

**Network Systematics :
The Morphology and Taxonomy
of Networks**

by Terrence McGarty Ph. D.

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NETWORK SYSTEMATICS
THE MORPHOLOGY AND TAXONOMY OF NETWORKS

by

Terrence P. McGarty, Ph.D.

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ABSTRACT

The development of policy positions towards new and innovative network offerings is all too frequently based upon a past understanding of networks and where they have been rather on where network are evolving towards. Two major trends have had a significant impact on the evolution of networks. The first is the general trend that is best expressed by the phrase "silicon is free", which implies that fully distributed architectures are the way of the future and that the true network is in the software. The second is that networks are an integral part of the users value chain, impacting directly, for commercial users as well as consumers, their selection of network alternatives. This combination of fundamental organic or genetic change in the network structure and the almost Darwinian selection process by the user environment leads to a different and now more clear path on how networks are evolving. A specific example is discussed on how policy must adapt to this change, specifically the current NPRM of the FCC on PCS networks.

1.0 Introduction

Networks are means to provide for the interconnection of a wide base of users and empowers the users in the interexchange of information. The users, in most cases involving the creation of economic value, use this resource as a means increase revenue, decrease expenses, increase market share, or some other rational process. The equation on the part of the consumer of the network resources 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 propose to shown that the underlying economics of that choice is going through a 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 developed. It is the intent of this paper to outline some of these concepts.

The focus in the paper will be upon private networks. Noam has defined these as:

" A Private Network is 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. "

This paper addresses five specific questions as relates to these networks:

- (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.
- (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-standardized networks can result in diseconomies.
- (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 answer these questions is fivefold. Specifically;

- (i) Networks are characterized in terms of their basic elements, called the morphology or appearance of networks. We then take these shape characteristics and then cluster them in an taxonomy, or classification of networks.

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 CITI conferences.

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(ii) We then discuss 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 are possessing of significant scale economies, whereas distributed networks have de minimus 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) We then use the paradigm of Darwinian Selection to show that fundamental forces will move to the selection of one of the two network types in preference of the other and that this selection is a critical observation for policy maker to understand.

(iv) A specific example of how this change is effecting policy is discussed, specifically 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) We finally combine these facts with the concept of value in an economic entity and discuss how Private Networks play a key role in that development.

This paper presents the fourth step in an evolving understanding of networks, information and economic value creation. 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.

2.0 Network Morphology and Taxonomy

The basic premise of this paper is that networks, as currently viewed by users, designers and policy makers are NOT evolved from the same common ancestor. Rather, there are at least two different network concepts in use today that are genetically different, and are genetically isolated. That genetic isolation gives rise to dramatically different evolutionary paths, and that the hierarchical system that we are most familiar with is doomed to extinction. The distributed genetic material of networks, new to the scene due to the dramatic changes in technology, is anticipated to be the survivor. It behaves dramatically differently and due to this difference, policy makers in particular must recognize the

fundamental differences. 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 phenetic, relating to externalities. We latter discuss the genetic differences that are at the heart of the 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 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. 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. 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

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 Network which developed the concepts that there are fundamental organic differences in Networks that result from basic evolutionary differences.

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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 underlying 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.

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 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.

Thus 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. 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.

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.

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, 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.

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. 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.

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.

2.1 Network Morphological Elements

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In order to develop a taxonomy and in order to provide a Key for the taxonomy in determining which network fits where, it is first necessary to identify the 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 or 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, 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 now begin to detail 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, that is saying it is not something.

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 sub divided 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 non parallel. 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. That is 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 a specific user. In the current developments of networks, there is a stronger trend to the user being the main user of the network.

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

o **Type:** The type of users 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.

o **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:

o **Simultaneous:** All users are communicating at the same time.

o **Displaced:** Some users are not at the same time frame and moreover, there is a disparate set of these time frames.

o **Shifted:** Time frames are equally shifted.

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

o **Shared:** All users may randomly access the services.

o **Sequenced:** A protocol of control from one to another exists.

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o Directed: Control is forced from a single point.

o 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.n₁, D.1.2.n₂, D.1.3.n₃, D.1.4.n₄)

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 we 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.

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

o **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.

o **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.

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

o **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.

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

o **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 that the

broader the reach of the switching, the higher in the network switch levels the switching or interconnection goes. The current public switched network is an example.

o **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

o **Local:** This type of addressing allows for addresses to be local to a select user group. There is now way to address a foreign user entity.

