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Local area network analysis

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THESIS

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THESIS

LOCAL AREA NETWORK
ANALYSIS

by

Larry W. Stone

September, 1991

Thesis Advisor: Norman F. Schneidewind

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This thesis focuses on the performance of the Ethernet local area network in Ingersoll Hall, room 250, Naval Postgraduate School, Monterey, California. The Primary research is in performing a cost benefit analysis, using the economic value imputed to a reduction in average response time as the return on investment. The major objective is to find the best configuration for the network, based on integrating user-computer response time guidelines and the cost benefit analysis to indicate what might be economically acceptable response times for processing initial simultaneous requests for software installed on network servers. Word perfect 5.0 software was chosen for performance evaluation tests becxause it is typical of the software that is used in the lab under conditions of simultaneous access. Additionally, some of the effects of response time on human performance will be researched and noted in the conclusions along with the results of the feasibility test of user-computer interfaces and related cost benefit values.

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Local Area Network Analysis

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of the requirements for the degree of

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ABSTRACT

This thesis focuses on the performance of the Ethernet local area network in Ingersoll Hall, room 250, Naval Postgraduate School, Monterey, California. The primary research is in performing a cost benefit analysis, using the economic value imputed to a reduction in average response time as the return on investment. The major objective is to find the best configuration for the network, based on integrating user-computer response time guidelines and the cost benefit analysis to indicate what might be economically acceptable response times for processing initial simultaneous requests for software installed on network servers. Word Perfect 5.0 software was chosen for performance evaluation tests because it is typical of the software that is used in the lab under conditions of simultaneous access. Additionally, some of the effects of response time on human performance will be researched and noted in the conclusions along with the results of the feasibility test of user-computer interfaces and related cost benefit values.

c.1

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I. INTRODUCTION

A. BACKGROUND AND OBJECTIVES

Most network analysts estimate the local area network (LAN) performance in terms of (1) network characteristics of propagation delay between devices and data rate of the transmission medium, (2) medium access control protocol and (3) network load[Ref. 1]. These methods isolate the performance of the network from the hardware, software and human interaction the system must utilize to perform the main function of the network, sharing information. Protocols and network load are only some of the variables required to manage a network. Hardware, software and human performance characteristics make up other functions in the performance evaluation. Network response times are a measure of effectiveness for performance evaluations and determining network configurations. The best network configuration is achieved by reducing response time under relevant constraints, while minimizing cost.

This thesis concerns evaluation of average initial request response times in a small local area network, using user-computer interface guidelines in combination with a cost benefit analysis to achieve the best configuration. Additional effects of response time on human performance are also addressed, but it is beyond the scope of this thesis to measure such performance.

Figure I-1 below is a block diagram illustrating the objective of this thesis.

