PRIVATE NETWORKS PUBLIC OBJECTIVES
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The Morphology and Taxonomy of Networks

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1. INTRODUCTION

Networks provide for the interconnection of a wide base of users and empower the users in the interexchange of information. The users, in most cases involved with the creation of economic value, employ the network resource as a means to, among other rational processes, increase revenue, decrease expenses, or increase market share. The equation on the part of the consumer of the network resource is a simple economic equation: is there more revenue or less expenses -- namely, is profit increased? Therefore, the choice of a network, be it public or private, is an economic choice. This paper attempts to show that the underlying economics of that choice are going through dramatic change. The change is precipitated by a fundamental change in the underlying structure of networks, driven not just by architectural and regulatory changes, but by more fundamental changes driven by technologies. These changes are, in many ways, beyond the control of the current players in the field, be they carriers or regulators. These changes are reforming and distorting all of the tools that we as policy makers have used in determining the social and political consequences of the policies we develop. It is the intent of this paper to outline some of these concepts of change.

The paper will focus on private networks. Prof. Eli M. Noam defines these as:

> "a network whose access is under the control of the closed user group or the user directly, albeit some of these control functions may be delegated to a carrier. The user controls access, exit, and internal pricing."[1]

This paper addresses five specific questions as they relate to private networks:

(i) What are the evolutionary paths that these networks are taking, and what affect might these paths have on the strategies of carriers, equipment makers, and large users?
(ii) How does a commercial entity gain a competitive advantage in a private network, and what is the value creation equation that provides the compelling reason for gaining an advantage? What are the specific sources of value creation? Is it possible that non-standardized networks can result in dis-economies?
(iii) Can private networks migrate to the consumer or residential user?
(iv) What is the impact of private networks on the value of information?
(v) How can one measure, unequivocally, the economic value that specialized and customized networks provide to an economic entity in terms of value creation and innovation?

Our approach to answering these questions is fivefold:

(i) Networks are characterized in terms of their basic elements, called their morphology or appearance. We then take these shape characteristics and cluster them in a taxonomy, or classification, of networks.
(ii) The fundamental underlying differences in these networks and demonstrate that there is an essential genetic difference between the basic two types -- hierarchical and distributed. Fundamentally, hierarchical networks possess significant scale economies, whereas distributed networks have minimial scale economies. This fact, the basic difference in the DNA of networks, is critical in determining the answers to all of the questions posed.
(iii) Using the paradigm of Darwinian Selection to show that fundamental forces will move to the selection of one of the two network types over the other, and that this selection is critical for policy makers to understand.
(iv) A specific example of how this change is effecting policy is discussed -- the NPRM on PCS/PCN, 1.8-2.0 GHz band for Personal Communications Systems. We argue, based upon current filings, that the change is upon us and will have a significant impact on network designers, users, and policy makers.
(v) Combining these facts with the concept of value in a economic entity we discuss how private networks play a key role in the development of value.

This paper presents the fourth step in an evolving understanding of networks, information, and economic value creation.[2] It presents for the first time the basic realization that networks are conceptualizable within the context of an organic entity, and thus the approach to deconstructing the dynamics of such evolution is achievable and strikes at the heart of policy making.

2. NETWORKS: MORPHOLOGY AND TAXONOMY

Networks, as currently viewed by users, designers, and policy makers are NOT evolved from a common ancestor. Rather, there are at least two different network concepts in use today that are genetically different and isolated. That genetic isolation gives rise to dramatically different evolutionary paths, and dictates that the hierarchical system that we are most familiar with is doomed to extinction. The genetic material of distributed networks, new to the scene due to dramatic changes in technology, are anticipated to survive. The distributed genetic material of networks behave dramatically differently, and policy makers in particular must recognize this. For example, scale economies disappear in such a structure, and thus all of the policy analyses based upon these issues are no longer applicable.

This section begins with a taxonomical and morphological analysis of networks in general. The approach is first phonetic, relating to externalities, and later discusses the differences that are at the heart of network differences.

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. It should be noted that these functions have evolved over the years in content and content and complexity. We view these elements in the context of a communications network that must support the current most advanced concepts in communications. Details of each are described below:

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, control schema, and products that allow for the custom control and management of their own networks. Companies such as IBM, AT&T, and NYNEX have developed network management systems that move the control from the network to the customer.[3] On the sub-network side, companies such as NET, Timeplex, Novell, 3-COM, and others have done similar implementations for local area networks, data multiplexers, and other elements. Centralized network control is no longer necessary and, in fact, may not be the most efficient way to control a network.

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

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, while 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 Department of Justice report to the U.S. Justice Department during the first Triennial Review of the MFJ.[4]

Transport: The transport element is provided by the underlying transport fabric, whether that be a twisted pair of copper wires, fiber optic cable, a radio, or other means. Transport should not be confused with other elements of the network. Transport is merely the provision of physical means to move information, in some form, from one point to another. It is generally expressed as bits per second(bps), or in terms of bandwidth. Bandwidth as a transport construct is the most enabling. Transport does not encompass the need to change the information or to make any other enhancement to the information.

It has been 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. In the current network environment, the issue of transport and its enabling capacity has arisen again. This was caused by the introduction of fiber. Fiber may be divided for the user in terms of bits per second, or bandwidth.

The fiber optic 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. The repeaters do not repeat data rates, they repeat framing sequences based on 64 Kbps voice frames. Thus any work station must use 64 Kbps as the underlying data fabric.

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.

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 it shall be discussed, 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 will be shown later, with the advent of Local Area Networks and CATV voice communications are the ones using distributed interconnectivity elements.

This argument for interconnection, combined with transport and control (namely horizontal integration) was valid in 1970. It is not, however, 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 Telephone Company, the Computer Scientist, and the User:

The Telephone Company 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 Scientist's view has been epitomized in the quote, "Every Packet is an Adventure." This is said with glee as each data packet is sent out across the network, and through the best hacking 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 his or her needs and minimizes cost. This is minimization of both obsolescence and cost strategy. Processing costs and capacity costs are declining every year. 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. The lost cost and 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.

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 to 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.

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 areas there are economies in market disaggregation.

