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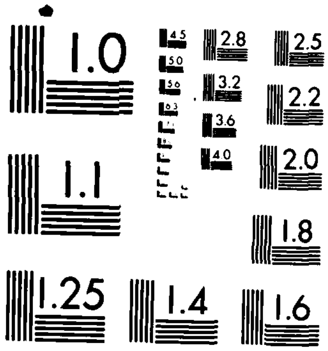

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THESIS

A PERFORMANCE EVALUATION MODEL
FOR THE STOCKPOINT LOGISTICS
INTEGRATED COMMUNICATION ENVIRONMENT
(SPLICE)

by

Jonathan B. Schmidt

September 1985

Thesis Advisor: N. F. Schneidewind

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This thesis investigates ways of improving the real-time performance of the Stockpoint Logistics Integrated Communication Environment (SPLICE). Performance evaluation through continuous monitoring activities and performance studies are the principle vehicles discussed. The method for implementing this performance evaluation process is the measurement of predefined performance indexes. Performance indexes for SPLICE are offered that would measure these areas. Existing SPLICE capability (Continued)

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ABSTRACT CONTINUED

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A Performance Evaluation Model for the Stockpoint Logistics Integrated Communication Environment (SPLICE)

by

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ABSTRACT

This thesis investigates ways of improving the real-time performance of the Stockpoint Logistics Integrated Communication Environment (SPLICE). Performance evaluation through continuous monitoring activities and performance studies are the principle vehicles discussed. The method for implementing this performance evaluation process is the measurement of predefined performance indexes. Performance indexes for SPLICE are offered that would measure these areas. Existing SPLICE capability to carry out performance evaluation is explored, and recommendations are made to enhance that capability.

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I. INTRODUCTION

Satisfactory performance is an objective that is often unstated in the day-to-day operation of a computer system. To gauge the fulfillment of this objective, operators must lay a foundation in the form of articulated standards, and then employ the proper tools to measure these standards against current performance. It is our intent to describe a qualitative model of a computer performance evaluation (CPE) system that will facilitate the efficient real-time operation of an information processing system composed of two or more host computers interconnected via a local area computer network. The model will be illustrated through application to the U.S. Navy's Stockpoint Logistics Integrated Communication Environment (SPLICE), a series of 62 computer systems currently being implemented service-wide to provide for interconnection of various elements of the Navy's logistics community.

Concepts of SPLICE network management were proposed in [Ref. 1] prior to selection of system hardware and software. It is the purpose of this research to further explore certain of those concepts that are pertinent to performance evaluation with the objective of proposing a conceptual model of a CPE organization that may be implemented to realize a high level of SPLICE system performance.

In this chapter the concept of local area network (LAN) management will be presented as a logical vehicle through which to implement such a performance evaluation effort. LAN management will be functionally decomposed and followed by a discussion of computer systems performance evaluation and monitoring. LAN management functions will be identified that are fulfilled by the evaluation and monitoring process. A brief description of a SPLICE LAN will follow.

Chapter Two will provide background information pertinent to SPLICE concepts and components. Chapter Three will discuss the process of measurement and how it fulfills performance evaluation. Chapter Four will see the development of a model of performance evaluation for implementation. In Chapter Five this model will be applied to a SPLICE LAN. Chapter Six will present a summary and recommendations.

A. ASSUMPTIONS

It is expected that the reader has a fundamental knowledge of information processing systems. Principal terms relating to performance evaluation and communications networks are defined in Appendix A.

This research will address the role of performance monitoring in up-and-running systems. There will be no discussion of the use of performance evaluation tools in the design phase of system development. Similarly, we will assume fully implemented SPLICE sites in this discussion, although at the time of this writing only partial capabilities have been realized at a handful of sites.

We will consider CPE methodologies appropriate to the characteristics of the SPLICE target system, e.g. technologies pertinent to multiprogrammed hosts servicing interactive users on a baseband, bus local area network. Existing UADPS-SP hosts, such as the Burroughs Medium Systems, will not be directly included in the performance evaluation discussion.

B. THE FUNCTIONS OF LAN MANAGEMENT

The management of a local area network is a multi-faceted endeavor that, in the opinion of Stallings [Ref. 2:p. 354]: ". . . encompasses those tasks, human and automated, that support the creation, operation, and evolution of a network." Stallings further specifies six functional areas that comprise network management: operations; administration; maintenance; configuration management; documentation/training; data base management; planning; and security. The following sections will briefly describe each functional area. [Ref. 2:p. 319]

1. Operations

Everyday operation of an LAN is overseen by operations management. Of particular concern in this area are the monitoring of network status and performance.

2. Administrative Management

Administration deals with day-to-day management concerns other than those on-line. Examples include assigning user passwords and billing users.

3. Maintenance Management

Network maintenance involves the process of detecting, isolating, and correcting problems. Both hardware and software degradations are included.

4. Configuration Management

This area describes network components, and controls the changes to components to maintain a coherent picture of the overall network structure.

5. Documentation/Training

The education of network personnel is accomplished through this management function. It includes the developing and maintaining of documentation.

6. Data Base Management

This area relates to the capability to develop and operate a data base for overall network management.

7. Planning Management

The planning function ensures proper sizing and capacity planning for the existing network throughout its life cycle. It necessitates an on-going requirements analysis effort to ensure network planners are aware of the system's needs.

8. Security Management

The security function ensures network integrity by denying access to all but authorized users.

C. COMPUTER PERFORMANCE EVALUATION OBJECTIVES

A conceptual foundation for the computer performance evaluation (CPE) of an information-processing system is provided by Ferrari. A system's performance may be objectively measured, calculated, or estimated by certain quantifiable indexes. These indexes may be given different weights by different people involved with the system, or even by the same person under different circumstances. Ferrari puts forth four objectives for performance evaluation: procurement; improvement; capacity planning; and design, all of which are discussed below. [Ref. 3:pp. 1-35]

1. Procurement

Evaluation for procurement reasons includes steps taken to choose the most suitable system from a range of alternatives. Examples include an installation's design, or hardware/software configuration.

2. Improvement

Performance evaluation is commonly performed for the purpose of improving the efficiency of an existing system. This objective will prove to be the focus of our research.

3. Capacity Planning

This category of evaluation involves sizing an information-processing system and its components to meet the needs of its users. It is a dynamic function that is necessary not only during system design but throughout the system's life-cycle as well.

4. Design

Problems faced by designers during the creation of a new system belong to this class.

D. CPE TECHNIQUES

Ferrari describes two techniques for defining performance indexes. These different methods, described in the following sections, are measurement and modelling.

1. Modelling

In a model, a representation of the computer system is constructed portraying system performance characteristics as accurately as possible. Modelling techniques are able to evaluate performance even though the target system may not be available or even in existence. Thus models are invaluable in certain situations, for instance during the design phase. At the same time, there may always be some level of doubt about modelling results until they are validated in reality.

