A Technical Evaluation of Fiber Distributed Data Interface and Asynchronous Transfer Mode for Defense Information Infrastructure Upgrades

by

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(ABSTRACT)

The purpose of this paper is to describe a technical evaluation process as applied to the Warner Robins Air Logistic Center (WR-ALC) Defense Information Infrastructure (DII) upgrade effort. The result is a practical example of how the systems engineering process and methodologies can be applied in order to implement solutions for the modernization of technical infrastructure upgrades to a campus metropolitan area network.

The WR-ALC has been selected as one of the first sites for the demonstration of the DII. The DII is a Defense Information Systems Agency (DISA) initiative that proposes to provide the engineering integration for communications infrastructure to support a suite of DoD standard systems. Bases must respond to the implementations of an evolving suite of DoD standard applications and must ensure that they develop the necessary information infrastructure. In most cases the current base level infrastructure is not sufficient to support the new applications. The challenge is to modernize and integrate

the technical infrastructure in support of planned standard systems in a efficient and effective manner.

This paper demonstrates the use of systems engineering evaluation techniques to determine the optimal technological approach to an engineering requirement. Problem requirements are defined and two technical solutions are evaluated based on compliance to the defined requirements, risk associated with each technological solution, and life cycle costs. A trade-off analysis is conducted to further identify the proper technological solution to pursue. Once a solution is identified, the implementation is taken through the detailed design phase and future areas of consideration are addressed.

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Acknowledgments

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I would also like to thank my mother and my father, Saundria A. Flythe and Edward H. Williams, showing me the importance of setting and striving for goals and instilling in me the confidence to believe that I can achieve.

1.0 Background

In February 1994, the Deputy Assistant of Defense for Enterprise Integration (EI) initiated the Defense Information Infrastructure and DISA the program manager. The objective of DII is to demonstrate the capability of the DISA target infrastructure to support DoD standard systems. There are initial implementations provided participating organizations with a telecommunications local area network (LAN)/wide area network (WAN), mainframe, and workstations infrastructure to support a suite of DoD standard systems.

In May 1994, the Deputy Under the Secretary of Defense for Logistics (DUSD(L)) acknowledged that, in order to be successful, substantial interfaces and integration will be required between standard systems and engineering data repositories, technical manual/orders, an other technical data. DUSD(L) has directed that an Automated System Demonstration of these interfaces be conducted at WR-ALC. DUSD(L) has further requested that DISA lead the matrix teams to assist the site for further deployment of standard and support systems, and directed that all standard and support systems fit into the DII.

The DII process begins with the coordination of a site survey to capture the existing telecommunications infrastructure at the base. Once the infrastructure has been surveyed and documented, its capabilities are compared to the performance and throughput requirements of the application to ensure the infrastructure is capable of supporting the new system. A feasibility analysis is conducted to compare the automated systems network requirements to the capabilities of the existing infrastructure. In situations where the existing infrastructure is inadequate to supporting the digital migration application, technical alternatives are evaluated as solutions to the inadequacies of the infrastructure and the appropriate upgrade recommendations are made.

After the appropriate infrastructure is installed at the base, an Automated Systems Demonstration of the application and the infrastructure is conducted. The objectives of the Automated Systems Demonstration are to:

- Initiate the integration and interfacing of standard logistic systems with engineering data repositories, technical manual/orders, and other technical data.
- Eliminate redundancy in the acquisition of technical infrastructure.
- Determine the optimum standard systems configurations necessary to support the overall logistics effort.

- Characterize and capture functional user profiles in order to architect and size networks and data archives.
- Define infrastructure requirements, including baselining the existing infrastructure and upgrading that infrastructure in support of the ASD.
- Define requirements for Defense Mega Center and wide area communications support and provide that information to DISA.
- Ensure technical infrastructure upgrades are sufficient to handle the ASD applications.

2.0 Objective

This paper takes an engineering analysis approach to the DII process for communication systems upgrades to WR-ALC. The objective of this approach is to define a structured process and sequence of events that are necessary to make the DII concept at WR-ALC and future DII sites successful. The system engineering process, as defined by Benjamin S. Blanchard and Wolter J. Fabrycky in Systems Engineering and Analysis, provides a systematic and structured process directed toward the development of an effective and efficient system. Systems engineering employs the process of iterative feedback through the engineering and design activities related to the system life cycle to ensure the convergence of the desired system. These activities include Conceptual Design, Preliminary Design, Detailed Design, Construction, Operation, and Retirement Phases. The following describes a tailored approach as applied in the context of DII for the specific requirement of providing infrastructure upgrades to portions of the communication systems at WR-ALC. Figure 1 depicts how the capabilities and limitations of the existing infrastructure are evaluated against the network requirements of the automated system in order to identify limitations in the existing infrastructure.

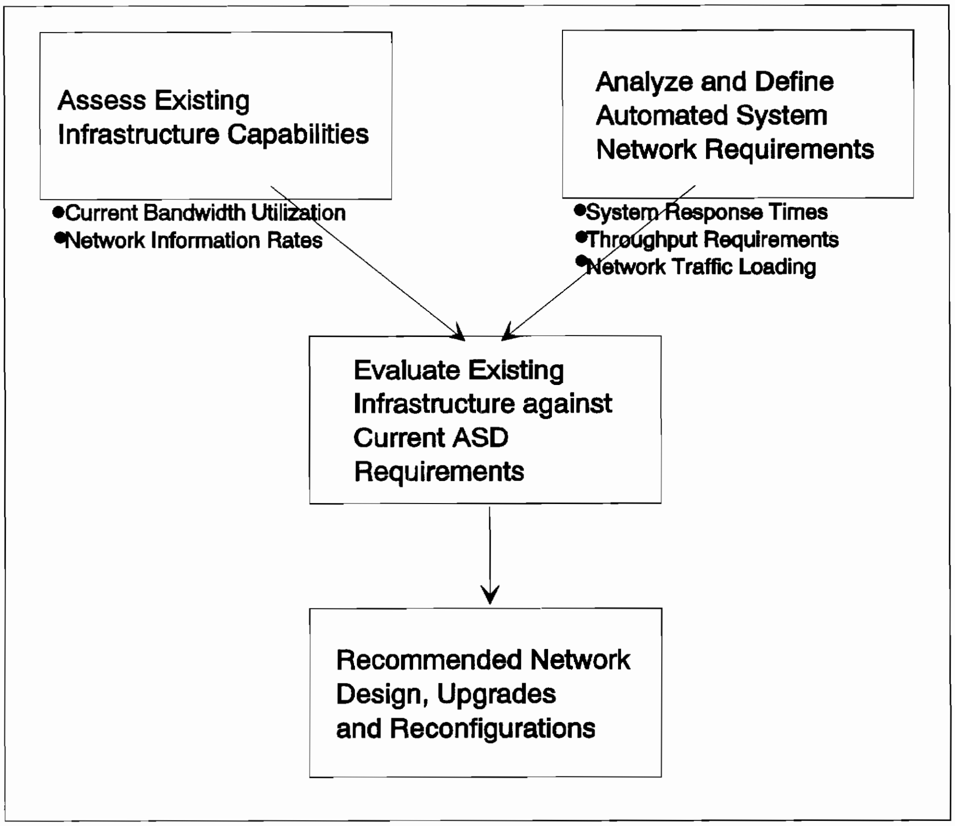


Figure 1. Identification of Required Upgrades.

In this particular situation, a suite of applications are in the process of being delivered to Warner Robins. In is necessary to evaluate the requirements of the application and assess the capabilities of the base infrastructure in order to conduct an Automated System Demonstration at the base. The Automated Systems Demonstrations serve as an initial implementation for an application that will be deployed across the digital communications networks on the base. The demonstrations will serve a subset of the actual user population before full operational deployment of the system onto the base. Actual user behavior can be extrapolated to derive future full operational needs. Network requirements can be gathered by obtaining user utilization profiles to determine what the traffic load on the infrastructure will be when the full user population for that particular system is supported. This future capacity planning must be done early to avoid costly re-architecture and a premature build out that would result in the disruption of base operations. Figure 2 demonstrates the iterative process of the development of telecommunications upgrades.

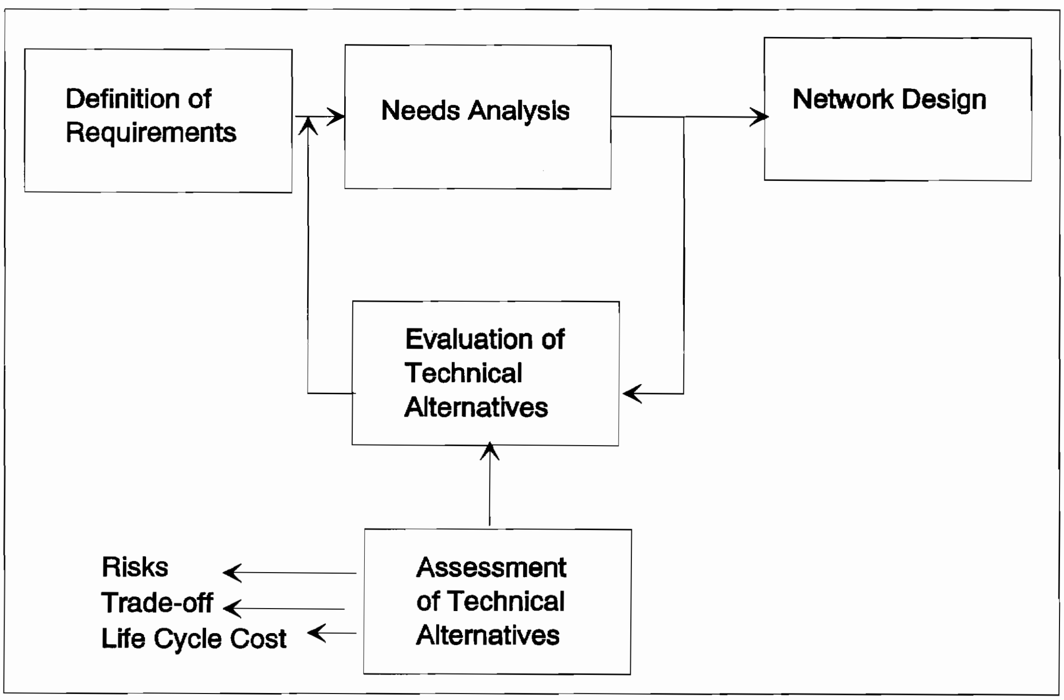


Figure 2. Development of Telecommunication Upgrades.

In the development of the upgrades, overall network requirements are established and a feasibility analysis is combined with an assessment of technical alternatives and projected life cycle cost. A specific technological approach is then designed toward an architecture that meets all requirements keeping in consideration the existing telecommunications equipment, performance, reliability, redistribution of resources, and cost. In most cases, extending the usefulness of existing resources and avoiding more expensive upgrades is the driving force behind technical recommendations.

3.0 The DII Evaluation Process

The DII process begins with the coordination of a site environment survey. The purpose of the site survey is to define the baseline telecommunications infrastructure. The baseline infrastructure includes legacy applications, associated data processing functional requirements, supporting infrastructures, network and configuration management systems, and interfaces that presently support existing systems. The technical baseline establishes an inventory of existing infrastructure components, external interfaces to the base, and types, quantities, and location of the hardware, applications software, systems software, communications, and cabling. The baseline focuses on major systems and functions that present the greatest potential for cross-service utility and savings. Figure 3 shows the mapping of the DII process to the systems engineering phases.

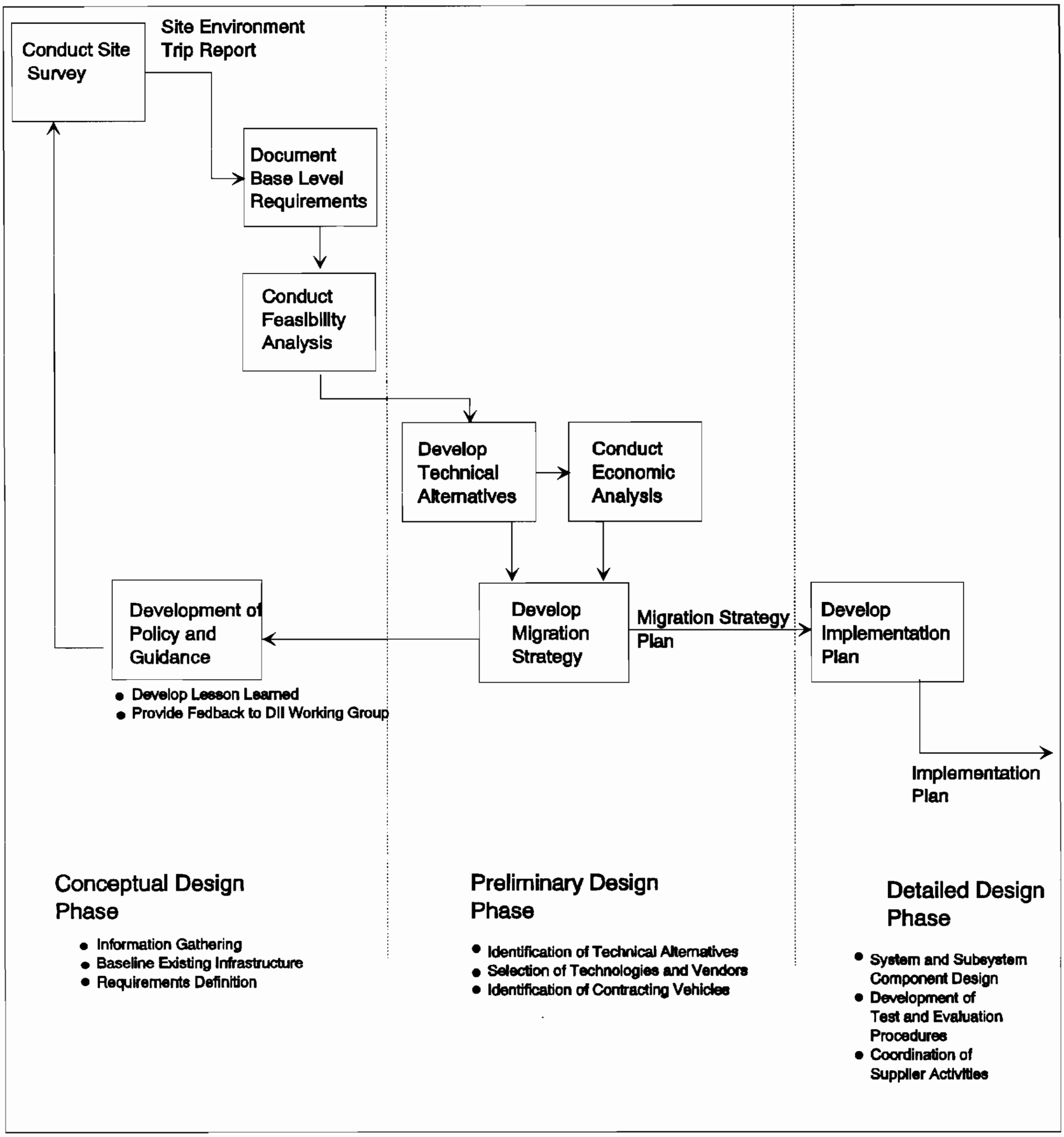


Figure 3. The DII Implementation Process.

The site environment survey represents beginning of the first stage of the establishment of the Conceptual Design Phase. The site environment survey represents an information gathering stage which establishes the baseline infrastructure at the base from which the system design and development evolves. The publishing of the site environment trip report and the distribution of the report through the proper organizations begins the iterative process of feedback to ensure that the proper infrastructure has been properly captured and documented so that further development of possible upgrades through the Conceptual Design Phase evolves from the proper baseline.

Once the proper baseline has been established, the applications requirements are evaluated and a needs analysis is conducted to compare the application and user requirements to the capabilities of the existing infrastructure to determine whether the infrastructure is capable of supporting the requirements of the application.

The Migration Strategy defines and documents current infrastructure limitations and defines a high level (conceptual design) approach toward migrating toward a network architecture capable of supporting the base. An assessment of technical alternatives capable of supporting the requirements for a target architecture is conducted during this phase. Technological solution are evaluated on capabilities to support the defined requirements, risks and trade-offs associated with each alternative, and projected life cycle costs. It is vital that the analysis identifies a cost effective solution and not just a functional one. It is the intent of the assessment to provide a objective analysis of different technological options and the financial impact of each alternative. The process proceeds forward to the Detail Design Phase upon formal approval of the Migration Strategy Plan.

The Implementation Plan begins the Detailed Design Phase. Once a specific technological approach is determined, vendor specific merchandise is selected and a phased approach is developed to implement toward the target network architecture. The Implementation Plan addresses all major components of the system and its integration into the existing architecture.

Feedback from the process conducted at Warner Robins is given to the DII Working Group and lessons learned from the experience are gathered to further develop the DII policy. Once an installed communications infrastructure is running, the process continues through the monitoring of the traffic on the network. Each Automated System Demonstration acts as an informational baseline for utilization profiles and operational characteristics of the user in determining the amount of network traffic each system will place across the network. Continued analysis and redesign of the network is pursued to alleviate bottlenecks and heavy traffic loads throughout portions of the network. As the number of digital applications that are migrated onto the base increase, new technologies and new design solutions should be investigated to provide the best technological and cost effective solutions through the life cycle of the implementation. Figure 4 shows the continuous iterative feedback process that leads to an efficient communications infrastructure.