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

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

(ii) Temporal Addressing

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

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

o **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

o **Selection:** This element of interconnect focuses on the issue of how the interconnect process is managed. Specifically, there are two currently observed descriptors; random, that is on a basis of algorithmic but arbitrary, and assigned or deterministic interconnect tables.

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

o **Assigned:** This is a preassigned system, where knowing the state of the network at

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any one time determines the connection path.

o 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.

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

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

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

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

o 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 these are described below.

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

o 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 reconstructable at any instant from the state of the network.

o 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.

o 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:

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

o 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. They are described below.

o Modality: This descriptor describes the nature of the information flowing from or into the user. There are the following types; Video, Voice, Text, Data, 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.

o 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.

o Integrability: This descriptor indicates the temporal, spatial or logical nature of the interface. In the simple temporal case, we can envision the interface operating in a synchronous mode with timing shared amongst 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.

o Conversationality: This describes the nature of the interface and the users as regards to the nature of the sessions that may be created on the network. They may range from the shared or party line method, to the conversational systems common in multimedia communications, into a private line and finally into a fully secure link.

o 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 control may span the issue of who owns and operates the network to specifically how the network is managed as a living and operating entity.

o Management: The management element describes the specifics of who owns and operates the network. It is in essence the legal control part of the network.

o Users;Direct: Each user has direct control over the network.

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- o Users;Indirect: Each user has an influence on the network but the control is indirectly applied.
 - o Shared: Users share in a pooling fashion the control over the network.
 - o Public: There is a publicly accepted control point for the network. Such is the case for the public switched network.
 - o Private: This is a network provided in a private basis. Control is in the hands of the private entity.
- o Maintenance: The maintenance element describes the philosophy to the real time control of the network. It describes how the network is managed as a operating entity. Several possible, and currently recognized descriptors are possible;
- o Centralized: Controlled by a single entity.
 - o Sectedored: Broken into segments that are controlled by separate entities divided by geography, or function or some other such factor.
 - o Distributed: A fully distributed and autonomous function.
- o Scope: The scope element describes the breath 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.
- o Inventory
 - o 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 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 ISO model (Tannenbaum) these represent the lower three levels, Levels, 1 to 3.

- o 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.
- o Method: This represents 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.

- o Mode: This represents the characteristics of the Layer 3 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 using these morphological elements. As with any taxonomical development, the choice is somewhat arbitrary, especially as we begin at the highest level. The works of Sokal and Sneath in taxonomical classification may be referred to and it is this work that has influenced the current approach. If we recall plant taxonomies, the partitioning is first along the lines of seed bearing and non seed bearing plants. Then the partition 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 partitioning 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 network.

Networks have evolved over time and some types no longer exist. Most step by step voice networks are out of existence at this time. 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 set of questions is to not only understand the past but recognizing that the past is the prologue to the future, to project possible network evolutionary trends.

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

3.0 Network Genetic Structure

The previous section discussed the phenotypic characteristics of networks. That is we focused on external observables and allowed classification of networks based upon these characteristics. A similar approach is done in the plant and animal worlds. Phenotypic characters are used for the most part to classify species, genus, families etc. In contrast, there is in the plant and animal world and 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 is 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 the difference in world view.³ 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 in software as possible.

(ii) Technology: The hierarchical networks are still replacing relays and operators. The views towards software in these networks is based upon de minimus intelligence in the home terminal and maximum control in the central switch. Distributed systems anticipate uncertainty, assume intelligent end user devices, and move towards emphasis on software. They assume that silicon costs will continue to decrease.

(iii) Organization: The distributed inclination is towards empowering the end user. The control is distributed and the interconnected is also. The hierarchical network is typified by a BOC with strong central control, excessive overhead, and large fixed costs.⁴

3. 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 follow that mold religiously.

4. 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 and order of magnitude better. This means that by eliminating high fixed organizational mindsets the costs can be driven down.

Clearly there is a difference between the structure of a Hierarchical network and a Distributed. We detail this in the next section.

4.0 The Selection Process

The selection process is essentially the issue of Darwinian Evolution of networks, phrased as survival of the fittest. Policy must follow this survival 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 function of an environment of a network is predicated upon the users of the network and the competitive advantage that the use that 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.⁵ 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 less relationship. We also see that current 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 that they require 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

5. 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!