2. Measurement

Empirical performance evaluations are made directly from the target system. The results of this monitoring must be taken from an existing, on-line system, although a test workload may be more convenient and efficient to evaluate than an actual workload. The advantages of measurement relative to modelling are increased accuracy and credibility. Measurement is a focus of this research.

E. SPLICE OVERVIEW

The U.S.Navy has developed the SPLICE concept to provide support to their suite of Uniform Automated Data Processing System for Stock Point (UADPS-SP) sites. SPLICE provides a minicomputer interfaced with existing UADPS-SP machines via a local area network for the purposes of absorbing the communications workload and providing services for interactive processing, front-end processing, Remote Job Entry (RJE), and terminal concentrator requirements. SPLICE will also provide a standardized telecommunications interface among the 62 logistics sites.

The standard SPLICE minicomputer is the Tandem NonStop TXP with between two and 16 central processing units, sized for the requirements of each individual site. The local area network selected for implementation is Network Systems Corporation's HYPERchannel, a baseband, CSMA-CD, co-axial medium with the capability of passing up to 50 megabits per second of data along each of two trunks. SPLICE sites will be interconnected through the Defense Data Network to realize vertical and horizontal integration among different elements of the Navy's logistics infrastructure.

Installation of SPLICE sites is underway in accordance with a schedule that calls for a phased implementation of SPLICE capabilities. A more thorough discussion of SPLICE concepts and design features may be found in [Ref. 4] and [Ref. 5].

F. RESEARCH FOCUS

In discussing system performance evaluation, it is helpful to distinguish between performance evaluation studies and continuous monitoring activities. Where the former is characterized by an effort of short time duration and is often performed as a result of specific problem symptoms, the latter may be carried out over a significant portion of a system's life cycle and is intended to identify problems as they arise. Both of these activities are of interest and will be addressed as viable methods of improving SPLICE network performance.

We have selected improvement of network efficiency as the CPE objective appropriate to this study. Since the environment in this research involves performance evaluation of a local area network, we consider it appropriate to frame the overall discussion in terms of the improvement in network performance that may be realized through the CPE technique of measurement of performance indexes. When the objective of improved performance is attained, it will fulfill certain LAN management functions.

Specifically, operations management may be carried out through the CPE processes discussed above [Ref. 2:p. 320]. Similarly, that portion of maintenance management involved with the detection of system failures may be carried out through performance monitoring. Planning activities also may be based on accumulated statistics gathered through performance evaluation. However, planning is accomplished best through the CPE objective of capacity planning and therefore will not be considered in this study. This research will explore ways in which operations management and that portion of maintenance management centering on detection of component failure may be fulfilled through the performance evaluation process.

II. SPLICE BACKGROUND

The purpose of this chapter is to establish the characteristics of the Stockpoint Logistics Integrated Communication Environment that are pertinent to the application of performance evaluation. The principal subsystems of the network will be described along with the hardware and software components that implement them.

Currently the computer hardware implemented in UADPS stock points is composed of Burroughs Medium Systems (B-3500/3700/4700/4800), various Perkin-Elmer suites, and terminal concentrator devices such as the B867, CP9400, and CP9500. Many of these systems are approaching obsolescence, and others are experiencing capacity problems. At the same time, many new applications are being developed which utilize interactive processing features that are awkwardly supported by these existing equipments.

SPLICE systems are being implemented to replace the present Burroughs-dependent communications processors and provide an on-line processing capability for UADPS-SP. There are three principal SPLICE objectives. One is to consolidate local and long-haul communications into a single integrated network, utilizing the Defense Data Network (DDN). Another is to relieve the currently saturated UADPS-SP processors by providing interactive transaction processing and distributed processing among SPLICE nodes. The third is to provide a measure of system integration through standardization of hardware [Ref.6].

The primary thrust of SPLICE, therefore, is to provide a base for communications support for the Navy logistics community. The processing power of SPLICE hardware also permits UADPS-SP applications to run on the Tandem systems, further relieving the tasking on existing Burroughs machines. One such application allows for replication of a number of UADPS-SP files onto SPLICE hardware. As the master Burroughs files are updated, the replicated files are also updated. Thus queries may be placed against the replicated files, reducing the traffic that must pass through to the Burroughs Medium System host. Another program is Transaction Ledger on Disk (TLOD) which maintains historical transaction data that allows researchers to reconcile inventory levels and improve inventory accuracy.

A. SPLICE SUBSYSTEMS

The brief overview of SPLICE from the first chapter set forth the computing areas in which the SPLICE concept would specifically lend support to the current UADPS-SP environment: telecommunications; interactive processing; front-end processing; remote job entry; and terminal concentrator requirements. This support will be implemented through a standardized SPLICE minicomputer, the Tandem NonStop TXP, interfaced with UADPS-SP processors via a local area network, NSC's HYPERchannel. Functional subsystems of SPLICE are described in the following sections [Ref. 4:pp.3-6 to 3-11]. These subsystems are executed through the SPLICE minicomputer, the Tandem NonStop TXP. It should be noted as these subsystems are reviewed that only a portion of SPLICE traffic will be seen by the local area network. For instance, queries against the activity's data base will be processed between a user terminal and replicated files accessed directly by the Tandem machine. Therefore it is necessary to measure indexes external to the local area network to ensure that SPLICE system performance is accurately portrayed.

1. <u>Terminal Management Subsystem (TM)</u>

The TM will support the requirements for terminal handling, security access, and user process selection. Terminals that are interfaced through TM include Burroughs TD-834/832 and MT 983, Teletype Data Speed 40/1 and 40/2, Zentec, Ramtec Omron 8030 B/8040 and Rantec 8025 AG, IBM 2780/3780/3270, and various others.

2. <u>Transaction Support Processing System (TSP)</u>

Transaction processing services that are supported by SPLICE are made available to users through this subsystem. The eight TPS components are:

-Exception Processing

-User ID Message Access

-Data Communication Network (DCN) Access

-Transaction Processing System (TPS) for stand-alone, interactive processing

-UADPS-SP Frame Manager

-Host Unique Pre-Processing for BMS and other host interface functions such as password validation

3. Site Management Susbsystem (SMS)

The SMS acts to provide access to the SPLICE system to CRT users, the console operator, and the System Administrator through the Tandem minicomputer command interpreter.

4. Internal Management Subsystem (IM)

This subsystem controls routing of files and data among the SPLICE system destinations: the Data Communication Network, the Local Computer Network, and system terminals. It also provides for monitoring of the system through a component called the Environment Manager.

5. Data Exchange Subsystem (DE)

DE controls the transfer of data set files entering and leaving the SPLICE system.

6. Site Data Communications Network Control Susbsystem

The Site DCN Control Subsystem exercises control over the SPLICE system's access to external networks. Tandem off-the-shelf software products EXPAND and TRANSFER provide this communications interface with satellite and other complex sites.

