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ECONOMIC COSTS OF
HETEROGENEOUS VERSUS HOMOGENEOUS NETWORK DESIGNS

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ECONOMIC COSTS OF
HETEROGENEOUS VERSUS HOMOGENEOUS NETWORK DESIGNS

By

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ABSTRACT

ECONOMIC COSTS OF HETEROGENEOUS VERSUS HOMOGENEOUS NETWORK DESIGNS

By

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Computer network designers must often choose between a heterogeneous versus a homogeneous network design. This research establishes an economic model to study the long term costs of heterogeneous versus homogeneous network designs using case studies.

Three sizes of networks were studied: local area networks, campus area networks, and wide area networks. For each sized network a heterogeneous and a homogeneous design were studied. Project books, profit and loss statements, and interviews, provided economic costs of each installed network. The data was summarized to see if a pattern was repeated supporting the thesis that the long term costs of a heterogeneous network are lower than that for a homogeneous network. The data supported the thesis and also provided some insight into the major cost factors involved in each network design approach.

This thesis is dedicated to my wife Jennifer for her never ending support, my daughter Bailey who reminded me what learning was all about, and to my parents Arthur and Evelyn for a lifetime of guidance and support.

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LIST OF ABBREVIATIONS

I/T	Information Technology
LAN	Local Area Network
WAN	Wide Area Network
PC	Personal Computer
Mbps	Megabits Per Second
FDDI	Fiber Distributed Data Interface
CPU	Central Processing Unit
TCP/IP	Transmission Control Protocol/Internet Protocol
UTP	Unshielded Twisted Pair
IEEE	Institute of Electrical and Electronics Engineers
ANSI	American National Standards Institute
CCITT	Consultive Committee on International Telephony and Telegraphy
SNA	Systems Network Architecture
ISO	International Standards Organization
OSI	Open Systems Interconnection
EIA	Electronics Industries Association
CS	Conditioned Stimulus
T/P	Twisted Pair
OA	Office Automation
VMS	Virtual Machine System
FOIRL	Fiber Optic Integrity Repeater Link

INTRODUCTION

For the network designer in the information services (I/S) industry, times are quickly changing. The choice between a heterogeneous and homogeneous network design has only existed for a few short years. Interoperability between various network product vendors is becoming the future trend, and current network designers must consider seriously the implications of selecting an open or closed design. "Rapid growth in open systems will dramatically reshape the I/S industry over the next five years. Once an industry dominated by the leading vendors and their proprietary protocols, it will become an industry that is dominated by innovation, speed, and low cost based on widely-accepted open systems standards."[1] It is estimated that by 1996, over one-third of all the I/S market will be based on open systems, rising from $23.2 billion dollars in 1991 to $81.2 billion in current U.S. dollars by 1996.[2] Countering the trend towards heterogeneous open network designs is the reality of the present. Many of the standards are not currently defined, and others do not guarantee interoperability. In an attempt to rationalize

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[1] Abstract of The U.S. Market for Open Systems (Frost & Sullivan, 1992) 1.

[2] Abstract of The U.S. Market for Open Systems (Frost & Sullivan, 1992) 2.

the decision for selecting a heterogeneous or homogeneous network design, an economic approach could be used.

It is the intent of this research to establish an economic analysis for comparing heterogeneous and homogeneous network designs. The goal will be to select Local Area Networks, Campus Networks, and Wide Area Networks which are currently installed and comparable to each other in terms of scope and functionality. Once the networks have been selected, financial information will be tabulated for homogeneous and heterogeneous networks in terms of hardware, software, training, maintenance, and personnel. It is this researchers belief that a heterogeneous network design will prove to be more cost effective in the long term than a homogeneous design.

A case study approach was selected over other treatments of the topic since the focus is on contemporary events in which the researcher does not require control over behavioral events. Additionally, in order to qualify networks, a wide variety of inputs are required which archival analysis or survey research could not encompass.[3]

The related cost for constructing and maintaining a network will vary greatly from implementation to implementation, yet each will contain many corresponding and identifiable costs. For the purpose of this model, the

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[3]Robert K. Yin, Case Study Research Design and Methods (Newbury Park: Sage Publications, 1989)

following costs will be compared: hardware & software, infrastructure, maintenance, network administration, inter networking, personnel, and miscellaneous installation costs. It is important for the network designer to consider the post implementation cost. Areas such as future inter networking, and system administration are often overlooked. "Too little attention has been paid to the ongoing costs of LAN management and administration. ... This kind of hidden cost is going to come up more and more, especially as MIS takes control of buying PC LANs."[4] One of the hardest parts in building a comparative economic model for comparing heterogeneous and homogeneous networks will be one of definitions and normalizing features and functionality. The first task will be to define the terms we will use in the model. A rationale will be given for the selection of various networks for our model. Finally, case studies will be reviewed and compared using the cost model.

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[4]Eric Smalley, "VINES Certified Most Cost Effective," LAN Technology Mar. 1992: 16.

CHAPTER 1

NETWORK DEFINITIONS

It is essential to define our terms before proceeding with case studies of various network designs. Although it is a simple task to define conceptually what a heterogeneous network is, or what constitutes a Local Area Network, in practice the lines become blurry and very few examples of pure homogeneous networks exist. Let us first look at the key characteristics of Local Area Networks (LANs), Wide Area Networks (WANs) and Campus Networks.

LANs are intended to fill the gap between stand-alone computers and corporate wide systems. LANs are intended to leverage computing resources at a local site (single building or small cluster of buildings). Another characteristic of LANs is the higher data rates than are typically found in WANs. "The geographic characteristic of local area networks lend themselves to the use of inexpensive media. For example, a simple twisted pair can be used to support point-to-point or broadcast communications with data rates of 1 to 10 megabits/second (Mbps) ranging in distance from 1 to 10 kilometers (km)."[1] As new technologies evolve the definitions will also evolve.

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[1]Paul J. Fortier, Handbook of LAN Technology (New York: McGraw-Hill, 1989) 17.

It is possible to use FDDI in a LAN today moving the data rates up to 100 Mbps. Perhaps the strongest definition of a LAN revolves around the local geographic arrangement of the computing resources. Another characteristic of a Local Area Network is the relatively inexpensive cost for bandwidth. "Bandwidth is expensive in wide area networks, but not in a local area network."[2]

Campus Networks are most often considered an extension of the LAN. A Campus Network is comprised of multiple LANs sharing a high data rate backbone for connections between LANs. Geographical coverage is similar to LANs but typically include multiple buildings and the use of hardware and software to manage network traffic on the backbone. The main distinguishing features which separate Campus Networks from WANs is the geographical limitations of the Campus Network, and the higher data rates supported by Campus Networks (typically 10 Mbps to 100 Mbps) over a WAN.

WANs were the first networks developed and used. They were born from the need of organizations to effectively leverage high cost computing power over multiple sites. "The road to these early networks began in the early 1960s. The major event viewed as the beginning of the technology and the reason for networking was the necessity to share expensive resources more effectively. The technology that

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[2]Dimitris N. Chorafas, Local Area Network Reference (New York: McGraw-Hill Book Company, 1989) 143.

first arose to meet the need was time-sharing operating systems. These early systems (RTOS for IBM 360, GECOS III for the Honeywell 600, Demand for the Univac 1108, and TSS/8 for the PDP 8) provided a means by which users could simultaneously (from a user's perspective) share and use the expensive central processing unit (CPU) and its associated resources."[3] WANs have no geographic limitations and typically use a mix of private and public data circuits for communications. Due to the nature of the long-haul media, data rates are typically lower (1.54 Mbps) for WANs than are found in Campus or Local Area networks.

> The wide area network (WAN) normally covers larger geographical areas than a LAN does, though the precise dividing line between the two types is vague. A major factor impacting WAN design and performance is a requirement that they obtain communications links from telephone companies or other communications common carriers. This restricts the communications facilities, and transmission speeds, to those normally provided by such companies. Transmission rates are typically 56 kbps or less (often 9.6 kbps, 4.8 kbps, or slower). Transmission quality, measured by such parameters as line error rate, also tends to be poorer than it is with LANs, and transmission delays are greater.
> With the advent of direct broadcast satellites, ISDN, and other technologies, it is likely that these data rates will increase.[4]

The case studies revolve around the cost effectiveness of heterogeneous versus homogeneous network designs. It is obvious that the definition of heterogeneous and homogeneous

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[3]Paul J. Fortier, Handbook of LAN Technology (New York: McGraw-Hill, 1989) 5.

[4]John D. Spragins and Joseph L. Hammond and Krzysztof Pawlikowski, Telecommunications Protocols and Design (Reading: Addison-Wesley Publishing Company, 1991) 106.

networks will be crucial in the evaluation of various cases. Homogeneous refers, in general terms, to analogous or alike items. Another generic definition of homogeneous is "Similar or identical in nature or form"[5]. When used to describe a computer network homogeneous most frequently implies single vendor product line. Most vendors find it difficult to incur development costs for all aspects of the information technology industry and are forced to remarket various components developed by other vendors. An example of this would be a Digital Equipment Corporation (DEC) network running an ULTRIX operating system and TCP/IP software. DEC did not develop the UNIX operating system which is the core of ULTRIX, so DEC pays a royalty fee for the use of the UNIX kernel. The TCP/IP software is available from several vendors including DEC, however the DEC version is a customized version of a product offered by Wollagong Corporation, and again DEC pays the company a royalty. These re-marketed products may have been purchased from a single vendor, but it is debatable if the resulting network is homogeneous in the strictest sense of the word. Additionally, vendors will often use standard components and media for their networks which are available from multiple suppliers. Such is the case with Unshielded Twisted Pair (UTP) as a media for carrying Ethernet 802.3 packets.

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[5]Sidney Landau, ed., Funk & Wagnalls Standard College Dictionary (New York: Funk & Wagnalls, 1977) 642.

Therefore, a network may have processors, end-user devices, and software all from one vendor and be able to use wiring from a third party. The resulting network could not be called homogeneous in the strictest sense of the word. With all of these factors considered, a working definition of a homogeneous network can still be presented for the purposes of classifying sites for the case studies. A network is considered homogeneous when the network servers, hardware, and software are only interoperable with products from the same vendor or other suppliers which have specifically designed products to work with that particular vendors network and are typically based on proprietary standards. An example of this would be a Novell LAN which only allows other machines running Novell software to connect to the server. It is important to note that within a given vendor you may design a heterogeneous network or a homogeneous network, depending on which products and platforms you select. For example, Novell can be configured to support TPC/IP, thus allowing non-Novell based systems to access the Novell server.

Heterogeneous network designs are characterized by multiple vendors, multiple protocols, and open non-proprietary architectures. A generic definition of heterogeneous is "Consisting of parts or elements that are dissimilar or unrelated"[6]. An example of a heterogeneous network would be a collection of UNIX based servers from multiple vendors running TCP/IP and an X.11 windows user interface. As standards continue to evolve more and more vendors are pursuing open architectures and standards-based non-proprietary systems. When selecting equipment and software for a heterogeneous network choices are made from a variety of vendors who support the standards which the network adheres to. In contrast, a purchase for a homogeneous network is most often accomplished by contacting the single vendor who supports the proprietary protocol. Mark Freund helps supply a popular definition of homogeneous versus heterogeneous networks in an article where he refers to a company which installed an open system for mail services but chose a single vendor implementation of the standard.

> The manager at this company opted to provide interoperability by implementing a single-vendor, homogeneous solution. The point of standards, though, is to enable heterogeneity via interoperability. Many companies try to create open systems by buying products based on standards. However, if you go to one vendor, you are really getting a single-vendor solution. By not choosing to be the integrator, IS managers are losing the flexibility that heterogeneous systems give them and are making it difficult for their organizations to adopt new networking technologies. ... The goal of standards and open systems should not be homogeneity. Heterogeneity is the reality in most organizations.[7]

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[6] Sidney Landau, ed., Funk & Wagnalls Standard College Dictionary (New York: Funk & Wagnalls, 1977) 629.

