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SWITCH CONFIGURATION FOR MIGRATION TO OPTICAL FIBER NETWORK

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ABSTRACT

The intent of this study is to investigate the migration of an Ethernet LAN segment to fiber optics. At the present time it is proposed to support an Fiber Distributed Data Interface (FDDI) backbone and to upgrade the VAX cluster to fiber optic interface. Possibly some workstations will have an FDDI interface. The remaining stations on the Ethernet LAN will be segmented.

The rationale for migrating from the present Ethernet configuration to a fiber optic backbone is due to the increase in the number of workstations and the movement of applications to a windowing environment, extensive document transfers, and compute intensive applications.

SUMMARY

The Computer Aided Design/Computer Aided Engineering (CAD/CAE) graphics network at Kennedy Space Center is composed of several Local Area Networks (LAN). These LAN's are interconnected through either bridges or routers. At present this LAN is an Ethernet network. The design/engineering workstations are various Intergraph and Digital Equipment Corporation products, mainly. The host is a VAX cluster and there are several Intergraph servers, for plotting/printing/disk.

The rationale for migrating from the present Ethernet configuration to a fiber optic backbone is due to the increase in the number of workstations and the movement of the applications to a windowing environment, extensive document transfers, and compute intensive applications.

In a NASA/KSC report presented in 1988 the Ethernet utilization was under 5% and there were only fourteen (14) Intergraph workstations on the Headquarters LAN. At present utilization of 60-70 % has been observed in short bursts and 30-40 % averaged over longer time periods. There are presently 58 workstations on the NASA/KSC HQ LAN.

The proposed solution is to use intelligent switches. There are various configurations for high speed intelligent switching bridges. They are used by to bridge multiple LAN's, either FDDI, Ethernet, Token Ring or others. The intelligent switch offers many advantages over shared channel LAN's. The advantages include an increase in the bandwidth, latency (propagation delay) reduction, an increase in connectivity, and better traffic management.

This configuration should also increase throughput due to the Ethernet LAN segmentation and the installation of FDDI controllers for the VAX cluster, various Intergraph servers, and several VAX workstations which have a high workload. One also has the option to privatize Ethernet workstations, if the load demands. It should also be noted that other developers have reported that until all workstations are upgraded to FDDI a sizable increase in throughput is usually not recognized, this is due not only to the 10 Mb/s output of the Ethernet controller, but applications are not taking advantage of the higher bandwidth available from FDDI.

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1. INTRODUCTION

The Computer Aided Design/Computer Aided Engineering (CAD/CAE) graphics network at Kennedy Space Center is composed of several Local Area Networks (LAN). These LAN's are interconnected through either bridges or routers. At present this LAN is an Ethernet network. The design/engineering workstations are various Intergraph and Digital Equipment Corporation products, mainly. The host is a VAX cluster and there are several Intergraph servers, for plotting/printing/disk.

The workstations use the VAX cluster for their work environment. There are various protocols on the LAN, mainly Transport Control Protocol/ Internet Protocol (TCP/IP) and DecNet, with some XNS (Intergraph protocol).

The intent of this study is to investigate the migration of the Headquarters Building portion of the LAN to fiber optics. At the present time it is proposed to support an Fiber Distributed Data Interface (FDDI) backbone and to upgrade the VAX cluster and Intergraph servers to a fiber optic interface. Possibly some workstations will have an FDDI interface.

In the sections that follow, the following items will be discussed. A review of the NASA/KSC CAD/CAE graphics network configuration, rationale for migration, Ethernet and FDDI principles and nomenclature, intelligent switch concepts, structured cabling and resultant configuration, and presentation of the proposed LAN re-configuration.

2. NASA/KSC CAD/CAE GRAPHICS NETWORK CONFIGURATION

The NASA/KSC CAD/CAE graphics network (1) configuration is composed of a VAXcluster utilizing a Star Coupler tying together a VAX 11/780, VAX 6000-610, and a VAX 6000-510. The VAX 780 and VAX 6510 are to be replaced with an ALPHA 7610 AXP and an ALPHA 4000 AXP (fig. 1). It has not been decided whether the host machines that are presently on-line will be removed are kept in the cluster. The VAX cluster is interfaced to the workstation environment through an Ethernet LAN, and by Bridges/Routers to workstations that are not situated at the Headquarters building (fig. 2).

The NASA/KSC CAD/CAE LAN presently provides connectivity for the CAD/CAE workstations, which are Intergraph, DEC, and PC's. The network communicates between HQ's, O&C, EDL, CIF, and the Merritt Island Courthouse (MICH) on Broadband Communication Distribution System (BCDS) Channel FM1. There is also a gateway to NSI-DECnet network.

There are several DEC workstations in the Mechanical Engineering area and Boeing has a DEC workstation. These are VAXstation 4060's and 3176's.

The Headquarters CAD/CAE LAN is a single segment Ethernet network and their is presently an FDDI fiber optic ring for the Kennedy Metropolitan Area Network (KMAN). KMAN is to provide connectivity to other sites (in the future) and presently to off-KSC sites.