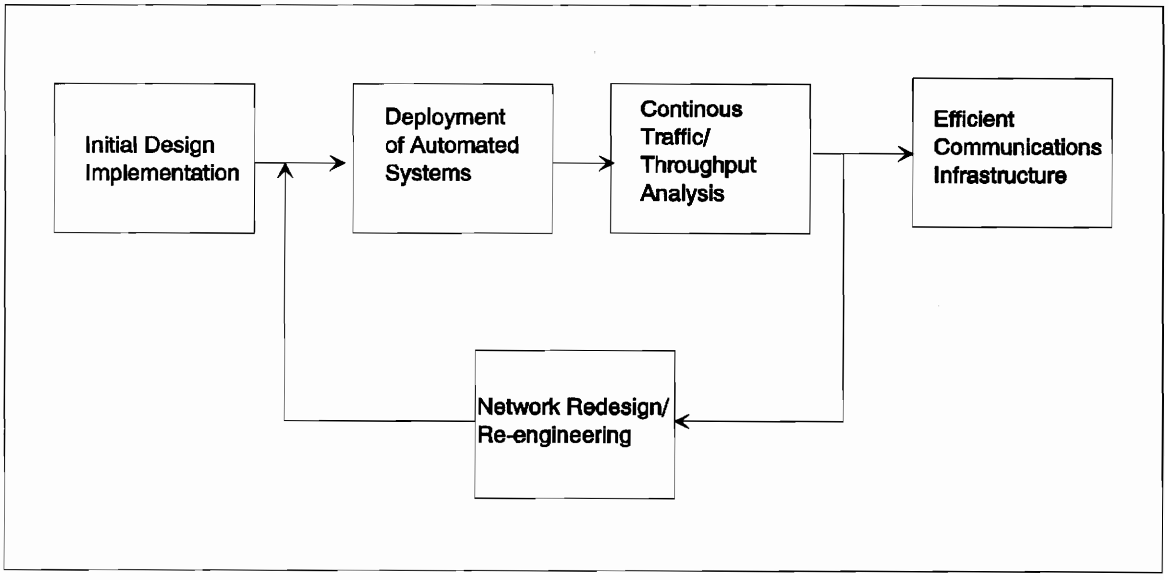


Figure 4. Network Redesign Feedback Process.

4.0 Site Survey Baseline Identification

The following represents the major communications systems and associated components captured as a result of the site-survey. The existing architecture consists a MAN of segmented LANs and large copper and fiber optic cable plant that provide switched and dedicated circuits from the base Dial Central Office (DCO). Certain portions of the base are connected by two separate network backbone systems, the ALC Dual Coaxial Cable Broadband LAN (ALC-LAN) and the Information Systems Network LAN (ISN-LAN). This baseline identification of the existing infrastructure represents the infrastructure at the time of the site survey. Configuration management must be maintained in order to communicate changes in the base infrastructure from the time of the survey through the time of the recommended upgrades so that the proper recommendations and design configurations are made.

4.1 Copper Cable Plant:

The copper cable plant consists of three wire centers, the DCO, the SAC Area and the Controlled Environment Vault. The DCO contains an AT&T 5ESS digital switch, the Base Central Test Facility and the Main Distribution Frame for the base. The Main Distribution Frame has over 20,000 pairs of base distribution cables as well as trunk circuits for local and long-haul service.

4.2 Fiber Optic Plant:

Fiber optic cable plant service is primarily provided from Bldg. 214. WR-ALC uses the "industry standard" fiber optic cable is 62.5/125 micron multi-mode fibers with cable sizes from 12 to 144 fibers. There are a total of 1,128 fibers terminated on a Lightguide Interface Unit in the Switch Room. There are two fiber optic cables that connect the various host computer systems of the Logistic Support Operations Center (LSOC), Bldg. 228, to the ALC-LAN Master Head End (Bldg. 300).

4.3 Fiber Distributed Data Interface (FDDI) Backbone:

The current FDDI backbone is primarily dual fiber optic cable (62.5/125 micron multi-mode fiber) connecting Bldgs. 140, 228, 214, 300 and 301. The FDDI backbone is formed using MMAC-8 Hubs, supporting 100 Mbps service. Bldgs. 183, 140, 376, 301, 155, and 640 are connected to this FDDI backbone as single-pair fiber optic attachment, providing 100 Mbps service. The current bandwidth utilization of the FDDI ring was determined to be 2% through the use of a network analyzer. Bldg. 214 has a Cisco AGS+ router attached to the FDDI backbone for service to the Air Force Reserve facility. Figure 5 represents a topological diagram depicting the primary hubs making up the backbone on the base.

4.4 ALC-LAN:

The ALC-LAN is a dual cable broadband system containing fifty 6 Mhz channels for asynchronous and synchronous connectivity. The ALC-LAN uses one cable for inbound traffic and a second cable for the outbound traffic. With this dual cable configuration, a full duplex system is created providing full broadband capabilities to all connected nodes. The inbound cable carries data from the individual access points, workstations, televisions, etc., to the headend. The outbound cable carries data to these same access points. This systems utilizes TRW Network Interface Units (NIUs), Interface Control Units (ICUs), and Attachment Control Units (ACUs), Chipcom Ethermodems, Wang NetMuxes, and other broadband devices. Channels from the broadband spectrum have been allocated for the network interface devices and RF Ethermodems. Broadband channels have also been allocated to support video signals for local TV stations, such as, CNN, weather, and training. Connectivity between the subnets is accomplished by using a token bus backbone between the Subnet Patch Panels and the Master Headend in Bldg. 300.

4.5 ISN-LAN:

The Information Systems Network LAN (ISN-LAN) is composed of AT&T proprietary hardware and transmission protocols. The ISN-LAN operates at a maximum of 19.2 kbps at the desktop and has a maximum throughput of 8.64 Mbps running across two fiber optic cable strands. These two fiber strands are used to make the ISN-LAN a full duplex system, i.e., sending and receiving of data can be accomplished at the same time. Even though this hardware is proprietary, there is an Ethernet card to connect to an Ethernet network. This gives users on the ISN-LAN connectivity to the FDDI base-wide backbone. Users are connected to the ISN-LAN, in most cases, over Category V cabling from an asynchronous port. This cabling either ties directly into the concentrator or to a block containing a maximum of 40 RJ-45 connectors. Each concentrator and node contains a maximum of 5 blocks of 8 ports each for a total of 40 ports. Bldg. 214 contains the primary node for the ISN-LAN. Figure 5 shows the connectivity of the FDDI backbone, the ALC LAN, and the ISN LAN.

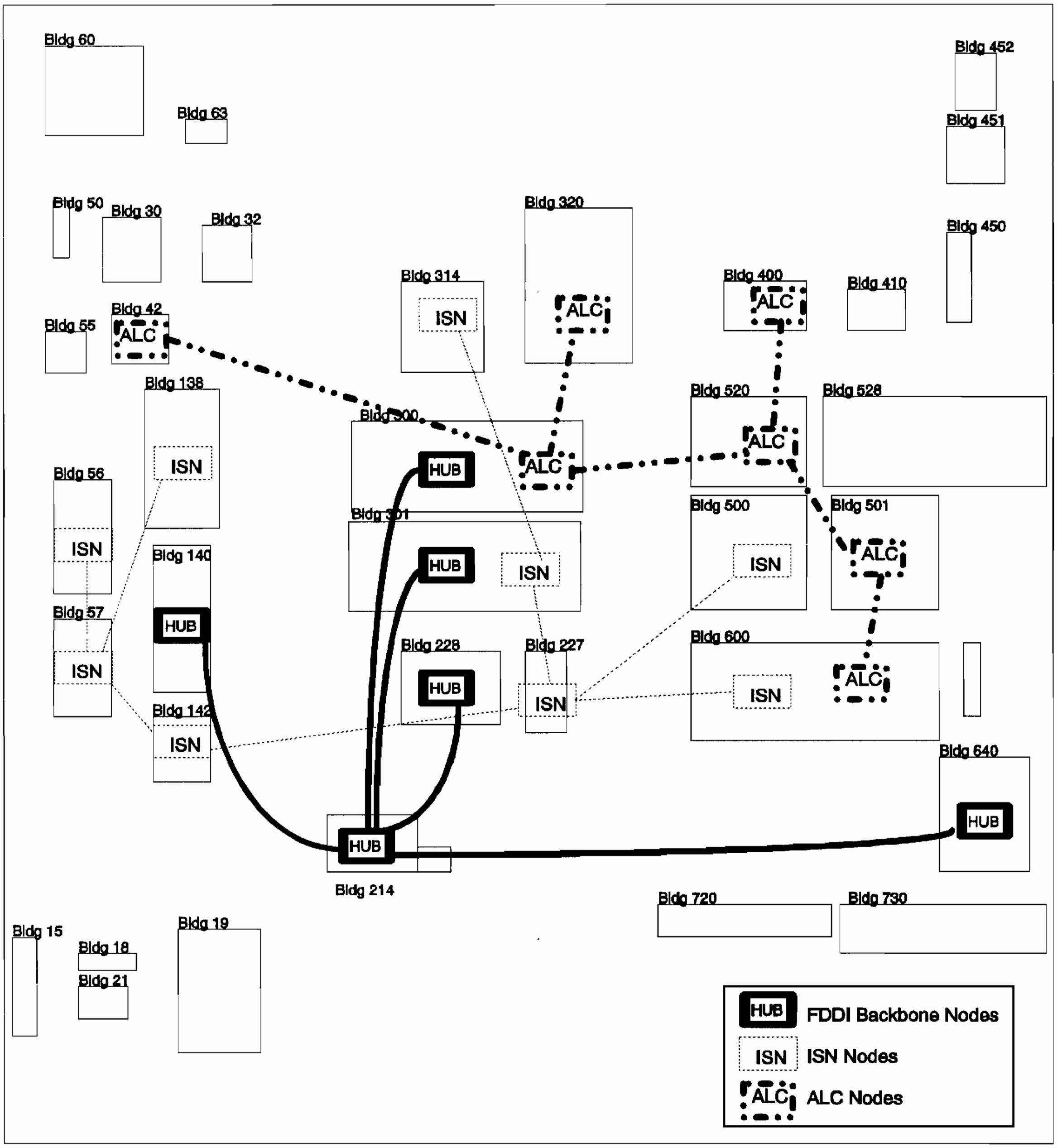


Figure 5. Current LAN Connectivity.

4.6 DATAKIT:

The Datakit is a virtual circuit switch (VCS) used for on-base connectivity to the Sperry SBLC. AT&T Datakit II equipment is located at various places on the base. The system currently runs Release 1.3.10 and can interface with the AFMC VCS system via a low speed connection. The hub for the VCS is at Bldg. 228, providing for remote terminal access to the SBLC Sperry computers.

4.7 Network Management Center:

Current network management capabilities include the Customer Service Center (CSC) in the LSOC; the Base Central Test Facility (BCTF); and monitoring centers in Bldg. 300 (ALC-LAN), Bldg. 225 (AUTODIN) and Bldg. 56 (Communications Systems). The CSC can monitor the LSOC computer systems and the base backbone. The BCTF uses systems monitors and test equipment to monitor DSN, Defense Data Network (DDN), the Air Force Integrated Digital Telecommunications Network (AFNET), and AFMC VCS. Cabletron's Spectrum Command 5000 is the current network management platform. With Spectrum, the CSC is capable of managing the FDDI backbone and the LAN subnets by pinpointing faults, correcting problems, and gathering traffic diagnostic information.

4.8 Long-haul Systems:

The long-haul systems include the Defense Switched Network (DSN), Defense Data Network (DDN), the Air Force InterNetwork (AFIN), AFNET, Virtual Circuit

Switch (VCS, the Electronic Collocation System (ECS), AUTODIN, and Defense Message System (DMS-AF).

DSN provides for switched long-haul DoD voice communications.

DDN (transitioning to DISN) provides for long-haul data communications.

Air Force Information Network (AFIN) is the prototype for the Defense Information System Network (DISN).

Air Force Network (AFNET) is a protocol independent long-haul information transfer network planned to consolidate AF long-haul circuit requirements.

VCS is a fast packet network used primarily to interconnect the various ALCs. The system supports a host of legacy systems and applications.

ACN is the AFMC Classified Network. ACN supports AFMC CS2 and WSMIS by providing connectivity from HQ AFMC to the ALCs, Newark AFS Ohio and Davis Monthan AFB, AZ via a secure X.25 network using KG-84 encrypted links.

ECS is a proprietary system managed by McDonnell Douglas and connecting McDonnell Douglas, Hughes Aircraft, Wright Patterson AFB, and WR-ALC via dedicated T-1 lines.

Long haul connectivity is accessed through the DCO. DISG1 is a Cisco AGS+ router in the DCO which provides connectivity between several interface points within the base infrastructure and the WAN. The Ethernet 0 (Eth 0) interface is connected to the fiber optic backbone of the base. The Ethernet 2 (Eth 2) interface is connected to another AGS+ router called Robins1. This router establishes connectivity to and is owned and controlled by Gunter Air Force Base. The Robins1 router establishes AFIN/DISN connectivity to Edwards AFB, Peterson AFB, Andrews AFB, Scott AFB, Gunter AFB, Hill AFB, Kelly AFB, Tyndall AFB, Wright-Patterson AFB, Dobbins AFB, Shaw AFB, and Seymour Johnson Air Force Base via 128 and 56 Kbps lines. The Serial 0 (Ser 0) interface is connected to the VCS Datakit in Bldg. 228. The VCS connects the AGS to the IDNX 70 T-1 Multiplexer in Bldg. 214 and to an IDNX 90 T-1 Multiplexer in Bldg. 228. The IDNX 70 provides for connection to AFNET in order to provide communications with the same bases mentioned above via T-1 and 56 Kbps lines. The IDNX 90 is connected through the IDNX 70 and establishes special prioritized links that connect to Gunter, Tinker, Denver, Andrews, Pope, Anniston Army Depot, and the Pentagon.

4.9 Defense Mega Center - DMC:

The DMC provides Air Force Standard Base Level Computing Services to Air Force bases across the entire eastern section of the United States. The DMC also provides data processing support for logistics systems, including world-wide support for all F-15, C-130, and C-141 aircraft parts tracking and supply; tracking of all Air Force vehicles and parts requirements; and depot support tracking for all Air Force helicopters.

The DMC resides in Bldg. 228 (LSOC) and occupies 70,000 sq. ft. for the computer center, help desk, printer room, tape and disk library, and other work rooms. The raised floor portion of the computer center is in excess of 20,000 sq. ft. The DMC contains one AMDAHL 5995-1100A mainframe computer with 3 domains, one HP-9000-I40 and one HP-9000-I60 midrange computers, two AT&T 3B2 midrange computers, two TANDEM T16-264 computers, one Pyramid midrange computer with two domains, two Sun Microsystems 690 computers, and numerous PC's and X-Stations. There is numerous peripheral equipment in support of each of these machines. This equipment includes tape drives, disk, printers, FEP's, and other equipment to support the everyday activities in a computer center.

5.0 JEDMICS Automated System Demonstration Requirements

The first automated system demonstration will be a deployment of the Joint Engineering Data Management Information and Control System (JEDMICS) to occur in mid June 1995. JEDMICS functions as the DoD's digitized data repository for technical drawings and technical data. JEDMICS stores and retrieves raster images of engineering drawing and associated list, neutral vector formats such as IGES, CGM, SGML, ASCII files and formatted files such as native CAD and other application specific file formats as well as raster graphic files.

Existing repositories of engineering data were analyzed to estimate the size of JEDMICS drawing files sizes. In addition, the volume and types of different engineering data input and output transactions were estimated. This estimation is critical considering technical drawings and detailed engineering documents can be very large and consume a great deal of bandwidth.

The JEDMICS user experiences services as follows; The JEDMICS repository contains drawing sizes A through H. The user can "scan" the repository to view particular drawings from the server without downloading them. Within a particular request, several drawings may actually be requested. Thus file transfers may range from 100 Kb to 20 Mb. Average compressed drawing size of all drawings was taken to determine the bandwidth requirement during digital file transfers. The average compressed drawing size was determined to be 527.2 Kbps.

Two types of workstation environments will attach to the JEDMICS host -

1. Graphics display workstation - operating as a "view-only" JEDMICS user, capable of zooming, panning, and rotating images.

   Requires 486 PC with MS-Windows 3.1

   Graphics accelerator board; 8Mb of memory; 40Mb hard disk space

   Requires a graphical "viewer software; TCP/IP;

   Compression/Depression software.

2. Engineering graphics Display Workstation - high performance workstation for performing editing and revisioning of image in raster editing environment

   Sun Sparc-5 with high resolution 20" monitor

   Solaris UNIX software

   Digital Image Library; TCP/IP (standard with Solaris)

   Compression Depression Software

   Raster Editor for revisioning engineering drawings.

PC to Server scenario has two variants; the graphics display workstation will work in a display or terminal emulation mode with a semi-permanent access to the server where continuous bandwidth will be required. The engineering display workstation will actually download drawings from the server where they will be modified and uploaded back to the server once changes are made. Each user is expected to make approximately 20 transactions in an 8 hour workday. Many users can perform these actions simultaneously.

JEDMICS is a Unix based system and is hosted on a Sparc Server. The JEDMICS host is capable of 255 simultaneous server queues for drawing request. The server holds 10 Gb of storage data. The computer facility will be located in Room, A02 of building 301.

JEDMICS devices are configured to connect to a sites existing or planned Ethernet plant. This assumes that the site's local area network is in accordance with IEEE specification 802.3 at a signal rate of 10 Mb per second. The broadcast protocol nature of Ethernet can make file transfer of large graphics files slow when many users are sharing a 10 Mbps Ethernet segment. Switched Ethernet is provided to each workstation to ensure dynamic allocation of network bandwidth during file transfers. This provides the functional user with a dedicated 10 Mbps of bandwidth to their workstation.

5.1 Quality of Service (definition of Technical Performance Parameters)

Quality of Service (QoS) is important for both network operators and users. Performance aspects of network implementations are particularly concerned with the special requirements for end to end delay and system throughput. The following parameters have been specified as the performance criteria for network implementations to support the JEDMICS system:

- Overall response time: overall response time is the accumulation of all relevant delay components of the telecommunications system. The system throughput should allow for very high peak traffic. Periods of unacceptable network performance (e.g. network delay) may be caused by short traffic overloads. **30 seconds (to include Processing Delay)**

  For the JEDMICS system, the delays associated with response time include:

  Transmission delay: the delay attributed only to the telecommunications network.

  Processing Delay: caused by processing that takes place in the server due to table look-ups, buffer management, address resolution, and error checking. This delay is dependent upon the processing speed of the server and independent of the underlying network implementation. The JEDMICS system has a maximum processing delay of 10 seconds.

