Wireless Access to the Local Loop[1]

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Abstract

The Local Exchange Carriers have been a single and monopolistic force in the provision of local telephone service for over one hundred years. This was justified both on a political and economic side due to the inherent scale and scope economies in the provision of the service. The control of the monopoly was through regulation rather than market forces. Technology has changed dramatically in the past five years. Specifically, there are today technological alternatives that provide for local exchange capabilities with de minimis scale and scope. Thus the monopoly argument disappears. Wireless is a paradigm change that will revolutionize communications providing that regulation and government policy allow it to occur. The RBOCs and other LECs are in bottleneck control positions to allow this to move forward or to be stalled. This paper presents the technologies that enable this and at the same time discusses the key microeconomic factors that are changing in this environment. Finally, key policy implications are presented.

1.0 Access; What is it and How is it Changing?

Wireless communications services introduce new sets of technologies that will create a new local loop access paradigm. The current view of the local loop is that of a bundled set of services that possess significant economies of scale and thus justify permitting the Local Exchange Carriers (LECs) to have a total monopoly in the local exchange. The new technologies allow dramatically lower capital costs per subscriber and also eliminate the scale and scope economies in local access. The only remaining stumbling block is the cost of switch access, called the access fee. This access fee currently represents an expense equal to fifty percent of the gross revenues of AT&T, MCI and the other IECs. Access fees account for one third of the gross revenues of the LECs. These fees are the last remaining barrier to entry in providing fully competitive communications services.

This paper presents the issues concerning local network access from both a technology and policy perspective. The technology shift is discussed showing how the current copper wire based network having high capital per subscriber values is being replaced by a wireless network having capital per subscriber numbers almost two orders of magnitude smaller. [2] The basic microeconomic implication is that there is a loss of economies of scale and scope that were at the heart of the old "Bell System." The technology shift demands a policy shift on the part of regulators and government officials.

The differing policy options are discussed and their implications on the telecommunications industry evolution are presented. The concept of disaggregation of the LECs into wholesale switch and transport companies is presented in the context of the current policy discussions on PCS at the FCC. The impact on new markets and services as a result of eliminating the local bottleneck is discussed . Key policy issues relating to providing a seamless interoperable national wireless network are presented. PCS, via a dramatic technology change, will create new business opportunities and will also challenge the policy makers and regulators to move quickly but carefully in developing and implementing these new directions for telecommunications evolution.

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[1] Presented at MIT Symposium on Universal Personal Communications, March 30-31, 1993.

[2] de Sola Pool, 1977 and 1990. The 1977 text gives a detailed description of the history and structure of the telephone market.

Access is the provision of services from a Local Exchange Carrier, LEC, to another carrier for the purpose of allowing the other carrier to interconnect with the LEC's customers. In a simple sense, if I place a call from my home to my daughter's home, then there are three fees that can be ascribed to that call. Specifically:

(i) I pay my local carrier, in this case New Jersey Bell, an imputed access fee per call. I do this by paying a $25 per month charge for my local service, and use the phone about 500 minutes per month. Thus I have an imputed access fee of $0.05 per minute.

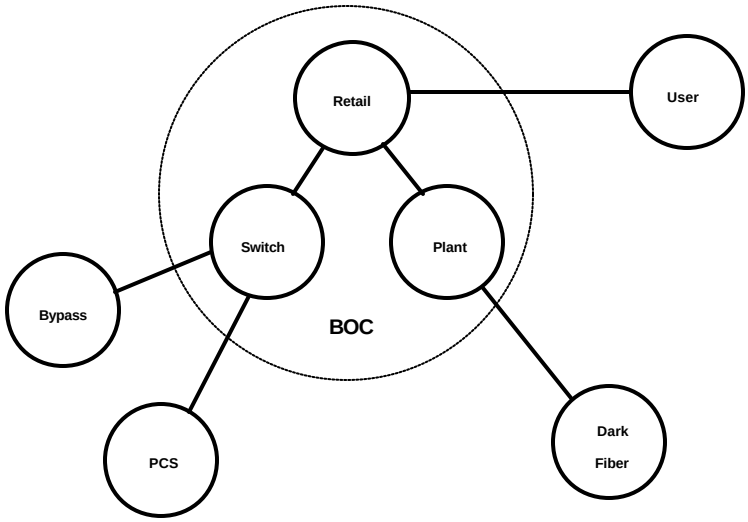
(ii) I pay AT&T a fee of $0.10 per minute for the call from New Jersey to West Virginia. This means that on my monthly phone bill there is an imputed fee of $0.05 from New Jersey Bell and a direct charge of $0.10 from AT&T.

(iii) However, AT&T pays C&P Telephone, part of Bell Atlantic also, an access fee of $0.05 per minute for terminating on their facilities in Morgantown and connecting "their" call into my daughter's home. Thus, AT&T charges $0.10 per minute but has a cost of goods of $0.05 per minute to the terminating LEC. This charge is made even though my daughter, like me was already charged the $0.05 per minute in her monthly bill for the privilege of attaching to C&P.

The name of the game in access is that the LECs have the right to charge anyone, anytime for connecting to their network. Point of fact, the relationship is not reciprocal.

The basis for the access charge is twofold. First, it is the collections of services that the LEC provides and second, it is based upon a rate of return pricing theory. Let us consider the first element. Figure 1 depicts the LEC as divided into three entities.[3]

Figure 1 LEC Disaggregation



They are:

(i) Switch Entity: This entity, frequently called the inside plant, provides the following services:

[3] Freeman or Stallings for a detailed discussion of the technical elements of the switching and transport functions of the telephone network.

o Switch Access: This is the physical access to the switch through the main distribution frame, MDF.

o Concentration: This is the collecting of twisted pairs, and the electronic identifying of the twisted pair with an available port on the switch itself. It connects active copper to active silicon.

o Interconnection: This is the physical switch. A switch is an NxN connection path that takes N active lines and connects them to N active paths. The switch may be blocking or non-blocking.

o Transaction Management: Fundamentally this is the billing function. It senses what the caller requested and records the caller, the called number, the duration and any other service specific requests.

o Network Management: This is the overall management functions associated with maintaining and operating the switch entity.[4]

o IEC Access: This is the provision to the caller of IEC access, or equal access functionality.