3. RATIONALE FOR MIGRATION TO FDDI

The rationale for migrating from the present Ethernet configuration to a fiber optic backbone is due to the increase in the number of workstations and the movement of the applications to a windowing environment, extensive document transfers, and compute intensive applications.

In a NASA/KSC report (2) presented in 1988 the Ethernet utilization was under 5% and there were only fourteen (14) Intergraph workstations on the Headquarters LAN. At present utilization of 60-70 % has been observed in short bursts and 30-40 % averaged over longer time periods. There are presently 58 workstations on the NASA/KSC HQ LAN.

This is then the rationale for obtaining an increase in bandwidth to relieve present congestion and provide the capabilities for future growth. It should be noted that in network communications terminology bandwidth is the amount of data that can be transmitted over a channel in bits/second. This is a different definition than used in electrical engineering terminology.

There are several alternatives for providing greater bandwidth for the CAD/CAE LAN. One is through segmentation, this is a reconfiguration of the LAN network into segments whereby one tries to keep traffic local to the segment and only obtain access to other segments if needed. This results in usage of Bridge/Routers to connect the various segments. Propagation delay will be increased every time a Bridge/Router is introduced into the network. Propagation delay is the amount of time between the time the message is sent from the source to being received by the intended destination. In the LAN being investigated it is presumed that most traffic is between the workstations and the VAXcluster, thereby segmenting would not alleviate the problem to a great degree, since the channel would be utilized between the workstation and the VAXcluster. It can be concluded that poor performance of the LAN under consideration is due to inadequate channel bandwidth and hence a network utilizing an FDDI backbone is warranted.

Segments can be composed of the entire LAN on one segment to having each workstation/host on a segment with appropriate bridging/routing. The entire LAN on one segment is suitable if the traffic does not warrant segmentation, i.e., keeping traffic local. The other extreme is probably useful if just certain workstations/hosts are provided with a private segment, i.e., those components which produce/receive the most traffic, or have highly localized traffic within a workgroup.

A "rule of thumb" to determine whether segmentation will increase LAN capacity is the 80-20 rule, i.e., if local traffic is 80 % of the traffic generated and remote traffic is 20 % then the LAN capacity will increase by segmentation of that workgroup. Of course, segmentation can sometimes increase congestion, if the remote traffic must take several "hops" across different segments to reach the destination. An increase of bandwidth could occur on other segments if their is considerable remote traffic from different sources traversing a common segment to get to their destination.

Another approach, i.e., as compared to segmentation, is the concept of Intelligent Switching. Intelligent switches are able to accommodate Ethernet and FDDI modes and able to switch, between segmented networks either internally or externally, at a very rapid rate. This not only reduces the propagation delays, but allows one to migrate to FDDI rather than configuring for fiber optics entirely.

They also provide concurrent communications between workgroups and can match different bandwidth LAN's through the switch interface. In general one can achieve a high-through-put, low-propagation delay (latency), and transparent communication between end-stations.

In the case of the NASA/CAE LAN this is a reasonable solution for several reasons. One, most of the workstations are not upgradeable to FDDI controllers and the cost would also be prohibitive. Two, the system is not yet saturated but if the workload increases in the future it will be needed. Thirdly, there is a movement to FDDI configurations at KSC and planning to migrate should be initiated.

4. ETHERNET TECHNOLOGY

Ethernet (IEEE 802.3 Carrier Sense Multiple Access with Collision Detection - CSMA/CD) (3) provides the services of the lower two layers in the International Standards Organization (ISO) Open Systems Interconnection (OSI) model for network protocols. There are seven layers in this model.

The layers and a brief description of their functions follow. The lowest layer is the Physical layer which is concerned with transmitting the bits over the transmitting medium, the next layer is the Data Link layer which is concerned with preparing the line for transmission and framing the packets so that there is a delineation of the packet boundaries, addressing, and error detection. This is the layer, along with the Physical layer, for which Ethernet is used. The next layer is the Network layer, this layer determines how packets are routed through the sub-networks. Above this layer is the Transport layer, which mainly fragments the packet into smaller units, if needed, and insures that these fragments will be correctly put back together. The next layer is the Session layer, which is basically the user's interface to the network. The other two layers are the Presentation and Application layers. They are used for tasks, such as data compression and data distribution, respectively.

The Physical layer characteristics for Ethernet are:

Data rate: 10 Million bits/second
Maximum station separation: 2.8 Kilometers
Maximum number of stations: 1024
Medium: Twisted pair, Coaxial cable, Optical fiber
Logical topology: Bus
Physical topology: Star, Bus, Hierarchical Star
Maximum frame size: 1518 bytes
Frames on LAN: Single

The Data Link characteristics are:

Link control procedure: Fully distributed peer protocol, with statistical contention resolution
Message protocol: Variable frame size, "best effort delivery"

Ethernet is a carrier sense protocol, i.e., all stations monitor the cable during their transmission, terminating transmission immediately if a collision is detected. When an Ethernet station wishes to transmit a packet a carrier sense is performed forcing the station to defer if any transmission is in progress. If there is no station sensed to be transmitting then the sender can transmit after an appropriate delay. It is possible that two, or more, stations will sense the channel idle at the same time and begin transmitting. This has the possibility of producing a collision. The station will continue monitoring and sense this collision. When a collision is detected the station will stop transmitting and will reschedule a re-transmission at a later time. Re-transmission time is random and is selected using a binary exponential backoff algorithm.