2.2. Network Morphological Elements

In order to develop a network taxonomy, and in order to provide a Key for the taxonomy in determining which network fits where, it is first necessary to identify the network's morphological elements. Consider the work of Linneaus in characterizing plants. After many centuries of naturalists' identifying differing plants it became quite clear that there were several key characteristics that were used for the identification and differentiation of plants. These characteristics were related to the morphology and appearance of each species. Thus for plants, we look at the leaves, the flowers, the fruits, the shoots, the roots, and the seeds. These represent the elements necessary for the morphological structure.

In describing any network we have the following four major elements: control, interconnect, interface, and transport. They are like the elements in plants of flower, fruit, seed, shoot, and root. Each may have added subtleties in their structure but they represent the first high level differentiators of the network morphology. We now define these elements in detail. We then proceed to further differentiate these elements to a depth adequate for the development of a taxonomy for segmentation.

Control: Control functions in a network describe all of those functions necessary for the operations, administration, and maintenance of a network. It includes such functions as network management, network restoral, billing, inventory management, and network reconfiguration.

Interconnect: The interconnect functions describe all of those functions that are necessary for the identification, selection, processing, and support of all user-to-user connections on a network. Interconnection assumes an addressing scheme, a management scheme for the addresses, and a means for one user to address and connect to any other user including the determination of where that user is and how to locate them.

Interface: The interfaces are the connection between the end user and the transport element. The interface includes all of the functionality necessary for the user.

Transport: This element characterizes the physical and electronic means of transporting the information from one location to another. Transport focuses on the point to point means of the network.

We add a fifth element, namely the user as a means to help differentiate the ultimate use of the network as a means to allow for partitioning along the lines of use. Thus:

User: This is the end user of the network. The user may or may not be a human, and as a user has needs to be met in terms of the network structure. For example, the user may be a software process which may be configured in a client server mode, and as such the set of users may be the clients and a single server.

We will now begin to describe each of these areas out in further detail. Our approach is to develop a morphological structure that provides detail on general structural elements leaving the specific choice of the element to the lowest level. A morphology has no repetition of low level element choices. Each is independent. In addition, each choice is descriptive and is not exclusive.

The morphological approach is as follows. Each element, E.k, has a set of sub elements, E.k.j. In turn, each of these may be subdivided into other elements, E.k.j.n, until the final step is a descriptor of a sub element. A descriptor, D.k.j.n is a positive, inclusive statement of that sub element. For example a flower may have sepals, petals, stamen, and pistil. The sepals have venation. The venation may be parallel, pinnate, or palmate. The characteristics or descriptors are parallel, pinnate, or palmate. They are positive statements. It is unacceptable in a morphology to have parallel and nonparallel. The latter must be descriptive and inclusive in a class.

In a morphology, a complete classification is the set of all descriptors, {D.k.j.n:k=1,..K, j=1..J,n=1..N}. We must be certain that the set partitions the space of all known networks into classes that are separate. Hence, only the same network may have the same descriptor set.

2.2.1. Users

We begin the development with the user division since in many cases it is the end user who ultimately defines the network. For example, the current focus is on the users being processes, processors, or data files. Rarely in the current environment do we see the human being as a specific user. In the current stage of development of networks, there is a stronger trend toward the user being the main user of the network.

The elements that further define the set of users are as follows:

Type: The type of user characterizes the nature of the end user or end user set. The end user may be a human, a data file, a process, or a processor.

Time: The time element describes the nature of the connection as perceived by the end user. Depending on the user, the time element may have multiple options. The descriptors for this type are as follows:

- ***Simultaneous:*** All users are communicating at the same time.
- ***Displaced:*** Some users are not in the same time frame and, moreover, there are a disparate set of these time frames.
- ***Shifted:*** Time frames are equally shifted.

Transaction: This element describes the nature of the interaction between the users. Specifically it may be:

- ***Shared:*** All users may randomly access the services.
- ***Sequenced:*** A protocol of control from one user to another exists.
- ***Directed:*** Control is forced from a single point.

Set: The set of users may be homogeneous or inhomogeneous. If the set is homogeneous then the descriptor of type is definitive. If the set is inhomogeneous, then the descriptor of type must be expanded.

Thus the user element can be fully characterized by the descriptor set:

$$\{D.1.1.n_1,\ D.1.2.n_2,\ D.1.3.n_3,\ D.1.4.n_4\} \quad (1)$$

where D.i.j characterizes the specific descriptor sequence and the n_k characterizes the specific dichotomous ending.

2.2.2. Interconnect

Interconnect in the broadest sense describes the totality of how the users are brought together in a shared community for the purpose of communicating. As stated before, communications is the ability to change the state of one user or another in the linkages of the total process. Interconnection is the establishment and maintenance of the infrastructures that are required for the maintenance of these paths of communication.

In a similar fashion, we can describe the interconnect sub-elements as follows;

Location: The location of the interconnect agents or elements are the first item in the morphology deconstruction in this area. The location reflects the nature of the network as well as the world view of the designers. The following are the specific descriptors.

Fully Distributed: Each user of the network has access to and control over its own interconnect facility, which in turn may act autonomously in the network.

Intra-Netted: Interconnecting is done on a clustered basis with a collection of users in a closed and geographically compact community, each having access to a server that facilitates all of the network connections in an autonomous fashion.

Regional: Interconnecting is performed on the basis of a closed user group that is loosely connected geographically. A system provides a local switching node that is itself autonomous.

Centralized: In this configuration, the interconnecting is performed by a single element, that controls and directs all switching.

Hierarchical: A hierarchical network is one in which the interconnection or switching is hierarchically distributed, in that each element may switch to a certain degree, possibly locally, but the broader the reach of the switching, the higher in the network switch levels the switching or interconnection must go. The current public switched network is an example.

Addressing: This is a key factor in the overall operations of the interconnect function. Specifically, addressing permits the naming of any node and the location of that node or user for access of the interconnect function. Addressing has two characteristics. The first is the geographical nature of addressing that states where, physically, in the network the addressing may be used and effected. The second in the temporal factor of addressing that relates to the issue of whether the addresses themselves are static or dynamic. Specifically, with dynamic addressing we change the address from time to time. Adaptive addressing changes addresses based upon other factors.

(i) Physical Addressing:

Local: This type of addressing allows for addresses to be local to a select user group. There is no way to address a foreign user entity.

Universal: This allows for global addressing of any user on the network.

Serialized: This approach allows for addressing of groups, then sub groups and then ultimately down to selected end user communities.

(ii) Temporal Addressing:

Static: In this addressing system all addresses are kept constant with time.