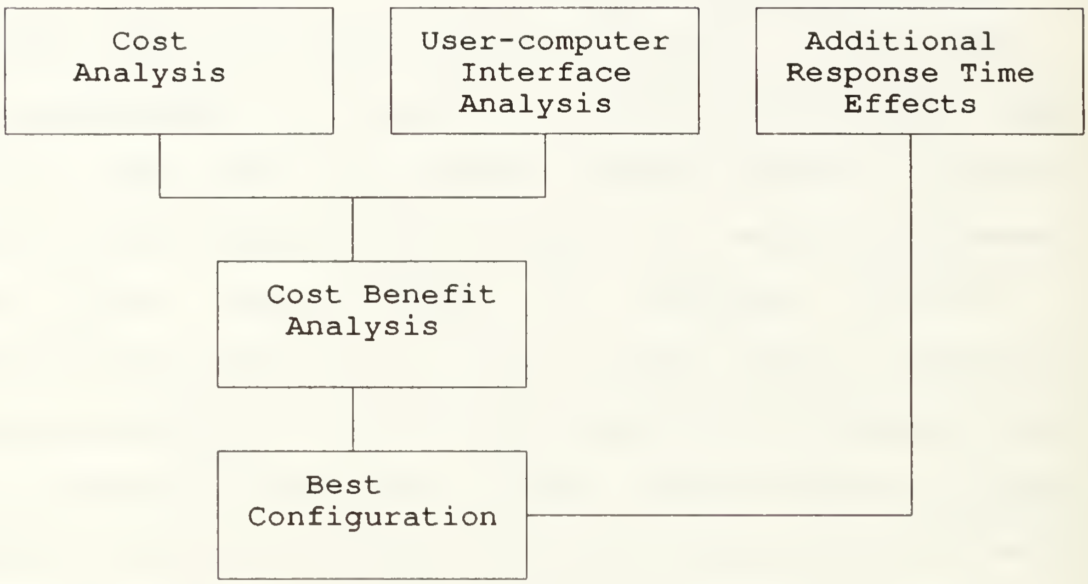

Figure I-1. Thesis objectives

B. SCOPE, LIMITATIONS, AND ASSUMPTIONS

The scope of this research focuses on deriving the best configuration for a relatively small network from cost-benefit analysis of response times and human interface guidelines. The specific network studied is a broadband Ethernet, with up to four servers processing requests from a maximum of twenty-five users. All applications for the Word Perfect 5.0 software are duplicated on each server, and it is assumed that the user computers (IBM-XT) respond uniformly for each request processed. The IS0123 word processing class is used to project initial request demand data for the network.

The average response time savings achieved by adding servers to the network is converted to a monetary value and a cost benefit analysis performed, using Net Present Value (NPV) method to provide data on payback amount, profitability index and return on investment.

Response time guidelines are used to integrate the human interaction benefits into the analysis. The primary purpose of the guidelines is to provide ergonomic bounds or constraints on the average response times, contributing additional guidance for determining the best configuration.

Human factors research will be limited to effects of the response times on performance. Acquiring empirical data and analysis of the data on human performance characteristics is highly task specific and beyond the scope of this thesis.

Several important assumptions are made in the analysis. It is assumed that all initial user requests arrive at the server simultaneously, and are processed as described in Dr. Schneidewind's model [Ref. 2]. Response times noted are average response times. For the purpose of this thesis, the investigation of standard deviation and variance was not conducted because the average response time provided the management guidance required. The model that is used is not the standard queuing model because the way in which the network is used does not conform to the assumptions of such models. Dr. Schneidewind's model was developed as a managerial tool to assist in determining network configuration.

To establish some base for the cost benefit analysis, it is assumed that the typical student using the LAN is a Navy Lieutenant selected from his/her first sea tour. Analysis of the net present value will use a discount rate equal to the assumed rate of return on an alternate project (i.e., if we can obtain a rate of return of 6% by using the funds to build a destroyer rather than spending them on buying servers, we should discount the savings on the project by that rate of return).

C. SUMMARY OF FINDINGS

This thesis concludes three major findings. First, using the historical data provided by the IS0123 class, collected data and the Ethernet LAN, as configured in Ingersoll 250, the best cost advantage for improving response time performance is achieved with the addition of one server (two total on the network). Cost advantage is defined as the cost of adding a server in relation to the economic value of average response time saved by adding a server.

Second, savings from adding servers can be used as a return on investment toward procuring additional servers. There was a payback within the five year assumed life of a server, when one, two and three servers, starting with no servers, were added to the LAN. The savings from incrementally adding the third server was not significant enough to payback in five years. The most economic benefit, based on the profitability index and internal rate of return, was achieved from the addition of the first server (i.e., starting with one server and adding a second).

The third finding indicated two factors contribute to human performance when communicating with machines. The factors are variability of display of data and system response times. Variability of display of information has more of an effect on human performance than response time. These factors directly affect two human reaction characteristics, subjective expectancy and psychological closure. Subjective expectancy is the tendency of humans to prepare for an average length of foreperiod when undertaking a series of trials. Psychological closure is psychological need in human communications which recognizes that humans organize activities into clumps that require completion of a subjective purpose.

Since variability has the greatest effect on human performance, the delays incurred in the initial response of the system degrade human performance to an extent, but are not as critical as the frequency of responses later, when an individual has been working with the system for some duration of time.

Response times do have an effect on human performance and constraints in the form of guidelines have been documented to reduce these effects. The optimum response time is fifteen seconds, with a maximum of sixty seconds. Response times in excess of sixty seconds cause an individual to focus his attention elsewhere and not react to the response as quickly or accurately as when his full attention is focused or held by the task.

D. ORGANIZATION

This thesis is divided into an introduction, one background chapter, three chapters on research and analysis and a final chapter of conclusions. Chapter II provides the characteristics of the Ethernet LAN being analyzed and the basis for the cost and cost benefit analysis performed, which will determine the economic feasibility of adding servers to the network. Discussion involves a specific Ethernet LAN configuration and specific software utilization.

Chapter III explains the parameters for doing the cost benefit analysis and explains how guidelines may be used to establish response time constraints in support of determining a response time which supports the economic configuration. Chapter IV describes the analytical model used to project average server response times and describes how the data for the cost benefit analysis was obtained. Chapter V provides the results of the direct cost and cost benefit analysis. The final portion of Chapter V discusses the effects of network response times on human performance. Research focuses on two area's, subjective expectancy and psychological closure.

Chapter VI summarizes the conclusion reached from the analyses.