5. FDDI TECHNOLOGY

FDDI is a token passing technology that uses a timed token protocol (4). There can be multiple frames on the network which is configured as a logical dual ring, or a dual ring of trees. The media standard is presently optical fiber, although transmission of the packet over copper is also being considered and should be in the standard, in the future. The designation for the later is Copper Distributed Data Interface (CDDI). The bandwidth is 100 Mb/s. Of course the transmission distance for a predetermined db loss is greater with a fiber optic cable, as compared to a copper cable. There is also concern with cross-talk and radiation with the copper media. These concerns are being addressed, mainly through twisted pair and shielding.

As in Ethernet FDDI provides services at the lower two levels of the OSI model.

A brief description of the communication on the ring is described below.

There are dual fibers in the ring network. One fiber is used as the primary transmission path and the other is the secondary transmission path. The dual rings are independent until a fault appears either in the cable or a component. At that time the rings are joined together to isolate the fault and continue communications. This is called "wrapping". If two faults occur then systems can become isolated.

Stations (components) are connected in series to form a ring. Data is transmitted serially from a station to the next station downstream. Each station performs the repeater function to regenerate the data frame and re-transmit to the next station, while possibly inserting data frames of it's own.

The right to transmit data frames is controlled by a token. The token is passed from station to station, and when a station has the token it can add data to the transmission frame as long as it is allowed to hold the token, this is determined by a system parameter called the token holding time. When a frame returns to the sending station it is stripped from the ring.

In the FDDI standard one can have multiple frames on the LAN, as compared to the IEEE 802.5 communications ring. In IEEE 802.5 once a station has captured the token and inserted data onto the ring, it has the channel captured until the receiving station removes the data and re-sends an appropriate token.

The fiber optic cable can be broadly classified as either Multimode (MMF) or Singlemode (SMF) fiber. Multimode optic fiber means that there will be multiple modes transmitted on the cable. The core sizes are typically, 50, 62.5, or 100 microns. This creates modal dispersion which affects both the distance and the achievable bandwidth. MMF can use inexpensive light sources, as compared to SMF. The main result from using MMF cable is that maximum station separation is considerably less than with SMF cable, but attendant costs for transmission components are cheaper.

SMF has only a single mode of transmission. The core size varies from 8-10 microns, laser's must be used for transmission and there must be precision alignment. Station separation can reach 20 Kilometers, or more with SMF. Normally, SMF cables are used for intra-building connections.

The characteristics of FDDI are:

Data rate: 100 Million bits/second
Maximum station separation: 2 Kilometers for MMF or greater than 20 Kilometers for SMF
Maximum number of stations: 500
Medium: Optical fiber and copper shielded twisted pair
Logical topology: Dual Ring or Dual Ring of Trees
Physical topology: Star, Ring, Hierarchical Star
Maximum frame size: 4500 bytes
Frames on LAN: Multiple
Access Method: Timed-token passing

6. FDDI COMPONENTS

The FDDI concentrator (3,5) has a basic role in the various FDDI topologies, which will be discussed later. The concentrator is a component that provides a connection point for various end stations in the network and other FDDI devices (fig. 3).

There are four port types used in FDDI components:

- o Port A connects to the incoming primary ring and the outgoing secondary ring of the FDDI dual ring.
- o Port B connects to the outgoing primary ring and the incoming secondary ring of the FDDI dual ring.
- o Port M connects a concentrator to a workstation/host or another concentrator. This port is only implemented in a concentrator.
- o Port S connects a singly attached component to a concentrator.

One can have either dual attached concentrators (DAC) or single attached concentrators (SAC). The DAC is used in the dual ring, while the SAC is connected to the upper level ring through a DAC. A DAC will connect to the dual ring via its A and B ports, while the SAC accesses the dual ring via its S port which is connected to an upper level M port.

The concentrator is a Physical level repeater, in that it allows the connection of hosts/servers/workstations and/or other concentrators to the FDDI dual ring.

There are two types of connections to the FDDI dual ring. One is the single attached station (SAS) and the other is the dual attached station (DAS). The SAS has one S type port and connects to the dual FDDI ring via a M type port of a concentrator. The concentrator that the SAS is connected to has a design feature that allows a defective SAS to be isolated if it faults, through "wrapping".

Dual attached stations connect to both the primary and secondary rings of the FDDI dual ring. A DAS has two ports an A port and a B port. The A port connects to another stations B port, while the B port connects to another stations A port. A DAS doesn't require a concentrator to connect to the FDDI ring like the SAS. A disadvantage of using DAS stations is that when two, or more, DAS's fail in the ring then the stations become isolated. Also, if several DAS stations are "turned off", without having optical bypass switches, the FDDI network will be become isolated. A DAS can be connected to a concentrator by using the B port for the connection.

FDDI controllers connect end user stations to the FDDI network. The controllers can be either SAS or DAS. The controller has an interface to a particular workstation/host or server system bus. It should be noted that not all components have FDDI controllers available, especially if there architecture is of an earlier generation. They can also be quite expensive in comparison to the value of the component to be upgraded.

