Alternative Networking Architectures
Pricing, Policy and Competition

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Abstract

The telecommunications network has evolved from a structure that was initially imbedded in a regulated monopoly through one that has been dictated by judicial mandate. The natural economic forces that tend to work in other market segments have been deliberately left out of this market. The result is a fragmented and less than efficient market for the delivery, development and expansion of services to the end users.

There are however, alternatives that may allow for a repositioning of these current structures and permit a restructuring of the current communications market infrastructure. This paper develops a set of alternative architectural constructs, integrates several technological trends, and describes multiple evolutionary paths.

The structure and viability of the paths are discussed in terms of their economic viability. This paper also discusses the potential and evolution of broadband networks and their role as infrastructure elements in a national network.

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1.0 Introduction

Networks have been developing in various forms since the time of divestiture, in response both to the opportunities afforded by deregulation as well as by the needs of the users themselves. There has evolved a clear lack of cohesiveness to the design and application of the network schemes and the evolution seems to presage a movement towards networks optimized for usage by a defined and bonded collection of shared users. The National Research and Education Network (NREN) concept clearly falls into this category. To better understand the implications of such evolutionary trends and to better develop a base of knowledge for the development of effective policy in this area, it is necessary to have a construct or model for these evolving networks.

The NREN concept is an evolutionary progression of networking capabilities that starts with the introduction of a shared data network at the 1.5 Mbps rate and then transitions to a 45 Mbps set of rates and then in its third stage it acquires a Gbps capability. The major focus is on that latter stage capability.

It is the development of this area that has been considered as the infrastructure portion of the effort. To quote from an OSTP report, (See Kahin, p.4);

" The NREN should be the prototype of a new national information infrastructure which could be available to every home, office, and factory."

This raises the expectations from that of a network to that of an infrastructure. In this paper, we shall develop the concept of infrastructure against the context of communications networks. We shall address the issue of NREN and its counterparts being either infrastructure or merely another network. For in the same paper, Kahin goes on to define the NREN as;

" Despite the name, NREN is not conceived as a centralized national network...The NREN is conceived as more coordinated than the present Internet...the vision of the NREN generally includes eventual transition to commercial users."

Thus there are two views of the NREN; that of a prototype network and that of a fully operational entity.

There are similarly multiple views of many of the types of networks that may be developed for the purpose of developing national expertise in the areas of broadband communications. The views, as indicated, flow from those that view the need for a purely research oriented network to those who see the current need for a fully operational physical national infrastructure.

This paper addresses several of the fundamental issues that may assist in resolving the issues presented by these network alternatives. Specifically, we address the concept of infrastructure, and describe its multiple embodiments. We then develop the concept of architecture and how that it includes several elements and that a network can be viewed only in the context of its architectural embodiment. We then develop the major exogenous drivers for any network, the end users. Finally, we consider the elements of policy and how policy may be developed in the context of the evolving network world views.

There are several questions that we investigate in this paper. First, what is a network and what is a network infrastructure, and within that context, how does one create a broadband, high data rate, network infrastructure. Second, does such a network capability already exist and if so how does one assess and use it as is. Third, what are the goals that are achievable with such an infrastructure network, in terms of international competitiveness, establishing an information infrastructure, or in terms of a national asset.

The main theme of this paper builds on these questions. Specifically, it will be argued that there are basic architectural alternatives for network designs. The existence of these different architectures is based upon a world view and a set of technologies that enable its embodiment. We argue that there is a fundamental change in the world view, one from a truly hierarchical environment to one that now empowers the end user. The result of this change is a fundamental change in the operative network architectures, moving from the world of large scale infrastructures to those of multiple overlay networks.

The current dominant carriers in the telecommunications market are generally regulated on the theory that they have monopolistic power in their respective markets by either a direct or implied exclusive franchise to provide services to the customers in those markets. Furthermore, market control allows the dominant carrier to exert price control as either a monopolist in the pure sense or at least as a simple oligopolist. It is the concept of the "Bottle Neck" that has dominated not only policy but also the flow of technology and services to the market. In this paper, we demonstrate that the dominant carrier concept is degenerating in many areas. It is becoming an environment of multiple network providers, where the functions of the classical carriers are now becoming distributed directly to the end users. Furthermore, we shall argue that as a result of the technological changes allowing for multiple carriers, that the current regulatory strictures on the telecommunications market are not only inhibiting to development but are the fundamental essence of the loss of international competitiveness.

The policy issues associated with these classical systems are based upon the fact that, in the past, there has been a perceived lack of growth and innovation, a set of barriers to entry on the part of new innovators and price competitors, and a set of price structures that inhibited the entry of competitors. We demonstrate in this paper that there are now a multiple set of alternatives for the network user. The alternatives are based upon a revised view of what a network is as well as major changes in the technology of networking.

Thus, these changes require an expanded development of new policies for these network infrastructures.

Networks have been viewed by some as an infrastructure such as highways, educational systems, and the military. Typically they have been thought of that way because they serve the general good, they require significant capital investments that are frequently beyond the bounds of most single users, even corporations, and because they must deal with both national and international elements of our society.

Thus, the three reasons for the infrastructure view are the general good, capital intensiveness and global in scope. In this paper, we argue that the concept of networks and infrastructure must be revised and expanded. That networks such as the NREN, are only one of several embodiments of a network, and that infrastructure must be understood in the context of the new world views of networks. Further, we argue that technology is changing what we can do with the network architectural elements and that this added use flexibility to create subnetworks that are optimized to meet their specific economic driving forces, makes the very concept of a single physical network architecture obsolete.

Specifically, market demands require that the networks have more customized structures and that in fact the general network that meets everyone's needs is both counter productive and adds additional costs.

Second, technology allows for segmentation in the network, using a commodity infrastructure of fiber to allow the end users to have the use specific designs that they need. For example, if we allow fiber to be used at its full potential to the end user, rather than as a segmented and compartmentalized structure matching a voice only world, this may free both market and technical forces to attain the segmentation.

Third, globalization has already occurred with the globalization of the business market.

There are currently five players in the networking area. They are the Government and its own networks, Public Switched networks provided by the common carriers, Private Networks, frequently called Bypass carriers, CATV networks, primarily carrying entertainment and not information, and customer specific networks, such as those of IBM, DEC and other large information intensive companies, as well as the regional educational networks, such as NEARNet and NYSERNet. Figure 1 depicts the five network providers and generally depicts the gross differences between each of them. It is essential to understand not only the microstructure of each of the players in this map, but to also understand that each of the players has a dramatically different world view of what they are to achieve in their networks. In this paper, we shall examine each of these players in the context of the new world view of networks
In this paper, we will prove the following thesis:

The use of a centrally conceived, non-market generated and driven, means to develop an economically productive implementation of a new electronic broadband communications network is not only an ineffective act but also is counter productive to the national economy.

We prove both sides of this thesis in the body of this paper. Moreover, we demonstrate that the broadband network is and must continue to be driven by end users motivated by such basic economic drivers as value creation. The evolution includes not only the basic transport features but the entire complement of elements necessary for a viable communications and business entity. The current environment is such that competitive market forces exist, inhibited only by regulation mired in an obsolete world view that must be adopted to the new paradigms of implementation.

The process that we take to prove this thesis is as follows:

First, we develop the concept of architecture and show that there is both a philosophical and material structure to the concept of architecture. The key observation of this first step will be to note that our understanding of communications architectures is dominated by a world view created by the available paradigms or technologies.

Second, we demonstrate that the underlying technologies have changed dramatically in the area of broadband. The change is dominated by the ability of the end user terminal to play a dramatic role in the network operations and that ability to have a fully distributed design. This technology change is reflected in new paradigms and thus agues for the development of a new world view.

Third, we demonstrate that the market is the ultimate arbitrator. That value creation as a measurable and definable entity is critical to the success of any broadband implementation and that this value creation must be perceived by and understood by the customer. Without the customer as user, buyer and decision maker being the focal element of the process, the effort is doomed to failure.

Fourth, there are several players all trying to evolve in the direction of developing the basic elements necessary for a broadband environment. We review them in some detail and show that there already exists many of the elements in place for such a system and that another scheme will result in reducing the current competitiveness of these players and impact negatively on the economy as a whole
These four steps build to the proof of the thesis.

2.0 Architectures

The concept of a telecommunications architecture has been a cornerstone in the development of new telecommunications systems. However, the structural elements of these architectures have not played a role in the development of policies. In this section we will develop the concept of an architecture as a means to understand the network as both a market and regulatory entity, and will provide a new set of perspectives for viewing the network in terms of a new paradigms and world views.

An architecture, first, requires that the underlying system be treated in terms of a set of commonly understood elements and that these elements have a clearly demarcated set of functions and interfaces that allow for the combining of the basic set of elements. The way the elements then can be combined, reflected against the ultimate types of services provided, determine the architecture.

An architecture, secondly, is driven by two factors; technology and world view. Technology places bounds on what is achievable, however those bounds are typically well beyond the limits that are self-imposed by the designer or architect in their view of the user in their world. This concept of architecture and the use of design elements is critical in understanding the paradigms used in the structure of information systems (See Winograd and Flores, pp 34-50, especially their discussion of Heidegger and Throwness in terms of design). World view is the more powerful driver in architecture (See Kuhn, pp 72-85). We argue in this paper that it is essential to develop a philosophical perspective and understanding of how to view networks. We argue with Winograd and Flores, and in turn with Heidegger, that we must be thrown into the network, to understand the needs of the users, and to understand the structure of the paradigms that are used to construct the world view.

To better understand the importance of an architecture we develop the concept of the historicity of architectures based upon the work of Kuhn and ten that of McLuhan. Kuhn begins his thesis of how scientific revolutions occur by the introduction of the concept of paradigms. He defines these as (see Kuhn p. 175);"...the term paradigm is used in two different senses. On the one hand, it stands for the entire constellation of beliefs, values, techniques, and so on shared by the members of a given community. On the other, it denotes one sort of element in that constellation, the concrete puzzle-solutions which, employed as models or examples, can replace explicit rules as a basis for the remaining puzzles of normal science, The first sense of the term, call it sociological, ..., “

The concept of a paradigm is in essence the collection of current technologies that we have at hand for the network and the ways we put these elements together. New paradigms result from new technologies. New technologies allow for the placing of the elements together in new ways. Kuhn, then goes on to demonstrate that the world view, that is how we view ourselves and our environment is based upon the our acceptance of these paradigms, as either collections of techniques and technologies or as collections of embodiments of these techniques and technologies in "examples". We then end to accept this as the way things are and should be. Then Kuhn argues, as the technologies change, changes in the paradigms do not occur in a continuous fashion but almost in quantum leaps. The new paradigms build and congeal until they burst forth with new world views. It is this model that we ague applies to the evolution of broadband.

It is this philosophical view, almost Hegelian in form, that is essential in understanding the underlying and formative changes in paradigms that will change our world view.

As a second perspective of the impact of technology as a dominant driver, we can refer to McLuhan and his development of the concept of media. Drucker has referred to the presentation of McLuhan's doctoral thesis and McLuhan is quoted as follows (See Drucker, p. 250):

"Movable type, rather then Petrarch, Copernicus, or Columbus was the creator of the modern world view.. "Did I hear you right," asked one of the professors as McLuhan had finished reading, "that you think printing influenced the course s the universities taught and the role of the university, altogether?”

"No, sir, " said McLuhan, "it did not influence; printing determined both, indeed, printing determined henceforth what was going to be considered knowledge.”

This concept later evolved into the medium being the message. In our context it is the fact that both Kuhn and McLuhan recognized, albeit in differing fields and in differing ways, that fundamental changes in technology and technique, call it paradigm or the medium, will change the world view, also the message.

It is the importance of understanding the change in the technology, its function and evaluate the possible change that this will have in the world view. It will be argued, that much of the thinking in the current broadband areas, NREN in particular, is based upon outmoded techniques and structures, and that a differing world view will evolve.

Thus, architecture is the combination of three parts; the common elements, the underlying technology and the world view. In Figure 2, we depict the conceptualization of architecture as the amalgam of these three elements. We shall develop this construct more fully as we proceed.

The concept of a world view is an overlying concept that goes to the heart of the arguments made in this paper. To better understand what it implies, we further examine several common views and analyze the implications of each. If we view our world as hierarchical, then the network may very well reflect that view. If we further add to that view a bias towards voice communications, these two element will be reflected in all that we do. The very observations that we make about our environment and the needs of the users will be reflected against that view. As an external observer, we at best can deconstruct the view and using the abilities of the hermenutic observer, determine the intent of the builder of the networks. (See Gadamer's interpretation as discussed by Winograd and Flores, pp 27-30. Also see the historical context of the hermenutic approach in the sciences as discussed by Greene in Depew and Weber, pp 9-10).

Take, for example, the use of twisted pair, pairs of copper wire, to transport telephone traffic. For years it was implicitly assumed that this transport medium was limited to 4,000 Hz of bandwidth, that necessary for an adequate quality voice signal. Specifically the world view was that of a voice network that was to be used for voice traffic only. Ten years ago, this was a true limitation, since the transmission was forcefully limited to 4,000 Hz by inductive loads or coils on the telephone lines, assuring that you could do no more than the 4,000 Hz of bandwidth. Then, there was a short period in the mid 1980s, when Local Area network manufacturers found that you could transmit 1.544 Mbps over the common twisted pair, and that data was viable in what was assumed to be a voice only medium. What had been almost religiously believed to be a limit was found to be untrue. Then with the introduction of digital switches, the old "inductive loads" were returned with the switch now limiting the data to 4 KHz or 64 K samples per second. The world view of a voice only network took hold again, but this time in the context of a data rate limitation, rather than a bandwidth limitation. In the early 90's there is another attempted break out of the world view and to put 100 Mbps on twisted pair, so called FDDI circuits. Again, due to the limitations on the part of the network as a voice dominated system, the world view keeps this high data rate capability on the customer's premise only, and not the network.

We describe this transport world view evolution in Figure 3. Here we indicate the two dimensions of information transport, bandwidth and data rate. The designer of the transport facility may limit the data rate by selection of signaling format or delimit bandwidth by filtering. Twisted pair actually has a bandwidth-datarate profile as shown in Figure 3. It encompasses a large capability of either providing bandwidth or data rates to the user. The two limiting world views are indicated as two solid lines, one at 4,000 Hz and one at 64 Kbps. Both are voice only world views. We can readily see, that with optical fiber superimposed the same issue of architecture dominated by world view may result. In the fiber case, the result may be a segmenting of the architecture along selected data rate lines, again formed by the voice world view.

Thus, architecture can be defined as the conceptual embodiment of a world view, using the commonly understood set of constructural elements, based upon the available set of technologies. For example, Gothic architecture was a reflection of the ultimate salvation in God in the afterlife, in a building having a roof, walls, floors, and windows, and made of stone and glass. Romantic architecture was, in contrast, a celebration of man, using the same elements, but some employing a few more building materials. The impact of the differences in world view are self evident in the embodiments of the architecture. (See the discussions on the impact of world view on architecture in Wolfe. In addition see the cultural or world view impact on the Gothic architectures in Jantzen and in Toy.)
Let us consider a second example of the impact of world view on architecture, specifically the difference between the ISDN architecture and the architecture embodied in Local Area Networks, LANs. ISDN is an architecture consistent with a voice dominated, hierarchical world view of single points of control. LANs are architectures of world views that reflect both end user self empowerment and the environment of a data driven utility. Figure 4 depicts the LAN embodiment as well as its extension in the CATV architecture of voice communications using a LAN world view. This evolution in thought is critical to understand the impact of world view. The LAN is an embodiment of empowerment of the individual view, developed in the context of the 1960's and 1970's. The LAN concept, originating at such locations as XEROX PARC, was driven by the developers needs to enable and empower the end user with computing capabilities heretofore unavailable. Out of this view came the LAN architecture of a fully distributed system, using a coaxial transport mechanism to do nothing more than provide bandwidth. The transport mechanism is a broad enabler. The actual implementation of the details is done at the users terminal in hardware and software. This is in sharp contrast to ISDN, where the ISDN central switch does the enabling. In ISDN, bandwidth is not provided, rather it is a voice based data rate, 64 Kbps or multiple thereof. Consider this contrast in terms of how cable TV companies provided voice communications in the early 1980's. Both Cox and Warner, using variations on LAN technology, delivered a voice, video, and data service over the coaxial transport medium, by empowering the end users terminal, not by regimenting the transport network, as shown in Figure 4.

Technology also plays a very pivotal role in telecommunications. Alfred Kahn (1971, p 300), indicates that in the pre-divestiture period of the Bell System, the arguments for the needs of both vertical integration and need for monopoly control were based on technology. Specifically, there was a contention made by the Bell System that a single point of control to the network was essential. Also, it was argued that an adequate scale economy was attained only through a single monopoly. Indeed, given the state of technology of that time, the argument may have held. For in point, the loaded copper transmission capabilities allowed only limited transport, namely one voice channel per twisted pair. However, as we shall demonstrate, the underlying technology has provided a dramatic change in the underlying system.

Functions now provided by the network, may be more efficiently provided by intelligent Customer Premise Equipment (CPE). The question to be posed is; what is the role of the network, and how do we provide the dimensions of creative freedom to allow these new roles to evolve? To effectively approach this problem, we must first develop a canonical structure of a network.

2.1 Elements

There are four architectural elements in the telecommunications network. These elements are the control functions, the transport function, the interconnect function, and the interface function (See Figure 5 where these are generically depicted). We now provide further detail on these functions. It should be noted that these functions have evolved over the years in content and complexity. We view these elements in the context of a communications network that must support the most advanced current concepts in communications. Specifically, the world view adopted in this paper that lead to an interpretation of this architecture are:

(i) End users desire to have interactions in a real time fashion with images and other high resolution information that must be provided in a fashion that meet both time and resolution requirements (See Barlow).

(ii) The end user devices are extremely intelligent and complex and can operate in a stand alone environment.

(iii) The users desire to operate in a totally distributed fashion. Data bases will be a different locations, users are at different locations and input output devices are also at different locations (See Dertouzos and Moses, and de Sola Pool pp 57-59 for details on these directions).

(iv) The network may provide different levels of service to different users. There is no need to provide universal service of full capability to all end users.

This view of the network will significantly influence how extensively we defined the elements and in turn will impact the combination of those elements in an overall architecture. All of these assumptions on the world view are different then before, in an all voice world. In this paper, we define a network as an embodiment of an architecture, in all of its elements.

The architectural elements are control, transport, interconnect and interface. In Figure 6, we depict the overall architecture of the element interrelationship and the elements of the functions of the separate elements. The details on each are described below:

o Control: Control elements in an architecture provide for such functions as management, error detection, restoral, billing, inventory management, and diagnostics. Currently, the voice network provides these functions on a centralized basis, although in the last five years there have evolved network management and control schemas and products that allow for the custom control and management of their own network. Companies such as IBM, AT&T and NYNEX have developed network management systems that move the control from the network to the customer (McGarty, 87). On the sub-network side, companies such as NET, Timeplex, Novell, 3-COM and other have done similar implementations for local area networks, data multiplexers and other elements. Centralized network control is now longer necessary and in fact it may not be the most efficient way to control the network.

What is important, however, is that network control providing the above functions is an essential element for either a public or private network. Thus as we consider network evolution, this element or set of function must be included.

Control has now been made to be flexible and movable. The control function is probably the most critical in the changes that have been viewed in the context of an architecture. All buildings need windows, for example, but where one places the windows and what one makes them of can yield a mud adobe or the cathedral at Chartres. The same is true of the control element. In existing networks, the control is centralized, but in newer networks, the control is distributed and empowered to the end users. The users can now reconfigure, add, move, and change their network configuration and capacity.

Let us briefly describe how the control function can now be distributed. Consider a large corporate network consisting of computers, LANs, PBXs and smart multiplexers, as well as a backbone fiber transport function. Each of these elements has its own control facility for management and restoral. Each has the capability to reroute traffic from one location to another, and the routing systems are programmed into the system as a whole. On top of these sub element control functions is built another layer of control that views the network as a holistic entity. This form of control has been termed a manager of managers.

It monitors all of the sub net elements and takes control if necessary. It is embodied in several independent controllers, each having the capability of taking control from a remote network. This form of organic network control has evolved in recent years and is now common in many corporate networks. In addition, this concept of the organic network was described in detail by Huber in the DOJ report to the U.S. Justice Department during the first Triennial Review of the MFJ (See Huber).

o Transport: The transport element is provided by the underling transport fabric, whether that be twisted pair of copper, fiber optic cable, radio or other means. Transport should not be mixed or confused with other elements of the network. Transport is merely the provision of physical means to move information, in some form such as digital, from one point to another. At most it is expressed in bits per second and at best it is expressed in bandwidth only. Bandwidth as a transport construct is the most enabling. Transport does not encompass the need to change the information or to do any other enhancement to the information.

In the early regulatory cases such as the Above 890 Decisions in the microwave systems that were the precursors to MCI (See Kahn (II p12)), the Bell System argued that the technology of transmission limited the transport to only those companies that had the transport, interconnect and control. MCI on the other hand recognized that the customer was able and willing to differentiate these elements of the architecture and would segment them in a more economically efficient fashion. Specifically, in the early days of MCI, customers in the mid west would select multiple transport paths and would do the control function on their own premises. In addition, the customers were willing to accept lower quality of service for a lower cost of service. The lower quality was reflected by possibly a higher outage time.

It could then be recognized that the horizontal scale economies of all of the network elements, including but not limited to transport, were actually diseconomies of scale in the market. (See Fulhaber for a discussion of a more detailed view of scale diseconomies in terms of the new architectural elements) Fragmentation and segmentation along architecture elements allowed for the growth and efficiency of MCI. The emphasis should also be made on the statement of the FCC Examiner in the MCI case who stated (Kahn II p 134), "MCI is a shoestring operation ... the sites are small and the architecture of the huts is late Sears Roebuck toolshed." It is prescient to note that the examiner used the term architecture for the microwave repeater sites when indeed MCI was changing the architecture of the network. This remark is more than just an embodiment of a metaphor.

In the current network environment, the issue of transport and its enabling capacity has again arose. This has been the case with the introduction of fiber. Fiber may be segmented for the user in terms of data rates or in terms of bandwidth. In the NREN, the three steps are all focused along the lines of increasing data rates, from 1.5 Mbps to 45 Mbps to Gbps. As we have discussed, bandwidth is the more enabling dimension, leaving the choice of data rate and data structure to the end user. This capability is best deployed by using a dark fiber network. Consider the two networks shown in Figure 7. The top network is a standard fiber network with repeater at periodic intervals. In current technology limitations these are necessary because of the losses in fiber transport. However, with the current state of the art technology, fiber can be strung for many tens of miles without such repeaters and still maintain adequate transmission capacity.