Three appendices are also included. Appendix A furnishes a glossary of terms used throughout the thesis. Appendix B is projected data results from applying the response time model. Appendix C is a verification of the cost benefit calculations performed by the Interactive Financial Planning System (IFPS) software.

II. BACKGROUND

A. ETHERNET (Broadband)

The Ethernet local area network is generally a multiple access, shared communication channel system that is controlled by Carrier Sense Multiple Access with Collision Detection (CMSA/CD). More specifically, access to the communications channel is achieved by sensing the medium prior to transmitting data. If the station acquires the channel, it transmits until a collision occurs and is detected. All transmission is aborted upon a collision and each station backs off a random time period and tries to reacquire the channel.

Much of the network performance evaluation reported in literature has been centered around the response time of the network system, disregarding the hardware, such as hard disks, software, and user-computer interface characteristics which contribute to the response times and are critical in managing the network.

Dr. Norman Schneidewind, Code AS/Ss, Naval Postgraduate School, Monterey, California 93943, conducted preliminary studies, published in his paper, ISSUES IN ALLOCATING SERVERS AND FILES IN A LOCAL AREA NETWORK. The research established a model for measuring average response time of a broadband

Ethernet system located in room 250, building Ingersoll (I-250), at the Naval Postgraduate School, Monterey, California [Ref. 2]. The model accounts for hardware and software interaction with the network system (IBM-PC Network). The model establishes the following average times for simultaneous user requests:

T_r = T1 + T2 + T3 + T4 + T5 + T6 where:

T1 = Mean delay on the line between the user request and arrival of request at the server input buffer.

T2 = Mean wait time by the user request in server input buffer for hard disk access.

T3 = Mean server hard disk access time.

T4 = Mean wait time by program file packets in server output buffer for hard disk access.

T5 = Mean delay on the line between transmission of program file packets from server out buffer and their arrival in the computer RAM.

T6 = Mean user floppy disk access time. [Ref. 2:450-451]

B. COST ANALYSIS

Dr. Schneidewind's study was conducted to measure average response times of a local area network, in processing simultaneous requests from the same word processing file, with up to fifteen users requesting the same file. The average response times decrease with the addition of servers to the network. The difference in average response times is a savings and can be used as a managerial performance factor when compared with the initial response time. The percentage increase in this managerial performance factor can be converted to a direct cost for the addition of the server and may be used in conjunction with the cost benefit analysis towards making a decision on the best economic configuration for the network.

Computer literacy classes, which include Word Perfect 5.0, are taught every other quarter, with a maximum of fifteen students attending eleven sessions, one hour a week for eleven weeks. Based on student average salary and benefits, a cost benefit analysis was be conducted to determine the pay back period for adding a server to the network. The average response time savings were converted to a monetary value and used as the return on investment.

The average response time model and the Ethernet system, as configured in building Ingersoll (I-250) are the basis for performing the cost benefit analysis in this research. Response time guidelines for user-computer interface in process control will be used as ergonomic constraints to control selection of the number of servers for the best configuration [Ref. 3]. Guidelines will be used in conjunction with the cost benefit analysis for determining the best configuration.

III. DETERMINING FEASIBLE RESPONSE TIME CONFIGURATION

A. COST BENEFIT ANALYSIS

Since an economic value can be imputed to savings in response time, the server response time savings can be determined and converted to a dollar value based on average salaries and related benefits.

For this research, the typical student of the IS0123, word processing classes, is a Lieutenant arriving from his/her first sea tour, which would place them in the officer, level three with over six years active duty, pay category. The estimating factors for additional benefits can be acquired from the Department of the Navy, Personal Statement of Military Compensation information sheet.

The dollar value of the server response time savings can be used as economic return amount for a net present value calculation of an investment value of one server (IBM AT with 30 megabyte hard disk drive). For standardization purposes, the equivalent server investment price was obtained from the Government Services Administration (GSA) Catalog.

To perform the Cost Benefit Analysis, four criterion will be used to evaluate the investment decision, (1) Net Present Value (NPV), (2) Payback Period, (3) Internal Rate of Return (IRR) and (4) Profitability Index (PI). [Ref. 4]

These criteria are used by many business firms to evaluate investment decisions.

B. RESPONSE TIME GUIDELINES

Most of the research analysis dealing with networks involves measurement of exact criteria for establishing performance standards. Standards are usually a series of generally stated requirements imposed in some formal way, such as by legislation, by contract or by management decree[Ref. 3:15]. When dealing in man-machine interface, standards are more difficult to establish because of the diversity of human behavior and the effect of response times on that behavior. A more practical approach to man-machine configuration control would be guidelines. Guidelines act as a general recommendations based on examples and analogies, and can be either accepted or rejected by the user[Ref. 3:15]. Therefore, for the purposes of this thesis, guidelines will be used to establish criteria for some measure of effectiveness in determining a feasible server to user configuration.