- Availability: availability of a system is defined as the percentage of time during which the system is conforming to its QoS specification and the percentage of time to which it is available to the user. This parameter is determined by the average failure rate of the components and by the mean-time-to-repair. Superimposing the two parameters with produces the overall availability of the network as seen by the user. **98.8%/month**
- Fault Report Delay: the period of time from which a fault develops in the system until the information is reported to the monitoring system.
  20 seconds

6.0 Feasibility Analysis

The needs of the existing campus infrastructure can be summarized by the following bullets:

- Expansion of the existing base-wide Metropolitan Area Network to provide high-bandwidth connectivity to support additional functional areas.
- Replacement of existing asynchronous LAN connectivity to the functional users with 486 workstation utilizing TCP/IP over Ethernet connectivity.
- Upgrading the existing Network Management System to provide network management functionality to the individual functional areas.

The current infrastructure does not provide the electronic data interchange required to support the simultaneous transmission to multiple users, for CAD/CAM, imagery, and other graphics and textual data files to all the required areas. Aside from the FDDI network, there are two separate network backbone systems, the ALC Dual Coaxial Cable Broadband LAN (ALC-LAN) and the Information Systems Network LAN (ISN-LAN). The Ethernet connectivity of the broadband ALC-LAN does not provide the necessary bandwidth from the user platforms to the host systems. Digital data is modulated onto the ALC-LAN through Ethernet modems at 9600 bps. This information rate is not capable of supporting the QoS requirements for transmitting large image files across the campus from host to workstation.

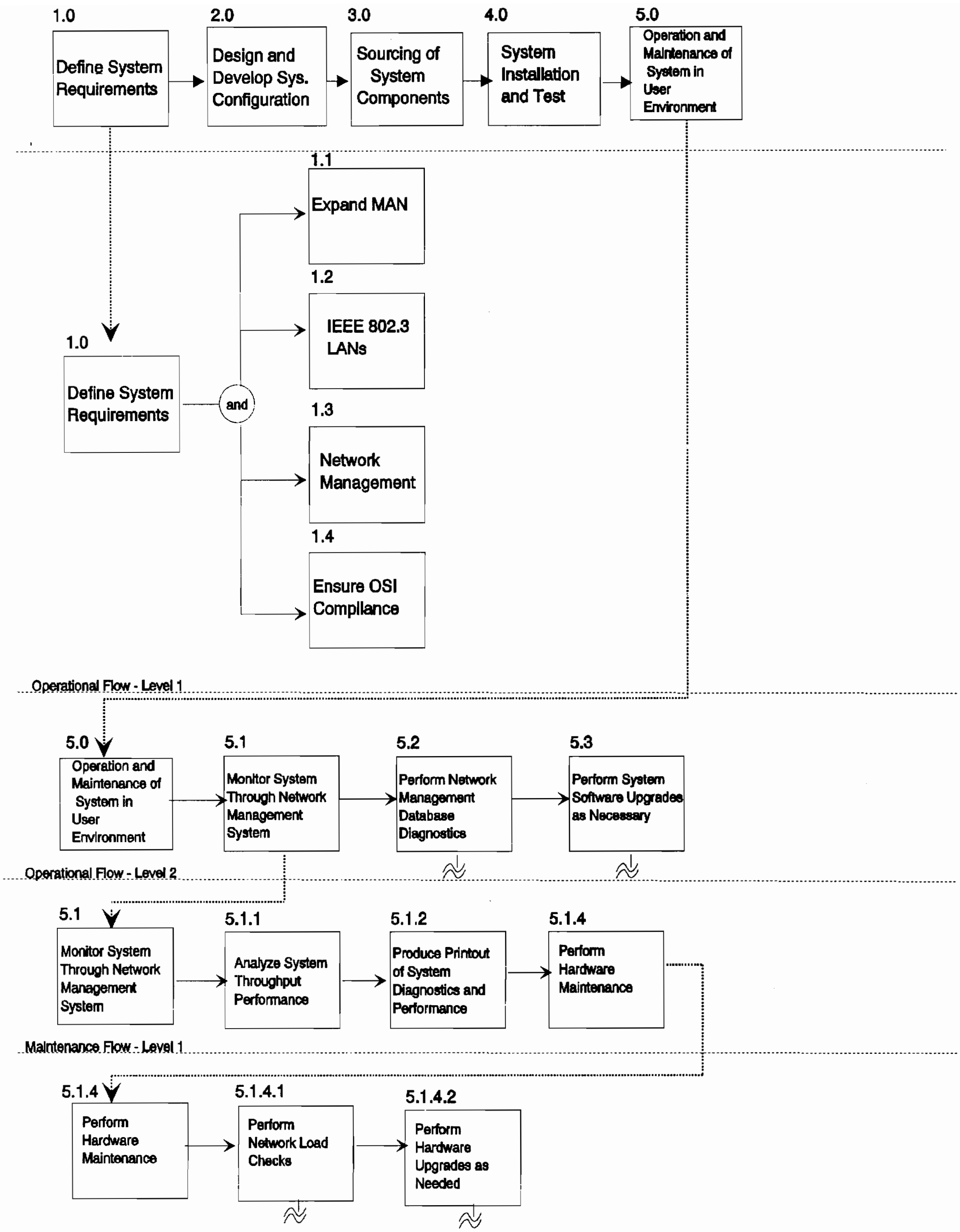
The ISN-LAN has an aggregate throughput of 8.654 Mbps. This aggregate throughput will not support the large number of users who will be utilizing the network to transport drawing files. The proprietary communications equipment forming the ISN-LAN topology limits data throughput to the desktop to 19.2 kbps and the number of concurrent users that can access the host systems (limit 40). This limits the number of individual functional user connections to the backbone. The ISN-LAN is not SNMP (Simple Network Management Protocol) compliant, thus it is not manageable by the Spectrum Network management software currently being used at the base.

The FDDI backbone is not complete in that it does not provide a dual redundant counter rotating ring to the functional areas that it currently provides connectivity to. It also does not extend to all the necessary buildings on the base the JEDMICS system is to support.

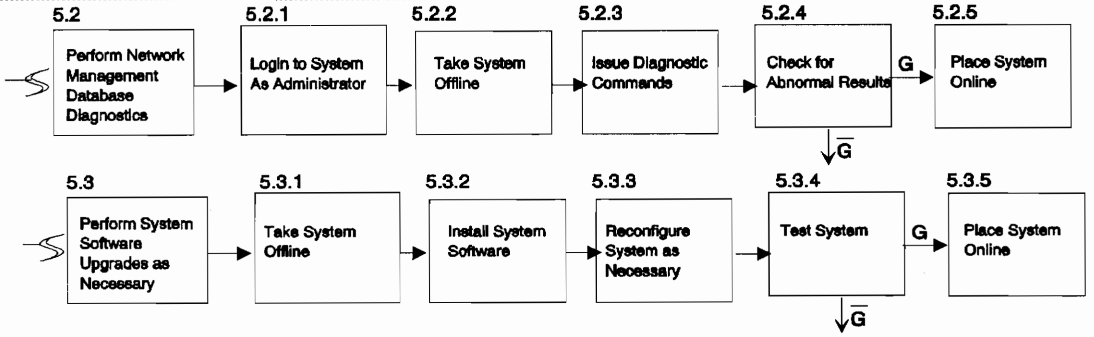
In recommending a technological solution that provides a telecommunications infrastructure that will support the JEDMICS Automated Systems Demonstration and provides the proper infrastructure to all appropriate areas, different networking technologies will be investigate to determine the most viable solutions for upgrading the Metropolitan Area Network (MAN).

7.0 Functional Analysis

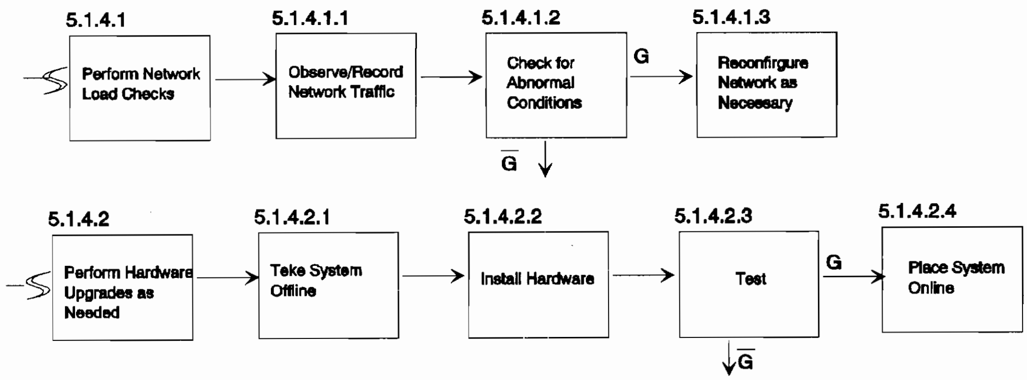
A Functional Analysis has been performed to develop the system in functional terms. The Functional Analysis has translated the top-level system requirements into functional design requirements. The complete Functional Analysis is represented in the flow diagrams on the following pages.


1.0
Define System Requirements
2.0
Design and Develop Sys. Configuration
3.0
Sourcing of System Components
4.0
System Installation and Test
5.0
Operation and Maintenance of System in User Environment
1.1
Expand MAN
1.2
IEEE 802.3 LANs
1.0
Define System Requirements
and
1.3
Network Management
1.4
Ensure OSI Compliance
Operational Flow - Level 1
5.0
Operation and Maintenance of System in User Environment
5.1
Monitor System Through Network Management System
5.2
Perform Network Management Database Diagnostics
5.3
Perform System Software Upgrades as Necessary
Operational Flow - Level 2
5.1
Monitor System Through Network Management System
5.1.1
Analyze System Throughput Performance
5.1.2
Produce Printout of System Diagnostics and Performance
5.1.4
Perform Hardware Maintenance
Maintenance Flow - Level 1
5.1.4
Perform Hardware Maintenance
5.1.4.1
Perform Network Load Checks
5.1.4.2
Perform Hardware Upgrades as Needed

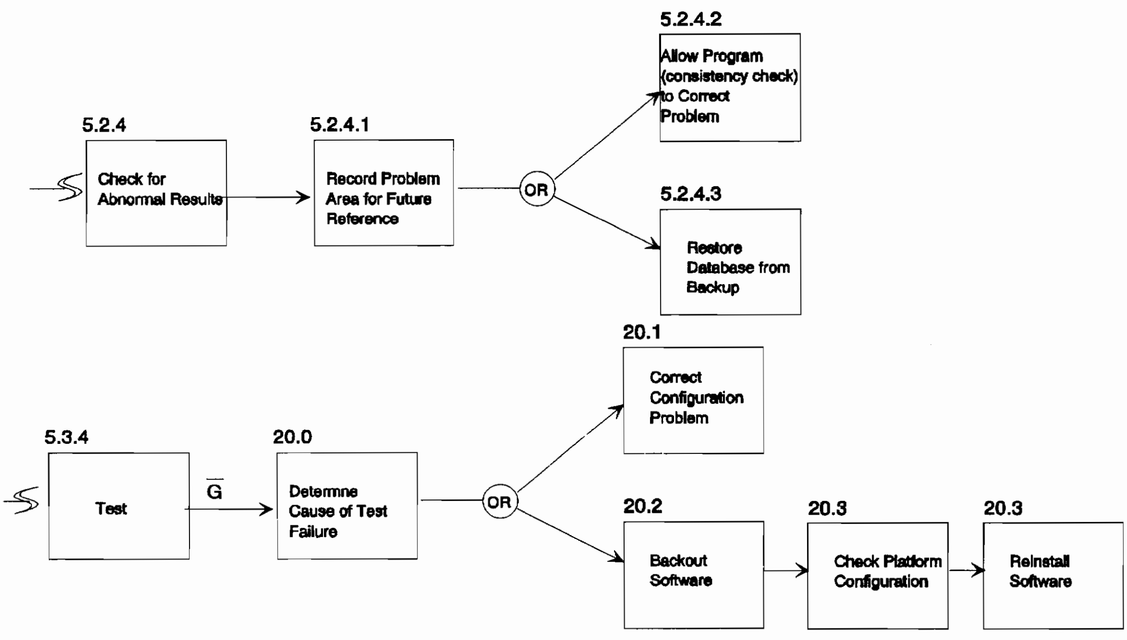
Maintenance Flow - Level 1

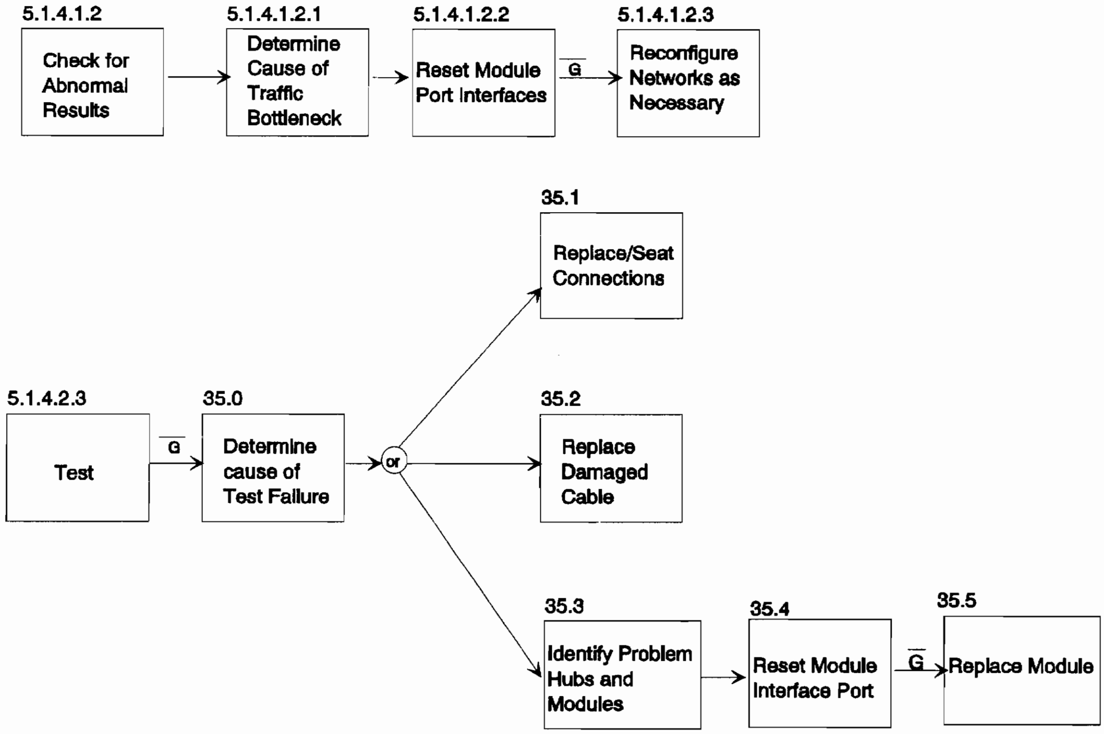


Maintenance Flow - Level 2



Maintenance Flow - Level 2




5.1.4.1.2
Check for Abnormal Results
5.1.4.1.2.1
Determine Cause of Traffic Bottleneck
5.1.4.1.2.2
Reset Module Port Interfaces
G
5.1.4.1.2.3
Reconfigure Networks as Necessary
35.1
Replace/Seat Connections
5.1.4.2.3
Test
G
35.0
Determine cause of Test Failure
or
35.2
Replace Damaged Cable
35.3
Identify Problem Hubs and Modules
35.4
Reset Module Interface Port
G
35.5
Replace Module

8.0 Migration Strategy

The Migration Strategy focuses primarily on addressing the following objectives:

- Expanding the existing base-wide Metropolitan Area Network to provide high-bandwidth connectivity to support additional functional areas.
- Replacing existing asynchronous LAN connectivity to the functional users with TCP/IP using Ethernet connectivity.
- Upgrading the existing Network Management System to provide network management functionality to the individual functional areas.

8.1 Upgrading the Metropolitan Area Network

The purpose of MANs is to provide a standardized, high-speed network providing LAN to LAN and LAN to WAN connectivity for public or private communications systems within metropolitan-range distances (up to 50 km). Several standards based technologies have been or are currently being developed to address this area of telecommunications.

Dual Bus Dual Queue (DBDQ)

DBDQ has been developed as a result of the IEEE 802.6 standard. The standard defines a high speed shared medium access protocol for use over a dual unidirectional bus subnetwork operating at 1.5 or 45 Mbps. Taken together, the two buses provide bi-directional connectivity. Typically, a MAN would consist of interconnected DBDQ subnetworks, with the interconnection of the subnetworks occurring via bridges, routers, and gateways. Lack of vendor support eliminates this technology as a viable option.

FDDI

FDDI is intended for use in a high-performance general purpose multi-station network. The intrinsic topology of FDDI is a counter rotation token-passing ring operating at 100 Mbps. A mature standard and a wide variety of vendor support make FDDI an attractive solution to Metropolitan Area Networking.

FDDI II

The FDDI II standardizes how up to sixteen 6 Mbps isochronous channels may be superimposed on the ring. The standard does not define how stations should signal each other to allocate these channels. Much of the FDDI mainstream has lost interest in FDDI II. New proposal continue to standardize a fiber distributed voice-video-data interface.

Copper Distributed Data Interface (CDDI)

CDDI is FDDI running over shielded and unshielded twisted pair wire at 100 Mbps. This technology is motivated by both the lower cost of electrical transceivers, compared to electro-optical transceivers. Vendor support for this technology is available, but it has not been accepted into the mainstream as FDDI over fiber optic cabling.

ATM

ATM is a high-bandwidth, low delay packet-based switching and multiplexing technology; it is a connection-oriented method, although it is designed as a basis for supporting both connection-oriented and connectionless services. ATM is attractive because of it's scaleable architecture that allows for bit rate allocation on demand. Transmission rates are available up to 622 Mbps (OC-12) speeds, with potential future interfaces at OC-48 speeds. Emerging vendor and scaleability support make this technology a viable solution for MANs.