Dynamic: In this scheme, addresses are changeable with time occurring to some prearranged system or protocol.

Adaptive: Adaptive addressing goes beyond dynamic addressing in that it responds not only to time and place, but also to other exogenous factors in the end user or network operating factors. An adaptive addressing scheme may change addresses depending on other factors.

Selection: This element of interconnect focuses on the issue of how the interconnect process is managed. Specifically, there are two currently observed descriptors: random and assigned.

Random: This system is based upon an algorithm or protocol, but the result depends on factors that are random.

Assigned: This is a preassigned system, where knowing the state of the network at any one time determines the connection path.

Performance: The performance determinant addresses the issue of the quality of service delivered. The quality may be judged along several axes. The following are the current set of determinants.

Time: This factor relates to the time of setup or other such factors.

Signal: This relates to the quality level of the voice signal, or the data or image signals.

Delay: This is the characterization of the delay in the network.

Blocking: This is the characterization of the blocking in the interconnect.

Links: The link element or descriptor of the interconnect function relates to the types of interconnect that are employed. Specifically, is the interconnect a physical interconnection, a virtual interconnection, or a relational one? The reader is referred to Tannenbaum for the full detail on these approaches. At a higher level each is described below:

Physical: This is a defined and measurable physical path between all interconnections and users.

Virtual: This is a path that is created on the basis of signaling vectors between all of the users. Although not a physical path, it is an algorithmically defined path that is reconstructible at any instant from the state of the network.

Relational: This is a fully random path built upon relations between users in the network. It depends upon states of the users and the network, unlike the virtual path that depends solely upon the state of the network.

Setup: This is the final descriptor of the interconnect element. It represents the nature of the interconnect signaling, as separate from or a part of the communication channel from user to user. The two forms are as follows:

In Band: ALL signaling in the same path as the user to user communications in all layers of the communication channel, physical or logical.

Out of Band: Signaling takes different physical and/or logical paths.

2.2.3. Interface

Interface describes the nature of the interaction between the user and the interfaces and transport. Interface describes the elements that allow for the users to take maximum advantage of the others users' interface needs.

There are five descriptors of the interface level:

Modality: This descriptor describes the nature of the information flowing to or from the user. There are the following types: Video, Voice, Text, Data, and Image. In addition to the above simple descriptors, there are a set of compound descriptors that reflect a multimedia environment. We develop those through a concatenation of the above descriptors.

Multiplicity: This descriptor indicates the nature of the number of end users connected to a single interface. Simply stated there may be one or many.
Integratability: This descriptor indicates the temporal, spatial, or logical nature of the interface. In the simple temporal case, we can envision the interface operating in asynchronous mode with timing shared by all of the users. In a spatial synchronous mode, we can envision all of the users sharing a common virtual spatial reference, even though all of the users may have different screens with different aspect ratios and other such factors. Logical synchronicity describes the ability to assure the cohesiveness of the information presented in the display interface. In a similar fashion, asynchronous integrability reflects the fact that there is no overall timing of the events and that they follow a system of one to one arrangements. The third level is sub-synchronous wherein some may be synchronized while others are not.
Conversationality: This describes the nature of the interface and its users as it relates to the sessions that may be created on the network. The interface may range from the shared, or party-line, method, to the conversational systems common in multimedia communications, to a private line, and finally into a fully secure link.
Links: This descriptor indicates the number of links that are supported per interface.

2.2.4. Control

Control is the broadest element in the morphology of networks. The issue of control may span from who owns and operates the network to how, specifically, the network is managed as a living and operating entity.

Management: Who, specifically, owns and operates the network. It is essentially the legal control part of the network.

- *Users-Direct:* Each user has direct control over the network.
- *Users-Indirect:* Each user has an influence on the network, but the control is indirectly applied.
- *Shared:* Users share in a pooling fashion the control over the network.
- *Public:* There is a publicly accepted control point for the network. Such is the case for the public switched network.
- *Private:* This is a network provided on a private basis. Control is in the hands of a private entity.

Maintenance: The philosophy behind the real time control of the network. It describes how the network is managed and maintained as an operating entity. Several possible, and currently recognized descriptors are possible:

- *Centralized:* Controlled by a single entity.
- *Sectored:* Broken into segments that are controlled by separate entities divided by geography, or function, or some other such factor.
- *Distributed:* A fully distributed and autonomous function.

Scope: The scope element describes the breadth of elements that are performed by the network as it is functioning in its operational management role The functions may include some of the following descriptors.

- *Inventory*
- *Maintenance*

These are the major descriptors of the control function. All too often designers have not focused on the control descriptors as an element in the network morphology. In this paper, we have presented several key control descriptors, and are quick to point out that there may be more discovered as control becomes a more significant factor in the design of a network.

2.2.5. Transport

Transport is the set of elements that relate to the underlying means of movement of the communications signals from one point to another. In its simplest sense, it represents the media of movement and the specific signals that are used to make that movement possible. In the context of the IS model (Tannenbaum) these represent the lowest three levels, Levels, one to three.

Medium: The medium characterizes the lowest level of transport, referring to the specific transport vehicle. In the following list we refer to fiber, radio, and other specific means of transport.

Method: The method or means of transporting the signal. There are two general descriptors that, in turn, have more specificity. They are analog and digital, in all their known variations.

Mode: The characteristics of the level three elements of keeping links in the network in operation. The two major ways of doing it to date are synchronous and asynchronous.

2.3. Network Taxonomy

Having developed the morphological concepts in networks, in this section we plan to develop the concept of taxonomies' use of these morphological elements. As with any taxonomical development, the choice is somewhat arbitrary, especially as we begin at the highest level. The work of Sokal and Sneath in taxonomical classification may be referred to, and it is their work that has influenced our current approach. If we recall plant taxonomies, the division is first along the lines of seed bearing and non-seed bearing plants. Then the division in the seed bearing branch are those with fruit (flowering plants) and those without (conifers). The same issues are present with networks. What factor do we start with that is as important as seeds and then flowers or fruits? The issue of taxonomy based on highest level of morphological division is critical.

In the development of a taxonomy, we begin with the available morphologies and generally attempt to generate taxa based upon the highest level of differentiators. As we have discussed before, we have presented architectural variants and infrastructure variants. These were developed at the highest level without any benefit of the morphology that we have also developed.

The concept of genera and species in plant taxonomy is a statement that says that there are sets of common elements that are in collections of different networks and that this collection is common to sub-classes of such networks.

