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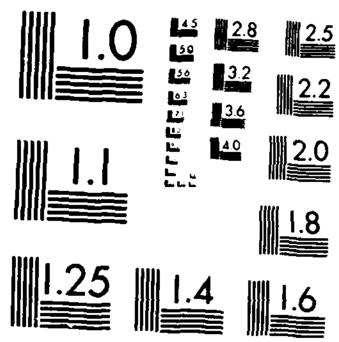

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Monterey, California

PROPOSED TECHNOLOGY AND PROCUREMENT

POLICY FOR SNAP III

by

Norman F. Schneidewind

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NAVAL POSTGRADUATE SCHOOL
Monterey, California

RADM. R. C. Austin
Superintendent

David A. Schrady
Provost

The research summarized herein was sponsored by Navy Sea Systems Command.

This report was prepared by:

Norman F. Schneidewind, Professor
Department of Administrative Sciences

Reviewed by:

Willis R. Greer, Jr., Chairman
Department of Administrative Sciences

Released by:

Kneale T. Marshall
Dean of Information and Policy Science

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The purpose of this report is to suggest ideas for the technology and procurement policy which would be appropriate for SNAP II in the next decade. Both technology and procurement policy are considered because it would be difficult to implement some of the technology proposed in this report withour a change in procurement policy.

The report describes the recommended architecture of SNAP III and the software acquisition and procurement policies to support the architecture.

Major recommendations are:

*Transition from minicomputer to microcomputer system,
*Transition to proven commercial office system,
*Use local area network technology,
*Acquire mass storage capability,
*Acquire improved graphics capability.
*Consider automating ship -- shore communication.
*Start to develop a procurement policy to support the acquisition of the above technology.

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1. INTRODUCTION

1.1 Purpose

The purpose of this report is to suggest ideas for the technology and procurement policy which would be appropriate for SNAP II in the next decade. To avoid confusion between current and future versions of SNAP II, the latter is referred to in this report as SNAP III. Both technology and procurement policy are considered because it would be difficult to implement some of the technology proposed in this report without a change in procurement policy.

The reader should note that although all of the technology described in this report is not available today, it will be available by 1992, the next milestone date for SNAP II equipment replacement.

Significant contributions to the ideas expressed in this report came from discussions with various participants in the SNAP II program, who are recognized in the Acknowledgements section.

1.2 Scope

Although the research sponsor's charter is SNAP II hardware, it is evident that software, including operating system and application packages, must be considered in order to develop a coherent procurement policy; SNAP III must be procured as an integrated system. A related concern is the method of acquiring the software -- whether to develop it in-house, or to buy it off-the-shelf.

The report describes the recommended architecture of SNAP III and the software acquisition and procurement policies to support the architecture. The report is divided into sections on technology, procurement policy, summary and an appendix on local area networks.

Although it is generally a good idea to have application requirements drive the specification of system architecture, requirements analysis is outside the scope of this study as specified by NAVSEA. In addition, a requirements analysis would require significantly more time and funding than is available for this study. Furthermore, we believe that a flexible architecture and procurement policy can be identified such that any foreseeable requirements can be accommodated through a strategy of modularization and incremental growth.

Finally, based on the charter for this research project as specified by NAVSEA, the project is limited to SNAP II and does not include SNAP 1.

2. TECHNOLOGY

2.1 Transition from Minicomputer to Microcomputer System

A great deal can be gained for SNAP II by making the transition from minicomputer to microcomputer technology. Among the advantages are the following:

* Most of the advances in chip technology, which provides the underpinning for advances in computer architecture, are taking place in the micro arena. Examples of available 32 bit processor chips are the Intel 80386 {5}, the Zilog Z80000 {19} and the Motorola MC68020 {15}.

Illustrative of the power of these chips are the following specifications from the 80386:

* 32 bit instructions, registers, addressing and busses
* 3 - 4 Mips
* 16 Mhz clock speed
* 4 gigabyte segment addressing
* virtual memory management
* cache memory
* memory protection
* pipelining

Furthermore, the Intel 80486,expected in 1987, will run at 4 - 5 MIPs {9}. In addition, 20 and 25 Mhz processor chips are expected this year {2}. However, in order for these advanced chips to be usable in SNAP III, a multitasking operating system must become available which will allow multiple virtual machines to execute programs in excess of 640K. Such an operating system is not expected until 1988 or 1989. In addition, application packages, such as DBMS, must be written by vendors to work with multitasking and extended memory {1}.