IV. METHODOLOGY

A. RESPONSE TIME ANALYSIS

Based on the model developed by Dr. Schneidewind the response time for the Ethernet (I-250) is the sum of six response times components, T1 through T6[Ref. 2]. Empirical data with responses being sent from one to ten users was collected to verify the model. Simultaneous requests for access to a server were sent and the response time for each user was measured with an accuracy to approximately 0.1 seconds to verify the analytical model.

The estimation of average response time will be based on Dr. Schneidewind's analytical model and calculations using the model will be rounded to the nearest tenth of a second which will correspond with the accuracy of the measurements used to support the model.

Data is obtained from computations or measurements from the analytical model [Ref. 2]:

T_1 = Negligible.

$T_2 = (N_{us} - 1)/2\ (T_3)$; N_{us} = # of user requests/server.

T_3 = 8.4 seconds; measured average.

$T_4 = (N_{us} - 1)/2\ (T_5)$

T_5 = 1.4 seconds; calculated from analytical model.

T_6 = 19.2 seconds; measured average.

Applying some algebra;

$T_2 = 4.2(N_{us}) - 4.2$

$T_4 = 0.7(N_{us}) - .7$

therefore $T_r = 4.9(N_{us}) + 4.9 + 19.2$

$= 4.9(N_{us} + 1) + 19.2$

For (S) servers, the average response time projections of the model will be written as:

$T_r = 4.9((N + S)/S) + 19.2$; N = number of users.

The savings in average response time, will be the difference in average response time (T_r), when adding 1, 2, or 3 servers to the network, under the condition of fifteen simultaneous requests.

B. COST BENEFIT ANALYSIS

The rate of return for the NPV calculation is based on the salary and benefits of the typical student attending the computer literacy class. Data provided by the instructor is indicated below:

- Number of students/session/week = 15 maximum
- Number of sessions/week = 11 maximum
- Number of quarters/year the course is taught = 2
- Number of weeks per quarter = 11

The number of requests to access Wordperfect each year is produced from the following calculations, where each of the fifteen students in each of the sessions generates a request for Wordperfect:

15 requests/session/week X 11 sessions/week X

11 weeks/quarter X 2 quarters/year = 3630 requests/year

The average paygrade of the student attending the course ranges from Lieutenants arriving from first sea tour to Commanders being assigned from Washington D.C. tours. The median paygrade of students, based on a single class is a married Lieutenant with six years service. For calculation purposes, this pay grade will be used as a baseline for the Cost Benefit analysis. The estimates from the Department of the Navy, Personal Statement of Military Compensation will be used to calculate the benefits other than basic pay and allowances. Calculations for monthly pay and allowances:

O3 over 6 years service (married):

- Basic Pay	$2643.30
- Basic allowance for subsistence	$ 129.00
- Basic allowance for quarters	$ 515.70
- Variable housing allowance	$ 355.09
Total	$3643.09

Additional benefits are assumed to be provided for members of the Armed Forces. Those benefits and estimated dollar value are calculated as follows:

Estimated Benefits

- Retirement (.07 X 2643.30)	$ 185.03
- Medical	$ 186.00
- Insurance (.024 X 2643.30)	$ 63.44
- Commissary (.11 X 2643.30 X .25)	$ 72.69
- Morale, Welfare and Recreation (.02 X 2643.30)	$ 52.87
- Counseling and Assistance	

(.0075 X 2643.30)	$ 19.80
- Leave (2643.30/12)	$ 220.28
- Retirement increases	$ 26.43
- Survivor Benefits	$ 39.65
Total	$ 866.19

Total monthly Pay and Benefits = $3643.09 + $866.29

= $4509.28 monthly

The savings achieved from adding servers will be designated in seconds, therefore the pay compensation must be of the same unit. The method use to breakdown monthly units to seconds is as follows:

4.3 weeks/month X 5 days/week X 8 hours/day

X 3600 seconds/hour = 619200 seconds/month

Benefit for each second saved therefore is:

($4509.28/month)/619200 seconds/month

= $.00728/second

This value times the savings in seconds for adding an additional server, multiplied by the total number of requests determines the return used in computing the Net Present Value, Internal Rate of Return, Payback, and Profitability Index for the Cost Benefit Analysis.

The Interactive Financial Planning System (IFPS) decision support software will be used to analyze the data derived from the average response time model [Ref. 4]. The results of the analysis are summarized and presented in Chapter V.