7. FDDI TOPOLOGIES

The FDDI standard permits a diverse set of topologies (5). In this report several will be discussed. The ones to be presented are the following:

- Standalone FDDI Concentrator Topology

  This topology consists of a single attached concentrator from which components can be attached. These stations can be either SAS or DAS. This topology can be used to attach endstations together that form a workgroup. This is a useful topology if the building is already prewired for fiber and one does not wish to install a dual ring FDDI backbone (fig. 3).

- Dual FDDI Ring Topology

  This topology consists of dual attached stations being connected directly into the dual FDDI ring. This topology can be useful if their are a small number of stations. The disadvantage is that it does lend itself well to additions/moves/changes. If a station is disconnected then one has caused a fault in the ring, if this is a single fault "wrap around" will occur. If there is more than one fault then stations will be isolated. This topology should not be used for DAS connections, unless there is little risk of the users disturbing the connection. The utilization of dual attached concentrators in a dual ring topology is an accepted topology, since they are presumed to be in service at all times and this also will provide for expansion (fig. 4). This will be discussed later.

- **Tree of Concentrators**

In this topology concentrators are wired in a hierarchical star topology. One concentrator is designated as the root of the tree, and other components are connected to it. These components can be SAS, DAS, or other concentrators. In this topology the LAN is not disrupted by disconnecting stations, and/or their movement to other locations. Additional stations can be added by attaching another level of concentrators. This topology is best suited for a single building FDDI LAN. This topology tends to be more manageable, since concentrators tend to isolate faults from the rest of the system (fig.5).

- **Dual Ring of Trees**

This topology is a merging of the dual ring and the tree of concentrator configurations. Basically, one connects distinct tree of concentrator topologies in a dual ring. This dual ring functions as the FDDI backbone. This is a suitable topology when buildings will be connected via a FDDI backbone. It has the advantages and disadvantages of both merged types. It is the most flexible topology since it has both fault tolerance and increases the availability of the FDDI dual ring backbone (fig. 4 and 5).

- **Dual Homing**

The FDDI standard allows for redundant paths in tree topologies. This redundancy is called "dual homing". Basically, this topology is constructed as follows. The dual ring has at least two concentrators in it. An M port from one concentrator is connected to the A port of a DAS (which is in the next hierarchical level) and an M port of the other concentrator is connected to the B port of the DAS. The B port connection is the primary connection to the DAS, while the A port connection of the DAS is the backup connection. If the primary connection fails then the backup connection will be activated. This concept can also be applied to two M port connections from the same concentrator. The concept can be further diversified by putting the concentrators that are being used in the dual homing concept on different FDDI rings. This concept can be utilized for single attached stations by installing two single attachment interface cards. This configuration is not supported in the FDDI standard (fig. 6).

8. FDDI INTERCONNECTION DEVICES

Bridges and Routers are interconnection devices for FDDI networks (5). Bridges act as Data Link relay between networks. In our case the bridge would have to connect FDDI to Ethernet LAN's. Bridges are protocol-independent and basically store and forward devices.

Basic FDDI to Ethernet bridge functions include:

- o Source address tracking: This will allow the bridge to determine when to forward a packet and when to keep local.
- o Frame forwarding and filtering: Frame forwarding is achieved through table lookup, while filtering is the process whereby frames are prevented from crossing the bridge.
- o Spanning tree: The logical topology of an extended LAN must be loop free, i.e., there must be a single path between all attached stations. To prevent logical loops bridges must form a logical configuration called a spanning tree.
- o Translation: The bridge must modify the fields of the forwarded frame to make it compliant with the format of the network to which it is being sent.
- o Fragmentation: Frames may have to be fragmented when moving across the bridge boundary. FDDI frames can be up to 4500 bytes, while Ethernet frames are restricted to a maximum of 1518 bytes. Therefore, the frame from FDDI to Ethernet may have to be fragmented.
- o Bridge management: Ability to monitor conditions and implement filters on extended networks.

9. INTELLIGENT SWITCH

There are various configurations for high speed intelligent switches (6). They are used to interconnect multiple LAN's, either FDDI, Ethernet, Token Ring or others. The intelligent switch offers many advantages over shared channel LAN's. The advantages include an increase in the bandwidth, latency (propagation delay) reduction, an increase in connectivity, and better traffic management.

Depending upon the vendor the switch may/may not interconnect various communication standards internally. Some of the configurations are:

- o Ethernet to Ethernet switching
- o FDDI to FDDI switching
- o FDDI to Ethernet to Token Ring switching externally
- o FDDI to Ethernet switching internally

There are switches which allow only Ethernet to Ethernet or Token Ring to be internetworked by bridging.

The FDDI to FDDI switching configuration is basically a FDDI concentrator. One can typically purchase FDDI line cards with two (2) or more ports. These ports would support SAS or DAS devices, or presumably SAC or DAC concentrators. Through the purchase of appropriate bridges FDDI and Ethernet segments can be interconnected. These switches can set up concurrent connections to obtain an aggregate throughput much higher than a single segment could obtain. These switches achieve low latency by not utilizing the store and forward concept, but to use cut-through forwarding. This technique forwards a packet as soon as the destination address is determined from the header.