One projection of microcomputer performance, in terms of MIPs as defined as (MHZ / machine cycles per instruction / memory figure of merit) is the following {13}:

Year	MIPs	MHZ	Cycles/Instruc.	Equivalent MIPs
1987	10	16	1.3 average	Faster than VAX
1988	20	32	1.3	IBM 3090
1989	40	40	1.0	Scalar Cray
1990	80	80	.8	Faster than Cray X-MP

The implication for SNAP III is the availability of current super computer MIP rates (not storage capacity and I/O rate) in microcomputers in the 1990s.

An interesting development is the integration of functions, such as floppy disk, fixed disk and communications controllers onto the motherboard in personal computers, freeing slots which are currently used for these controllers. For example, Intel's 82072 floppy disk controller replaces 26 chips in the IBM PC controller and 34 chips in the IBM AT controller. In addition, the motherboard controllers use 5 to 10 times less power than the older chips. The portent for SNAP III is more space for I/O boards (e.g., graphics adapter) and memory expansion boards, or smaller size and lighter weight for a given number of functions.

Chip size reduction efforts continue in the semiconductor industry, led by the movement to CMOS integrated circuits. Most new 32 bit microprocessor chips, such as the Intel 80386, use CMOS because the power dissipation is low {7}. This means the chip can be small because a large area is not needed to dissipate heat generated by the large number of transistors in a 32 bit microprocessor. In addition to low power dissipation, some versions of CMOS are very fast. For example, Fairchild's Advanced CMOS Technology can be clocked at 33 MHZ in a 32 bit processor.

Aiding the continuing reduction in size is the development of surface mount components, including processors, printers, input devices and disk drives. Surface mount chips have one-third the size, 30 percent the weight and half the lead spacing of the traditional Dual In Line package {7}. Perhaps more important than size reduction is the savings in assembly costs made possible by surface mount techniques.

These reductions in chip size, power requirements and cost, coupled with increased speed, will result in SNAP III hardware having several times the processing power per dollar of SNAP II.

With regard to memory chip storage capacity, this year National Semiconductor introduced the first 1- megabit Dynamic RAM controller/driver chip which eliminates memory access CPU wait states and controls and drives up to 8 megabytes of memory with error correction {6}. LSI reduces both power dissipation and size by 75 percent compared to discrete DRAM controller designs. Intel also introduced a 512 Kbit, 170 ns EPROM. One implication of projected multi-megabit memory chips for the 1990s is that, for a given file size, bigger chunks of data can be processed in RAM at a time, thereby requiring fewer disk accesses and faster processing for SNAP III. Also, aided by a high speed cache memory, large RAMs provide the hardware foundation for a microcomputer-based SNAP III system.

* Off-the-shelf business software (e.g., dbms and word processing), which is applicable to SNAP II requirements, is readily available for microcomputers.

* Powerful workstations, suitable for storage and display of SNAP II technical data and drawings, emphasize microcomputer-based technology {16}.

A. Transition to and Capitalize on Available Packaged Software

The modern approach to implementing solutions to information systems problems is to develop generalized software packages which can be applied to various applications. For example, a DBMS can be applied to financial data, engineering data or SNAP II. A word processor has similar applicability. Commercial software has functions built in which allow the package to be applied to a variety of tasks; if this were not the case, there would not be the sales in the thousands of these packages. The reason for the generality is that there are basic data processing functions which are application independent. These are: search, update, insert, delete, select, retrieve, sort, merge, index, compute, display and print. It is often stated that Navy applications are unique. They cannot be truly unique because there are only a finite number and kind of data processing functions which can be performed by any application, as illustrated in the above list. What is `unique' is the particular combination and sequence of basic data processing functions which are used in an application. A package is tailored to an application by the appropriate selection of functions and parameters. The implications of this approach for the Navy are enormous. Rather than being a producer of COBOL programs, it becomes a manager of information resources, focusing its efforts on collecting, processing and disseminating data to meet fleet information requirements.

In addition to the organizational implications of using packaged software, there are significant economic and technical benefits as well. Software development costs are drastically reduced because it is not necessary to pay for the design, programming, debugging, testing and maintenance of a large number of application programs. Instead, the Navy pays the software vendor for the package (a site license may be required when many copies are required). This cost is significantly less than in-house software development, since the vendor's life cycle costs are absorbed by hundreds of customers, whereas in-house costs are absorbed by only one organization -- the Navy. Technical benefits -- with cost implications -- are realized from the fact that the vendor does the debugging and testing, not the Navy. Since the package will have been subjected not only to the vendor's tests, but also to the hard use by many customers as well, packaged software will, in general, have fewer bugs than software produced in-house. Furthermore, the cost of improving the reliability of packaged software, through bug reporting and correction, is spread over many organizations. Finally, by buying packaged software, the Navy would achieve operational capability with an application much sooner than with in-house development.

Since it is well known that the cost and effort involved in producing software far exceeds hardware costs, the above benefits would significantly reduce the risk to the Navy of implementing new systems.