(ii) Transport Entity: This is the outside plant entity and it install, operates and maintains the totality of outside plant, be it copper or fiber. The outside plant is inter-office trunk, plant trunk to local feeder plant. For the most part, the trunks in the local plant are fiber and the last 1,000 feet still is copper. The functions provided in this entity are as follows:

o Local Loop Plant: The provision of the physical interconnect plant outside the C.O., Central Office.

o Inter facility Transport: The interconnecting of C.O. s and other PoPs, Points of Presence, for IECs.

o Loop Management: The O&M on the loops.

o Loop Concentration: The multiplexing of traffic to be handed off to the IECs. The concentration puts the signal in a DS format, namely DS-1 or DS-3, with a SS-7, signaling system 7 out of band signaling and control link, and in a consistent physical format such as SONET.[5]

(iii) Retail: The retail function of the LEC are all of those functions related to acquiring customers and supporting them and in providing enhanced type services such as call waiting, call forwarding, voice mail and other such services. The functions performed in this entity are as follows:

o Advertising: The normal function of market promotion.

o Sales: Typically this is order taking.

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[4]See McGarty and Ball for a detailed discussion of Network Management. In that paper, the authors introduce the concepts of distributed network management. This concept shows how distributed processing and not central control facilitates network management and control.

[5] Stallings. The author describes SS-7 and DS-3 formats in detail. They are at the heart of current telecommunications systems.

o Customer Service: This primarily requests for service, calls on billing errors, service complaints and other such customer interactions. Included in this is directory assistance.

o Billing: The preparation and management of the overall billing process.

o Enhanced Services: This is the development, management, operations and support of any enhanced services such as voice mail and others.

o Research and Development: This is a significant factor. Bellcore, for example, has almost a $1.5 billion budget annually, or almost $200 million per RBOC, or in a typical RBOC of 10 million access lines, $20 per year per customer. That represents almost 10% of the customer bill. It is amazing that a set of companies that are prohibited by law to manufacture can spend so much on hardware related items. In addition, such RBOCs as NYNEX, US West and others have their own R&D facilities that raise that number even higher. As AT&T has begun to become competitive and move their R&D closer to value creation for the customer and the shareholder, the RBOCs and Bellcore seem to be moving in an opposite direction.[6]

o Corporate Management: This is the general management and overhead of the LEC. For example, NYNEX has almost 13 million access lines and 26,000 management employees. This is 500 customers per employee.

All of these expenses and their associated capital are put into the rate base and are charged against the access fee. The fees are further determined on the basis of the rate of return formula. This is based upon the assumption that the LEC is a natural monopoly and as such has significant scale economies. Thus it is in the public good to have a monopoly and such an entity must be managed via a regulatory process rather than a free market process.

The rate of return concept is based upon that theory that the LEC, as a monopoly in a business with significant economies of scale, has already achieved maximum efficiencies based upon expenses and capital resources used to achieve that scale.[7] Thus, the profit to the utility should be based upon invested capital and should be a a rate that is competitive with returns in comparable industries. Specifically, the Revenue generated by a monopoly is not a competitive based revenue, it is a regulated revenue. Price is not held fixed in the market by supply and demand forces. Price is controlled by the PUCs or Public Utility Commissions, based solely the expenses and capital deployed. Specifically, for a LEC, under rate of return regulation, the Revenue is:

[6]See the paper by Cox. This is a detailed example of the Bellcore efforts in wireless. The paper is clearly presents a Bellcore architectural solution that further enhances the LECs position in terms of maintaining control over access. The paper vehemently attacks other solutions such as CDMA. This is an blatant attempt to delimit the ability to achieve parity in access.

[7]See the works by Fisher and those by Spulber. They describe the evolution of rate based pricing. The classic volume by Kahn is the detailed text that was used for the initial deregulation efforts during the Carter Administration.

Revenue = Expenses + Taxes + Depreciation
+ RoR(Total Assets-Accumulated Depreciation)[8]

So that Profit is:

Profit = RoR (Total Assets-Accumulated Depreciation)

Note that for a regulated utility we do not have the normal rule of:

Profit = Revenue - Expenses

This latter rule only applies in a competitive market. This fact will be a critical fact when determining the competitive environment in the PCS market. If we look at the Revenue line for the utility then we can se that prices are based upon all expenses and capital. The expenses are as we have discussed them above. The LEC combines all of these expenses into a bundle, charges them on a gross allocation to the customer. If that customer is a PCS company seeking just access to the switch, then all of these expenses are charged. The incentive for the LEC to increase profit is also based upon the need for more capital. Recall that Profit in an LEC is based upon asset base, not on how efficient the company is. Thus, in an LEC the grater the asset base the greater the profit. The incentive then is to maximize plant, and sustain the scale economies via the *architecture* of the system.[9]

This rate of return regulation, combined with the old paradigm of system design in the LEC architecture drives that access fees up. Thus it is not uncommon for a cellular carrier to pay $0.11 per minute in New York, or $0.08 per minute in Boston. In some areas of Maine, the rates are $0.28 per minute, where the local phone service is only $0.05 per minute. These are controlled by the PUCs. They follow old paradigm and hold for a fully aggregated cost base.

2.0 Current Access Issues

There are several key items that determine the current view on access and are at the same time at the heart of changing the view of access. Before analyzing these issue, we first review the basis of why the monopoly is set to have such access fee structure. The historical argument for the LEC monopoly is based upon the assumption that there are significant economies of scale and scope in the telephone business. In terms of scale it means that the cost to provide the service is significantly smaller the greater the number of customers. The argument of scope is that the cost of service is less if one entity does the switching, the transport and the retail functions. The latter argument for scope is based upon the assumption that there are synergies between switching and transport and that there are similar synergies between those two and sales, customer service, billing and R&D.

To quote Kahn:

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[8] Brenner, p. 12. The author describes the RoR and Rate based pricing scheme. Also see Spulber, pp. 274-277, for a detailed discussion on how this will also be the basis of a barrier to entry.

[9] McGarty, Architectures, where the author develops the theory of Architectures as a means to embody world views in the context of existing technology. In the nineteenth century the human was viewed as a machine, in the twentieth the human was viewed as a computer and in the twenty-first the human may be viewed as a strand of DNA. This world view, shaped by technology, controls our way of viewing the future. It is viewed through the most recent paradigm, or example, of how things work. For the LECs, that paradigm is still Alexander Graham Bell and voice telephony, managed in a centralized fashion by Theodore Vail, in a nineteenth century hierarchical system. The current world view is driven by technology that is highly distributed, technology that is driven by software, with silicon being almost free, and having an end user that is totally empowered. This is not the view of the LEC.