[7] Mark Freund, "Are Your Open Systems Open?," LAN Technology Aug. 1992: 35-6.

Before leaving the topic of definitions, there are a few concepts mentioned above which need further clarification. Proprietary systems refer to a vendor having legal rights to the inner workings of the network components (software or hardware) and reserves the right to release the information to select third parties for developing additional products for the network. Non-proprietary networks are based on standards which are part of the public domain such as the seven layer OSI network model. The importance of all of these issues (open or closed, proprietary or non-proprietary, etc.) is in the final goal of network infrastructure; interoperability. These issues are expressed in an article by Mark Freund, president and CEO of Interconnect Network Consulting Group Inc. out of Santa Monica, California.

> The focus for IS (Information Services) should be on providing interoperability. A product is open only to the degree that it offers interoperability. Most vendors claim to have open systems; the danger is that these are often proprietary. Part of the problem is that the definitions of 'standard' and 'open' are muddy. These words are often used synonymously. In the simplest terms, standards are any set of published specifications that one of the industry's recognized planning bodies (such as the IEEE, ANSI, or the CCITT) puts its rubber stamp on. There are also de facto standards, which emerge due to market forces and are embraced by multiple vendors. For example, because of the installed base of IBM's SNA, many vendors have built SNA-compliant products, and so SNA has become a de facto standard.
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> Open refers to specifications or architectures that one or more vendors have published and that any vendor can write to or use. It has come to mean a wide range of

> things to different people. In some parts of the world, 'open' means OSI-based product. In the United States, 'open' has come to refer to TCP/IP. I've also seen the word 'open' stretched to refer to the Simple Network Management Protocol (it has been described as an open network management protocol). In many circles, the phrase 'open system' equals Unix.[8]

Mark Freund sums up the issues as they relate to heterogeneous versus homogeneous designs and concludes: "The goal of standards and open systems should not be homogeneity. Heterogeneity is the reality in most organizations. While some IS professionals are flocking to the nirvana of 'openness,' addressing the earth-based realities of integration remains the real challenge."[9]

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[8]Mark Freund, "Are Your Open Systems Open?," LAN Technology Aug. 1992: 35.

[9]Mark Freund, "Are Your Open Systems Open?," LAN Technology Aug. 1992: 35.

CHAPTER 2

STANDARDS

The discussion of standards is essential for a complete understanding of network design options. The issue of homogeneous versus heterogeneous networks would be moot if a set of standards existed governing networks which were current, comprehensive, globally adopted, and enforceable. It is outside the scope of this paper to expound upon the regulatory issues surrounding the establishment and enforcement of standards for computer networks, however, the issue is summarized briefly by the following observation from Paul Fortier.

> Unless you are part of the military establishment and must follow the directives of a higher authority when developing a new product, the choice of which standard, if any, to use is discretionary. The end result of this reality is that standard adherence is voluntary, and that standards are subject to public approval by virtue of their popularity. Thus, each standard-producing organization proposes standards, whether de jure or de facto, for industry acceptance. For instance, ISO's reference model, called Open System Interconnect (OSI), and IBM's System Network Architecture (SNA) offer different views on the 'correct' layering of functions in a network environment.[1]

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[1]Paul J. Fortier, Handbook of LAN Technology (New York: McGraw-Hill, 1989) 237.

The exact number of standards organizations which relate to computer networking varies from year to year as new groups are formed and others disband, but currently there is a catalog available listing over 3000 groups. The organization bases include international, national, trades, corporate, and consumer. Among these groups are these major players: the International Standards Organization (ISO), the Institute of Electrical and Electronics Engineers(IEEE), the Consultative Committee for International Telephone and Telegraph (CCITT), the National Bureau of Standards (NBS), the American National Standards Institute (ANSI), and the Electronics Industries Association (EIA).[2] Many of these groups develop and publish standards relating to various aspects of computer networking. Other groups merely critique standards and make recommendations to other organizations. Standards are established to guarantee compatibility across products and to reassure the consumer of the functionality offered by a product. In addition to committee or group-produced standards there is a class of de facto standards. De facto standard evolve when a proprietary product gains a large enough market share in the absence of committee standards that multiple vendors feel it necessary to offer support for the product. IBM's SNA is an example of a de facto standard.

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[2]Harry M. Kibirige, Local Area Networks in Information Management (New York: Greenwood Press, 1989) 57.

The challenge to a network designer is to adopt the appropriate standards. The selection process is further complicated by the lack of standards for many of the emerging technologies. Any network design requires a best guess as to the future needs of the network and of the future direction emerging technologies will take. The complexity of this task has lead many network designers to abandon the pursuit of standards and opt for a homogeneous proprietary network design. Selecting a design which is standards based does not necessarily guarantee interoperability with other networks based on the same standard. Standards groups and industry are making an attempt to normalize this collection of mismatched directions.

> The normalization effort is steady. It is also continuously faced with new challenges. To a very significant extent normalization and standardization trail the implementation of new technological developments; they demand considerable time to establish themselves. However, once they are established, there is a tendency to follow a standard, though different vendors interpret it in their particular way, leading to a number of dialects.[3]

A standard can be defined as "a collection of criteria, principles, and guidelines that together form a model to be used as a basis for construction and comparing systems. A specification, on the other hand, enumerates the specifics

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[3]Dimitris N. Chorafas, Local Area Network Reference (New York: McGraw-Hill Book Company, 1989) 43-44.

of a given implementation. Thus, a specification may be based upon a given standard, and two or more specifications that claim adherence to the same standard may actually be incompatible."[4] Once again, the network designers task is more involved than just the selection of the appropriate standards, the issue of interoperability still remains to be resolved.

[4]Paul J. Fortier, Handbook of LAN Technology (New York: McGraw-Hill, 1989) 236.

CHAPTER 3

SELECTION CRITERIA

Several assumptions on the nature of cost effectiveness are involved in the development of this thesis. At the core of most of these assumptions resides economic theory. The first area of interest is the idea that proprietary vendors offer a monopolistic market pricing approach to products and services after the initial purchase. Expansion or enhancement of a proprietary network requires products and services which only a single vendor can provide, and since "a monopoly is said to exist whenever the product of one firm has no close substitutes, whenever cross elasticity is close to zero."[1] it is likely that prices will be higher for a homogeneous network upgrade than for a heterogeneous network upgrade. Before a network system is purchased, vendors compete for the contracts in an oligopolistic manor, offering similar functionality with a rather inelastic pricing curve.

> An oligopoly is a market of only a few sellers, offering either homogeneous or differentiated products. There are so few sellers that they recognize their mutual

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[1]Peter C. Dooley, Elementary Price Theory (New York: Appleton-Century-Crofts, 1973) 88.

> dependence. The firms are large, relative to the size of the market. If one firm cuts its price or intensifies its advertising, other firms lose a noticeable volume of sales. When one firm acts it must consider how other firms will react.[2]

Once a network system is in place heterogeneous network owners still have access to the multi-vendor pricing. Homogeneous network owners are forced to operate with a vendor or a selective group of vendors, pricing in a monopolistic fashion.

Another variable which effects the study is related to learning theory. Learning theory states that as the complexity of a system increases, the S-shaped learning curve rises slower and requires a greater period of time for an individual to reach proficiency. The S-shape refers to a graph of skills acquired on the y-axis with time or number of trials listed on the x-axis (see Figure 1). The top of the S-curve represents a leveling off point or asymptote where little additional skills will be gained with ongoing training.[3]

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[2]Peter C. Dooley, Elementary Price Theory (New York: Appleton-Century-Crofts, 1973) 110.

[3]Barry Schwartz and Daniel Reisberg, Learning and Memory (New York: W.W. Norton and Company, 1991)

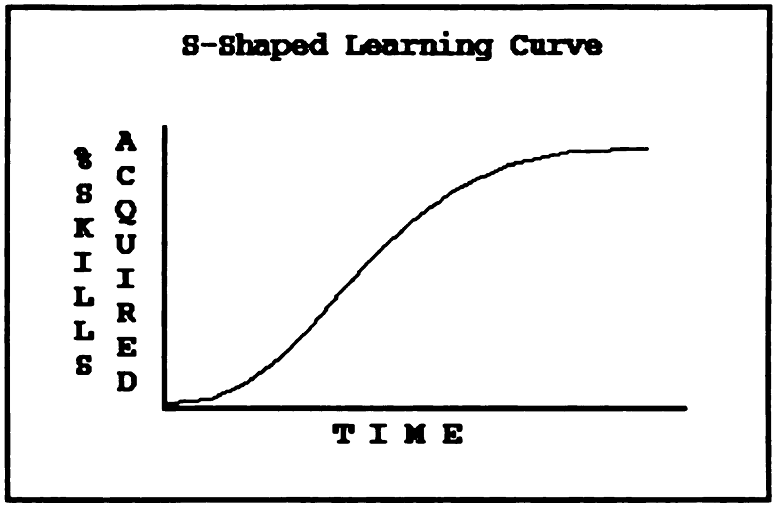

Figure 1. S-Shaped Learning Curve

Individual tasks are learned at a normal rate, but in a heterogeneous network there are several similar tasks that must be learned simultaneously. This mixing of similar learning tasks produces overshadowing which will negatively effect the rate of skills acquisition. "Overshadowing refers to the fact that if two stimuli are presented together as a compound CS (conditioned stimulus), one may completely dominate or overshadow the other even though both would be perfectly effective if presented separately."[4] In a homogeneous network, the learning curve should rise faster than in a heterogeneous network, which is by its very design more complex. The time required to train on a new network in most cases translates into dollars spent by an organization. The costs can include formal training, use of

[4]Barry Schwartz and Daniel Reisberg, Learning and Memory (New York: W.W. Norton and Company, 1991) 71.

consultants, opportunity cost for having employees time taken up reading various manuals, and network implementation delays.

As mentioned previously, this study will look at costs associated with various network designs. The main variables in the model revolve around three central themes; functionality, hardware/software/maintenance costs, and personnel. Functionality is a required variable because it allows the comparison of networks based on similar scope and offering. Two networks of the same size but offering different levels of functionality would not make a good case pair. The hardware, software, and maintenance costs are the most obvious cost incurred for various network implementations. All network implementations report costs for these variables. The final variable associated with cost is personnel. This area is often overlooked when determining network costs but is becoming a greater portion of the total network costs. "Dataquest/Ledgeway calculated that the worldwide network support market reached $16 billion at the end of last year (1991) and predicted a near 20% compound annual growth rate for the next five years."[5] The personnel costs associated with network support is a crucial cost variable required for the model. The selection of cases to study is designed to control these variables as

[5]Joanie M. Wexler, "Distributed computing drives support costs: managers cite network complexity reason.," Computerworld July 27 1992: 55.

much as possible. Ideally, an experiment could be designed to address identical functional requirements using identical purchasing agents and implementation personnel on both a heterogeneous network design and a homogeneous design. The cost of the previously mentioned study would make the project financially prohibited. Multiple-case study selection will be used to compare network designs of similar functionality and scope. The multiple-case design is chosen to produce an expected set of contrary results in terms of the dependent variable, cost, based on the predictor variable of network design methodology (heterogeneous versus homogeneous).[6] Although the same personnel are not used across cases, the same organization will be studied. All of the case studies will be from the same company which uses a corporate negotiated pricing agreement to procure hardware, software, training, and maintenance. The corporation also uses a single pool of computer networking personnel which are billed out at a corporate standard rate. This selection should minimize the effects of the extraneous variables of vendor contract price variations, talent, and functional requirements.