Networks have evolved over time and some types no longer exist. Most step-by-step voice networks are no longer in existence. They have been superseded by cross-bar and then electronic switching systems. The question may be asked -- what is the evolutionary past of the local area network? The reason for this question is to not only understand the past, but also to recognize that the past is the prologue to the future, and to project possible network evolutionary trends.

As in plant taxonomy, there is a set of hierarchical relationships among networks. The collection of networks at lower levels, such as genera and species, can be concatenated upwards into the taxa.

3. NETWORK GENETIC STRUCTURE

The previous section discussed the phenotypic characteristics of networks. We focused on external observables and allowed classification of networks based upon these characteristics. A similar approach is taken in the plant and animal world. Phenotypic characters are used, for the most part, to classify species, genus, families, etc. In contrast, there is in the plant and animal world an underlying genotype. This genotype is driven by the genetic material of the species. The gene is what expresses the phenotype characters. The basis of the gene is the carbon in the DNA. We argue that a similar approach can be applied to networks -- that we can deconstruct the genotypes of certain broad classes based on silicon rather than carbon. This argument is in its earliest stages of development, but its usefulness in evaluating the evolution of networks appears to be significant.

In the analysis that we have developed, the genetic makeup is driven by the difference in technology as well as by the difference in world view.[5] The genetic makeup of the network therefore is composed of the following:

> (i) ***World View***: The world view is based upon the paradigm or example from which all development proceeds. RBOCs still are working from the hierarchical voice-based approach of Vail and Bell. Distributed systems evolve from the LAN technology of the late sixties and early seventies, driven by the desire to put as much investment into software as possible.
> (ii) ***Technology***: The hierarchical networks are still replacing relays and operators. The view towards software in these networks is based upon minimal intelligence at the home terminal, and maximum control at the central switch. Distributed systems anticipate uncertainty, assume intelligent end-user devices, and move toward emphasis on software. They assume that silicon costs will continue to decrease.
> (iii) ***Organization***: The distributed inclination is toward empowering the end-user. The control is distributed and interconnected also. The hierarchical network is typified by an RBOC with strong central control, excessive overhead, and large fixed costs.[6]

Clearly there is a difference between the structure of a hierarchical network and a distributed. We shall detail this in the next section.

4. THE SELECTION PROCESS

The selection process employs Darwin's idea of natural selection -- survival of the fittest -- to networks. Policy must follow this concept and not fight it. At best, by fighting the Darwinian path, policy will delay, but not change, evolution. The genetically more fit network will be the survivor. Fitness relates to the overall value chain impact of all users of a network. The fitness quotient of an environment of a network is predicated upon the users of the network, and on the competitive advantage that the use of such a network provides.

From an evolutionary perspective, each species has a set of phenotypic characteristics that allow it to handle the challenges of its environment.[7] These phenotypes are a reflection of its basic genetic materials. Species are generally closely related in an evolutionary sense, and as we ascend to genus, families, divisions, and classes, we see a decrease in relationship. We also see that members of those classes, for example, demonstrate differing abilities to handle changes in their environment.

Consider two simple examples: oaks and grasses. Oaks are in the class of plants called dicots. They are woody and take twenty years to go to seed. If their environment changes quickly in that period they will not go to seed and will perish. Thus oaks, mighty oaks, have an Achilles heel in their requirement of long-term stability. Grasses are monocots, a more recent evolutionary class. They grow from year to year, go to seed many times in a year, are propagated by the wind, and are very insensitive to water, sun, cold, and other factors. One need think no further than the friendly crab grass. They spread by runners in a highly distributed fashion in their local domain. They are highly flexible and have shown rapid rates of genetic mutations. The survival of a species and its evolution depend upon two factors -- its basic genetic makeup, and the change that the environment has with respect to how the species can cope. Thus for networks we can address these two issues and reflect a conclusion. Let us consider the two different classes of networks; hierarchical and distributed.

(i) ***Genetic Makeup***

Hierarchical: As described above, it is a rigid, centralized, and control-oriented system.

Distributed: This is software directed, user-empowered and allows for full flexibility.

(ii) ***Environmental Stresses***

Hierarchical: This system cannot readily reorient itself for change.

Distributed: This is a highly flexible organism readily adaptable to change.

When we compare these two factors for the two network classes, we argue that the survivor will be the one that matches the changes in the environment with its underlying genetic makeup. It seems clear from this preliminary study that a fully distributed architecture will have a better chance of surviving because of its underlying flexibility to adapt to its enviroment and because of its flexibility to mutate to meet the needs of the user.

5. CURRENT NETWORK EXAMPLE

A current example of networks that exemplify the characteristics discussed in this paper are those presently being developed in the PCN/PCS arena. This new network architecture offers several interesting and timely examples of where policy must recognize the essential changes in networks. We argue that the FCC has failed to do so in its current filings, and that it is basing its current policy positions on assumptions consistent with hierarchical networks but totally inconsistent with distributed networks. In this section we work through this example and provide a list of the key policy issue that must be reconsidered in light of this evolutionary change.

The FCC has released a Notice of Public Rule Making (NPRM) in the area of Personal Communications Services (PCS). This new and innovative form of networking will be the first national network that will be based upon a distributed architecture, at least as proposed by some of the contenders. This architecture consists of the following elements:

Radio Frequency Transport: In this case the 1.8-2.0 GHz bands will be allocated for transmission. As we have stated, this open bandwidth approach, like dark fiber and coaxial LANs, opens up many dimensions for new networking operations.

CDMA Switching and Interconnect: One of the proposed technologies for switching is Code Division Multiple Access (CDMA) which would allow many users to access the same frequency band by giving each user an access code that is mathematically and electronically orthogonal to all other users. By using extensive, and distributed processing power, both in cell sites, and more importantly, in the end-user's terminal, a fully distributed switching fabric is established.

Distributed Network Control: The control of these networks is based not only on the control at some central facility but, more importantly, is based upon control at the user's terminal.

Interface with Complexity but Low Cost: The end-user's terminals enough processing capability so that they can be reprogrammed, in some cases by downloading new software to them. The net result is that the network can change in a real-time and organic fashion.