Thus the repeaters are not there solely as a result of fiber constraints on transport. They are also there because they enforce the voice regime of the voice based world view. Namely, the repeaters do not repeat data rates, they also repeat framing sequences based on 64 Kbps voice frames. Thus any work station must use 64 Kbps as the underlying data fabric. As an extreme example, NREN in its Phase 2 will provide 45 Mbps to the users. Regrettably, there is no 45 Mbps modem. That is, direct access to 45 Mbps is not achievable. It must be sub multiplexed to the equivalent of voice grade digital circuits. Thus the world view is pervasive in this design. The same is true as SONET protocols are used in upgrades to broadband ISDN, especially over an ATM switch (See Fleming for a discussion of broadband switching and the voice paradigm).

In contrast, dark fiber is the provisioning of an optical fiber to be used as the end user sees fit. It is the world view analog of the LAN. The LAN provides co-axial bandwidth of several hundred MHz whereas the fiber provides the bandwidth of GHz to TeraHz. In Figure 7, we depict the fiber as the maximizing enabler that is interfaced through the end user terminal. It is the user who drives the applications.

o Interconnect: The interconnect element of the architecture describes how the different users are connected to one another or to any of the resources connected to the network and is synonymous with switching. Interconnection assumes that there is an addressing scheme, a management scheme for the addresses, and a scheme to allow one user to address, locate and connect to any other user.

Interconnection has in the past been provided by the Central Office switches. As we shall discuss latter, this implementation of an architectural element was based on certain limitations of the transport element.

With the change in the transport element of structures allowing greater bandwidth, the switching needs have changed. Specifically, distributed systems and scale economies of the distributed architectures allow for interconnectivity controlled by the CPE and not the Central Office. As we shall show later, the advent of Local Area Networks and CATV voice communications are ones using distributed interconnectivity elements.

Again, Alfred Kahn noted (II, p 127),

"We have already alluded to the technological explosion in communications after World War II,...The case for a national telecommunications network monopoly has the following aspects..Aggregate investment costs can be minimized.. if the planning for the installation and expansion is done with an eye for the total system....Since any one of the 5 million billion possible connections that the system must stand ready to make at any point in time may be performed over a variety of routes....justifies the interconnection...completely dependent on its own resources alone."

This argument for interconnection, combined with transport and control (namely horizontal integration) was valid in 1970. It however is not valid today. They are separable functions and scale economies are in the hands of the CPE manufacturers not the network providers. In effect, there exists no monopoly in interconnect as a result of these technology changes. This is a dramatic change from 1971 and Kahn's analysis.

There are three general views of interconnection that are valid today; the Telcom, the Computer Scientist, and the User. The Telcom view is based on the assumption of voice based transport with universal service and the assumption of the inseparability of interconnect and control. The Computer Scientist view is based upon the assumption that the network, as transport, is totally unreliable, and that computer hardware and software must be used in extremis to handle each data packet. Furthermore the Computer Scientist's view of the network is one where timeliness is secondary to control. The Computer Scientists view has been epitomized in the quote, "Every Packet is an Adventure". This is said with glee, in that each data packet is set out across the network and it is through the best of hacking that the Computer Scientist saves the packet from the perils of Scylla and Charybdis. The third view is that of the user, who is interested in developing an interconnect capability that meets the needs and minimizes cost. This is minimization of both obsolescence and cost strategy. Figure 8 depicts the challenge to the User view of interconnect.

Processing cost or capacity is declining every year. Thus an investment must try to follow the curve. In a hierarchical view of interconnect, such as a large centrally switched network, the changes occur once every few years. Thus the lost cost or performance efficiency can become significant. In contrast, in an end user controlled environment, with a fully distributed architecture, the lost efficiency is minimized as technology advances.

o Interface: The interfaces are the end users connection to the transport element. The interface element provides for the conversion from the end user information stream and the information streams that are used in the transport form of the network. For example, the telephone interface for voice is the analog conversion device.

Interfaces were originally called "Alien Attachments". In Kahn (II p. 140-145,) he discusses the history of the interface leading up to the Carterfone decision. The most significant position in CPE control was the Hush-A-Phone debate from 1921 to 1946. The Bell System at that time took total and full control over the quality of the delivery of the service of voice. The Hush-A-Phone company provided a mechanical cup device that could be placed over the mouthpiece of the telephone to assist in making the conversation more private. AT&T took the position that it interfered with the network and the quality of service and battled this for 25 years. Such is not the case today. CPE computer equipment has proliferated and the current costs for 9,600 bit per second modems are comparable to high end voice telephone devices.

Clearly, this fourth architectural element is separate and apart.

We have divided the network elements into these four categories to demonstrate that there are clearly four distinct and separable areas for growth and policy formation. Issues of regulation, due to potential monopolist control are always a concern, but it will be demonstrated that in all four there are economies in market disaggregation.

Natural monopolies have been studied by many, and in the context of utility regulation there are many key studies. In this context, Spulber has defined a natural monopoly as:

".. a property of productive technology, often in conjunction with market demand, such that a single firm is able to serve the market at less cost than two or more firms."

Natural monopoly is due to economy of scale and in the current architecture, elements of the monopoly concept no longer applies. Potential monopolist tendencies in all of these elements, separately, have been reduced by the ability of the end user to fabricate the elements of the network in a set of separable fashions. Together these elements clearly demonstrate no monopolistic power. The traditional theory on regulation has focused on the control over the transport facilities. As we enhance the network structures and provide differing forms of information transported, concern should also be focused on the other three elements (see Kahn p II 127). In addition, monopoly power even over transport was based on the users inability to individually justify the capital costs on the transport infrastructure. In certain cases, this is no longer the case, finding many users easily justifying payback in less than one year on new transport infrastructure

2.2 Architectural Alternatives

Is there a natural taxonomy for the set of network architecture alternatives? Do these present limitations on what can be done or are they extensive? Is there a natural limitation in the existing architectures that prevent the new technologies from introducing the new paradigms to the communications world? We address these issues in the context of several existing network hierarchies.

o Hierarchical: The current network architectures are structured in a hierarchical fashion. As we have already indicated, there are historical and technical reason for this architecture. We show in Figure 9 a sample design of such a network. Specifically, we see the set of transmission schemes connecting from a lower level to higher ones. A path may or may not go horizontally. It may go vertically, all controlled by a single control at the highest level.

o Centralized: A centralized architecture is similar to a hierarchical system in that the control function is centralized. However, the transport elements are not in a hierarchical format. This is shown in Figure 10.

The hierarchical structure is no longer present, but there is a single point of control. The control element covers all other elements in the system. A typical example of this type of network is that of a large bank in a metropolitan area. Part of the network is the local ATM (Automated Teller Machine) network and the voice network for the bank. Each are separate but the bank controls both from a single point of control.

o Distributed: The distributed system has distributed control, distributed interconnection and flat transport alternatives. This is shown in Figure 11. Here we first note the reduction in concatenated switch and transmission elements. The network is much less dense and the switch is actually co-located with the interface. The LAN networks are typical example of distributed designs.

o Segmented: A segmented network is really a hybrid. Each segment uses a sub architectures that meets the requirements of the existing system but the networks are interconnected through standard interfaces.

This is shown in Figure 12. In this case we show that this network architecture is an amalgam of the first three. What is still common, however, is the partitioning into local and long distance nets. A typical example of this network is that of a large corporate network. Part of the network can be for the voice circuits, controlled at a single point and based upon use of both local and inter-exchange carrier circuits.

The second part of the network is the data network, again using both local and long distance carriers, and control from a separate location.

o Partitioned (Local and Long Distance combined in a community of interest): In all of the above, we have assumed that local and long distance transport are separate. This is a world view dominated by the regulatory environment. We can see the segmentation along community of interest lines rather than along these more traditional lines. Thus one community of interest is a network for financial service companies and a second for a network providing service to the residential user. These each have all of the local and long distance services, but are now segmented by the user market or the community of interest. The sub architecture may be any of the above. This is shown in Figure 13. The major difference in this system is that we have segmented several overlay networks, each containing elements of the above four. This architecture allows for local and long distance in separate partitions. It says that you can segment the network by users not just by function. Had the MFJ understood users rather than functions, the results could have been dramatically different. An example of a Partitioned network would be that for American Express or Sears. It contains the set of local and long distance networks as well as subnets for specific distributed applications. However, each of these companies may have access to a separate public switched environment.

Understanding that there are several varying architectural designs allows one to better understand that each reflects not only connectivity but also the world view.

2.3 Impact of Technology on Architecture

We have just discussed the elements of the architecture and the embodiments of design that these elements may lead to. We shall later discuss the details of the technology evolution but it is appropriate at this stage to make several observations about the current impact of technology on architecture.

In the current telephone system, the interconnect element of the architecture is provided by the Central

Office Switch and the physical interconnection of the wires from the street to that switch. The point a which the many wires from the street meet the switch are at a device called the Main Distribution Frame (MDF). The Frame must be able to connect any incoming wire to any outgoing wire. The MDF, as it is called, has been the same for over fifty years. It is a manually connected system , where the craft person must connect each incoming telephone wire to a corresponding location on the switch, each time a customer moves or changes their phone number. In computer systems, this is all done in an electronic fashion.

In contrast, the central processing unit in computers goes through changes once every two years. The standard processing capacity curves show a doubling of processing capability in the same two year period, as shown in Figure 8. Computer users have a more rapid turnover of technology because they generally work in an environment with no regulation, shorter depreciation schedules and a focus on meeting specific business needs.

In contrast, the centrally based network must meet a collection of common needs and serve them in a least common denominator basis. The conclusions from these observations is clear. If change is at the heart of the services and technology is driving them, then migrating the elements to the customer of control, interconnect and interface maximize the change and innovativeness of the network.

In terms of a national network, this then begs the question, should not the network, as infrastructure, be nothing more than a broadband transport of open single mode fiber and let all other functional elements be provided by the end user.

Consider what was written by a Bell System polemicist in 1977 at the 100th anniversary of the Bell System at MIT. The author was ***John R. Pierce, Executive Director at Bell Labs***, who stated:

" Why shouldn't anyone connect any old thing to the telephone network? Careless interconnection can have several bothersome consequences. Accidental connection of electric power to telephone lines can certainly startle and might conceivable injure and kill telephone maintenance men and can wreak havoc with telephone equipment. Milder problems include electrically imbalanced telephone lines and dialing wrong and false numbers, which ties up telephone equipment.An acute Soviet observer remarked: "In the United States, man is exploited by man. With us it is just the other way around." Exploitation is a universal feature of society, but universals have their particulars. The exploitation of the telephone service and companies is little different from the exploitation of the mineral resources, gullible investors, or slaves." (de Sola Pool Ed, Pierce, pp 192-194).

The readers should note that this was written nine years after the Carterfone decision and five years before the announced divestiture. Pierce had a world view of an unsegmentable telephone network. This paper has the view of a highly segmentable communications system. The world view of the architecture has taken us from "slavery" of Pierce to the freedom of the distributed computer networks of today. Kuhn has described technologists as Pierce as the "Old Guard", defenders of the status quo. They defend the old paradigms and are generally in controlling positions for long periods of time.

2.4 Architecture versus Infrastructure

It is important to distinguish between architecture and infrastructure. We have extensively defined architecture in terms of its three parts; elements, world view and technology. Infrastructure unfortunately has been reified in terms of some physical embodiment. The discussion of NREN being an infrastructure is viewed by many as being a determinate thing. Kahin has, however, de-reified the concept in terms of it being an embodiment of a concept or set of common goals. We expand that and state that an infrastructure is an enabling capability built around a common construct.

There are four types of infrastructure views that are pertinent to the current discussions of networks. These are of particular import to such networks as NREN since they will lead to the policy directions that it will take. These four infrastructure types are as follows:

o Physical: This is the most simplistic view of an infrastructure. It requires a single investment in a single physical embodiment. The old Bell System was such an infrastructure. The National Highway system is such an infrastructure.

o Logical: This network may have separate physical embodiments, but all users share a common set of standards, protocols and other shared commonalities. All users have access through an accepted standard interfaces and common higher level transport facility. IBM had attempted in their development of SNA in the mid 1970's to develop a logical infrastructure in data communications. This was expanded upon by the ISO OSI seven layer architecture, selecting a specific set of protocols in each layer.

o Virtual: This type of infrastructure is built on intermediaries and agreements. It provides shared common access and support
interfaces that allow underlying physical networks to interconnect to one another. Separately, the individual networks may use differing protocols and there are no common standards. The standards are at best reflected in the gateways to the interconnection of the network. Thus this infrastructure is a loose binding through gateways. It is in many ways what is the INTERNet today, if we include all of the subnets.

o Relational: This type is built on relationships between the network parties and the establishment on higher level accessing and admission. Specifically, a relation infrastructure is based on agreements on sharing addresses, not necessarily common addressing, and on the willingness to share data formats and types. It is an infrastructure based on shared common interests but not shared common access. This type of infrastructure is what in essence exists in most cases today. Users can move from network to network through various gateways. The difficulty is the fact that the interfaces are cumbersome and may requires sophistication on the part of the users. However, more intelligent end user terminals and interfaces will reduce this cumbersome interface problem.

We show the relationship of these four infrastructures in a diagrammatic fashion in Figure 14. Our conclusion is that understanding the type of infrastructure that the coalition of users want, will also impact the architecture, based upon an imputed world view. Arguably, a physical infrastructure leads to maximum hierarchical control and the resulting impacts that such control leads to. This is a critical issue for networks such as NREN, since by choosing infrastructure and architecture may not be as uncoupled as desired. In particular, the selection of Gbps capability may really be GHz capability and is best suited to a Virtual or Relational infrastructure.

3.0 Technological Factors

In the previous discussions, we have assumed that there are certain underlying stabilities in the transport structures that enable the separate network providers to perform their tasks. There is a growth in technological capabilities that may cause dramatic changes in structures that we have discussed in the previous sections. In this section, we will focus on some of the dramatic technical changes and discuss the impact that they may have on the market equilibria established.

3.1 Transport Capabilities

Transport is the raw power to move information from one place to another. Transport is also viewed in its most primitive form, specifically bandwidth, rather than data rate. In current systems, transport has significant capital in the twisted pair plant as well as the fiber backbone. There are several alternatives to twisted pair that are evolving and we shall discuss their directions briefly. These directions may significantly change the view of capital allocation to the transport portion of the network.

Specifically the raw transport capabilities have been dominated by the capital cost of a twisted pair, with that single pair limited to a single voice channel. There are at least three technology areas of change that may impact the capital asset allocation equation. These areas are developments in fiber, radio and surprisingly in twisted pair itself. One of the goals of transport development is to have "Free" bandwidth access, or as close to it as possible, in relation to the other three network elements.

Under the current structures, this bandwidth is so segmented that it is impossible to foresee a free state.

Another factor in increasing the capital costs of the existing network is the need to add capital in large amounts and not in incremental amounts. Thus, a central office is added with the capability to handle several hundred thousand users. In contrast, with a fully distributed network, it is possible to add user capital as each user is added. We have discussed this issue in the last section and demonstrated that in an environment of rapidly changing technology, the cost-performance curve versus time is rapidly improving, so that small incremental changes allowed by fully distributed system optimize economic performance.

The following are three technological factors that will lead to the goal of freer bandwidth.

3.1.1 Fiber; Uses, Users, and Costs

Fiber has revolutionized the data networks in the United States. A single strand of fiber can transmit 10 12 bits per second of data. If we allocate each home, 100 million residences, with 100 Kbps of full time data, that is 10 13 bits per second if everyone in the US is talking simultaneously in this high speed data fashion. That is the capacity of just a single strand of fiber. A typical bundle of fiber has 25 to 50 strands and these are connected to other such bundles. The current fiber network is structured like past voice networks, and generally does not take advantage of the bandwidth of the fiber. Albeit the technology is not yet totally operationally capable, the world view of the system designers is one that is to use fiber as copper. Use it for one voice circuit after another.

As we have discussed, dark fiber is the most flexible form of access for the more sophisticated user. It enable the user to maximize the impact of processing power and it optimizes the tracking of the cost performance curves. However, it is a fully distributed system and thus requires the careful control of the infrastructure relationships established. It should also be noted, that although the fiber loss characteristics necessary to support a wide dissemination of dark fiber are theoretically available, this is only in a laboratory setting. There are no commercially available fiber systems to allow this in toady's network.

3.1.2 Radio Spectra; Access, Capacity and Cost

The current cellular system is being supplanted by new digital cellular technology that can support in excess of 100 times the number of voice channels in the same spectrum. It will be able to support data rates of from 1 Mbps to 100 Mbps. There is pressure to allow the cellular companies to widely deploy this technology and it has been estimated that the capital costs per cellular phone will become less than the capital costs of a wireline phone. The change in technology may make the replacement or build decision not one between fiber or copper, but between copper or cellular. The policy issue is the effective use of bandwidth. If the FCC, in the Common Carrier Bureau, and the FCC, in the Radio Carrier Bureau, can arrive at two different decisions, then there will clearly be a significant policy debate.

The two positions are as follows. First, assuming that the radio bandwidth is free, then if the new cellular technology is less capital and operational cost intensive then copper or fiber, should the FCC allocate the bandwidth in the public interest. If the answer to this is yes, then how should the FCC allocate this resource in the most competitive fashion. Does the current Cellular policy of two operators per system still hold, or should there be an imputed cost to the bandwidth in a bid process. If there is an imputed cost, who is to receive the economic benefit.

The radio technology will allow many others to enter the market, restrained only by the bandwidth limitations on available spectra. This represents a potential destabilizing technology, especially for residential and rural networks.

3.1.3 Twisted Pair; Utilization, Capability and Sunk Cost

As we mentioned before, twisted pair has been limited by culture to single voice channels or 64 Kbps at a maximum rate for data. Current advances allow for transmission at rates of 100Mps on unshielded twisted pair. Thus it is possible to continue to utilize much of the existing copper plant for the types of data services that are required by many customers. Therefore twisted pair should not be considered defunct.

3.2 Interconnection

Interconnection is the architectural element that provides for the function of allowing each user to interface with other that are connected to the network. In the existing telephone network, switching as we know it was introduced since bandwidth was very expensive. It was not primarily introduced for the purpose of interconnection. Thus the central offices of today are not there for the sole purpose of connecting one user to another. They are there, primarily, for the purpose of concentration on trunk circuits, and thus preserving bandwidth. If one looks at the development of the communications technology through the Electronic Switching Systems, the intention was always to utilize the voice channel trunks at as great a level as possible. It was not just to interconnect one user to another.

Past interconnect technology began first recognizing that bandwidth was expensive and that concentration on the trunks was also essential. In the past, a twisted pair could support only one voice channel. A central office could readily connect one local user to another local user through the switch by merely closing a crossbar relay or a fereed switch. For connections to other central offices, trunk networks were needed.

Since copper was expensive but of very limited carrying capacity, it was necessary to design the switching or interconnection network to first minimize the need for copper trunks and then to assure that full interconnection could be achieved. The view of the network as a hierarchical design was a world view based upon the paradigm or technology of copper twisted pair, of copper as a limited bandwidth transport vehicle.

Changes in technology show that interconnection can be migrated to the customer premise. As we have indicated, the capability of a single fiber is adequate to handle all of the telephone users in the United States. The interconnection in this system may be done by assigning each user a separate frequency and using a laser tuned circuit to perform the switching function. Thus the switch is at each customer telephone, and all that is necessary for the transmission function is a single strand of fiber. Point of fact, there is research under way at MIT and other institutions to develop just such systems. In extremis, this approach reduces the public switched network to a commodity based transport only facility. If we accept the validity of this alternative world view, then we can dramatically see the changes that may occur in the national network.

3.2.1 Central Switched Networks; Monopolistic Necessity

The central switched network was the result of the bandwidth preserving approach of the nineteenth century. It was further reinforced by the regulatory emphasis on rate of return regulation. In addition, this approach assured a barrier to entry to any form of competition.

Figure 15 depicts the architecture of the current centrally switched networks. This starts with the Class 5 central office switches, moves up to Class 4 trunk or tandem switches and migrates even up to a class 1 switch, which handle only excessive overflow traffic.

3.2.2 Fully Distributed CPE Based Interconnect; Free Bandwidth

The first entry into a distributed interconnection capability was the local area network technology, LANs, particularly Ethernet connections. The Ethernet connection provides a fully distributed interconnect capability. In the Ethernet configuration, each user has an Ethernet card in their machines and it is in this card that the signaling on the Ethernet channel carries the signaling and interconnection information. The signals have information of the source and destination of the packet message. This is read and decode by each of the terminals on the network.

Ethernet was the first architecture to challenge the existing hierarchical architecture in the interconnect element. It empowered the end user to control the interconnect function directly and enhance it as the needs required. With the introduction of routers, bridges, and gateways, more complex inter-network connections can now be achieved. Thus LAN intensive companies can inter-network all of their locations on a fully switched basis by use of CPE based systems, and use only the direct point to point transport of the common carrier.

As we see the expansion of the bandwidth on a fiber loop, the capital investment of fiber per unit data is de minimus. For example, if the fiber costs are $50,000 per mile, and one can carry even one Terabit per

second, or 10 12 bits, then the cost per bit per mile is $5 10 -8 per mile. That is it is one the order of a millionth of a cent per mile. If we use a million miles and the capital costs are a cent per bit per second. In effect, technology is driving the bandwidth costs to zero, as compared to other costs,
In Figure 16 we depict a simplistic view of a fiber network. In this network, we envision that all of the transport is in the network and that the interconnect, control, and interface are part of the CPE. This is a Terabit per second network that allows the end user the maximum in interface capability. The end user may access any and all of the data capabilities of the transport network, not limited by switching or other elements.

This technological change will undoubtedly change the world view of network providers. If bandwidth is relatively free then the use of processing at the CPE becomes a vital ingredient in the network design. The hierarchical network is no longer the only choice, in fact its viability is called into question. The move towards that end, as we have already shown in the LAN area, is already under way. The development of new means of interconnect will result in significant changes to the network. Specifically, we see;

o The network will become more organic. The end user will have direct control and access to the interconnect, interface and control functions.

o There will be less materiality of scale. In the current architectures, there is scale and the performance of interconnect is a result of the scale of the network. Simply stated, we need a big network with a great deal of switches so that we can talk to one another. In the network with user controlled interconnect and "free”

bandwidth, the materiality of this scale is no longer a factor. That is, infrastructure is at best irrelevant and at most counterproductive.

o Multiple overlay networks are connectable, from both within and without the core net. Thus, viable overlays can lead to local short term optimizations that meet end user needs.

o Intelligence in the CPE is expansive and reduces the capitalization needs for networks. It also reduces the time scale factor for the introduction of new technologies mapped to the technology change curves.

3.3 End User Interfaces

The use by the end user is the driver for new network applications. That end user must have some economic justification for the use for it to be meaningful. It must fit the value chain of the user or of the customers. Unless this is the case the result is a technology in search of a market. There are four elements of the end user interface that must be explored, the first the physical constraints and the later three the application specific elements. Specifically, the user interface must first be a functional input/output device, displaying information in its broadest sense as well as enabling the user to interact with all elements connected to the network.

For the most part, the last ten years has seen the evolution of the end user interface from a dumb terminal to an intelligent, highly interactive, display device. It will be in the end user interfaces that the new drivers for network usage will arise. As we have indicated before, the world view of the telecommunication network was based on a voice modality of instantaneous communications. The new modalities are focused on multi media and multi user communications systems. There will be an integration of video, voice, text, image and other sensory interfaces. More importantly, there will be more processing power in the terminal to perform the tasks that the network now performs best in its hierarchical way.

