. Wireless costs about $250, which does not include the handset. However the incumbent has these as sunk costs whereas the new entrant has these as entry costs. This is a significant difference. Add to this the license costs, which in many cases equals the cost of the capital plant.

There is also the issue of bundling. Personal Communications Service (PCS) generally is a voice only system, although some data is available. Local Multipoint Distribution Service (LMDS) is a voice, video and data system at 28 GHz. The question is, does the ability to bundle significantly increase the entry opportunity?

Finally, all of these wireless financial numbers are exclusive of any universal service coverage commitment. If one adds a surcharge on all players then the approach is simple and each customer is taxed for the universal service fund. If however there is a build-out requirement, then this is generally uneconomic. We shall show the value per PoP vs population density. It is clear that in most wireless systems at densities at less than 100 PoPs per square mile there is no economic value to the business. The policy issue is related to providing universal service but not forcing universal coverage by all participants.

Universal service

Universal services is the mandate to provide services by any carrier to any person not individually financially able to obtain the service in the area in which they inhabit. Namely the low income and rural customers. The universal service provisions are as follows:

> (b) Universal service principles–the Joint Board and the Commission shall base policies for the preservation and advancement of universal service on the following principles: (1) Quality and Rates; (2) Access to Advanced Services; (3) Access in Rural and High Cost Areas; and (4) Equitable and Non-discriminatory Contributions.
> (c) Definition (1) In General—universal service is an evolving level of telecommunications services that the Commission shall establish periodically under this section, taking into account advances in telecommunications and information technologies and services ... such telecommunications services; (A) are essential to education, public health, or public safety; (B) have, through the operation of market choices by customers, been subscribed to by a substantial majority of residential customers; (C) are being deployed in public telecommunications networks by telecommunications carriers; and (D) are consistent with the public interest, convenience, and necessity.....

Universal service has been in effect *de facto* since the Kingsbury decision of 1913.[1] This implicitly allowed AT&T to retain its monopoly subject to the agreement to provide, ultimately, universal service. The universal service would mean that all people would have access to telephone services and that for people on low income the service would be subsidized. The state PUCs then followed up on this and embodied this in state regulatory requirements. In effect, AT&T and the BOCs were transferring wealth from the 'rich' to those who could not pay for such services, either because of their income or because the costs to provide services to that individual would be prohibitive. This was then an enforced payment, established and managed by the BOCs, for the purpose of collecting moneys from the haves for redistribution by the BOCs to what was perceived as the have nots. Needless to say this is per se taxation. From a Constitutional perspective, such rights inure solely to the states and the Federal government, and under the Commerce Clause it is highly problematic that any independent third party has any right to tax especially as regards to interstate commerce. Needless to say there has never been a challenge here.

The universal services fund was and still is a taxation by the BOCs to redistribute income. It also is a pool of funds to be used by them as a vehicle to bar competition. The universal services issue, however, goes to the heart of the interconnection debate. The RBOCs have used this ruse as a means to control competition in two ways. First, in interexchange access they have charged an access fee disproportionately higher than

[1]Weinhaus, CL and Ottenger, AG, *Behind the Telephone Debates*, Ablex Publishers, Norwood, NJ, 1988, p. 57.

costs since it was then used as a basis for universal services. This was the taxation issue. Second, they have used a unilateral fee for any other interconnect player. Thus cellular companies, arguably provide local services, and pay for initiating and terminating calls. This has been changed by the new Act.

The Act has mandated a separate universal services fund to be managed by the Government, and thus the Government's powers to tax are valid and this is a legal act in contrast to the arguably illegal actions of the RBOCs in the pursuit of taxation. Second, the Act mandates balanced interconnection.

To better understand where the legal applications will be addressed, we first present an overview of the major theories behind the applications of the antitrust laws. This will be important since these theoretical proposals are not only applied to antitrust law but also to the enactment of the administrative regulations in the application of the Telecommunications Act. The litigation of any case in this area will require an understanding of the philosophical framework that underlies its application.

Philosophical underpinnings

The issues of political philosophy may seem a far cry from wireless communications but they are actually central to it. Any process that provides a service, and where the government is in the middle, will perforce have a political element and in turn an overriding political philosophy. We consider two philosophies and their implications.

The first is the Rawls philosophy of John Rawls. His philosophy has three elements. The first is his concept of an Original Position. The Original Position is that all governments are based on a 'contract' between its citizens and that the ideal contract is one developed in a consensus between all its citizens that allow he or she and them to agreement on principles of government. From this follow the two Rawls principles of justice; the First Principle states that each person shall have equal rights to the most extensive total system of equal basic liberties with a similar system of liberty for all, and the Second Principle argues that social and economic inequalities are to be arranged so that they both, (i) provide the greatest benefit to the least advantaged, and (ii) are attached to offices and positions open to all under conditions of fair equality of opportunity.[2]

The next question is, how do we measure welfare? If we are a Rawlsian, then we measure welfare as the welfare of the least of us and not the average welfare. Rawls states that if we maximize average welfare then we disadvantage the least of us and this is not just. Thus, as a Rawlsian, we demand universal service. We must insist that all people have access to all service elements, whether it makes economic senses or not, we do so via wealth transfer.

Hopefully, this political theory should now not seem too foreign. Ralwsians favor the implementation of access fees and the implementation of universal service. Indeed, the true Rawlsian would impute universal service to even computer terminals as has been stated by Vice President Gore.

In contrast, the classic liberal, now called the libertarian view, is more a combination of minimal government involvement and maximum consumer utility. This is the philosophy of the utilitarian. Here we assume

[2]Kukathas, C, Pettit, P, *Rawls*, Stanford University Press, Samford, CA, 1990; Rawls, J, *A Theory of Justice*, Harvard University Pess, Cambridge, MA, 1971.

that government has a *de minimis* role and that the market follows of its own accord and that the market, in an Adam Smith fashion, will clear any inefficiencies of distribution and pricing mechanisms. It assumes that each business should stand on its own stead and that utility is maximized on average. The result from the libertarian school, as opposed to the contractarians or Rawlsians, is the elimination of access fees and the elimination of universal service.

It will be important to recognize that these political philosophies dominate the overall play of regulation in all markets. These two schools of thoughts, the libertarians vs the contractarians, whether they know they are one or not, will have a great deal to do with our development as an industry.

Rawlsian approach

Rawls has proposed a theory of justice that is a statement of what many proponents of antitrust theory promulgated in the mid-1950s and 1960s. The essence of Rawls' theory has the following three elements.[3]

Original Proposition: there exists a means and method for a society to establish a Contract amongst and between themselves. This Contract thus created in this just society is one that maximizes the return on every transaction to the least of the individuals in the society.[4] This approach to contractarianism is one related to individuals in a non-bargaining environment, and establishing between and amongst themselves a 'contract' to govern their society.[5] There are two elements contained herein. The first is the essence of a contract, and in fact a form of social contract between the members of society and amongst them as a whole. The second element is that of a view towards man as a constrained and unconstrained view of human nature.[6] The unconstrained view states that man, individually and in concert, has the capabilities of feeling other people's needs as more important than his own, and therefore we all act impartially, even when the individuals own interest are at stake. The constrained view is to make the best of the possibilities that exist within the constraint.

For example, the constrained view of universal service is one that would state that if it costs a certain amount to provide the service, and there is a portion of the society not able to purchase the service, then there is no overriding need to provide it if such a provision is uneconomical and places a significant burden on the other members of society. The unconstrained view, as a form of socialism, states that if there is the least of us in want for whatever the telecommunications revolution has in store, then they should have access to it at whatever cost.[7] One can see that the current trend in universal service is such an unconstrained view, especially as viewed by the current Vice President in his actions over the past 4 years.

Rawls approach to this contract is one wherein the individuals in the society collect themselves as individuals, and agree to a plan for the operations of that society.