A recommended procedure for SNAP III is to use a strategy of inventorying and assessing commercial software against system requirements, acquiring it where it satisfies requirements, and resort to in-house software only when it is evident that the packaged software will not meet requirements.

B. Establish Software Compatibility

Related to the approach of using microcomputers and packaged software in SNAP III is the idea of capitalizing on available software in the commercial marketplace by acquiring a system which has software compatibility with a large amount of personnel computer business software. SNAP II does not have this compatibility. Its hardware and operating system are used by relatively few organizations. The crucial aspect of having access to a large body of software is not the software library created by the hardware vendor; even a large vendor can only contribute a fraction of the total business software. Rather, huge software libraries are created by independent software vendors who write software for popular personnel computers. It is no criticism of the present vendor but rather a fact of life in the marketplace that software vendors have not and will not develop extensive libraries for this gear. At present, the only way the Navy can produce the software base for SNAP II is to use the expensive process of writing the software itself.

It is recommended that the Navy not be locked out of access to commercial software in SNAP III.

C. Establish Magnetic Media Compatibility

For SNAP III to be compatible with business software libraries, it must contain I/O devices which are compatible with popular software recording media, such as 5 1/4 and 3 1/2 inch diskettes. Relatively little software is available on the 8 inch diskettes used in SNAP II. The Navy should note that, although 5 1/4 inch diskettes are dominant today, 3 1/2 inch diskettes are forecast to be the predominant floppy disk medium by 1988 {12}.

It is recommended that the Navy provide for compatibility with commonly used software recording media in SNAP III.

2.2 Transition to Proven Commercial Office System

Although not identical to SNAP II applications, there is enough similarity with commercial system applications in maintenance, supply, finance, and administration, to warrant consideration of systems that have been used successfully in the office place. The advantage of this approach is that these systems have already been proven in thousands of corporations and with software and hardware which has been throughly tested and applied by the business community.

Given the nature of federal computer procurement policy, it is not clear how the record of a vendor in similar commercial applications could become a criterion for procurement, but it is important to note, nevertheless, that extensive experience in office systems and the ability to provide a full library of business software should weigh heavily in SNAP III procurement decisions.

A. Ruggedize Commercial Systems

Of course, commercial systems must be made seaworthy. An elegant solution to the problem of ruggedization has been suggested by personnel at NAVSEA. This involves ruggedizing computer furniture aboard ship, rather than ruggedizing the computers. The great advantage of this approach is that ship alterations are made only once -- when the furniture is installed; computers do not have to be ruggedized because they will be bolted to a table or enclosure which has been previously ruggedized.

B. Establish Flexibility of System Modification

A characteristic of microcomputers is that they allow the customer to tailor and expand the hardware according to application needs by means of adapter boards for memory and peripherals. This kind of system modularization is important for the SNAP III because it would allow configurations to be tailored to the workload and requirements of various ship classes. Thus, it would not be necessary for SNAP III to be locked into one hardware configuration for every ship and for the Navy to pay for capacity it does not need.

2.3 Use Local Area Network (LAN) Technology

A network of microcomputers has a number of advantages over standalone microcomputers and minicomputers, as described below. (See Appendix A for an overview of LANs). In addition to the advantages cited below, a LAN would also provide an effective shipboard electronic mail system.

Figure 1 shows a block diagram of the proposed SNAP III LAN.

A. Achieve Higher Reliability

Higher software and hardware reliability are achieved because a software or hardware failure in a node will only put that node and its application out of operation rather than cause the entire system to fail. If a failure in the cable or fiber occurs, the system can still survive in a standalone mode. It is easier to isolate and quarantine a malfunction than in a centralized system. Contrast these characteristics with the reliability properties of a centralized system, where a failure in the cpu or major attached peripheral will bring the entire system down.

B. Achieve Easier Expandibility

It is easier to expand a system and to tailor it to a particular applications and class of ship by adding user and server nodes as required. Modularity and expandibility can be achieved because equipment is not tied to a central cpu.

C. Achieve Sharing of Hardware and Software Resources

Hard disks, printers and modems (for communication in port) can be shared in a LAN rather than being installed in each workstation. Although the cost of providing these devices for every user node on one ship may be considered insignificant for one ship, it would be significant when all SNAP ships are considered.

D. Achieve Easier Software Implementation

Due to the modularity of a LAN, and the use of message exchange for communication between nodes, it is easier to design, partition and configure application software than with a centralized system. Also, since there is finer partitioning and more isolation of software modules by virtue of executing in separate nodes, the ripple effect of application software maintenance changes is less severe.