8.2 Evaluation of Technical Alternatives (FDDI and ATM)

Two technologies are considered in support of providing the infrastructure upgrade requirements for the campus MAN. These two technologies have been selected due to the following criteria:

- Amount of vendor support
- High information rates
- Desires of customer

An assessment of each technology is considered, keeping in mind the capabilities of the existing infrastructure, the capabilities of the current staff, and the estimated overall cost to the customer in recommending the most cost effective solution. It is vital that this analysis identifies a cost effective solution and not just a functional one. It is the intent of the assessment to provide a objective analysis of two different technologies and the concerns and financial impact of each alternative.

8.2.1 Fiber Distributed Data Interface (FDDI)

FDDI is a high speed, dual ring, token passing network designed to run over multi-mode fiber-optic cabling. FDDI deliver a data rate of 100 Mbps utilizing a 4B/5B encoded signal (NRZI) at 125 Mhz. The maximum number of stations (FDDI Nodes) on a FDDI network is 500. The maximum distance between any two FDDI nodes is 2 km, with a link budget of 11 db, and a maximum total ring distance of 100 km (Minoli, 1991, p 612). FDDI was originally designed using a single medium of multi-mode fiber optic cable but has been modified to work on single-mode fiber optic cable, unshielded twisted pair cable, and shielded twisted pair. The FDDI technology has grown over the last several years and interoperability has been tested and demonstrated through many installations. The dual ring architecture and speed of 100 Mbps provides the backbone for many network installations.

FDDI is based on the Open Systems Interconnect model shown in Figure 6. It addresses the physical layer (layer 1) and the data link layer (layer 2) of the OSI model.

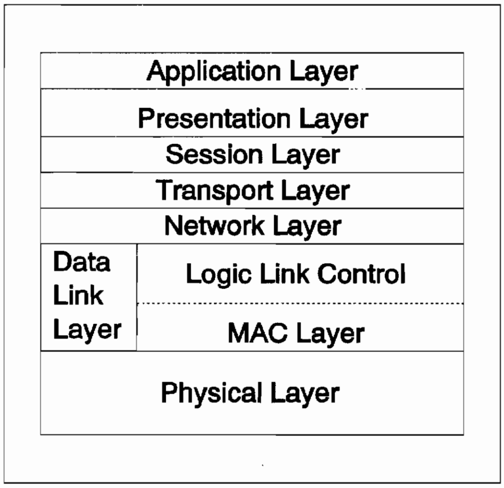


Figure 6. OSI Protocol Model.

The networking concept behind FDDI has been to establish connectivity from LANs through a campus environment. As a means of interconnecting LAN, FDDI serves as a high-speed communications backbone. Two typed of topologies are possible with point to point links: active star and active ring. The problem with an active star is that it has a single point of failure that may incapacitate the entire network; a similar problem exist with a single ring (Minoli, 1991, p 615). Warner Robins current FDDI configuration is an active star. Consequently, the FDDI specification call for a dual fiber optic ring topology.

A dual ring topology consist of two distinct, separate rings; the primary ring and the secondary ring. Under normal conditions data frames travel on the primary ring and the secondary ring is used as a backup path. If a fiber is cut, the node wraps a port by internally connecting the primary ring to the secondary ring an maintains a data path form frame transmission by effectively creating one continuous loop.

FDDI is a token passing communications protocol. When an FDDI node needs to transmit a frame onto the ring, it must first capture the token as it enters the node. The node transmits the frame(s) onto the ring and then transmits the token. The frames will circulate around the ring, being repeated by each node, until it reaches the destination node. This node recognizes the frames destination address and copies the frame into its receive buffer, and then repeats the frame back onto the ring. The frame will continue to circulate the ring and is then stripped from the ring by the originating node. The FDDI protocol permits variable frame sizes with a maximum frame size of 4,500 bytes.

The devices connected to the ring are all contending for the 100 Mbps of bandwidth. For greater control over the network capacity, FDDI defines two types of traffic: synchronous and asynchronous. Synchronous traffic allocated a guaranteed portion of the 100 Mb of bandwidth available on the ring and guarantees response time to a particular device at all times. Asynchronous traffic allocates multiple levels of bandwidth priority after transmittal of synchronous traffic. Asynchronous traffic is available to devices after all synchronous frames have been transmitted. The protocol defines a token rotation time defined by:

$$\Sigma SAi + D\_Max + F\_Max + Token\_Time \leq TTRT \qquad \text{Eq. 1}$$

where

Sai = synchronous allocation for station I
D_Max = propagation time for one complete circuit of the ring
F_Max = time required to transmit a maximum length frame (4500 bytes)

All stations have the same value of TTRT and separately assigned values of Sai. Several other variables are required for the operation of the FDDI algorithm:

- Token Rotation Time (TRT)
- Token-holding timer (THT)
- Late Counter (LC)

Each station's TRT is initialized to TTRT; when it is enabled, it counts down until it expires at TRT = 0. It is then reset to TTRT and enabled again. LC is initialized at zero and is incremented when TRT expires. Thus LC records the number of time that TRT has explored since the token was last received at that station. The token is considered to arrive early if TRT has not explored since the station has last received the token (Stallings, 1990, p 233).

Assuming a four node FDDI backbone, each device can be allocated 25 Mbps of throughput. A FDDI backbone serving 2 full duplex Ethernet segments at 20 Mbps could potential be undersized for servicing data throughput to each of the Ethernet Segments. This is an extreme case since the scenario is assuming that all communication must transverse the backbone. As a networking goal using FDDI, the goal is to keep 80% of the network traffic localized to the individual LANs, and 20% of the network is transferred to other subnetworks through the high speed backbone. This is know as the 80/20 networking rule that is usually applied to FDDI (Minoli, 1991, p 620).

The use of both rings to transfer data can effectively increase the throughput from 100 Mbps to 200 Mbps. Four FDDI rings can be used to transfer data among the nodes to increase the ring throughput to 400 Mbps and thus provide each node with a guaranteed 100 Mbps of synchronous traffic in a four node configuration. Implementing multiple rings becomes linearly more expensive for the additional hardware and cabling to support the ring.

FDDI has been available for some time. Interoperability and multi-vendor FDDI solutions are not questioned due to the complete development of standards and testing. The current FDDI network at Warner Robins is currently being used to 2% of its capacity. A diagram of an FDDI solution is shown in Figure 7.

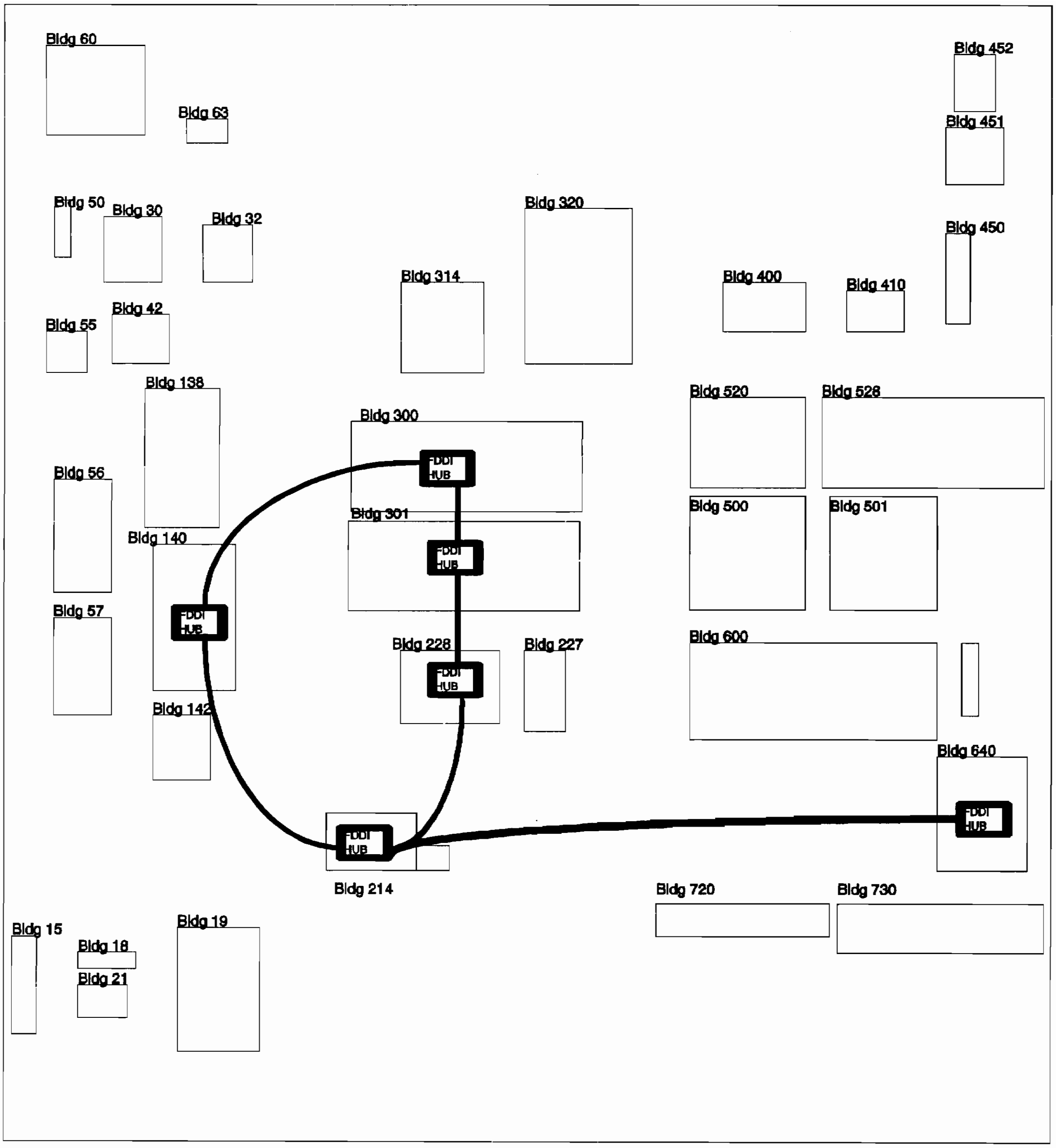


Figure 7. Diagram of FDDI Configuration.

The following summaries assessments of a FDDI technical solution:

Advantages

- Interoperability
- Mature Standard
- Industry Wide Vendor Support
- Self-Healing Redundancy
- Fiber Optic Cabling
- Current staff familiar with technology

Concerns and Risk

- Contention Based Access Protocol
- Limited Future Scaleability
- Limited capabilities for future Multi-Media

8.2.2 Asynchronous Transfer Mode

ATM is an emerging networking technology that has been developed to take advantage of multi-media capabilities and is scaleable to grow to faster speeds without requiring massive upgrades.

ATM is based on a fixed-size virtual circuit oriented switching methodology. A cell consist of 5 bytes of header information and 48 bytes information field. The header field contains control information for the cell such as identification, cell loss priority, and routing and switching information. Figure 8 depicts the ATM cell format.

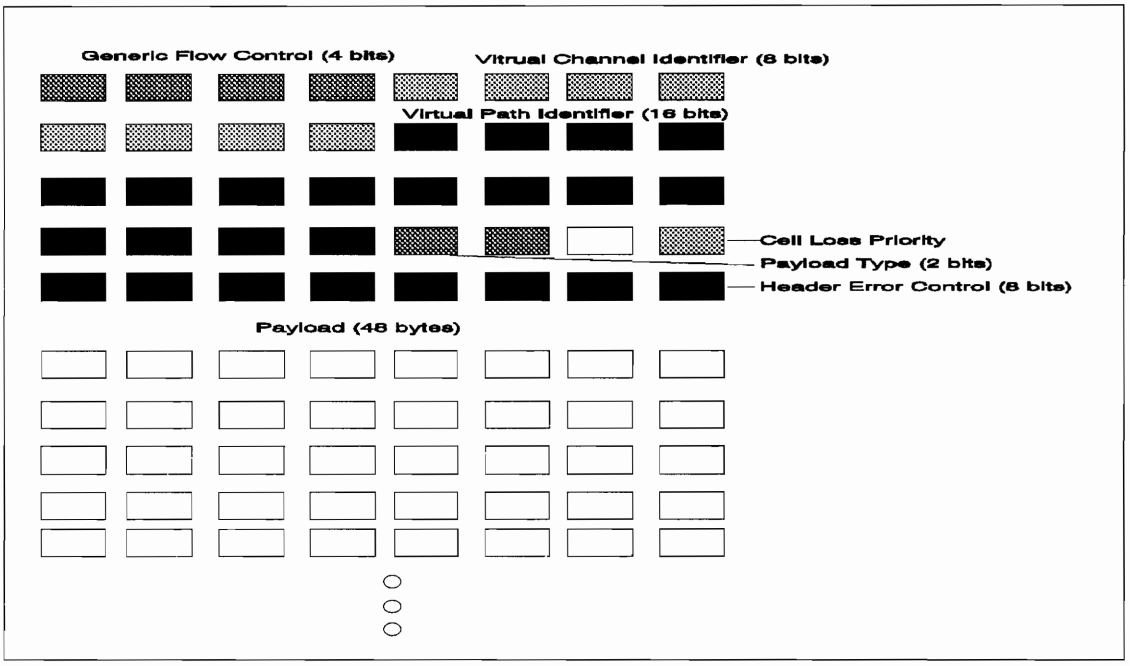


Figure 8. ATM Cell Format.

Two parts of the header field are the virtual path identifier (VPI) and the virtual channel identifier (VCI). The VPI and the VCI values are used by the routing protocol to determine which path(s) or channel(s) a cell will traverse.

In integrating an ATM network into an existing network infrastructure, the success of ATM is primarily contingent upon the interoperability of ATM with existing legacy LANs. The Internet Protocol (IP) is the network layer protocol which provides a connectionless delivery mechanism of packets from source to destination. Connectionless delivery implies that there is no fixed or logical path from the source host to the destination host; each packet is routed individually and may follow different paths in the network between source and destination (Choa, 1994, p 54).

Existing LANs are based on shared interconnects and employ the IEEE 802 family of LAN protocols. In contrast to IEEE 802 LANs, ATM LANs are connection oriented. A connection must first be established between ATM host before any data can be transferred. Once a connection has been established, the connection remains dedicated for the duration of the data transfer, preserving cell sequence and integrity.

ATM is not based on the 7 layer OSI model shown in Figure 6. It is based on the Broadband-Integrated Switching Data Network (B-ISDN) model. The B-ISDN model is shown in Figure 9.

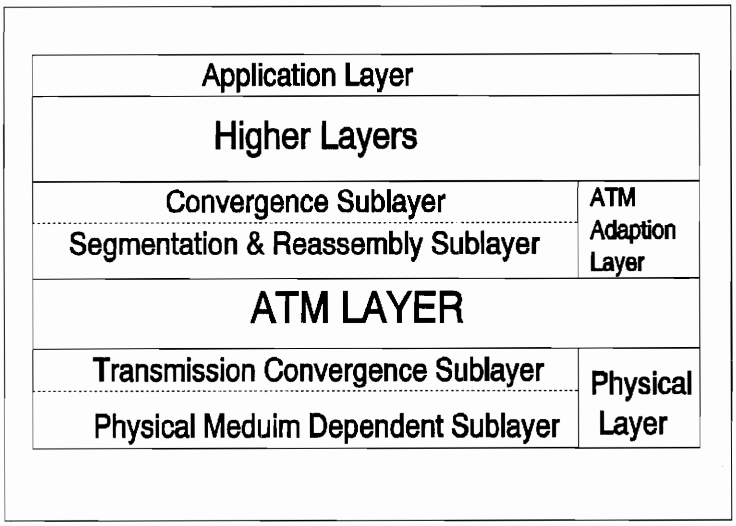


Figure 9. B-ISDN Protocol Stack

The ATM-relevant portions of the B-ISDN model comprise the bottom three layers: the ATM adaptation layer(AAL), which is divided into two sublayers; the ATM layer; and the physical layer, also divided into two sub-layers. There is not a one-to-one correspondence between the B-ISDN stack and the OSI stack. The three layers of the ATM portion of the B-ISDN stack is roughly equivalent to the OSI physical layer and datalink layer (Warner, Oct 1994, p 19). The ATM physical layer defines the electrical or optical interface requirements, and the line speed, which determines the rate of information or bandwidth. The ATM layer defines the cell format and the ATM adaptation layer defines the process of converting raw application information into ATM cells. By essentially by-passing the network layer in the OSI model, the ATM model is able to process cells much more quickly and efficiently than packet-based routing (Suzuki, April 1994, p 83).

With respect to IP and other network layer protocols, ATM can be configured either as a separate data link layer protocol or as a MAC protocol below the LLC. The former approach results in IP and other network layer protocols to be implemented directly over ATM. The second approach is the key concept behind LAN emulation, which allows the ATM switch to be transparently interconnected to the IEEE 802 family of LAN protocols (Chao, 1994, p 54).

Despite superficial similarities, the goal of LAN emulation and IP over ATM are completely different. LAN emulation works with all protocols, both routable and unroutable, and completely hides ATM from the upper layers. IP over ATM supports only one protocol and does not attempt to emulate the existing MAC layer. Since it only has to handle one protocol, it generates much less overhead

(Jeffries, 1994, p 96). This makes it much simpler to implement. LAN Emulation and IP over ATM are addressed in the following sections.

8.2.2.1 ATM LAN Emulation

The goal of LAN emulation is to use ATM's connection oriented fabric to mimic the connectionless nature of legacy LANs. LAN emulation also enables applications on legacy LANs to access ATM-attached servers, workstations, routers, and other network equipment. LAN emulation forwards upper layer protocols across ATM connections without requiring any modifications to legacy software.

As indicated, all the devices on the Ethernet and token rings require no modification. Devices plug into legacy LAN to ATM converters. This is a layer 2 device that accepts native ATM packets and modifies then by adding an ID header and stripping off the frame-check sequence (FCS) and sends them onto the backbone as AAL 5 PDUs (Protocol Data Units)(Jeffries, 1994, p 97). In addressing FDDI, there is no direct ATM LAN emulation. In this case, it requires FDDI frames to be translated into either Ethernet or token ring frames, then converted into ATM cells.