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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 adapted 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 and because of its flexibility to mutate to meet the needs of the user.

5.0 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. The author argues that the Commission 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 PCS, Personal Communications Services. 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:

o Radio Frequency Transport: In this case the 1.8 to 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.

o CDMA Switching and Interconnect: One of the proposed technologies for switching is Code Division Multiple Success, CDMA, which allows many users access to the same frequency band. It accomplishes this by giving each users an access code that is mathematically and electronically orthogonal to all other users. Therefore, by using extensive, and distributed processing power, both in cell sites and more importantly in the end users hand terminal, a fully distributed switching fabric is established.

o 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 users terminal.

o Interface with Complexity but low Cost: The end user terminals have more than 200 MIPS worth of processing capability and thus can be reprogrammed, in some cases by downloading new code to them. The net result is that the network can change in a real time and organic fashion.

This new network configuration has several new and innovative features. There is a current mind set in 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 obtain back again. In the current cellular duopoly, 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 by price management. Penetration of the total market has been gradual and the relative share has been held at 50% each.

With the increase in additional carriers in the 1.8 GHz 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 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 through a three prong 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 \$300 price points. The same price points are there for the Wireless market. The quality of the set and the service must meet a minimal level of expectations. System 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 difference 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.

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There is a distinct difference. Benefits may be cost justified, even understood to be important, but are displaceable. 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 are 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 they have limited fixed cost structures. Thus the strategy to reduce costs is simple; increase productivity. There are no significant scale economies.⁶ One cannot reduce costs by increasing volumes. Thus the imbedded carriers at 800 MHz are at the same advantage or disadvantage as any other player in the market. There are no economies of scale and thus there are no abilities 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 map directly on the four areas of acquisition, retention, operations and depreciation.

The 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 churn 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 adaptive network management technologies to monitor, manage and match customer perceptions with system performance. 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 on how this four point strategy may be implemented and detail the implementation impacts have been developed elsewhere.⁷

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 MTSO 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 a 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 to other non cellular users.

MTSO operations are comparable to a small central office. Software maintenance and switch control are the typical functions performed. The additional costs of a MTSO are the carrier charges from the MTSO to the PSTN, a Class 5 Central Office. These charges are of an ongoing nature and consist of a fixed plus variable element. Specifically, under the current tariffs, the amount 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 and switch costs only. In fact, on a per line basis, the cost for carrier access charges dominate the cost per subscriber. Specifically, charges of \$0.70 per minute for cellular include the \$0.11 cost. Some systems have to cost as high as \$0.24 depending on the LATA interconnect permitted.

6. 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.

7. 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.

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A dramatic change is occurring. This is the move to co-location and to unbundled marginal cost pricing on an equitable basis. Simply put, this means that anyone may gain just switch access, without an allocation for the plant, and priced at the same level as the Telco, namely marginal pricing, and that a wireless company may co-locate their equipment in the Telco 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 the 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, allows for the management and control of spares and inventory, and allows 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.** 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 several key technical factors that will result in cost reduction. These are;

o **Co-Location:** Eliminates MTSO and reduces the per line access charge.

o **Network Management:** Reduces the up-front planning costs and reduces the ongoing

maintenance and repair costs. Improves performance and customer reception.

o **CDMA Digital:** Increases the number of cells and thus reduces depreciation. Makes for simpler planning.

Let us now consider the implications these changes in the economics of these new systems. Specifically we 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 from amount, as in an auction, to a variable amount as in a CATV system. In contrast to the wireline BOC 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 possible 40,000 customers. It may cost \$1 million. Unlike analog cellular, CDMA requires only one for coverage, rather than the forty or fifty. The re-rads are low cost and handle the coverage problem.

(iii) **Interface:** The handset is fully variable in cost, one being available for each customer and purchased by them.