First Principle of Justice: each person shall have equal rights and access to the greatest set of equal fundamental personal liberties.

Second Principle of Justice: social and economic inequalities are to be arranged so that they both: (i) provide the greatest benefit to the least advantaged; and (ii) are attached to positions available to each individual under conditions of fair equality of opportunity.

[3]See Kukathas, CP and Pettit, P, *Rawls*, Stanford University Press, Stanford, CA, for an excellent expository of the Rawlsian theory.

[4]Indeed in the Rawlsian world the individual posits their position and does so without any negotiation, and thus posits a position assuming that the individual will be the least amongst players in that society. Such a position, to create justice in that society is a *maxi–min* position.

[5]This is the same in many ways of the Social Contract envisioned by Rousseau.

[6]See Sowell, T, *A Conflict of Visions*, Wm. Morrow, New York, 1987, pp. 18–24.

[7]See Schumpeter, JA, *Capitalism, Socialism, and Democracy*, Harper & Bros, New York, 1942, pp. 167–186. Specifically, he defines socialism as; "an institutional pattern in which the control over the means of production and over production itself is vested in a central authority—or, as we may say, in which, as a matter of principle, the economic affairs of society belong to the public and not the private sector." Indeed in the case of universal service, the FCC and other elements of the Executive Branch have taken the property and means of production from the carriers and mandate how they are to be deployed, irrespective of an economic justification.

This latter element is the means to establish a Schumpeterian form of socialistic control. If we were to define the public welfare by a function W, and each individual listed as a variable I_n, then the policy choice, P_k, is chosen such that the welfare is maximized for the least advantaged. Specifically, if the utility of policy P_k to I_n is a function U, then we defined a Rawlsian system as one that performs the following mathematical function:[8]

$$\max W(u_1,\ldots\ldots u_N:P_0,P_M)+\lambda\Sigma(U(I_n:P_M)-U(I_n:P_0))$$

where P_0 is the initial state and P_M is the application of the new policy. What this states is that we want to maximize the society welfare, subject to the constraint that no individual suffers due to the change.

We can compare this to the utilitarian school, which states that we seek the maximization of:

$$\max \text{average } W(u_1,\ldots u_N:P_0,P_M)$$

which is not constrained on what happens to any one individual but to society as a whole. This approach is also one applied by Baumol and Willig in the establishment of interconnections and access rates and is the basis of the Ramsey tax policy. The Ramsey approach is Rawlsian whereas the approach of an Adam Smith or other utilitarians is the average approach.[9]

The application of the Rawlsian theory of justice is a key factor in the current telecommunications act. Specifically it is an element of the universal service portion in that the Act requires that the least of us receive the same as the greatest of us.[10]

Habermas theory

A slight distinction to Rawls is the theory of Habermas. In the Rawlsian case, the contract is generated in a mass meeting of all people. Rawls assumes that such a meeting would engender the development of a justice system that would provide for the equal justice for all, and ensure the result that the least of all would be protected. Habermas, and as recently stated in his most current publications, takes a somewhat different tract. He assumes some form of representative government that comes up with a more average form of justice. One could state that this is what we see in many republican democracies. In contrast to the least getting the same, in the Habermas system one would expect a more averaging of the welfare function over the population.

The Habermas distinction is that the contract is created by a different and representative group that takes into account certain economic realities. In some sense this is a representative democracy. The Habermas approach is in many ways intermediate to Rawls and Bentham.

Utilitarian school

The utilitarian school has as one of its key developers, Jeremy Bentham. Bentham, to paraphrase Posner, states that people are rational maximizers of their own utility or satisfactions in all areas of life and that

[8]This is a modification of the Ramsey pricing scheme of constrained maximization. Also the variations as discussed by Baumol are: the classic Pareto, the Kaldor, the Scitovsky, and the Bergson. The problem with these approaches is that they are all *ad hoc propiter hoc* approaches.

[9]See Brown, SJ and Sibley, DS, *The Theory of Utility Pricing*, Cambridge University Press, UK, 1986, p. 39. This is the Baumol Willig theorem, which uses the first Rawlsian approach to maximizing the return subject to a single constraint; namely that the monopolist suffers no harm. This has been the basis of non-mutual interconnection fees and has been corrected by the new Act but is currently stayed by the Sixth District Court after an avalanche of suits by the RBOCs. This is of course a different approach to Schumpeterian socialism, wherein a monopolist like the RBOC usurps the power of the state for his or her own benefit.

[10]See Section 254, universal service.

economic efficiency is an ethical and scientific concept.[11] The utilitarian approach does not generally focus on the individual, and thus that constraint of Rawls is absent. It assumes that the individual can make an economic choice. For example, as regards universal service, if I decide to live in Montana in the mountains, I have made a utilitarian choice of maximizing my satisfaction.

In that choice, independent of government intervention, I have chosen to forgo the advantages of a broad based telecommunications access. I will not have a Mbps link to my cottage, I will not have video on demand, and I may not have access to the Internet. I have no social contract with others and deal solely with myself. That choice is then my choice. If however, the Government uses a Rawlsian approach, and mandates that I have the telecommunications access, then this may or may not be reflected in my choice of where to live, but it clearly costs the other members of society who are now taxed to pay for this added satisfaction, albeit questionable, which I am now the recipient of.

As a utilitarian policy analyst, I would not require any form of universal service, and in particular I would argue for free and competitive open markets. These two extremes will be at the heart of the battle over universal service.

Local Multipoint Distribution Services

Local Multipoint Distribution Services (LMDS), is a generic term for the deployment of an integrated two-way voice, video and data services using the generic 28 GHz band.[12] The LMDS systems are to be deployed after the FCC auctions the spectrum in this band. This is expected in late 1996 or early 1997. LMDS is an immediate extension to MMDS, microwave Multipoint Distribution Services. LMDS may very well supplant MMDS. MMDS in many ways is merely microwave to buildings, and is in reality a real estate business since, the target market is multiple dwelling units. LMDS, it has been argued, is focused on all forms of residential and commercial applications.

The services provided are a mix of video, voice and data. The system must have the capability to reallocate the amount of capacity between all three general areas. This allocation must be both on a quasi-static basis as well as adjustments on a real time basis. The system thus has a dynamic management capability that it must provide.

Services

The system may provide, at a minimum, the following general services:

Voice: the system may provide full switched toll grade quality voice service. The voice quality may be telephone toll grade or better and there may be no delays in speech that are perceptible to the user. The user may interface with the system by a standard method or means typically being an RJ-11 standard telephone jack employing their own standard telephone in the case of a residential user. The voice user is not expected to change any of their infrastructure interfaces. The 'normal' telephone connection may be provided by means of the LMDS local interface unit, the LIU. The LIU may be compatible with any and all normal accepted telephone interfaces. The system must also provide all typical custom calling and CLAS features as expected in normal delivery of a competitive wire based telecommunications service.

[11] See Posner, RA, *Economics of Justice*, Harvard University Press, Cambridge, MA, 1983, p. 13. In addition, Posner, RA, *Economic Analysis of Law*, Little, Brown & Co., Boston, MA, 1992; Posner, RA, *The Problems of Jurisprudence*, Harvard University Press, Cambridge, MA, 1990; Posner, RA, *Overcoming Law*, Harvard University Press, Cambridge, MA, 1995; Posner, RA, *Antitrust Law*, University of Chicago Press, IL, 1976, develops a powerful theory of justice and the law and his economic analyses are powerful tools in the overall economic and policy analysis of this area.

[12] This is from the FCC R&O on LMDS, FCC Fourth Report and Order, CC-Docket No. 92-297, 17 July, 1996. This may be amended from time to time and the compliance with the FCC rules and regulations is incumbent upon the vendor.