An emulated LAN has two main components: LAN emulation clients (LECs) and a single LAN emulation service (thus it follows a client server model). LEC software can be deployed in the converter or as part of the driver in an ATM-attached network server or other device. The client software has several jobs, one of the most important being the mapping of MAC addresses into ATM addresses. Figure 10 shows a functional block diagram of the ATM host interface for address resolution in LAN emulation.

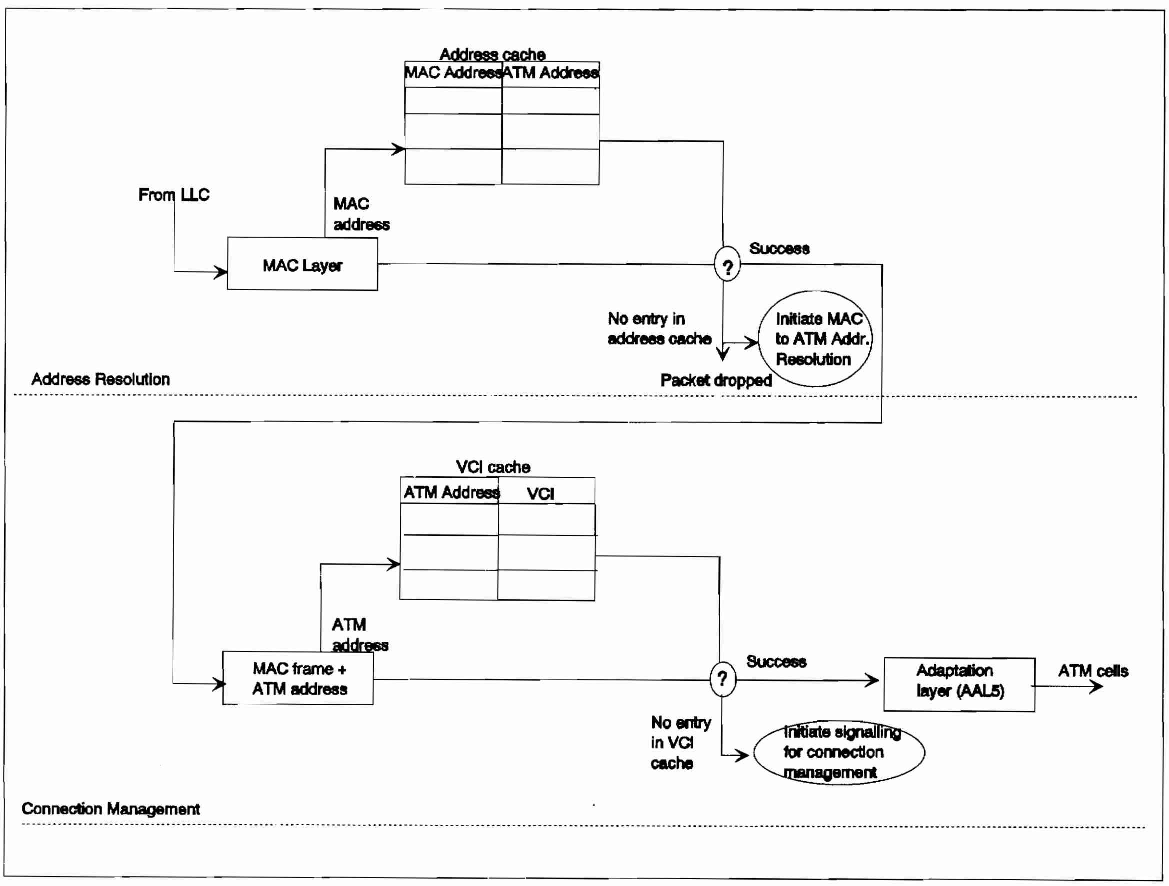


Figure 10. ATM Host Interface.

LAN emulation is a Layer 2 service and is completely independent of upper layer protocols. Thus is can handle common routable protocols such as IPX and TCP/IP. Figure 11 depicts the translation of the protocol stacks for LAN Emulation from an Ethernet host to an ATM host.

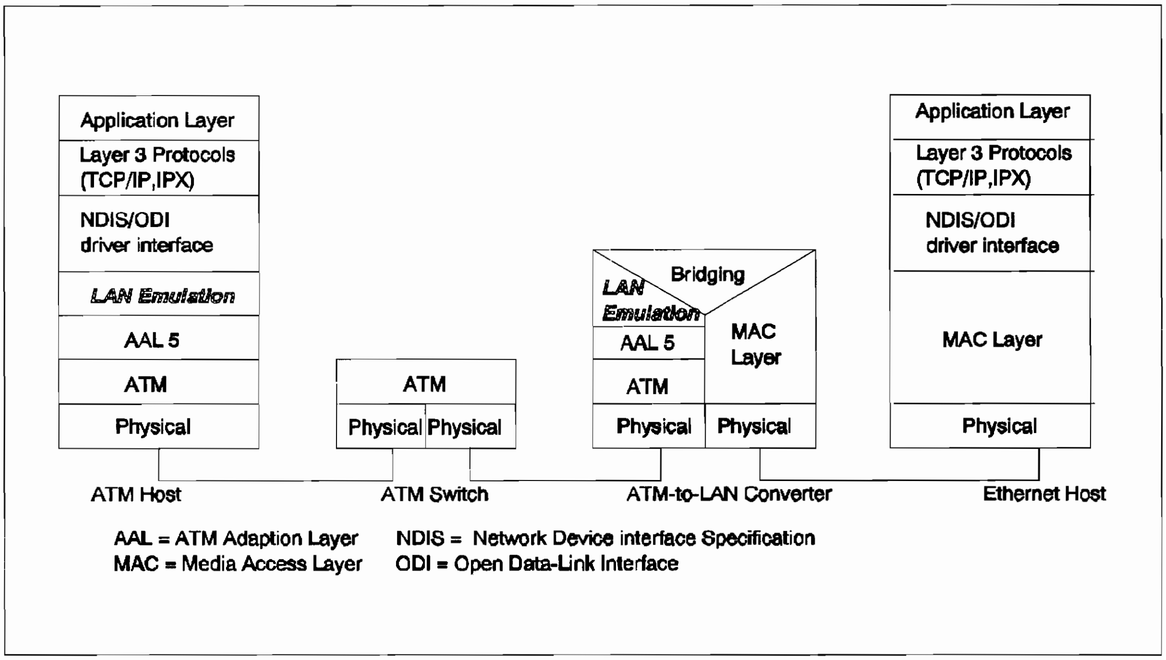


Figure 11. ATM LAN Emulation.

Although the goal of LAN emulation is to allow an ATM network to look like a conventional legacy LAN, it also offers a number of advantages. Today's conventional Ethernet and token ring LANs suffer from distance limitations. In contrast, the LEC can be located anywhere on the ATM switching fabric; it does not need to reside at the same geographic location as the other members of its emulated LAN. The physical connection is used can actually be shared by several hundred emulated LANs. Also, congestion is less of a problem on an emulated LAN. In order to keep conventional shared-media LANs from bogging down, they must be segmented when traffic congestion reaches a certain level. Since most traffic on an emulated LAN reside on independent point to point connections, there is far less congestion.

8.2.2.2 IP over ATM

In a LAN consisting of only ATM switches, it is possible to simplify the protocol stack an run IP directly over ATM. Implementing IP directly over ATM will require translating IP address to an ATM address. The straight forward approach is to maintain a server, referred to as an IP-ATM-ARP Server (Chao, 1994, p 56). The IP-ATM-ARP Server maintains tables than can translate an IP address to an ATM address. IP over ATM encapsulation is shown is in Figure 12.

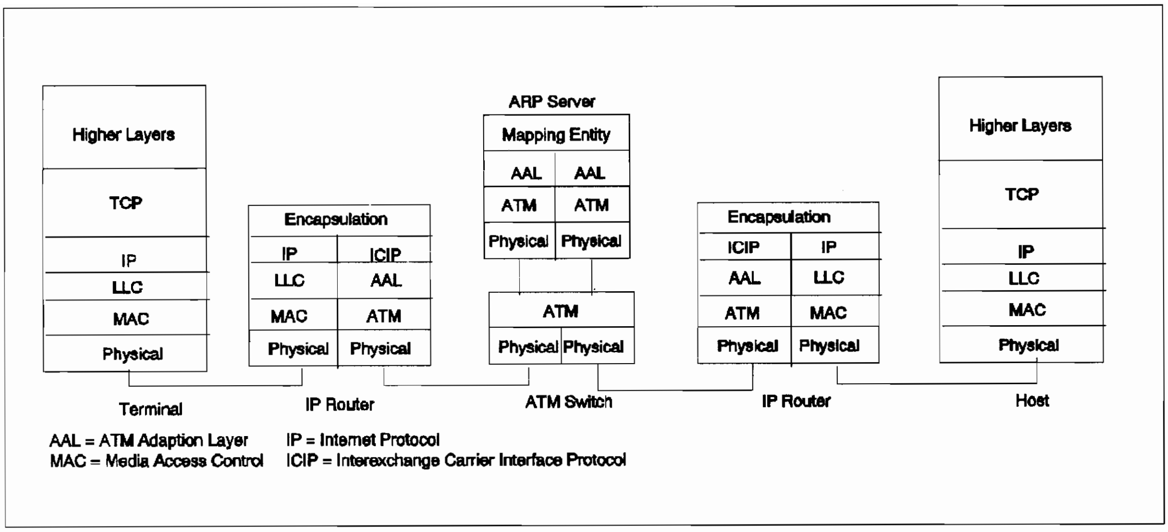


Figure 12. IP over ATM Encapsulation.

Encapsulated IP frames are stored in the payload of an ATM Adaptation Layer 5 convergence sublayer PDU (PDU) for subsequent segmentation and transmission via the ATM network. The address resolution is conducted via the connectionless service of the ARP Servers (Suda, 1994, p 37). The ARP Servers maintain the tables that can translate the addresses. The interaction between the host and the ARP Server can be implemented using a simple query/response protocol (Chao, 1994 p 55). The ATM host interface is the same as that for LAN Emulation as in Figure 10 except that the address cache contains IP addresses rather than MAC addresses. When the host needs to send a packet to a destination IP host, it obtains the corresponding ATM address from the address cache and passes the IP packet and the ATM address to the processing entity that performs the connection management function (Suda, 1994, p 38).

When a new host is added to the network, it goes through a registration process with the ATM network and obtains the ATM address. In order to update the IP-ARP-Server it sends an "add host" message giving its IP and ATM addresses. The IP-ATM-ARP Server updates the IP to ATM address map and allocates a new reserved VCI to the new host and returns a "confirm" message with the new reserved VCI.

8.2.2.3 Network Monitoring in ATM

While nearly all vendors are committed to SNMP, and most to SNMPv2, there is a fundamental and complex problem with motoring ATM networks. Other technologies (i.e. Ethernet and FDDI) contain a two byte "Type" field to identify the network layer protocol associated with the frame. ATM cells have to such field. Since the ATM cells does not identify the protocol of the data carried within the payload, it then becomes necessary to reassemble cell streams in order to make protocol identification. Also, since ATM is a connection-oriented technology, cells are not broadcast across the network. This means there is no common location on the switch to collect data. Vendors do offer graphical monitoring tools which offer functionality including virtual circuit status, cell loss statistics, and PVC setup. More developments still need to be made to further define network management in ATM.

ATM particular advantages come in the form of emerging multi-media applications. ATM provides more flexibility than other technologies in scaling from small to large configurations. Some ATM standards are still emerging. Thus, an ATM solution that is provided by a vendor is a proprietary solution to the incomplete portions of the standard. For designs based on new technologies, the risk for failure is always greater. A diagram of an ATM solution is shown in Figure 13.

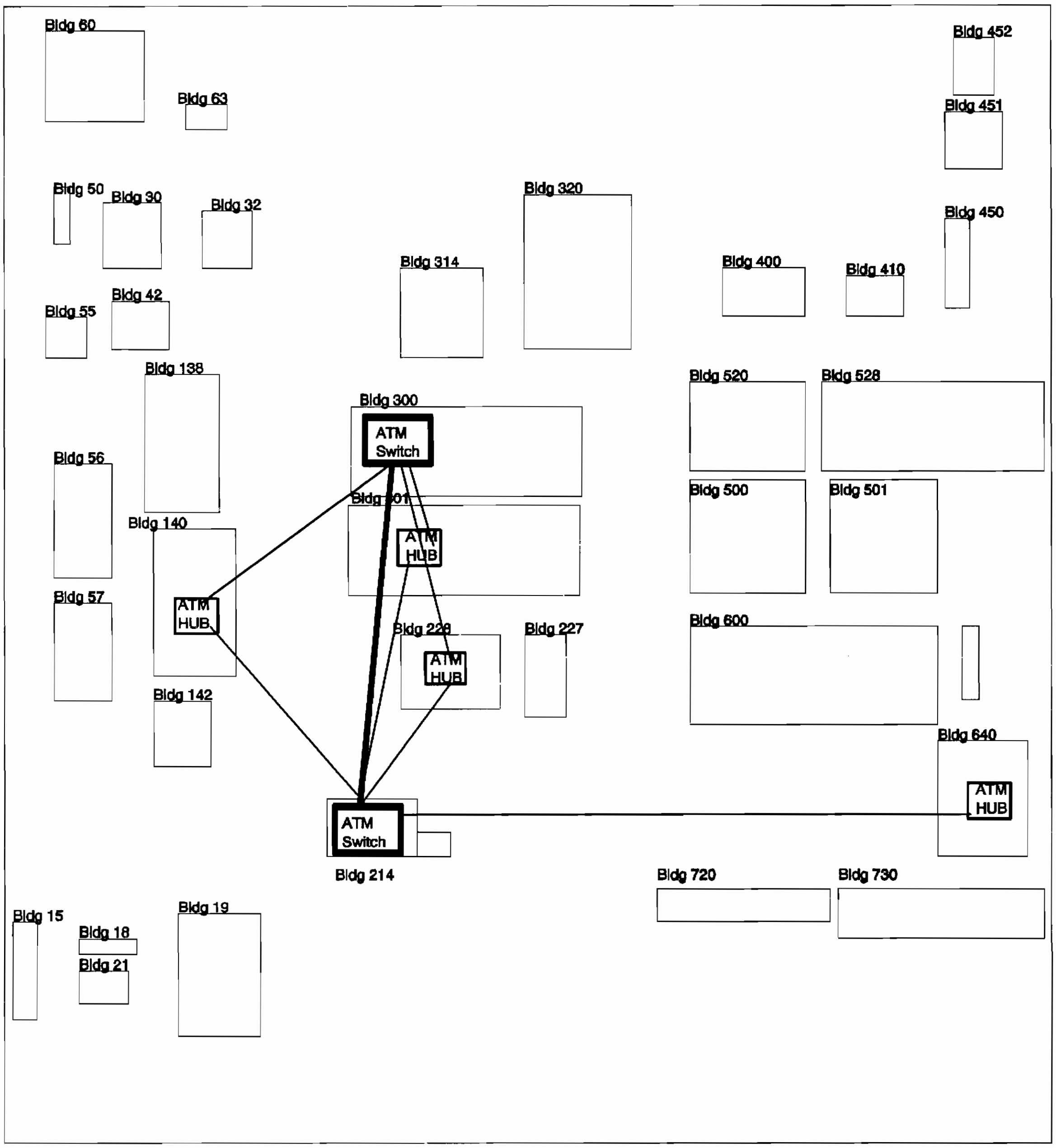


Figure 13. Diagram of ATM Configuration.

The following summaries the technical assessments of an ATM technical solution:

Advantages

- Scaleable Information Rate
- 155 Mbps Bandwidth
- Fiber Optic Cabling
- Transmission of text and Multi-media

Concern and Risk

- Immature Technology
- Emerging Vendor Support
- Incomplete Standard (Proprietary Vendor Solutions)
- Unknown cost due to training, installation and integration of technology.

8.3 Life Cycle Cost Analysis of Technical Alternatives

The cost breakdown structure for the development of life cycle cost for this analysis is show in Figure 14. All contributing cost are addressed, but those with the most significant contribution overall are emphasized.