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[6]Robert K. Yin, Case Study Research Design and Methods, Applied Social Research Methods Series (Newbury Park: Sage Publications, 1989) 53.

CHAPTER 4

CASE STUDIES

A selection of three paired cases will be studied covering a range of network requirements. The first pair will consist of two local area networks providing office automation functions to an engine manufacturing group. The networks will consist of less than 200 users and provide single building network access. The second pair of cases will be two campus area networks providing office automation services, distributed processing, and gateways to other networks. The geographic scope of the two networks are similar and are provided for the same division but in two separate cities. The third and final case pairs are two wide area networks. Both networks service the same user base and perform equivalent functions.

Each network studied will include the following sections: Network Type and Overview, Scope and Functionality, Topology, and a Financial Model. The Financial Model will look at the following cost categories: Salary & Related, Book Depreciation, Maintenance, Telecommunications, Technical Support, Expensed Equipment, Training, and Software.

One further note on the selection and analysis of the case study data is the time frame of operation. Since ongoing support and systems upgrades are major factors which effect the dependent variable of cost between heterogeneous and homogeneous networks, the study will look at data for networks from implementation through 36 months. The number of months chosen ensures that the original standard one year maintenance contracts would have been renewed, and ample time had elapsed to allow for some system enhancements to be implemented. Additionally, a 36 month time frame allows total asset depreciation based on the case studies technology products accelerated depreciation schedule. As a last note on time frames, all matched pairs are implemented within six months of each other to ensure that market prices have not changed significantly with the introduction of new products. This point is significant since the cost of computer related equipment tends to decrease rapidly for equivalent functionality over time.

CHAPTER 5

MODES AND METHODOLOGY OF ANALYSIS

The case studies will use nonequivalent dependent variables to attempt to identify a pattern between homogeneous versus heterogeneous network designs. For the proposed thesis to be supported by the data, a theoretical replication of dependent variables will need to be observed.[1] In this study, the dependent variables will be cost related. The following table outlines each of the major cost areas that the studies will be collecting data about. An explanation of each heading is provided following Table 1.

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[1]Robert K. Yin, Case Study Research Design and Methods, Applied Social Research Methods Series (Newbury Park: Sage Publications, 1989) 110.

Table 1. Network Financial Worksheet

	Year 1	Year 2	Year 3	Total
Salary & Related	XXXX	XXXX	XXXX	XXXXX
Book Depreciation	XXXX	XXXX	XXXX	XXXXX
Maintenance	XXXX	XXXX	XXXX	XXXXX
Telecommunications	XXXX	XXXX	XXXX	XXXXX
Technical Support	XXXX	XXXX	XXXX	XXXXX
Expensed Equipment	XXXX	XXXX	XXXX	XXXXX
Training	XXXX	XXXX	XXXX	XXXXX
Software	XXXX	XXXX	XXXX	XXXXX
TOTAL EXPENSES	XXXXX	XXXXX	XXXXX	XXXXXX

*All figures in $1000

Salary & Related: Refers to personnel on the payroll who support or help design and implement the network. For example, if a System Engineer is going to devote 50% of his or her time to network administration, then half of their salary and benefits will be represented in this number.

Book Depreciation: Refers to the annual depreciation on any capitalized equipment. In the case studies, all equipment with a purchase price with tax of over $1000 is considered a fixed asset, and placed on a three year depreciation schedule.

Maintenance: This account holds any on-going hardware or software maintenance costs. This account will also contain any items not under a maintenance contract which required one-time charges for service or repair.

Telecommunication: This account contains any one-time or re-occurring communications charges such as leased phone lines, installation of point to point copper lines, fiber polishing, etc.

Technical Support: This account is used to collect all people related expenses not performed by account employees. This would cover any contract labor for consulting and monthly or one-time charges for technical support.

Expensed Equipment: All hardware, cabling, and miscellaneous items which are purchased for under $1000. This does not include software which is tracked separately for tax purposes.

Training: This account includes course fees, materials, books, travel, and lodging cost associated with training.

Software: Both expensed software (under $20,000) and amortized software ($20,000 or greater) appear in this account.

The theoretical replication will be achieved by finding a consistent cost difference over the study period between each pair of heterogeneous and homogeneous cases. Given the size of the sample for the study, it is not possible to assign what percent cost difference could be considered statistically significant. Even without statistical significance the research would tend to support the thesis

if a cost savings were seen in each of the three pairs for a heterogeneous network design. In any given account category listed in Table 1, differences between homogeneous and heterogeneous network designs may point to which dependent variables are critical factors in building a framework for future research.

The data gathering for the case studies included review of project books for all of the networks. In some cases financial worksheets were available in the project books. Where the financial worksheets were not included in the project books, or where the out year tracking of the costs associated with the network were not included, review of the departments Profit and Loss Statements provided additional financial data for the project. In addition to the reviews of documentation associated with each network installed, interviews were conducted either in person or over the phone with project leaders, support personnel, and informed users. The informed users and support personnel were invaluable in bringing out certain issues which project leaders tended to gloss over. One example is the costs associated with a network design flaw, which required additional conversion costs in one project. The project leader did not volunteer this information, but interviews with end-users and operators brought the issue out.

CHAPTER 6

LOCAL AREA NETWORK CASES

Network Type and Overview- LAN1, as this case will be referred to, is a heterogeneous network per the issues presented in previous sections. The main operating system is AT&Ts System V Unix version 3.2.3 and 4.0. This operating system has no proprietary extensions of the language since AT&T is the originator of Unix System V. Unix is recognized as the preferred open system operating system across multiple hardware platforms.[1] The network layers which the network utilizes are as follows: NPP-Stargroup OSI Network Program Version 3.3a, TCP/IP, RFS (Remote File Sharing), NFS (Network File Sharing), and Unix Basic Networking software including UUCP (Unix to Unix Copy), UUX (Remote execution), and CU (Unix connection service). These network products allow connection to and resource sharing with any TCP/IP node, any host running an OSI network program without proprietary extensions, any host running any version of Unix which supports the standard networking calls including UUCP, UUX, and CU.

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[1]Mark Freund, "Are Your Open Systems Open?," LAN Technology Aug. 1992: 35.

Connection to LAN1 can be accomplished in the following methods: asynchronous via a serial interface, synchronous through a sync/async converter, via Ethernet 802.3 10baseT, or through baseband with a transceiver. At the time of the study end-user device support included PCs, XTs, ATs, 386s, 486s, sync tubes (i.e. IBM 3278), async tubes (i.e. DEC vtxxx), Unix workstations, X-window terminals, PLCs (Programmable Logic Controllers), and various non-Unix based hosts (i.e. DEC MicroVax 3400). The mix of vendors in hardware and software and the support for various connection methods based on standards classify this network as a heterogeneous installation.

Scope and Functionality- The network, as it was installed originally, was to support 128 users of mixed types. Approximately half of the users were to access the DOS services on the network from Intel based machines and the other half connecting to Unix services via synchronous or asynchronous end devices. Over the course of the project X-terminal support had been added, and 48 additional seats were provided. These costs are reflected in the financial worksheets. Office automation software was provided for any end device via the network. The basic OA software included in the project was a word processor, spreadsheet, SQL database, electronic mail, and mainframe access via an SNA gateway.

Services provided included disk storage, data backup, maximum 1 day down-time, shared laser printers on the network, and end-user training. Geographic scope initially was for a second floor office area covering approximately 6500 square feet. During the course of the project a plant floor area of approximately 350,000 square feet was added. The cost of the additional coverage is included in the financial worksheets.

Topology- LAN1s topology provides for 10Mbps data rates on the network to all geographic points in the coverage area. A star topology is used with cascaded hubs to conform to Ethernet 802.3 5/4 repeater rules. The 5/4 rule refers to the standard which states that an Ethernet signal can pass through no more than four repeaters or five segments before the signal is bridged. The network as it was designed and installed is shown in Figure 2. The current diagram, with the expanded coverage and end device support, is shown in Figure 3. In Figure 2 and 3, only a representative number of end user devices is included to keep the size of the drawing legible.