Low Speed Data: the system may be able to provide data at the rates of 1.2 to 9.6 Kbps on a transparent basis and have this data stream integrated into the overall network fabric. The system may handle all data protocols necessary in a transparent fashion. The network may allow local access to value added networks from the local access point. The low speed data may be provided for over a standard voice circuit from the users premises as if there were no special requirement. There may be toll grade or better quality. The system may also be capable of support all Group 3 fax services.

Medium Speed Data: the network may be able to handle medium speed data ranging from 19.2 to 64 Kbps. The interfaces for such data may be value added network local nodes. The medium speed data may be provided for over a standard voice circuit from the users premises as if there were no special requirement. There may be toll grade or better quality. The interconnection for 64 Kbps may also be ISDN compatible.

High Speed Data: data rates at and in excess of 1.544 Mbps may also be provided on an as needed basis and a dedicated basis. The data rates may be between 1.544 Mbps and a maximum of 155 Mbps. The BER may be less than 10^{-9}. Also it may be required to provide access to such high speed data services as Fast Ethernet and FDDI at 100 Mbps. This may require both physical layer interfaces and the datalink and network layers as specified in the particular protocol. The system must also support multiple layer protocols including TCP/IP. Also the data must be point-to-point, point-to-multipoint, and multipoint-to-multipoint.

Video: the network may be able to provide the user with access to analog and digitized video services. This may also enable the provisioning of interactive video services. The video services may enable a system with a minimum number of channels of 150 video channels of remote programming, 10 of local off-air programming, and 20 locally generated programming. The interactive video may allow for 10 channels of 'pay per view' at a minimum, and interactive channels for local information selection. Video must also support such tiered services as basic, premium, 'pay per view', and interactive. The inputs to the system are from such sources as off-air, local generated, satellite, and other sources. Sources may be analog or digital, encrypted or not.

LMDS architecture

This section presents an overview of a possible LMDS architecture. The overall design is shown in Figure 1. Here is shown a connection to the Telcos and to external video sources. There is a connection to a Telecommunications Switching Unit, TSU, and to a Video Provisioning Unit, VPU. The connections between these and the DCU, the Digital Connection Unit, is a digital signal. The DCU takes the digital signals from the TSU and VPU and combines them in a common broadband digital signal, assigns it in a TDM form for transmission and then places it in the appropriate RF format for transmission to the BSU, the Base Station Units or nodes. The input from the BSU is also passed throughout the DCU and is fed to the TSU if it is data or voice, and to the VPU if it is a video control signal.

The actual embodiment of these units will be left to the system integrator to complete. However, it will be essential that these be separate embodiments and separately controllable and upgradeable.

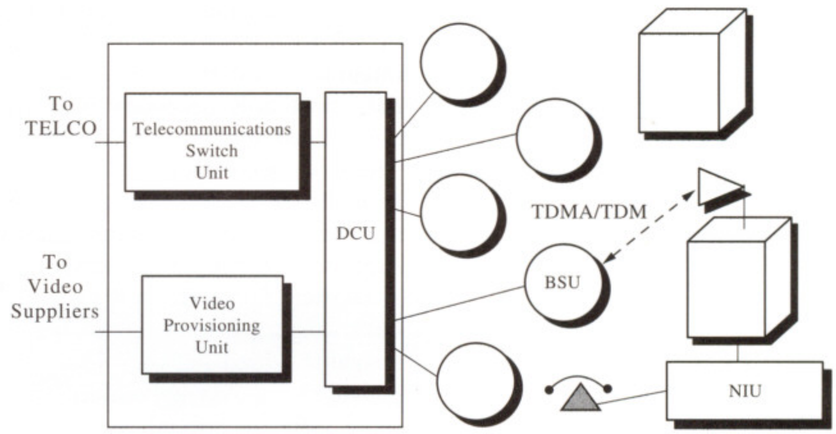

Figure 1. System architecture.

The BSU transmits in the LMDS band to the NIU in the end users premises. The signal from the BSU is TDM and the NIU return is TDMA.

The proposed carrier plan is shown in Figure 2. It shows a broadband video carrier which is TDM and a set of narrowband local video digitized inserts. It also shows a transmit voice band comprised of sets of carriers and a guard band separating the receive TDMA carriers. The receive carriers may also be 40 MHz or some other bandwidth occupancy. The detailed carrier plan in Figure 3 shows a low band of 850 MHz and a high band of 150 MHz. The low band is further split into a video sub-band and a voice sub-band. The low band may be used for transmission from the node to the end-user and the high band for transmission from the end-user to the node. Allocations other than what have been proposed may be deployed depending on the ability to achieve overall system performance and services acceptability.

The BSU can use multiple frequencies by segmenting the sectors. Figure 4 depicts a sectoring of 60° sectors with hexagonal patterns. The sectors are separated by vertical and horizontal polarization as allowed expressly by the FCC. The sectors, here six, can each have higher gain antennas and can each be driven by separate systems. The added gain allows for wider coverage. There is a balance between sectoring and increased antenna gain and the number of sectors and their cost. The larger the number of sectors the smaller the beamwidth and the greater the gain and the longer the effective range. It is anticipated that there is an optimum sectorization depending on the terrain. In hilly areas the line of sight, LOS, is limited by obstructions so that no matter how great the

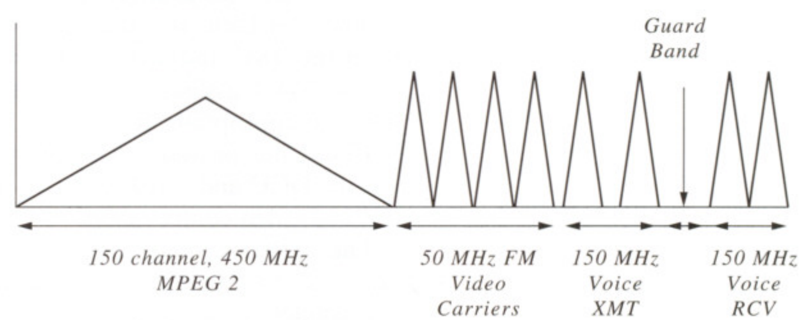

Figure 2. Carrier plan.

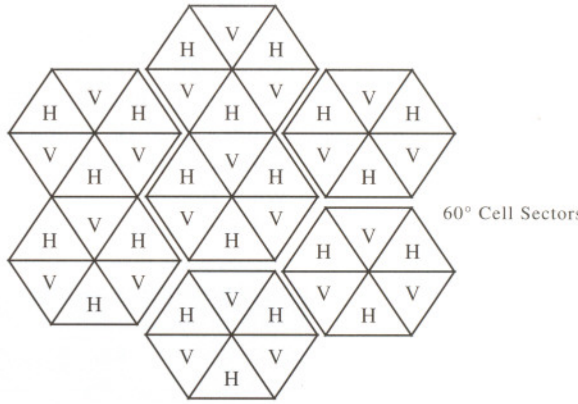

Figure 3. Six-way BSU frequency architecture.

gain on the antenna, and effectively how many sectors, there is a diminishing return in the design. Many designs will employ a single beam or sector.

The BSU to NIU connection is from the sector antenna at the BSU to the NIU antenna which is a narrow beam and high gain antenna. The antenna beam from the NIU assures that frequency interference is kept at a minimum. This is the standard approach as was used in such systems as the Interdigital system.[13]

Personal Communications Services systems

Personal Communications Services (PCS), is nothing more than the expansion of bandwidth and the introduction of competition in wireless. It is not a specific frequency band, a new technology, nor added features and services. It is the introduction of competition in the new markets. This is a definition that is economically driven and not technologically. One should avoid the battles between TDMA and CDMA, between 800 MHz and 1.9 GHz, between voice, and two-way paging. PCS is the commoditization of air time. It will allow entrepreneurs to take unbundled air time and create highly competitive new services and systems.