3.3.1 Terminals and Displays; Uses, Access and Price

The evolution of the end user terminal has been and will continue to be the major driver in changing the architecture of the network. The use that is made of the conversational nature of communications, the sources and structure of the dialogue, will combine multiple media modalities. The second trend is that of a more intelligent end user terminal. This intelligence is not only
in the physical processors in the terminal but also in the distributed software capabilities that reside on top of the device. A fully distributed operating system environment, as well as a fully distributed database

environment, will allow for highly interactive communications environments. Users will be able to share information of significant data content in a fully distributed and real time fashion.

Moreover, the functions of network management, network administration, and interconnectivity will be controllable at the terminal end and not reliant upon a single hierarchical network. In fact, the structure of a regimented network with its hierarchical structure may actually inhibit certain types of applications development. For example, in the areas of multi media image communications, the need is for as great a bandwidth as possible, with as little network control as possible. The use of the OSI lower layers, such as data link, network and transport, actually add significant delays into the communications link. For example, in the transfer of a compound multimedia image of a 100 Mbit image, a set of four synchronized voice signals, and a video segment, the use of either an ATM switch or SMDS switch, using cell transfer rather than full frame transfer, can result in delays exceeding five seconds. The packetization required seriously effects the overall response time and performance.

3.3.2 Information; Target Markets and Economic Returns
Information networks have evolved over the past fifteen years with the early introduction of the database services of such market leaders as Lockheed, with the Dialog system. This industry has evolved along market niches, providing such markets as the financial services market with a wealth of information sources. Companies such as Reuters, Knight Ridder, Quotron, and others have made this segment a billion dollar industry. However, there has been little or any interest in the consumer side of the information market. Information is a strategic element in a corporation's competitive advantage in the market. It is not, and has not been a major element in the consumer market. The consumer is focused on entertainment and not information.

However, the evolution of the network architectures will depend upon and will influence the information interfaces to the end user. Currently, there are significant delays on the Dialog link due to limited transport and the single location of the database storage. With a fully distributed architecture, the Dialog system can be moved from it current location on the San Andreas Fault and become distributed in multiple locations. Users will be able to obtain real time full text information for off line perusal.

Information can also be provided in a distributed form, and no longer in a hierarchical form.

3.3.3 Transactions; The Electronic Distribution Channel
Judge Green has looked to Gateways as a means to enter the information age. As noted, information services are naturally a valued added benefit to commercial users and the consumer is generally interested in entertainment or at most a limited transaction capacity. Transactions are also purchases and to obtain the purchase the seller must not only have access to the buyer but also must promote and persuade. The video medium that currently exists is a promotional medium and creates awareness. It is still questionable whether it is persuasive.

The vision of Videotex has been significantly blemished over the past ten years in the United States. We all too frequently look to the success of Minitel in France, but we all too often have no knowledge of the French Telephone System. Telephone Information Operators in France are almost non existent and when available have been known to hang up on customers in less than the most polite fashion. In addition, the French Telephone company, in conjunction with the French Newspapers, developed a way to ensure a noncompetitive advertising market in an electronic fashion. The classic yellow pages were abandoned, the terminals were underwritten by the government as a social action move to develop a technology base, and the public turned to their favorite pastime, now in digital form.

Minitel is not the harbinger of things to come in the area of home information systems. The regional Phone companies have all introduced videotex gateways for use of information services. These have been of little success. It is still to be determined what the consumer wants from electronic information services.

As indicated, the use of the communications channel through the end user interface allows for a distribution or sales channel for products or services. Promotion and persuasion are critical and these require high quality, personalized, self segmented, full motion video. The impacts on the network are significant and it is possible to perform this task only with the extended network that we have developed.

The architecture of user empowerment is essential and existing networks cannot meet the needs.

3.3.4 Entertainment:Generator of Revenue

The entertainment interface has been the television set and the transport mechanism has been the coaxial cable of the CATV operator. Fiber to the home or other possibilities are dependent upon the entertainment driver. As we shall discuss latter, the CATV provider has a secure monopoly of service. The entertainment interface will be driven by that supplier.

3.3.5 Totality of Interfaces

In Figure 17 we have dedicated the totality of interface elements. It is a conjunction of transaction, information and entertainment, overlaid on displays and input/output devices. The focus on the residential side will require an amalgam of these factors. The convergence on the commercial side will require transactions and information. The transaction element is key to the overall success. Thus in evolving networks, we should not disregard the transaction portion.

The key conclusion from this section is that technology has changed and with the power to perform most if not all of the network functions placed in the user's hands, at drastically different cost factors, the need for infrastructure, viewed as a single logical reality, is no longer necessary or possible. In the next section, we shall show the need, first, to meet the market demands, and second to create value for all users.

4.0 Market Environment

The primary driver for the development, application and usage of any resource or asset is the set of market elements who view this asset as a means to increasing value in some form. We assume that there exists a rational consumer and that in turn the consumer has a set of utility functions that can be maximized or optimized by use of this exogenous asset (See Henderson and Quandt). Understanding the current segmentation of the market by use and user allows for a rational approach to the focusing of additional assets by the provider of the communications infrastructure (Porter, 1980, 1985). However, one must be careful of the possibility of a circular reasoning that says that the current market is the basis set for extending the future market. The current market is conditioned by the existing trends in prices, accessibility, and performance. If this is changed, we must be careful to assess the change in the future market. Specifically, Mandelbaum has indicated that the users become de facto market makers and that they are empowered by the unbundling of the network elements. The market maker influence is critical in understanding the dynamics of the network architecture revolution.

Value creation and transfer is the key construct in understanding the market and its relationship to the new paradigms created by broadband networks. Value creation and transfer (See the discussions in Fruhan in terms of the quantitative measures of value for users). Value can be measured if the impact of the new technology or paradigm is understood in terms of its impact upon the user of the new technology. Meeting the needs of the end user is creating this value or the transfer of this value. Understanding the market is truly understanding the needs of the user as the user perceives them and not assuming in a Kantian sense what the user "should need".

In the current market understandings of the market even by regulators there is a change in the understanding that value to users mus be created. For example, Noam has indicated that:

" Perhaps the greatest common failing of these traditional organizing ways of looking at the telecommunications principles is that they concentrate "supply-side" analysis. That is, they look at the subject from the angle of the production and the producers... Thus, one should not view deregulation as a policy of primarily liberalizing the entry of suppliers. Just as importantly, though much less obviously, it is the liberalization of exit, by some partners, from a previously existing "sharing coalition" of users which has become confining.”

Clearly, the need for user empowerment, the formation of new coalitions and the establishment of infrastructures unbound by the physical only are critical. It is essential to look at telecommunications from the users standpoint and not the suppliers. Deregulation is not, as Noam points out, the freeing of the suppliers as much as it should be an empowering of the users. Thus, in this section we discuss the dimensions of the market makers and the market players. We also note that regulation all too often controls the providers and all too often dis-empowers the user.

4.1 Market Players

The market players represent the segmentation of the users of the telecommunications markets assets.

They are motivated to do so in a rational fashion and do so as to maximize their utilization criteria. For example, if the set of market players are large corporations, then the use of telecommunications is that of a strategic asset to increase their overall competitive advantage. That advantage may, and often is reduced to a simple set of financial returns. In contrast, the consumer or residential user tends to maximize a utility function that is much less well defined and is of increased complexity. It relates to alternative expenditures for such items as leisure and entertainment.

4.1.1 Commercial User

The commercial user of communications network generally is a corporation who is using this communications capability for either strategic or tactical purposes in their business. Such companies as American Airlines have used the communications networks as a means of capturing market share through the concept of the electronic marketing and distribution channel (See Konsynski and McFarlan for a discussion of how this may expand beyond just a single user into a coalition of users. This builds on the concept of Noam as well as that of de Sola Pool). The tactical application is the use by companies in the operations of point of sale services.

The commercial user's market dynamics are most easily understood. Value creation can be measured because the commercial entity has carefully analyzed and studied the structure of the business and can immediately measure the impact of new means of productivity.

4.1.2 Consumer User

The consumer user of communications has the lowest level of expectations in terms of the delivery of services. This user is expecting at best adequate local and long distance communications. The suppliers of communications view this segment as a significant source of new revenues. The CATV companies use their access channels as means for entertainment distribution, only (See McGarty & McGarty, 1982, for a discussion of the market needs for CATV). They offer a level of service and a level of expectations that is dramatically different than that of the telephone provider.

Consumers have a complex set of benefits. This set is often not readily measurable and there may not be a ready realization of the quantitative benefit. The concept of a utility function or preference function defined for the consumer on an individual is generally quite difficult to measure. In contrast, in consumer markets, market segmentation allows for effective and efficient measures of impact. This will allow for a measurement of the impact of such new products and services that broadband can bring to the consumer.

However, past experience, as we have already discussed, has shown that consumers are quite complex and their behavior in the use of electronic elements has been difficult to predict and variable in its response.

Corporations who have based their future on understanding the consumer have failed in repeated cases in developing electronic services to the consumer. This is a clear warning to academics who attempt to think that their needs are reflective of the masses that make up the consumer market. One can simply imagine an MIT student designing a consumer product, assuming that a UNIX (TM, AT&T) interface and use of LISP is essential because it gives him/her the best response.

4.1.3 Government User

The government user is focused on meeting policy driven directives. The government user is generally slower to act, acts in a highly competitive cost efficient fashion, and is generally risk averse. In addition, the government user must deal with large coalitions of users with often conflicting goals and objectives.

This market represents the most difficult to deal with as a result of the internal stress.

4.2 Market Drivers

The market for communications services is driven by the needs of the end users. These clearly are different for the three market segments that we have just described. market drivers are those factors that lead users to demand and use services. The market cycle is shown in Figure 18 depicts the need benefit cycle for the user and the provider. This cycle is the same for both the commercial and the consumer user.

For example the cycle has the following dynamics (See McGarty, 1989):

o First, The supplier has the need for new revenue. This need is recognized and an investment in a changing distribution capability is created.

o Second, the user is provided a certain set of benefits. The user is first to benefit. In some cases, even though the supplier of the service desires to benefit, he must first provide that benefit to the customer.

o Third, these benefits convert into user needs. The user takes time to recognize the benefits and then to internalize them into needs. Needs the create demand. A need provides the basis for a sustainable demand.

o Fourth, the user needs convert into supplier benefits. This occurs latter in the cycle. It is critical to note the significant time delays in this process.

This cycle takes time for new and innovative products or services. This cycle may also be broken at any single point and result in the dissolution of the specific market opportunity. However, the basic concept of the need-benefit cycle still holds true. The dynamics of the cycle impact the value of innovations to all players. Delays and the impact on imputed interest costs will increase the need for payback to the investor.

Thus the cycle and its dynamics show that value creation results in lower value as the time to complete the cycle increases.

Consider the example of the development of electronic banking, specifically the use of ATMs (See McGarty, 1980, 1981, for a detailed discussion of this technology and its early development). Initially banks wanted or needed to have less costly means of service their customers. In addition, the banks viewed this electronic marketing channel as a means of attaining greater market share based on the concept of location. This service was not needed by the consumer at fist but it did provide a set of benefits. These benefits were targeted at the select share of the market, namely the young and well to do segment. By having the ATM network, the bank could provide this segment of their market with the benefits of cash at any time and at any location. This consumer benefit then changed into a consumer need and the broader base of banking consumers requested the service. Then, this resulted in a direct benefit to the banks as the size of the electronic banking led to them (See Zuboff, pp 132-145). The same will apply to accruing the benefits from use of the NREN. The market drivers then are the factors that meet the needs of the supplier and the benefits of the user.

We can expand this into the needs for broadband communications services. As we discussed before, NRI is interested in developing broadband, as defined by Giga bit per second data rates, from from a national infrastructure perspective. Their initial focus is on national super computing networking. In contrast, there are many applications for imaging that are directly related to solving end user requirements of current interests. For example, the printing, publishing and advertising industry is going through an major infrastructure change. There are Apple Macintosh computers in use for ad composition, editing, and layout. There are digital prepress systems that allow for digital printing. There are not, however, the electronic means to connect these two systems. If there was an effective system, then advertising agencies could cut operating costs an estimated 5%, and press time could be shortened several hours. These are significant impact factors in this business (See McGarty, Nov., 1990).

A second current application is in meeting the needs of the medical imaging community. For example, if a large hospital can take the responsibility of reading the x-rays for a local HMO, the current costs are on the order of $60 per patient per procedure. It has been shown that just clustering the readings have a scale economy that reduces this cost to $40. If we further include and electronic imaging system with a Hospital Information system, these costs drop to $20 (See McGarty and Sununu, 1991, for a detailed analysis of the impact of the use of imaging technology in a Health Care environment. The authors detail the cost savings directly attributable to this technology and presents results from actual operations. The authors have also developed an extensible methodology for determining cost benefits in this type of broadband environment).

These two simple examples show that there are clear and present opportunities for broadband that are local and that, if properly structured, meet the market needs. These two examples also result in two conclusions. In addition, these examples show that customers can and do, today, create their own infrastructures using the new technologies. In the small, this clearly shows that a global infrastructure is not only not needed but would be redundant. Specifically:

o End users drive technology through their value chain productivity gains. Lowered costs or better competitive positioning are essential. Broadband provided scale economies to businesses that heretofore may have had little.

o The development of broadband does not require a large infrastructure. It can be built around focused local networks and applications. The needs of the users are not just transport. The interfaces and interconnections are more significant drivers in an information rich environment such as imaging.

Moreover, these examples have shown that today's transport, control, interface and interconnect technologies meet current needs. The migration from current systems to broadband is possible and achievable and are also economically efficient. Speculative applications based upon non-market drive idealizations will clearly not replace currently customer directed and driven applications.

4.3 User Value Chain

The generation of value by a user has been discussed in a dynamic sense as the creation of value by increasing productivity on the part of a user or allowing for the development of new revenue sources.

Value was defined in terms of the increase of the flow of funds to a firm by performing a specific task.

The value chain concept, in contrast, is a static view of value projected back onto the operational elements of the firm. It is a key concept in the full grasping of the value flow to a firm with the introduction of a new technology. The value chain analysis, as developed by Porter (Porter, 1980, 1985, 1990), is a construct that overlays the rational utility function maximization process of the commercial user. As we indicated in the preceding paragraphs, we will focus on the commercial user because their utility function is generally more evaluateable and can be readily related to a rational decision process.

We demonstrate the concept of the value chain in Figure 19. We show the provider, the user and the customer. This is the natural food chain of the economic market place. The provider must provide the user with effective supplies necessary for the production and delivery of goods. The user, to attract a customer, must also provide the customer a similar set of benefits. If we view the revenue of the user as the size of the total box, and the expenses as their corresponding areas, then the users profit is the area left over after all expenses are taken care of. The revenue is provided by the customer, the expenses controlled in part by the provider. The company, namely the user, spends money on horizontal elements such as Administrative functions, and vertical elements such as Software development. The allocated profit is represented by revenue less expenses in each segment. The expenses are a product of a factor driven by the customer demand, the revenue factor, the company's productivity, and a unit cost. Thus for a fixed revenue, profit is increased by lowering costs or increasing productivity. The information networks that we have described are productivity enhancers, thus profit enhancers. This is the essence of the Porter theory.

The value chain concept views the user as an operating entity with sequential and simultaneous operations as part of running the business. The sequential operations follow the flow of goods into the establishment, through the processing done to add value and then out of the establishment. The simultaneous operations are followed over all tasks and may include such functions as finance, legal, and marketing. The company can then allocate costs and value to each of these elements, and then can compare them to its competitors.

The costs of each step in the process are the result of three factors; the revenue drivers, the unit productivity, and the unit costs. The use of information or communication networks allow the user to improve the productivity or reduce the costs. This allow for increased competitiveness and thus better margins. If the seller recognizes the value chain of the buyer, then the product that is sold can be positioned in a similar fashion, thus helping the buyer to improve their value chain. This will increase the revenue to the seller.

The value chain analysis provides a methodology to integrate the effects of communications and information services into the evaluation of a business. Porter has done this for many segments of many industries and McGarty (1989) has developed a detailed micro model to use in a detailed competitive analysis. As we look at the market factors, value chain theory states that the use of any new technology must be evaluated in terms of not only the end users value chain but also the value chain of their customers. The chains are linked and the effect is complex

5.0 Government Networks

Recent changes have seen a migration of Government networks from the totally owned and operated FTS to the leased FTS 2000 evolve. It will be argued that the Government, as a customer, is neither a key player in defining architectures nor do they drive the trends in new and innovative systems and services.

In fact, as we shall demonstrate, they are at best the preservers of the existing world view in an attempt to minimize risk and reduce perceived increased costs.

However, before continuing, there are several factors about the Government nets and their past achievements that are appropriate. Dr. Robert Kahn, formerly Deputy Director of DARPA, husbanded the ARPA net through its infancy (See Markoff, 1990). During that phase, he approached AT&T to work with DARPA on the new and emerging packet technology. Kahn indicated that AT&T not only failed to understand the technology at that time but further were very slow in providing the Government with the information to use the existing modems that it provided in its existing network. Thus Kahn, despite the position of AT&T, developed a true infrastructure network. Out of this evolved the current packet nets of today. However, these networks have been supplanted in many ways with other technologies, primarily those on the customer premise, such as LANs, combined with user specific virtual networks. The reason for the change was that the original premise of the packet networks usefulness as an infrastructure which was that of cost reduction for the computer user. With the breakup of AT&T that equation changed and now users have a variety of cost performance tradeoffs that are both available and more attractive.

Currently Kahn is moving in other directions, as head of NRI (The Corporation on National Research Initiatives), a not for profit research consortium, he is pursuing the vision of a broadband network, called Aurora, that will build on a research consortium of various universities. The goal is to interconnect supercomputer over a Giga Bits per second network. In the ARPA Net days, the goal was clear; computer to computer communications in a cost effective fashion. In the current scenario, the goal is more elusive.

However, the world has changed. The world now is one of high competition, intelligent terminals, and a migration of many of the networks old functions into the end users devices. Can even such a government infrastructure be justified in light on the underlying equation?

In addition, the drivers of networks today are the applications that the end users are to put on the network, not just needed to transfer large computer data files. Thus one is faced with the quandary of placing a sophisticated network in place to challenge the applications developers, or to let the applications developers stress the network to its limits using the driver of customer or end user demand. A research network must be flexible to stress the technology but not too costly to result in preordained failure. The major accomplishments of the ARPA Net were electronic mail and layered communications protocols.

The former was what every Net user found of use on the net and the layered architecture was a natural offshoot of all of the interfaces required to meet some form of flexibility.

5.1 Structure

The Government networks can be divided into federal and state networks. For the most part we shall focus on the Federal networks. There are two extremes in these networks, DoD based networks and non DoD efforts. We shall not focus on DoD because of their special infrastructure requirements. Non DoD networks have been focused on the meeting of a wide set of standards. They must balance the needs of the voice user and the data user. Further, there is currently a need for both interconnection as well as ensuring security in the network. For the most part, the Government networks have outsourced the management and control. The control functions, such as billing, are eliminated by the bulk buying characteristics.

5.2 Competitive Environment

Clearly, the Government networks are in a noncompetitive environment. At best they are limited market makers as described by Mandelbaum

5.3 Optimization Criteria

Performance in the Federal Networks is best exemplified by the FTS 2000 effort. The requirements for the network were developed and the selection of the provider based on cost competitiveness.

5.4 Evolutionary Constraints

The major evolutionary directions for the Government networks are based on meeting their user coalitions needs while doing so at a minimal cost. In certain cases, such as in DoD networks, advanced technology will be employed. Other than this specific case, they will generally be followers of other network leaders.

6.0 Public Switched Network

The Public Switched Network is the result of an evolutionary process that had given rise to the Bell System and has resulted in the current structures under the Modified Final Judgment (MFJ) strictures (Coll; Geller; Kraus and Duerig). The network is based upon a set of technologies that require massive investment in capital assets to allow for the interconnection of many users to each other. The system requires massive switching infrastructures since the underlying transport facilities, the classic copper cables called "twisted pairs", have very limited information carrying capacity.

6.1 Structure

The public switched network is built around a hierarchical architecture that makes several assumptions of its environment and the customer base. These assumptions are (See von Auw for the insider Bell System view, pp 334-398; see Toffler for the external consultants vision of where the Bell System could have gone):

o Bandwidth is a costly commodity so that it is necessary to provide for concentration of circuits on trunks and tandem lines. This concentration leads to the need for multi layered switching centers, a Class 5 Central Office being the lowest level.

o Voice is the primary means of communications and all circuits are to be considered multiples of voice circuits. In addition the voice is to be sampled at a rate of 8,000 samples per second and the number of bits per sample may be from 7 to 8.

o Universal service is necessary in order to meet the needs of the state regulatory bodies, This means that telephone service must be structured to cover the gamut of the rural home to the large corporation.

o Quality of service is to be as high as possible with overall system availability to exceed 99.95%. This implies redundancy, disaster recovery systems, and a trained workforce that will permit as near as real time restoral as possible. New York telephone has in twenty years responded to crises that would have sent other US corporations reeling in chaos. Their response allowed restoral of services in extreme conditions of distress (See the recent paper by Bell discussing the fragmentation of the telephone network).

o The focus is on operations, namely keeping the network service up to the performance standards set, and this implies that the work force must have the capability to deal with complex operations requirements in multiple positions. All people should be cross-trained to meet the level of service expected by the consumer of the service.

These assumptions make the local telephone company an infrastructure entity. The telephone company as the local operating company has a highly redundant, high quality of service, with a highly integrated work force.

If we look at this network in terms of our architectural elements we see the following:

o Control: The control is highly centralized. The control emanates from a set of methods and procedures, flows through the overall control mechanism for the network and is integrated to the maintenance and restoral efforts.

o Interconnect: This is a truly hierarchical interconnect. It is based upon the Central Office Switch, which is designed to conserve bandwidth at the trunk side. It provides a level of common access based on a single voice channel.

o Transport: The basic transport is the twisted pair to the end user. There is fiber in the loop and some fiber to the user, specifically those users in the higher data rate category.

o Interface: Generally the interface if the telephone handset. More recently, the interface has been expanded to include data sets.

In contrast to the ongoing performance levels of the Regional Bell Company, the interexchange carriers (IECs) do not have to meet the same levels of service. The recent AT&T service outage in New York with their Class 4 and Class 3 switch outages showed how the level of service has dropped for the IEC level (See Bell p. 36). Specifically, the IECs have recognized that a level of service may be priced on a differential basis. This is in contrast to the pricing structures for the local operating companies whose service levels are more closely controlled by the state Public Service commission. It is of question if there is to be a divergence in service levels over time, between these two types of carriers.