> *" That the provision of local telephone service is a natural monopoly is generally conceded. The Bell System makes a powerful argument that the same is true of the entire national telecommunications network. The argument, as all others for natural monopoly, can be embraced under the familiar rubric of decreasing costs over the entire range of production. But it has so many facets in addition to the familiar one of progressive economies of scale in the production of a standardized service that it is worth examining in detail: ...*
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> *1. Simple economies of scale in the provision of standardized service...*
> *2. Aggregate investment costs ca be minimized... if the planning... is done for the entire system.*
> *3. The higher standards of service demanded requires centralized responsibility and control.*
> *4. If the network is to be truly national... No company is likely to assume such responsibility unless it is given a monopoly.."*

These words were written in 1971. A total of twenty two years have passed and there is now dramatic competition in the IEC market, despite Kahn's predictions and argument for a monopoly. AT&T has only 62% of the market but is healthier now than ever.

The monopoly argument is also an argument that establis hes a bottleneck or a barrier to entry. Consider how this may be the case.

(i) Assume that the LEC maintains monopoly power and that they can continue to exclusively charge access fees. Namely, let us assume that the LEC charges $0.10 per minute access.

(ii) Let us assume that the LEC charges the access fee on a fully aggregated basis. Namely, that the LEC takes all of their rate base expenses and capital, and takes total minutes of usage, and increase that for an extra handling fee. For example, let us assume that the LEC sells its totally bundled service for $0.05 per minute. It then charges the alternative carrier $0.08 per minute. The additional fee is for "handling".

(iii) Let us assume that the alternative carrier has customer that use the service 500 minutes per month, the same time that the LEC's customers do. The LEC's customers are charged $25 per month but the alternative carrier has a cost of goods, namely the access fee, of $40.

(iv) In addition, the alternative carrier must provide the transport and retail service in toto, as well as providing most of the switch services.

Thus, from the above example, the alternative carrier can never compete on costs, since the alternative carrier' s cost of goods are always above the total cost of the LEC service. This is a barrier to entry. We can further view this if we can disaggregate the LEC. Consider Figure 1 again. If the LEC were to sell all of its disaggregated services on a marginally priced, however, this may no longer be the case. Let us look at the LEC from a disaggregated basis. The LEC sells its service at the rate of $0.05 per minute. It, internally, "buys", on a transfer price basis, switch and transport service. It buys switch service at $0.01 per minute and transport at the rate of $0.025 per minute. It make a 10% profit, or $0.005 per minute. The retails costs are $0.02 per minute. Thus, if the LEC were to sell aggregated switch access, it would be at $0.01 per minute plus profit and handling costs. That value, in effect, is what the LEC is internally charging itself. Thus, if we can further disaggregate the switch costs, we can drive the access fee even lower.

There is one further point on access that needs attention. Namely, if the LEC transfer price for switching is $0.01, what is the marginal cost? We should remember that AT&T, MCI and Sprint, as well as the cellular companies are paying extraordinary high access fees. If that is the case, then one questions whether the marginal cost of switch access may be greater than $0.01. If that is the case, then the LEC may actually be

selling itself access at a price below its marginal cost. That is called predatory pricing and is a violation of the Robinson Patman Act. [10] The result of this brief analysis is that there are many key issue relating to access that need detailed consideration. Wireless local loop access will provide the first significant competitor to the LEC. This competition must be done in concert will all antitrust laws as well as in the public interest.

There are several ways in which the regulatory bodies, both nationally and on the state level, may address the access issue. These possible means are:

(i) CoCarrier Status: This implies that if there are two common carriers or more, then each is a carrier and has a right to charge comparable access fees. For example, if the LEC charges $0.10 per minute for all calls terminated to its customers, the corresponding PCS Common Carrier should charge the LEC the same or a comparable amount for all calls initiated by the LEC customer and terminated on the PCS CC. This option for access arrangement is a balanced option and is economically the most efficient.

(ii) Disaggregation of the LEC with Equitable Marginally Priced access fees: This approach to access management requires that the LEC generate a set of disaggregated services and that in addition it develop a tariffing or pricing schedule for these services. This is a difficult task and has not met with significant success. It may have to be approached ultimately but it is argued herein that this is best done under normal market forces. Co-carrier status will force this disaggregation.

(iii) Bypass through an IEC Class 4 Access Point: The technology discussed in this paper provides a capability to obtain access via a Class 4 Switch. This means that there is no need for LEC access but that access can be attained via an IEC. This has the advantage of reducing access to IEC rates but does not address the final goal of balanced access fees.

(iv) Alternative Class 5 Bypass Functionality: The alternative Class 5 access is the least desirable. As will be shown latter in this paper, this drives up the entry costs and is effectively a barrier to entry.

The FCC in its recent OPP Report concomitant with its NPRM filing that raises issues of scale and scope economies in the PCSbusiness.[11] The conclusions reached are in serious question. Specifically, the Report demonstrates that economies of scale are de minimis but that economies of scope are significant.

The operations of a communications system involve the use of capital resources, namely those items depreciated, and expense resources, namely those expensed as used. A system has scope, if for any set of these resources, and if the resources are used inother operating entities, and that by having them bundled together, there result in lower total per unit costs,depreciation plus expenses. Namely, if an entity has existing switching or interconnect, then that entity may provide additional switching or interconnect at a unit cost lower than an entity that must create such elements. The assumption used by the Commission in its report was that in these two specific areas there was limited creativity on the part of the new network player. Specifically, in switching, for example, the new player, through the use of new technology may easily eliminate the need for a MTSO or even a Class 5 Central Office. Thus the new player may have a unit cost, even at low usage rates, lower than that of the existing entity. Similarly, the interconnect unit costs have been argued to be lower for Cable or Telco entities. It is argued that this is not only the wrong conclusion but leads to dramatically divergent policy implications.

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[10] Hovenkamp, pp. 95-124. Specifically, see the discussion on the Areeda Turner Test for predatory pricing. The Test uses the average variable cost rather than the marginal cost due to its difficuly to measure.

[11] Reed, FCC OPP Report 28.