When viewed in this sense, PCS is comprised of two 800 MHz providers of 30 MHz each, three 1.9 Ghz providers of 30 Mhz apiece, three 1.9 Ghz providers at 10 Mhz apiece, and a SMR set of providers in 900 Mhz at about 5–10 Mhz apiece. Thus there are nine wireless providers of a commodicizable product, namely airtime.[14]

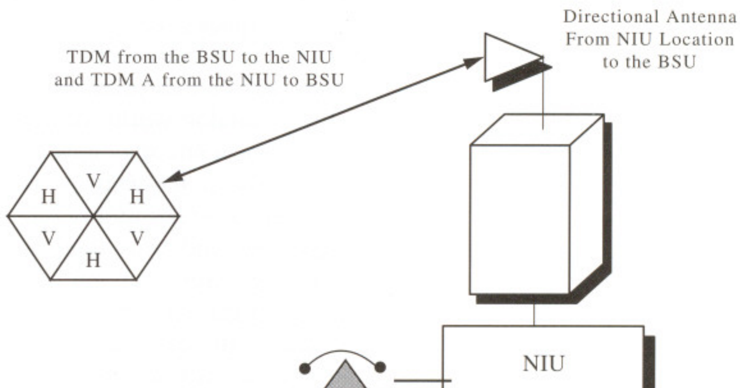

Figure 4. Node to NIU.

[13]See Patent No. 4675863, 23 June, 1987.

[14]See McGarty, TP, 'Disaggregation of Telecommunications', Presented at Columbia University CITI Conference on The Impact of Cyberc. In that paper the author develops the theory of disaggregation. Also see McGarty, TP, 'competition in the local exchange market: An economic and antitrust perspective', *Federal Communications Law Journal*, in which this theory is extended. "What the theory states is simply: The theory of disaggregation states that technology and industry has developed in such a fashion that it is possible to effect all elements of a business in a virtual form by obtaining all functions necessary to deliver a service by purchasing them from third parties each of whom has themselves other similar customers and thus each of whom can deliver their element of the functionality in a minimal marginal cost manner. The disaggregation theory then concludes with the result that in many technologically intense services business, a virtual company can exist wherein all the functions can be purchased from third parties or capital equipment may be purchased in a fully interconnected fashion so as to achieve near equality between average and marginal costs from the very commencement of the business. The Disaggregated Company is the embodiment of the virtual business."

The current wireless technology as embodied in the cellular communications systems is composed of several key technological elements. Specifically they are the Cell Sites, the MTSO (Mobile Telephone Switching Office) or Mobile Switching Center ('MSC'), and whatever connections or management systems are in place. The connections between the cell sites and the MTSOs are digital circuits carrying the voice signals.

Unlike LMDS, PCS is mobile. PCS has less bandwidth and is generally focused on large regions of coverage. LMDS is fixed as a service, it may be delimited as a LEC to a single state, whereas PCS, as is all of cellular, able to cross state boundaries. This is a dramatically different regulatory constraint. PCS providers are Commercial Mobile Radio Service (CMRS) providers. LMDS providers are LECs.

System elements

The design strategy in this section proposed uses a CDMA approach which has been selected since it provides the lowest cost per subscriber. The design of the system using CDMA demonstrated the ability of that technology to balance coverage and capacity. However, it can be shown that with the cost reductions in GSM TDMA technology, the differences are getting smaller over time. We can characterize these two domains as follows:

Capacity domain. In this case there are enough cell sites and they are deployed so that at no time is a unit too far from a cell. For high powered units this may be a great distance. For lower power units this may be quite a small distance. However, there are so many users per cell area that the load exceeds the capacity of a cell. To meet the demand, cells must be split and the frequency reused. This installation of new cells for the reason of reaching a capacity limit is called the Capacity Domain.

Coverage domain. As with the capacity domain, the coverage domain is that situation when new cells are added because users are too far away from any cell. The coverage domain of PCS is that time when there are less than the saturation number of subscribers per cell in all of the cells. It generally is that period where the system has just been deployed and the customer base is growing.

The current analog systems were in the Capacity domain several years ago and they were predicting dire results. With the sale of portables this has shifted to the coverage domain. TDMA was a response to the capacity driver only. CDMA is a response to the coverage driver as well as the capacity driver. To balance the fluctuation between the two domains in a cost-effective fashion, it is necessary to have a technological infrastructure that meets the two needs, this is provided by CDMA.

In the analog world, cell capital costs are typically \$1 million per site and a typical site may cover a radius of 10 miles for a 3-watt mobile or 2 miles for a 0.6-watt portable, and a cell has a capacity of 40–50 instantaneous calls at any one time. The adjacent cells must use separate frequencies and thus there is a proliferation of cells and a significant amount of capital in cell sites. For example, New York has over \$350 million in cell sites per carrier and Boston has over \$150 million. This number is for each carrier, A and B side. Thus in New York, at \$250 million and for 125 000 subscribers, this is \$2000 of cell capital per subscriber.

Capital in the system will be divided into two major categories; local service infrastructure (LSI) and national service infrastructure (NSI). The LSI portion consists of all elements of the system up to and including the switch. The NSI portion is all elements from the switch on back. The NSI will also include elements that comprise the databases and computer support.

Six independent elements have been identified in the overall PCS architecture. They are as follows;

(1) *Portable*: provides the end user access to the network for voice and or data services.
(2) *Local Service Infrastructure* (LSI): the LSI provides three elements. The first is the establishment of a virtual circuit between the portable and the LSI. The second is the interconnection within the LSI covered areas between portables. The third is access to the other network interfaces to allow off net connections to LECs and IECs. It is important to note that the LSI has a sense of switching but that the implementation of the LSI switching can be implemented in many ways.
(3) *Operations Support Systems* (OSS): the OSS provides for the overall national amendment functions of the PCS network, including network management, customer service, billing, operator services and other elements.
(4) *Service Provider Infrastructure* (SPI): the SPI is a third-party service node that can provide such services to the PCS users as may be found in Intelligent Network Services. These may be the services such as messaging, voice mail, etc.
(5) *Local Exchange Carriers* (LEC): this is the access to the LEC and the LECs customer base. It allows the LEC customer access to the LSI and the PCS customer access to the LEC customer.
(6) *Interexchange Carriers* (IEC): the IEC provides access to other inter LATA LEC customers and other PCS customers in different regions.

LSI elements

CDMA dramatically changes the cost equation. First, CDMA will allow 10 to 20 times the capacity per unit bandwidth as analog. Second, CDMA allows for use of the same frequencies by keeping separations through the direct sequence codes in the technology. Simply put, a CDMA cell site may cover a 3-mile radius, yet have the capacity of 75 channels per 1.25 MHz of Bandwidth. Using a CDMA system, one may cover a greater area and thus be run at maximum utilization of close to 90% or more per site.

The costs associated with this configuration are those capital and operating costs of the cell and the MTSO as well as the carriers charges for the PSTN. For a cell, the specific life cycle factors that control its overall costs are: cell site location and planning, cell construction, cell capital, cell installation, cell operations, cell maintenance, and cell repairs.

The first four items are part of the initial capitalization and may take anywhere from 6 months to 2 years, depending on how quickly access is allowed to the site. The last three elements are ongoing. In some systems, the sum of all these costs for the full life of a cell, 7–10 years, may be two to three times the cell installation capital. Thus cell-site life cycle costs are a critical factor to manage in a system.

Figure 5 depicts the PCS architecture used for pricing.