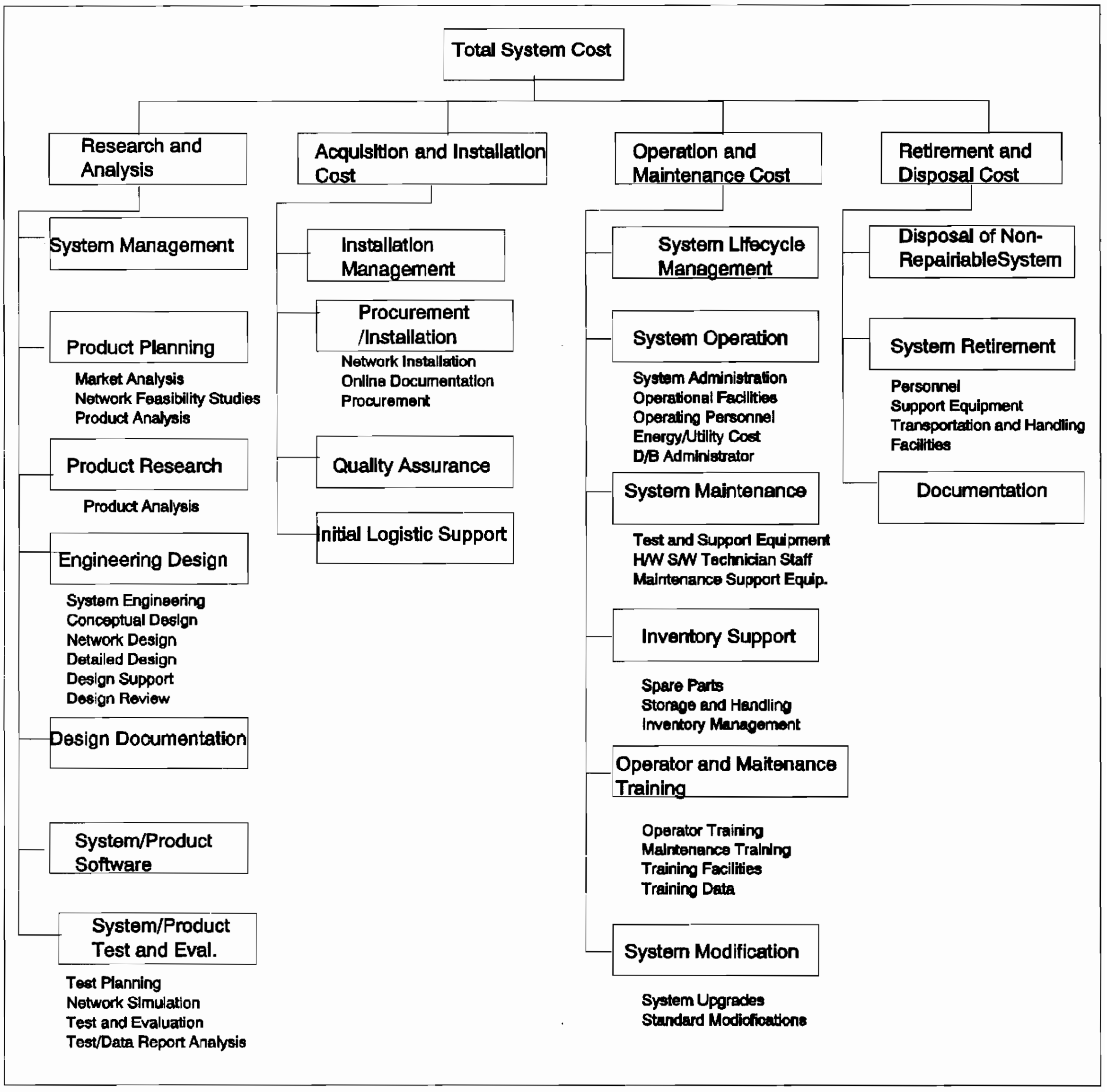


Figure 14. Cost Breakdown Structure.

In both the FDDI and the ATM alternative technical solutions, there are cost associated with Research and Analysis, Acquisition and Installation, Operation and Maintenance, and Retirement and Disposal. It is assumed for this analysis that the Retirement and Disposal Costs are assumed equal.

For this analysis, all Research and Analysis cost are assumed equal since this phase is represented by the DII effort provided to WR-ALC by DISA. Thus the life cycle cost analysis will emphasize the Acquisition and Installation, and the operation and maintenance phases. All dollar values for the life cycle costs over the next five years are reflected as net present value dollars.

Table 1. FDDI Acquisition and Installation 5 Year Cost.

FDDI Technical Alternative — Acquisition and Installation Cost Summary

Program Activity	Cost by Program Year					Total Actual Cost
	Year 1	Year 2	Year 3	Year 4	Year 5	
A. Installation Management	**4,000**	**5,000**	**6,000**	**6,500**	**6,700**	**28,200**
B. Hardware Acquisition	**800,000**	**20,000**	**20,000**	**15,000**	**7,500**	**862,500**
C. Procurement and Installation	**17,000**	**11,000**	**9,900**	**10,000**	**7,500**	**55,400**
1. Network Installation	12,000	6,000	5,500	5,500	4,000	
2. Network Integration	2,500	3,000	2,500	2,500	2,000	
3. Procurement	2,500	2,000	1,900	2,000	1,500	
D. Quality Assurance	**2,500**	**2,500**	**2,500**	**2,500**	**2,500**	**12,500**
E. Initial Logistics Support	**17,000**	**13,600**	**13,000**	**7,500**	**4,750**	**55,850**
1. Training and Equipment	5,000	2,500	2,000	1,500	1,000	
2. Supply Support	11,000	10,000	10,000	5,000	2,750	
3. Test and Support Equipment	1,000	1,100	1,000	1,000	1,000	
Total Acquisition and Installation cost for FDDI Technical Solution	**838,000**	**49,600**	**48,900**	**39,000**	**26,450**	**$1,001,950**

Table 2. ATM Acquisition and Installation 5 Year Cost.

ATM Technical Alternative — Acquisition and Installation Cost Summary

Program Activity	Cost by Program Year					Total Actual Cost
	Year 1	Year 2	Year 3	Year 4	Year 5	
A. Installation Management	**7,000**	**5,000**	**2,200**	**2,000**	**1,900**	**18,100**
B. Hardware Acquisition	**1,200,000**	**50,000**	**20,000**	**8,000**	**7,000**	**1,285,000**
C. Procurement and Installation	**40,000**	**23,250**	**12,200**	**9,500**	**9,750**	**94,700**
1. Network Installation	20,000	12,000	5,000	5,000	5,000	
2. Network Integration	5,000	2,500	1,200	2,000	1,750	
3. Procurement	5,000	1,250	1,000	1,000	1,000	
D. Quality Assurance	**10,000**	**7,500**	**5,000**	**1,500**	**2,000**	**26,000**
E. Initial Logistics Support	**28,000**	**22,750**	**8,750**	**7,220**	**6,200**	**72,920**
1. Training and Equipment	10,000	5,500	3,000	3,000	2,700	
2. Supply Support	15,000	14,250	3,000	2,220	1,550	
3. Test and Support Equipment	3,000	3,000	2,750	2,000	1,950	
Total Acquisition and Installation cost for ATM Technical Solution	**1,245,000**	**108,500**	**39,400**	**3,500**	**3,900**	**$1,400,300**

Table 3. FDDI Operation and Maintenance 5 Year Cost.

FDDI Technical Alternative — Operation and Maintenance Cost Summary

Program Activity	Cost by Program Year					Total Actual Cost
	Year 1	Year 2	Year 3	Year 4	Year 5	
A. System Life Cycle Management	**5,000**	**4,500**	**3,000**	**3,000**	**3,000**	**18,500**
B. System Operation	**227,000**	**257,500**	**282,000**	**302,000**	**325,500**	**1,394,000**
1. System Administration	40,000	45,000	49,000	54,000	60,000	
2. Operational Facilities	7,000	7,500	8,000	8,000	8,500	
3. Operating Personnel	80,000	90,000	100,000	105,000	107,000	
4. Energy/Utility Cost	100,000	115,000	125,000	135,000	150,000	
C. System Maintenance	**95,000**	**82,000**	**87,000**	**91,500**	**98,000**	**453,500**
1. H/W S/W Technician Staff	90,000	80,000	85,000	90,000	97,000	
2. Maintenance Support Equip.	5,000	2,000	2,000	1,500	1,000	
D. Inventory Support	**9,500**	**5,200**	**4,250**	**4,200**	**4,000**	**27,150**
1. Spare Parts	5,000	1,000	0	0	0	
2. Storage and Handling	2,000	2,200	2,500	2,700	3,000	
3. Inventory Management	2,500	2,000	1,750	1,500	1,000	
E. Operator and Maintenance Training	**6,250**	**3,250**	**3,250**	**2,000**	**2,000**	**16,750**
1. Maintenance Training	3,000	2,500	2,500	2,000	2,000	
2. Training Facilities	2,000	0	0	0	0	
3. Training Data	1,250	750	750	0	0	
F. System Modification	**0**	**2,000**	**1,000**	**1,000**	**0**	**4,000**
1. System Upgrades	0	2,000	1,000	1,000	0	
2. Standard Modifications	0	0	0	0	0	
Total Operation and Maintenance cost for FDDI Technical Solution	**333,250**	**349,250**	**376,250**	**403,700**	**432,500**	**1,913,900**

Table 4. ATM Operation and Maintenance 5 Year Cost.

ATM Technical Alternative Operation and Maintenance Cost Summary

Program Activity	Year 1	Year 2	Year 3	Year 4	Year 5	Total Actual Cost
	Cost by Program Year					
A. System Life Cycle Management	**7,000**	**9,000**	**7,000**	**5,000**	**4,000**	**32,000**
B. System Operation	**239,000**	**272,500**	**308,000**	**336,000**	**365,500**	**1,521,000**
1. System Administration	50,000	55,000	65,000	78,000	82,000	
2. Operational Facilities	7,000	7,500	8,000	8,000	8,500	
3. Operating Personnel	82,000	95,000	110,000	115,000	125,000	
4. Energy/Utility Cost	100,000	115,000	125,000	135,000	150,000	
C. System Maintenance	**97,500**	**98,000**	**103,000**	**107,500**	**113,000**	**519,000**
1. H/W S/W Technician Staff	90,000	95,000	100,000	105,000	111,000	
2. Maintenance Support Equip.	7,500	3,000	3,000	2,500	2,000	
D. Inventory Support	**12,000**	**7,700**	**6,250**	**6,200**	**5,750**	**37,900**
1. Spare Parts	7,500	3,500	2,000	2,000	1,750	
2. Storage and Handling	2,000	2,200	2,500	2,700	3,000	
3. Inventory Management	2,500	2,000	1,750	1,500	1,000	
E. Operator and Maintenance Training	**11,550**	**9,500**	**7,500**	**5,000**	**6,000**	**39,550**
1. Maintenance Training	7,550	7,500	5,000	4,000	5,000	
2. Training Facilities	2,000					
3. Training Data	2,000	2,000	2,500	1,000	1,000	
F. System Modification	**0**	**12,500**	**9,500**	**7,000**	**6,500**	**35,500**
1. System Upgrades	0	5,000	4,500	3,000	3,000	
2. Standard Modifications	0	7,500	5,000	4,000	3,500	
Total Operation and Maintenance cost for ATM Technical Solution	**367,050**	**409,200**	**441,250**	**466,700**	**500,750**	**$2,184,950**

There is a considerable difference in the operation and maintenance cost associated with ATM due to the incomplete standard. This increased cost is due to future upgrades to proprietary solutions currently provided by vendors. There is also increased cost due to training of technicians in ATM, where as the current staff is familiar with the FDDI technology.

8.4 Trade-off Analysis

The following analysis is conducted in order to determine the most feasible technological solution. As part of the trade-off analysis, evaluation criteria are established and an analytical equation is developed to facilitate in identifying the proper solution. The evaluation criteria relate directly to the problem statement and to the overall effectivenss fo the implementation. The evalution criteria are also weighted within the equation base on the relative importance to each other.

ATM offers signicifcant price/performance benefits over shared media networking tehcnologies such FDDI because of its parallel processing capabilies allowing it to establish multiple communication paths through its switching fabric simultaneously. Figure 15 shows the relative price vs aggregate bandwidth performance of ATM and FDDI.

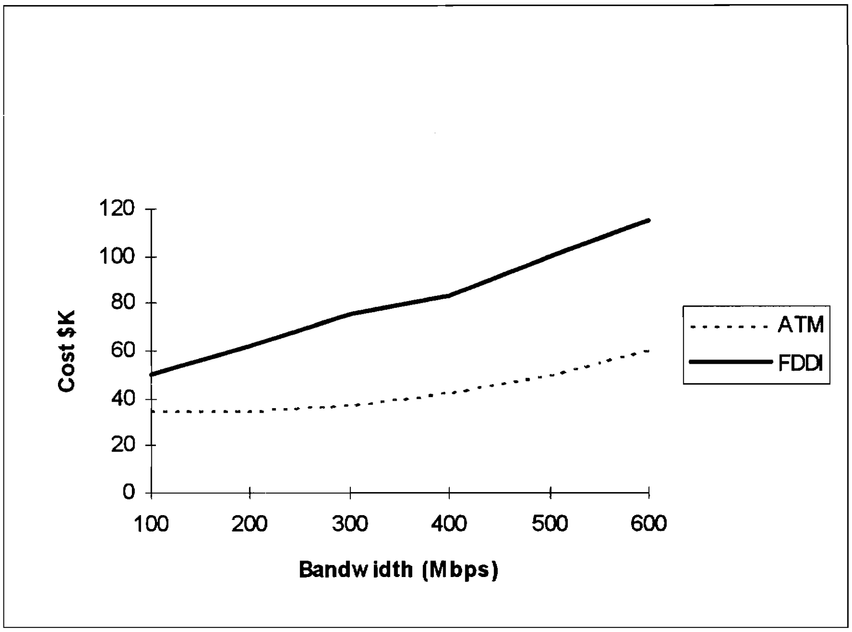


Figure 15. Relative Cost versus Performance Benefits of Alternatives.

The curves in Figure 15 are based on the comparison in cost of a single ATM switch which is capable of support multiple high speed lines simultaneously. In increasing the aggregate bandwidth an FDDI ring, additional cabling and hardware is needed to support additional fiber rings.

From the life cycle cost analysis, the resulting cost showed that implementing an ATM network would result in increased life cycle cost over the next five years, primarily as a result of higher O&M cost. Figure 16 shows the total life cycle cost for each approach over the next five years.

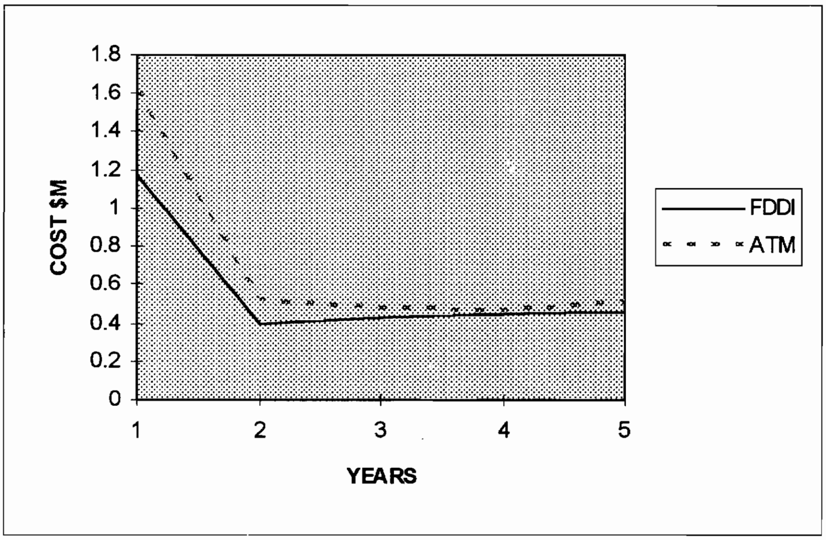


Figure 16. Total Life Cycle Cost Over 5 Years (includes Acquisition and O&M).

In both approaches, the largest cost initially is due to the acquisition of the hardware and installation of hardware and cabling for the network. Particularly in the first two years, ATM has higher cost due to acquisition and O&M. The FDDI cost rise slighted from years 2 through 5. This is due to the fact that additional hardware would be needed to increase bandwidth as traffic increases and the developed of more bandwidth intensive application (i.e. multi-media) progresses.

8.4.1 Trade-off Evaluation Expression

In determining the appropriate technology to pursue for the required expansion of the campus MAN, the following parameters have been identified as evaluation criteria for the overall assessment of each technology based on the previous analysis:

- Meets Existing Requirements (R) - how well the technology is capable of meeting the existing requirements
- Bandwidth (B) - aggregate bandwidth of the implementation
- Expandability (E) - expandability to migrate to other technologies and interfaces
- Life Cycle Cost (C) - overall life cycle cost
- Integration and Re-Use of Existing Infrastructure (I) - simplicity of integrating into existing architecture
- Scaleability of Information Rates (S) - ability to use multiple information rates
- Interoperability (I') - interoperability among other vendors and technologies
- Maturity/Vendor Support (M) - maturity of technology and amount of current vendor support
- Network Manageability (N) - manageability of technology through existing network management applications

Based on the assessments from the previous analysis of the two technologies, each parameter for each technology is ranked on a scale of 1 to 10 based on its compliance to that parameter. The parameters are then evaluated in the following equation to determine the technologies overall assessment rating:

$$\text{Overall Assessment Rating} = 5*R + 3*B + 2*E + 5*C + 3.5*I + 2*S + 5*I' + 4*M + 3*M' \quad \text{Eq. 2}$$

The multipliers in the overall assessment rating equation are determined by the relative importance of the parameter. Thus overall life cycle cost has a higher multiplier than scaleability. The multiplier for each parameter is on a 1 to 5.

Conducting an analysis of the technologies in this format is beneficial in several ways. It give an overall perspective of all the issues surrounding the technologies and the relative importance of each with respect to the overall implementation. The trade-off for each of the parameters for each alternative can be evaluated and compared readily. It also allows for a direct comparison of the overall feasibility for each alternative resulting in a numerical value on a common scale. The assessment equation can be altered and adjusted in order to accommodate different situations and applications. Table 5 gives the rank for each alternative for each parameter and the overall assessment ratings for each alternative.

Table 5. Trade-off Analysis Assessments.

	ATM	FDDI
Requirements (R)	10	10
Bandwidth (B)	10	8
Expandability (E)	9	9
Cost (E)	5	9
Integration (I)	5	9
Scaleability (S)	10	7
Interoperability (I')	5	10
Maturity (M)	4	10
Management (M')	4	10
Overall Rank	213.5	302.5

The values for each of the evaluation criteria from this project are shown Figure 17. From the charts comparisons, it is seen that FDDI offers significant benefits in several areas, particularly maturity and management, over ATM.