The existing CATV entities have argued that they have an infrastructure that is highly suitable to use for PCS. It has been previously demonstrated use of this technology but has also clearly demonstrated its severe drawbacks. In a CATV environment there are several reasons for lack of CATV infrastructure:[12]

(1) Interconnect: In a reasonable radius from any large metropolitan area there are one to several dozen CATV entities. The issue of interface and interconnect has never been adequately addressed and there are no standards that allow for this. In addition, CATV switch access uses the same dated architecture as does cellular and thus is highly reliant upon the existing LEC. This will merely drive up the costs of goods for the carrier.

(2) Availability: CATV systems have system availability numbers that are less than 90%, whereas communications networks have availability numbers in excess of 99.5%.The inherent structure, operations and management of the two networks are currently incompatible. Specifically CATV, as currently operated cannot provide toll grade quality service.

(3) Bandwidth: Bandwidth in a CATV system is limited, except on Institutional loops. Local bandwidth is structured for video and the two way systems have limited return path.

(4) Performance: Data transmission performance on coaxial or fiber/co-ax has been shown to have significant problems due to an excessively noisy environment resulting from many open cable access terminations in homes of current or prior subscribers. Admittedly this may be ameliorated but it will require significant rebuilds as well as management and administration of the subscriber loop.

(5) Inactivated Two Way Returns: Two way cable almost ceased to exist as an operating entity with the demise of the famous QUBE system. [13] Currently there are less than 0.1% of the CATV systems with active and operational cable return paths and supported bi-directional amplifiers. For the CATV system to function this must be addressed.

Having addressed the above five issues with CATV, the we argue that CATV is theoretically an alternative but it requires massive rebuild and restructuring. Once that is accomplished, the we argue that the incremental and allocated unit costs will be greater than those of alternative technologies presented elsewhere.

As to the LEC ability to use its existing plant, the argument has two elements. First, prima facie, the LEC plant capital is currently in excess of $1,500 per subscriber, most of that in outside plant. Thus, based upon the prior showing, and most recent Ex Parte filing with the Commission, the current state of the art PCS technology provides the service at less than $100 capital per subscriber. [14] Thus, the first observation is that new PCS technology, such as CDMA with intelligent Class 4 connectable cell controllers, has leap-frogged that of the Telco base. The second observation is made indirectly by looking at the Bellcore

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[12] McGarty, T.P., R. Veith, Hybrid Cable and Telephone Networks, IEEE CompCon, 1983. and, McGarty, T.P., S.J. McGarty, Impacts of Consumer Demands on CATV Local Loop Communications, IEEE ICC, 1983.

[13] McGarty,T.P., G.J. Clancy, Cable Based Metro Area Networks, IEEE Jour on Sel Areas in Comm, Vol 1, No 5, pp 816-831, Nov 1983. and McGarty, T.P., Local Area Wideband Data Communications Networks, EASCON, 1982.

[14] Telmarc Telecommunications, Inc. (TTI) Ex Parte filing of December 21, 1992, based on presentations made to the OPP on success criteria for PCS. Specifically TTI showed that $100 capital per subscriber was achievable and that further disaggregated telco access was essential.

technology proposal.[15] In the current Bellcore model, the TDMA proposal is for many small micro cells still highly dependent upon the LEC network. The Bellcore approach "allows" the PCS carrier to move outside of the house but still the new PCS carrier and the consumer of the service must be burdened with an antiquated technological base. The Bellcore approach attacks the credibility of the new technology, specifically CDMA, since this new technology obviates the need for local loops as well as local switch concentration and thus threatens the monopolistic bottleneck of the LEC.

We argue that the Commission's assumptions on LEC scope should be viewed rather as potential or possible barriers to entry to new competitors. The LEC infrastructure is, at even marginal rates, more costly than the new technology, and the LEC proposed architecture imposes the unnecessary burden ofaccess fees for the existing network on the new PCS providers.

We further argue that the Commission must recognize that existing providers of transport have neither the most effective Architectures nor the existing capacity to cost effectively provide any service element in the best public interest.

SCOPE IN CAPITAL PLANT

The Capital required for a PCN operation consists of the following elements; Cells, Interconnect, Switching, and Management. The use of alternative capital elements provided by third parties on a fair and equitable basis results in loss of economies of scope in the capital base.

The capital elements combine to result in a depreciation of the form:

$$\mathbf{D(C,I,S,M) = D(C) + D(I) + D(S) + D(M)}$$

where the terms represent the respective four elements. Consider the issue of switching. The argument made by the Commission is that if the PCN entity has an existing switching infrastructure then SP and ST are the switching requirements for PCN service andT for normal telephone service. It is further argued that if the-same entity has both services that scope exists, namely;

$$\mathbf{D(S) = D(S_P)^* < D(S_P)}$$

where:

$$\mathbf{D(S_{Telco}) = D(S_P)^* + D(S_T)^* < D(S_P) + D(S_T)}$$

where $D(S_k)$ is the depreciation if the service is supplied separately and $D(S_k)^*$ the allocated depreciation if the service is supplied together. It is argued that it is less expensive to sell switching when there is a use of it in another context.

It has been argued elsewhere that if the cell sites use aco-located adjunct processor and if the LECs are required to sell switch access at equitable marginally based rates consis tent with a disaggregated LEC operation, then a PCN entity can buy switch access at an expense, E(S), that is;

$$\mathbf{E(S) = D(S_P)^*}$$

and scope does not exist.

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15 Cox, Wireless Network Access for Personal Communications, IEEE Communications Magazine, December, 1992, pp. 96-115.

This argument requires that the Commission understand that switching is not a necessary element in PCS and that switching may be obtained from the PCS company itself, the LEC on a disaggregated basis, or from any other third party switch service vendor, be they Class 5 or Class 4 access capabilities. Specifically one can note that intelligent PCS cells that hand off voice channels in a DS3 format with accompanying SS-7 formats allow direct Class 4, Toll-Tandem, access. This is a dramatic paradigm shift from past network Architectures that were constrained by dramatic investments in outside plant of twisted copper pairs.[16]

The second element of capital is that of interconnect. We argue the fact that using CDMA it is possible to connect the cell controller and the micro cells or rerads via 40GHz microwave interconnect, doing so with digitized microwave at higher data rates, allowing for full dynamic range and lower interconnect costs. Point of fact, without a MTSO, it is possible to achieve a capital per subscriber at 50,000 subscriber penetration of less than $100. [17] This is in sharp contrast to the cellular number of $750 and the LEC number of $1,500.