Another switching configuration has backplanes for various communication LAN's, such as FDDI, Ethernet, and Token Ring, i.e., internal to the switch is a collapsed network backbone appropriate to the technology to be utilized. One could connect SAS/DAS stations to the internal FDDI dual ring, Ethernet workstations to the internal Ethernet LAN via an Ethernet card, and also suitable connections for Token Ring. Then externally through appropriate bridging one can interconnect the various communication configurations. This offers more flexibility than an FDDI switch, but the switching speed is determined by the manufacturer of the bridge.

Both of the above solutions offer the advantage of non-proprietary solutions for obtaining interconnectivity. Therefore, if bridge technology is upgraded one could purchase a bridge with that technology and integrate into the network. The disadvantage is that numerous components will have to be purchased to integrate the network into the switch environment and overall propagation delay will probably be larger, than if the bridging/interconnection is integrated into the switch.

Another type of switch can be called the intelligent switch, in that the internal configuration is such that FDDI can be integrated with Ethernet communications (fig. 7). The concept is to have a collapsed FDDI backbone internal to the switch and be able to bridge from external FDDI or Ethernet stations through the FDDI backbone. There is also the possibility of switching at the module level without going through the FDDI backbone for the Ethernet module. The FDDI module must go through the FDDI backbone internal to the switch.

Each Ethernet module contains ports which can have either Ethernet LAN segments connected or a private Ethernet channel, i.e., an end-station. Ethernet segments attached to a unique module are switched by an internal bridging function to the appropriate output port. Ethernet segment connections for ports on separate modules must go through the FDDI internal backbone to arrive at the destination address. The same is true for FDDI SAS/DAS connections.

This allows very sophisticated interconnections between dissimilar LAN segments and also allows gradual migration to FDDI devices as bandwidth needs increase. The communication between Ethernet and FDDI is transparent. Due to the usage of the FDDI internal backbone (backplane) there is a maximum of two low latency "hops" between any two stations.

Normally, a switch will have filtering capability based on; source address, destination address, protocol type, or some combination of these attributes. This can be usually done on a per port basis, or workgroup. Some routing functions can be obtained through this capability.

10. WIRING SYSTEM TOPOLOGY

The wiring topology (fig. 8) is divided into several subsystems (5):

- o Campus backbone system
- o Building backbone subsystem
- o Horizontal subsystem
- o Work area group subsystem

The campus backbone system links clusters of buildings together within a site. The building backbone subsystem provides the link between the campus backbone and the horizontal areas. The horizontal subsystem provides the connection from the building backbone to the work area group. The work area group subsystem connects the user end stations to the LAN system. Typically, there is also an administrative subsystem for managing the other subsystems and their various components.

One could propose that the FDDI KMAN which is currently in operation would be the campus backbone and the configuration which is proposed in the next section would comprise the building/horizontal/work area subsystems. This is not completely true, since there are numerous other LAN's for communication, specifically the BCDS. In fact, the BCDS is proposed as a backup network for the proposed configuration.

11. CONFIGURATION FOR MIGRATION TO FDDI

The present Ethernet LAN in the Headquarters building is a single segment LAN with bridge/router connections to other CAD/CAE LAN's and other parts of the KSC network. To provide capabilities for migration to FDDI when resources permit and loading necessitates, the intelligent switching configuration is proposed.

This configuration consists of a Building switch and several Workgroup switches for the third floor of the building, and a proposed switch for the first floor, where an additional LAN is present. This configuration will allow migration to FDDI when workstations are upgraded to FDDI. It will also allow the Ethernet LAN to be segmented, which should provide greater access for each segment to the VAX cluster. Components of the VAX cluster and the various servers have FDDI controllers available and hence will be integrated into the building switch through a concentrator module. The connection to the Metropolitan Area Network will be provided by a Router.

The VAX cluster has the capability of utilizing both Ethernet and FDDI controllers, where one would be designated as the primary and the other the secondary. By utilizing this option the existing network would remain in usage. This would provide a backup if the building switching hub is out of service, or if there is overloading both entry points to the network could possibly be utilized.

The proposed intelligent switch is from the Synernetics Corporation and has four modules available (7):

- o System Processor Module (SPM)
- o FDDI Enterprise Access Module (FEAM)
- o FDDI Concentrator Module (FCM)
- o Ethernet Switching Module (ESM)

The SPM module is dedicated to the management of the system and it continually monitors the system and is used to configure the system. This module is required.

The FEAM provides A/B ports for connecting the switch to an FDDI backbone.

The FCM is an FDDI concentrator and allows one to connect end stations and other intelligent switches to the FDDI backbone. The FCM has either four (4) or six (6) M ports

The ESM has eight (8) ports for Ethernet connections which can be switched and a fully translational Ethernet to FDDI bridge which can forward messages to other ESM modules or to FDDI stations via the FDDI collapsed backbone internal to the intelligent switch. Messages can be switched between ports on an ESM without going through the FDDI backbone (fig. 9).

There are two switch sizes, one has four (4) slots and the other has twelve (12) slots available. The modules can be utilized in both switches.