(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

$$C = C_F + C_V$$

$$E = E_F + E_V$$

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

$$D = D_F + D_V$$

Now it can readily be shown that fixed depreciation depends on fixed capital. Thus let us focus on capital. As we ha 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 busy hour, 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, 1500 square miles requires one cell plus 50 re-rads. 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 for 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. At the same \$1 million capital, 2000 channels are provided at a fixed 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. In the paper by Lehman and Weisman in this TPRC session, the authors 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 telecommunications, 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 allowed change to occur in a more fluid fashion. Silicon, although not really free, is extremely low cost. The cost is in the software. In this new CDMA world, the projected prices for the 200 MIP chip is in the tens of dollars range and decreasing. The entire hand set will, in five years be below \$200. The continuing costs will be in the software development. 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 a slow and litigious process to agree to 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 policy issue is to strengthen coalitions, and not force 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 commodicizability of the service offerings and the change from high fixed cost structures requires a re-evaluation of the regulation assumptions and a clear statement of them.

6.0 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 can also be manipulated via tax or fiscal policy.

6.1 Value Measures

All too frequently analysts will go immediately for the change in productivity in a business or the 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 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 th year, $E(k)$, the expenses of the business for the k th year and $C(k)$ the capital expenditures for the business for the k th year, then, assuming de minimus effects of working capital and an all equity financing scheme, the years cash flow is:

$$CF(k) = R(k) - E(k) - C(k)$$

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. Thus the value of business entity I is;

$$V(I) = CF(1)/(1+m)^1 + \dots + CF(n)/(1+m)^n$$

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

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 and has no

8. 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.

9. 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 of the essential features.

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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:

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

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;

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

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 determinant. 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 engineering, marketing, sales, customer service, inventory, administration etc. Let us assume that such process are identifiable and that the business is a collection of these. Thus the expense for the business is;

$$E = E(1) + E(2) + \dots + E(n)$$

Now $E(i)$ is the expense associated with a single process. It can be expressed, if properly decomposed, in the following; 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:

$$E(\text{Sales}) = RD(\text{Sales}) PF(\text{Sales}) UC(\text{Sales})$$

$$E(\text{Sales}) = \text{Number of New Customers*} \\ (1/ \text{Number of New Customers per} \\ \text{Salesman}) * \\ \text{Expense per Salesman}$$

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. We can increase the productivity or reduce the productivity factor. This can be done by more effective targeting

of the sales force through telemarketing, inbound 800 services etc. Third we can reduce the salary of the salesforce. This third factor is probably the worst. Sales people 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 where the use of networks have 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 commoditization was first done 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, US Air, 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.¹⁰

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 integrates satellite, radio and land line network system.

Case 3: Healthcare

In the area of health-care, McGarty and Sununu have shown that the use of Private Networks can reduce the costs of health care provision by 20%. The test that

10. 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.

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these figures were based upon were performed in Boston.

7.0 Conclusions

We began this paper with this paper with a definition of Private Networks that in essence stated that they were a collection of networking elements with the power to manage them in the hands of the 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, that they were in some sense genetically different. Hierarchical or RBOC type networks were fundamentally and genetically different than Distributed or LAN type networks. This concept of genetic different was based upon an ability to adapt by the different species.

Although we began this metaphorical analysis in the attempt to demonstrate limited relationships, one soon finds that the underlying relationships that Darwin found for natural species are fundamental to man created species such as networks. This strengthening of the metaphor allows one to use the observations and techniques to answer the questions posed.

(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. It further is based upon observing that the new paradigm of "silicon is free" makes the survival of distributed networks highly favorable and that of hierarchical problematical. 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 it 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-standardized 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 in essence the silicon version of biodiversity in the carbon world. More silicon gene flow from non standardized networks 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 operations. Business is run on a continuum 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 a single individual basis, unpredictable and unanalyzable. All that having been 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 a change on 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) 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.

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 relooking at 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 singular fact is the major policy observation that should be made. Many of the companion papers, such as Lehman and Weisman or Oniki, all assume significant fixed

11. 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.

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costs and de minimus variable costs. The opposite will and in certain cases is true for the distributed network. Thus, because of the economic imperative, business will be converging more and more on distributed private networks, at the detriment of the Hierarchical RBOC type network. Regulation to the contrary will but slow this process and not stop it.