7. <u>Complex Local Computer Network Control Subsystem</u>

This subsystem is comprised of the elements that provide the physical and logical connection between the HYPERchannel local area network and the various hosts in the SPLICE system.

B. THE TANDEM NONSTOP TXP MINICOMPUTER

Computer systems manufactured by Tandem Computers, Inc. are characterized by a multiplicity of processors, controllers, data paths between system modules, and power supplies. There are at least two of each of these components in every Tandem system. Thus it is likely that some processing will be possible even in the presence of casualties. In normal usage, all resources may be employed by the workload. When a casualty occurs, the workload from the failed component is automatically assumed by another unit. Thus Tandem systems are often employed in environments where continuous availability is of great operational importance. The modularity of the Tandem architecture allows failed components to be repaired without the necessity of powering down the entire system. And it is relatively easy to add or remove components from the system as the workload is increased or reduced. The NonStop TXP system is Tandem's most sophisticated product, designed for heavy transaction processing applications in an on-line environment and incorporating additional performance features, such as cache memory, not shared by other Tandem models.

Automatic switching of components occurs when the primary, active data path is interrupted. The most complex illustration of this is at the CPU level. When an application is scheduled and run on a NonStop TXP system, it is assigned to a primary CPU and a secondary CPU. All CPUs communicate via Tandem's DYNABUS, a set of two high speed, bidirectional buses that provide for CPU interconnection. A process performs the application in the primary CPU and transmits periodic signals, termed "I'm alive" signals, to the secondary process in the alternate CPU via DYNABUS. Should the signal fail to arrive indicating a casualty to the primary CPU, the secondary CPU is ready to execute the application. Thus duplicity of components provides a stable, fault tolerant data processing environment that automatically adjusts for system casualties to maintain processing continuity.

C. HYPERCHANNEL LOCAL AREA NETWORK

The HYPERchannel LAN from Network Systems Corporation is capable of transmitting data at rates up to 50 megabits per second. It interfaces a relatively small number of devices over a distance of up to 5000 feet. These characteristics classify HYPERchannel as a very high speed local computer network [Ref. 7:p. 249]. (The alternative classification is the high speed local computer network which is slower, up to

10 megabits per second, but accommodates more devices over a longer distance). The HYPERchannel bus consists of up to four trunks of passive coaxial cable that can interconnect heterogeneous hosts via bus interface units known as HYPERchannel adapters. These adapters consist of three components: trunk interfaces, a microprocessor, and device interfaces. The device interfaces are unique for each interconnected host. Trunk interfaces and microprocessors are identical for all adapters. The functions of an adapter include trunk selection, trunk access, and adapter-to-adapter interface. The adapters support protocols for each function as described in the following sections. [Ref. 14]

1. Trunk Access Protocol

Adapters gain access to HYPERchannel based on a carrier sense multiple access (CSMA) scheme. An adapter with data to transmit will sense any activity on the bus and will defer transmission until the bus is silent. As soon as a bus transmission is completed, the following events occur in sequence:

a. Fixed Delay

There is a delay period following transmission in which the adapter that received the last message transmits a short response frame.

b. N Delay

After the initial fixed delay has elapsed, adapters waiting to transmit data are allowed to do so in a fixed, prioritized order. Each adapter is programmed according to its priority in the transmission sequence. Thus lower priority adapters must wait for a predetermined delay period to expire before they can transmit. The unique time delay for each adapter is known as the N delay.

c. End Delay

If an entire N delay interval elapses without a transmission, then an end delay period begins. During end delay, any adapter may transmit as long as the bus remains silent. If two adapters transmit nearly simultaneously, a collision may result. The mechanism for synchronizing adapters during this entire transmission cycle is a timer in each adapter. All timers are disabled and initialized during a transmission. When the bus is silent, timers are enabled and begin to count through the periods of fixed delay, N delay, and end delay.

2. Adapter-Adapter Protocol

Adapters exchange data through predefined bit quantities known as frames. There are three kinds of frames associated with HYPERchannel adapters. Transmission frames are short in length and function to exchange control signals between two adapters. Examples of control signals would include a frame indicating the end of a message, or a frame requesting that an adapter reserve itself pending imminent traffic from the sending adapter. A second frame type is the data frame. A data frame may be short (38 bytes) and contain a complete message, in which case it is termed a message proper frame. Or it could contain a block of data (up to 2k bytes). Both transmission and data frames are acknowledged by the receiving adapter by way of a response frame.

Viewed at the next higher level, frames may be grouped in sequences. A message-only sequence is comprised of transmission frames and a message proper frame together with appropriate response frames from the receiving adapter. Message-only sequences transmit short, complete messages. Message-with-data sequences are longer and include the lengthier block data frames for transmission of bulk data.

A virtual circuit between two adapters may be established through transmission frames. A sending adapter may request that a receiving adapter reserve itself pending a dedicated exchange of data between the two adapters. If the receiving adapter has not been otherwise reserved, i.e. it is idle, it transmits a response frame. The virtual circuit is thus established and data is transferred between the two adapters via one of the frame sequences discussed above.

3. Trunk Selection Protocol

A HYPERchannel adapter may be connected to up to four trunks, with identical components independently serving each trunk. A single trunk in the network may be dedicated to certain hosts by programming each host's adapter to either attempt to access or to refrain from accessing it. Hence each adapter is programmed to contend for certain trunks on the bus. When an adapter has a message to transmit it listens in turn to each trunk it is scheduled to contend for until it senses an idle trunk.

III. THE MEASUREMENT PROCESS

Various techniques have been identified through which the LAN management functions of operations and maintenance management may be carried out. In this chapter we will discuss these techniques, emphasizing how network management is enhanced. Then the discussion will become more specific with regard to how CPE techniques are implemented. We will discuss various network measurement tools and we will establish what kinds of information network managers need to conduct meaningful performance evaluation. Finally we will link these last two topics to determine what measurement tools are appropriate for a generic local area network.

A. IMPLEMENTING OPERATIONS MANAGEMENT

It is our opinion that the goal of LAN operations management is to enhance the performance of the information-processing system through an evaluation and monitoring effort that may be divided into areas of on-line preventive monitoring, system balancing and tuning, program tuning, and system validation.

1. On-line Preventive Monitoring

This function is composed of measures that, in the words of Kee [Ref 8:pp.124-6] ". . . ensure that the network performs properly." He advocates the monitoring of a local area network under normal conditions to establish typical traffic flows and loads. The purpose of this is to establish a reference frame from which to identify abnormal network conditions indicative of a fault or inefficiency. Additionally, knowledge of network behavior allows operators to identify cyclic states such as activity peaks and may facilitate operator actions to enhance network performance. We recommend that this function further include monitoring to ensure that a network's minimum required performance standards are being met.

Hence this activity emphasizes the prevention of performance degradation. By contrast, maintenance management is corrective by nature. It is concerned with restoring network casualties and returning network performance to full operability.