Therefore with regard to interconnect, neither the CATV entities nor the LECs have any economy of scope if one considers fully digital microwave back haul. In fact, it can be shown, that if $D(I_{CATV})^*$ and $D(I_{Telco})^*$ are the respective annual depreciation of CATV and Telco interconnect per user, then$D(I_{MW})$, the microwave fully allocated depreciation per user for interconnect is:

$$\mathbf{D(I_{MW}) < D(I_{CATV})^* \text{ or } D(I_{Telco})^*}$$

as has been shown by the Commentor and in comparison to the Commissions report.[18]

SCOPE IN EXPENSES

A similar set of arguments can be used to demonstrate that scope does not exist in expense also. Specifically we will develop the general argument and shall use as reference documents already submitted to the Commission.

The Expense elements of PCS service consist of the following; Sales, Operations, Maintenance, Access, and Installation. There exists no commonalty of function that would make for economies of scope in any of these entities.

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[16] McGarty, Alternative Networking Architectures: Pricing, Policy and Competition, (B. Kahin Ed, Building Information Infrastructures, McGraw Hill, NY, 1992), or McGarty, T., and S. McGarty, Architectures et Structures de L'Information, Reseaux 56 CNET, 1992, Paris. In these two works the authors show that Architectures and architectural implications are a reflection of the designers world view based upon existing paradigms. Specifically, the Commissions study is mired in a Telco wire based paradigm. Clearly the Bellcore proposals, if deconstructed according to the above work, will show that their design will allow small cell radius and high reliance on the local exchange carrier. In contrast, the new paradigm is de minimis reliance on the local exchange. We argue here and in the referred works that one must look at this deconstructionist view and deal with the changes in technology that dramatically change paradigms.

[17] TTI NPRM Comments dated November 9, 1992. In these comments the Commentor has included a detailed microeconomic analysis of the PCS system. The Commentor further argues that since the Commentor has on its staff the former CEO and two former COOs of two of the top five cellular companies, it has the detailed professional, technical, operational, and business knowledge to assert this information. In referencing the FCC Report from the OPP, it is clear to the Commentor that there has been specific and explicit reliance on the data from both the RBOCs and Bellcore for the model. Clearly these entities have vested interests in continuing the potential barrier to entry through high aggregated costs and through the possible preservation of their dated technology base.

[18] TTI Appendix to NPRM Comments, November 9, 1992, and compare to the FCC OPP Report 28, November, 1992. The TTI report details each of the depreciation elements and the OPP Report shows their analysis for the network using an old paradigm of physical interconnect. The OPP report uses an ad hoc propiter hoc argument based upon extensive RBOC and Bellcore input. A re-evaluation of the financial results using the new paradigm leads to drastically different results.

This implies that the expenses can be expressed as:

$$E(S,O,M,A,I) = E(S)+E(O)+E(M)+E(A)+E(I)$$

The major issue of scope on the expense elements is that ofaccess. Clearly, if the argument as developed above is used, if an entity has switch capacity that is already in place, such as an LEC, then;

$$E(A_{Telco}, A_{PCS}) = E(A_{Telco})^{*}+E(A_{PCS})^{*} < E(A_{Telco})+E(A_{PCS})$$

where these are the scope costs and the non-scope costs respectively. However, if the LEC is required, as a monopolistic player in each market, to provide access at equal and equitable rates, as has been argued elsewhere, then;

$$E(A_{PCS}) = E(A_{Telco})^{*}=E(A_{PCS})^{*} = E(A_{Telco})$$

Namely, all access rates are the same. Then and only then will there be fair and equitable market entry.

POLICY IMPLICATIONS DUE TO LACK OF SCOPE

As a result of the above analysis, there are several clear Policy implications that both counter the OPP Commission recommendations as well as add to them. They are as follows:

(1) LEC Disaggregation of Switching, Interconnect, and Retail is necessary for adequate competition in the PCS market. Failure to have the LECs disaggregate switch costs, and to provide the switching access on an equitable marginally based price level will clearly result in a barrier to entry to any other participant.

In the areas of access fees, economies of scope are existent only in the sense that the LECs provide pricing levels in the existing cellular markets that may be viewed in some limited contexts as predatory. Price on access to cellular carriers clearly does not reflect costs. Transfer price of access, internal to the LEC, can be argued to be less than the marginal cost, in certain circumstances, as has been discussed previously. As such the LEC can possibly present a market bottleneck element in the provision of PCS access and interconnect services.

(2) A National PCS Consortium is not only possible as a direct result of the lack of scope, but that the lack of scope opens the market for many entrepreneurs to provide the most competitive of markets for PCS services. Furthermore, the lack of scope indicates that even for a National Consortium there is no compelling economic argument that states there should be anational Manager. A Manager is a convenience to assure quality not a necessity to ensure Pareto efficiency.

3.0 Technological Changes and Paradigm Shifts

Technology has changed dramatically in the past five years. The two current ways of providing voice service are via wireline twisted pair telephone service and through cellular voice service.[19] New technological innovations have allowed the wireless PCS services to be provided by another form of technology. This technology takes advantage of a distributed telecommunications architecture and places as much "silicon" in the field as possible. It also performs as much processing as possible so as to minimize the functions required by the LEC interconnect.

[19]See the works by Lee. The author has provided several key bodies of analysis that provide insight into the history and current status of cellular.

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. The CDMA system described is that of QUALCOMM [20]. Fundamentally the system is characterized in the following fashion:

(i) An air interface of a CDMA signal is provided by a cell or cell re-rad over the air to the portable. The signal is encoded in a direct sequence CDMA spread spectrum code. Thus a 9.6 Kbps signal is spread, or multiplied by a unique code at the rate of 1.25 Mbps. The codes are orthogonal. Namely, if two or more codes are combined, then if they are multiplied by the desired code, the residual of the other signal appears as a low level noise signal. Thus CDMA is frequently interference limited no random noise limited.

(ii) A cell controller is used to ensure hand off between other cell controllers. The cell controller has a capacity that depends upon the bandwidth, the interference level, the size of the cell and other factors. Typically a cell controller has the capacity of 500 to 1,000 trunks. Note that this is given in trunks and not portables. If a portable is busy 5% of the time then this means a cell controller with 1,000 trunks can handle 20,000 portables. The cell controller is a highly intelligent distributed processing node. The CDMA codes assure signal orthogonality and inherently manage the interference. The cell controller assures a soft hand-off between the other cells in the grid. In addition, the cell controller establishes the relationship between the call and the switch. Namely the cell controller passes an intelligent and digitally "packed" set of voice channels.