6.2 Competitive Environment

There has been great discussion on the threat to the local carriers from the bypass carriers. The bypass carriers have had some impact but has not been as serious as expected. The true competition has typically been from the changes in technology. Specifically the user has in the past used a set of single voice circuits not having the capability to multiplex them over several higher data rate lines. With the introduction of T1 or DS1 (1.544 Mbps) circuit, now it is possible to get 24 voice circuits for the cost of 8.

In addition it is also possible for customer to get DS3 or 45 Mbps circuits for 8 times a DS1. Thus the technological innovations in multiplexed circuits are the internal competitors to the existing single voice circuits.

6.3 Optimization Criteria

The economic performance of a public switched network has evolved over the past ten years in a new direction. The rational behavior of any firm is to maximize their profits (Pindyck and Rubenfield). This rational economic behavior has been the incentive for any company to invest. However the PSN is inherently a monopoly in many market segments and thus operated as a monopolist. In 1980, the strategy of the PSN provider was to maximize the rate base subject to the constraints applied by the Public Service Commission (Kahn, Spulber).

We introduce performance elements, P_i, which defines the measure that is maximized or minimized in the rational business decision process. We can relate it to the standard utility function of microeconomics, but will not do so in this paper. In the past, the optimization criteria for a telephone operating as a public utility was;

$P_{PSN} = \max(\text{Rate Base}|\text{Universal Service, Level of Service})$

In contrast as the regulation as been changed some new forms of performance measures have evolved.

Specifically, we have;

P_{PSN} = min(Cost| PSC Price Caps)

From a rational investment point of view, the corporation should be acting in such a fashion so as to maximize the net present value of the company as reflected in its discounted cash flow. This is the strategy that leads to maximum return for the shareholder (See Fruhan for value creation, transfer and destruction, also Lawrence and Dyer for the analysis of the transition of AT&T from strategy 1 to strategy 2). This optimal strategy can be given as:

P_{PSN} = max(NPV(Cash Flow)| Level of Service)

6.4 Evolutionary Constraints

The current evolutionary thinking in the public switched network takes it from ISDN to Broadband ISDN with ATM switching. It is an evolutionary path that is built on the world view of the nineteenth century system of hierarchical switches and the need for universal service. It is driven by a need to provide the same data transport, at almost the same time, to business customers as to the residential customer. It does not readily admit the flexibility of multiple overlay networks, allowing for segmentation of service. It is predicated on the assumptions of high per user capital investment and allocation of costs in a rate based world. Much of this thought process is, however, driven by responding to a Public Service Commission demand on a state by state basis for equality of service.

The question may be asked as to why the local operating companies have not taken a more active role in the development of the regional networks. There are several obvious answers and those not so obvious.

Clearly, in the case of most regional networks, NYSERNet being one, inter LATA transport is necessary.

New York Telephone took a key role in the early stages, however it had to deal through Rochester Telephone to legally work with the NYSERNet efforts. In fact, it is even considered in violation of the MFJ to manage an inter LATA network. Thus, for MFJ and other regulatory reasons, the local operating companies are wary of involvement. A second reason is the general voice focus of the Regional Phone Companies. The emphasis on data in the networks of the type such as NREN go beyond the general network infrastructure supported by the local operating companies. A third reason is the questionable economic viability and extensibility of such academic networks.

7.0 CATV Networks

CATV networks have evolved over the past thirty years from a simple local distribution service for off the air television transmissions to highly complex communications networks with a centralized architecture.

In the early 1980s the CATV carriers were required to make all of the cable systems have the capacity to carry two way transmissions and it was implemented in 1980 by the Warner Cable company in the now classic QUBE system (See McGarty 1982, 1983 for a technical description of the system and Couch, McGarty and Kahan for the market structures). Two way cable was further expanded to provide for both data and voice transmission. The first data circuits were provided in 1982 by Warner in Pittsburgh, providing 1.5 Mbps data communications to Westinghouse in a metropolitan area network. In 1983, Cox Cable (see Tjaden) implemented, with the assistance of MCI, a fully switched voice communications system over the cable network. In 1983, Warner Cable reached 100% penetration of optical fiber in its backbone trunks, from hub to head ends, in the large Metro systems. In late 1983, Warner Cable developed, and field tested a full motion video, on-demand, videotex system in a joint venture with Bell Atlantic, Bank of America, Digital Equipment Corporation and GTE. After determining that the time was not appropriate this trial was canceled (See McGarty and McGarty, 1983). However, GTE took the Warner developed technology and further developed for its cable trials in California. Unfortunately the GTE trials lacked a market driven partner and they too failed. Despite the failures, these trials showed that the cable industry, almost a decade ago, had developed, tested and marketed systems that are still to be implemented in the telephone network. This limit is not a technical or market limitation, it is clearly a limit of judicial mandates on market expansion.

Thus in many ways the cable industry was far ahead in meeting the needs of all classes of users as

compared to the telephone companies. Much of this was a direct result of the lack of regulation and willingness on the part of the customer to infer the existence of and agree to an underlying priceperformance
curve.

7.1 Structure

The CATV networks are structured to provide for the distribution of entertainment to the home. These networks are centralized in form an as shown in Figure 20 they have a head end that operates the local area, a set of hubs that are distribution points and possibly sub hubs for local regeneration. The systems are generally one way broadcast but have a two way capability. The one way may be 50 MHz or more and the return channel is 50 Mhz or more. The systems are primarily coaxial cable, although they are being expanded to include fiber. Some of the existing systems have a fiber backbone
The architectural elements for the CATV networks are as follows:

o Control: The control is generally from a central facility in the network. The systems are broadcast only and thus distributed control of the network is limited.

o Transport: The transport is very passive. The coaxial cable used in these systems is a limiting factor. It has repeaters along the route and and these are limiters to the cable design. With the introduction of fiber in the CATV local loop, however, this will change and the cable transport will have the capacity for any bandwidth. Even in the current systems, there is not the segmentation as in copper. Cable could provide any user in the reverse path with any part or all of the reverse 50 Mhz of bandwidth today. In fact, in several of the Warner QUBE systems, this was commonly used for commercial data circuits. Thus the CATV systems are dramatically different than Telco system in that ability to assign and allocate full capacity on transport to any user.

o Interconnect: The interconnect capability of a cable system is fully distributed. In the QUBE system, a polling scheme was used which was centralized. In the Cox INDAX system, the scheme was a CDMA system that was fully distributed. Thus in CATV both extremes have been used. In fact, CATV used the first version of the IEEE 802.6 protocol in the CDMA designs, this being the basis for SMDS systems.

o Interface: Cable allowed a wide variety of interfaces, ranging from TV converters, to PCs and video games. This is dramatically different from the limitations on Telco networks.

7.2 Competitive Environment

The cable systems have a natural monopoly in their underlying franchise licenses. These licenses are awarded on a municipality basis and generally assure the local governments a certain percent of the gross revenues from the system. Thus it is of immediate gain to the local governing bodies to maximize the revenue from the cable systems to achieve the greatest revenue source from the cable operator. The current law limits this implicit tax to 5 %. We consider the competitive environment of the cable system under three differing scenarios and these are presented in Appendix A. The conclusion of that analysis is that cable is a stable monopoly under current conditions.

7.3 Optimization Criteria

The original criteria for economic performance was one that was driven by returns to investors. The CATV business was a means for many investors, using both tax shelters and capital gains rates to obtain significant overall returns from their investment. Thus, negative cash flow in the early years was very important to shelter income and positive cash flow deferred to later years was essential for the payout.

This led to the following criteria for cable systems.

$P_{CATV} = \max(\text{Cash Flow}|\text{Service Areas, IRR})$

This has been changed to:

$P_{CATV} = \min(\text{Cost}|\text{IRR, Level of Service})$

due mainly to the change in the tax laws. In addition, there has been a maturing of the cable systems and they are now run on the basis of commonly accepted operations and business factors. That is, the driving need for capitalization is no longer as critical. It could be questioned, that given the great capital needs for the cable systems, if the tax law had been changed ten years earlier, would there be the cable infrastructure that we see today. Clearly in the current finance markets, the answer would be no. CATV systems were means to ends for many investors in the early 1980's. The success in building a CATV infrastructure was clearly a success of a carefully executed tax policy that allowed for the investment in potentially risky investment. The change in that policy as clearly changed the CATV investment market.

7.4 Evolutionary Constraints

The evolution of the CATV networks has been based on the assumption that the CATV operators will assume the massive capital investment risks with the opportunity to attain an adequate return on their investments. That return has for the most part, been focused on the use of the transmission medium for the almost exclusive purpose of entertainment distribution. The fact that the current cable business passes almost 80% of the US homes and has about 50% penetration, thus providing service to 40% of the US households. In contrast however, even at the current rates of service, the revenue for the CATV industry as a whole is only $18 billion, comparable to one RBOC, there being seven, plus GTE. The total RBOCs plus GTE equal the interexchange carriers in revenue, including AT&T, MCI, Sprint and the other IECs.

Thus the total CATV industry is about one sixteenth or 6% of the telecommunications transport business for voice and data. Such a position is not one of any market dominance in the network area. However, as has been noted, this industry has a network in place with both existing capabilities and new transport capacity that greatly expands what the the RBOCs have in all their networks. The difference is driven by both the unregulated nature of cable plus the fact that cable is not forced to be the transmission provider of last resort. That is cable is not required to provide "Life Line" services below cost.

CATV companies now find themselves in an environment where the RBOCs are potential alternative carriers competing with CATV (See Carnavale). Specifically, the RBOCs have indicated their intent in providing local loop fiber transport. That transport would have the capability to provide transport for CATV systems. The large capital intensiveness of these systems, however, will slow their installation. The inertia of local governments, the true regulators and customers in this market, will probably, for the short term, maintain the status quo. It does however allow for the CATV companies, as they progress to fiber based transports to themselves become the alternative carrier. If the CATV companies, in the current rebuild cycle that will occur in the 1990s, position their rebuilds in fiber, then they are in the position to have the transport base for transmission to the home. It is then possible, in extremis, for the RBOCs to become leasors of transport service from the CATV companies who will have fiber passing the majority of homes, and not vica versa. It will be an issue of who will be at the home first with the transport facility and then it will become an economic decision.

8.0 Private Networks

Private networks are those offered to select portions of the general market and are owned and operated by network operator other than the common carriers. Typical of such network operators are Teleport in New York and Boston. These private network operators build their own bypass capability, including cable or fiber, along rights away that they may lease from local agencies. They then also provide some limited switching but for the most part connect to the local point of presence of the Inter Exchange Carrier. Their selling proposition is generally lower cost for the same service. In fact, their actual benefit may lie in the shortened time to installation and the support on moves, adds, and changes.

8.1 Structure

Private networks are structured on a local basis, allowing direct access by the end user or customer. They focus on the segment of the market that desires an additional carrier and who are concerned about cost.

The networks generally are built to maximize the local market penetration advantage and are not structured to provide universal service. For example, in Chicago, the Chicago Fiber Network, was built in the coal tunnels as rights of way, directing traffic off the Michigan Avenue business district. Teleport in New York is directed at both the financial district and the mid town business district.

The networks are, for the most part, fiber point-to-point and have limited any switching. Specifically, they are built around the smart mux technology and are positioned to attract customers on the basis of competing with bulk transport buys. For example, they sell DS0, DS1, and DS3 circuits at significant discounts.

We can now compare the four elements of these networks to those of the others discussed. Specifically;

o Control: The control of these networks is centralized and is generally under the control of the organization responsible for their operation. This is an organizational control philosophy and there is generally no reason for not having a distributed control.

o Transport: The transport is usually over fiber networks. In contrast to CATV, the transport is controlled, generally by voice mux equipment and is thus no different than the Telco networks. However, some private networks are using special data transport facilities and non standard data rates. Thus it is possible to use any amount of the available bandwidth.

o Interconnect: The interconnect is highly flexible and allows for all types of device interface. The switching is done by multiplexers that are intelligent and generally are controlled by users segments. Thus distributed control is possible.

o Interface: Most interfaces are possible.

8.2 Competitive Environment

There are few examples where Private Networks compete with each other, Boston have three smaller versions. Generally their self competition is along common rights of way and it is yet to be seen that there is sufficient traffic for them to survive. In Boston, as in many other cities, the key to a Private network provider is the Right of Way. Usually the local electric, transportation, sewer, water or gas company has existing rights of way that are usable. The problem however, is the pricing of that right of way as well as the ease of exp anding it. For example, in 1984, the New York Metropolitan Transit Authority, MTA, was approached by several private network providers with an offer to lease rights of way. Six years latter there is still no effective policy on how to do it. In Boston the process took only three years. In Washington, D.C. it took eighteen months. In Chicago, only nine months. Typical rights of way rates are $0.50 per foot per month. That is about $2,500 per mile per month. In New York, if rights of way were available, the entire network would need no more than 50 miles of fiber, thus costing $125,000 per month or $1.5 million per year. Such a system could supply service to several hundred customers at the level of a gross revenue in excess of $50 million per year.

Thus the right of way is a fixed fee and if efficiently run, the network may have that fee represent a small percentage of the total revenue base.

The Private carriers receive little if any competition from the common carriers since the common carriers generally have higher rates commensurate with the switching, management, and distribution services that they provide.

8.3 Optimization Criteria

The approach of the private network companies is to provides for the least cost design in the early phases subject to minimal market coverage. This financial strategy assures them the ability to compete on a price basis during the start up phase where they capture market share based solely on price competition.

P PVT = min (Cost|Service Area)

As they have evolved the criteria has changed to;

P PVT = max (Cash Flow| Service Area, Level of Service) which demonstrates the rational approach of focusing on cash flow out of the business. As we indicated in the studies by Fruhan, value creation is based on cash flow subject to market retention.

8.4 Evolutionary Constraints

Private Networks have evolved on both the local and the long distance basis. On the local side, there will be a continuing fragmentation of some of these network until the consolidation phase occurs. The consolidation will not occur unless and until it becomes clear what the market is. As we have indicated, the provision of service to the residential user still requires capital per user that exceeds that for the short term payback. In contrast, the commercial user still has the short term payback and thus will be a buyer for these services. The main evolutionary factors will be:

o Market consolidation: Will there be enough clustered revenue potential for the independent private network providers, especially if they are competing on price and in a pure transport commodity market.

o Scale consolidation: If there are no other elements other than transport, will there be scale economies in transport on the local level. On the long distance level, such companies as Williams have found scale economies via leveraging their gas transport facilities. Are such consolidations available in local transport? Is there a stable environment in the franchise fee for rights of way. As has been seen in the cable industry this has been the case on the local basis as long as predatory pricing is not perceived? This however will not be the case in the private network area.

o Technology consolidation: As we shall note in a latter section, there are certain technologies that may make the capital intensiveness of fiber a non issue. Specifically radio technologies may be capable of providing some modest bandwidth requirements.

o Usage expansion: As the bandwidth is liberated in private networks, as it will be before the public switched network, will such bandwidth drive up the revenue per fiber while at the same time driving down the price per bit per second? It is anticipated that if the private carriers are able to provide dark fiber and that if vendors such a start up as UltraNet and others provide high Mbps customer based switches, the applications will increase.

Clearly, the possibility exits for the Private Network providers to cream skim the market.It has yet to be proven that such has occurred. At present, therefore, there is limited regulation on such networks and it is appropriate to let that continue until they have stabilized with a recognizable character and understood economic effect in the telecommunications community.

The directions of Private networks are in the balance between the Public Switched networks and the Customer Networks. Clearly, the former provide the network of both universality and last resort. The latter provide the network of optimized user customizability. Noam has recognized this dynamic and had indicated a possible direction:

" The breakdown of monopoly is due to the very success of the traditional system in advancing telephone service and making it universal and essential (eg a need). As the system expands, political group dynamics take place, which lead to redistribution and overexpansion. This provides incentives...to exit sharing.. to a system of separate sub-coalitions."

This then begs the question, if this approach is the true market dynamic, what is the stable point of the evolutionary telecommunications architectures. Undoubtedly there is both an economic need and social need for a Public Switched network. User sub-coalitions, namely user empowerment, will lead to effective Customer Networks. What then is the future of the Private Networks? Specifically, if Public networks support the wide base of users and the need for universal service, and if customer networks provide service optimized for the larger user, what does this leave for the private networks. It is argued here that the private networks will become niche market players, providing a boutique service to mid tier market users of communications service and a broad and common functionality basis. Thus it is concluded that the private networks will have limited broadband functionality, providing at best raw fiber transport, marketable on a limited basis.

9.0 Customer Networks

Customer networks are the newest of the five networks to have evolved. They are currently the creature of large corporations that have the need to meet specific high density data and voice traffic and academic consortia that are meeting the needs of their research communities. In addition these companies have a wealth of experience in managing data and voice networks and may even be computer companies themselves. Thus IBM and Digital are examples of companies that have their own networks. These companies have had third parties build fiber networks that the individual company then takes over and operates as a part of the corporate infrastructure. These networks cover areas of heavy traffic and are priced in as cost competitive on the basis of being less costly than leased lines. However, in most of the situations discussed the networks also are part of the companies strategy to expand its product offering to include networking products and expertise. Thus IBM and DEC clearly are interested in expanding their product offerings in the network area and the most effective way to do that is through a network of their own.

In contrast, the academic networks, such as NYSERNet and NEA RNet, have focused on the needs of their constituent members. Some of the networks use a leased circuit transport but there are many user owned and operated fiber networks extensions. MIT, for example, has an extensive campus wide fiber network that is used to support its local interconnect and transport requirements. A detailed discussion of campus networks is presented in Ames.

On the commercial side, there is also the creation of shared networks for the use of market leverage. The recent study by Kosynski and McFarlan provide several example of corporations and their networks applications and infrastructures. In all cases they lead to a sustainable competitive advantage.

9.1 Structure

A customer based network is generally a closed environment that is created solely on the basis on providing better service at lower costs. The Customer Network may be for a single customer or for a coalition of customers. It should be recalled that the network consists of the control, interconnect, interface, and transport functions. The nature of a Customer network is that each of these may be separately or jointly under the control of the customer or the customer coalition. For example, the transport may be leased from a Public Switched Network provider or from a Private Network provider.

The control may be directly under the customer or it may be outsourced. However, the ultimate control is that of the customer.

The network architecture is based on purely economic factors and they are generally established between clusters and high usage and traffic premises of large companies. The networks are built on the following basis:

o Transport: The transport is a fiber network that is built between locations. The transport is provided on the basis of both dark fiber and a switched transmission facility common to the switched network fabric.

o Interconnect: In the corporate network, the interconnect function is provided by the inherent point to point links and the addressing generally done by the TCP/IP transport layer protocols that are used on the data transport. Voice interconnect is accomplished via the PBX facilities that are on the customer premises.

o Control: The control of these customer networks is based on separate network management facilities.

Data networks are controlled by systems that are now a natural part of the computer systems. The control of the Customer networks has taken several operational directions. Some companies have decided that outsourcing of the control directly under their management is the way to proceed. Other companies have maintained control under their direct corporate control. Others such as NYSERNet have found third party companies which that had prior relationships with to take a more active role.

o Interfaces: These are provided as a common part of the end user devices.

The corporate networks allow for expansion and customization.

9.2 Competitive Environment

The competitive environment is limited in this type of network. Competition is generally from an internal comparison with other carriers. The network is viewed as a strategic corporate asset that is part of the overall company value chain. Thus for example, the network for Citicorp or ADP may be part of the overall financial services system that is provided to their customers. The choice of build versus buy is both a strategic and tactical decision. On a strategic level, the issue is that of establishing a barrier to entry to the competition, allowing the provision of new and innovative services. The tactical issue is that of lowest cost for a required level of performance.

The advantage of a Customer Network is the ability to optimize it for the benefits of the user. Thus NREN, if viewed in the paradigm of the Customer Network solution, will allow for maximization customizability in all four network elements. This is in contrast to the Private Network which will provide a common denominator capability focused on its market niche.

9.3 Optimization Criteria

The initial optimization criteria is based on the need to prove the system in on the basis on return on investment. Specifically;

$P_{CUST} = \max(\text{ROI}|\text{Performance, Coverage})$

As the networks have evolved the measure has changed to;

$P_{CUST} = \min(\text{Op Costs}|\text{Level of Service, Functionality})$

Specifically, the tactical issues of cost containment are key. Levels of service and extent of operational functionality also play roles as constraints.

9.4 Evolutionary Constraints

This type of network has the greatest potential for evolving. The key to this expansion is the use of the dark fiber option allowing for the use of data rates that exceed the 45 Mbps maximum provided by the common carriers. Companies such as IBM will undoubtedly use these networks to expand their own products, stretching the abilities of computers to communicate at higher data rates. The challenge is to allow the network to act as a computer backplane and reducing the overall latency of the transport. Such low latency transport will evolve with new applications and new computer architectures. In addition there will be a more fully distributed computer architecture for the use of these transport facilities.

In addition to the corporate players in the Customer Networks, the coalition players, be they companies or academic institutions, have a significant opportunity to customize and experiment with these networks. It is possible that it will be with the Customer Network, such as an NREN, that the maximum amount of innovation will occur. This is clearly the case from a commercial perspective with Customer Networks in other areas. The Securities Industry Association Network in New York presents an opportunity for this market segment, in their coalition structure, to establish a highly cost effective transaction processing network. This is leading to changes in database, transaction processing computers and interface workstations.

10.0 Conclusions

Networks represent the asset allocation of capital resources to meet market needs and provide the end users with a means to maximize their utility function. In the area of commercial networks, the network functionality goes to the heart of the value chain of the user and in turn to all those affected by the user.

Networks play an important role in value creation not just value transfer. Networks are no longer just intermediaries that facilitate the work of other information users, they become an integral part of that use.

In this paper we have substantiated several key conclusions.

o First: Networks will evolve in a dynamic fashion, not being driven by a single vision but being responsive to a collection of constituencies. This will result in a collection of multiple overlay networks.

The challenge will not be in controlling a single standard, but in developing a flexible interface to these multiple overlay networks. Infrastructures are important, but the infrastructure is not a physical infrastructure, it is rather a logical or relational infrastructure.

o Second: The future of networks is driven by uses and users. We are entering a network generation dominated and driven by the end user and their uses. Admittedly, the use of regulation has been argued as necessary for the attainment of limited social goals but for the commercial or government user, networks should be designed and evolved to meet the needs of such business entities. Market makers are the users.

They will define the boundaries of their networks in terms of the uses to which it is applied. Thus, the users will seek networks that are enabling and not delimiting. User communities are not homogeneous as in the classic paradigm for hierarchical networks. It is because of that paradigm shift and the needs to meet niche interests that the change is occurring.

The end user community is not going to wait for an ultimate infrastructure. That is an economic reality.

The end user will be empowered by a new architecture and this architecture will result in sets of quasi independent multiple overlay networks.

o Third: Current regulation is based upon past paradigms. Networks are evolving and creating new paradigms. In this changing world view, regulation serves to buffer obsolescence but should be carefully controlled not to endanger the facilitation of value creation and transfer. Multiple overlay networking is the essence of true competition. If the goal is to maximize the benefit for the consumers and to avoid the monopolistic bottleneck, this is best accomplished by fostering the ability of users to have the networks of their choice.

o Fourth: Technology is a fluid change agent in the stability conditions of networking. The free market drivers of minimum cost and maximum utility impact will assist to integrate the new technologies into the alternative network solutions. The technological lifetime of new network architectures may be significantly less that in the past. The capital intensiveness of networks are changing as a result of both existing infrastructure and technological changes. The mind set of the rate based regulation and barriers to entry due to capital investment may no longer be valid. This will force a change in the view of networks as distinct logical or relational infrastructures as distinct from a national highway physical infrastructure.