2. <u>System Tuning and Balancing</u>

A bottleneck in a computer system [Ref. 3:p.241] is ". . . a limitation of system performance due to the inadequacy of a hardware or software component or of the system's organization."

Ferrari [Ref 9:p. 350] considers a balanced system to be a system without bottlenecks. He defines tuning [Ref 9:p. 18] as ". . . the adjustment of a system's parameters to adapt it to the workload of an installation." One goal of a performance evaluation study is to improve a system's performance through identification and elimination of bottlenecks via tuning and balancing. In the context of a local area network, bottlenecks may occur in such components as host interface adapters, terminals, terminal concentrators, and workstations [Ref 8:p. 126]. A balancing action might be a reconfiguration of network resources such as reallocation of application programs among hosts in order to remove the bottleneck in a particular host interface adapter. A tuning action might be adjustment of a CSMA-CD network minimum packet size to reduce maximum network delay.

One new idea in the area of workload balancing may prove useful as a continuous monitoring technique. The concept of dynamic load balancing provides for connection of a user to the network host facility with the least traffic. An associated concept is the resource eligibility listing service which would respond to a user query by listing currently available network resources. These measures would act to improve a network's efficiency by steering computing activity away from heavily used resources toward more responsive ones. [Ref 10:p. 85]

3. Program Tuning

The process of optimizing a computer system's workload by optimizing individual programs and the mix of programs executed on a host is called program tuning [Ref 3:pp. 309-311]. This also is a technique employed as part of a performance evaluation study. It is a process complementary to but different from the system tuning described above.

a. Optimizing Individual Programs

This action has two objectives: to reduce required memory; and to reduce host CPU execution time. Depending on the bottlenecks in a particular system, one of these objectives might be more important than the other. The methods of program optimization are not pertinent to this research. It is, however, pertinent to note that program optimization is a valid avenue to explore in eliminating LAN host bottlenecks and improving overall performance.

b. Optimizing Program Mix

Performance evaluation studies frequently demonstrate that certain programs, termed critical programs, impact significantly on overall performance. The identification of critical programs is an early goal of any study since they are the object of both mix and program optimization. A critical program is characterized by frequent execution and by heavy resource demands. Action taken to optimize program mix in a local area network context would typically involve distributing applications among hosts to best balance composite network resources with application resource demands.

4. <u>System Validation</u>

One more function of CPE measurement is that of validating the design of the network [Ref. 11:p. 288]. Statistics accumulated over time that support network design parameters add credence to the validity of the initial plan.

B. IMPLEMENTING MAINTENANCE MANAGEMENT

As noted above, maintenance management is corrective in nature. It is the process of detecting a system casualty, isolating it, and correcting it to restore the system to full operability. It is helpful here to differentiate the portion of this function that is the concern of performance evaluation. Continuous monitoring techniques provide operators with the ability to detect, isolate, and report system problems [Ref. 12:p. 64]. However, network monitoring systems do not provide the ability to correct casualties [Ref. 13:p. 97a]. Correction is largely the domain of operators controlling the network from a centralized facility. Network control centers will be discussed in a later portion of this research.

Detection of casualties may be done through the same sort of on-line monitoring process described above. There is often a fine line separating degradation from failure in a component, blurring the distinction between the operations and maintenance management functions. However, the principle vehicle is the continuous monitoring activity. There is essentially no role for performance studies in this management function.

C. MEASUREMENT TOOLS

There are three principal tools employed in the measurement of performance parameters. These tools are accounting software, the software monitor, and the hardware monitor. [Ref. 11:pp.283-288]

1. Accounting Software

It is common for a computer system to include software for tracking usage of its resources by users among its capabilities. Typical measures would include CPU utilization, I/O accesses, memory required, and connect time per user. Since the purpose of accounting software is for billing the system's users, it frequently does not give the kind of detailed data required for performance evaluation.

2. Software Monitor

A software monitor is comprised of code embedded in an operating system to gather data. If it is event driven, data is collected only for certain predefined events. If sampling is employed, data is collected over time according to a sampling schedule. There are disadvantages to a software monitor. Since it is composed of executeable code, it adds overhead to the entire system and impacts on overall performance. Also, it is specifically designed and written for its target system, i.e. is not transportable.

3. Hardware Monitor

A hardware monitor is made up of digital circuitry that is attached to the target system at predetermined probe points. As the target system changes states, data is passed through the probes to accumulators within the monitor. Difficulties with hardware monitors include complexities in identifying the correct probe points in different computer systems, and the limitations to collectable information imposed by the finite number of probe points. On the other hand, a hardware monitor is a passive device that does not impact on system performance, yielding more accurate data. Leach discusses three types of hardware monitors applicable to communications networks [Ref 14:pp.48-49].

a. Individual Measurement Tools

These machines may be attached to a single device to monitor its usage. The information gathered from such a monitor will be too restricted to measure the performance of the entire network. However, it is a very effective tool to use in maintenance management. An individual monitor may be used to validate a trouble call on a device to determine whether a casualty has occurred.

b. Sub-Network Measurement Tool

This device allows the gathering of information from several communications lines at the same time, making it more representative of network performance.

c. Total Network Measurement Tool

Every line in a network is measured continuously.

D. MEASURABLE PARAMETERS

In this section we will identify performance indexes that are suitable for satisfying the CPE objective of improved performance. In the next section we will integrate performance indexes with the measurement tools just discussed to form a CPE vehicle for implementation in a SPLICE LAN.

The claim has been made that CPE is not a science but rather an art [Ref. 4:p. 5]. As we move closer to application of theory to fact this becomes more apparent. It is appropriate at this point in our research to select performance indexes that will best fulfill the objectives of measurement. There is a great variety of options and approaches to this question. We will present a number of different network performance philosophies to provide perspective on a complicated subject.

Ferrari discusses quantitative indexes in the context of information processing systems in general. He divides a system's performance into three measurable areas: productivity; responsiveness; and utilization. Indexes measuring these areas are detailed in Table 1. [Ref. 9:pp. 12-13]

Other approaches are specific to local area networks. Franta and Chlamtac set forth four measures of performance: channel utilization; channel capacity; expected message delay; and buffer occupancy [Ref. 15:pp. 169-170]. They point out that channel utilization and throughput are equivalent measures as long as the channel is not saturated.

Previous research into SPLICE network management illustrates other methods [Ref. 1:pp.55-56]. One method

TABLE 1

COMPUTER SYSTEM PERFORMANCE INDEXES

INDEX CLASS	INDEX
Productivity	Throughput rate Production rate Capacity (maximum throughput rate) Instruction execution rate Data-processing rate
Responsiveness	Response time Turnaround time Reaction time
Utilization	Hardware module (CPU, memory, I/O channel, I/O device) Operating system module

measured acquisition probability, wait time, and channel efficiency to gauge the performance of a contention network [Ref. 16:p.401]. Another measured communication capability via throughput, response time, and file transfer rate; and resource utilization of processor, buffer, and communication line [Ref. 17:p. 48].