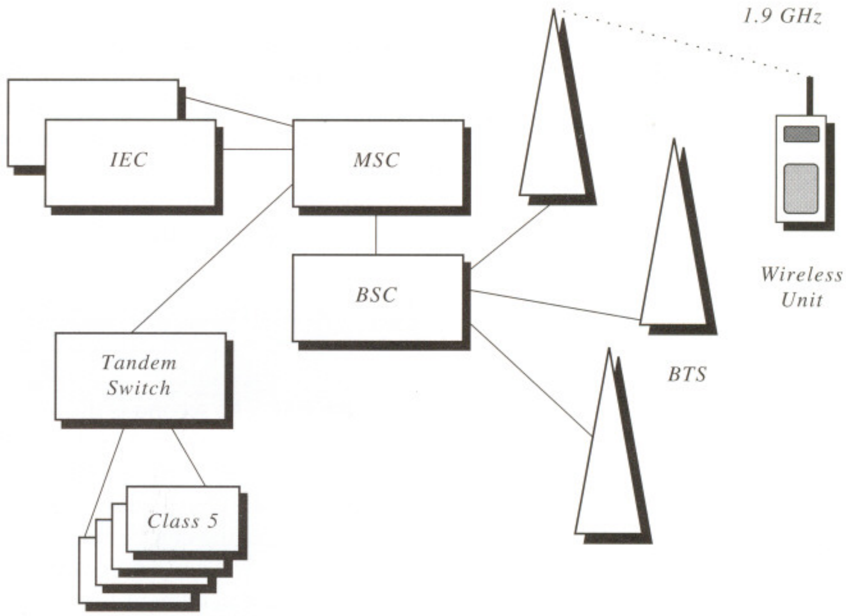

Figure 5. Architecture of PCS.

To effectively compare technological alternatives we must have models for the effective utilization of capital in the two cases. In this section we shall develop these models in summary form. We assume that the system is composed of the following three generic elements;

Base Terminal Stations (BTS): these devices are placed in the field and there are as many BTSs as are need for either coverage or capacity. The first demand is coverage. A BTS may cover 20–30 square miles, depending on the power, the modulation, the multiple access, and the capabilities of the wireless end user terminal. For example, in CDMA with PCS, a BTS has three sectors, and covers a 3-mile radius or about 33 square miles per BTS. If there are no customers, then for 1000 square miles, one needs approximately 30 BTSs. A BTS also serves one or more CDMA channels. In narrow Block CDMA (namely 1.25 MHz per channel), the CDMA channels must be added each time the system load goes beyond the capacity of one link. Namely, a CDMA channel at 1.25 MHz and with three sectors services 75 instantaneous channels or 'trunks', whereas an analog services seven.[15] If a user is busy only 100 minutes per month, then this is an activity ration of 1%, thus 75 trunks handle 7500 subscribers in this 30 square mile area. If there is a 10% penetration, then the population is 75 000 people, or PoPs, in 30 square miles, or about 2700 PoPs per square mile. This is a high population density. As the traffic increase, more CDMA channels must be added. Also in any system, trunk interfaces are added as the trunks are added, perforce of traffic growth.

Base Station Controllers (BSC): the BSC provides for the overall coordination and processing of the switched signals. It typically can handle a multiple set of BTSs and a multiple set of trunks. In the current CDMA narrowband system, a BSC handles up to 50 BTSs.

Switches (SW): the switch for Mobile Switching Center ('MSC'), interfaces with the LECs and the IECs. It is sized based on a fixed component and a component dependent upon the number of trunks. Newer systems use ATM switching, which has proven to be more efficient

[15]The calculation for analog goes as follows. Each analog signal occupies 30 KHz of Bandwidth. There are 42 such channels in 1250 KHz. Yet there is a reuse factor of 7 for analog. This means that for every cell, the surrounding 6 cells cannot use the same frequency amongst them, thus the 42 number must be divided by 6, yielding 7 channels. The CDMA system thus has a 10:1 ratio over analog.

Table 1. CDMA (1.25 MHz Channels, 10 MHz Spectrum).

Number of subscribers	**10 000**	**25 000**	**50 000**	**100 000**	**150 000**	**200 000**	**300 000**
Total area (square miles)	1000	1000	1000	1000	1000	1000	1000
No sectors/BTS	3	3	3	3	3	3	3
Total bandwidth (MHz)	5	5	5	5	5	5	5
Bandwidth/CDMA channel	1.25	1.25	1.25	1.25	1.25	1.25	1.25
No CDMA channels (Max/BTS)	4	4	4	4	4	4	4
Capacity/BTS (per CDMA Channel)	75	75	75	75	75	75	75
No BTS/BSC	50	50	50	50	50	50	50
Erlang load/customer	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Number of trunks	800	2000	4000	8000	12 000	16 000	24 000
Radius/cell cluster	3	3	3	3	3	3	3
No sectors	36	36	36	36	36	36	36
No BTS	13	13	14	27	41	54	81
No BSC	1	1	1	1	1	2	2
No CDMA channels	13	13	14	27	41	54	81
No trunks	800	2000	4000	8000	12 000	16 000	24 000
No CDMA channels/BTS	1	1	1	1	1	1	1
No trunks/BTS	61	153	285	296	292	296	296
No trunks/BSC	800	2000	4000	8000	12 000	8000	12 000
Maximum subscribers (000)	146 250	146 250	157 500	303 750	461 250	607 500	911 250
Fixed capital/BTS	$8	$8	$8	$8	$8	$8	$8
Capital/sector/BTS	$18	$18	$18	$18	$18	$18	$18
Capital/CDMA channel/BTS	$85	$85	$85	$85	$85	$85	$85
Capital/trunk/BTS	$3	$3	$3	$3	$3	$3	$3
Fixed capital/BSC	$700	$700	$700	$700	$700	$700	$700
Capital/BTS/BSC	$6	$6	$6	$6	$6	$6	$6
Capital/trunk/BSC	$1	$1	$1	$1	$1	$1	$1
BTS capital	$4290	$7878	$14 028	$27 945	$41 943	$55 890	$83 835
BSC capital	$1578	$2778	$4784	$8862	$12 946	$17 724	$25 886
Total capital	$5868	$10 656	$18 812	$36 807	$54 889	$73 614	$109 721
Capital/sub	$587	$426	$376	$368	$366	$368	$366
Efficiency	7%	17%	32%	33%	33%	33%	33%

for the packet-type voice signals integrated with data in a wireless environment.

The financial models for a narrowband CDMA system is presented in Table 1. It assumes that there are 1.25 MHz channels along with a total available spectrum as discussed above, and it assumes that the area covered is 1000 square miles. The results show Capital per subscriber as a function of the total subscriber base. It should be noted that there is significant scale in the lower end.

The following set of sizing are based upon vendor supplied financial numbers, but are retail and do not include any volume discounts or other factors. Note that the system capital for the 10-MHz system is about $366 per sub and reaches that at almost 50000 subs as we have specified. From that point on, Capital per sub is all marginal, namely it lacks scale.[16]

Note in the second case, where we have 30 MHz, we have reduced Capital per subscriber from $366 to $336. This is a $30 per subscriber penalty for only 10 MHz but may be more than set aside by the lower cost of the spectrum (Table 2).

CDMA has a larger single cell radius at 0.6 W than do any of the other systems. This is due to the lower E_b/N_o needed for the link. This will have a dramatic effect in achieving the targeted cost per customer number. We shall use the example of CDMA technology to demonstrate how this new technological infrastructure can enable the new market. We shall briefly describe the CDMA system and then proceed to the financial implications of using this new technology.

Operations support systems

The OSS elements are generally computers, workstations, memory units and other MIS type systems. Capital is composed of initial fixed capital

[16]It should be noted that in the C Band auctions the bidders bid an average of $50 per PoP. The F Band is less than one-tenth that number. However, from the above analysis, there is less than a 15% capital penalty for the use of 10 MHz CDMA. Thus the lower bid price must reflect the dilution of the market from the larger number.