A Research Network and in some sense LANs are distributed suboptimal consequences of the continuing asymmetrical regulation rather than independently successful technological changes for end user application. If regulatory policy would respond to the changing world view, if it would allow for the implementation of less controlled broadband systems, unfettered all players, optimal solutions are more likely. These more efficient solution would further be in the best economic interests of the user.

This paper has viewed networks not as a national physical infrastructure, as some have argued, a parallel to the national highway system. Rather, it is argued that networks are flexible and less capital intensive logical or relational infrastructure. NREN is a concept that fits that view and could potentially provide the basis for future users and use development. However, NREN as conceived and to be implemented should be nothing more than an academic test bed which may have the potential to evolve into a limited operational network for use limited to researchers. NREN is not and cannot be of any value to a commercial set of entities because of its fundamental lack of value creation end user support.

In addition, technology changes in networks at rates that dwarf the highway model. Roads are built today in a fashion similar to the Romans of two thousand years ago. Networks built today are dramatically different than those of ten years ago. Thus the paradigm that states that networks are the next highway infrastructure may lead to disastrous results if implemented. It will result in the strategy of least common denominator, the most intensive capital costs, and the greatest regulation. In contrast, if we view networks as fluid creativity and value creation for the end user, then it is essential that successful economic development be left in the most open market possible.

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Note
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APPENDIX A
CATV MARKET DYNAMICS
In this appendix we develop the details of the argument that leads to the conclusion that the current CATV market is an established monopoly. We proceed by considering the set of cases tat may be considered in the evolution of competition in this market. The demonstration relies on an understanding of Game Theoretic analyses in econometric systems. The presentation is non-mathemetical. Consider, now the following cases;

o Case 1: Franchise Licenses (Exclusive):

The exclusive franchise license is inherently a stable monopoly (See Shubik, 1987 for a description of the applications towards game theoretic approaches). It allows for a maximization of the cable franchise fee by providing a maximum value to the underlying asset. The only competition that the CATV provider would then have is the alternative displacement competitors such as home video, off the air television, and the movie theaters. Generally, the pay as you buy alternatives such as rentals and movie theaters are incremental and more discretionary, whereas CATV is considered a fixed monthly expense. Thus there is an inherent bias on the part of the consumer, based on the standard consumer inertia factor, to rank order the cable purchase as the first choice. There is also, as has been shown in the past few years, been an inelastic demand for cable services, almost independent of price. The response of the local governments has been de minimus as compared to Federal Congressional bodies. The local governments have seen their local revenue increase almost 350% in the past five years.

o Case 2: Non Exclusive Franchise, No Alternative Incremental Transport:

In this environment we assume that each CATV provider must build their own transport network and that the franchises are non exclusive. We will argue that the result of this is again a stable solution which is again monopolistic, assuming that there is an existing cable provider, established as the dominant. If there are no dominant providers, we will argue that the stable solution is that no CATV provider will either bid or survive.

It should be first noted that the value of the franchise is less in this scenario to the franchise holder.

Nonexclusivity has reduced the potential revenue to the local government, so that this and the third scenario have lower marginal returns to the local government.

Let us now consider the two such classes of this case:

o Prior Dominant Carrier:

Assume that there is a prior dominant carrier, one who has the existing franchise and that the build of the system has been completed and penetration in excess of a minimum level has been achieved. In this case, the customers have been captured, they are accustomed to the service and have adapted to the monthly fee.

Further assume that the service provided, namely the basic service channels and the pay channels are generally available to any CATV provider on a comparable basis. This is a key assumption, it assumes that there is no differentiator of the service based on the product. Namely, that all CATV products, that is the video content, is comparably the same.

Let us now proceed with the market dynamics under this scenario. It will be noted that this scenarios has the structure of a two person zero sum game. Thus, from an analytical point of view, the dynamics are those that satisfy the Nash criteria (see Shubik, 1984, p. 194 and Luce and Raiffa p. 140; also see the original work by von Neumann and Morgenstern).

o We assume that the underlying competitive factor is price, since all providers have equal access to all products.

o We assume that the dominant carrier has already established the system at an average cost less than any average cost of a subsequent carrier, and that the marginal cost per new subscriber for the established dominant carrier is smaller than for any new provider.

o We assume that the established carrier has raised per monthly rates for several cost increase cycles so that
the marginal revenue significantly exceeds the marginal costs and capital requirements. Thus the existing carrier has at least a positive marginal cash flow.

o A new competitor enters the market. The new carrier must build a new system and must "buy" the new subscribers from the existing system or from the pool of non subscribers. The only economic way to do this is with lower prices.

o The established carrier then responds with lower prices, still sustaining at least positive marginal cash flow. The new carrier, due to the entry cost structure, and the fact that it has considerable higher marginal cost structures, is at a negative marginal cash flow. This cyclic price war escalates until the newcomer is forced from the market.

o The final stable point is again with the single player, who can again raise the rates and wait for another competitor.

o The net result for the local municipality is lower franchise fees.

o No Prior Dominant Carrier:

In this case, we can readily reach a conclusion based upon the results of the prior case. Since competition is based upon price, there is a stable solution if and only if there is a clear segmentation of the market by geography that allows for the reduction of prices to a level that meets positive marginal cash flow. Again, this solution assures only a minimal franchise fee for the local municipality.

o Case 3: Non Exclusive Franchise, Alternative Incremental Transport:

Let us assume that no CATV provider must build their underlying network because it is provided by a third party. Thus there is limited capital investment provided and that transport is provided by a third party, such as the local telephone exchange company. Let us further assume that the transport can be provided at a cost that depends upon only each new subscriber an is available on the market on an equal price basis. Thus there is no competitive advantage on any transport provisioning. Further there is no competitive advantage on the provision of the video product. Thus the only controllable costs of each CATV provider is that of its local sales and operations organizations, all else being fixed. There are then limited scale economies available and thus the marginal costs generally equal the average costs.

Competition in this case is based upon price and the perceived quality of service. It can be shown that this case generates the most cost competitive market and that the franchise fees are minimal to the municipalities. However, it may be argued that the consumer may get the lowest priced service, the switching costs from one provider to another being minimal.

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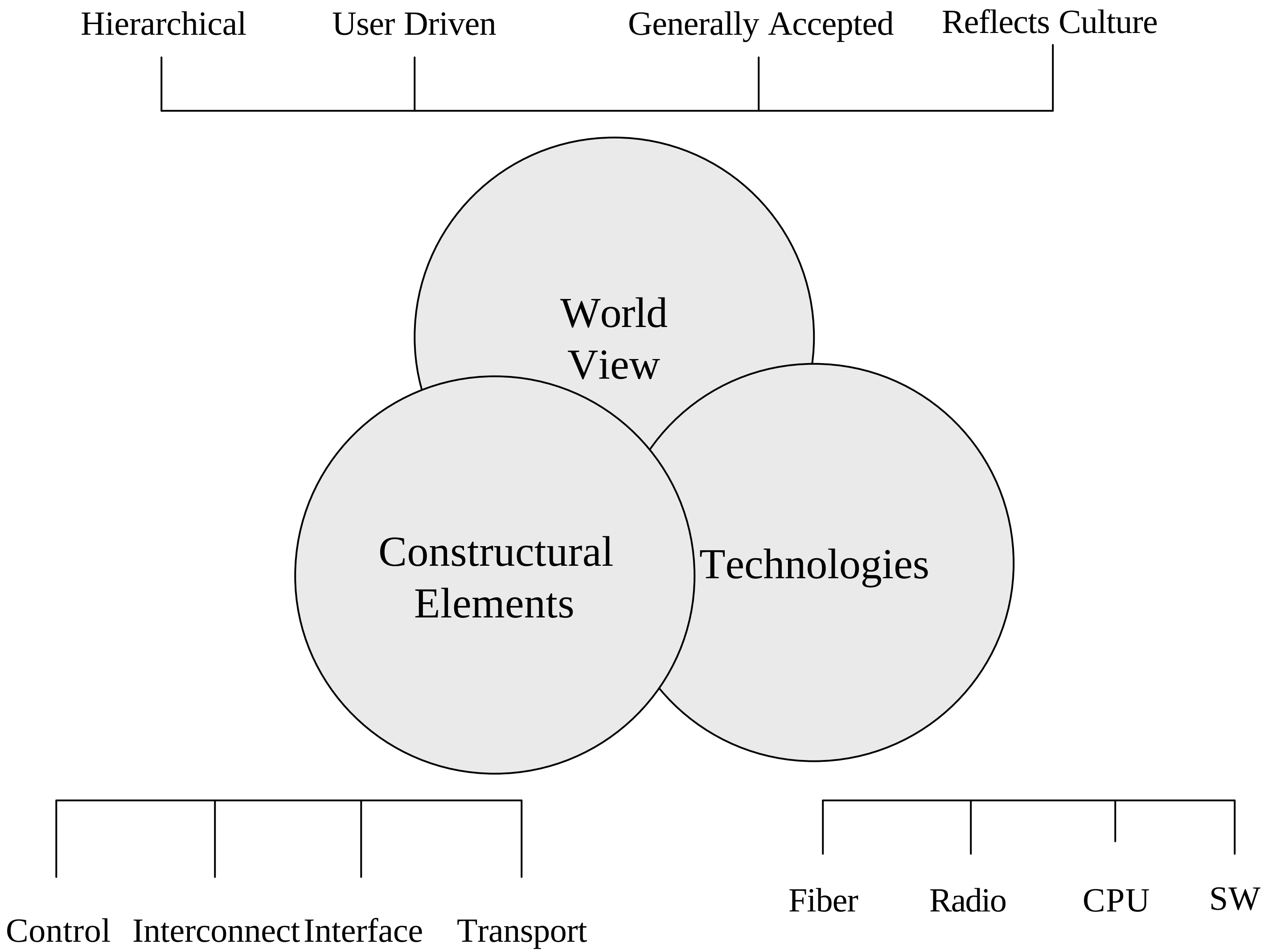
Architecture



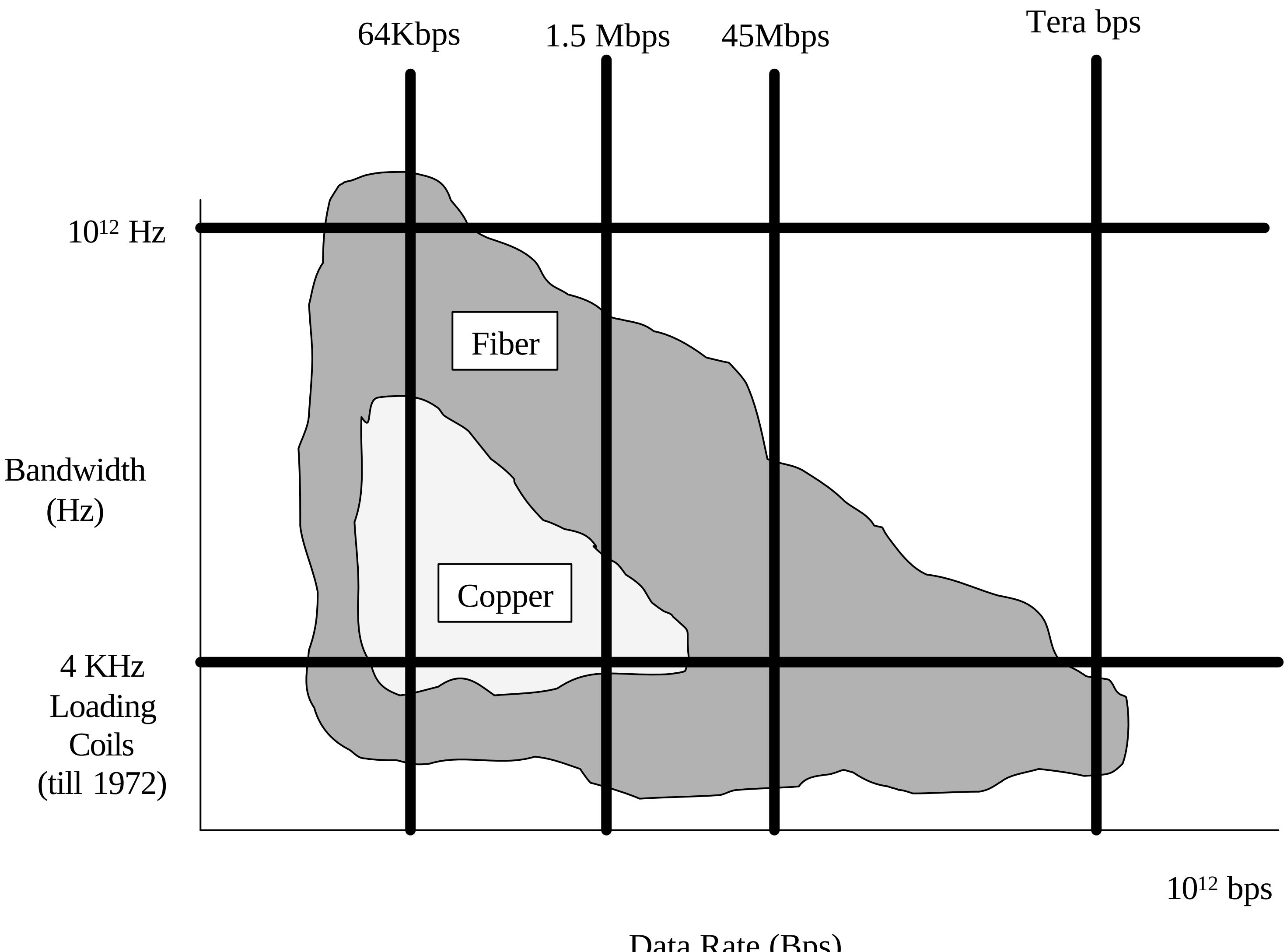
McGarty, Harvard November 1990

Figure 1

Network Providers

Type	***Customers***	***Architecture***
Public Switched	RBOCs	Hierarchical Centrally Controlled
CATV	Cable Companies	Local Branched
Customer	Local Campus	Point to point Point to Multipoint Branched
Government	Federal, State, Local	Point to point Point to Multipoint Branched
Private	Corporations	Point to point Point to Multipoint Branched