E. Maintain Compatibility with Existing System

Since the transition to a different form of technology, which is recommended in this report, should be performed incrementally and will require a period of parallel operations with existing applications and equipment, it is important to provide compatibility between SNAP II and SNAP III equipment. This would be accomplished by making the Harris equipment a node(s) on the LAN. To achieve this, adapter software would have to be written to make the Harris equipment compatible with the LAN protocols. Since there is a five year lead time to do this prior to procurement, there would be adequate time to create this software. Furthermore, even though the SNAP III vendor will not be known until 1992, the Navy could ensure compatibility by specifying one of the IEEE 802 standard protocols for the LAN. Figure 1 shows the Harris equipment as a node on the LAN.

F. Acquire a High Performance Local Area Network

There has been much discussion in the networks community about the relative merits of contention networks, such as CSMA/CD, versus networks with managed user access, such as token ring, (see Appendix A). In order to provide reasonable response time under the user input load and large file access activity imposed by some SNAP II applications (e.g., supply), it is recommended that a managed access type of LAN be acquired.

It is possible that the Navy will employ mixed networks with equipment from several vendors on SNAP III. We recommend against this approach because there are significant technical problems involved in getting a network from a single vendor running without creating more problems with a mix of equipment and software. The problems are more software-related than hardware related and involve the inability of some microcomputer application software vendors to make their software operate correctly in a network environment. This has been a problem with some single vendor networks and the problem is exacerbated when application packages must be integrated to work with several network operating systems. Another form of mixed network is one which contains more than one topology, such as a bus and ring. A third possibility is a combination of communications media, such as coax and optical fiber. The last two possibilities, confined to a single vendor system, incur much less risk than the first alternative. The three possibilities are discussed below.

Mixed Vendors

The way to resolve differences in protocols among vendors in a mixed vendor network is to use a gateway between the networks. The gateway is a dedicated computer which contains software to resolve differences in message and address format, message and address size, acknowledgement procedure, routing procedure, etc. between two networks which are interconnected by the gateway.

Mixed Topologies

Mixed topologies, such as the connection of a bus network to a ring network, usually implies a significant difference in protocols, independent of whether the same or different vendors are utilized. For example, most bus networks use contention (e.g., CSMA/CD); ring networks are determinisitic and normally employ a token for controlling access to the network. Due to the difference in protocols, a gateway is also required in this situation.

Mixed Communication Media

Some vendors provide networks which can use more than one communications medium. Usually this involves the use of optical fiber to extend the distance of a LAN beyond that which can be obtained by using coax or twisted-pair alone. The use of optical fiber, with optical fiber repeaters, to extend the distance of a IBM Token-Ring Network containing twisted-pair segments, is one example (10). In addition to providing greater distance, the repeaters serve to convert electrical signals to light signals and vice versa. Another example is the Codenol Corporation Ethernet to coaxial cable - optical fiber interface.

G. Use Optical Fiber as LAN Communications Medium

Although the dominant LAN communication media today are coaxial cable and twisted-pair wires, optical fiber will be the major medium in 1992. The reasons for this are its high bandwidth, immunity to noise and interference, and the capability of providing secure communication. Enhancing the stature of fiber optics is the Fiber Distributed Data Interface (FDDI), a proposed American National Standard for a 100 Mb/s token ring using a optical fiber medium and providing both packet and circuit switching protocols {20}. This effort will accelerate the trend to making the use of optical fiber commonplace in LANs in the next decade. Assuming potential problems of installing and maintaining fiber in a shipboard environment can be solved, optical fiber is the preferred communications medium for SNAP III.

To provide some idea of the problems involved in installing optical fiber, the following are the provisions for installing this medium in an **office environment**, as given by IBM {11}; obviously, the situation would be worse aboard ship.

- o A lubricant must be used when pulling fiber through conduit.
- o Maximum pull force must not be exceeded when installing the fiber.
- o Large radius 90 degree bends (minimum of 6 inches) must be used in conduit runs.
- o No more than two 90 degree bends can be used between pull boxes. Pull boxes should be placed close to the 90 degree bends.
- o Tubing or conduit must be used to protect the fiber in places where it might be damaged.

We recommend that optical fiber cable not be spliced; rather, pull boxes should be used between conduit runs. We also recommend that the cable not be repaired aboard ship; instead, a damaged cable should be replaced with a new cable segment.

It appears unlikely that there will be any relief from the above precautions for installing and maintaining optical fiber in the near future. However, this should not be a major deterrent to its use in SNAP III, given the superior performance properties of this medium. Optical fiber can be used successfully if precautions, such as the above, are observed and if programs are established to train shipboard personnel in the proper handling of optical fiber.