This new network configuration has several innovative features. There is a current mind-set among many of the cellular carriers that it is important to keep the minutes of use up, and that the revenue for minutes of use must also be held constant. In contrast, most consumer-oriented companies recognize that success is determined by gaining market share and that share, once lost, is extremely costly to regain. In the current cellular market, most players are in a game of limited price competition, and the stabilization of share along standard duopolist lines of controlling market growth while retaining profitability through price management. Penetration of the total market has been gradual and the relative share has be held at 50% each. With the increase in additional carriers in the 1.8GHz band, this will change significantly. The new objective will be to maximize market share through the rapid increase of market penetration. Penetration increases mean that market share is obtained through the acquisition of new, untapped, customers, and not through the buying away of an old customer base. The means to achieve this new and rapid market penetration increase is a three pronged strategy: price, quality, and accessibility.

The price of the set and the service must be dropped to a critical point to make it readily accessible. This is clearly the success point of the VCR strategy when penetration blossomed at a $300 price point. The same price points are there for the wireless market. The quality of the set and the service must meet a minimal level of expectation. Systems such as those in Hong Kong were the first to recognize and implement this approach. Systems such as those in New York have failed. The difference is in the penetration in these two markets: 8% for Hong Kong and 2% for New York. Accessibility means that the customer can get both the set and service with minimal effort. Thus, even a short trip to a store, or the need for installation, or the process of additional credit approval is counter-productive.

In short, the success of the new players in attaining and retaining the growing market share is to create a system with a low barrier to entry and a high barrier to exit. In essence, low entry barriers imply low costs and ease of access; high exit barriers mean high service quality and low fixed and predictable costs. The overall strategy is one where there should be no ambiguity of expectations on either side.

The main driver in gaining increased penetration is the ability to reduce the costs to the consumer to a critical level. That level and the way in which it is priced is critical to customer acceptance. At best, the service may present a package of benefits to the consumer.

However, these benefits are not needs. There is a distinct difference. Benefits may be cost justified, even understood to be important, but are displayable. Needs have taken a life unto themselves. The need can become less cost-sensitive after it has been established.

Thus the pricing for new wireless services, must follow the low barrier to entry approach. As such, if the service is provided on a fixed-price basis, independent of the level of local usage, then there is not the fear of the "meter ticking." Thus the recommendation is the provision of service at $30 or less per month for unlimited local usage. In fact, recent tests have shown that users will actually give up their local telephone service at this price level and use wireless alone.

Price is only part of the equation. The service must be profitable. Thus the fully loaded costs must be reduced dramatically. It has been shown that wireless systems are predominantly variable in cost and that they have limited fixed cost structures. Thus the strategy to reduce costs is simple: increase productivity. There are no significant scale economies. One cannot reduce costs by increasing volume.[8] Thus the imbedded carriers at 800 MHZ have the same advantage or disadvantage as any other player in the market. There are no economies of scale and thus there can be no ability to dominate the market by having initial presence. Market power is attained through pricing, and pricing through performance.

If one believes that dramatic penetration is achievable at $30 per month per customer for unlimited local usage, then a profitable operation can be developed wherein the fully loaded expenses are $300 per year per customer or less. Moreover there are four strategies that help achieve this goal. They fall clearly into the four areas of acquisition, retention, operations, and depreciation.

Our four point strategy for success in this business is as follows:

(1) Separate the set from the service and market, and sell the service through cost-effective channels used by other service entities, such as direct mail, telemarketing, etc.

(2) Reduce turnover through the development of brand loyalty, quality service, and effective customer support. Balance customer expectations with those of the delivered service. Manage, monitor, and match the customer perceptions with systems performance.

(3) Automate all operations as much as possible, from the initial design to the daily upkeep. Use controllable variable expenses that may be outsourced to minimize unit costs.

(4) Utilize the most frequency and power efficient technology to maximize the cost per unit spectrum per customer. This currently calls for the adoption of CDMA technology rather than other digital or analog systems. Use controllable variable costs where appropriate. Co-location in central offices will eliminate the need for MTSOs, or cellular switches.

The details of how this four point strategy may be implemented, and detail the implementation impacts, have been developed elsewhere.[9]

The current wireless technology, as embodied in the cellular communications systems, is composed of several key technological elements. Specifically they are the Cell Sites, the MTSO (Mobile Telephone Switching Office), and whatever connections or management systems are in place. The connections between the cell sites and the MTSOs are digital circuits carrying the voice signals. It should be emphasized that the MSTO is necessary for the purpose of establishing the connection between a time-varying wireless circuit and a fixed twisted pair circuit. In addition, it should be noted that a MTSO is an historical artifact, representing a pre-divestiture barrier between the wireless circuit and the switched network. With Signaling System 7, such a barrier is no longer needed. It will be argued that with co-location, the switched network can be turned into a fixed "Backplane" for the wireless interconnection fabric.

The MTSOs are interconnected via the Public Switched Telephone Network (PSTN) of the local carrier. The local carrier receives a set of digital circuits, and their signaling information, for interconnection with other non-cellular users.

MTSO operations are comparable to a small central office of an average local carrier. Software maintenance and switch control are the typical functions performed. The additional costs of an MTSO are the carrier charges from the MTSO to the PSTN, a Class 5 Central Office. These charges are ongoing and consist of a fixed charge plus a variable element. Specifically, under the current tariffs, the cost is about $0.11 per minute per voice call. This includes an amortization of many charges from the local telephone company. It is not a marginal cost price of access costs and switch costs only. In fact, on a per line basis, the cost for carrier access charges are the dominant cost per subscriber. Specifically, charges of $0.70 per minute for cellular include the $0.11 cost. Some systems cost as high as $0.24 depending on the LATA interconnect permitted.

A dramatic change is occurring with the move to co-location and to unbundled marginal cost pricing on an equitable basis. Simply put this means that anyone may gain switch access alone, without an allocation for the plant cost and priced at the same level as the telephone company, (namely at the marginal price); and it also means that a wireless company may co-locate their equipment in the telephone company central office. The Qualcomm QTSO is such an architecture where the cells are intelligent and an adjunct processor, the QTSO, is placed in the central office. This will eliminate the need for a MTSO, shorten the access lines, reduce the access line costs, and increase overall system reliability. It will, in effect, put the wireless company in the wireless radio business and keep it out of the telephone switching business.

In extremis, this old paradigm uses design philosophies that select optimal cell sites and result in fights to access the right piece of real estate. The old paradigm takes extensive time to select and install, and yields a large value for the cell life cycle cost factor.