Flexibility, Standards and Reality

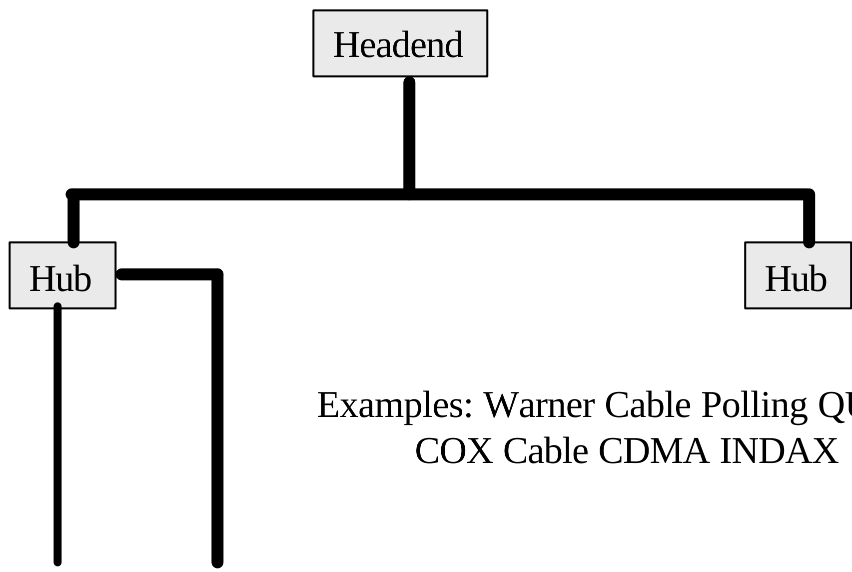


Enabling Networks

Interface
Interconnect
Control

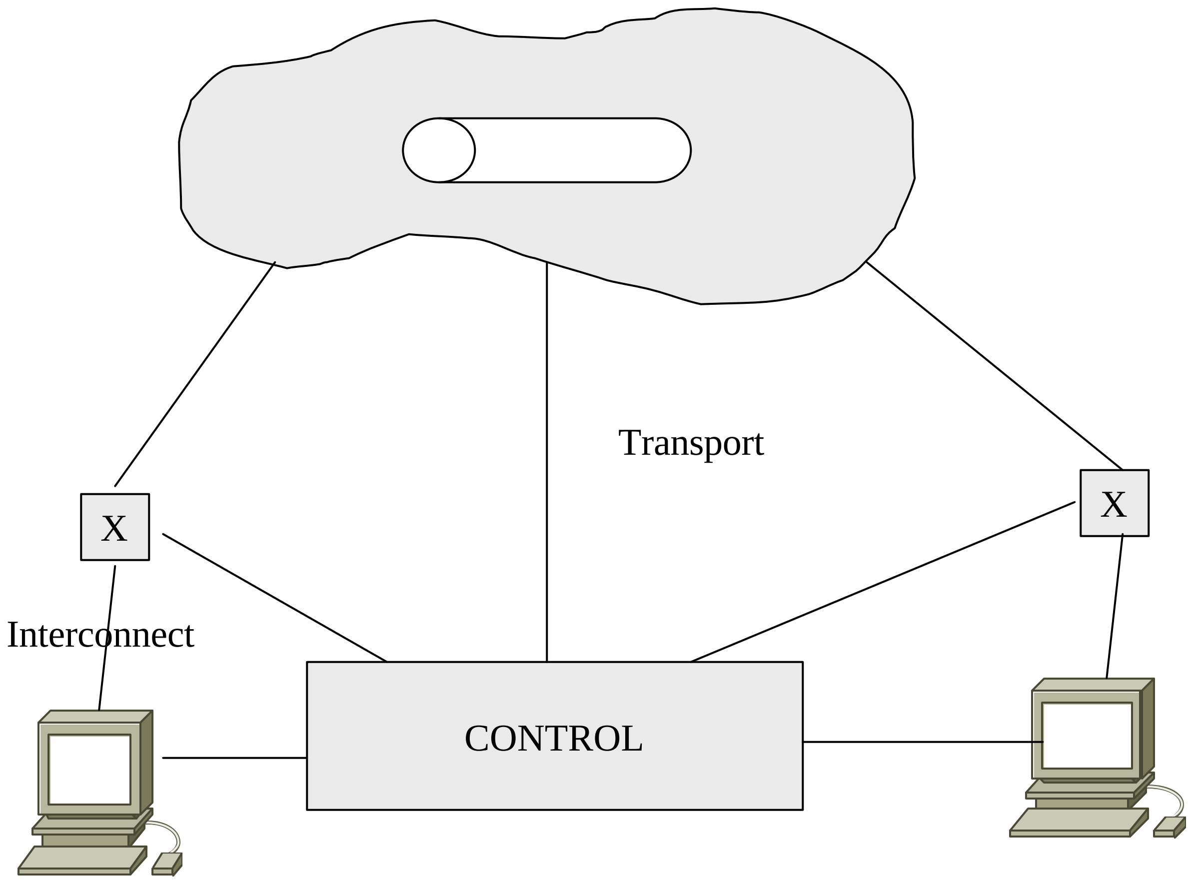
Ethernet
LANs

CATV

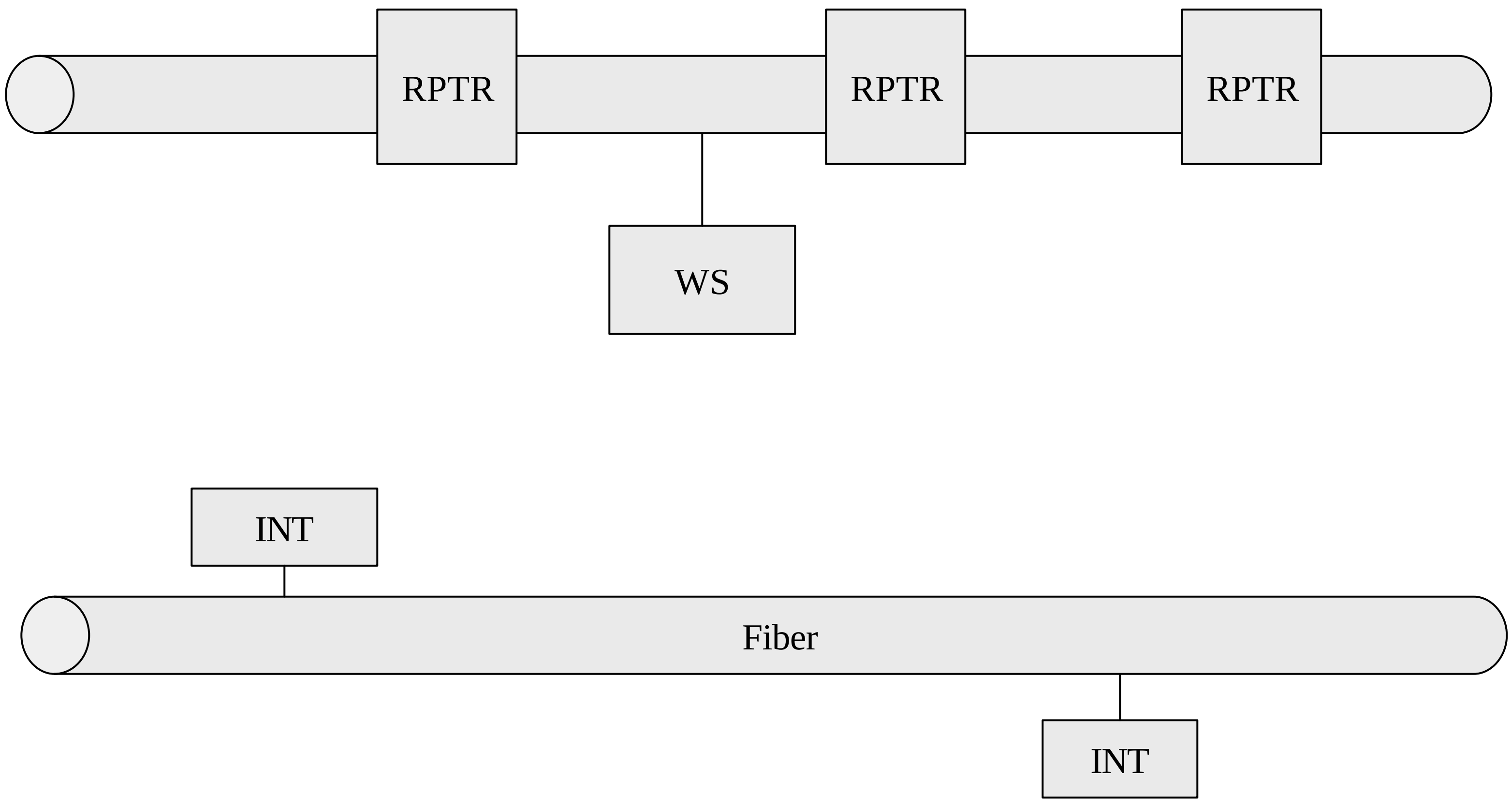


Examples: Warner Cable Polling QUBE,
COX Cable CDMA INDAX

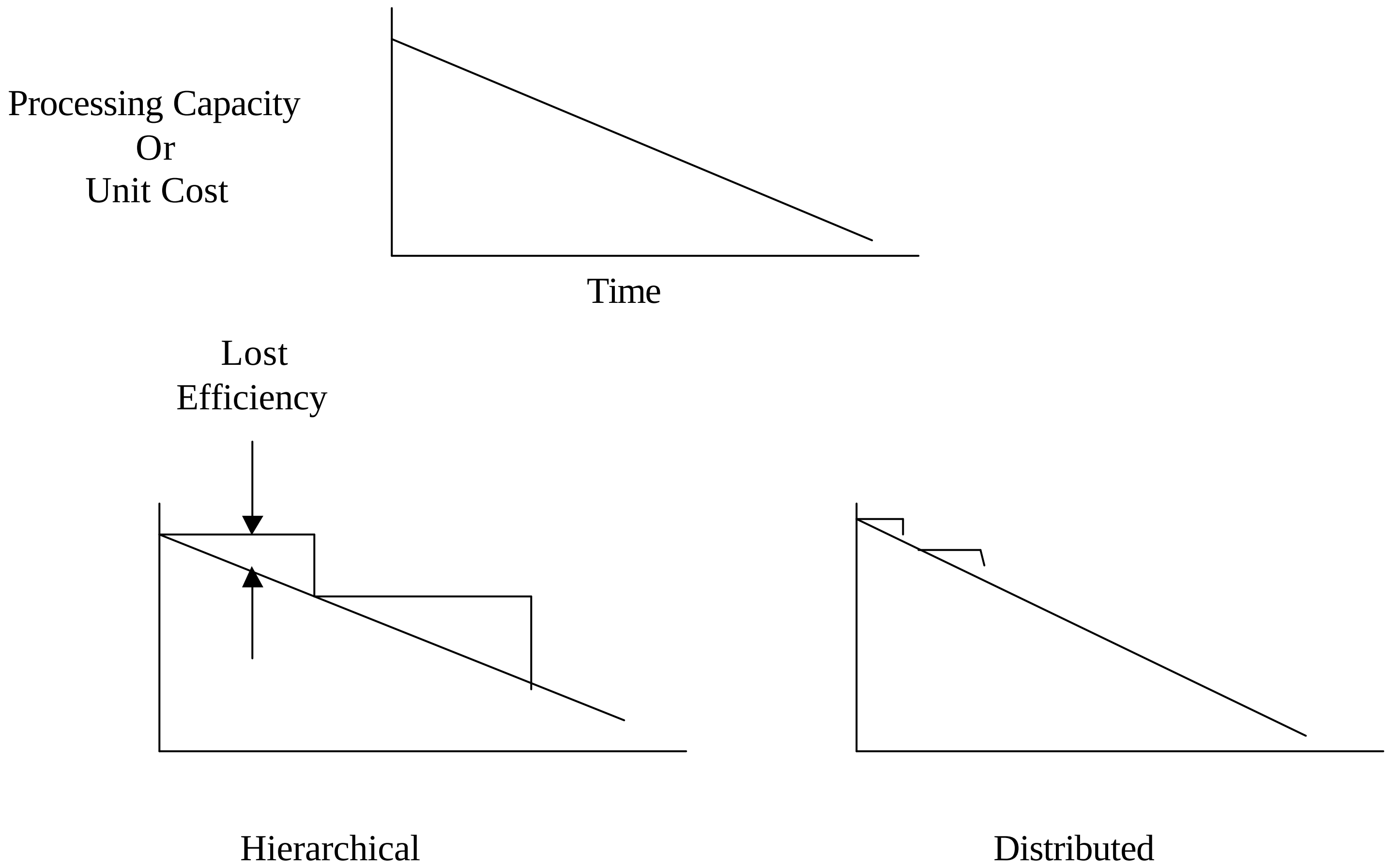
Architectural Elements



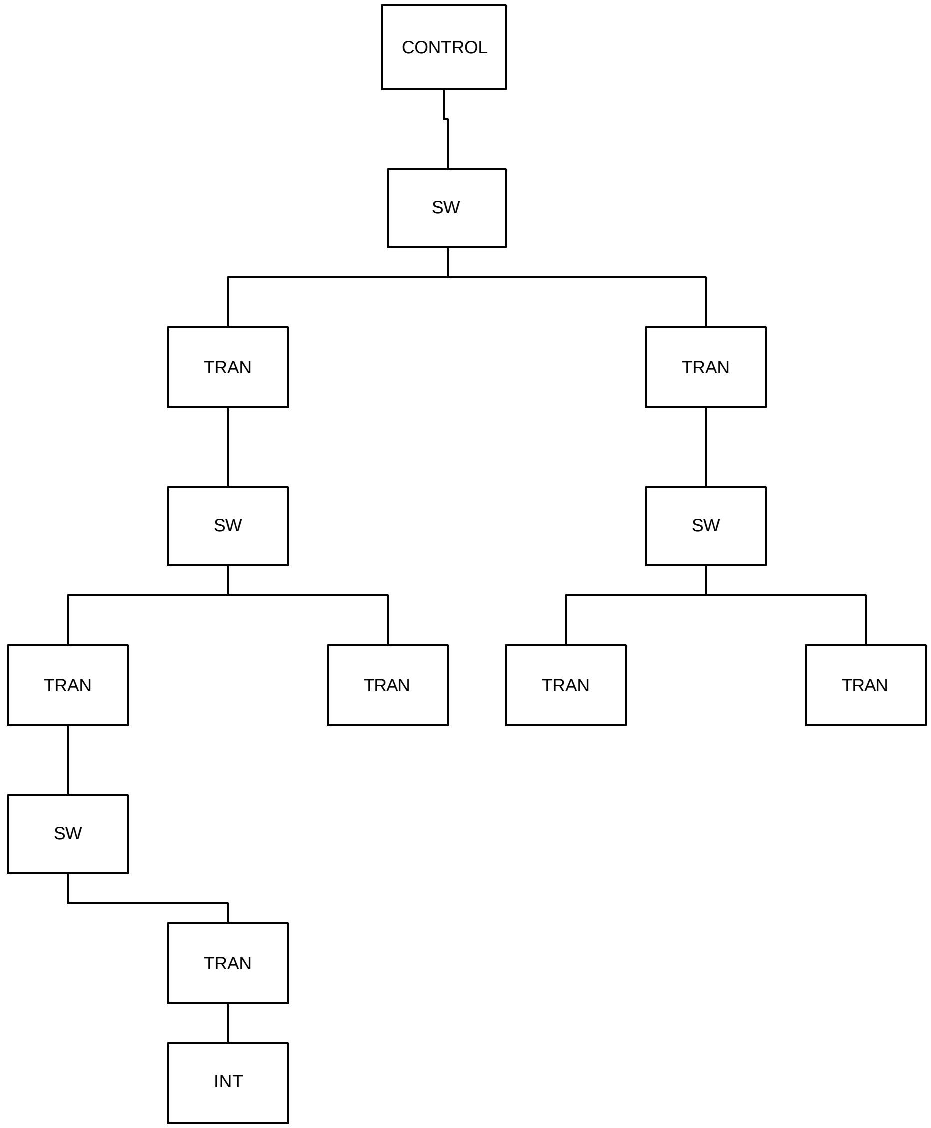
Dark Fiber Progressions



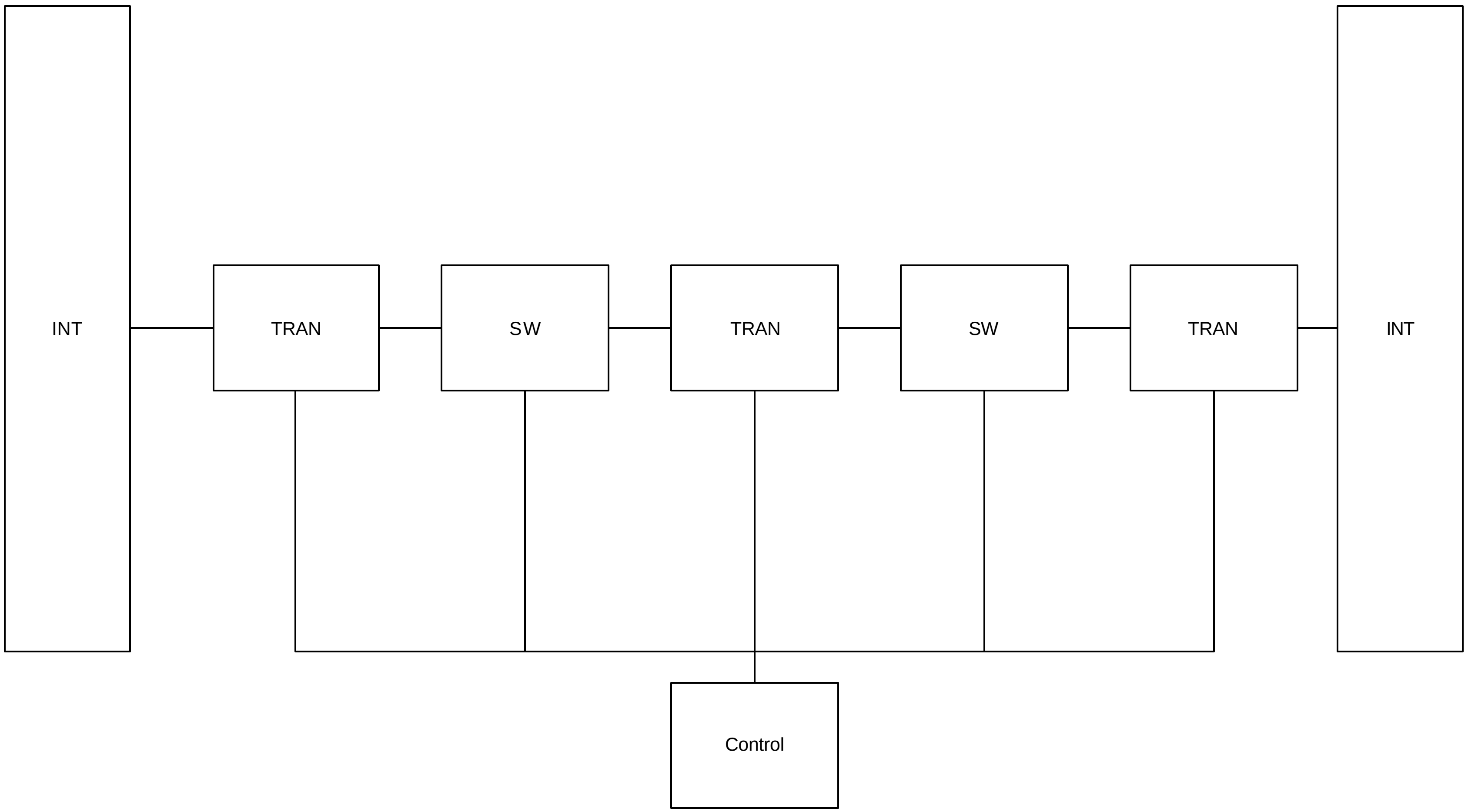