H. Disadvantages of LANs

Of course, there are disadvantages associated with using a LAN. One is the extra layer of software called the network operating system. Among other functions, this software directs user commands to the appropriate server node and handles message communication between nodes. This operating system is in addition to the common microcomputer operating system residing in each node which is used to provide normal intra node services (e.g., node directory display). The additional operating system software complexity requires some new skills to be learned by Navy system implementors, users and maintainers. Furthermore, this network software must be included in software configuration management and maintenance activities.

Another problem is the weak vendor support provided for these systems,as compared to mainframe and mini system support. This problem can be alleviated by negotiating a contract with the vendor or system integrator which provides adequate user training, and software and hardware maintenance.

2.4 Acquire Mass Storage Capability

Optical disk drive technology is maturing rapidly and promises to provide much greater recording density for SNAP III than is the case for SNAP II, with densities ten times that of today's magnetic disks {14}. These disks, with capacities of 100 to 1000 megabytes and image storage capability, are today write once-read mostly media {14,17}, suitable for SNAP III archival storage of technical manuals, ship drawings and ship configuration technical data. Unfortunately, no popular microcomputer operating system supports write once disk drives at this time {4}; it is expected that this will not be the case in 1992. Writable optical disk drives, in 5 1/4 inch format, are expected to be available by 1988 {14}.

It should be noted that formidable problems of directory management and file update, which result from write once limitations, have not been completely solved {17}. Also, as with any on-line storage system, the user must develop a backup system. For optical systems, with their massive storage capability, providing backup capability is a significant challenge for the user. Since the media is inexpensive, one solution is to write a duplicate on separate optical disk surfaces. However, if the disk controller fails, the duplicate is of no use. For this reason, dual optical disk controllers (network servers) would be used.

No microcomputer can store the gigabyte files that comprise parts of SNAP II, using current magnetic disk technology; also, it is not economically feasible to equip every microcomputer in SNAP III with a mass storage system, such as optical disk. Therefore, an optical disk system is shown as one of the server nodes on the LAN in Figure 1, which would be accessible to user nodes for such operations as downloading and uploading files or file segments which require reading or updating.

2.5 Acquire Improved Graphics Capabilities

Microcomputers, provided with appropriate software, can give the user full screen edit capabilities as opposed to the line-at-time data manipulation capability of ordinary terminals. Also, some microcomputer displays and their software are designed to be icon driven. The use of symbols, controlled by a mouse or light pen, to issue commands such as file or delete, would seem to provide the sailor-user with a system which is easier to learn and use than a keyboard driven display. Also, the error rate of such a system should be substantially less.

In addition to improved graphics, SNAP III has need for work stations with bar code reading capability.

SNAP III has requirements for technical data and drawings storage and display. Since this type of display would require an interactive graphics workstation, is relatively expensive, and is not required for every SNAP III user station, only one or two of these units need be provided, as shown in Figure 1.

Although none of the display technologies which are in the R & D stage satisfy all desirable performance and cost criteria, the active matrix liquid crystal display (LCD) is the furthest developed with respect to satisfying multiple criteria of: light weight, low power consumption, good graphics resolution, high speed display, color support and reasonable cost. Although lack of 'viewability' remains a major drawback, this technology is improving in resolution for reading the display under various lighting conditions and from various viewing angles. A major problem to be overcome is the inability to support screen sizes larger than those for portable computers {8}. Another promising LCD technology is super-twisted bifringent, offering the sharpest LCD image to date; this technology is used in the Zenith Z-181 lap top.

DC plasma and AC thin film electroluminescence displays offer better contrast ratios and larger screens than LCD but at higher power, slower speed, higher cost and less support for color {8}.

The flat tension mask (FTM) tube used by Zenith is claimed to be a dramatic improvement over conventional CRT displays {18}. This display is claimed to have a flat, virtually reflection-free faceplate and offers superior resolution, contrast (70 % higher than standard displays) , brightness (80 % over standard displays), and color properties, in a retail price range of $1000 - $1500.

Another important development in graphics is the Intel 82786 graphics coprocessor and the Texas Instruments 34010 Graphics System Processor {3}. These processors relieve the CPU of much of the graphics processing load similar to the way a math coprocessor relieves the CPU from floating point computations. In addition to relieving the CPU of graphics work, the coprocessor contains programs for activating complete drawing routines and provides a large video memory (4 MB), which would permit a 256 color image with 1024 X 1024 pixel resolution.

It is impossible to obtain high resolution at low cost. It is possible to obtain high resolution and other desirable display properties at reasonable cost. Display technology like FTM coupled with a graphics coprocessor would appear to be adequate for SNAP III graphics applications which can be foreseen at this time.