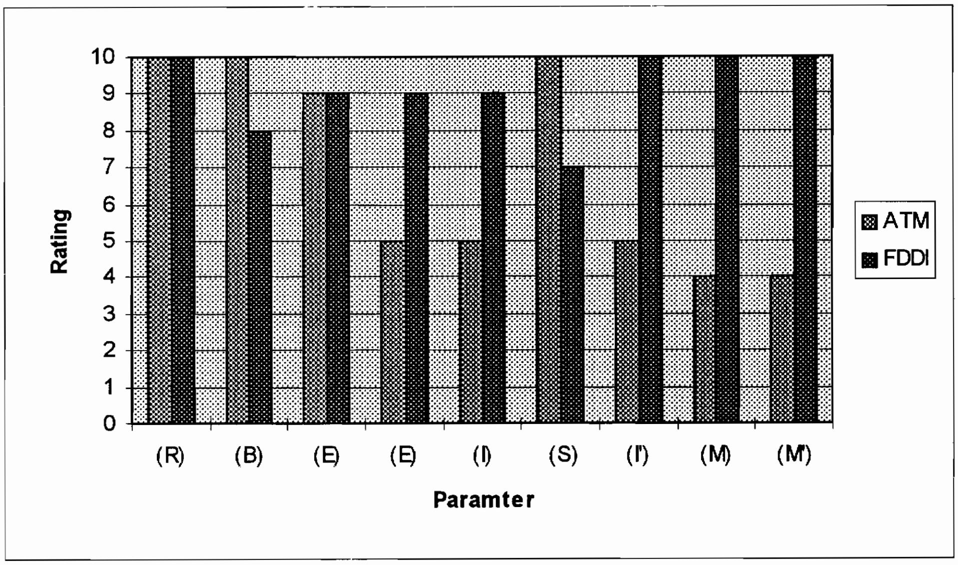


Figure 17. Parameter Ratings for Technical Alternatives.

Figure 17 shows the rating for each technological alternative by each category. Out of a total of 325 total overall assessment points, ATM was evaluated to have 213.5 points and FDDI was evaluated to have 302.5 points. This is primarily because FDDI was assessed to have high values in parameters that had high multipliers.

8.5 Technical Evaluation Conclusions

It has been shown that ATM can provide significant price/performance benefits (acquisition cost) over FDDI. Although increased bandwidth demands can be handled in a flexible manner with an ATM backbone, the maximum available bandwidth available to a user is still limited to the local network bandwidth and throughput is limited by the processing capabilities of the LAN to ATM devices.

There is considerably more O&M cost in providing ATM to this project than to expanding on the existing FDDI infrastructure. The maintenance and operation of a new technology is significantly more costly that the use of a mature technology. With ATM, this is essentially due to the incomplete standard and proprietary solutions currently offered by vendors. All of the ATM standards have not been completed and in a networking environment, interoperability cannot be an option. Considerable software changes will have to be made over the next several years as vendors provide standards compliant software and firmware to the products. Furthermore, the requirements have not proven that ATM is a required function.

The standards issue has become an important concern for the deployment of ATM. With the evolution of networking technologies, the transition to standards based equipment from proprietary solutions has resulted in network downtime, upgrade cost, and hours of work in the replacement of hub modules and NICs (Network Interface Cards)

Upgrading with an FDDI solution result in the following attractive features:

- Meets existing QoS specification.
- reduced 5 year life cycle costs.
- Most easily integrated into the existing communications environment.
- Guaranteed interoperability and network management system compliance.

8.6 Recommended configuration

Through the previous technical assessments of the two technologies, it becomes clear that FDDI represents a better alternative for this project at this point in time. It is recommended that the current FDDI backbone be reconfigured into a dual counter-rotation fiber optic ring. Along with redundancy, this results in the added benefit of eliminating Building 214 as a single point of failure for the MAN. The primary ring of the fiber optic backbone will include buildings 140, 214, 228, 300, and 301. The existing Cabletron MMAC-8 hubs that currently connect the FDDI segments of the will be replaced with 14 slot MMAC Plus hubs. The MMAC hubs that are replaced will be relocated to support the subnetted IEEE 802.3 LANs in buildings that currently require connectivity to the FDDI backbone. The ISN-LAN and ALC-LAN currently support functional areas that will require access to other areas. These functional users require access to sufficient high-speed bandwidth to support electronic data interchange with the migration systems, while still maintaining connectivity to the existing legacy systems. This electronic data interchange includes graphics, engineering drawings, and Computer Aided Design (CAD)/Computer Aided Manufacturing (CAM) drawings.

Ethernet will provide the capability to achieve high-bandwidth connectivity to each functional area or facility from the FDDI backbone. This connectivity will be extended within each building or functional area to the workgroup LANs to support each user. Connectivity to the FDDI backbone via Ethernet will provide each functional user's desktop workstation access to the legacy and migration system applications and will support future requirements.

The concept of operations for the application is based on high-end workstations, using TCP/IP protocols; however, a large number of users now have low-end workstations, such as VT-100s or 8088-based PCs, which do not support the system requirements. The low-end workstations are to be replaced with a standard high-end workstation, with the capability to support the graphical user interfaces and application programming interfaces (API) for the systems, support Ethernet connectivity, support the data protocols for both the migration and legacy systems, and support the future developing standards.

The last focus area that needs to be addressed is Network Management for the infrastructure. This infrastructure is composed of several interconnected and inter-related segments, all of which require a degree of Network Management. These sections include the Point of Presence (POP) for all voice, video and data service, the backbone, the various LANs connecting the backbone to each facility or functional area, the intra-building backbone LANs, the various organizational LANs, the interfaces between each segment, the electronics supporting each segment, and the various network operating systems supporting the LANs. Network Management for these various segments will be upgraded to provide the following capabilities and services:

- Configuration Management to maintain a physical inventory of all network equipment components, system topology, software version control, and network changes.
- Element Management to maintain the status of all elements within the infrastructure, provide for fault isolation, support system trouble-shooting, and system diagnostics.
- Performance Management to provide for system performance monitoring and trend analysis.
- Security Management to provide for overall network security, system audit, password administration, and monitoring security status.

This configuration will provide the near-term infrastructure to support and provide a framework to support future system deployment and to migrate to ATM technology. Network redundancy, backbone LAN bandwidth, and data throughput to support the functional users with connectivity to the demonstration systems and the legacy systems will be supported. In addition, this approach will enable the infrastructure to expand to meet future system requirements. Future network upgrades might be required to support additional systems and applications, such as video teleconferencing and other high bandwidth applications.

8.6.1 VENDOR RATIONALE

Expanding with Cabletron merchandise results in the following benefits:

- High flexibility and migration path to ATM.
- Continuity of vendor merchandise on the campus.
- Gauranteed interoperability among the existing infrastructure equipment.
- Reduced O&M and training cost.

This section describes the rationale for the vendor specific merchandise that is to be used during the detailed design phase of the implementation. The Migration Strategy proposes to implement an infrastructure that will support the requirement for providing a high-speed fiber optic backbone to the base. Currently, the fiber optic backbone and the subnetted systems are configured with Cabletron MMAC-8 hubs and modules. Also, Cabletron Spectrum Command 5000 is network management system in use.

The expansion to the dual ring Fiber Optic backbone provides connectivity to the various functional areas and buildings, computing systems, and migration systems using a combination of switching hubs and other equipment. The infrastructure will provide 100-Mbps service to the existing hubs supporting the backbone and network connectivity to multiple Ethernet LANs in the buildings being added to the backbone. This infrastructure also provides expandability for future migration efforts, such as to ATM if necessary.

The specifications of the Cabletron family of switching hubs, Ethernet modules, Token-Ring modules, and ATM equipment provide an architecture that is easily expanded and scaleable to support future requirements:

- The MMAC Plus contains 14 slots for modules to support combinations of Ethernet, Token-Ring, and FDDI modules.
- The MMAC Plus supports a maximum of 168 Ethernet segments or Token-Ring channels or 28 FDDI channels.
- The MMAC Plus chassis also supports bridging, routing, and switching capabilities and all modules automatically connect to each other, regardless of topology, by integrated switching, routing, or bridging services.

- Supports both packet and ATM cell transfer matrix that allows hub to act as backbone ATM switch with up to 10-Gbps aggregate bandwidth.
- Dedicated bandwidth per port packet switching for Ethernet that can also be managed by HP/Open View, Novell Network Management System, and NV/6000 Network Management System in addition to Spectrum Command 5000 Network Management System.

The existing FDDI network utlizes MMAC hubs and modules and the Cabletron Spectrum Network Management System. Coupled with the rationale described, the cost effective vendor of choice is Cabletron and the MMAC hubs and modules the better choice for completing the upgrade to the base infrastructure. Expanding with Cabletron equipment, as opposed to integrating a new vendor into the infrastructure results in the following:

- Using a single vendor will result in reduced costs associated with operating, administering, and maintaining the infrastructure. Additionally, planning for and implementing a single vendor solution will require less time and will result in less configuration and interoperability problems. Using Cabletron as the primary vendor provides for continuity of hardware and configurations, and ensures the technicians who will be responsible to operate and maintain the equipment, are already trained and available.
- Designing and implementing a single-vendor system is cost effective and practical. Expanding the base backbone using Cabletron products ensures complete interoperability among the devices supporting the fiber optic backbone, the subnetted segments supporting the functional users, and

provides the base with the capability for future upgrades to other technologies. Its will result in a reduced spare parts inventory and result in a higher quality of equipment maintenance. Additionally, being able to reuse the MMAC-8s and modules displaced by the MMAC Plus will result in a reduced cost to implement the Migration Strategy.

The MMAC Plus is fully compatible with the Spectrum Network Management System currently in use. Using the MMAC Plus and modules in conjunction with the redistribution of the MMAC-8s and modules facilitates network administration, configuration and monitoring. The proposed logical configuration of the FDDI backbone and subnets is shown in Figure 18.

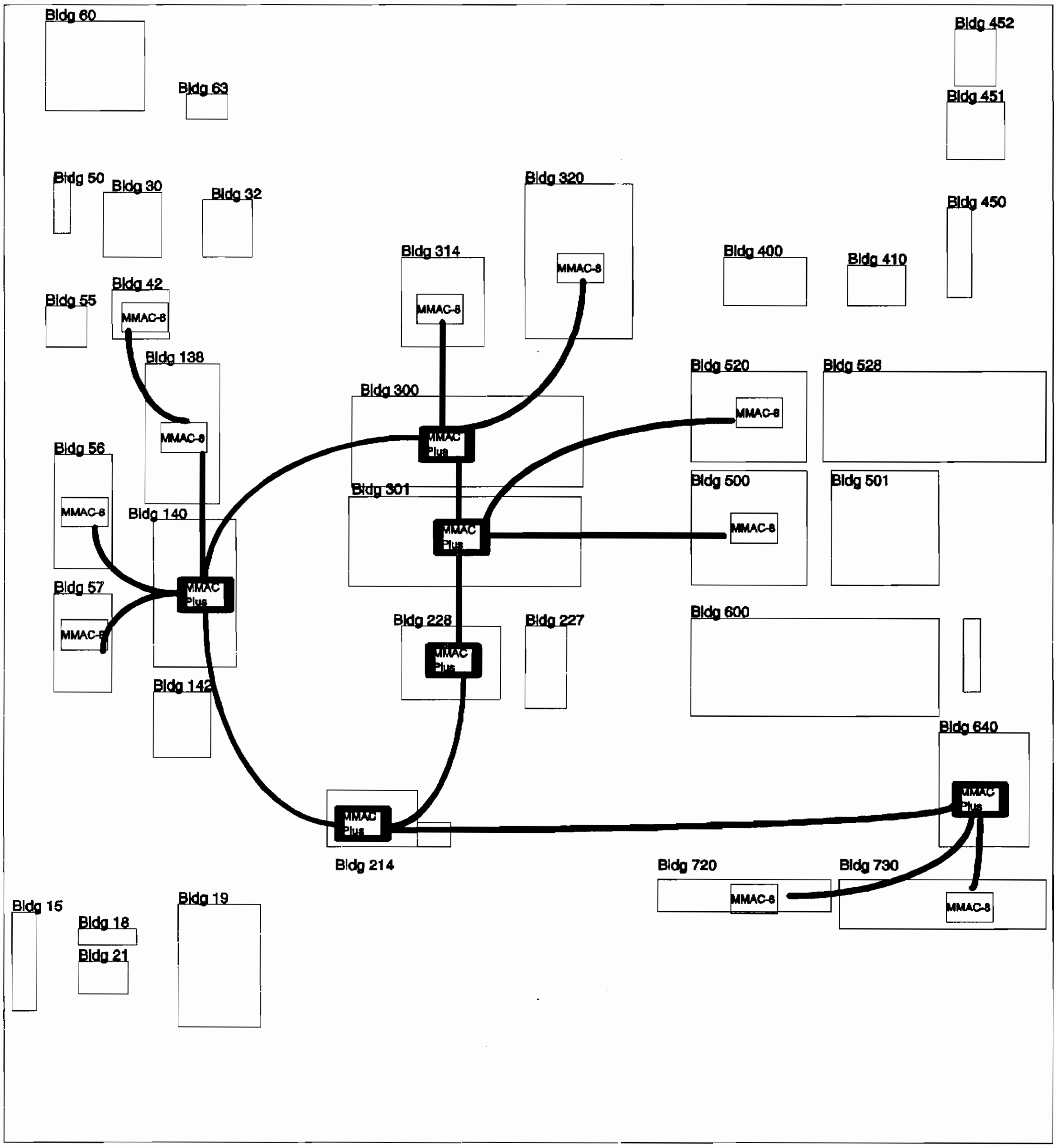


Figure 18. FDDI Ring Topology and Subnets.

9.0 Implementation Plan (Detailed Design)

The infrastructure upgrades require an expanded campus-wide FDDI backbone. This expansion is achieved by reconfiguring the fiber optic connections to Bldgs. 140, 301, and 640 to include them as part of the physical ring as opposed to the current sub-netted configuration from Bldg. 214.

The installed hubs will be capable of supporting a 100 Mbps backbone, extending Ethernet connectivity to all major facilities and functional user workstations, and be capable of supporting an upgrade to ATM, switched Ethernet, or other future technologies. In addition, switched Ethernet capabilities will be provided to the functional users who have been identified as high-capacity users; providing them with dedicated 10 Mbps bandwidth as needed. By building upon the current base of MMAC hubs, a fully redundant FDDI backbone ring will be implemented using Bldgs. 140, 214, 228, 300, 301, and 640 as the backbone.

The buildings currently served by the ALC-LAN Ethernet backbone will also be transitioned to the FDDI backbone. The functional users will retain all of their current capabilities. This will provide the high-speed bandwidth necessary for accessing the applications.

All LANs supporting the functional users will support the communication protocols and network bandwidth required for the transmission of engineering drawings, graphics, and data files.

VT-100 and like terminals will be replaced using workstations that comply with the migration system requirements. All user workstations will be capable of accessing migration and legacy applications, support base-wide backbone connectivity, and serve the computing needs of the user.

Access to the campus POP will remain as currently configured, connecting the Cisco AGS+ router (Robins Firewall) from Bldg. 228 to the IDNX Multiplexer. As off-base connectivity requirements increase due to migration system requirements, the connectivity will be expanded using additional routers and multiplexers. As the requirements increase, it is feasible that additional connectivity requirements may be identified.

Network Management will support the entire technical infrastructure, from the DISN POP to each Ethernet LAN at the functional organizational areas.

9.1 Cable Plant Installations

There are many considerations in implementing a network. The most important is arguably the cable plant. The cable plant is typically the largest cost in a network design. The plan is to install composite fiber cables of 12 strand multimode fiber and 6 strands of single mode fiber where new fiber installations are required. Multi-mode fiber is not expected to support transmission speeds above 155 Mbps at 2 km. Single mode fiber is expected to support future transmission speed developments up to OC-48. The use of fiber optics between buildings is an optimal choice because it is not effected by outside interference such as lighting or magnetic flux interference, and can span further distances. Newer, faster technologies are most often introduced over fiber optics. The most expensive cost in cable installations is the actual digging of trenches and the laying of conduit. For this reason, it is recommended that more fiber optic cable than is currently needed be installed.

It may appear that it would make sense to bypass multi-mode fiber and use single mode exclusively. The reason that single mode is not used as much is due to the cost the electronic required to drive it. Single mode electronics are typically three times more expensive than multi-mode electronics.

9.2 Transition Phases

The architecture can be phase-implemented to support the migration strategy for upgrading the technical infrastructure to support the upgrade with minimal disruption to the functional areas.

Phase 1. Expand the backbone to a fiber optic ring to include Bldgs. 140, 301, and 640, upgrading to MMAC Plus hubs.

Phase 2. Remove the ISN-LAN concentrators and node equipment supporting the current ISN-LAN system to Bldgs. 46, 47, 48, 49, 54, 81, 83, 50, 56, and 125. Leave the multi-mode fiber optic cabling in place, installing MMAC hubs. The MMAC hub Bldg. 56 would be connected to Bldg. 214 providing FDDI connection. Bldg. 125 will be hubbed from Bldg. 140.

Phase 3. Disassemble the ALC-LAN Ethernet connectivity and connect these users to the expanded FDDI backbone described in Phases 2 and 3 using IEEE 802.3 compliant LANs.

Phase 4. Upgrade the Network Management System. The Cabletron Spectrum Command 5000 system will be upgraded to support complete network management capabilities.

Phase 5. Expand the DISN POP to support the future systems and applications as appropriate.

Phase 6. Upgrade of the functional user workstations to a standard functional workstation, or to new 486 workstations will occur on a schedule developed by the integration contractors for each migration system.

9.3 Maintenance Concept

WR-ALC currently has an maintenance organizational structure in place. Each of the functional areas on the post have a LAN administrator who is responsible for the network supporting their area up to the hub supporting their network. The CSC group is responsible for the primary hubs supporting the campus wide MAN and the devices supporting of base long-haul communications. In the event of the hub chassis failure or any of the supporting modules, a spares inventory keeps 2 spares for every chassis and module that is in support of the infrastructure. In the event of software interoperability problems or hardware problems, Cabletron provides 24 hour immediate technical support by providing personnel to provide support directly on the base.

The MMAC-Plus chassis and modules support the 98.8%/month Quality of Service requirement by supporting a Mean Time Between Failure Rate (MTBF) of >200,000 hours (8770 hrs = 1 yr.) and a Mean Corrective Time (Mct) of < 1 hour.

9.4 Acquisition Cost

Following is the acquisition cost associated with the purchase of completing phase one of the implementation. The hardware cost are broken down by buildings and is detailed in Appendix I. The cost to upgrade the Network Management System to support the reconfiguration is included in Phase 1.