To achieve reliability in the switch environment, the horizontal switches are dual homed off separate concentrator modules in the building switch. This will allow alternate access if one of the concentrator modules becomes inoperative. The building switch also has provision for dual power supplies. One could utilize another horizontal switch dual homed off of the building switch to integrate the VAX cluster and various servers into the network, but this would provide another failure point and would reduce the reliability. Another possible solution to provide FDDI redundancy for the VAX cluster would be to provide two SAS FDDI controllers and dual home into these, if the VAX's can operate in this manner. At present there is no DAS FDDI controllers available for the VAX cluster, there are DAS FDDI controllers available for the Intergraph servers that are in the present Ethernet network and for some of the Intergraph workstations.

Spare modules and a spare switch are to be purchased to ensure that minimal down time would result from a failure. Since this network is not mission critical these precautions should be sufficient at this time.

This configuration, which is a dual ring of trees topology, should provide a reliable network for the CAD/CAE design/development environment and also provide a path for a complete migration to a FDDI network environment as resources become available and/or the network becomes saturated (fig. 10).

13. SUMMARY

The proposed intelligent switch configuration provides a path for migration from Ethernet to FDDI as resources become available and loading necessitates greater bandwidth. The intelligent switch configuration also provides a gateway to Asynchronous Mode Transmission (ATM) when it becomes available in the future. The proposed solution also is redundant due to dual homing of the horizontal switches, purchase of spares, and dual power supplies on the building switch.

This configuration should also increase throughput due to the Ethernet LAN segmentation and the installation of FDDI controllers for the VAX cluster, various Intergraph servers, and several VAX workstations which have a high workload. One also has the option to privatize Ethernet workstations if the load demands. It should also be noted that other developers have reported that until all workstations are upgraded to FDDI a sizable increase in throughput is usually not recognized, this is due not only to the 10 Mb/s output of the Ethernet controller, but applications are not taking advantage of the higher bandwidth available from FDDI.

Several items should be addressed in future work:

- A simulation of the proposed system should be done to determine throughputs/latency/utilization and a comparison to various alternative systems, so that the configuration can be "fine-tuned".

- A reliability study of various configurations so that one can intelligently predict the redundancy that is required for a certain level of reliability.

- There should be a network image constructed, which will be updated automatically, if possible, as additions / deletions / movement / upgrades of components are done.

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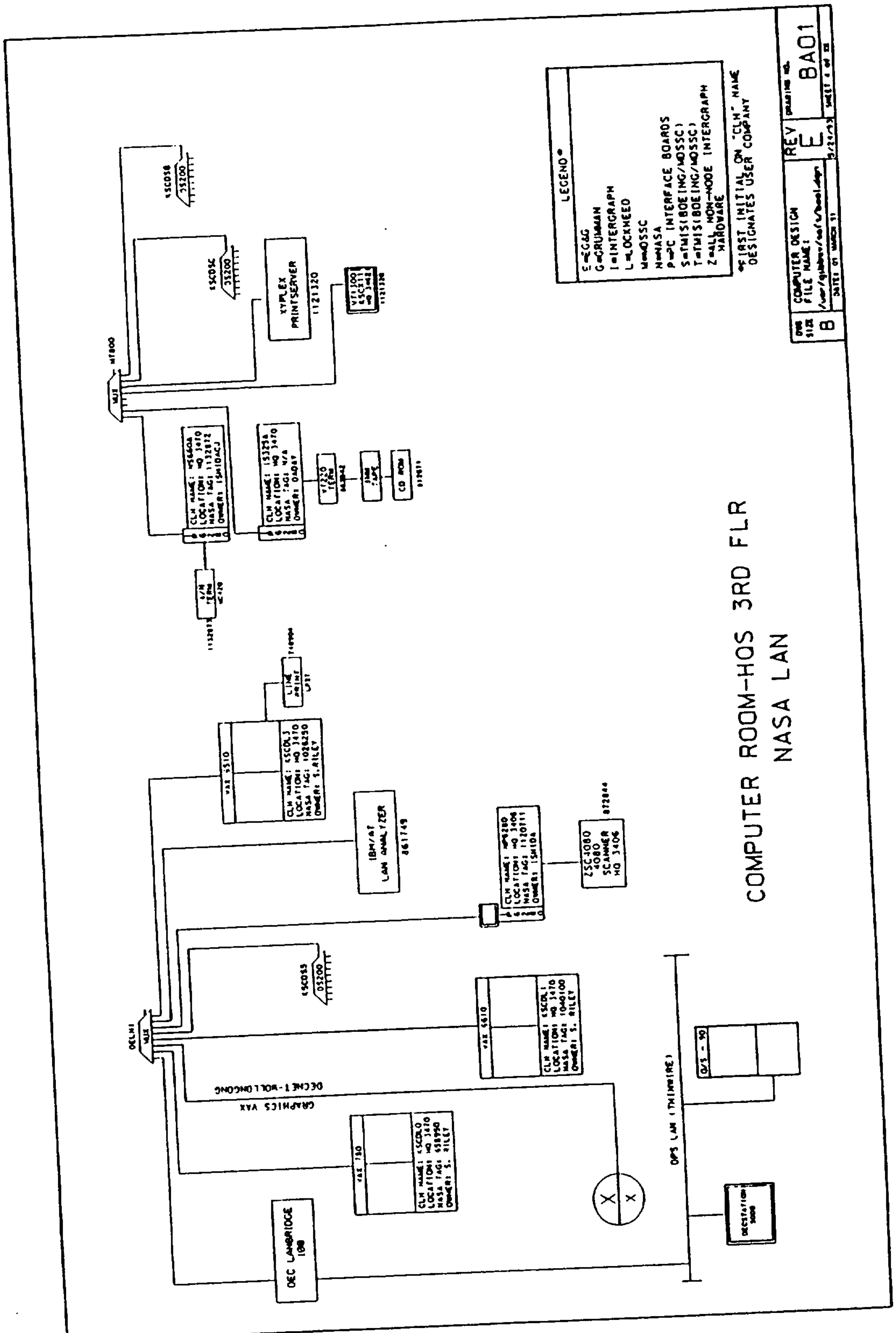