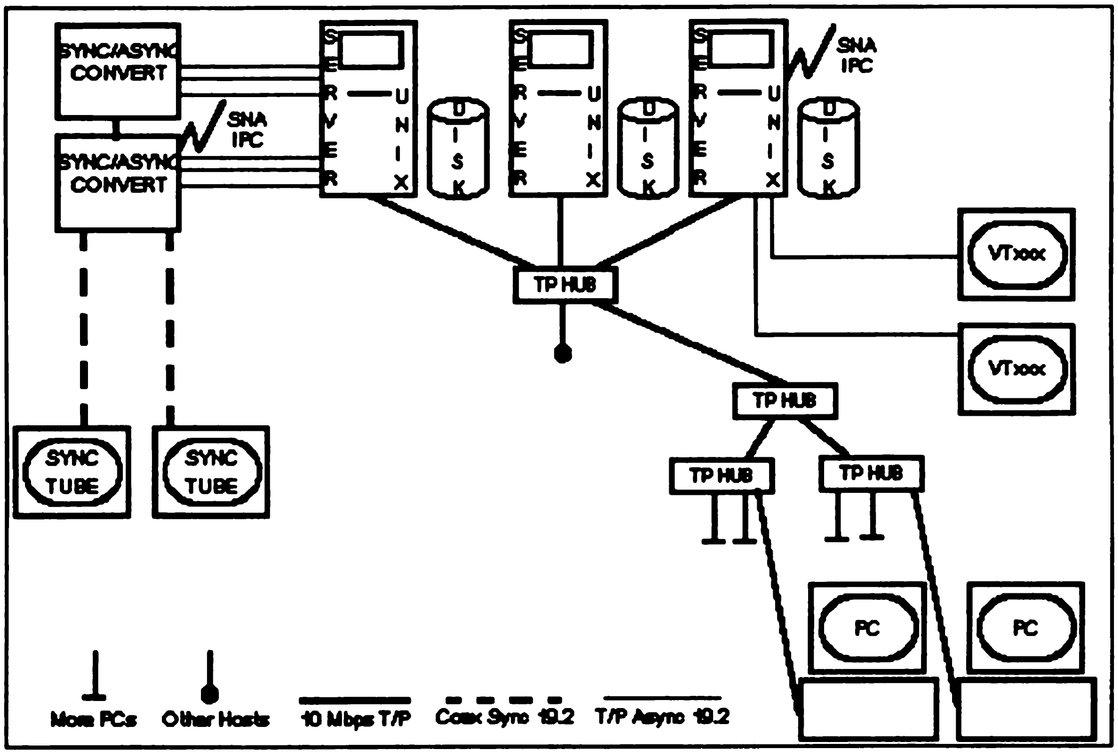

Figure 2. LAN1 ORIGINAL TOPOLOGY

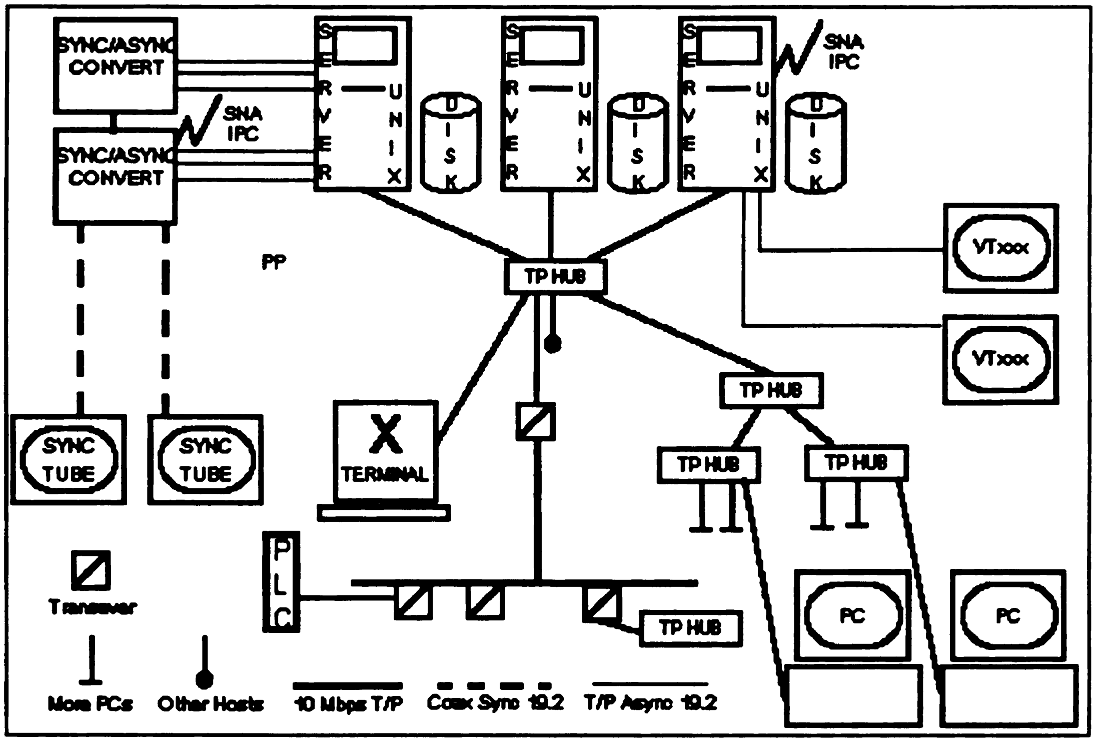

Figure 3. LAN1 UPGRADE TOPOLOGY

Financial Model- The figures presented in Table 2 include; initial, upgrade, and on-going costs for LAN1. Details for each account are listed below the table.

Table 2. LAN1 Financial Worksheet

	Year 1	Year 2	Year 3	Total
Salary & Related	72	48	48	168
Book Depreciation	40	40	42	122
Maintenance	14	14	16	44
Telecommunications	21	12	15	48
Technical Support	7	2	2	11
Expensed Equipment	24	4	12	40
Training	8	2	2	12
Software	15	8	4	27
TOTAL EXPENSES	201	130	141	472

*All figures in $1000

Salary & Related: Includes 25% of a system engineer for the implementation phase in year one and 50% of a system engineer for years one through three for network administration.

Book Depreciation: Includes all hardware over $1000. The major components covered are 2 sync/async converters, SNA gateway hardware, 3 Intel based Unix servers, 3 laser printers, 8 10baseT T/P hubs, and 3 asynchronous fan-out interfaces for device connection. No end-user computing devices were included in the cost of the project since existing devices were used.

Maintenance: Includes years 2 and 3 for all components on the network except for end-user devices. Both software and hardware are in these figures along with line maintenance for the T/P connections.

Telecommunication: Includes the installation of 72 T/P lines from end-user devices to a phone closet. Installation performed by the local phone provider at $150/line. This figure also includes the on-going cost of 2 SNA synchronous lines at $450 a month each.

Technical Support: This includes year 1 through 3 of 24 hour phone support for the server hardware and software. Also included in these figures is a week of a technical consultant on the sync/async converter.

Expensed Equipment: All equipment under $1000. The main components of the account are 72 Ethernet cards and component cards for the servers.

Training: This account contains 3 vendor provided training courses for various network administration skills and 2 non-vendor classes covering network integration and standards.

Software: This account holds all expensed and amortized software. The main components are Unix, TCP/IP, OA software licenses, and end user device support packages such as X11 windows and SNA emulation.

Variable Highlights- The network for LAN1 did not add or upgrade any end-user seats. Instead of requiring a common end-user device configuration, money was spent on integrating existing and potential future end-user devices. Due to the complexity of the original heterogeneous network design and the ongoing skills required to maintain and administer the network, systems engineers were used in the project. In a typical homogeneous network design it is possible to use vendor provided designs and expertise for installation and an operator for ongoing support. The costs for a systems engineer are higher than those for operators in the cases under study. Due to the complexity of the relationship between the network components, operating systems, and network protocols, one individual is responsible for network, system, and user administration. The level of dependence on this single SE is high, and re-training of new personnel to assume the role will be more costly than finding an operator familiar with a proprietary network. This situation has not arrived at this case study site, however the management is aware of the potential cost.

Network type and overview- LAN2 as it will be referred to is a homogeneous network by previous definitions. The main operating system is Digital Equipment Corporations (DEC) VMS version 5.4. DEC is the only supplier of VMS and it is proprietary. VMS runs on two DEC 6510 servers. The servers used were already existing and had the space to run the network, so the costs of the servers is not included in the financial worksheet. The network protocol which is used on the network is DECNet, which is a proprietary Ethernet collision detect protocol. For DOS network services the network utilizes DEC PCSA a proprietary implementation of Microsoft's LAN Manager product. The network is able to connect to any other system running DECNet and VMS (only available on DEC) or any system running PCSA with DECNet (only available on DEC).

Connection to LAN2 can be accomplished via an asynchronous serial interface for running VMS but no OA functions or through Ethernet 802.3 for OA services. The end user devices supported for OA functions is Intel-based boxes and VTxxs for VMS applications.

Scope and Functionality- The network was originally designed and installed to support 72 end-user seats all running DOS services from an Intel-based box. Over the course of the project an additional 48 Intel-based seats were added. These cost are reflected in the financial worksheet. OA software was provided for end-user seats via the network. The software included word-processing, spreadsheet, and database applications. SNA access via a gateway was provided in the second year of the project.

Services included disk storage, data backup, maximum of 2 days downtime, shared laser printers, end user training, and maintenance on the Intel-based end-user devices. The geographic coverage was for a 5200 square foot office area on the first and second floor. During the course of the project, additional coverage was added for another 3000 square feet on the second floor office area. The costs for the additional coverage are reflected in the financial worksheet.

Topology- LAN2s network supports 10Mbs data rates to all areas supported by the network. Thin Ethernet wiring is used in a daisy chained topology (sometimes referred to as bus topology). The leg of the network which runs to the first floor has a repeater to maintain distance limitations of the Ethernet. Additionally, the expanded second floor coverage required another repeater in the network. The network as diagrammed in Figure 4 represents LAN2 as it was originally installed. Figure 5 shows the expanded coverage of the second floor office area and the addition of the an SNA gateway.

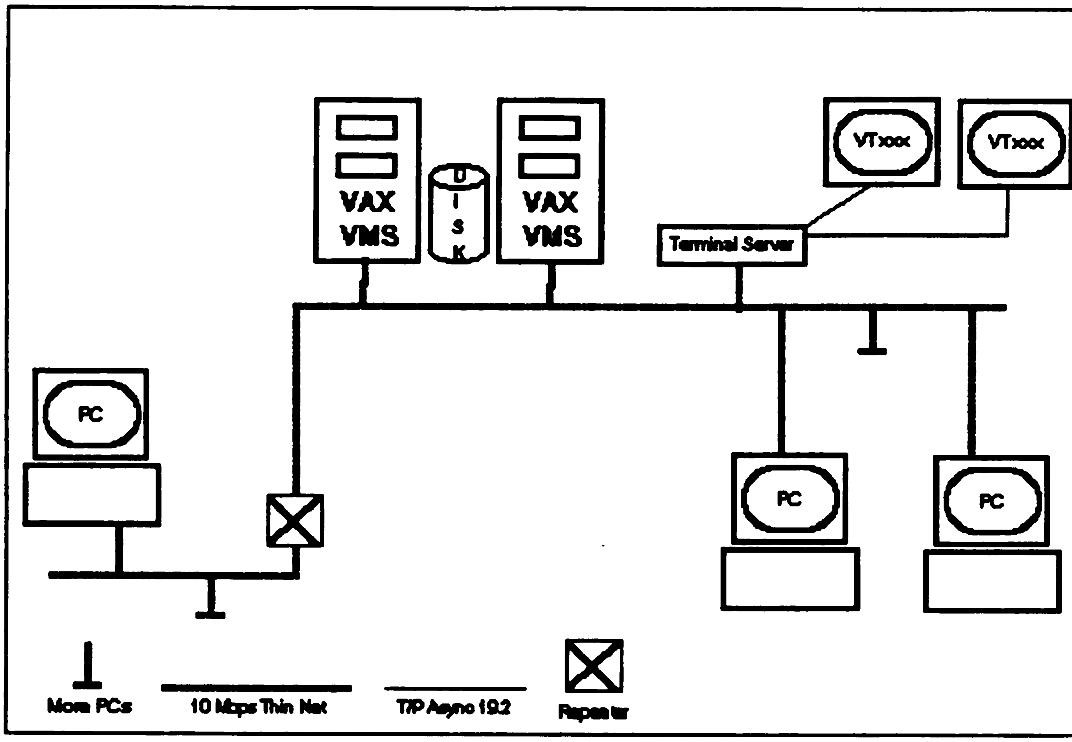

Figure 4. LAN2 ORIGINAL TOPOLOGY

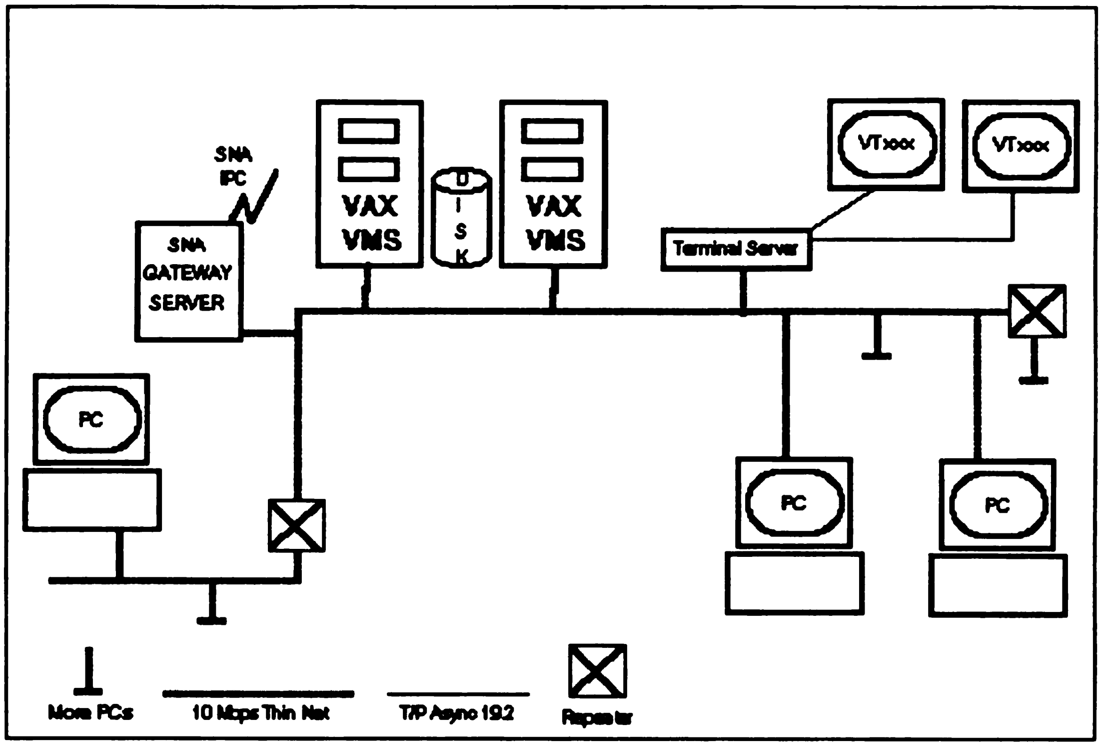

Figure 5. LAN2 UPGRADE TOPOLOGY

Financial Model- The figures presented in Table 3 reflect original network costs and the enhancements in year two including the additional seats and the SNA gateway server. Details for each category are listed below Table 3.