Phase I addresses the expansion of the WR-ALC base backbone and establishment a dual fiber optic ring through the upgrade of hubs to connect Bldgs. 140, 301, and 640 to the existing fiber optic base backbone (Bldgs. 214, 228, and 300). Cable must be run from Bldg. 300 to 301, and from Bldg. 301 to 140. Additionally, the existing Cabletron MMAC-M8FNB hubs in each of the buildings should be upgraded to MMAC-Plus to ensure that access to migration and legacy applications will be fully supported without requiring further enhancements.

Fiber Optic Cable Cost:	$	39 K
Six MMAC Hubs & Modules Cost:	$	752 K
Labor Cost:	$	47 K
TOTAL:	$	838 K

9.5 Schedule of Activities

Following is a schedule of the remaining integration activities up to the deployment of the JEDMICS Automated System Demonstration. In order to illustrate the activities, a detailed gamut chart is provided on the following pages. It can be seen that there is a significant coordination of activities that must occur in order to have a timely demonstration.

ID	Task Name	April Apr	May May
1	**Develop Installation Plan**		
2	Schedule network downtime		
3	Notify network staff and users		
4	Schedule access to specific locations		
5	Coordinate with WR-ALC directorates		
6	Coordinate with Customers for downtime and unavailability		
7	Coordinate with Facilities Engineers		
8	Prepare for Computer and Associated H/W Installation		
9	Identify secure storage facilities for network equipment		
10	Identify installation team office area		
11	Coordinate for building access		
12	Prepare equipment closets		
13	Prepare for Media/Cable Installation		
14	Identify and tag existing cable.		
15	Prepare and Identify Training Requirements		
16	**Develop Transition Plan**		
17	Describe Hardware Installation description		
18	Describe Software Installation description		
19	Describe Network Management and software description		
20	Describe Coordination of installation activities.		
21	Perform configuration and performance verification.		
22	**Training Plan**		
23	Identify necessary training curriculum		
24	**Develop O&M Plan**		

ID	Task Name	April	May
		Apr	May
24	**Develop O&M Plan**		
25	Prepare organizational plans		
26	Prepare organizational policy		
27	Prepare organizational procedures		
28	Conduct user assessment		
29	Conduct technical assessment		
30	Develop Lessons learned		
31	**Develop Test and Certification Plan**		
32	Conduct Configuration Management		
33	Prepare Infrastructure Topology Diagram		
34	Write Network Management Documentation		
35	**Perform Contractor Testing**		

ID	Task Name	April	May
		Apr	May
39	Conduct Optical Time Domain Reflectometer (OTDR).		
40	Conduct End to End Power Check		
41	Validate Cable Plant		
42	Conduct Equipment Test		
43	Simulate Stress Test		
44	Conduct Dynamic Network Tests		
45	Conduct Software Testing		
46	Validate Spectrum Network Management		
47	**User Verification**		
48	Verify Connections to equipment		
49	Verify Previous LAN Connectivity		
50	Verify Communication Software by Type		

9.6 Installation and Test Plan

The following section represent an outline for identifying task and milestones toward developing to the ultimate goal of customer satisfaction and a fully operational LAN/MAN.

- Conduct building survey
- Perform cable run mapping and document findings
- Document building requirements
- Design building configuration
- Plan the building preparation
- Perform Cable runs
- Perform cable continuity checks
- Plan hardware/software installation
- Install and test hardware/software
- Develop release information profile
- Monitor network activity during normal hours for two weeks.

9.6.1 Installation Plan

Basic procedures for implementation are as follows:

1. Inventory and record material shipped

2. Stage material

3. Begin target installation

    - install hubs and associated modules

    - assign cross connects at patch panels

- Verify Equipment/Electrical Rooms

  Schedule communications equipment room access;

  determine need for asbestos protection/scheduling;

  Determine current HVAC information (Power, Heating and A/C, Lighting, and door opening requirements);

  Obtain communications room dimensions and drawings;

  Equipment room contents;

  - Number and type of racks;
  - Cable entry;
  - Excess cable entry/exit space;
  - UPS locations;
  - patch panels;
  - other equipment;
  - Used for storage;
  - Obtain mounting rack dimensions;
  - begin test and certification/identifying crisis to network users
  - receive project sign-off

9.6.2 Test Plan

A series of post-installation test must be run to insure the physical layer integrity and network compliance with applicable standards. These test must consist of:

1. Static measurement to be taken of coaxial cable using a Time Domain Reflectometer (TDR). These measurement establish base line references of cable terminations, impedance mismatching and physical length.

Active physical layer components will be tested by dynamic node emulation, simulating an IEEE 802.3 data communications environment. Communication simulators and analyzers will test all components ports for packet passing integrity throughout the logical network.

2. Static measurements must be taken of the fiber optic strands and cable segment using an Optical Time Domain Reflectometer (OTDR). These measurements will establish base line references of inherent manufacturing characteristics, attenuation and signal loss and physical length.
3. End to end power loss must be measured across terminated fiber optic strands.
4. Continuity checks on traditional solid or stranded core cabling must be performed using standard ohmmeter or equivalent to test path and connector termination integrity.
5. The network must be fully analyzed under a simulated stress test in operating at 50% of band utilization.

9.6.2.1 System Certification

Standard certification verifies that the network conforms to the applicable industry standard and that the performance of the physical layer was fully exercised, tested and operational at the time of acceptance subsequent to completion of the installation phase. This also includes:

1. Listing of the as-built cabling and components installed.
2. Recording of the dynamic test results, both data communication simulation and the real time photographs showing the TDR measurement of the individual cable segments.
3. Topology diagram depicting the network configuration.

10.0 Conclusions

The result of this paper has shown a practical application of evaluating two technologies in determining the optimum approach to meeting the evolving telecommunication needs of an existing campus network. This same approach can be used in order to successfully develop the upgrades in other situations.

This paper has successfully demonstrated the DII process Site Environment survey through Migration Strategy Planning and finally through Implementation Planning. The assessment of Fiber Distributed Data Interface and Asynchronous Transfer Mode presented a practical method of evaluating different technological solutions in order to determine the most feasible and cost effective solution for upgrading the campus backbone (MAN). Asynchronous Transfer Mode was shown to have promise in providing significant cost/performance benefits over FDDI, but due the fact that it is an emerging technology and it has an incomplete standard that vendors are currently offering proprietary solutions for, its was shown that FDDI was the appropriate technological solution at this time. The mature and proven standard made FDDI the recommended solution.

Several issues need to be addressed in the future before ATM becomes the technology of choice for LAN and MAN environments. ATM's fast packet circuit switching technology should make it the inter-networking solution of the future when the standard is fully developed and demonstrated and when economies of scales are reached.

11.0 Future Considerations

The process of evaluating the network configuration does not stop with the implementation of the proposed design. After initial deployment of the system, the design configuration should be monitored and analyzed to optimize the network implementation. Techniques should be investigated alleviate network traffic "bottle necks" and heavy traffic segments. The network should continually be monitored through the use of the Spectrum Command 5000 Network Management System and the industry should be continually be monitored to determine if and when new technologies should be pursued.

11.1 Hybrid FDDI/ATM Solution

The current solution is to install a dual fiber optic ring with the use of MMAC-Plus network hubs. This network topology and these hubs provide an easily accessible migration path to ATM. ATM should continue to be investigated as the standards near completion and as economies of scale make it a more attractive network solution.

When the current FDDI backbone saturates, installing ATM switches in parallel between all hubs, yielding the topology shown in Figure 20, provides redundancy for both the FDDI and the ATM portions of the MAN. ATM should also be investigated as to its viability for the on/off base point of presence. With the use of SONET(Synchronous Optical Network), information transfer rates of 622 Mbps (OC-12) can be achieved for long haul communications.

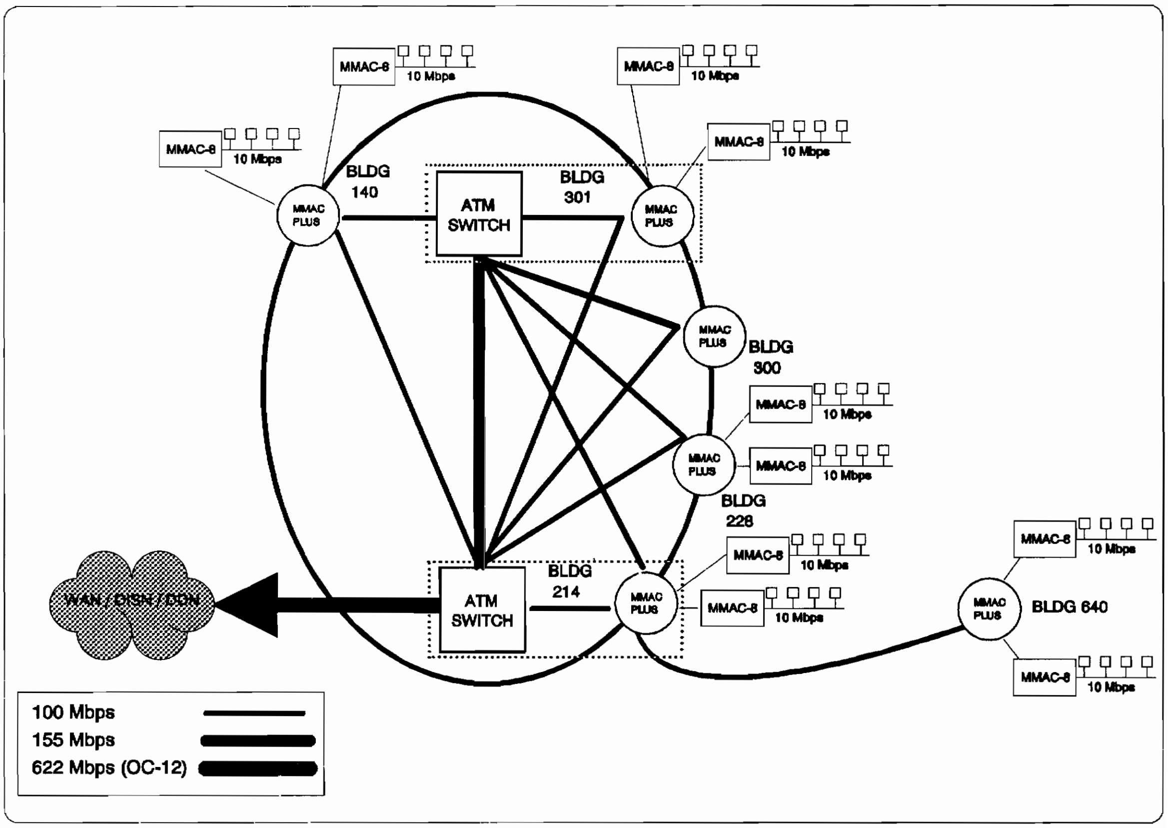


Figure 20. Hybrid FDDI/ATM Solution.

12.0 References

1. Chao, H. Jonathan "IP on ATM Local Area Networks" IEEE Communications. (August 1994), 52-59

2. Fischer, Wolfgang "Data Communications Using ATM: Architectures, Protocols, and Resource Management" IEEE Communications. (August 1994), 24-33

3. Jeffries, Ron "ATM LAN Emulation: The Inside Story. Data Communications" (September 1994) pgs 95-100

4. King, Steven "Switched Virtual Networks" Data Communications. (September 1994), 66-80

5. Minoli, Daniel Telecommunications Technology Handbook. Artech House, Inc, 1991

6. Stallings, William Local Networks. MacMillan Publishing Company, 1990

7. Schwartz, Mischa Telecommunication Networks. Addison-Wesley Publishing Company, 1991

8. Suzuki, Toshikazu "ATM Adaption Layer Protocol" IEEE Communications. (April 1994), 80-83

9. Suda, Tatsuya "Connectionless Service for Public ATM Networks" IEEE Communications. (August 1994), 34-42

10. Warner, Peter "Connecting with ATM" Byte (October 1994) pgs 17-20

Appendix I

Below list the procurement of hubs and modules by building for phase I.

Bldg. 214

QTY	PART NUMBER	DESCRIPTION	COST
1	9C114	14 Slot MMAC-Plus Chassis	$ 4,990
1	9C300-1	Environmental Module	$ 2,995
2	9C214-1	MMAC-Plus Power Supply	$ 6,990
1	9F106-02	FDDI Repeater Module	$ 2,995
2	FPIM-00	FDDI Port Interface Module	$ 1,500
4	9E106-06	6 Port Ethernet Switching Module	$49,980
24	EPIM-F2	Ethernet Port Interface Module	$ 5,880
1	94116-01	FDDI Bridge/Router Board	$15,000
		Total	$90,330

Bldg. 228

QTY	PART NUMBER	DESCRIPTION	COST
1	9C114	14 Slot MMAC-Plus Chassis	$ 4,990
1	9C300-1	Environmental Module	$ 2,995

2	9C214-1	MMAC-Plus Power Supply	$ 6,990
1	9F106-02	FDDI Repeater Module	$ 2,995
2	FPIM-00	FDDI Port Interface Module	$ 1,500
4	9E106-06	6 Port Ethernet Switching Module	$49,980
24	EPIM-F2	Ethernet Port Interface Module	$ 5,880
		Total	$75,330

Bldg. 300

QTY	PART NUMBER	DESCRIPTION	COST
1	9C114	14 Slot MMAC-Plus Chassis	$ 4,990
1	9C300-1	Environmental Module	$ 2,995
2	9C214-1	MMAC-Plus Power Supply	$ 6,990
1	9F106-02	FDDI Repeater Module	$ 2,995
2	FPIM-00	FDDI Port Interface Module	$ 1,500
13	9E133-36	Ethernet MicroLAN, w/3x12 port Telco	$194,935
		Total	$214,405

Bldg. 301

QTY	PART NUMBER	DESCRIPTION	COST
1	9C114	14 Slot MMAC-Plus Chassis	$ 4,990
1	9C300-1	Environmental Module	$ 2,995
2	9C214-1	MMAC-Plus Power Supply	$ 6,990
1	9F106-02	FDDI Repeater Module	$ 2,995
2	FPIM-00	FDDI Port Interface Module	$ 1,500
13	9E133-36	Ethernet MicroLAN, w/3x12 port Telco	$194,935
		Total	$214,405

Bldg. 140

QTY	PART NUMBER	DESCRIPTION	COST
1	9C114	14 Slot MMAC-Plus Chassis	$ 4,990
1	9C300-1	Environmental Module	$ 2,995
2	9C214-1	MMAC-Plus Power Supply	$ 6,990
1	9F106-02	FDDI Repeater Module	$ 2,995
2	FPIM-00	FDDI Port Interface Module	$ 1,500
4	9E106-06	6 Port Ethernet Switching Module	$ 49,980

24	EPIM-F2	Ethernet Port Interface Module	$ 5,880
		Total	$ 75,330

Bldg. 640

QTY	PART NUMBER	DESCRIPTION	COST
1	9C114	14 Slot MMAC-Plus Chassis	$ 4,990
1	9C300-1	Environmental Module	$ 2,995
2	9C214-1	MMAC-Plus Power Supply	$ 6,990
1	9F106-02	FDDI Repeater Module	$ 2,995
2	FPIM-00	FDDI Port Interface Module	$ 1,500
4	9E106-06	6 Port Ethernet Switching Module	$ 49,980
24	EPIM-F2	Ethernet Port Interface Module	$ 5,880
		Total	$ 75,330

Spectrum Network Management

QTY	PART NUMBER	DESCRIPTION	COST
1	SM-CSI1012	FDM Management Module	$ 1,000

1	SM-CSI1031	MMAC Plus Management Module	$ 1,000
1	SM-CSI1030	MMAC-Plus Support for MicroLAN Module	$ 1,000
1	SM-CSI1004	MMAC-Plus Support for EMM	$ 1,000
1		MMAC-Plus Support for FDDI Repeater	$ 1,000
1		MMAC-Plus Support for EVM Module	$ 1,000
		Total	$ 6,000

Appendix II - List of Acronyms

Acronym	Description
ACN	AFMC Classified Network
ACU	Attachment Control Unit
AFB	Air Force Base
AFMC	Air Force Materiel Command
AFNET	Air Force Integrated Digital Telecommunications Network
AFIN	Air Force Internetwork
ALC	Air Logistics Center
ARP	Address Resolution Protocol
ASD	Automated Systems Demonstration
async	Asynchronous
AUTODIN	Automated Digital Network
ATM	Asynchronous Transfer Mode
CAD	Computer Aided Design
CALS	Computer-Aided Acquisition and Logistic Support
CDDI	Copper Distributed Data Interface
CDR	Commander
CFI&I	Center for Integration and Interoperability
CIM	Corporate Information Management
CNN	Cable News Network
CSC	Customer Service Center
DBDQ	Dual Bus Dual Queue
DCO	Dial Central Office
DDN	Defense Data Network
DII	Defense Information Infrastructure
DISA	Defense Information Systems Agency
DISN	Defense Information System Network
DMC	Defense Megacenter
DMS-AF	Defense Message System - Air Force
DoD	Department of Defense
DSN	Defense Switched Network
DUSD(L)	Deputy Under Secretary of Defense (Logistics)
ECS	Electronic Collocation System
EI	Enterprise Integration
e-mail	electronic mail
FDDI	Fiber Distributed Data Interface
FEP	Front-End Processor
FTP	File Transfer Protocol
GOSIP	Government Open Systems Interconnect Profile
GUI	Graphical User Interface
H/W	Hardware
IEEE	Institute of Electrical and Electronic Engineers
IP	Internet Protocol
ISN-LAN	Information Systems Network LAN

Acronym	Description
JEDMICS	Joint Engineering Data Management Information Control System
JLSC	Joint Logistics Support Command
LAN	Local Area Network
LSOC	Logistic Support Operations Center
MAN	Metropolitan Area Network
MMAC	Multiple Media Access Center
MS-DOS	Microsoft - Disk Operating System
NIU	Network Interface Unit
PC	Personal Computer
POP	Point of Presence
QoS	Quality of Service
RAM	Random Access Memory
RF	Radio Frequency
S/W	Software
SNMP	Simple Network Management Protocol
TAFIM	Technical Architecture Framework for Information Management
TCP/IP	Transport Control Protocol / Internet Protocol
WAN	Wide Area Network
WR-ALC	Warner Robins Air Logistics Center