Kee recommends monitoring three different areas: load; traffic information; and failures. We will discuss these areas briefly.

Awareness of a network's load allows operators wide freedom of action in fulfilling their management functions. Changes in a network's load may provide operators with the opportunity to take actions to meet approaching conditions before any service degradation occurs. Thus the preventive monitoring function of CPE may be greatly facilitated. System and program tuning require accurate load information to establish baseline references for their results. And the validation of network design depends on whether the medium is able to function under real load conditions as planned.

Useful information can be derived from traffic information, i.e. counts of messages among a network's various nodes. Traffic bound for or arriving from an external network is also of interest. Knowledge of error counts will assist operators in identifying failing or failed components. Message counts will also help them to tailor their actions to respond to real-time traffic flow. Performance studies will benefit through identification of possible bottleneck sources. Traffic counts will also serve to validate the network's original design.

Detection of failed components is a continuous monitoring activity essential to the fulfillment of maintenance management. Network operators must maintain a real-time status of every network resource to serve as a monitoring reference. Corrective on-line monitoring is the function served through failure detection.

Finally, Leach measures three areas through the Computer Management Systems Network Performance Monitor: determination of end user satisfaction; problem recognition; and capacity planning [Ref. 14:p. 48-49]. Categories constituting the first two areas along with specific indexes are detailed in Tables 2 and 3.

TABLE 2

COMPUTER MANAGEMENT SYSTEMS NETWORK
PERFORMANCE MONITOR USER SATISFACTION

CATEGORY	INDEX
Response Time	Poll/Poll Time Poll/Response Time CPU Wait Time CPU Message Time Terminal Message Time Response Time
Indicators of Failure	# Timeouts # NAKs # Sense Messages
Ratios of Failure/Inefficiency	# Timeouts/ # Polls # Frmr & Frames Retransmitted/# Messages # Sense Messages/ # Messages
Management Reports Summarized By	Terminal (Physical Address) Control Unit Line Location Program

TABLE 3

COMPUTER MANAGEMENT SYSTEMS NETWORK
PERFORMANCE MONITOR PROBLEM RECOGNITION

CATEGORY	INDEX
Counts of Error	# NAKS # Sense Messages # Timeouts
Ratios of Error	# Timeouts/ # Polls # NAKS/ # Messages # Sense Messages/# Messages
Measure of Service Level	Response Time CPU Wait Time Overhead Factor (%) Utilization Factor (%)
Management Reports Summarized by	Terminal (Physical Address) Control Unit Line Location Program

IV. MODEL DEVELOPMENT

We propose to bring performance evaluation techniques to bear on a local area network model in an effort to illustrate how overall network performance may be facilitated. Implementation will take place along the two central paths of CPE, continuous monitoring activities and performance studies. A personnel structure to best support both efforts will also be discussed. For our underlying network we will address the SPLICE configuration of a small (2-4) number of hosts (including a Tandem NonStop TXP) linked via HYPERchannel.

A. APPLICATION OF PERFORMANCE STUDIES

The concept of conducting performance studies through a site computer performance evaluation team is discussed by Morris and Roth [Ref. 18:pp. 19-50]. The following points are based on concepts from that source. The authors emphasize that their treatment is not academic but rather is based on unverified empirical experiences. It is offered here as a practical discussion of an important subject that has not seen much quantifiable research.

To begin with, there is the very real question of whether it is feasible for an activity to become involved with CPE studies at all. There are two primary reasons why organizations do. One reason is that computer system problems may mandate performance evaluation in an effort to find solutions. A computing activity confronting a substantial addition to its workload may employ CPE to find the best ways to stretch its existing resources. There are numerous valid reasons to cause an organization to look deeply into its own operation, and CPE provides a valid avenue for that introspection. A second reason is simply the expected return on investment. For instance, one industry guideline is that if a modest increase in computer system productivity of 2% to 5% is enough to save the cost of two to three technicians, CPE is probably a productive investment.

Once a decision has been made, by either of the above criteria, to employ a performance study methodology, its first efforts should be aimed at system resource hogs, i.e. those applications that account for the most resource usage. Another industry rule of thumb maintains that 10% of the applications running on an information processing system account for more than 50% of its resources. Although not scientific, this serves to assert a point that early CPE efforts should identify and target for improvement those objects that offer the most potential for improvement.

Goals should be modest at first. For instance, it may be feasible to set an objective of reducing resource usage of the two most active programs by 5%. Attainment of this objective will be of tangible benefit to the computer system and result in a learning experience for the CPE technicians involved in the effort. Moreover, others will become aware of the possibility of improving system inefficiencies and may well become sources for further improvement suggestions.

Another assertion by Morris and Roth is that the greatest impact of performance studies will be realized at the beginning of the CPE effort and that this impact will decline as continued attention results in improved performance. In determining the frequency of performance studies, a guideline of every six months is a recommended minimum. With all other factors constant (e.g. workload), as the computer system matures the frequency of measurement will decrease. A variety of unique circumstances suggest that performance studies would be appropriate. When new applications are installed, or when the mix or number of users changes significantly, system performance might be well served by a CPE effort.

Performance studies are often conducted most successfully at sites where a CPE team is formally constituted. One configuration that is frequently effective is a team composition of three members whose total combined annual effort in the CPE area is at least one man-year. Therefore performance studies do not become anyone's full time job, but are a serious collateral job for a number of people. Desirable backgrounds for CPE team members include systems and application programming experience and experience in equipment maintenance. These guidelines depend on variables such as the size of the investment in the computer system. The larger the value it represents, the more likely the benefit from frequent measures. The more stable the workload, the less frequent the required measurement.

B. APPLICATION OF CONTINUOUS MONITORING ACTIVITIES

Our opinion is that numerous valid approaches could be developed for structuring the monitoring of a SPLICE LAN. The author will adopt that of Leach [Ref. 14], principally because the areas of performance measurement he cites correspond closely to the LAN management areas that this research is intended to support. The capacity planning area meets the needs of the planning management function but, for reasons cited earlier, will not be addressed. The problem recognition area seen in Table 3 will provide measurements for the maintenance management function. And the user satisfaction indexes such as those in Table 2 are proposed to fulfill the operations management function.

It isn't possible to directly adopt every index due to differences in the characteristics of the SPLICE LAN and the target network in [Ref. 14]. Nor, in our view, is it desired. The model proposed below is intended to be as simple as possible, offering a small number of measurable indexes reflecting desirable information. More indexes could be incorporated to increase the information yield, at the discretion of the implementor.

1. Measurement of User Satisfaction

Response time is proposed as the primary index. Response time can be quantified various ways to offer more refined information, however mean response time is the basic index recommended. An indicator of failure, or reflection of user dissatisfaction, may be gained from counting NAKs over time. To add another perspective, a ratio of failure or inefficiency may be calculated by comparing the number of NAKs to the number of messages transmitted. It would be useful to compile these measures in reports summarized along the same lines as the system in Table 2:

-By terminal

-By control unit

-By communication line

-By location

-By program

Such categorization provides additional valuable information for analysts.