The new paradigm is driven by the desire to be flexible and to drive the cell allocation and utilization in a fashion that maximizes the Net Present Value of the business. It clearly is a system approach that does not follow the old book. The new paradigm is characterized in three key ways:

> ***(1) Flexibility of design and layout***. Using sophisticated design tools, sub-optimal sites are chosen based upon a life cycle cost methodology.
>
> ***(2) Maximization of NPV of Business***. The costs of leases, service care, and upkeep are critical. The system uses a dynamic network management and control system that dynamically measures the field strength of the system via sensors in the field, and from this generates a feedback to the cell sites to optimize performance. This allows for a fully automated optimization of the cell operation in a holistic fashion. It focuses on reducing the operations side of the life cycle costs. It does

this by allowing for maintenance and repair dispatching on a more orderly basis, allowing for the management and control of spares and inventory, and allowing for the changes in cells when new ones are added, or in the event of environmental propagation changes.
(3) User measurement with the intent to maximize customer perception. By having the *in situ* measurement devices not only can we adjust the cells to meet system performance factors, but we can also adapt and manage the system to meet the necessary customer perception factors.

In this section we have focused on several key technical factors that will result in cost reduction. These are:

Co-Location: Eliminates MTSO and reduces the per line access charge.
Network Management: Reduces the up-front planning costs and reduces the ongoing maintenance and repair costs. Improves performance and customer reception.
CDMA Digital: Increases the number of cells and thus reduces depreciation Makes for simpler planning.

Let us now consider the implications of these changes in the economics of these new systems. Specifically, we shall comment on each network element.

(i) ***Transport***: The transport in this case is radio. It can range from being free, as in a lottery, to being a large fixed up front amount, as in an auction, to a variable amount as in a CATV system. In contrast to the wireline RBOC, business transport costs are controlled by policy, not by rational economics. Let us defer this item for the moment.

(ii) ***Interconnect***: The switching is done via the CDMA code network using the handset along with the cell sites. There are two types of cells, larger full cells, and smaller re-radiators or microcells. The larger cells are driven by capacity. A typical cell can handle 400 voice trunks, or a possible 40,000 customers. It may cost $1 million. Unlike analog cellular, CDMA requires only one MTSO for coverage rather than the forty or fifty. The re-rads are low cost and handle problems of coverage.

(iii) ***Interface***: The handset is fully variable in cost, and available to each purchasing customer.

(iv) ***Control***: The control is integrated into both the cell site and the handsets.

Thus, if we look at the economics of the new wireless technologies we note that the capital and expenses are composed of fixed and variable amounts. Specifically:

$$C = C_F + C_V \tag{2}$$

$$E = E_F + E_V \tag{3}$$

Where we have C for capital and E for the operating expenses. It has been shown elsewhere that for this business E_F is small and can be disregarded. Thus E is all variable. Now consider depreciation, D:

$$D = D_F + D_V \tag{4}$$

It can readily be shown that fixed depreciation depends on fixed capital. Thus let us focus on capital. As we have shown the capital consists of the cell sites and the re-rads. If we assume that 2.5% of the users are active at any time in the busiest hours, then a 400 channel cell site can handle 10,000 users. This means that the scale increment is 10,000. If we also assume that a cell can handle a 3 mile radius or about 30 square miles, then using re-rads, 1,500 square miles requires one cell plus 50 re-rads. A cell costs $1 million and the re-rads cost $20,000 each. This means that the first 10,000 customers will cost $2 million. Therefore, the fixed costs are $2 million capital.

Let us now contrast this for analog cellular. Each cell can handle only 40 channels, and a new cell is required per coverage site. Thus, despite the 40 cell capacity, 50 cell sites are needed to cover 1500 square miles. Each cell site costs the same $1 million. 2,000 channels are provided at affixed capital of $50 million. Thus the scale increment is 50,000 customers, and the fixed capital is ten times higher. This does not include the added fixed cost of the MTSO.

Therefore, we can show that the marginal costs, Co_M, approach the average costs, Co_A, in a very small time frame for the new wireless system. Therefore, we argue that there are *de minimus* scale economies.

This new technology will result in the following new policy observations:

(i) ***Lack Of Scale***: The *de minimus* scale economies in these distributed networks mean that the arguments from the theory of monopolistic pricing no longer apply. There is no basis for monopoly, there are no barriers to entry, and there are de minimus barriers to exit. Policy makers should re-evaluate their basic premises and review the results. In particular, the FCC should use the PCS NPRM as the first vehicle to open up this new line of insight. Lehman and Weisman argue from the premise of significant fixed and imbedded costs. They further argue on the basis of an existing infrastructure. The author has argued before that telecommunication, due to the rapid change in technology, is not equipped to be an infrastructure and that, based on the argument herein, the scale issues negate all of the proposed policy recommendations.

(ii) ***Rate of Change***: Technology is now allowing change to occur in a more fluid fashion. Silicon, although not really free, is extremely low in cost. The continuing cost is in the software development. In this new CDMA world, the projected prices for the neccessary chip is in the tens of dollars range and decreasing. The entire handset will, in five years, be below $200. It will be the software that will lead the change in the network.

(iii) ***Openness versus Standards***: Standards are a way to ensure a form of universal service. Standards are arrived at by a slow and litigious process and hope to result in a single result. Pressed by the technology change, however, the standard is often out of date or excessively compromised. The net result is that coalitions, not standards, are the way of the future. The direction of policy should be to strengthen coalitions, and not enforce standards.

(iv) ***Coalitions Versus Regulation***: Coalitions are the alternative to regulation. Regulation can be a control in a monopolistic market to ensure public good. In a free and openly competitive market this no longer holds. The ability to commodify service offerings, and the change from high fixed cost structures, requires a re-evaluation of the regulation assumptions and a clear statement of them.

6. VALUE CREATION WITH NETWORKS

Value creation in a network has been a matter of study by both academics and users over the past ten years. For the purpose of this paper, we shall consider value creation as the ability to take any economic entity and to add to that entity a capability with a network that will change the value of that entity in some measurable fashion. The concept of value that we shall use will be that of the net present value of the business entity. We can then readily show that the value is decomposable into revenue, expense, and capital elements, and that this value can also be manipulated via tax or fiscal policy.

6.1. Value Measures

All too frequently analysts will use a change in productivity in a business to attempt to show some amorphous competitive advantage. We argue, however, that there exists a clear and simple approach, deployable on the unit business scale, that demonstrates all of these elements in full and complete analytical detail and is subsequently measurable in any market environment.