(iii) The cell-controller hands the switch a DS-3 formatted voice signal, with a SS-7 signaling channel, on a SONET interface. As far as the switch is concerned, the call may have originated from a Class 5 or Class 4 switch. As we have discussed before, the Class 5 LEC functionality is not required. What is required is the Class 4 toll-tandem switching capability. The only need for Class 5 functionality is that needed for billing.

(iv) The re-rads are clustered around the cell controller. A re rad is used to manage the coverage issue, whereas the cell controlled is used for the capacity issue. The re-rads are an order of magnitude less expensive than the cell controller. The re-rads are interconnected to the cell controller via a microwave path, at 40 GHz, or over CATV or a bypass carrier.

When looked at in this fashion, the use of CDMA dramatically reduces the needs from a LEC environment. All that is needed is the ability to backward access to the local user, namely a customer of the LEC. Thus the access fee should be reduced.

A simple calculation will show how this new technology dramatically reduces the capital per subscriber.

- o Assume that there are 1,000 square miles of coverage and 48,000 subscribers.
- o Assume that a cell controller or a re-rad handles a 3 mi. radius or about a 30 mi. cell coverage area. This implies that 3 cell controllers and 30 re-rads will cover the area.
- o Assume that the cell-controller is equipped to handle 800 trunks per cell controller. Assume that the peak usage ratio is 5%. Thus each cell controller can handle 16,000 subscribers, 800 instantaneously active in the busy hour.
- o Assume that the cell controller are about $1 million each and that the re-rads, with microwave back haul are at $50 thousand each. The total capital is $4.5 million. This the is about $100 of capital per subscriber.

[20] See the works by Gilhousen for the QUALCOMM approach. Also see the paper by Pickholtz et al for a differing approach to CDMA. The latter approach is Broadband CDMA compared to mid-band.

Now this can be compared to the capital per subscriber in the LEC and cellular environments. In the LEC world the capital per subscriber is almost $1,800. This is split between switch and transport as follows; $500 for the switch and $1,300 for transport. Namely, the LEC is outside plant dominated. Moreover, under rate of return regulation, the LEC makes most of its profit off of its outside plant. In the cellular world the capital per subscriber is $750. This includes the cells and the MTSO, Mobile Telephone Switching Office. It does not include access to the LEC Class 5 switch.

4.0 Wireless Business Implications

The wireless communications services defined as PCS, Personal Communications Service, has been defined as:

" The provision of toll grade wireless voice and data telecommunications services in a national seamless interoperable network."

This implies the following:

(1) "Toll Grade": The quality of the service is equal to or better than that of the current telephone service provided by the LEC.

(2) "Wireless": The service is provided in a totally wireless fashion in a wide variety of locations. The use may use the system, namely the same terminal device, for access the service from their home, auto, office, or any other such location. The service is not delimited in any fashion.

(3) "Voice and Data Telecommunications Services": This implies that the service is flexible enough to support voice and data and that the voice is that of toll grade quality and the data is of rate and performance adequate to meet most of the customer's needs. The concept of being telecommunications services is that the service be more than just a voice or data connection in that it provides a wide variety of enhanced network services.

(4) "National": The service must be a national service, providing, ultimately, a national coverage. This is a challenge in terms of assuring that all areas of the country are covered, especially those that have very low population density. This may require a system approach that is integrated with other wireless systems, such as satellite.

(5) "Seamless": This implies that one can use the same terminal in one city and another, in one location and another. It implies that the home terminal may be brought into the office and that the terminal also works in the auto. The seamless requirement is s significant requirement in terms of the goals of single terminal. This does not necessarily mean a single service. The terminal may be multi mode in terms of its operations.

(6) "Interoperable": The service must work with other complementary systems, such as satellite systems. It must function in a transparent fashion to the user and allow the user to access communications without necessarily knowing where the service is provided.

(7) "Network": The service is a network of services. The services are provided in an integrated fashion with a common set of service platforms and capabilities.[21]

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[21]See the paper by Huber on the Geodesic network. Huber agues that the evolution of networks is into a network of networks, thus the geodesic. The arguments in McGarty, Architecture, are similar but are must more specific. McGarty and McGarty, in Architectures et Structures, Reseaux , argue further that this fits the nature of infrastructures and as such are key to the policy discussions underway in Washington. The authors argue that an infrastructure requires more than just a financial investment in a large national entity. The qualities of an architecture are those that sustain it and allow it to become an enabler of other economically viable entities. In particular, the authors have defined an ***infrastructure as a***

There is a five point strategy to achieve the Goal described. This strategy is as follows:

(1) Operational Availability by 1994: It is assumed that AT&T and subsequently the RBOCs are the most significant competitors. In addition it is assumed that they will have equal capability to develop modifications in infrastructure to compete in this business in a two year time frame. Thus it is essential that the Consortium have some operational capability by the end of 1994. In addition it is assumed that if the FCC awards a license in early 1994 or earlier that operational status must be achieved at least in eighteen months and thus a target operational frame of twelve months allows for modifications if necessary.

(2) Capital per Customer less than $100 at penetrations of 50,000 per system: The technology base currently allows for this number and this number is what is necessary to keep the capital and cash requirements at reasonable levels. Some vendors of equipment, such as Motorola and others have capital per sub factors four to six times this number. These systems do not allow for commodicization of the service and are barriers to entry to competition in the LEC market. This number is for outside coverage and does not address the issues of internal systems as well as external.

(3) Cost for acquisition of each new customer of less than $300: This implies that there is a national branding and promotional capability in the Consortium and that sales is centralized and highly efficient. It also assumes that there are minimal numbers of dealers and that for the most part the sales are performed on a direct basis with no intermediary overhead. It has been suggested that this can be done via national advertising with a direct in bound telemarketing accompanied by direct ship of the portable.

(4) Access fees per minute of less than $0.03: The access fees are the cost of goods. Currently cellular pays about $0.08 to $0.11 per minute. With PCS user rates this implies that with 300 minutes per person per month, $33 per month cost of goods is unacceptable. The strategy is to disaggregate the LEC and to do so via several fronts. These fronts are direct frontal attacks, indirect bypass via Class 4 interconnect, and co-carrier status. The scale and scope of resources are necessary for this to occur.