Technology, Timing and Cost



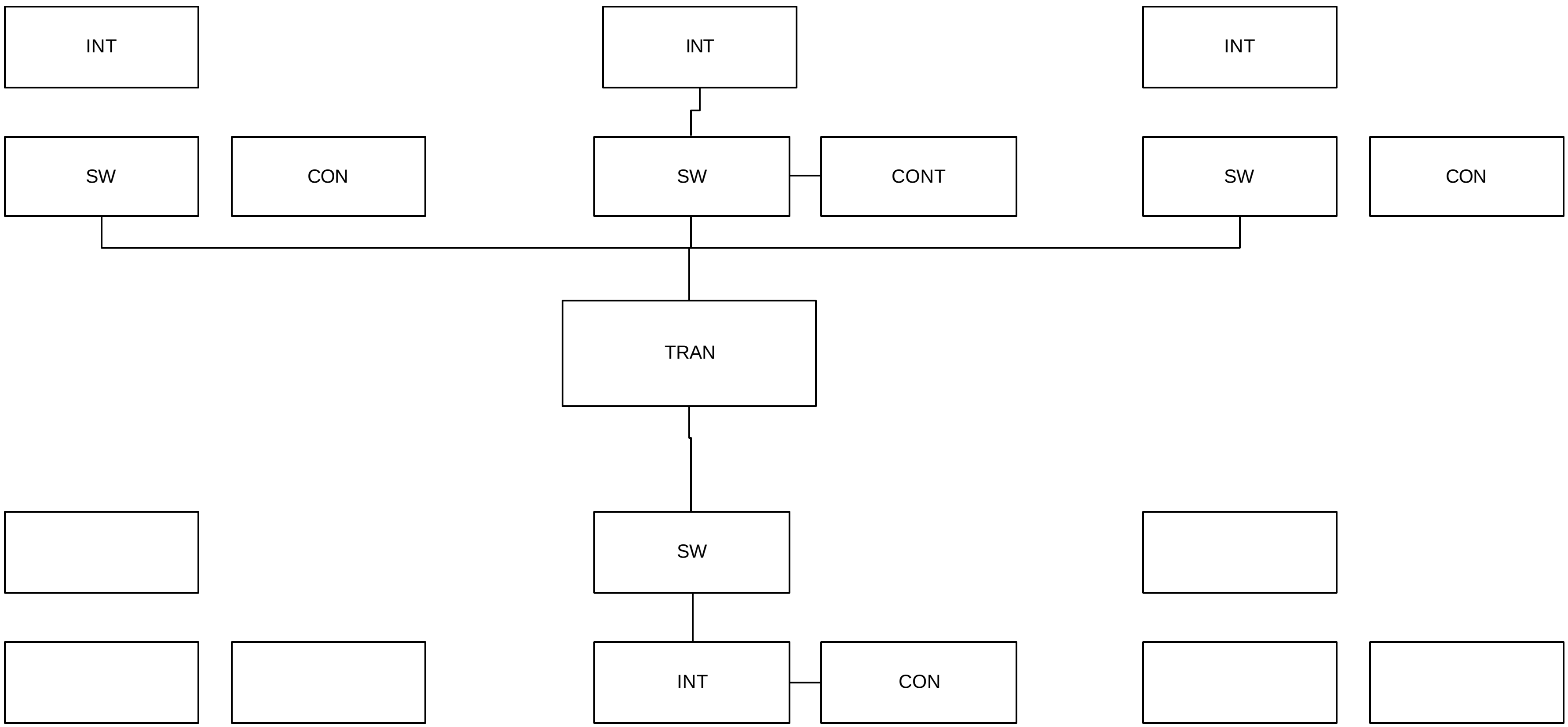
Hierarchical



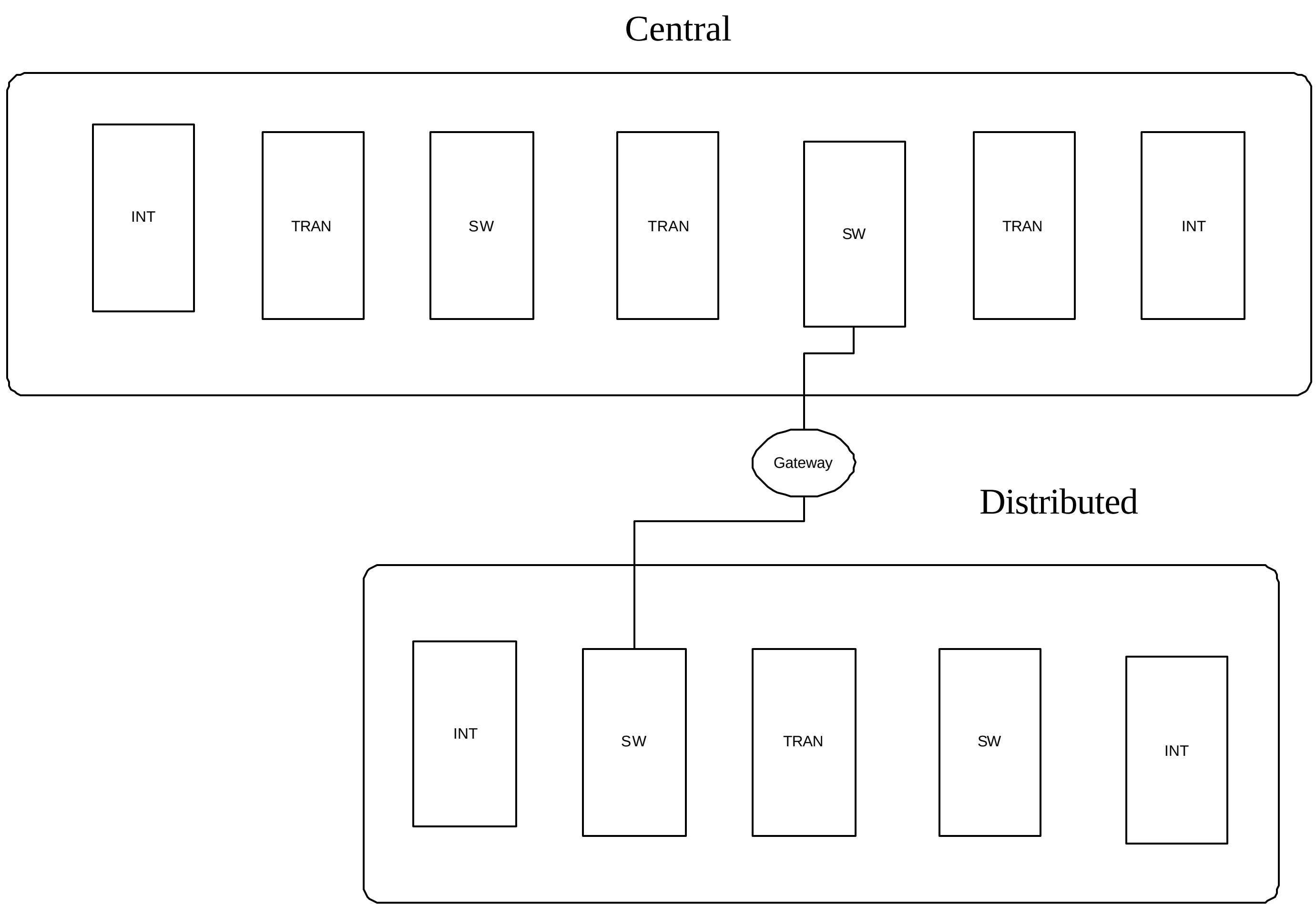
Centralized



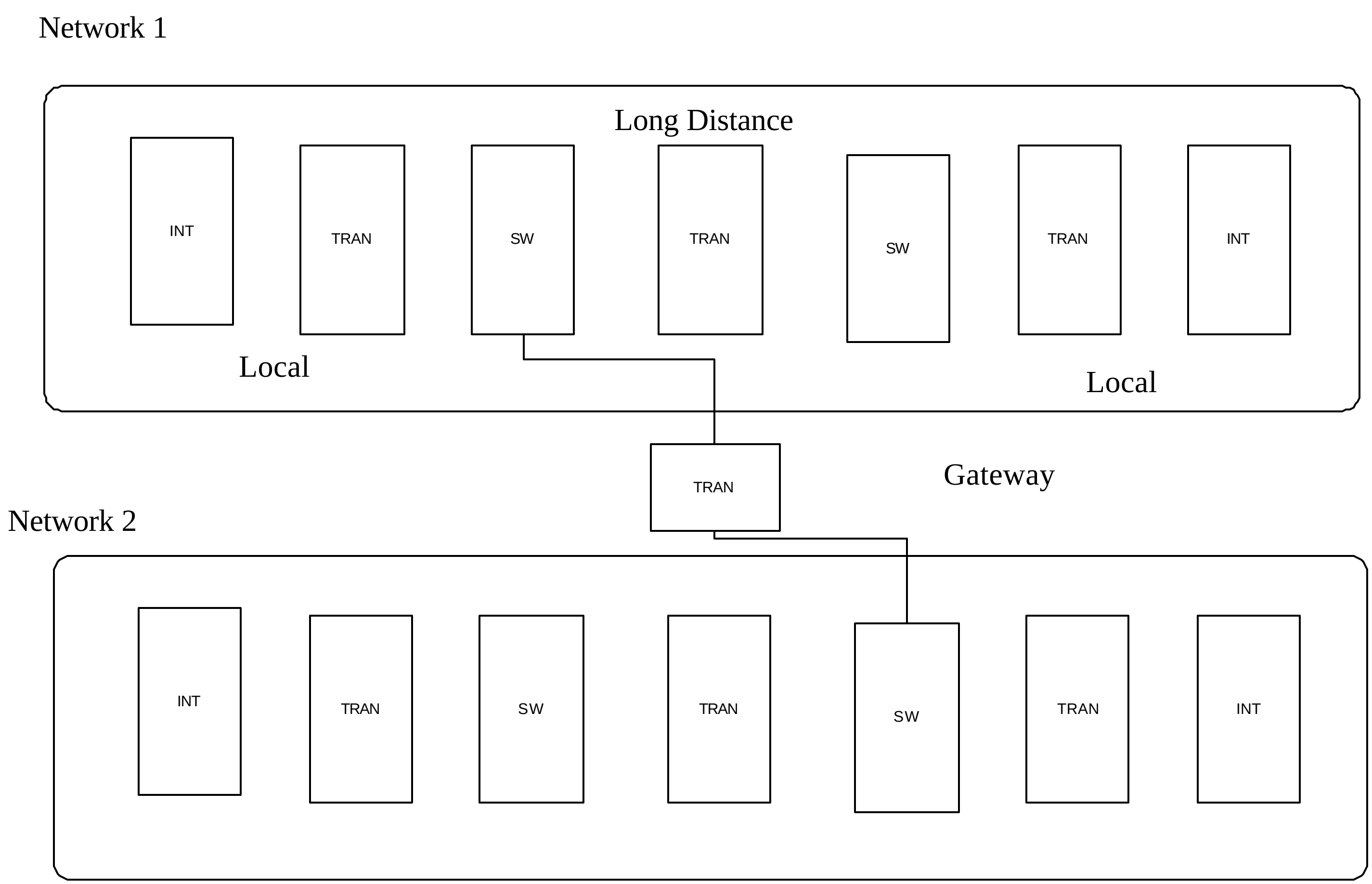
Distributed



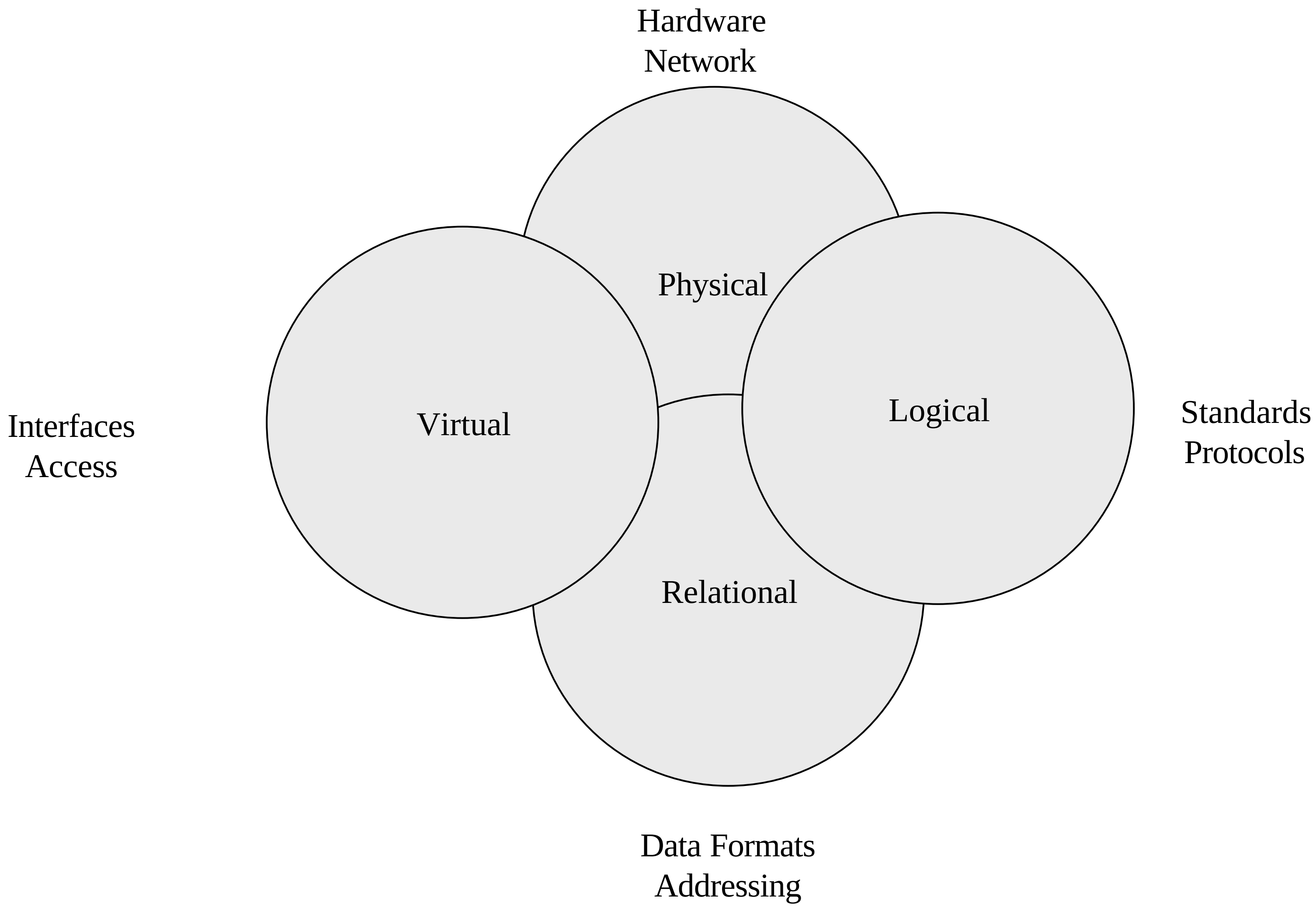
Segmented


Central
INT
TRAN
SW
TRAN
SW
TRAN
INT
Gateway
Distributed
INT
SW
TRAN
SW
INT

Partitioned

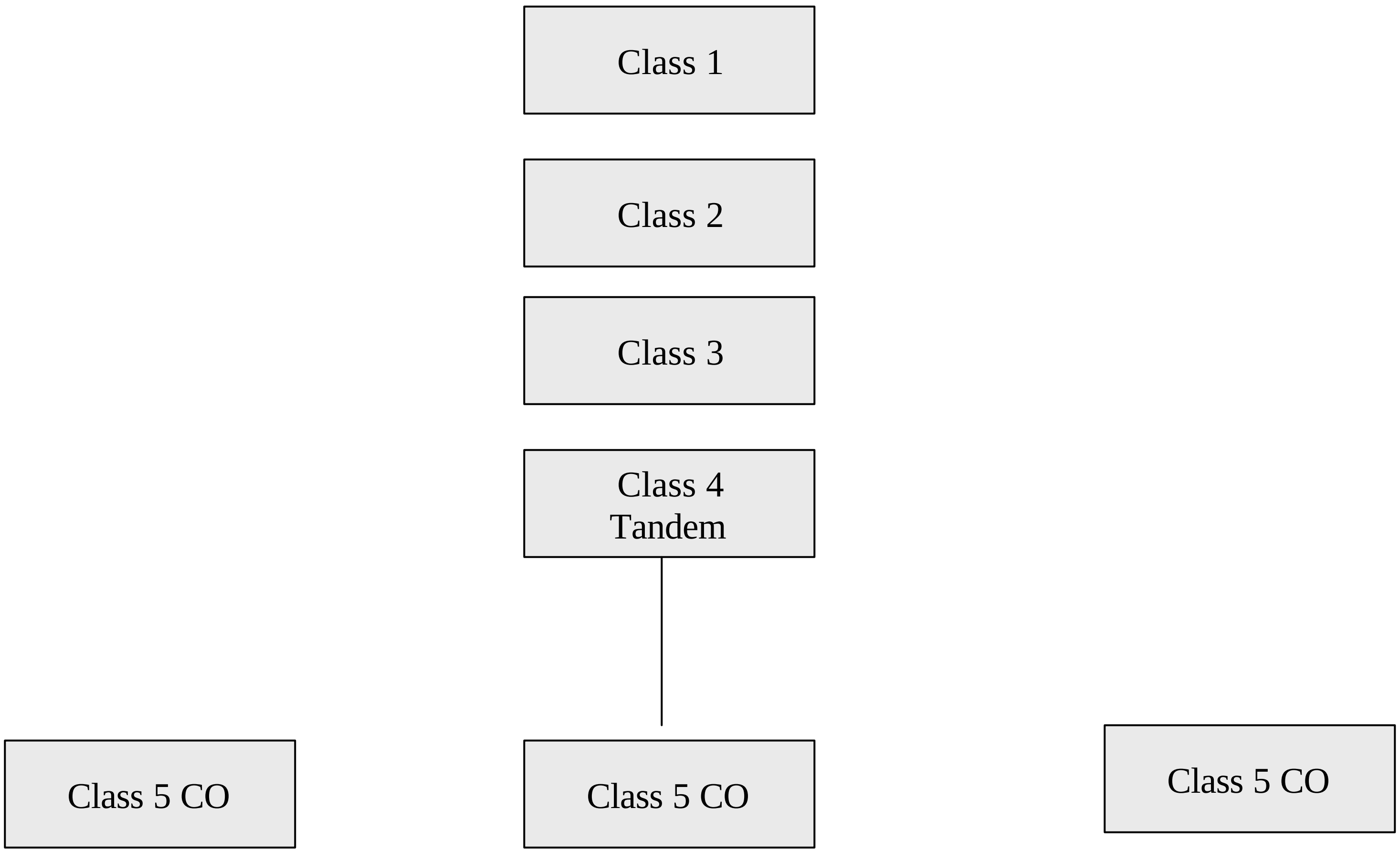


Infrastructure



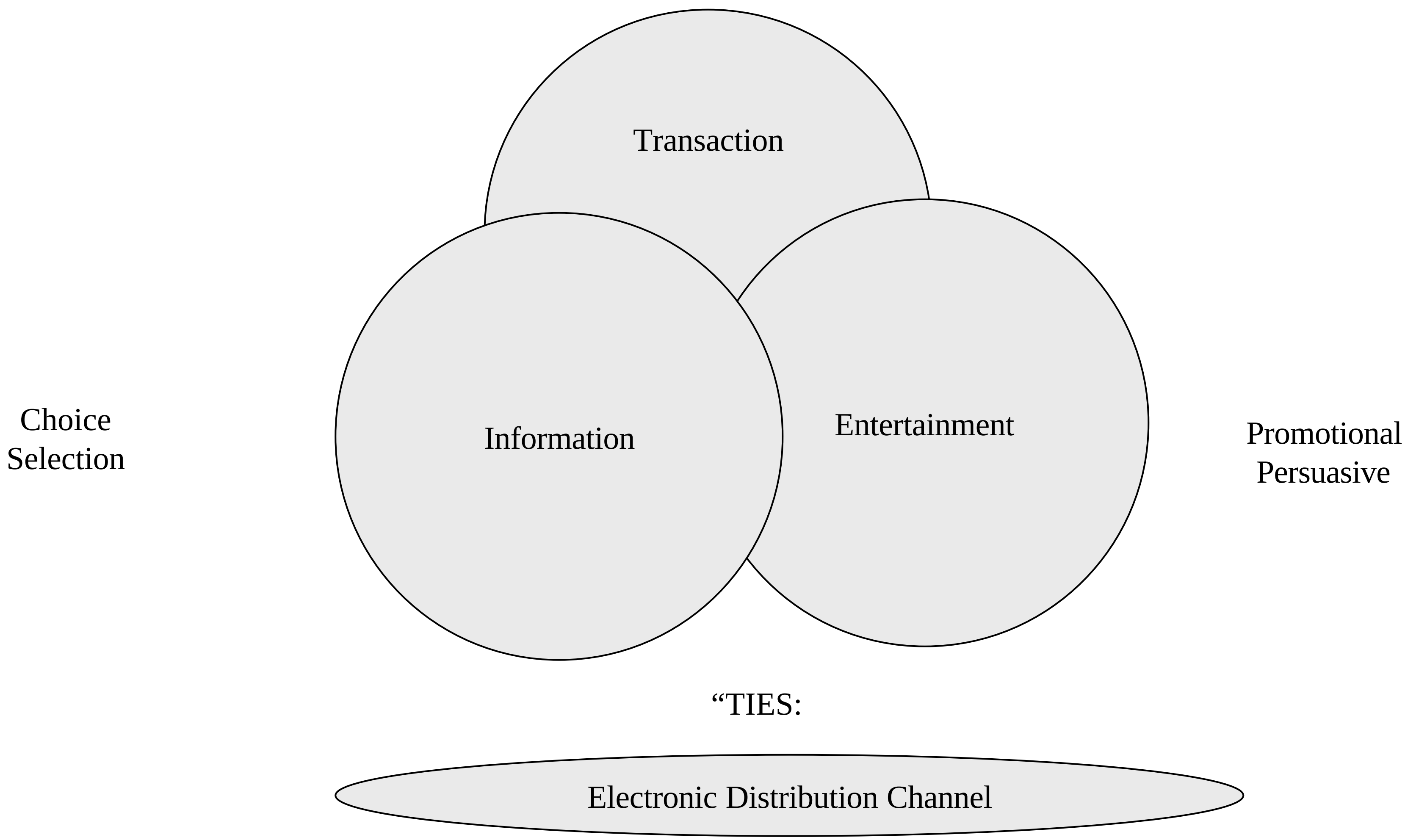
McGarty, Harvard November 1990 *Figure 13*