The value of a business is defined as the net present value of the business based solely upon its long term cash flows. Specifically, if R(k) is the revenue from the business for the k year, E(k), the expenses of the business for the k year, and C(k) the capital expenditures for the business for the k year, then, assuming *de minimus* effects of working capital and an all equity financing scheme, the year's cash flow is:

$$CF(k) = R(k) - E(k) - C(k) \tag{5}$$

The net present value, or value, is defined as the discounted sum of these cash flows. The discounting used is the cost of capital for this entity.[10] Thus the value of business entity I is:

$$V(I) = CF(1)/(1+m) + \ldots\ldots + CF(n)/(1+m^n) \tag{6}$$

where n is the business investment time horizon, and there is no salvage value to the business.[11]

6.2. Value Creation

Now consider a business entity that has a value, V(I,b), where we denote b as before the use of the new networking technology. Similarly we denote a as after, and the value as V(I,a). Let us consider a business that has revenue and expenses but has no capital. The extension to capital is trivial. Let us first begin with revenue.

The revenue of a business with a single product is considered. Let us assume that the product has a unit price of p and that there is a demand elasticity that says the demand for the product at p is q(p). Let us assume that we know this function. Let us also assume that:

$$q(p_1) > q(p_0) \text{ for all } p_1 > p_0 \tag{7}$$

Now let the T be the total market base. The addressable market is the demographic percentage of T, namely D(T). The feasible market is the psychographic percentage of D(T), namely P(D(T)). The adoption percentage of the feasible market is the target market, namely

A(P(D(T))), equals the target market, TM. Finally, the actual units sold are based on share, S, and are total units, TU, where:

$$TU = q = S(TM) = S(A(P(D(T)))) \quad (8)$$

Recall that S, A, P and D, depend on p. Some of these factors also depend on other intangible factors such as brand recognition, advertising, etc. In general in a commodity market, all things being equal, price is the sole determinator. Therefore, market size depends solely on price, and price on cost. Therefore, we argue that we can neglect the revenue side in this case and focus solely on the expense side.

The expenses of a business can be broken down into the expenses for a set of processes. If we view a business in the Porter context of its value chain, that chain is composed of a set of supportive processes. These processes may be engineering, marketing, sales, customer service, inventory, administration, etc. Let us assume that such processes are identifiable and that the business is a collection of these. Thus the expense for the business is:

$$E = E(1) + E(2) + \ldots\ldots + E(n) \quad (9)$$

Now E(I) is the expense associated with a single process. It can be expressed, if properly decomposed into the product of a revenue driver (RD), a productivity factor (PF), and a unit cost (UC). For example, a sales force has as the revenue driver the number of new customers. The productivity factor is the number of new customers per year per sales person. The unit cost is the expense per sales person. Thus the sales expense is:

E(Sales)[12] = RD(Sales) PF(Sales) UC(Sales) (10)

To reduce the cost we can do three things. First, we can reduce the number of new customers. This is not at all appropriate and thus is not done. Second, we can increase the productivity and thus reduce the productivity factor. This can be done by more effective targeting of the sales force through telemarketing, inbound 800 number services etc. Third, we can reduce the salary of the salesforce. This third factor is probably the worst; salespeople are motivated by money. If anything the compensation should be increased to further increase productivity. Thus, in this case we can see how sales productivity is targeted by better acquisition of customers.

Thus networks can reduce costs in several ways: eliminating processes, reducing unit costs, reducing the productivity factor, or in some cases reducing the revenue driver. This can be shown in the examples discussed in the next section.

6.3. Value Creation Examples

In this section we will show that there are several common examples of cases where the use of a network has clearly created value for the firm in many ways.

Case 1: American Airlines

American Airlines has developed a significant competitive advantage in the use of their private network and their SABRE reservation system. It was, and is, a strategic tool based on networking and the control of information. It allows for ease of access to all products and in a way has commoditized the market. This concept of commodicization was first used in airlines, so that competition was essential to be based upon the most efficient carrier. The distortions in this market are due to the fact that the owners of such airlines as TWA, Continental, USAir, the late Eastern and Pan Am have been the U.S.Government through the bankruptcy courts. This distortion has, through a policy position, distorted the normal market efficiencies. One can argue that this is a paradigm for what could happen in private networks if the government subsidizes via policy the RBOC positions.[13]

Case 2: Federal Express

Federal Express has market share based on end user accessibility. Their network keeps costs down and share up. The private network that they use tracks all items from beginning to end, and suffers a fairly low, although not zero, error rate. They have a fully integrated satellite, radio, and land line network system.

Case 3: Healthcare

In the area of health care, McGarty and Sununu[14] have shown that the use of private networks can reduce the costs of health care provision by 20%. The test that these figures were based upon were performed in Boston.[15]

7. CONCLUSIONS

We began this paper with a definition of private networks that essentially stated that they were a collection of networking elements, wherein the power to manage them lay in the hands of their users. The two forces that have enabled this have been deregulation as well as technology. We further went on with a discussion that stated that although networks have all the same physically viewable characteristics, they were in some sense genetically different. Hierarchical or RBOC type networks were fundamentally and genetically different from Distributed or LAN type networks. This concept of genetic difference was based upon an ability to adapt by the different network.

Although we began this metaphorical analysis in the attempt to demonstrate limited relationships, we soon found that the underlying relationships Darwin saw in natural species are also fundamental to man-made species like networks. This strengthening of the metaphor allows us to use the observations and techniques to answer the questions posed earlier.

(i) What are the evolutionary paths that these networks are taking, and what are the implications that these paths will have on the strategies of carriers, equipment makers, and large users?

The evolutionary paths of networks are first determined by recognizing the two types of networks that have evolved: hierarchical and distributed. Further, it is based upon observing that the new paradigm of "silicon is free" makes the survival of distributed networks highly favorable, and the survival of hierarchical networks problematic. Users will migrate towards value increasing network solutions. If the distributed technology tends towards that end, as it has been argued, then that is where the users will go.

(ii) How does a commercial entity gain a competitive advantage in a private network and what is the value creation equation that provides the compelling reason for making such a choice?

What are the specific sources of value creation? Is it possible that non-standarized networks can result in diseconomies?