(5) Cost per portable of less than $100 at the one million sold point: This can be done only through bulk buys and also only through the use of a single sales channel for national distribution.

These five strategies will assure the ability to commodicize the basic product and compete directly with the LEC and any other competitors.

As a result of using these strategies, one can obtain a detailed financial model of the PCS business. [22] Specifically the average and marginal costs of the PCS business have been calculated and are shown in Figures 2 and 3, for both a no-co-located and co-located business. The co-located option describes a business that attains the performance numbers presented above. It assumes marginally equitable pricing and also that disaggregation occurs. The no-co-located assumes that this is not the case and that the PCS carrier must work as a cellular carrier.

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shareable, common, enabling, enduring resource that has scale in its design, is sustainable by an existing market, and is the embodiment of an underlying architecture.

[22] McGarty, Business Plans. The author develops a model for the analyses of business like the PCS market. The model referred to in this paper was also in the paper by McGarty, ATI CMU, February, 1993 and 1992. The model is revenue driven and is detailed in terms of revenue drivers, productivity factors and unit cost elements. The model is based upon extensive cellular and LEC modeling and is focused on demonstrating how an entrepreneurial entity may perform.

Figure 2 Scale Economies of Co-Located Services

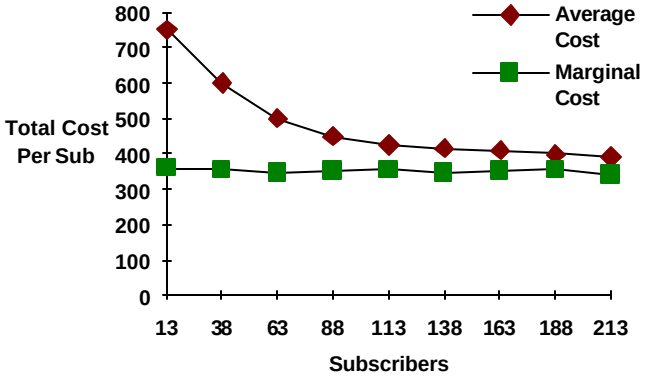
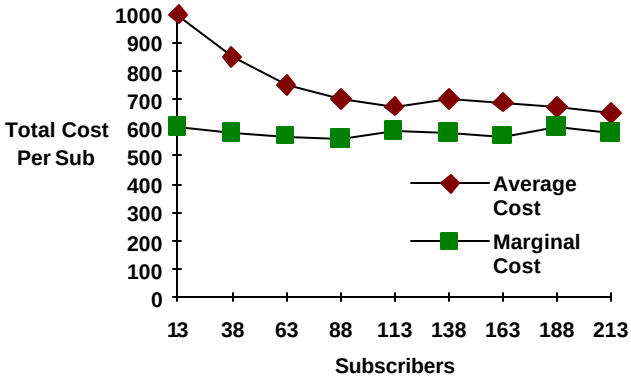


Figure 3 Scale Economies in a Non-Disaggregated Environment



From the figures one can see the dramatic differences in cost per subscriber. These costs are all costs including depreciation. They show costs of less than $400, per year per subscriber for a co-located assumption. It should be noted that this analysis also assumed 250 minutes per user per year and also assumed $0.06 per minute access. Access fees are therefore $180 per year and are a dominant amount of the total annual cost per subscriber. Less the access costs, the cost per customer per year is close to $200. This is dramatically different that the LEC structure. From the adjoining Figure with no co-location, there is a dramatic increase in cost due to the need for switches and increased access fees. Clearly, from a public policy perspective, co-location and controlled access are critical.

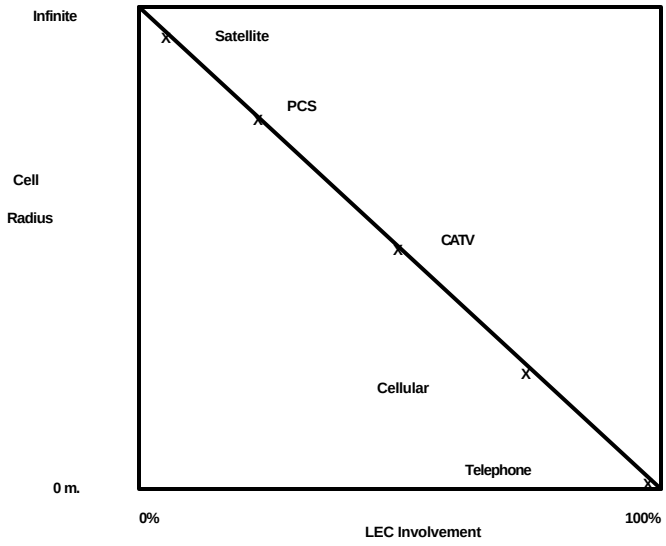
5.0 Policy Implications

As a result of this analysis, it is clear that there are several major policy issues that must be reconsidered in light of the changing technological and business environment. There are differing world views as to PCS and each of these result in differing policy implications. Figure 4 demonstrates the position of the players in terms of the world views.[23] This shows two dimensions of the PCS market; radius per cell site and LEC

[23] This Figure is due to John Battin at Motorola. It is one of the better representations of how each of the players view the PCS marketplace and their role in it.

involvement. Clearly at two extremes there are two well known cases. First, at infinite cell radius and no LEC involvement is the satellite business. At the other extreme, no cell radium and 100% LEC involvement is the current telephone business. The interesting positions are those in between. We have argued in this paper that PCS is a moderate to large cell radium and de minimis involvement with the LEC. Cellular has large cell radii but high LEC involvement. [24] As a result of these positions, we have taken a set of policy issues that relate to the PCS position that is higher in radius and much lower in LEC involvement.

Figure 4 PCS World Views



These issues are as follows:

(i) LEC Disaggregation: As was shown in the earlier section, the current LEC operations are a fully aggregated provision of the switch, transport and retail functionality. The aggregation of costs result in high unit costs to third parties while at the same time ensuring the LEC with low internal transfer pricing of the unit service. The need for disaggregation is predicated on two factors. First, the LEC may provide a bottleneck to new services by charging higher costs of service externally than internally, and using the new and innovative service providers as a sources of capital to fund internal inefficiencies. Second, the LEC must disaggregate in order to allow regulators to ascribe fair and reasonable costs to the total base of residual services. Disaggregation implies that the LEC has a clear and measurable means to determine the elements provided in any one of its bundle services. The LECs were requested to perform a disaggreation during the 1987 ONA Docket by the FCC but failed to adequately address the issue. Possibly this was a result of not having a viable paradigm of the business or possibly it was because the data was yet not available so soon after divestiture. At this time, however, the information and paradigms to perform the task are at hand and the policy to provide such disaggrgetaion must be developed.