Table 3. LAN2 Financial Worksheet

	Year 1	Year 2	Year 3	Total
Salary & Related	35	35	35	105
Book Depreciation	79	124	124	327
Maintenance	20	28	28	76
Telecommunications	6	8	5	19
Technical Support	0	0	0	0
Expensed Equipment	28	12	0	40
Training	2	0	0	2
Software	89	31	0	120
TOTAL EXPENSES	259	238	192	689

*All figures in $1000

Salary & Related: Includes 50% of an operator for years one through three for network administration.

Book Depreciation: Includes all hardware over $1000. The major components covered are 72 end-user Intel-based boxes purchased in year one and 48 more purchased in year two. Also in the figure is 4 laser printers, 3 terminal servers, and an SNA gateway server purchased in year two. No servers were included in the cost of the project since existing hardware was used.

Maintenance: Includes years 1 through 3 for all components on the network except for the VMS servers. End user Intel boxes are included in this figure. Both software and hardware are in these figures.

Telecommunication: Includes the installation of main runs of thin Ethernet and tap wires. Attachment performed by the local system administrator. This figure also includes the ongoing cost of 1 SNA synchronous line at $450 a month.

Technical Support: This account is empty since the maintenance contract they use provides technical support. All initial installation and configuration support was provided by the network vendor as part of the hardware cost.

Expensed Equipment: All equipment under $1000. The main components of the account are 120 Ethernet cards and component cards for the end-user seats.

Training: This account reflects 1 vendor provided training course for various network administration skills on PCSA.

Software: This account holds all expensed and amortized software. The main components in this account are the vendor specific OA packages, server network software (PCSA), and the SNA gateway software. Each end-user seat also incurred a one time charge of $150 for network workstation software.

Variable Highlights- The inclusion of end-user Intel boxes and the exclusion of server hardware are of great interest to this case. The cost of the 120 end-user Intel

boxes added approximately $212,000 over the three years of the study. The main accounts effected by this inclusion are depreciation and maintenance. The exclusion of the server hardware was due to the method used to deploy the project. Since existing DEC equipment was used for a network server, no purchase was made. Had the cost of the server been included it would have added approximately $382,000 over the three years of the project, mainly in the depreciation and maintenance accounts.

CHAPTER 7

CAMPUS NETWORK CASES

Network Type and Overview- Campus1, as it will be referred to in this study, started as a homogeneous network and is slowly evolving into a more heterogeneous network as site requirements for mix protocol access increases. As the Campus network was originally installed, it supported only DECNet protocol and used all DEC equipment. The current network also supports asynchronous traffic using point-to-point modems and broadband point-to-point channels. Since asynchronous communications can not be considered a network protocol, the network is still a homogeneous, proprietary design.

The media used is broadband, fiber optic, Unshielded Twisted Pair (UTP), and Thick Ethernet. The protocols supported are DECNet and Hughes LAN Systems (An asynchronous point-to-point proprietary systems for broadband.) Data rates on the campus range from 9600 Baud to 10Mbps. All media was installed with the campus design except for the broadband which was already on the site. All components used were provided by DEC or Hughes and meet 802.3 specs for media, however, the repeaters, bridges, routers, and transceivers are DEC proprietary and have problems supporting any protocols other than DECNet. In particular, the network components can not at this time support TCP/IP packets without bringing down the DECNet traffic. Where fiber segments exist, no standards were used for the repeaters, hubs, or transceivers. The fiber is rated in one segment to support FDDI.

Scope and Functionality- Campus1 covers nine buildings within a mile radius. The network carries DECNet traffic and point-to-point asynchronous traffic on the broadband segments. Data rates are a function of the desired path for connectivity. Some communication links can run at 10Mbps while others run at 1.5Mbps or even 19200baud. The network, as designed, covers delivery to a building with a router as the end attachment point. The routers support DECNet only, and were provided by DEC. The network supports approximately 2500 end-users capable of moving data on the campus. Of these end-user seats, over half utilize the broadband segment running asynchronous Hughes LAN Systems point-to-point access.

Maintenance of components, up to and including the routers, is provided in the project, except for the broadband. The other service provided in the project is maintaining a network throughput of no less than 80% of path capacity. For example, a connection that is capable of 10Mbps must maintain a throughput of 8Mbps. Part of the support of throughput is maintenance of router and bridge tables. These tables help optimize network packet traffic and isolate segments of the network to maintain an acceptable throughput.

Topology- Campus1 mainly utilizes a modified bus topology, with two star breaks off the bus. Four of the buildings can support 10Mbps traffic, two can support 1.5Mbps, and the last three can access only asynchronous 19200baud or 9600baud channels.

Segments include broadband, UTP, fiber, and Thick Ethernet. The original design did not include the three buildings which access the campus through the broadband. The original design can be seen in Figure 6 below.

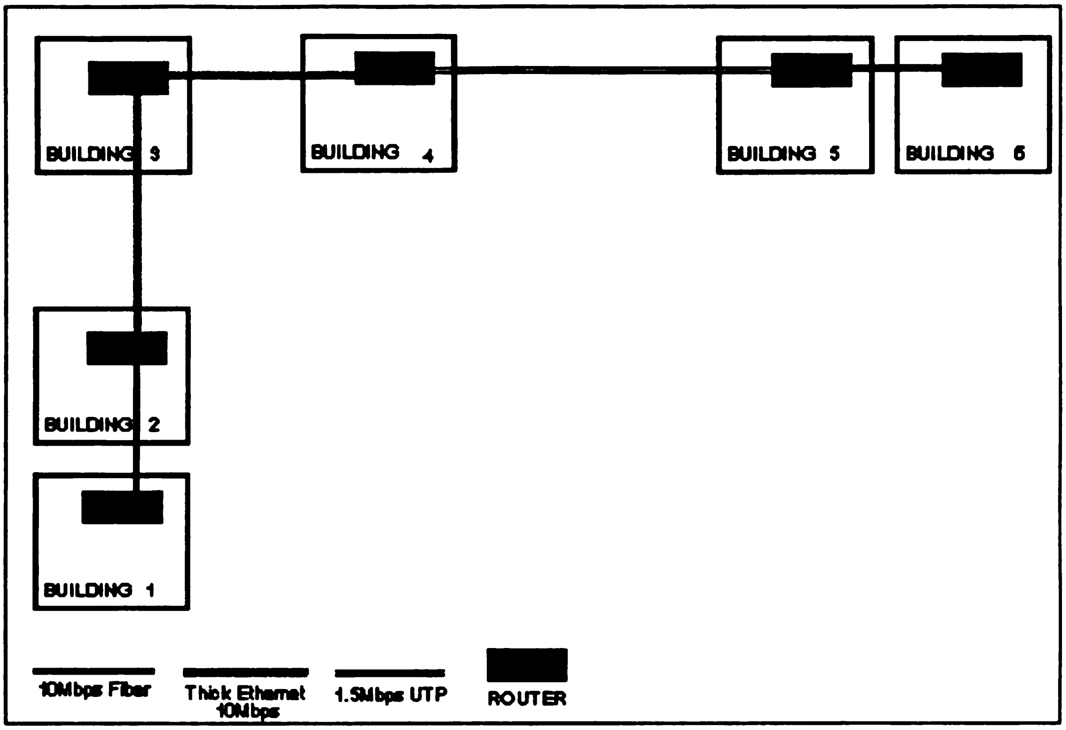

Figure 6. CAMPUS1 ORIGINAL TOPOLOGY

During the course of the project three additional buildings required connection to the campus network. The distance between the new buildings and the existing wiring required a change to the existing hardware and a rewiring of some of the segments on the campus. Due to the cost of these changes, the network designers chose to use the existing point-to-point asynchronous channels available on the broadband, which reached the additional buildings. The trade off was the lower data rate and the inability to run any Ethernet protocols. There was an Ethernet channel available on the broadband, but it was not compatible with the

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the DEC Ethernet equipment in use on the campus network. The upgraded Campus1 network can be seen in Figure 7 below.

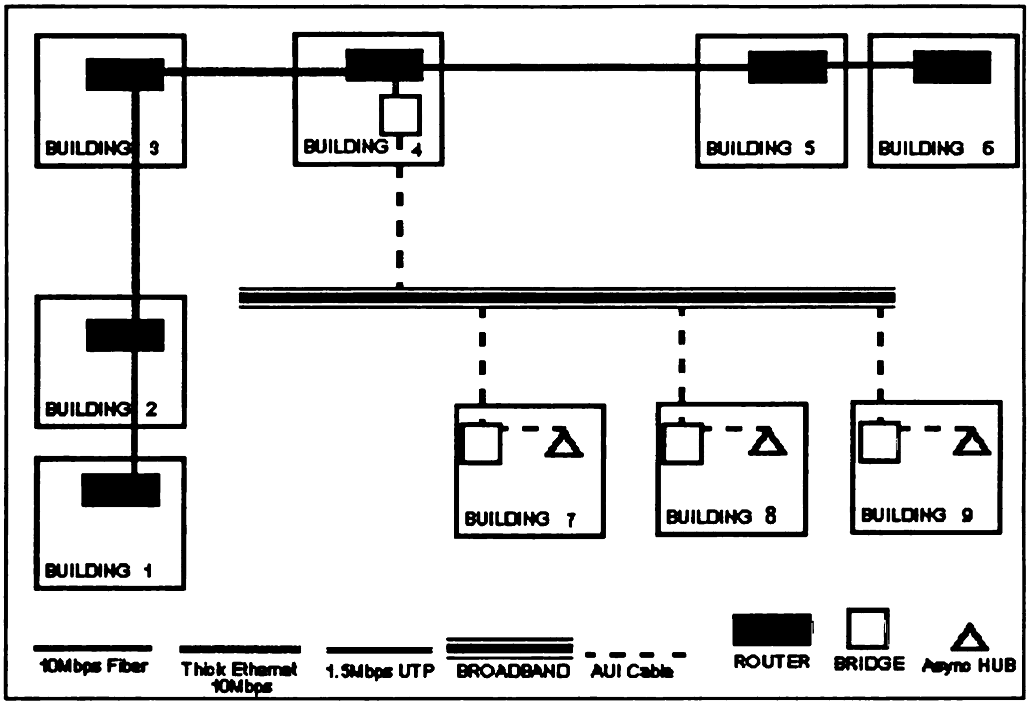

Figure 7. CAMPUS1 UPGRADED TOPOLOGY

Financial Model- The financial worksheet for the Campus1 network can be seen in Table 4. The numbers reflect the upgrade coverage in year two.

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Table 4. CAMPUS1 Financial Worksheet

	Year 1	Year 2	Year 3	Total
Salary & Related	225	375	375	975
Book Depreciation	28	36	36	100
Maintenance	5	7	7	19
Telecommunications	41	24	24	89
Technical Support	0	12	0	12
Expensed Equipment	22	9	0	31
Training	6	4	0	10
Software	14	12	0	26
TOTAL EXPENSES	341	479	442	1262

*All figures in $1000

Salary & Related: Includes three Systems Engineers in year one, and an additional two Systems Engineers in years two and three. The additional SEs were required to manage the broadband interfaces.

Book Depreciation: Includes all hardware over $1000 except for cabling. The cable was broken into price per meter, and thus was not considered a fixed asset by the financial systems. Part of this is done to cover local property tax. To assign percentage of the asset over a wide area would be too much work for the small financial advantage of depreciating the asset. This is common practice in all of the networks this study covers. The major

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major components in the account are DEC routers, bridges, and hubs.