V. ANALYSIS

A. HYPOTHESIS

This chapter will seek the answer to three questions about the total network performance of the Ethernet located in Ingersoll 250. (1) What is the optimal number of servers for processing simultaneous requests to Word Perfect 5.0 software on the network? This primary question leads to two additional questions about what management factors need to be considered for determining the network configuration.

(2) What is the cost/benefit of decreasing the average response time?

(3) Are there ergonomic constraints on response time and what are the effects?

Question (1) can only be answered by evaluating the data and performing the research required in answering questions (2) and (3). The IFPS decision support software was used to calculate the data for use in question (2). Guidelines will be used to support the recommended maximum response time acceptable for human interaction when loading a program. The acceptable maximum response time will determine, in conjunction with the cost benefit analysis, the best server configuration.

B. ANALYSES

1. Response Time Performance

The projected data from the analysis model involves the number of users (simultaneous requests), the number of servers and the derived average response time for the Ethernet. Since the network in I-250 has twenty-five user-computers and has used a maximum of four servers, the model average response times were also projected out to twenty-five users with four servers. The average response times with varying number of users and servers are shown in Appendix B.

The addition of servers improves the network's average response time performance. The network's average response time performance is the decrease in average response time of the network for adding servers (the savings), as compared to the original average response time with only the one server, as defined by (19.2 + ((4.9*(N + S)/S)). The number of users transmitting simultaneous requests to the server was previously determined to be fifteen. Accordingly, the calculations for the average response time will use fifteen requests. Using the model, the savings gained for the addition of each server can be calculated. The calculated average response times along with corresponding savings are shown below:

-- One server response time = 4.9((15/1)+1) + 19.2

= 97.6 seconds

-- Two servers response time = 4.9((15/2)+1) + 19.2

= 60.9 seconds

-- Three servers response time = 4.9((15/3)+1) + 19.2

= 48.6 seconds

-- Four servers response time = 4.9((15/4)+1) + 19.2

= 42.5 seconds

Corresponding average response time savings:

-- (1-2) Servers = 36.7 seconds

-- (2-3) Servers = 12.3 seconds

-- (3-4) Servers = 6.1 seconds

Evaluating the data above, to decrease the average response time performance by 38% (36.7 seconds/97.6 seconds) would result in a cost of $1300 (GSA price for one comparable server), by 50% would cost $2600 and by 56% would cost $3900.

2. Cost Benefit Analysis

The response time data and savings obtained in response time performance calculations will also be used in the cost benefit analysis.

The time savings corresponding to the addition of each server will be converted to a monetary value and used as the rate of return for the cost benefit analysis. It should be noted that a discounted rate of return will be used in the cost benefit calculations based on the Net Present Value.

The rate of return for adding each server calculation is :

1-2 Servers = 3630 requests/year X 36.7 seconds/request

X $.00728/second = $969.85/year

2-3 Servers = 3630 requests/year X 12.3 seconds/request X \$.00728/second = \$325.04/year

3-4 Servers = 3630 requests/year X 6.1 seconds/request X \$.00728/second = \$161.20/year

1-3 Servers = 3630 requests/year X 49.0 seconds/request X \$.00728/second = \$1294.89/year

1-4 Servers = 3630 requests/year X 55.1 seconds/request X \$.00728/second = \$1456.09/year

This data is used to produce the analysis criteria, with the results displayed in Tables V-1 through V-1D.

The greatest return on investment based on profitability index and internal rate of return, is achieved with the addition of the first server. It provides the largest internal rate of return (0.69) at five years and pays back one year. The addition of two servers will pay back within two years, but the net present value at the five year mark is only \$69.23 more. Both the internal rate of return (.41) and profitability index (2.09) of adding two servers are lower than the corresponding values of adding the first server.

3. Human Interface

In man machine interface there is always one question that continually arises. What is the optimum response time for user requests? The trend these days is that faster is always better, optimize the system in relation its physical characteristics to perform at the fastest response speed possible.