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8.0 References

- Blackwood, M.A., A. Girschick, *Theory of Games and Statistical Decisions*, Wiley (New York), 1954.
- de Sola Pool, I., *Technologies Without Barriers*, Harvard University Press (Cambridge, MA), 1990.
- de Sola Pool, I., *The Social Impact of the Telephone*, MIT Press (Cambridge, MA), 1977.
- Dertouzos, M.L., J. Moses, *The Computer Age*, MIT Press (Cambridge, MA), 1979.
- Dugan, D.J., R. Stannard, *Barriers to Marginal Cost Pricing in Regulated Telecommunications*, *Public Utilities Fortn.*, vol 116, No 11, pp 43-50, Nov 1985.
- Futuyama, D.J., *Evolutionary Biology*, Sinauer(Sunderland, MA), 1986.
- Harvey, P.H., M.D. Pagel, *The Comparative Method in Evolutionary Biology*, Oxford (Oxford), 1991.
- Henderson, J.M., R.E. Quandt, *Microeconomic Theory*, McGraw Hill (New York), 1980.
- Hopper, M., *Rattling SABRE-New Ways to Compete on Information*, *Harvard Business Review*, No 3, 1990, pp. 118-125.
- Huber, P.W., *The Geodesic Network*, U.S. Department of Justice, Washington, DC, January, 1987.
- Kahin, B., *The NREN as a Quasi-Public Network: Access, Use, and Pricing*, J.F. Kennedy School of Government, Harvard University, 90-01, Feb., 1990.
- Kahn, A.E., *The Economics of Regulation*, MIT Press (Cambridge, MA), 1989.
- Lehman, D.E., D.L. Weisman, *Access Charges for Private Networks, Interconnecting with Public Systems*, Twentieth Telecommunication Policy Research Conference, September, 1992.
- Mandelbaum, R., P.A. Mandelbaum, *The Strategic Future of Mid Level Networks*, J.F. Kennedy School of Government, Harvard University, Working Paper, October, 1990.
- McGarty, T.P., *Business Plans*, J. Wiley (New York), 1989.
- McGarty, T.P., G.J. Clancey, *Cable Based Metro Area Networks*, *IEEE Jour on Sel Areas in Comm*, Vol 1, No 5, pp 816-831, Nov 1983.
- McGarty, T.P., *Growth of EFT Networks, Cashflow*, pp 25-28, Nov. 1981.
- McGarty, T.P., L.L. Ball, *Network Management and Control Systems*, IEEE NOMS Conf, 1988.
- McGarty, T.P., *Local Area Wideband Data Communications Networks*, EASCON, 1982.
- McGarty, T.P., M. Sununu, *Applications of Multi-Media Communications Systems to Health Care Management*, HIMSS Conference, San Francisco, Feb. 1991.
- McGarty, T.P., *Multimedia Communications in Diagnostic Imaging*, *Investigative Radiology*, April, 1991.
- McGarty, T.P., R. Veith, *Hybrid Cable and Telephone Networks*, IEEE CompCon, 1983.
- McGarty, T.P., S.J. McGarty, *Impacts of Consumer Demands on CATV Local Loop Communications*, IEEE ICC, 1983.
- McGarty, T.P., *Multimedia Communications Systems*, IMAGING, Nov. 1990.
- McGarty, T.P., *Multimedia Communications Architectures*, SPIE Optical Communications Conference, Boston, MA, September, 1991.
- McGarty, T.P., *Alternative Networking Architectures; Pricing, policy and Competition*, *Information Infrastructures for the 1990s*, Harvard University, J.F. Kennedy School of Government, Nov. 1990.
- McGarty, T.P., S.J. McGarty, *Information Architectures and Infrastructures; Value Creation and Transfer*, 19th Annual Telecommunications Policy Research Conference, Solomons Is, MD, September, 1991.
- McGarty, T.P., *Communications Networks: A Morphological and Taxonomical Analysis*, Columbia University, CITI Conference, October, 1991.
- McGarty, T.P., *Wireless Communications Economics*, Carnegie Mellon University, ATI Conference, June, 1992.
- Noam, E. M., *Network Tipping and the Tragedy of the Common Network*, J.F. Kennedy School of Government, Harvard University, Working Paper, October, 1990.
- Oniki, H, R. Stevenson, *Efficiency and Productivity of Public and Private Networks of NTT*, Twentieth Telecommunication Policy Research Conference, September, 1992.
- Porter, M., *Competitive Advantage*, Free Press (New York), 1985.
- Porter, M., *Competitive Strategy*, Free Press (New York), 1980.
- Porter, M., *The Competitive Advantage of Nations*, Free Press (New York), 1990.
- Shubik, M., *A Game Theoretic Approach to Political Economy*, MIT Press (Cambridge, MA), 1987.
- Shubik, M., *Game Theory in the Social Sciences*, MIT Press (Cambridge, MA), 1984.
- Spulber, D.F., *Regulation and Markets*, MIT Press (Cambridge, MA), 1990.
- Stace, C.A., *Plant Taxonomy and Biosystematics*, Arnold (London), 1989.
- Telmarc Telecommunications Inc., *Pioneers Preference*, FCC Gen Docket 90-314, PP 76, May 4, 1992.