Figure 1. VAXcluster - Computer Room

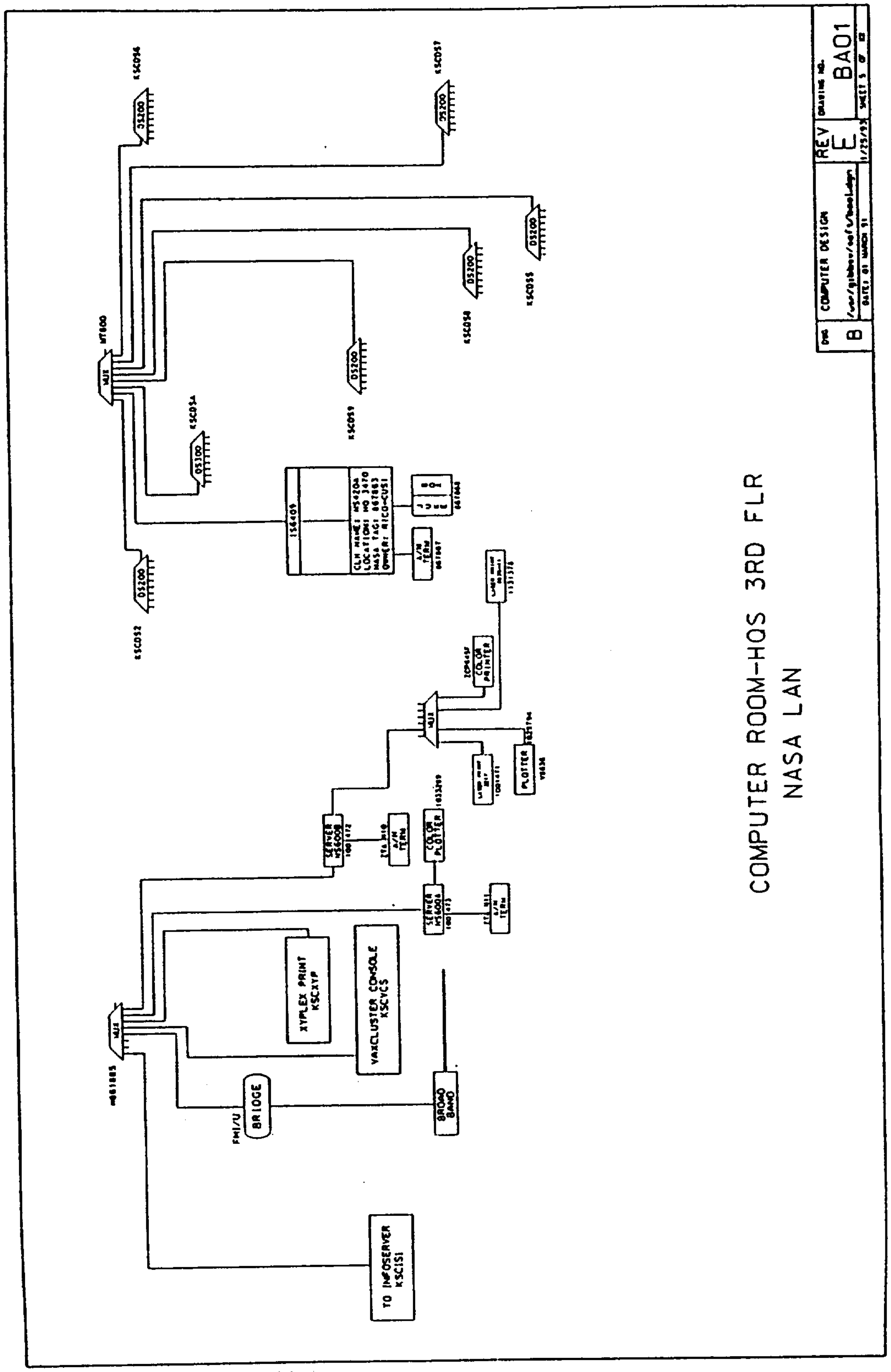

Figure 1. VAXcluster - Computer Room (Continued)