	1	2	3	[illegible]	[illegible]
INVEST	1300	0	0	0	0
Return	969.84	969.84	969.84	969.84	969.84
Discount Rate	0.06	0.06	0.06	0.06	0.06
NPV (Cumul.)	-385.06	478.10	1292.39	2060.60	2785.32
Payback Amount	-330.16	639.68	1609.52	2579.36	3549.20
Discount Payback	0	1	1	1	1
IRR		0.31	0.54	0.64	0.69
Present Value	914.94	1778.10	2592.39	3360.60	4085.32
PI	0.70	1.36	1.99	2.58	3.14

Table V1. Cost-Benefit Calculations 1-->2 Servers

	1	2	3	[illegible]	[illegible]
INVEST	1300	2	2	0	0
Return	325.04	325.04	325.04	325.04	325.04
Discount Rate	0.06	0.06	0.06	0.06	0.06
NPV (Cumul.)	-993.36	-704.07	-431.16	-173.70	69.19
Payback Amount	-974.96	-649.92	-324.88	0.16	325.20
Discount Payback	0	0	0	0	1
IRR					0.08
Present Value	306.64	595.93	868.84	1126.30	1369.19
PI	0.24	0.46	0.66	0.87	1.05

Table V-1A. Cost-Benefit Calculations 2-->3 Servers

	1	2	3	4	5
INVEST	1300	0	0	0	0
Return	161.20	161.20	161.20	161.20	161.20
Discount Rate	0.06	0.06	0.06	0.06	0.06
NPV (Cumul.)	-1147.93	-1004.46	-869.11	-741.42	-620.97
Payback Amount	-1004.46	-977.60	-816.40	-655.20	-494.00
Discount Payback	0	0	0	0	0
IRR					-0.14
Present Value	152.08	295.54	430.89	558.58	679.03
PI	0.11	0.23	0.33	0.42	0.52

Table V-1B. Cost-Benefit Calculations 3-->4 Servers

	1	2	3	4	[illegible]
INVEST	2600	0	0	0	0
Return	1294.89	1294.89	1294.89	1294.89	1294.89
Discount Rate	0.06	0.06	0.06	0.06	0.06
NPV (Cumul.)	-1378.41	-225.96	861.26	1886.93	2854.55
Payback Amount	-1305.11	-10.22	1284.67	2579.56	3874.45
Discount Payback	0	0	1	1	1
IRR			0.23	0.34	0.41
Present Value	1221.59	2374.04	3461.26	4486.93	5454.55
PI	0.47	0.91	1.33	1.73	2.10

Table V-1C. Cost-Benefit Calculations 1-->3 Servers

	1	2	3	4	5
INVEST	3900	0	0	0	0
Return	1456.09	1456.09	1456.09	1456.09	1456.09
Discount Rate	0.06	0.06	0.06	0.06	0.06
NPV (Cumul.)	-2526.33	-1230.42	-7.85	1145.51	2233.58
Payback Amount	-2443.91	-987.82	468.27	1924.36	3380.45
Discount Payback	0	0	0	1	1
IRR			0.06	0.18	0.25
Present Value	1373.67	2669.59	3892.15	5045.51	6133.58
PI	0.35	0.68	1.00	1.29	1.57

Table V-1D. Cost-Benefit Calculations 1-->4 Servers

This portion of the thesis will try to derive some basic ideas on what are "useful" response times. Since each user's reaction to the system is different, there are certain factors which will determine user requirements for response time.

Two psychological requirements exist for the human to deal with the system response times, subjective expectancy and psychological closure.

When dealing with a machine, humans make certain preparations in dealing with the machine. This is known as subjective expectancy. If the time is too short, the average preparation will not be complete; if the time is too long, the average preparation may have been partly lost by the time the response signal arrives. The inability of hold state of the preparation period (i.e., maintain focus on the task) will increase the reaction time to an indicator, but with constant frequency warnings, reaction times improve. [Ref. 5] The magnitude of the response time doesn't impact user performance as much as variability of delays[Ref. 3]. This consistency of frequency concept in the presentation of response stimuli is such a strong response time characteristic that one author wrote:

> These conclusions are so strongly supported by the data presented that a general recommendation to system designers would have to be that increasing output display rates should not be attempted without corresponding increase in CPU power in order to guarantee consistency in the output display rate.[Ref. 6:418]

The reason for this need for consistency is the working/short-term memory. Rehearsal maintains information in the working memory. If rehearsal is stopped, information is lost, an event as known proactive inhibition [Ref. 7]. When the information is lost, humans have to interrupt the reaction process, search and reestablish the information in memory. This interruption effects the second factor regarding response time, psychological closure.

Psychological closure is the human ability to organize their mental activities into clumps and the need to terminate these activities by completion of a subjective purpose or subpurpose. An interruption in this completion can result in frustration with greater chances of forgetting or error. Any delay in communications between man and machine over two seconds changes the character of the thought process [Ref. 8]. With regards to man-machine initial response requests, the user becomes psychologically locked into communications with an increased capacity for annoyance with the system. The system should have the performance capacity to respond to user requests within fifteen seconds, though delays of one minute may be tolerated depending on how busy the person is. However, as a general rule, if the system cannot respond within fifteen seconds, it should be designed to free the user from physical and mental captivity to allow him/her to perform other activities and return at his convenience [Ref. 8]. As an important note, the fifteen second rule of thumb is further supported as a guideline, with an addition upper bound of sixty seconds[Ref. 3].