(ii) Bottlenecks and Barriers to Entry : The concept of a bottleneck is based upon the theory that a single entity may be able, through nothing more than the intensive practice of its own business, to prevent or

[24] It should be noted that cellular is a technology dating back to the late 1960's. As such, it has limited technology advances and works in a fully analog fashion. Moreover, in order to protect the Central Office from outside forces, the cellular technology introduced the MTSO, Mobile Telephone Switching Office. This is a Class 5 Switch. It does exactly what any Class 5 does, plus the functions of cell hand-off. The reason for the added and significantly redundant functionality was that it ensured that no non-Bell company could then co-locate with the LEC. Thus, the cellular involvement is not optimum, is based on twenty five year old technology, and is designed to protect the old Bell System.

inhibit a competitor from entering the market, or after entering, from surviving. The issues of access fees as representing the cost of goods is the basis of such a bottleneck. The LEC, can, if not adequately monitored and instructed, establish such a bottleneck.[25]

(iii) Universal Service: Universal Service was a Theodore Vail desire that was based upon Vail's desire to obtain a national monopoly. Vail promised this to Congress and the ICC to assure his ability to get the national monopoly for AT&T. This latter became a public policy issue for the PUCs as they increased their powers over the LECs. Universal service may not mean universal competition. The RBOCs will argue cream skimming for the alternative carriers and will argue that the RBOCs must serve the rural customer, leaving the more profitable, and possibly only profitable, customer in the urban area where competition exists. The issue of universal service does not demand universal competition. Namely, universal service means that as a public policy issue, the total infrastructure may have to deal with providing service to all who are citizens and can afford a lifeline type of service. This may be handled by a fiscal or taxation approach, separate and apart from the running of a business, thus leveling the field for all of the players.

(iv) Competition: The advent of wireless creates competition in the LEC. Limited bypass competition has existed for several years with the likes of Teleport and MFS. These companies struggled for many years to obtain co-location for more efficient cost reduction. They service the major business customers and have not entered the consumer market. The cellular companies are not really competition, since almost 75% of all cellular markets, and 80% or more of the major metropolitan markets are RBOC or GTE dominated. Now with AT&T owning McCaw, this number is over 90%. Clearly, there is no cellular competition. The bypass carriers have tried to compete but only in a niche. The CATV companies are technically unable to compete having less than 0.1% activated and usable two way plant. The only major contenders will be a "RBOC-less " wireless PCS carrier. Thus, if the goal from a public policy perspective is seamless interoperable national service with competitive prices and service offerings, then this form of competition meets all public policy goals.

(v) Common Carrier Status in a Competitive Environment: A common carrier as defined by Brenner in the context of the 1934 FCC Act is:

> *"...a communications common carrier is defined under the law as one whose services are open to public hire for handling interstate or international communications by electrical means. Broadcast stations are not considered common carriers. "*

Thus any PCS carrier is obviously a common carrier. It will, by its very nature cross state lines. As such, it is under the common carriage restrictions of the FCC. In contrast to the LECs, who are also common carriers, the PCS companies are not in monopoly positions. They must compete in an open market with the existing carrier. Yet, as we have shown, cost of good not withstanding, the PCS carriers do not have business with significant scale. They may enter the market with de minimis capital as compared to wire based carriers. The technology change allows this to happen. The only barrier to entry is the access fee. A competitive environment can then ensue if and only if the access fee is made competitive. The only way for this to occur that is the least disruptive appears to the use of the co-carrier status. [26]

(vi) Regulation without Tariffs: If PCS and other wireless type service create a truly competitive market for local exchange service, then there is the question of what is the function of regulation and what are the roles

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[25] Fisher, Tirole and Fudenberg and Tirole. These authors discuss the barriers to entry from an economic market perspective. McGarty and McGarty, Information Infrastructures, and Telmarc Telecommunications, November, 1992, also discuss these in detail.

[26] MCI, NPRM filing of November 8, 1992, to the FCC. This is the first filing requesting co-carrier status. As indicated before, co-carrier status, as sanctioned and authorized by the Commission, implies that all call terminating pay. This is a reciprocal process. If the calls are equally balanced in-bound and out-bound, then the access fees are de facto zero. This implies zero cost of goods and maximum competition.

of the state PUCs. Tariff regulation was predicated upon the need to have a monopoly due to the dramatic economies of scale and scope in local carriage. As we have shown here and elsewhere, these economies are de minimis. Thus, the justification for a monopoly are no longer valid. It was technology that allowed this to occur. What then is left for the PUC to regulate. This is not the case of CATV with many systems but each having a monopoly. It is a case of many systems, each having multiple presences. The role of regulation therefore is to ensure competition and to ensure that the quality promised is met. Namely, the role is that of consumer advocate and market policeman.

(vii) Consumer Choice: The consumer must have choice in carrier options. This choice, however, must be based upon a fully disclosed level of service and the consumer must have access to redress if the service is inadequately provided or misrepresented. The examples of IEC serve is an example of how this may be effectively done. The three dominant carriers, namely AT&T, MCI and Sprint, have all demonstrated quality service with minimal customer complaints. In contrast the COCOT, Customer Owned Customer Operated Alternative Carrier Systems are ran with complaints. What this demonstrates is that the customer as the ultimately selector of service, as they do with MCI for example, chooses and maintains a relationship based upon quality. In contrast, when the choice of the customer is usurped by a third party as in COCOT, both quality and ethical behaviour often suffer. Thus, in a competitive LEC environments, the customer, if directly allowed to select, is the ultimate arbiter.

6.0 Conclusions

This paper has presented an overview of the issues relating to access history and policy and has used PCS as a means to establish key policy issue as requiring debate and resolution to effectively move the U.S. telecommunications infrastructure forward. The author argues that telecommunications is at a cross road. The barriers across these cross roads are not technical or economic. They are policy barriers. They are barriers that, if removed, will create new and competitive infrastructure enabling entities, new value creation both within and without that infrastructure and new value for the country.

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