Table 2. CDMA (1.25 MHz Channels, 30 MHz Spectrum).

Number of subscribers	10 000	25 000	50 000	100 000	150 000	200 000	300 000
Total area (square miles)	1000	1000	1000	1000	1000	1000	1000
No sectors/BTS	3	3	3	3	3	3	3
Total bandwidth (MHz)	15	15	15	15	15	15	15
Bandwidth/CDMA channel	1.25	1.25	1.25	1.25	1.25	1.25	1.25
No CDMA channels (Max/BTS)	12	12	12	12	12	12	12
Capacity/BTS (per CDMA Channel)	75	75	75	75	75	75	75
No BTS/BSC	50	50	50	50	50	50	50
Erlang load/customer	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Number of trunks	800	2000	4000	8000	12 000	16 000	24 000
Radius/cell cluster	3	3	3	3	3	3	3
No sectors	36	36	36	36	36	36	36
No BTS	13	13	13	13	14	18	27
No BSC	1	1	1	1	1	1	1
No CDMA channels	13	13	13	13	14	18	27
No trunks	800	2000	4000	8000	12 000	16 000	24 000
No CDMA channels/BTS	1	1	1	1	1	1	1
No trunks/BTS	61	153	307	615	857	888	888
No trunks/BSC	800	2000	4000	8000	12 000	16 000	24 000
Maximum subscribers (000)	438 750	438 750	438 750	438 750	472 500	607 500	911 250
Fixed capital/BTS	$8	$8	$8	$8	$8	$8	$8
Capital/sector/BTS	$18	$18	$18	$18	$18	$18	$18
Capital/CDMA channel/BTS	$85	$85	$85	$85	$85	$85	$85
Capital/trunk/BTS	$3	$3	$3	$3	$3	$3	$3
Fixed capital/BSC	$700	$700	$700	$700	$700	$700	$700
Capital/BTS/BSC	$6	$6	$6	$6	$6	$6	$6
Capital/trunk/BSC	$1	$1	$1	$1	$1	$1	$1
BTS capital	$4290	$7878	$13 884	$25 896	$38 052	$50 598	$75 897
BSC capital	$1578	$2778	$4778	$8778	$12 784	$16 808	$24 862
Total capital	$5868	$10 656	$18 662	$34 674	$50 836	$67 406	$100 759
Capital/sub	$587	$426	$373	$347	$339	$337	$336
Efficiency	2%	6%	11%	23%	32%	33%	33%

and then incremental growth capital. These have been sized and are part of the overall model. We will show their impact when we develop the design of the system.

The provision of OSS will entail several dimensions of service capabilities. These may or may not be from a single service provider, but must be able to be integrated into a single service provisioning element. The following are the sets of functions to be provided:

Network management

The local and national backbone network must be managed and controlled in a real time fashion. Operating entities, at all levels of operation, must have the capability of being monitored as to operational effectiveness, network performance, and impact on their interconnecting network elements. The Network Manager must be able to determine the locations of any and all outages or system degradation points in the network, or in any other network that a customer may have access to.

IEC interface management

IEC management must be performed to ensure the establishment and proper maintenance of any and all IEC interfaces and connections to the local PCS network. The overall management service will include such items as circuit ordering and scheduling, circuit interface negotiations, optimization of network design, and the physical management of the integration of the networks. It has been assumed that the IEC interfaces will be consistent with all other equal access provisions and that no IEC will receive any preferential treatment.

Customer service

The customer service function will provide customer service capabilities supporting such areas as billing, service quality, inquiries, service features, service upgrades, and complaints. Customer service is the most important part of the provision of service. The customer only needs customer service when the service is not totally transparent and thus when the service is not meeting the customers needs. Therefore, customer service is the most critical function that can be provided and must be provided with utmost care and effectiveness.

Billing

The billing function must be responsible for the full life-cycle factors associate with billing. This includes the capture of billing data, both local and IEC, the processing of the data, the preparation of the bill, the issuance of the bill, and the collection, reporting of and corrections to the bill. The billing function in essence consists of all functions necessary to collect the bill for services rendered, commencing from the time the service is requested, through the necessary intermediate steps and through all intermediaries.

Roaming implementation

The roaming functions are required to provide a national and seamless service. The roaming functions require the establishment of a national database and a national identifier system. All portables must have an identifier and self-registration facility to identify themselves as they enter a new system. This must then be integrated into the active roaming database and all calls must be routed accordingly.

Repair dispatching and maintenance

The repair dispatching and maintenance (RD&M) function is required when a fault is detected. The function prepares the trouble ticket and the dispatch ticket and the inventory dispatch ticket. It closes out all repairs and reports on the results.

Inventory management (MRO/MRP)

The inventory management function, also providing materials resource planning (MRP) and material resource ordering (MRO) functions, will be responsible for the ordering and inventorying of all system and network elements needed for growth, spares, and maintenance. The function must be fully integrated and electronically supported ensuring the minimum response time and cost for inventory carrying. As a goal, the Manager seeks to have a 'Just in Time' system that ensures the availability of the parts needed without the need for any stockpiling of equipment. This not only applies to the network elements but to the portables sent to the customers as well.

Operator services and directory assistance

The operator services and directory system intended to support access to all PCS customers. This system must allow any individual in any location to obtain ready access to any PCS subscriber. The objective is to ensure that all calls are equally inbound and outbound.

Operations expenses

The operations of a PCS system, or any telecommunications system, for that matter, has intrinsically several costs to be included. We divide these costs into the following categories:

Cost of goods: the costs associated with the provision of materials that may be held in inventory. We shall consider in this case that provision of the terminal, namely the portable, as a cost of goods. We have assumed a terminal cost of $200.

Cost of service: this will be the costs associated with the access fees. We have assumed zero access fees throughout. It should also be noted that we have assumed that we are not charging AT&T or the other IECs with an access fee. This will be $0.05 per minute. This will be used to compete against the LEC.

Cost of sales: this is the cost of all of the elements of acquiring and maintaining the customer. We have assumed that all costs are about $200 per new customer or 15% of the gross revenue.

Cost of operations: this includes the LSI Operations as well as the OSS and are estimated at about $8 per month per subscriber.

The following listing depicts the capital models for this type of PCS operations. PCS Capital Plant

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Switch Capital	$40 000	$100 000	$100 000	$100 000	$130 000	$245 000	$315 000	$375 000	$430 000	$515 000
BTS Capital	$27 803	$112 811	$175 981	$245 896	$456 200	$685 097	$817 893	$947 176	$1 067 454	$1 311 769
BSC Capital	$6273	$36 906	$48 514	$70 985	$152 819	$222 148	$263 401	$303 563	$340 928	$416 825
CPU Capital	$1000	$1000	$1000	$1000	$1000	$1000	$1000	$1000	$1000	$1000
Cell interconnect	$5370	$20 400	$28 620	$32 700	$36 810	$40 890	$40 890	$40 890	$40 890	$40 890
Switch interconnect	$1600	$4000	$4000	$4000	$5200	$9800	$12 600	$15 000	$17 200	$20 600
Total new capital	$82 046	$193 071	$82 997	$96 466	$327 448	$421 907	$246 849	$231 846	$214 843	$408 612
Accum. capital	$82 046	$275 117	$358 115	$454 581	$782 028	$1 203 935	$1 450 784	$1 682 630	$1 897 473	$2 306 084
Deprecation	$8205	$27 512	$35 811	$45 458	$78 203	$120 393	$145 078	$168 263	$189 747	$230 608
Accum. cap.–accum. dep.	$73 842	$239 401	$286 587	$337 595	$586 839	$888 352	$990 123	$1 053 706	$1 078 802	$1 256 805
Accum. dep.	$73 842	$313 243	$599 829	$937 424	$1 524 263	$2 412 616	$3 402 739	$4 456 445	$5 535 247	$6 792 052
Capital per sub. (Eff)	$2532.85	$1263,07	$668.54	$491.76	$427.84	$400.86	$373.38	$362.05	$353.14	$358.47
Depreciation per sub. (Eff)	$253.29	$126.31	$66.85	$49.18	$42.78	$40.09	$37.34	$36.20	$35.31	$35.85