During these interruptions, the human will perform at a level which is the subjects basic ability to react to the response without preparation, defined as his/her implicit utility function. Depending on the confidence requirement, the implicit utility function will be the best response time the individual can accomplish while having to rescan short term memory. This is determined by the probability of correct responses in relation to response times to ambiguous stimuli [Ref. 9]. Since individuals have varying implicit utilities, general conclusions about the criteria and the quality of responses imply the following:

If the criteria for making high confidence responses is relaxed, the working memory will be rescanned, degrading the quality and speed of the reaction to the response. If the criteria is set stringently, fast, low error, high confidence reactions to responses can be accomplished. [Ref. 5]

All of the presented information supports the theory that consistency of data presentation is critical for fast, confident, highly accurate responses to any stimuli. Any interruptions create a degradation in performance caused by the phenomenon proactive inhibition.

VI. CONCLUSIONS

A. CONCLUSIONS

The focus of this thesis was to determine the most feasible configuration of the Ethernet network system located in Ingersoll 250, using the following criteria: 1) average response time, 2) rate of return and 3) human factor considerations.

To conduct a cost benefit analysis required first, to find the most favorable benefit-cost relationship with respect to the number of servers utilized. This was accomplished by finding the most efficient system configuration for processing simultaneous user requests for Wordperfect 5.0. The best configuration was realized with the addition of one server. This configuration improved network average response time by 38% under the condition of 15 simultaneous requests to the same program file. This was achieved at a cost of $1300 (See Table VI). Adding two servers improves average response time by 50%, but would cost $2600, while only providing a 12% increase in performance over the addition of the first server. Adding three servers, improves average response time by 56%, a net improvement of 18% over the increase achieved by adding one server and 6% over the performance improvement of adding two servers.

	(1) Server	(2) Server	(3) Server
Cost	$1300	$2600	$3900
Performance Increase	38%	50%	56%
Profitability Index	3.14	2.10	1.57
Payback Period	2 years	3 years	4 years
Internal Rate of Return (5 year life)	0.69	0.41	0.25
Net Present Value (5 years)	$2785.32	$2854.55	$2233.58
Average Response Time	60.7 sec	48.6 sec	42.5 sec

Table VI. Summary Evaluation Table

The best economic benefit is derived by using the savings from adding one server. The estimated rate of return using the life of the server (5 years) resulted in an internal rate of return of (0.69) with a profitability index of (3.14). This indicates the additional server will pay for its usage more than three times within its five year life. The corresponding values for adding two and three servers are indicated in Table VI. The results of the cost benefit analysis indicate the current usage and user pay rates do provide an economically feasible benefit for adding up to three servers to the system.

The final conclusion of this thesis involves the effects of response time on human performance.

Two factors of human performance were studied, subjective expectation and psychological closure. Both indicated a lower productivity rate if the display rate of the information was variable and if the decision instructions were ambiguous. Personnel work at their implicit utility function level under these conditions, continuously requiring them to rescan short term memory to reinforce the validity of their decisions. While information was presented at a continuous frequency, with stringent decision requirements, the rate at which information was presented did not affect performance as much as interruptions. Therefore, the delay in the initial request to the system is not as important for user performance as delays further along, when the user has developed a rhythm in synch with the system. However, the need for psychological closure does affect human performance and certain guidelines are generally recognized in dealing with response times. The guideline recommended for acceptable response time for loading and starting a program is a maximum of sixty seconds. This time could not be achieved using one server, but is possible with the two servers. (See Table VI)

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APPENDIX A

GLOSSARY

DIRECT COST: Cost that can be obviously and physically traced to a particular segment under consideration.

ETHERNET: Multi-access, packet switching communications system for carrying digital data among locally distributed computing systems.

GUIDELINE: Recommendations supported by examples, explanation and commentary.

IMPLICIT UTILITY FUNCTION: The optimal point of an individuals speed-accuracy tradeoff in reaction time when presented ambiguous instructions.

INTERNAL RATE OF RETURN: True interest yield promised by the investment over its useful life.

NET PRESENT VALUE: Expressing future receipts in present dollar terms so future receipts may be compared on an equivalent basis.

PAYBACK PERIOD: The length of time it takes for an investment to recoup its own initial cost out of cash receipts it generates.

PROACTIVE INHIBITION: Activity of trying to recall the most currently displayed items being hampered by exposure to previously displayed items.