A commercial entity is concerned, if it is a rational business entity, with value creation and value increase. Value in this context is an increase in the net present value of the firm. This value can be increased by increasing revenues, decreasing expenses, or decreasing capital flow, or any combination of these elements. The specific sources of value creation can be determined by examining the microstructure of a business, understanding process and productivity flow, and showing how the network improves each. Non-standardized networks are essentially the silicon version of biodiversity in the carbon world. More silicon gene flow from non-standardized networks will allow for the ability to adapt to rapid change in a business environment. Looking at today's business networks one sees an amalgam of different interconnections, each selected for optimal performance. It is specious at best to assume that a business entity may stand still and optimize its entire operation. Business is run on a continuim of sub-optimum choices.

(iii) Can private networks migrate to the consumer or residential user?

Value creation is measurable and demonstrable from the perspective of the business entity. It is not the case for the consumer. The consumer is in one sense an irrational entity whose maximization and choices are, on an individual basis, unpredictable and unanalyzable. All that said, however, the PCS example presented in the paper clearly shows the potential for migration to the end user as consumer. The major driving factors for consumer penetration is access and cost. The lower the entry cost the better the opportunity.

(iv) What is the impact of private networks on the value of information?

Information has value only in its ability to change something. That change results in a change in the operations of the economic business entities that we have discussed herein. This change therefore results in a measurable change in the value of the company. The issue of information and private networks is therefore a coupled concept. Information will have an effect in an entity. The change will be proportional to the cost of gathering the information and its timeliness. If a private network changes those factors, then the network, per se, creates value, in addition to the information. We have discussed this in our discussion of examples in the paper.

(v) Can one measure, unequivocally, the economic value that specialized and customized networks provide to an economic entity in terms of value creation and innovation?

Value creation was definitively described for any economic entity as the change in net present value of the firm. The impact of the network in creating value can therefore be measured as we have discussed.

These five questions were posed in the context of the paper, to focus the effort on the impact of private networks on business entities. More importantly, however, this paper provides a broader view of the evolution of networks, and a reevaluation of the underlying assumptions that have been at the heart of policymakers. In particular, the fact that distributed networks using today's technology can have *de minimus* scale economies. This one fact is the major observation that should be made by policy makers. Many of the companion papers, such as Lehman and Weisman[16] or Oniki,[17] all assume significant fixed costs and *de minimus* variable costs. The opposite will occur and in certain cases is only true for the distributed network. Thus, because of the economic imperative, business will be converging more and more on distributed private networks, to the detriment of the Hierarchical RBOC type network. Regulation, to the contrary, will slow this process but not stop it.

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ENDNOTES

[1] E. Noam, private correspondence to the author. This is based on a general consensus of the opinions of several authors during the 1991-1992 year at the Columbia Institute for Tele-Information (CITI) conferences.

[2] There are three previous papers that have been developing the theme of networks and their evolution. The first, Alternative Network Architectures, was presented at Harvard in the fall of 1990. It introduced the concept of world view in networks and the ability to deconstruct the intent from the results of the

design. The second paper, Information Infrastructures, presented at the 19th TPRC, developed the value concept of information in the context of a network. The third was Morphology and Taxonomy of Networks which developed the concept that there are fundamental organic differences in Networks that result from basic evolutionary differences.

[3] McGarty, T.P. and L.L. Ball, "Network Management and Control Systems," IEEE NOMS Conference, 1988.

[4] See Huber, P.W., *The Geodesic Network*, Washington, DC: U.S. Department of Justice, January, 1987.

[5] The Author has argued in "Alternative Network Architectures" that world view is the driving factor in the analysis and deconstruction of networks. This world view is developed based upon a paradigm or example used to drive all development. It has been shown in that paper that the RBOC world view is that of a hierarchical voice based centrally controlled network. Suffice it to say that any attempt by any one of the seven RBOCs to break from that mold has resulted in failure. In fact their operations of cellular carriers follow that mold religiously.

[6] The current staff reductions in the RBOCs is a sign that they are recognizing that their cost infrastructure is much too high. Take NYNEX as an example. They have 26,000 management employees and another 52,000 craft for 13 million access lines. That means one management per 500 and one craft per 250. In contrast in the new wireless systems the ratio is an order of magnitude better. This means that by eliminating high fixed organizational mindsets the costs can be driven down.

[7] From an evolutionary perspective each species as a result of its genetic structure presents the outside world with certain phenotypes or characteristics (see Futuyama). The world in turn presents conditions for survival. Survival of the fittest then is the matching of species phenotypes to the conditions of the environments. Those that do not match well die off and those that match grow and survive. This is all based on the concept of a fitness function namely a measure of how easily a species can reproduce. If we view reproduction as a measure of success then distributed systems are cockroaches!

[8] See the Telmarc Telecommunications Inc. filings with the FCC, especially the NPRM response. In the NPRM response, Telmarc includes a detailed model of the wireless communications business, and it is based upon this model that the lack of scale is demonstrated. There has been no other model to date that has been developed to demonstrate this. It should be noted that the Telmarc model relies heavily on the QUALCOMM technology.

[9] See the paper by McGarty on Wireless Network Economics. This paper details the results in this paper and constructs a demand and business model based on extensive experience in the industry.

[10] See McGarty, Business Plans. The author details the selection process for the choice of the costs of capital as well as details the model that is developed in this section. The model is based upon what is called a "tops down" and "bottoms up" approach to the business.

[11] The restraint placed upon this model can be readily eliminated by including a market for salvage, impacts of financing, impacts of fiscal policy, and all other issues. We have shown this elsewhere and are in this paper focusing only on the essential features.

[12] E(Sales) = Number of New Customers*(1/ Number of New Customers per Salesman)*Expense per Salesman

[13] See the paper by Hopper. The author of this paper is a Senior Vice President of AMR, the parent of American, and the person responsible for the development and operation of the system. Hopper presents one of the most compelling arguments for information systems and private networks.

[14] McGarty, T.P., and M. Sununu, "Applications of Multi-Media Communications Systems to Health Care Management," HIMSS Conference, San Francisco, Feb. 1991.

[15] McGarty and Sununu performed a detailed several month study at several Boston hospitals evaluating the impact on costs with the use of a private network base multimedia communications system. The paper details the results in the context of process flow as has been developed in this paper.

[16] Lehman, D.E., and D.L. Weisman, "Access Charges for Private Networks Interconnecting With Public Systems."

[17] Oniki, H. and R. Stevenson, "Efficiency and Productivity of Public and Private Networks of NTT."