2. Measurement of Problem Recognition

The number of NAKs is proposed as the principal index of casualties. It may be seen that faulty adapters and many software problems will manifest themselves directly through unsuccessful attempts at communication, reflected in the control frame NAK. A different perspective may be gained by calculating the ratio of NAKs to total messages. And to reflect the level of service provided, response time may be used. It is noted that response time and NAK count are somewhat complimentary measures. A casualty in a host adapter may prevent that host from transmitting data on the HYPERchannel, yielding an aberrant response time. If the host had no traffic to send its casualty would be discovered when its adapter failed to properly receive and receipt for message sequences, yielding a large NAK count. The same report summaries seen in the user satisfaction measurement are recommended here as well.

3. Model Summary

The following indexes would require continuous measurement:

-Mean response time

-# NAKs

-# messages

An efficient method of monitoring response time is the sub-network measurement tool discussed previously, which will measure a number of different devices at once. The measurement of NAKs and messages suggest a software monitor, necessitating embedding code in the HYPERchannel operating system.

4. Establishing Performance Standards

One of the previously stated objectives of continuous monitoring is to provide network operators with a picture of normal network operation so that they can discern abnormal conditions. This allows them to take preventive action to avoid system degradations. It is logical to define a normal range of conditions in some manner that will permit operators to easily identify aberrant conditions. A set of performance standards, defined through observation of network behavior over time, would meet this need. Such a set of standards could be accumulated, defined, and modified on the local site level and in an informal manner.

C. NETWORK CONTROL CENTER

Closely wedded to the process of continuous monitoring is the concept of the Network Control Center (NCC). Its functions include continuous monitoring of the network, and also the capability of isolating faults and the capability to manually manipulate LAN configuration [Ref. 1:p. 321]. Thus we find full expression of the LAN maintenance function, as well as the operations management function. Rarely, though, does communication network technology allow complete implementation of all this functionality. If we define the suites of equipment intended to implement the NCC as network management systems we may discuss five separate varieties of such system [Ref. 13:p. 102a].

One category of network management system is comprised of host-based software. This software gathers status information about intelligent terminals and communications controllers through continuous on-line testing. Thus there is a running status that provides for notification of an operator should a component develop trouble or an error threshold be reached. This information is useful but usually is not a very thorough performance evaluation. And there is no capability for reconfiguration.

Network control systems are vendor supplied systems that monitor and exercise some control over a narrow range of network functions. Their purpose is to manage modems and multiplexers. They perform continuous monitoring of this equipment, they can run diagnostic tests and loopback tests to isolate casualties, and they can switch from a failed port on a modem or multiplexer to an active one. Their modest scope of action often limits their effectiveness.

Technical control systems are essentially systems of diagnostic equipment such as data monitors, datascopes, and VF test equipment. Their purpose is to troubleshoot faults on communications lines and circuits. They are expensive, have no monitoring capability, and provide only a line level view of performance.

Network monitoring systems are valuable continuous monitoring tools. They perform the essential operations management functions of measuring network performance and alerting operators to casualties. But they do not have the control capabilities to reconfigure and correct problems.

Digital and analog switching systems are matrix switches that permit prompt reconfiguration of lines and equipment. Some of these systems provide information about network configuration and some allow control of diagnostic and test equipment attached to the switch. However, none have performance measurement capabilities.

Some networks use combinations of the above systems to complement each others' capabilities in order to achieve full network control center functionality. A typical small-scale configuration for a bus topology LAN is comprised of a central activity which connects to the bus through an adapter and contains a keyboard, a microcomputer, and the personnel necessary to observe the network and exercise control. This would essentially combine a network monitoring system and a digital switching system to constitute an NCC.

V. APPLYING THE MODEL TO SPLICE

The purpose of this chapter is to compare the attributes of our performance evaluation model to existing SPLICE system capabilities to determine whether there are areas of significant difference. We propose to bring performance evaluation techniques to bear on a SPLICE local area network in an effort to improve overall network performance in support of the LAN management functions of operations and maintenance management. This discussion will be divided into the areas of continuous monitoring and performance studies.

A. CONTINUOUS MONITORING CAPABILITIES

1. XRAY

The principle monitoring tool at the disposal of SPLICE operators is a Tandem off-the-shelf performance software package called XRAY. Resident in the NonStop TXP, XRAY conforms to our definition of a host-based software system. The following description of XRAY is drawn from [Ref. 19].

XRAY runs on most Tandem systems, is fully integrated with the Tandem operating system and their off-the-shelf data base and communications programs, and can be operated from any asynchronous, point-to-point terminal. A large number of computer system components may be the subject of data gathering. In XRAY parlance, components are called "entities" and include physical devices, (such as CPUs, printers, tape drives, discs, communications lines, and terminals), processes, disc files, and other computer systems in the same network. XRAY is a sampling program which collects data at user specified intervals. Performance measurements are made through a four step process which involves:

-stating the measurement question

-selecting the entities to be measured

-making the measurement

-analyzing the data

A statement of the problem is prerequisite to all CPE efforts and is not unique to measurement via XRAY. It involves a clear articulation of the perceived problem and must be based on sound knowledge of the application being run on the system and the physical hardware configuration involved.

The next step is to decide what software and hardware components are to be measured. A configuration file is created, specifying the entities involved. Principal configuration options include:

-buffer activity

-physical devices

-files

-application programs

-host system or remote host

A configuration file can be created at any time, including during execution of a measurement. The new file is then immediately implemented. Within an application program, a code range may be specified to measure which sections of a target program are consuming the most CPU time. Along with the configuration file, a separate data file is created to serve as the collection point for measurements.

Measurements are made by executing the configuration and data files through a Tandem program called XRAYCOM. XRAYCOM also specifies the time interval of data sampling (one to 3600 seconds).

Analysis of the collected data is done by a program called XRAYSCAN. This program is run on the data file either after the measurement period or, if on-line monitoring is desired, during the measurement period. Analysis can be conducted on any entity by specifying it in XRAYSCAN. Information can be presented in any of three formats: reports; time plots; and histograms. A range of performance indexes is measured on each entity. For instance, the following items can be derived from the measurement of a terminal:

-response time

-terminal rate

-read rate

-write rate

-byte rate

-transmission rate

A complete list of measurable performance indexes may be found in [Ref. 19:p. 4-69].

A number of performance evaluation applications result from XRAY's measurement capabilities. XRAY is capable of:

-mix balancing

-capacity planning

-application tuning

-continuous monitoring

The capabilities of this software monitor make it a powerful tool in measuring the performance of the Tandem computer. Since it is resident in the SPLICE front-end processor it is able to measure parameters associated with all SPLICE subsystems.