Economic comparisons

This section presents several of the general economic factors that give the value per PoP to a PCS property and an LMDS property. The assumptions on both cases are similar:

(i) Revenue is based on a competitive pricing against existing services. The pricing is generally 20% lower than the existing service.
(ii) Penetration is based in discount and a 5-year penetration curve to the full discount potential. For example, at a 20% price discount, the 5-year penetration is 10% of the market, at 30% discount it is 15%, and at 50% discount it is a 25% penetration.
(iii) Operations costs are fixed and outsourced and are priced at $8.00 per month per subscriber. These are based on analyses performed by the author in other papers.
(iv) Sales costs is 15% of the gross revenue assuming the use off network marketing forces.
(v) Infrastructure capital is based on coverage requirements and penetration and the resulting capacity requirement. We assume an effective area per unit cell and we assume a fixed amount of allocated common capital.
(vi) End-user capital is assumed to be financed by the system operator at a 100% financing schedule.

The following reflects the results of these assumptions.

PCS valuations

The issues of PCS valuations is based on several factors:

(1) *Market penetration and size*: the greater the market penetration the greater the share. The greater the share the more effect the competitor can then be. Share is dependent upon brand recognition. Thus a large entrant with a brand will tend to have a better share.
(2) *Capital efficiency*: the efficiency of capital use in the local plant by the bidder. This is technology dependent and size of purchase dependent.
(3) *Operating efficiency*: the ability to provide a national infrastructure of such services as network management, billing, roaming and customer service will allow for a lower set of operating costs per customer, and possibly even operating costs on a marginal rather than average basis. This will dramatically change cash flow.
(4) *Cost to acquire customers*: the issue of brand reflects not only the revenue element but also the costs element of acquiring a new customer.
(5) *Access fees*: access fees will make or break this business.
(6) *Cost of capital*: the cost of capital will dramatically effect the price of a bid. This is dramatically different for a PCS provider and an RBOC.

The analysis has developed a detailed model for each BTA from which the NPV per PoP can be determined. The anticipated bid value is typically set at 50% of the NPV per PoP. Higher values can be placed, but a reservation price of 85% of the NPV will be set.

Table 3 depicts the value per PoP depending on total market size and terminal penetration in year ten. It should be recalled that bidding is at 50% of NPV. Figure 6 depicts this value per PoP in terms of the same factors.

Table 3. Typical values for BTAs that were bid upon their total PoPs and bid values, 5.2 LMDS Economics. The Boston kernel and cluster.

City	State	Pop.	NPV	NPV/P op	Bid/Pop	Bid
Hartford	CT	1 123 678	$32 405 632	$28.84	$14.42	$16 202 816
New Haven–Waterbury–Meriden	CT	978 311	$27 018 810	$27.62	$13.81	$13 509 405
New London–Norwich	CT	357 482	$8 008 615	$22.40	$11.20	$4 004 308
Boston	MA	4 133 895	$223 745 901	$54.12	$27.06	$111 872 951
Hyannis	MA	204 256	$4 313 019	$21.12	$10.56	$2 156 509
Pittsfield	MA	139 352	$2 866 548	$20.57	$10.29	$1 433 274
Spingfield–Holyoke	MA	672 970	$16 859 882	$25.05	$12.53	$8 429 941
Worchester–Fitchburg–Leominster	MA	709 705	$17 999 199	$25.36	$12.68	$8 999 599
Bangor	ME	316 838	$6 989 902	$22.06	$11.03	$3 494 951
Lewiston–Auburn	ME	221 697	$4 713 778	$21.26	$10.63	$2 356 889
Portland–Brunswick	ME	471 614	$11 017 638	$23.36	$11.68	$5 508 819
Presque Isle	ME	86 936	$1 750 044	$20.13	$10.07	$875 022
Waterville–Augusta	ME	165 671	$3 444 571	$20.79	$10.40	$1 722 286
Keene	NH	111 709	$2 271 977	$20.34	$10.17	$1 135 989
Lebanon–Claremont	NH	167 576	$3 486 861	$20.81	$10.40	$1 743 430
Manchester–Nashua–Concord	NH	540 704	$12 945 488	$23.94	$11.97	$6 472 744
Providence, RI–New Bedford–Fall River, MA	RI-MA	1 509 789	$48 437 394	$32.08	$16.04	$24 218 697
Burlington	VT	369 128	$8 305 629	$22.50	$11.25	$4 152 815
Rutland–Bennington	VT	97 987	$1 981 600	$20.22	$10.11	$990 800
TOTAL		12 379 298	$438 562 490			$219 281 245

The economics of LMDS follow a similar path as does that of PCS. The differences, however, are several:

(i) Revenue is a combined revenue based on video, voice and data.
(ii) Coverage can be more focused than can PCS since it does not involve mobility.
(iii) Operations costs are the same per subscriber and thus they may be a smaller percent of the gross revenue.
(iv) The capital per subscriber may be higher but the fixed amount may be smaller due to the smaller coverage.
(v) Penetration is on a household basis not a PoP basis. Thus we typically must focus on the household density.

This then leads to a summary model for LMDS that simplistically shows what its value is.

Specifically we assume:

(i) The revenue is a combination of voice, video and data. The assumption is that a user has $40 per month of voice, $30 of video and some added mix, say $10 of data. This is a revenue of $80 per household per month. We further assume 2.5 people or PoPs per HH, Household. These revenue assumptions are purely hypothetical and reflect no specific marketing strategy.
(ii) The fixed operations expenses for the normal operations can be outsourced at the rate of $8.00 per month per subscriber. These numbers are readily achievable from an outsourced system of services.
(iii) The capital for infrastructure is assumed to be $1 million for a 2-mile radius of coverage. This is an effective of 10 square miles and thus is $100 000 per square mile. This number reflects an assumption based upon projections from PCS and assumptions from the unbanding to 28 GHz.
(iv) The capital per household may be comparable to direct broadcast satellite systems and thus are about $1000 per HH. Again, the hardware is similar but the difference is the 28-GHz front end. There is a major difference, however, and that is that this system is two-way from the home. In the following analysis we vary this number significantly.

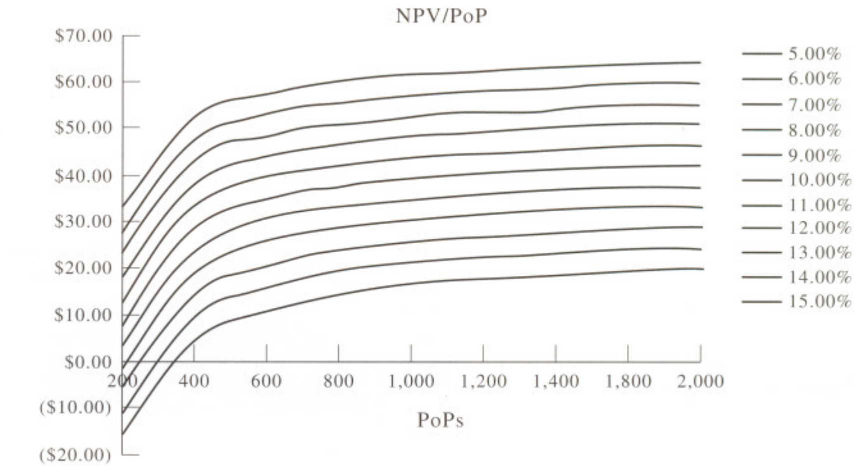

Figure 6. NPV ($0.00)/PoP vs number of PoPs (000) for PCS.