2.6 Consider Automating Ship -- Shore Communication

It is evident that supply, maintenance, ship configuration, and other SNAP II data could be more timely if ship to shore and shore to ship data transfer could be automated via the Defense Data Network (DDN). There are protocols in DDN that allow the user to: (1) connect with remote nodes (e.g., Inventory Control Point and Stock Points) for inquiry purposes, (2) perform file transfer, and (3) communicate very effectively via electronic mail. A LAN could provide data input directly for keying the transmitter for ship to shore communication, (as shown in Figure 1) rather than employing paper tape for this purpose.

There is great reluctance in some parts of the Navy to routinely communicate (or to communicate at any time) logistics data, due to: (1)requirements to maintain emission control during combat or exercises or (2) the need to use available circuits for tactical data transmission. This is a policy question that can only be decided at the highest levels of the Navy and is beyond the scope and capabilities of this project to solve. We can only note that it appears that it would be feasible to transmit SNAP II data during non-critical time periods. We understand that communication via the DDN will be possible when SNAP II ships are in port.

Lest it be construed that automating ship -- shore communication is the solution to all the problems of data timeliness, it should also be noted that lack of timeliness of data base maintenance on shore (e.g., ship configuration), is also part of the problem.

It is recommended that there be clarification of policy on ship to shore communication for SNAP II so that this policy can be used to establish the technical possibilities for automating ship -- shore communication in SNAP III.

3. PROCUREMENT POLICY

Since the emphasis of this study is technology, only a brief summary can be given of a the elements of a procurement policy which will support the acquisition of the above technology for SNAP III. The key parts of this strategy are:

* The procurement process should start now to provide sufficient lead time to actually acquire SNAP III in 1992.

* Proven commercial hardware and software should be acquired.

* The contract should be long term (minimum of 8 years) with options for the Navy to periodically upgrade the system.

* The contract should be modelled on the Inventory Control Point resolicitation project.

* Software as well as hardware should be included in the acquisition.

* A system integrator should be used, who would, with the approval of the Navy, upgrade the system.; the Navy would have strong veto power to prevent unqualified, low bidder vendors from winning the subcontract.

4. SUMMARY

Major recommendations are summarized below:

* Transition from minicomputer to microcomputer system

* Transition to proven commercial office system

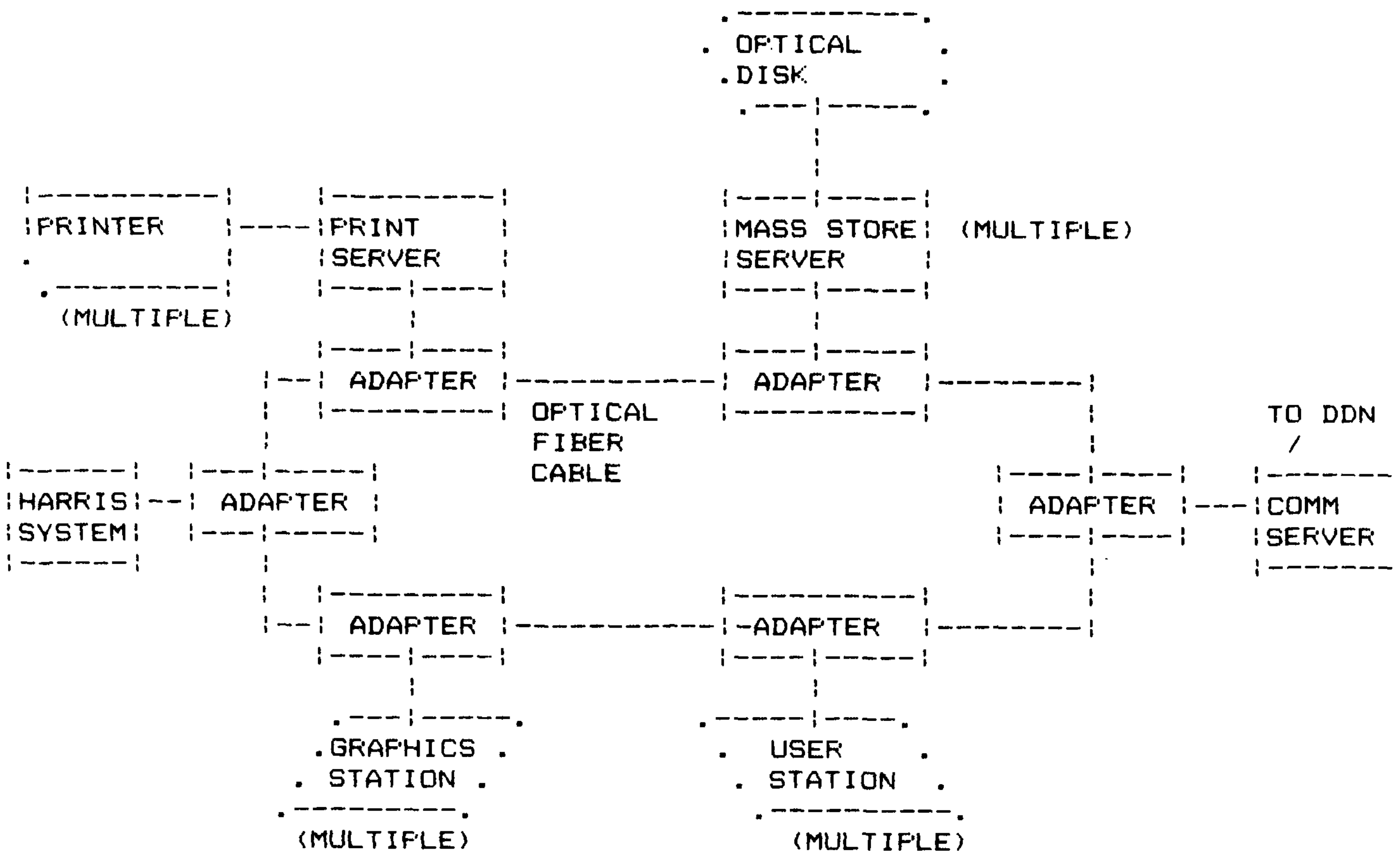
* Use local area network technology

* Acquire mass storage capability

* Acquire improved graphics capability

* Consider automating ship -- shore communication

* Start to develop a procurement policy to support the acquisition of the above technology.



SERVERS AND STATIONS ARE MICRO COMPUTERS

FIGURE 1 ... PROPOSED SNAP III LOCAL AREA NETWORK

5. APPENDIX A

Principles of Local Area Networks {21}

INTRODUCTION

Definition

A local area network (LAN) consists of a set of nodes which are interconnected by a set of links. The nodes and links cover a relatively small geographic area, ranging from a few feet to a mile. The nodes may be terminals,microcomputers, minicomputers, mainframes, printers, hard disks or work stations. The links may be coaxial cable, twisted-pair wires or fiber optic cable.

PURPOSE

There are many reasons for developing and using LANs, including the following:

1. Message communication.
2. Resource sharing.
3. Improved office worker productivity.
4. File transfer.
5. Application performance improvement.
6. Combinations of the above.

Each of these reasons is elaborated below.

1. With a LAN it is possible to provide an electronic mail capability because the nodes are connected, thus allowing for the transfer of a message from one node to another.

2. As microcomputers continue to proliferate, it becomes increasingly expensive for management to provide every worker with his own fully equipped machine, including disks, printers, modems and software. A more economical alternative is to provide only a minimal work station capability for hundreds of workers and to provide fewer expensive devices which can be shared by many users. In some cases, certain users have repositories of software and files which many users wish to access. Accessibility is improved significantly if users can access these resources electronically by file transfer from a server node (e.g., a relatively expensive microcomputer which contains a hard disk and printer) to their work stations or by using the server as a remote computer.

3. Lagging productivity of office workers and professional people is of great concern to American industry. One of the first steps which was taken to alleviate this problem was the widespread use of personal computers in the office. This movement represented only a limited attack on the problem. Although each worker had access to his own data, two important ingredients were missing: ability to communicate electronically with other workers and access to corporate data. Without going through an expensive mainframe, data accessibility was not available laterally from worker to worker nor vertically from worker to management and vice versa. If there is one aspect which characterizes the modern work force it is multi channel communication. A LAN facilitates this communication through its inter-nodal message paths and, when equipped with the necessary hardware and software, provides communication with corporate mainframe computers.

4. A frequent need of computer users is to transfer a file which is stored on one local computer to another local computer. The file may consist of a program, data or both. There can be many reasons for doing a file transfer, including the following:

* The program or data is needed at a particular local computer in order to execute a program.

* The file may reside on a server node and the user wants to transfer it to his work station. Typically, the copy at the server node is read-only so that important information cannot be altered by unauthorized users; the system manager controls access and updating action. However, a user can transfer a copy to his work station where he can both read and write the data and treat his copy as a private file.

* The user receives a request to transfer a file to another user.

5. If a user has access to more and better software packages and hardware via a network, he ought to able to improve the functional performance of his applications. This is the motivation for much of today's networking. The advantage of greater accessibility to resources must be weighed against the following possible disadvantages: slower response time caused by the use of communication facilities; increased complexity of operations engendered by being a member of a LAN; and temporary lock out from file access to server nodes caused by concurrent multiple user activity.

6. Seldom is a LAN built for a single application (e.g., electronic mail). Since LANs are built from general purpose computers, it is possible to provide for a variety of applications in a single LAN. Thus a user can integrate his applications of, perhaps, data base management, electronic mail and word processing.