Maintenance: Includes years one through three for all components of the network up to and including routers. The media is not covered in this account.

Telecommunications: This account holds the cost of the media installation and on-going communications costs. The major ongoing costs are the use of two T1 lines for the UTP. The media included approximately 650 meters of 4 strand fiber, 600 meters of Thick Ethernet, and 3200 meters of leased copper (UTP).

Expensed Equipment: All equipment under $1000 is reflected in this account including the cable. The broadband was already installed and did not require additional purchases. In addition to cable, this account carries transceivers, connectors and modems for the T1 lines, and connection to the broadband.

Training: This covers training for three SEs in year one on management of the DEC network components and training for two additional SEs in year two on the asynchronous broadband network components.

Software: Includes the DEC router and network management software in year one, and the asynchronous network software and management tools in year two.

Variable Highlights- The main cost in this network is the personnel. The network requires multiple SEs to maintain the router tables, bridges, and the transport layers of the network. A central network support group could not be leveraged due to the inability for this network to support SNMP. When additional buildings required access, the protocol could not run on the existing media at those plants, so a new asynchronous network and associated management tools were required. The two SEs added in year two support the asynchronous part of the campus. The proprietary network components and software have not translated into reduction in staff required to support it, like it often does in Local Area Networks. Due to the requirements of a Campus network to be more highly integrated any deviations from OSI standards make managing the network harder.

Network Type and Overview- The Campus2 network is a heterogeneous campus network in a variety of ways. The equipment on the network comes from a wide variety of vendors. The equipment supports any Collision Detect protocol including, at this time, OSI, DECNet, and TCP/IP. The network support SNMP, and most of the components are self-learning based on OSI standards.

The main media for the backbone is FDDI rated fiber. Data rates are 10Mbps across the entire campus. The backbone could support a higher data rate if the site chose to switch to FDDI. The network was installed in two phases by different account personnel and different vendors, but compatibility and seamless networking was maintained based on standards.

Scope and Functionality- Campus2 covers eight buildings within a one and a half mile radius. The network supports any collision detect protocol without bridging, and can support other protocols with appropriate bridging. Currently the network runs OSI Ethernet, DECNet with Local Area Transport (LAT) support, and TCP/IP. The TCP/IP, and OSI are running from several vendors on various platforms. All links support 10Mbps data rates. The network covers all components and media up to and including buildings, bridges, or routers. Although the network only covers eight buildings at this time, multi-port repeaters are installed in three other buildings and are ready to connect additional LANs.

The network carries approximately 2200 end-users two thirds of which have intelligent workstations, with the remainder connecting through terminal servers to the network. The network project was installed in two phases and includes support of all devices and media up to and including building bridges or routers. Throughput of no less than 90% efficiency is provided in the project through the use of monitoring tools and intelligent network devices. The adherence to standards in the design of the network has allowed the use of a single management tool for the entire network. The use of standards has also allowed support for intelligent devices on the network which are self optimizing and configuring such as self learning bridges which do not require table maintenance.

Topology- Campus2 was installed to support FDDI rings and because of this, has a series of patch panels at all buildings that it reaches on the campus. Each patch panel supports either a multi-port fiber repeater supporting Fiber Optic Integrity Repeater Link (FOIRL) or a fiber hub. This leads to a star configuration at every building and redundant bus topology between buildings. The entire network utilizes fiber for the media and adheres to Ethernet's 5/4 rules. As FDDI is implemented, additional standards will be supported.

The first phase of the network covered five buildings and two thirds of the distance for the media. The second phase added three additional buildings. Twelve strand fiber was used in both phases, although it was provided by different vendors. All segments are FDDI rated using 125/62.5 micron fiber. The phase-one topology can be seen in Figure 8 below. The second phase is identical to the first phase in terms of components used and connection methods. The additional buildings and fiber can be seen in Figure 9.

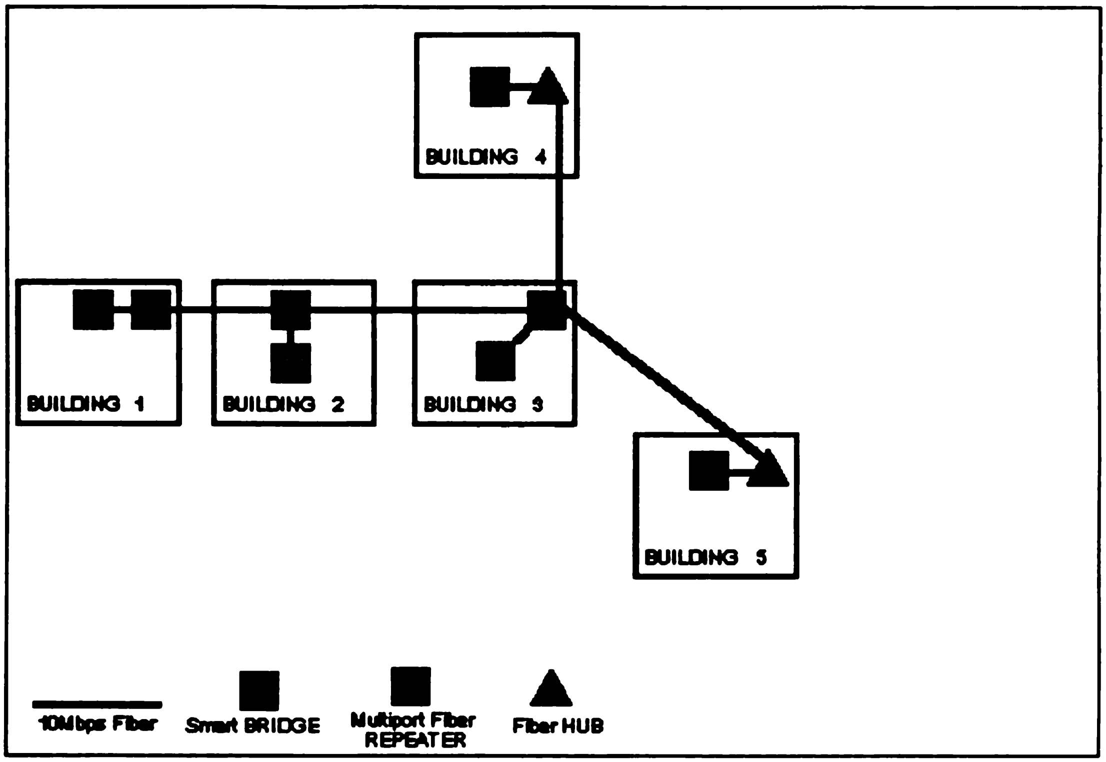

Figure 8. CAMPUS2 ORIGINAL (PHASE 1) TOPOLOGY

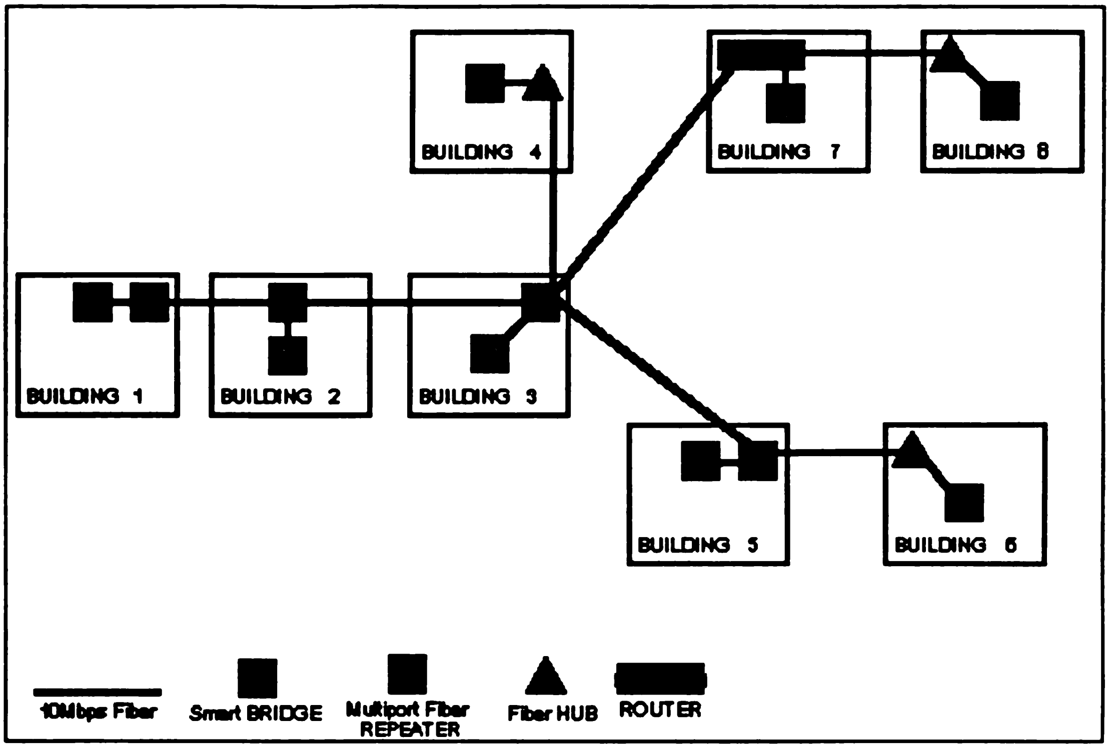

Figure 9. CAMPUS2 UPGRADED (PHASE 2) TOPOLOGY

Financial Model- The project financial worksheet for Campus2 is represented in Table 5 below. The worksheet reflects the additional coverage starting in year 2.

Table 5. CAMPUS2 Financial Worksheet

	Year 1	Year 2	Year 3	Total
Salary & Related	300	150	150	600
Book Depreciation	10	18	18	46
Maintenance	2	3	3	8
Telecommunications	12	8	0	20
Technical Support	10	0	0	10
Expensed Equipment	74	36	0	110
Training	2	0	0	2
Software	5	0	0	5
TOTAL EXPENSES	415	215	171	801

*All figures in $1000

Salary & Related: Includes four Systems Engineers in year one and two Systems Engineers in years two and three. The additional SEs in year one were used for network design and implementation and development of SNMP network management tools. The two SEs which carry on throughout the project are responsible for network management.

Book Depreciation: Includes all hardware over $1000 except for cabling. The cable was broken into price per meter, and thus was not considered a fixed asset by the financial systems. The major components in the account are self learning bridges, fiber hubs, multi-port fiber repeaters, and one router.

Maintenance: Includes years one through three for all components of the network up to and including repeaters, bridges, hubs, and one router. The media is not covered in this account.

Telecommunications: This account holds the cost of the media installation. The media included approximately 4600 meters of 12 strand FDDI rated fiber. Labor for fiber polishing is included in this number.

Technical Support: Includes two weeks of an outside technical consultant on network design and management. The consultant provided a template for conducting a site analysis and made recommendations on SNMP tools.

Expensed Equipment: All equipment under $1000 is reflected in this account including the fiber. In addition to cable, this account carries transceivers, connectors, and fiber patch panels.

Training: This covers training for one SE on the use of a SNMP tool.

Software: Includes a SNMP management tool and SQL database for tracking of SNMP data.

Variable Highlights- The Campus2 network use of fiber and self learning devices has made it an easy system to maintain. The up-front costs for the construction of the network was offset by the lower ongoing support costs. The self learning devices, ease of protocol support, and SNMP tools is only possible due to the standards based design of the network.

CHAPTER 8

WIDE AREA NETWORK CASES

Network Type and Overview- WAN1 is a homogeneous, though de facto standard based, network. The network supports IBM's System Network Architecture (SNA) and no other protocols. Due to the proliferation of IBM's SNA, it has evolved into a de facto standard.[1] The age of this network along with its many sub-nets makes it prohibitive to study the entire original implementation costs. For the purposes of this case study we will look at a new division in the organization which had to connect seven sites across four states. The organization had purchased seven front end processors (FEP) for connection to a central mainframe.