Twentieth Telecommunications Policy Research Conference

Telmarc Telecommunications Inc., Pioneers Preference, West, E.H., et al, Design, Operation, and Maintenance Reply to Comments, FCC Gen Docket 90-314, PP 76, June 25, 1992.

Telmarc Telecommunications Inc., NPRM Response, FCC Gen Docket 92-333, November 9, 1992.

of a Multi Firm Shared Private Network, IEEE MONECH Conf, pp80-82, 1987.

Winograd, T., F. Flores, Understanding Computers and Cognition, Addison Wesley (Reading, MA), 1987.

Vickers, R., T. Vilmansen, The Evolution of Telecommunications Technology, Proc IEEE, vol 74, No 9, pp 1231-1245, Sept 1986.

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9.0 Glossary

Architecture: The conceptual embodiment of a world view constructed of the system elements utilizing the available technology.

Benefit: An unexpected positive influence, of a monetary or non monetary nature, that is attained by a user of a service.

Centralized: A system philosophy that ensures the overall operations of a system based upon a single and centrally located point of control and influence.

Control: The means of monitoring, managing, adapting, and reconfiguring all information network elements to ensure a consistent level of service delivery.

Data Base: A device or set of devices that stores and retrieves data elements on one or many types.

Distributed: A system that has a fully disconnected and independent set of elements that separately or together provide for all of the elements necessary for the support of the full service.

Distribution Channel: The complete and uninterrupted set of tasks and functions necessary to ensure the economic viable flow of information goods and services from the source to the consume of those services.

Hierarchical: A system with a single point of definition, development, management and control, with reporting relationships of all elements that flow ultimately upward to a dominant control point.

Infrastructure: A sharable, common, enabling means to an end, enduring in a stable fashion, having scale of design, sustainable by an existing market, being the physical embodiment of an underlying architecture.

Interconnect: The ability to and systems necessary to effect that ability to provide the connection between any viable set of entities in a network.

Interface: The layers of protocols, tools, development mechanisms that enable an end user to achieve the maximum use of all resource available to them on the network to which it is attached.

Logical Infrastructure: An infrastructure wherein the commonality is based upon the agreements on single set of protocols that operate on differing physical elements that may be under disparate control and management.

Market: The collection of users who create an economically efficient and effective set of transactions for information.

Multimedia: The use of multiple sensory data and inputs by human end users that allows for the interaction of the sensory data with the user.

Multimedia Communications: A multimedia environment consisting of multiple human users in a conversational format in a temporally or spatially based environment.

Need: The creation of a sustaining economic imperative based on consistent benefits to a user.

Network: A transport mechanism combined with the interconnect and control functions.

Paradigm: A specific example, experiment, or physical test case that is used by a large group to explain a broad set of phenomena that are directly or indirectly related to the underlying physical example. A typical set of examples are the use of the Apple MAC icon screen to redefine human interface, the Watson and Crick view of DNA as the coding mechanism for life or waves used by Maxwell to describe light.

Physical Infrastructure: A fully integrated, centrally controlled and defined and regulated physical embodiment of an architecture.

Process: An embodiment of a set of procedures in a software program to effect a set of well defined changes to input.

Processor: A physical device that is used to run a process.

Relational Infrastructure: An infrastructure that is the loose coupling of totally independent sub infrastructures. The interfacing is built upon agreements to interface and sharing of internal standards in each sub infrastructure.

Segmented: A structured partition between two tightly controlled subnetworks.

Transport: The movement of physical information from a set of points to another set of points.

User: Any entity or agent that uses resources on the network.

Value: An economic measure of the effectiveness of the use of information.

Virtual Infrastructure: An infrastructure that is based upon common but disparate sets of protocols that are agreed to on the basis of group decisions.

World View: A philosophy, either explicitly or implicitly, adopted by the system designer, owners, or managers, that reflects the accepted limitations of the prevailing paradigm.

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