PROFITABILITY INDEX: Ratio of present value of cash inflows to the investment required to achieve cash inflows.

PSYCHOLOGICAL CLOSURE: Psychological need in human communications which recognizes that humans organize activities into clumps that are terminated by completion of a subjective purpose.

SUBJECTIVE EXPECTANCY: Implication that human's tend to prepare for some average foreperiod prior to responding to a series of trials.

APPENDIX B

AVERAGE NETWORK RESPONSE TIMES

	User 1	User 2	User 3	User 4
Serv 1	29.00	33.90	38.80	43.70
Serv 2	29.00	29.00	31.45	33.90
Serv 3	29.00	29.00	29.00	30.63
Serv 4	29.00	29.00	29.00	29.00
	User 5	**User 6**	**User 7**	**User 8**
Serv 1	48.60	53.50	58.40	63.30
Serv 2	36.35	38.80	41.25	43.70
Serv 3	32.27	33.90	35.53	37.17
Serv 4	30.23	31.45	32.68	33.90
	User 9	**User 10**	**User 11**	**User 12**
Serv 1	68.29	73.10	78.00	82.90
Serv 2	46.15	48.60	51.05	53.50
Serv 3	38.80	40.43	42.07	43.70
Serv 4	35.13	36.35	37.58	38.80
	User 13	**User 14**	**User 15**	
Serv 1	87.80	92.70	97.60	
Serv 2	55.95	58.40	60.85	
Serv 3	45.33	46.97	48.60	
Serv 4	40.03	41.25	42.48	

APPENDIX C

IFPS SOFTWARE CALCULATION VERIFICATION

PRESENT VALUE (PV) = $F_n/(1+r)^n$;

where F_n = Future return on investment

r = Interest rate

n = End year of investment

NET PRESENT VALUE (NPV) = Sum (PV) Returns - Investment

PAYBACK AMOUNT = Sum Returns - Investment

DISCOUNTED PAYBACK = (NPV) Returns - Investment > 1

DISCOUNT FACTOR = Investment/Return

INTERNAL RATE OF RETURN = Verification of IFPS interest rate in formula Discount factor = $1/r(1-(1/(1/r)^n))$ [Ref. 10]

PROFITABILITY INDEX = Sum (PV) Returns/Investment

CALCULATION VERIFICATION: PV, NPV, DISCOUNT PAYBACK

Year 1 PV = $969.84/(1.06)^1 = 914.94$;

NPV = 914.94 - 1300 = -385.06; DISCOUNT PAYBACK < 1

Year 2 PV = $969.84/(1.06)^2 = 863.15$;

NPV = 1778.09 - 1300 = 478.09; DISCOUNT PAYBACK > 1

Year 3 PV = $969.84/(1.06)^3 = 814.29$;

NPV = 2592.38 - 1300 = 1292.38; DISCOUNT PAYBACK > 1

Year 4 PV = $969.84.(1.06)^4 = 768.20$;

NPV = 3360.58 - 1300 = 2060.58; DISCOUNT PAYBACK > 1

Year 5 PV = $969.84/(1.06)^5$ = 724.72;

NPV = 4085.30 - 1300 = 2785.30; DISCOUNT PAYBACK > 1

CALCULATION VERIFICATION: PAYBACK AMOUNT, IRR, PI

Year 1 PAYBACK AMOUNT = 969.84 - 1300 = -330.16;

IRR = 1300/0 = 0;

PI = 914.84/1300 = .70

Year 2 PAYBACK AMOUNT = 1939.68 - 1300 = 639.68;

DISCOUNT FACTOR = 1300/969.84 = 1.340;

IRR = .314; Verified = $1/.314(1-(1/(1+.314)^2))$
= 1.340;

PI = 1778.09/1300 = 1.368

Year 3 PAYBACK AMOUNT = 2909.52 - 1300 = 1609.52;

DISCOUNT FACTOR = 1300/969.84 = 1.340

IRR = .543; Verified = $1/.543(1-(1/(1+.543)^3))$
= 1.340;

PI = 2592.38/1300 = 1.99

Year 4 PAYBACK AMOUNT = 3879.36 - 1300 = 2579.36;

DISCOUNT FACTOR = 1300/969.68 = 1.340;

IRR = .644; Verified = $1/.644(1-1/(1/(1+.644)^4))$
= 1/340;

PI = 3360.58/1300 = 2.59

Year 5 PAYBACK AMOUNT = 4849.20 - 1300 = 3549.20;

DISCOUNT FACTOR = 1300/969.84 = 1.340;

IRR = .692; Verified = $1/.692(1-(1/(1+.692)^5))$
= 1.340;

PI = 4085.30/1300 = 3.14

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