The network project, as it was installed in the new organization, covered approximately 7000 end user devices or Logical Units (LUs). The project includes FEPs, controllers, multiple access units, modems, and leased lines to the central Information Processing Center (IPC). The equipment at the IPC was already in existence, and the only charge related to the IPC is the connect charge for each

[1]Paul J. Fortier, Handbook of LAN Technology (New York: McGraw-Hill, 1989) 237.

line coming in from each FEP. The network supports various data rates and protocols including Bisync, Synchronous, and Asynchronous ranging from 4800bps to 1.5Mbps.

Scope and Functionality- WAN1 covers seven sites across four states. The network only supports SNA and data rates up to 1.5Mbps. The subnet contains seven IBM FEPs, 67 IBM or Memorex 3274 controllers, and three SNA gateways. Support includes generation of port configuration, hardware maintenance, and software up to but not including the IPC.

Topology- WAN1 uses leased lines for all wiring from the FEPs to the IPC. The network can be viewed as a star topology with the IPC as the center of the star. Communications from site to site can be accomplished only through the IPC. To reduce the number of leased lines used, some of the sites use Multiple Access Units to multiplex signals to the FEPs. From the end-user devices to the controllers, 75ohm coax cable is used, or balins and Twisted Pair to simulate the coax cable. From the FEPs to the IPC, leased lines are used. An overview of the topology for WAN1 can be seen in Figure 10 below.

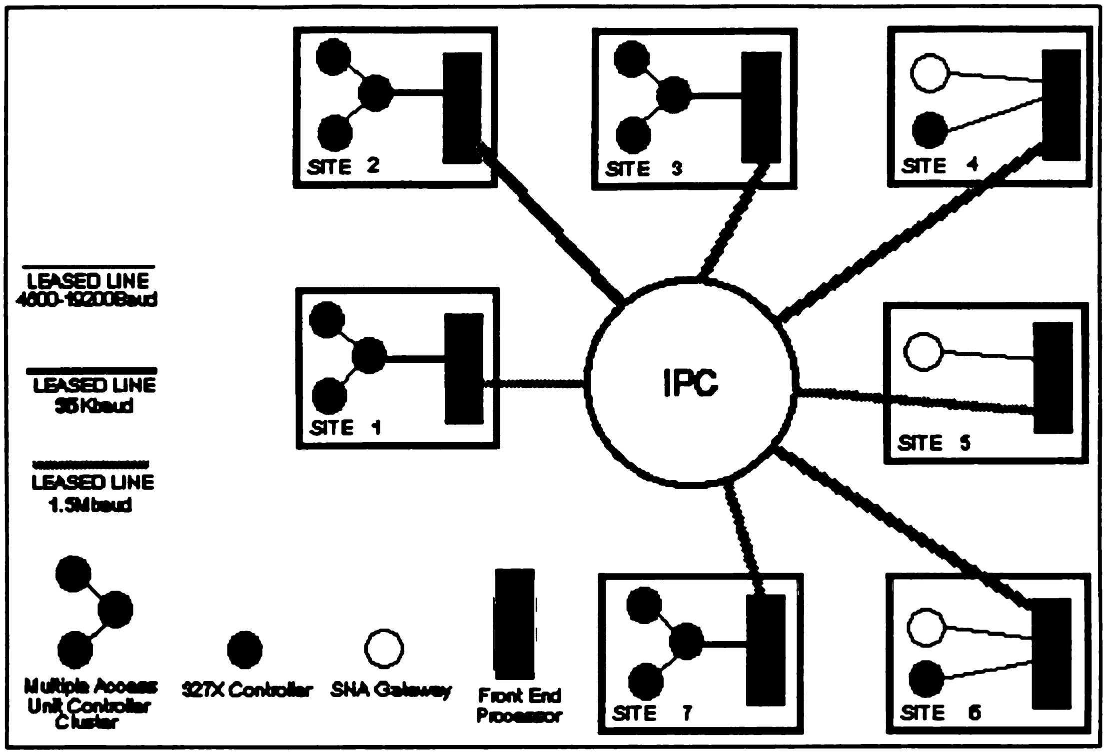

Figure 10. WAN1 SNA DIVISIONAL SUBNET TOPOLOGY

Financial Model- The projects financial worksheet for WAN1 can be seen in Table 6 below. The costs for IPC services are not included in the table since the project scope is from controllers up to but not including the IPC.

Table 6. WAN1 Financial Worksheet

	Year 1	Year 2	Year 3	Total
Salary & Related	1750	1750	1750	5250
Book Depreciation	407	407	407	1221
Maintenance	40	40	40	120
Telecommunications	1908	1812	1716	5436
Technical Support	3	0	0	3
Expensed Equipment	22	2	2	26
Training	0	0	0	0
Software	11	0	0	11
TOTAL EXPENSES	4141	4011	3915	12067

*All figures in $1000

Salary & Related: Includes two Systems Engineers and two Operators in all years of the project for each of the FEP locations (total of 14 SEs and 14 Operators). These employees are used to maintain the FEP at each site including software upgrades as distributed by the IPC, configuration of new users at the site, and trouble shooting connections to individual buildings on there site.

Book Depreciation: Includes all hardware over $1000. The main components of this account are the seven FEPs, 67 327X controllers, three SNA Gateways, and the MAUs.

Maintenance: Includes years one through three for all components of the network from the 327X controllers up to and including the FEPs. The media is not covered in this account since all circuits are leased and the maintenance is included in the lease price.

Telecommunications: This account holds the cost of the monthly circuit leases. The leased lines include 23 4800Baud to 19200Baud lines, four 56KBaud lines, and seven 1.5Mbps lines.

Technical Support: Includes two days of an outside technical consultant to help install and configure the SNA Gateway software.

Expensed Equipment: All equipment under $1000 is reflected in this account including balins, modems, and miscellaneous cables.

Training: No training was taken for support of this implementation. The IPC provides on-line phone support for any SNA related questions at no additional charge.

Software: Includes SNA Gateway software only. The controller software was bundled with the 327Xs and the FEP software was part of a license out of the IPC.

Variable Highlights- WAN1 required little site level knowledge to install and design since the SNA environment was already established at a corporate level. A raw implementation would require considerably more investment in design, training, and establishment of an IPC.

This network is used mainly for character-based applications and print services. No intelligent end devices are supported, and less than 5% of the end users access the network for file transfers. The SNA network was a requirement for the new division because several of the corporations common systems run only at IPCs via SNA.

Network Type and Overview- WAN2 is a heterogeneous network utilized by the same new division as covered in WAN1. The same seven sites were connected to an existing network creating a new subnet. WAN2s network is an internet based network and has secured access to the internet. Unlike the SNA network in WAN1, WAN2 users and sites are not required to go through a central IPC to communicate with other nodes on the network. This network was installed to augment the shortcomings of the SNA network and to support higher data transfer rates among sites. WAN2 supports 1.5Mbps to 10Mbps across the division. Certain members on the internet support even lower throughputs, but are not discussed in this case. The network supports most Collision Detect protocols, but the main traffic is TCP/IP and DECNet. Two of the sites utilize an OSI transport layer, and all sites use TCP/IP from one or more vendors.

The network, as it was designed and implemented, is completely router based. The routers serve to optimize network throughput locally and on the WAN. Additionally the routers help control secured access since portions of the network are accessible from the internet.

Scope and Functionality- WAN2 covers seven sites across four states. The network supports TCP/IP, DECNet, OSI, and most other Collision Detect protocols supported by the routers. Data rates range from 1.5Mbps to 10Mbps. The total user base is approximately 5050 users at the time of the study. The network can support 1024 internet hosts per site currently, however, not all sites have implemented a TCP/IP Campus Network able to access the WAN. Another reason for the lower end user seats is the smaller need for the expanded data rate services. File transfers and distributed client server applications are the main functions used on the network. The growth of client server applications in the division is driving usage of the network up on a monthly basis. When the 1024 nodes are used per site, the sites will have to break up into subnets on the network. This expansion will not require additional hardware or software, but will require a project to recreate or optimize routing tables.

Topology- WAN2 uses a mix of privately owned fiber and microwave for all wiring from the site routers to four regional hubs. The hubs, in turn, are connected with leased lines to public circuits. Data rates of 10Mbps are supported on the lines connecting routers to the regional hubs, and 1.5Mbps data rates are supported on the public circuits which connect the regional hubs. The network can

be viewed as a star topology with the regional hubs as the first star and the public circuits as a network of stars.

The project covers the site routers out to the public circuits. The cost for use of the public circuits is a function of bandwidth used and is a variable expense not unlike the IPC connection charge. The variable public circuit charge is not included in the case study since the sites do not pay them directly. The corporation picks up the public circuit charge as part of the infrastructure they maintain for the divisions.

An overview of the topology for WAN2 can be seen in Figure 11. The diagram does not try to map out the public circuit paths since they are not always the same from request to request, and the permutations are too numerous to map in this study. The public circuit portion of the network will appear the same way that the IPC was shown in WAN1. The public circuit leg of the network does not provide processing, but rather a dynamic data path to connect nodes on the internet.

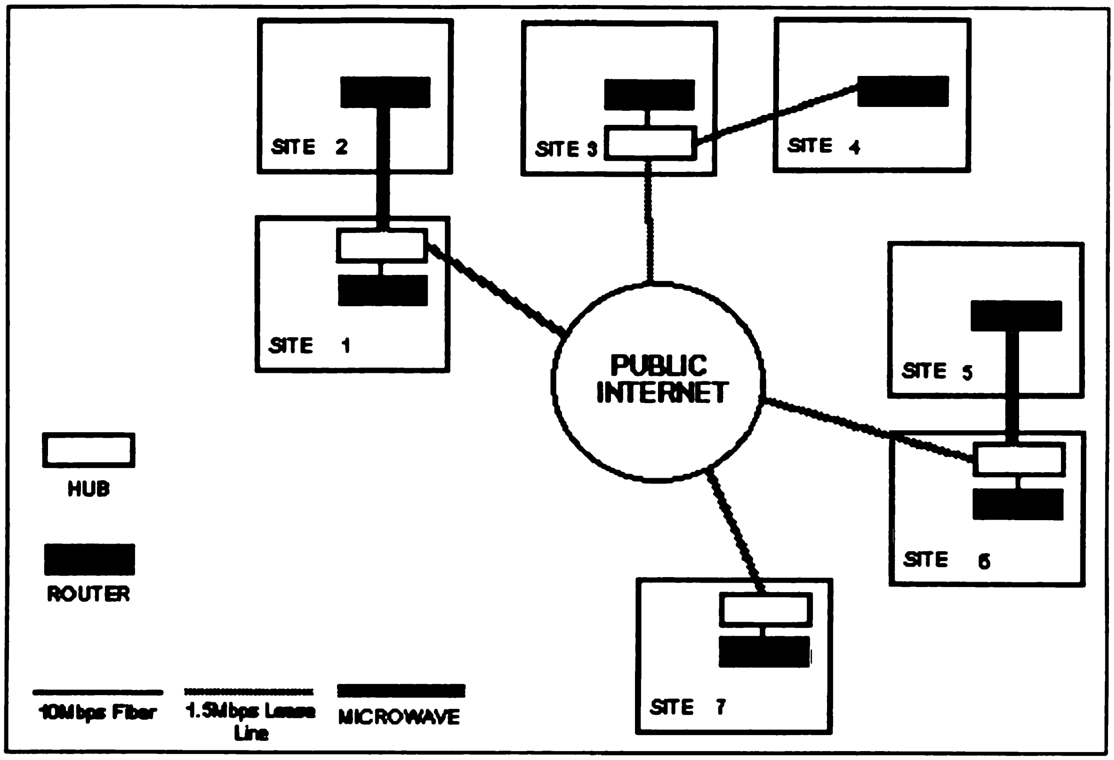

Figure 11. WAN2 DIVISIONAL NETWORK TOPOLOGY

Financial Model- The financial worksheet for WAN2 can be seen in Table 7 below. The project does not reflect the cost of public circuit usage charges as they are covered by the corporation as an infrastructure component. This is consistent with the treatment of WAN1s non-tracking of IPC connection charges and presents a more comparable financial picture of the two WANs.