Based upon these assumptions and using a linear model for a rollout with the final percent being the 10th year of operations, the following two figures depict the net present value per PoP of LMDS as a function of the average capital per subscriber and as a function of the terminal HH penetration (Figure 7).

Figure 8 presents the NPV/PoP as a function of the average capital per subscriber.

Those numbers are generally comparable to the PCS numbers. The bidding for these properties, again being based on BTAs are expected late in 1996 or sometime in 1997.

Interconnection

The interconnection issue is a major factor in the deployment of any wireless systems. The new Act provides a significantly changed platform upon which the new entrants may operate. This section provides an analysis of the interconnect problem from the CMRSs facilities to the I-LEC, the incumbent Local Exchange Carrier and from a C-LEC to the I-LEC. As has been discussed in previous papers, the interconnect issue for a wireless carrier falls into two categories; intraplant and interplant.[17] 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

[17]See the papers by McGarty in Interconnect and access; McGarty, TP, 'Internet architectural and policy implications, Kennedy School of Government', Harvard University, Public Access. These discuss the detailed economics and the costs models. Also see the paper by McGarty *ibid.* Ref. 18, Federal Communications Law Journal. This latter paper presents a detailed antitrust analysis of the interconnection issue.

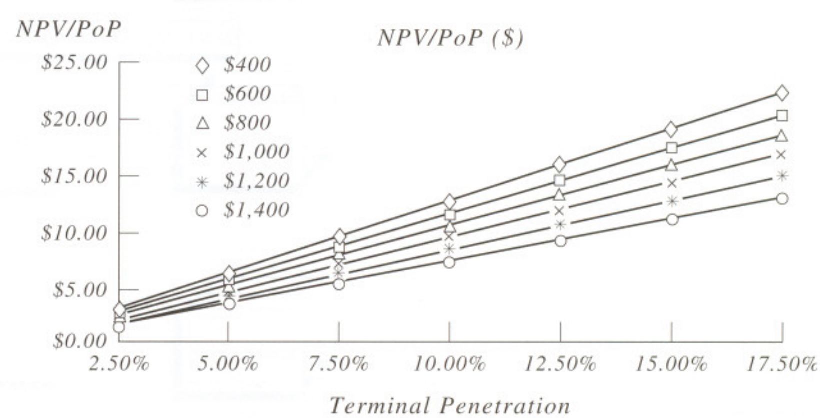

Figure 7. NVP/PoP ($).

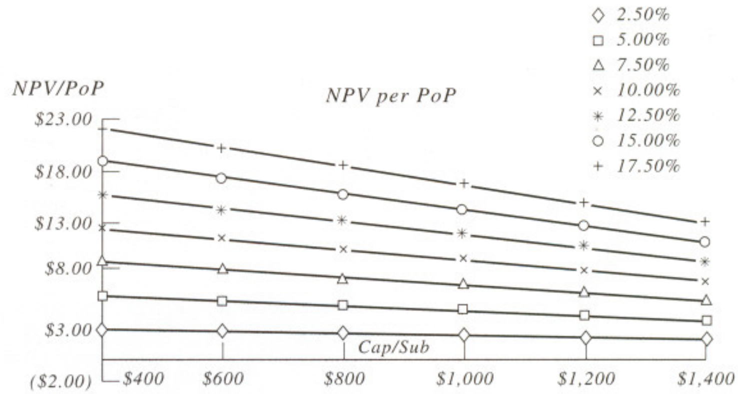

Figure 8. NVP per PoP.

facilities. The intra was discussed in Telmarc Report TR-96-008. The overview of these issues is shown below.

Figure 9 depicts three issues: first is that the intraplant 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 goal of this section 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.

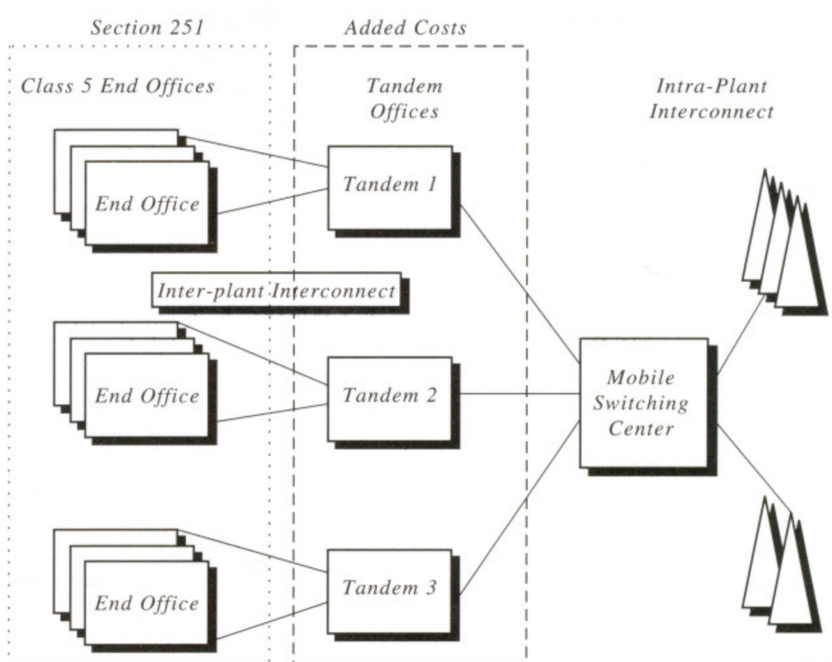

Figure 9.

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.

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.

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 USC 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 are 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 USC Sec. 332 and from the Code, Sec. 153(n). Specifically, Commercial Mobile Radio Service means any mobile service (as defined in Sec. 47 USC 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 USC 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

Table 4. Carrier comparisons.

Characteristic	I-LEC	C-LEC	CMRS
Coverage	IntraState	IntraState	MTA
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

> two-way radio communication services, (2) a mobile service that 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 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:[18]

> 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 resellers are CMRS and thus also must be concerned with this issue.

Rates for interconnection

The rates for interconnection have been established in the FCC First R&O. However this has been set aside by the Eighth Federal District Court until it is reviewed. However, many of 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.

Table 4 compares the LEC status with that of a CMRS. This report focuses on the CMRS advantages

[18]See FCC GN Docket No. 93-252, 3 February, 1994, FCC 94-31; #p. 37.

Table 5. CFR Pricing schedule.

Connection	Rate	Reference
Symmetrical reciprocal	Yes	CFR §51.711
Termination of local traffic	No less than $0.002 per min and no more than $0.004 per min	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 min of use	CFR §51.715(b)(3)

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 importance 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 significant advantage over any LEC. The default tariffs applied by the FCC in the new CFR are shown in Tables 5 and 6.

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.

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, at

Table 6. New England Telephone and WinStar agreement.

Connection/service	Fixed	Variable
Termination of local traffic		$0.0080 per min
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 min	[(Carrier OPM+ILEC OPM)* Peak Rate]+[(Carrier OOPM+ILEC(PM)*OffPeak Rate]/ [Total Carrier Min+Total ILEC Min]	
Peak rate=$0.009 per min Offpeak rate=$0.0065 per min		
OPM=originated peak min OOPM originated offpeak min		

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/square mile. This is especially true in rural areas. Possibly point-to-point may work but even this is debatable.

The major concern is the general assumption that bandwidth is a scarce resource. This is true if it can not be 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 many academic policy analysts have tried to raise is that a wireless provider, in return for the right given them by the government, has a corresponding right to 'play fair' with the monopolists and be required to provide universal wireless service. This bizarre 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 many cases usurped their properties at the turn of the 19th 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 commodotized with wireless, then as we have seen in long distance communication, the market is very efficient without any governmental structures such as compulsory universal service.