LAN ARCHITECTURES

There are three characteristics which differentiate LAN architectures: control, topology, and communication technology; they are not mutually exclusive.

Control

Control refers primarily to techniques used for allowing access to the communications medium and resolving contention. There are three major control techniques: carrier sense, multiple access with collision detection (CSMA/CD); token passing; and centralized switching.

In CSMA/CD systems, nodes are connected to a bus and have multiple, or concurrent, access to the communication medium (e.g., coaxial cable). Nodes 'listen' for existing transmissions to determine whether it is safe to transmit; hence, the terminology 'carrier sense' or sensing the carrier. Unfortunately, this terminology is a misnomer in those LANS which do not use modulated transmission. If no transmission is detected, a node will transmit. Due to signal propagation delay, a node can not be certain that no other node is transmitting. Therefore, overlapping transmissions, or collisions, can occur. The heavier the traffic, the more likely it is that collisions will occur. As t he name of the technique implies, nodes are designed to detect a collision. When a node detects a collision, it transmits a jam signal so that all transmitting nodes can recognize it and abort their transmission. Affected nodes probalistically reschedule their next attempt to transmit. This technique is inexpensive and has good performance at low to medium loads; performance is significantly degraded at high loads. Due to repeated collisions, a node may be delayed in transmitting for an indefinite amount of time (if collisions persist beyond a system-specified limit, an error is reported). Thus there is no upper limit on response time and performance must be described probalistically.

Token passing is a control technique which guarantees an upper limit on response time (i.e. deterministic performance) but is more complex and expensive than CSMA/CD. This technique is used on rings and busses and uses a control message called the token for granting permission to a node to transmit. In a ring LAN, for example, the token is rotated in the ring until a node that has data to transmit captures it. Since the node which acquire the token must release it after transmitting and the token returns to the transmitting node, every node is guaranteed to have access to the communication medium within a calculable time. Generally, this method has poorer performance than CSMA/CD at light loads (more overhead) and better performance at high loads (no collisions).

Centralized switching is used primarily in private automatic branch exchange (PABX) systems, which were first used for voice communication, and currently are challenging other types of LANs for market supremacy by emphasizing the integration of voice and data in one network. This technique is used in star configurations where all data is sent from the origin, through a switch, and out to the destination. Its performance is usually worse than the first two techniques but has the significant advantage of capitalizing on the fact that every American firm and agency has telephones and many of them have switching equipment, so it is a natural extension of this technology to use it for data communication.

Topology

Topology refers to the way that nodes are connected. There are three major arrangements: bus, ring and star. It was stated previously that LAN characteristics are not mutually exclusive. This is demonstrated as follows:

(1) When nodes are connected to a bus, they can all access the bus simultaneously; therefore, there must be an arbitration technique like CSMA/CD to referee access. An alternative is to use token passing on a bus; there is such a network which creates a logical ring by using a physical bus.

(2) When nodes are connected in a ring, there is the opportunity to regulate their access to the communication medium by circulating a token in the ring which must be captured by a node in order for it to acquire the right to transmit.

(3) The star topology is natural for centralized switching because every node is connected to the hub of the network; this central node performs switching and routing.

Communication Technology

There are two major technologies: baseband and broadband. Baseband is unmodulated transmission;it transmits at the original frequency of the digital data. It is used with CSMA/CD coaxial cable or twisted- pair wire bus topologies, or with token passing coaxial cable or fiber optic cable ring topologies. A fiber optic bus is also a possibility, but it is more natural to use it on a ring, since fiber optic transmission is unidirectional. Since transmission on a bus spreads in both directions simultaneously from the source, it is difficult to control multiple reflections in a bus-type fiber optic cable. Since baseband is unmodulated transmission and does not transmit in different frequency bands, it is usually limited to a single service (e.g., data).

Broadband transmission is modulated ; is based on community antenna television (CATV) technology. It is used with CSMA/CD coaxial bus topologies; systems can be single cable or dual cable. In the former, transmissions are directed to a frequency translator called the headend which converts all transmitted frequencies to higher received frequencies.The headend retransmits at the higher frequency to the receiving node. This method is necessary to distinguish transmission and reception on a single cable. It is unnecessary on a dual cable system because one cable is used for transmitting and the other is used for receiving. The dual cable system has twice the capacity of a single cable system but it is more expensive.A feature of any broadband system is its multi service capability. This is the result of its multi channel communication characteristic,wherein different frequency bands can be used for different services (e,g., data, voice and television).

The PABX uses a different communication technology. Pulse code modulation is used to quantize the analog voice signal into a binary bit stream for efficient digital transmission.This method is also compatible with integrating voice with data, since the data is already in digital form and can be merged with the digitized voice information.

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