Table 7. WAN2 Financial Worksheet

	Year 1	Year 2	Year 3	Total
Salary & Related	1960	1960	1960	5880
Book Depreciation	545	545	545	1635
Maintenance	52	52	52	156
Telecommunications	960	912	867	2739
Technical Support	28	0	0	28
Expensed Equipment	16	3	2	21
Training	48	6	5	59
Software	15	0	0	15
TOTAL EXPENSES	3624	3478	3431	10533

*All figures in $1000

Salary & Related: Includes four Systems Engineers in all years of the project for each of the seven sites. These SEs are responsible for controlling Internet addressing and management, hardware trouble-shooting, and network performance monitoring. The complexity of the administration prohibits the effective use of operators. The sites which use microwave links to the regional hubs do not support the devices, but call in for time and material repairs. This has yet to happen in the two sites with support microwave.

Book Depreciation: Includes all hardware over $1000. The main components of this account are the microwave transponders, site routers, and regional hubs.

Maintenance: Includes years one through three for all components of the network from the routers up to and including the regional hubs. The maintenance of the fiber optic runs is included. The microwave transponders would show up in this account as a time and materials call. To date no maintenance has been required from an outside vendor.

Telecommunications: This account holds the costs of the monthly circuit leases. The leased lines include four 1.5Mbps lines. As stated previously, the packet costs on the public circuits are not reported here. It is estimated that only 10% of the packets on WAN2 ever leave the region, and therefore incur no public circuit charges. Typical rates for these packets paid by the corporation cost $1.30 per Kilosegment carried over the public network.

Technical Support: Includes one month of an outside technical consultant to help design the subnets and routing logic. Addition advice was given on the selection of network monitoring software.

Expensed Equipment: All equipment under $1000 is reflected in this account including modems, and miscellaneous cables.

Training: This account includes two weeks training for one SE from each of the sites. The training was in the use of network management tools and proper internet addressing and naming conventions. As account personnel turns over and new standards evolve, addition training is taken.

Software: Includes network monitoring software for each of the sites. The router software was bundled with the routers and the software for the microwave transceiver stations was included with the hardware.

Variable Highlights- WAN2 assumes that each site has a campus of LAN which supports a collision detect protocol. If a site does not have an existing network, additional costs would be incurred, where as WAN1 provides the network at the site level from the controllers up. For a similar scope, WAN2 would be responsible for installing hubs on the site. The cost of such a wiring scenario would be marginal, approximately an additional $20,000 per site.

The WAN2 requires more skilled personnel on the sites to maintain the network, although it has not occurred during the period covered in the case study, loss of a lead SE at a site would result in additional training expense and a short period of an outside consultant to help manage the network during the training period.

A final note on WAN2's heterogeneous design is the limitations of router standards. Router protocols are still in an evolutionary stage, and no clear standard has yet to evolve. Due to this, the router protocols used are not totally open and are provided by a single vendor. The cost of routers will drop when a standard is developed.

CHAPTER 9

SUMMARY

The goal of the case studies was to collect financial information as dependent variables to the independent variable of network design (heterogeneous or homogeneous). Table 8 presents a summary of costs associated with each of the cases.

Table 8. CASE SUMMARY FINANCIAL WORKSHEET

NETWORK TYPE	LAN		CAMPUS		WAN	
DESIGN TYPE	HOMO	HETERO	HOMO	HETERO	HOMO	HETERO
Case Name	LAN2	LAN1	Campus1	Campus2	WAN1	WAN2
Salary & Related	105	168	975	600	5250	5880
Book Depreciation	327	122	100	46	1221	1635
Maintenance	76	44	19	8	120	156
Telecommunications	19	48	89	20	5436	2739
Technical Support	0	11	12	10	3	28
Expensed Equipment	40	40	31	110	26	21
Training	2	12	10	2	0	59
Software	120	27	26	5	11	15
TOTAL EXPENSES	689	472	1262	801	12067	10533

*All figures in $1000

From the figures presented in summary form in Table 8, the financial incentive to use a heterogeneous network design looks apparent. Over the three years that the case studies covers the homogeneous designs have cost 46% more in the LAN cases, 57% more in the campus cases, and 14% more in the WAN cases. An interesting question which comes to mind when looking at the aggregate data is why would anyone design to a homogeneous network? A further breakdown in the data revels two possible reasons.

When selecting and designing a network it is easy to focus on known variables and short term costs. The nature of networks however requires more attention to long term issues and a changing environment. If each of the cases are viewed from year one cost, the information in Table 9 can be created.

Table 9. YEAR 1 SELECTIVE WORKSHEET

NETWORK TYPE	LAN		CAMPUS		WAN	
DESIGN TYPE	HOMO	HETERO	HOMO	HETERO	HOMO	HETERO
Case Name	LAN2	LAN1	Campus1	Campus2	WAN1	WAN2
Salary & Related	35	72	225	300	1750	1960
TOTAL EXPENSES	259	201	341	415	4141	3624

*All figures in $1000

As Table 9 shows, year 1 costs favor the implementation of a homogeneous network in four out of six criteria. The two areas where homogeneous networks cost more in an area in year one are highlighted. In the individual case studies related to these two areas, explanations can be found for the added costs of the homogeneous design. In the LAN pair where the homogeneous networks total year 1 costs were $58,000 higher than the heterogeneous network, the homogeneous network included end user devices, which if removed would drop the costs in year one below the heterogeneous LANs costs. The second highlight was for the year 1 total costs for the homogeneous WAN. In this case again, the scope of year 1 included enabling equipment for connectivity, which added to the costs. As stated earlier, if this equivalent acquisition was used in the heterogeneous WAN, year 1 total costs for the heterogeneous network would have been higher.

When looking at Table 9 it is clearer why a homogeneous network design may be selected. The focus is often on the predictable costs, and too little attention is paid to ongoing network costs.[1] Salary expenses are consistently higher in year one for heterogeneous networks as a result of the complexity inherent in heterogeneous network design and administration. Total year one costs are higher as a result of salaries, consulting, and training for heterogeneous networks.

Total three year costs are higher for homogeneous networks due to the incremental costs of adapting to added network requirements. The only exception to this is WAN1 which did not experience any changes over the three years of the case study. WAN2 did not experience any change during this time either, and the main cost difference between the two cases was the higher ongoing telecommunications cost in the homogeneous SNA network. As stated earlier, the

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[1]Eric Smalley, "VINES Certified Most Cost Effective," LAN Technology Mar. 1992: 16.

difference in costs between the two networks was only 14%. Of all the network pairs, this was by far the smallest difference. The two factors which appear to cause this is the lack of upgrades in the two WANs and the de facto standard which has evolved for SNA. Of the two remaining case studies, it appears that the greater the change of scope, the greater the costs difference between the heterogeneous and homogeneous networks. In LAN2's upgrade, which occurred in year three, an expansion of current access increased 48 seats with an incremental cost of $53,000 or $98,000 if end user device purchases were included. For LAN1s upgrade, which occurred in year two, an additional 48 seats were added for $19,000. The difference between these two upgrades is attributed to higher software and hardware costs of the homogeneous network components. This difference is relatively small since no new services or method of connectivity was required, just an expansion of identical connections and services. Campus1's upgrade on the other hand required larger scale changes due to the proprietary limitations of the homogeneous network and cost $197,000 more for the addition of three more buildings on the campus. Campus2 added three additional buildings for an incremental cost of $53,000. It appears that the heterogeneous network designs become more cost effect than homogeneous designs when greater levels of change are required during the life of the network. If a network never standard and has component prices which are more in line with oligopolistic supply and demand curves.

These findings add to our overall understanding of network design financial considerations. The field of cost analysis of network designs is just developing and this research helps isolate some of the variables which impact network costs. The case study approach does not definitively support the idea that a heterogeneous network design is more cost effective than a homogeneous network design, but it does provide a methodology for future study in this area.

CHAPTER 10

AREAS FOR FUTURE RESEARCH

Three main areas of future research are suggested by the information gathered in these case studies. The first two areas are focused on isolating the components of the independent variable of network design. The third area is a different methodology for simulating various network designs and costs to allow the researcher to manipulate more of the independent variables.

Future Research Topic 1.

Perform similar case studies as used in this research, but add detail to the rate of change to the various networks. A criteria for measuring level of change in design would have to be established, and then data relative to the changes would be added into the evaluation of the cases. The research in the current thesis pointed to this effect of change, but did not focus on the issue up front in the data collection. A modified thesis could be stated that heterogeneous networks become more cost effective than homogeneous network designs as the level of change in design over time increases.

A possible set of metrics for the variable of change would likely include a measure of additional geographic coverage as a percent change, the addition of traffic as a percent change, and the addition of another protocol to support as an absolute number of protocols supported. Additional features might also be incorporated in the change variable and could be tracked as percentage of the network users accessing the new services. These metrics would be refined as each one was tested against actual cases.

Future Research Topic 2.

This research would focus on network types to a greater degree. The current thesis uses LANs, Campus, and WANs as categories of networks and treats each the same way. In the course of the study, it appears that each level of networks has its own particular properties when it comes to the effect of homogeneous or heterogeneous design. For example, WANs as a group are much more likely, in their original design, to encompass open interconnection. Very few totally proprietary WANs exist, whereas, LANs come in many proprietary homogeneous flavors. Future research could apply different measurements to each type of network and propose a thesis that heterogeneous networks are more cost effective than homogeneous networks as the number of end users increases.

Future Research Topic 3.

This area is for a proposed method to simulate network designs and evolution. As stated earlier in this paper, it is cost prohibitive to design and implement networks in order to study a controlled set of installations, however, a simulation may be able to provide valid data. A random set of organizations and network requirements could be generated and two designs could be done for each, one homogeneous and one heterogeneous. Calls could be made to various vendors to establish the install prices and estimates could be provided for each of the other cost line items. Then a set of random events could be generated effecting the two networks requiring modifications and enhancements. These random events could be gathered from an actual companys changing needs, or a system could be constructed where a trade journal of computer networking is used. Each simulated month could pick a publication, page, and article location at random, and the technology or service described (if appropriate) would be required on the simulation. Once the changes generated from these random methods are collected calls could be made to vendors, as if the networks existed, and prices for expansion could be calculated. This research would allow a direct comparison of two networks, one homogeneous and one heterogeneous, for the same site. The hardest part of this type of study would be finding non-biased individuals to do the original network designs, but once obtained, the data from the study would be very accurate. A possible source for the design might be a computer course assignment at a university where one group is required to construct heterogeneous networks and another group is chartered to build homogeneous networks from the same set of specifications. The purpose and intent of the designs would not be disclosed to the students until after their designs were submitted. As computer networks become more common place, issues of design and standards will become more and more important. The economic impacts of various network designs has not been studied thoroughly to date and yet there appears to be a growing demand for this sort of information. As stated earlier, the need for this kind of information is a result of changing or missing standards in networking. In the future it is probable that standards will evolve that make this area of research unnecessary. Given the current rate of technology change it appears that the field of network economics, based on design type, will be required for many decades.