Current Switched Network

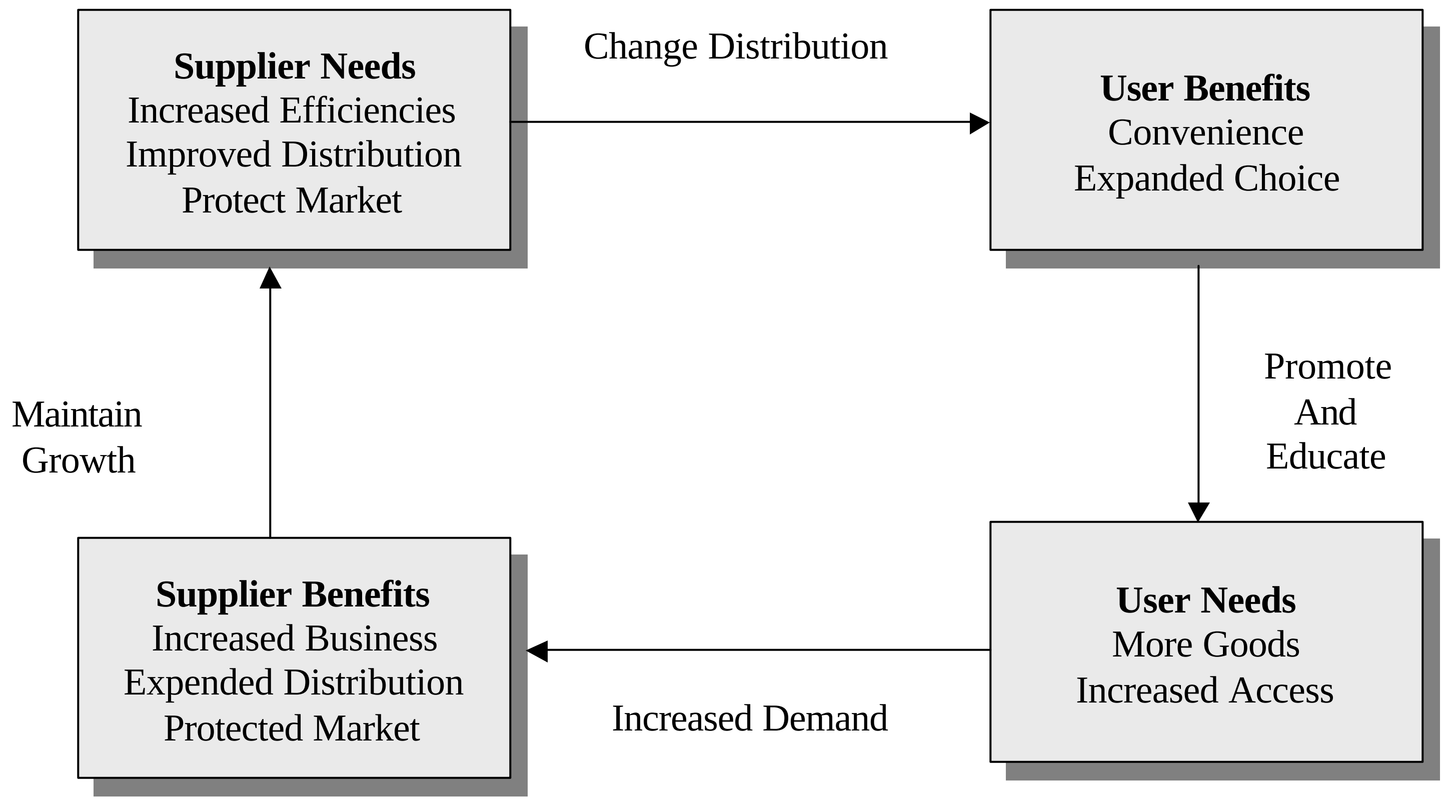


Fiber Distributed Network

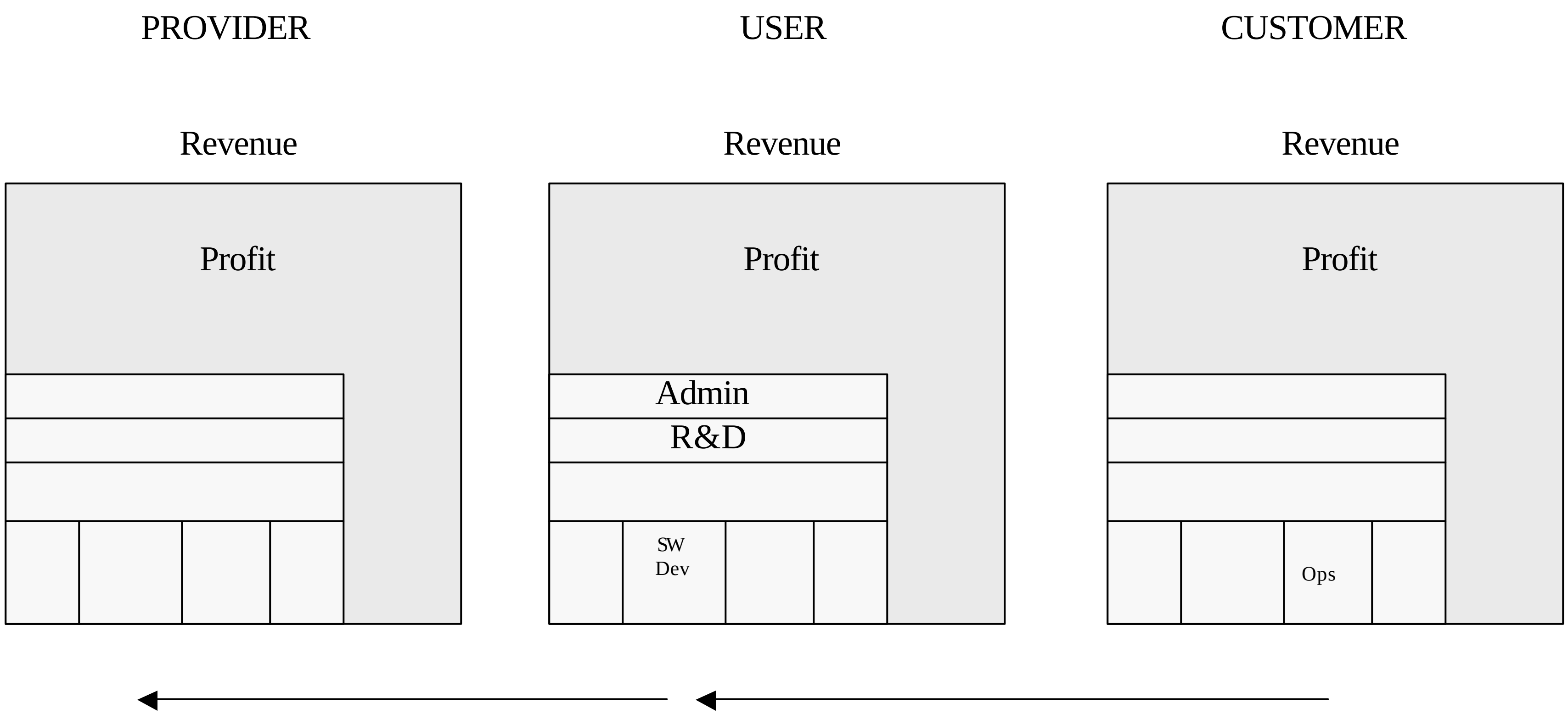
Major Technology/Service Drivers



Needs/Benefit Cycle

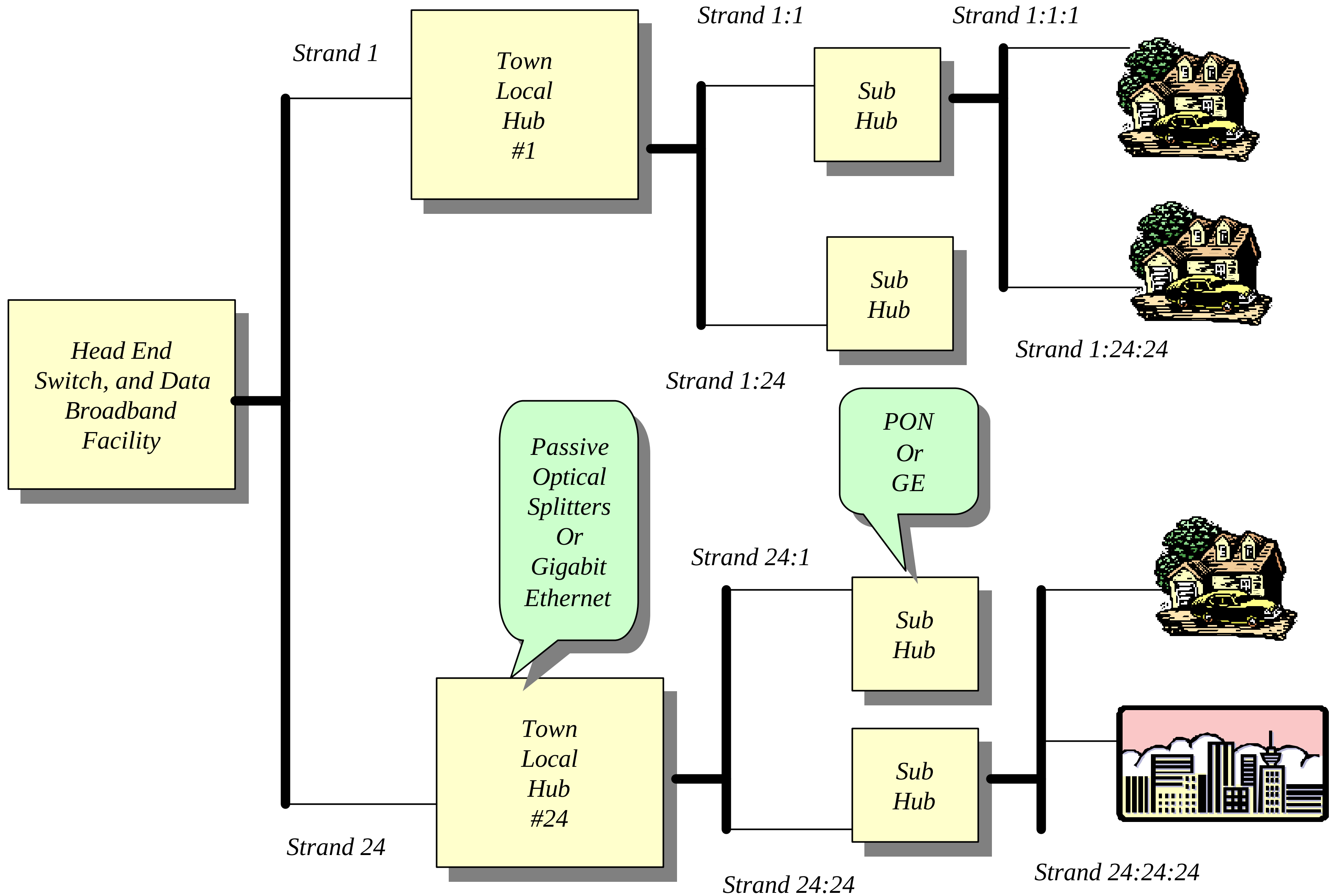


User Value Chain



Profit=Revenue-Revenue Driver*Productivity Factor*Unit Cost

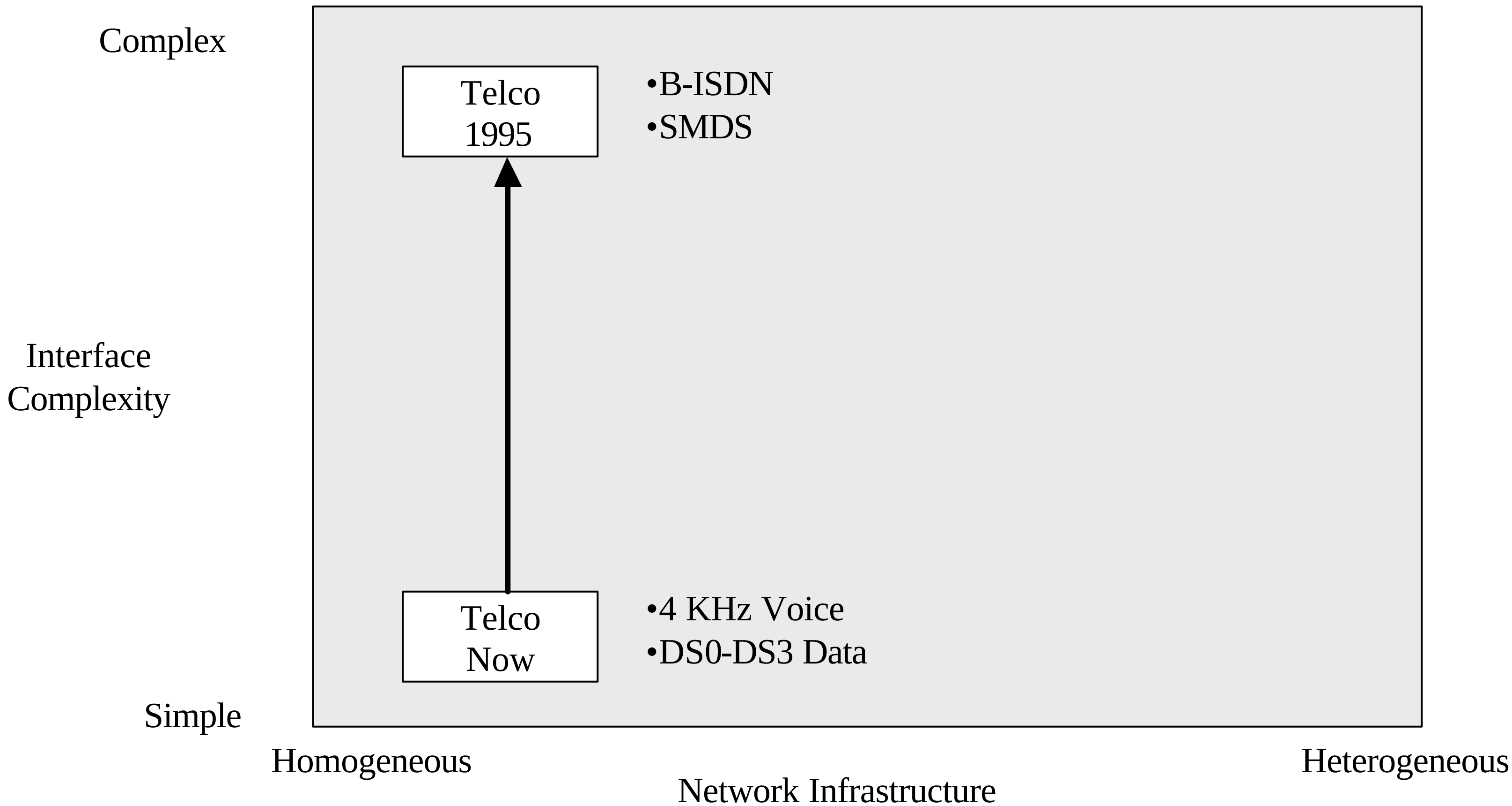
CATV Network Structure



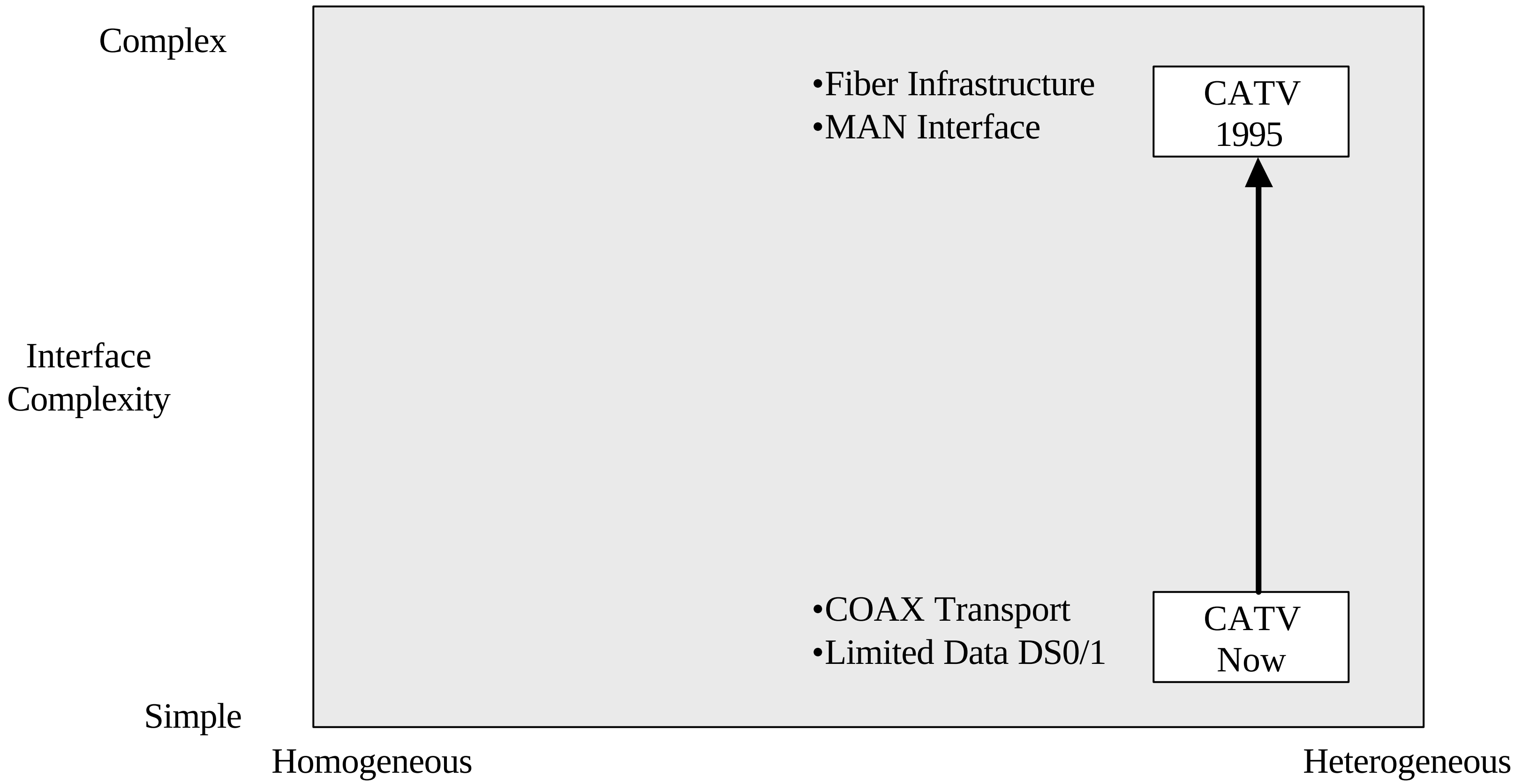
McGarty, Harvard November 1990

Figure 19

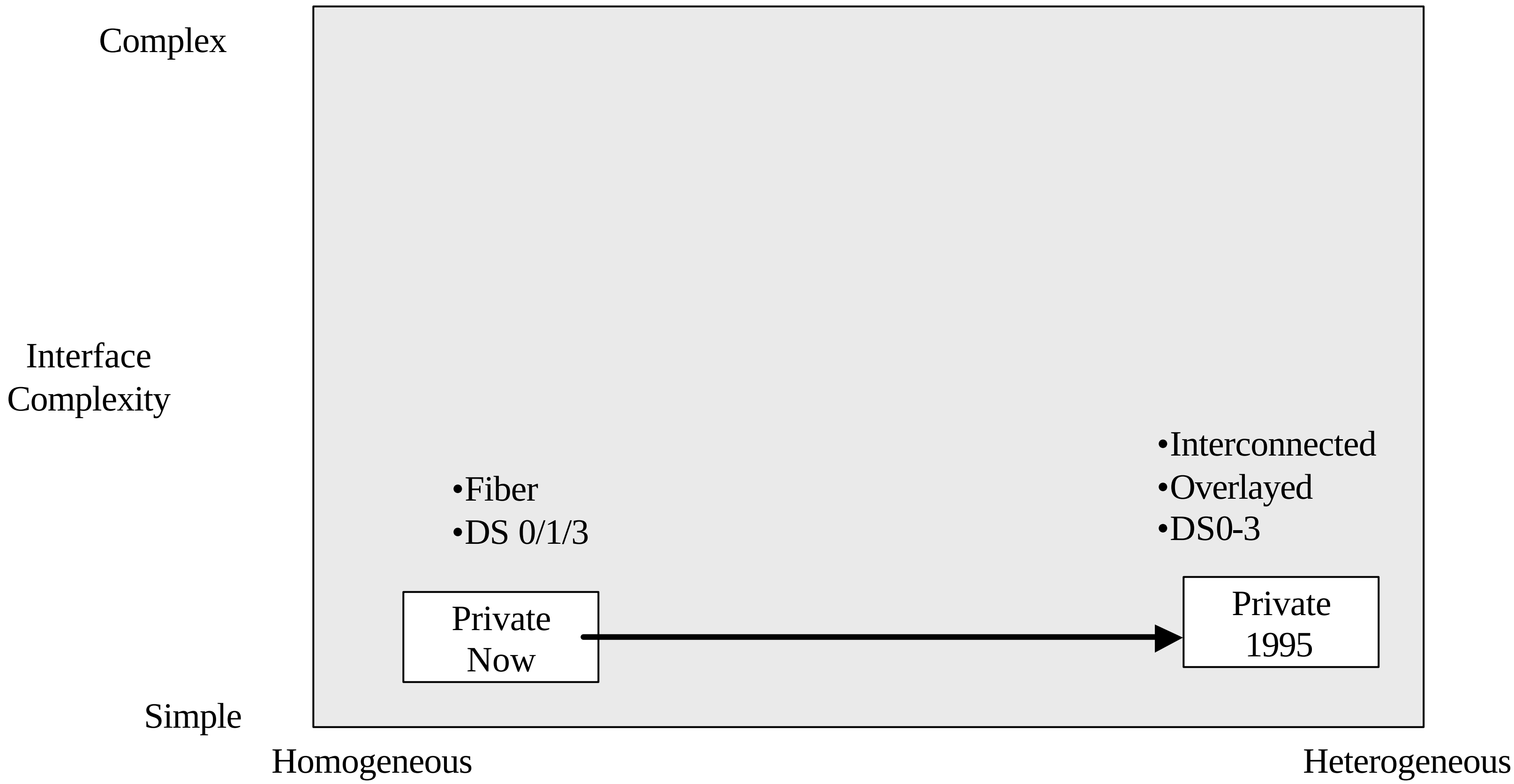
Network Evolution Map: Public Switched



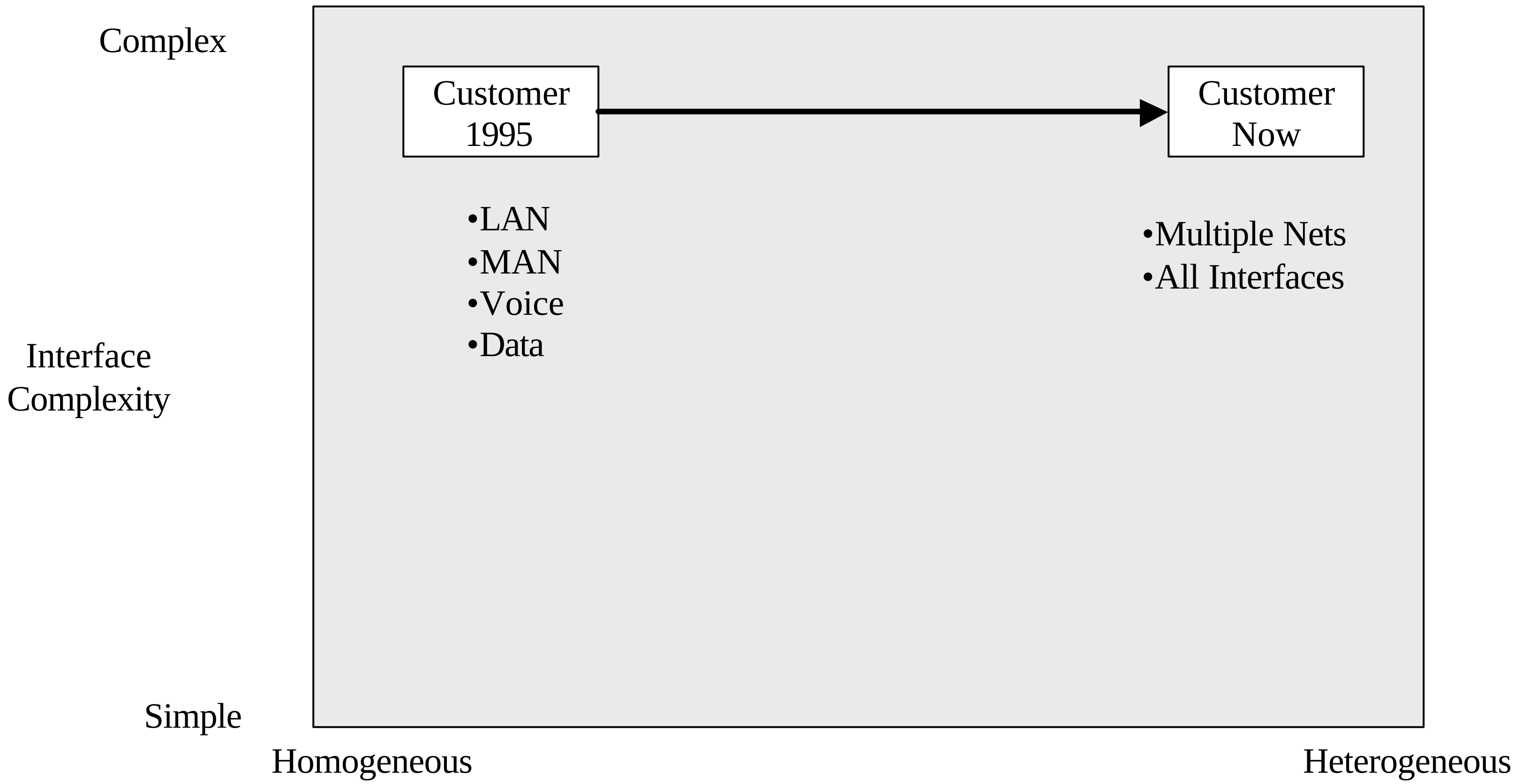
Network Evolution Map: CATV



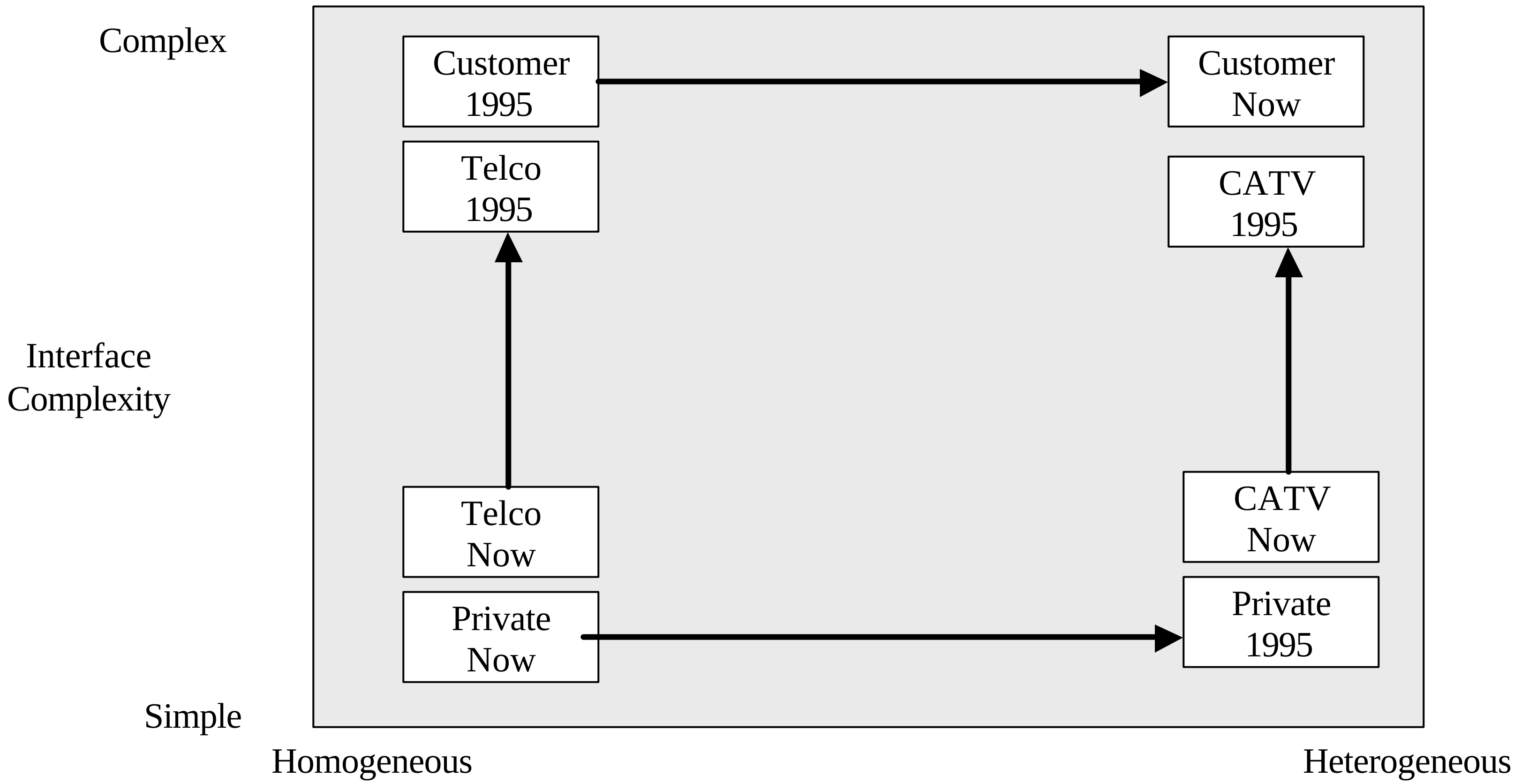
Network Evolution Map: Private Networks



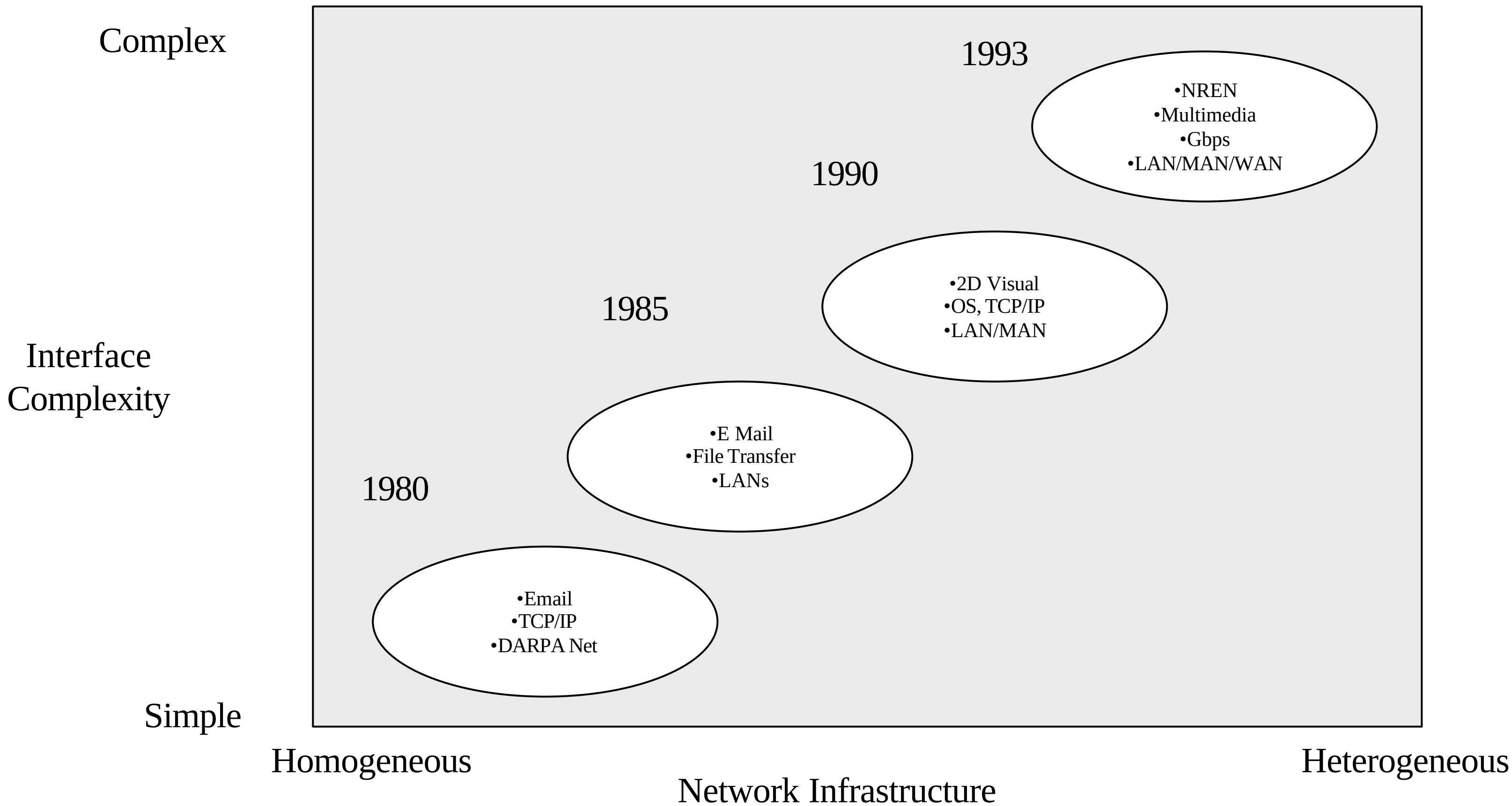
Network Evolution Map: Customer/CoOp



Network Evolution Map: Combined



Network Evolution Map: Internet



McGarty, Harvard November 1990 *Figure 25*

Network Characteristics

Factor	***Public Switched***	***CATV***	***Private***	***Customer***
Ownership	Regulated Telcos	Unregulated	Unregulated	Customer
Control	Telco	CATV Operator	Third Party	Self Control
Management	Telco	CATV	Third Party	Customer or Third Party
Interface	CCITT, ISO	Some standards	Limited Standards	Customer Specific
Interconnection	Hierarchical	None	Limited	Limited
Extent	Nationwide	Local	Local	As needed
Costs	Tariffs	Negotiated	Negotiated	Cost Based
Evolution	Complex Standard Interfaces	More capacity Complex Interface	More Capacity Limited Service	More complex Increased Interfaces
Examples	RBOCs	Time Warner TCI	Teleport CFO	IBM DEC