This is of particular interest in the measurement of the Terminal Management Subsystem (TM). Since all terminals are interfaced through TM it is possible to monitor the response times at individual devices without the need for separate hardware monitors. The calculation of response time is slightly different because it is referenced from the CPU and not the device. However, since this difference is constant across all measurements it is a matter of definition and not substance.

2. <u>Network XRAY</u>

Also of interest is XRAY's ability to monitor the DDN gateway. Current SPLICE planning involves interconnection of the 62 separate SPLICE sites using the Defense Data Network as the wide area network medium. Interface to the DDN will be via Tandem's EXPAND and TRANSFER off-the-shelf software packages [Ref. 4:p. 4-28]. The use of Tandem software will permit monitoring of selected nodes from any Tandem host using Network XRAY. Specific capabilities include:

- -Measurement of packet traffic with every remote system and the measured system, with distinction between "local" packets and forwarded packets
- -Measurement of the total time to transmit a logical message to each remote system
- -Network communications line utilization
- -Number of bytes sent and bytes received in Level 2 protocol communication on the lines
- -Number of bytes sent and received in level 4 protocol communication, distinguishing between data bytes and control bytes
- -Number of messages sent which were smaller than 64, 128, 256, etc. bytes long, respectively
- -Measurement of file activity against files opened on a remote system, on a per-file-open basis, tied to the opening process
- -Measurement of disc file activity on the measured system which originated on the various remote systems, again on a per-file-open basis . [Ref. 19:p. 1-9]

3. NETEX

Monitoring of the HYPERchannel local area network may be implemented via the Network System Corporation's operating system, a program called NETwork EXecutive or NETEX. NETEX provides for the accumulation of network utilization statistics through its Network Administrator function [Ref. 5:p. 2-6]. There are no preprogrammed continuous monitoring modules in NETEX, although users are able to embed their own code to affect a software monitor [Ref. 20]. Moreover, although several commercially marketed hardware monitors are available for slower speed local area networks such as Xerox's Ethernet, none is available for high speed networks such as HYPERchannel.

4. Identifying Performance Standards

It might seem logical to look to the SPLICE benchmark, requirements for which are contained in [Ref. 21], as a source of usable performance measures. Unfortunately the benchmark was conducted using a synthetic test workload, i.e. a workload composed of a combination of real components and purposely constructed components. Although its on-line performance parameters are defined in terms of response time, consistent with our model, specific standards are not transferable to actual network traffic. We propose the accumulation of a CPE data base, as recommended in [Ref. 18:p. 45] to build a base for employable standards. Since the workloads vary significantly among SPLICE sites, this effort should be undertaken locally and used locally.

B. PERFORMANCE STUDY CAPABILITIES

It is unlikely that many SPLICE sites will realize the kind of savings through performance studies that would justify the dedicated effort described in the last chapter. This is not to say that no such effort is advisable. SPLICE systems are in the fledgling stages of implementation with a burgeoning workload of new, interactive applications that add up to a dynamic picture of performance and growth. Local sites may find themselves engaged in performance studies driven by unforseen performance problems. Even without the purchase of specialized CPE tools, local site personnel have some capability at their disposal through the continuous monitoring capability described above.

Another logical possibility would be to remove the regular execution of performance studies to an echelon higher than the local site. Fleet Maintenance Support Office (FMSO), the SPLICE project manager, already conducts some performance oriented work at individual sites. FMSO teams visit each SPLICE site prior to equipment installation, during equipment installation, and at intervals thereafter and in some instances conduct performance evaluations of SPLICE systems [Ref. 22]. It may be feasible to implement dedicated SPLICE performance study teams for the purpose of conducting ongoing evaluations of SPLICE sites. This would enable systematic tuning of hardware systems and software applications while enjoying the benefits of continuity and the experience gained across the full range of SPLICE sites. Whether this is advisable or not, it is certainly a capability at the Navy's disposal.

D. NETWORK CONTROL CENTER CAPABILITY

System specifications for SPLICE provide for exercising control of the local area network through a network administrator utility, allowing an operator to modify LAN node status, control access to resources, and display current sessions. This control is exercised through an operator console communicating through a host to a HYPERchannel adapter. Tables resident in the network adapters permit this control to be realized.

Control of the data communications network is implemented through Tandem software. The Network Monitor (NETMON) program allows logging network status changes, remote system processor status changes, and a display of network volumes.

It is possible to control the LAN and indeed the site by centrally locating the above functions together with a vehicle for monitoring terminal response times (XRAY or a subnetwork measurement tool/response time monitor).

VI. SUMMARY AND RECOMMENDATIONS

Improvement in the real-time performance of a SPLICE local area network can be realized through application of computer performance evaluation techniques to the network and associated hosts. The method for implementing this performance evaluation process is the measurement of predefined performance indexes. The principal measurement vehicles are continuous monitoring and the performance study, both of which are pertinent to improvement of real-time performance. Two principal management areas, operations and maintenance management, will benefit from this overall improvement in performance. Operations management may be realized through on-line monitoring and through the tuning and balancing of hardware systems and software applications. Maintenance management is principally fulfilled through on-line monitoring.

Performance indexes for SPLICE were offered that would measure these areas. We recommended realizing operations management functionality by gauging user satisfaction and proposed response time as one representative measure. The other proposed index was problem recognition. This would fulfill the maintenance management function and could be measured through a count of NAKs, a HYPERchannel subnetwork response frame indicating non-receipt of a transmitted data frame. Many other measures are possible and feasible and could be employed to render more detailed and complete information about system performance. Response time could be measured through a hardware monitor or through existing Tandem software. NAKs would be counted through a software monitor integrated with the NETEX operating system.

Performance studies are best conducted by dedicated teams. SPLICE sites might well be too small to justify the investment in manpower and resources necessary to conduct an ongoing performance study program. However, it might be practical at a higher level.

A network control center is the logical site for centralizing the performance evaluation functions discussed in this research. The network control center has other functions as well, principally involving control of the network and host resources. A SPLICE NCC could conceivably combine network control functions through NETEX, wide area network traffic control through NETMON, and terminal monitoring through XRAY.

We offer the following recommendations for future consideration:

-A formal performance evaluation effort may be of particular benefit to SPLICE sites due to the dynamic schedule of interactive applications forseen by network planners. Changing workloads and an expanded user base are conditions that could complicate planning estimates. Performance evaluation can be a valuable tool for validating system design.

-Act early to implement CPE. Don't wait until it's needed.

-The performance evaluation efforts currently conducted on existing UADPS-SP hosts might be integrated with the CPE program proposed here. It might help cost justify a local performance study team.

-Local SPLICE sites should consider implementing a Network Control Center to centralize the control and monitoring functions cited above.

-Local SPLICE sites should be encouraged to conduct continuous monitoring activities on their own initiative, to build a local CPE data base, and to formulate their own performance standards.

-Monitoring of wide area network traffic should be included as a function of the SPLICE NCC. But note that this capability depends on implementation of interconnection via Tandem software (EXPAND). If full DDN integration is anticipated, other means must be found to monitor the gateway.

-Fleet Material Support Office should consider formally constituting performance study teams to perform periodic system and software tuning at SPLICE sites. This means more than ensuring that a newly installed application runs. It would mean frequent balancing of total system resources to increase the value of the SPLICE dollar to the Navy.

-Dynamic Load Balancing and a Resource Eligibility Listing Service are low-effort methods of improving on-line system performance.

APPENDIX A

GLOSSARY OF PERFORMANCE EVALUATION TERMS

-ACK
A HYPERchannel communications subnetwork term referring to the response frame transmitted by a receiving adapter when a data frame has been received correctly.

-Availability
Ratio of the time during which the network is working to the time when it is not. [Ref. 8:p. 122]

-Baseband
The system whereby digitally encoded information is directly connected to the transmission medium without being modulated. [Ref. 23:p. 177]

-Bottleneck
A limitation of system performance due to the inadequacy of a hardware or software component or of the system's organization. [Ref. 3:p. 241]

-Bus
One or more conductors used for transmitting signals or power. In an LAN, a bus usually is in a broadcast transmission mode. [Ref. 23:p. 178]

-Capacity
The maximum theoretical value that the throughput of a system can reach. [Ref. 3:p. 12]

-Carrier Sense Multiple Access (CSMA)
A contention algorithm for a bus LAN whereby a station wishing to transmit determines first whether another transmission is in progress by sensing if a carrier is present. [Ref. 23:p. 179]

-Concentrator
A communications device that provides communications capability between many low speed, usually asynchronous channels and one or more high speed, usually synchronous channels. Generally, different speeds, codes, and protocols can be accommodated on the low speed side. [Ref. 23:p.182]

-Continuous Monitoring Activity
An activity performed for a substantial portion of the lifetime of an existing, running system. Its objective is to keep the system's performance under observation in order to detect performance problems as soon as they arise. [Ref. 9:pp. 9-10]

-Evaluation Study
An activity generally limited in time which is usually triggered by the identification of a performance problem or the suspicion of its presence. [Ref. 9:p. 10]

-Event
A change of state in some component of a system. [Ref. 3:p. 148]

-Expected Message Delay
The average delay experienced by a message following its arrival to a node until its successful transmission, assuming a homogeneous set of nodes, that is, with the arrival process of all nodes being governed by the same exponential distribution, and a single distribution governing the lengths of all messages. [Ref. 15:p. 169]

-Frame
In bit-oriented protocols, the vehicle for every command, each response, and all *information* that is transmitted. [Ref. 23:p. 189]

-Front-end computer
A communications computer associated with a host computer. It may perform line control, message handling, code conversion, error control, and applications functions such as control and operation of special purpose terminals. [Ref. 23:p. 190]

-Gateway
A node common to two or more networks through which data flows from network to network. The gateway may reformat the data as necessary and also may participate in error and flow control protocols. Used to connect LANs employing different protocols and to connect LANs to public data networks. [Ref. 23:p. 190]

-Input Load
The rate of data generated by the stations attached to the local network. [Ref. 2:p.236]

-Local Area Network (LAN)
A communications system whose dimensions typically are less than five kilometers. Transmissions within an LAN generally are digital, carrying data among stations at rates usually above one megabit per second. [Ref. 23:p. 193]

-LAN Management
The effort that encompasses those tasks, human and automated, that support the creation, operation, and evolution of a network. [Ref. 2:p. 354]

-Loopback Test
A test in which signals are looped from a test center through a data set or loopback switch and back to the test center for measurement. [Ref. 23:p. 194]

-Model
A representation of a system which consists of a certain amount of organized information about it and is built for the purpose of studying it. [Ref. 9:p. 19]

-Monitor
A mechanism for collecting information on a system's activity. [Ref. 3:p.149]

-Multiplexing
The support on a single physical link of two or more logical links. A device which performs this function is called a multiplexor. Unlike a concentrator, a multiplexor is not programmable. [Ref. 23:p. 195]

-NAK
A HYPERchannel communications subnetwork term referring to the response frame transmitted by a receiving adapter when a data frame has not been correctly received.

-Network delay
The time required for a message to be transmitted from a source and accepted at the designated sink. [Ref. 24:p. 45]

-Node
A point where one or more functional units interconnect data transmission lines. Distributed system nodes include information processors, network processors, terminal controllers, and terminals. [Ref. 23:p. 196]

-No Polls
Cessation of a polling routine indicating failure of a host, front-end processor, or modem.

-Offered Load
The total rate of data presented to the network for transmission. [Ref. 2:p.236]

-Packet
A group of binary digits, including data and call control signals, switched as a composite whole. The data, all control signals and possible error control information, are arranged in a specific format. [Ref. 23:p. 197]

-Performance Index
A descriptor which is used to represent a system's performance or some of its aspects. [Ref. 9:p. 11]

-Point-to-Point Connection
A connection established between only two data stations for data transmission. [Ref. 23:p. 198]

-Polling
Interrogation of devices to avoid contention, determine operation status or determine readiness to send or receive data. In data communications, the process of inviting data stations to transmit, one at a time. [Ref. 23:p. 198]

-Program Tuning
The process of optimizing a computer system's workload by optimizing individual programs and the mix of programs executed on a host. [Ref. 3:p. 309]

-Productivity
The volume of information processed by the system in the unit time. [Ref. 9:p. 13]

-Query
In interactive systems, an operation at a terminal that elicits a response from the system. [Ref. 23:p. 199]

-Reliability
The extent to which the network performs in the expected manner. [Ref. 8:p.122]

-Remote Job Entry (RJE)
Submission of jobs through an input unit that has access to a computer through a data link. [Ref. 23:p. 199]

-Responsiveness
(See Response Time)

-Response time
The time interval between the instant the inputting of a command to an interactive system terminates and the instant the corresponding reply begins to appear at the terminal. [Ref. 3:p. 11]

-Synthetic Test Workload
May consist either of a subset of the basic components of the real workload (a natural synthetic workload), or of a mixture of real workload components and purposely constructed components (a hybrid synthetic workload). [Ref. 3:p. 53]

-System Tuning
The adjustment of a system's parameters to adapt it to the work load of an installation. [Ref. 9:p. 18]

-Throughput
The amount of work performed by a system in a given amount of time. [Ref. 3:p. 11]

-Timeouts
Failure of a control unit or terminals, manifested as no response to a poll.

-Trace
A sequence of events in chronological order. [Ref. 9:p. 30]

-Utilization
The ratio between the time a specified part of the system is used (or used for some specified purposes) during a given interval of time and the duration of that interval. [Ref. 9:p. 13]

-Virtual Circuit
A communications path established by computerized switching. The virtual circuit exists only while it is carrying data. [Ref. 23:p. 205]

-Wide Area Network
A data communications network designed to serve an area of hundreds or thousands of miles. [Ref. 23:p. 205]

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