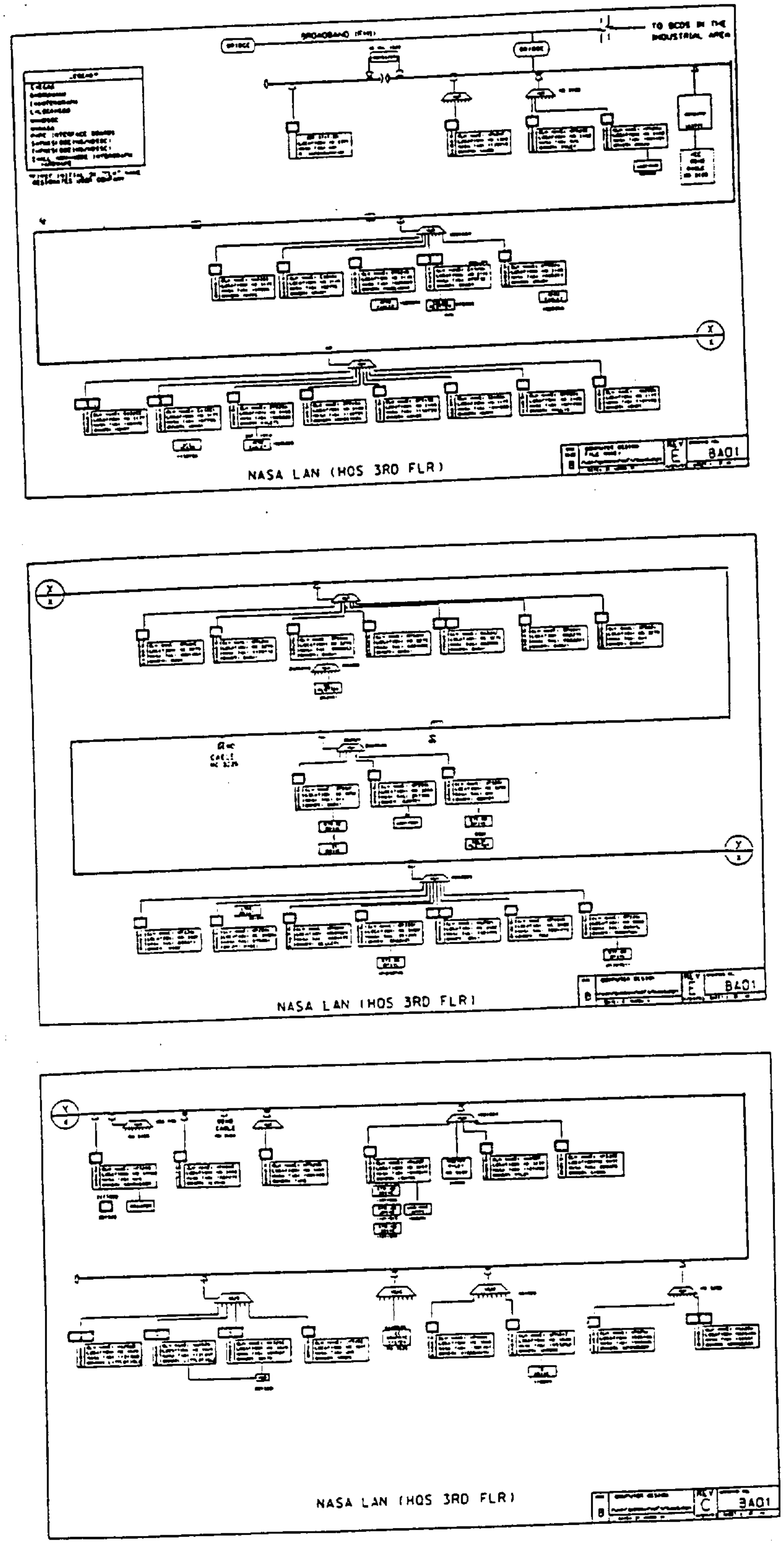

Figure 2. NASA/KSC CAD/CAE LAN - HQ's Building

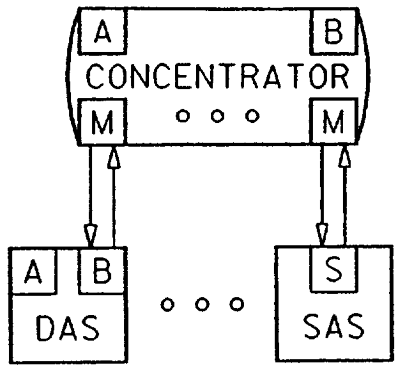

Figure 3. FDDI Concentrator

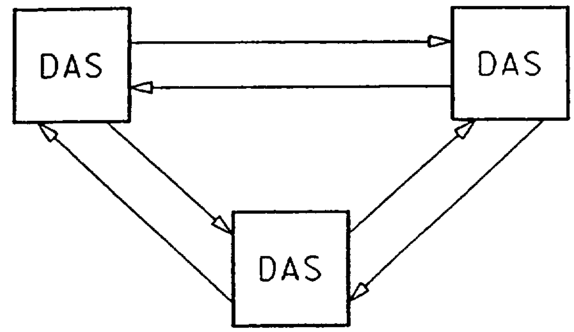

Figure 4. Dual Ring Topology

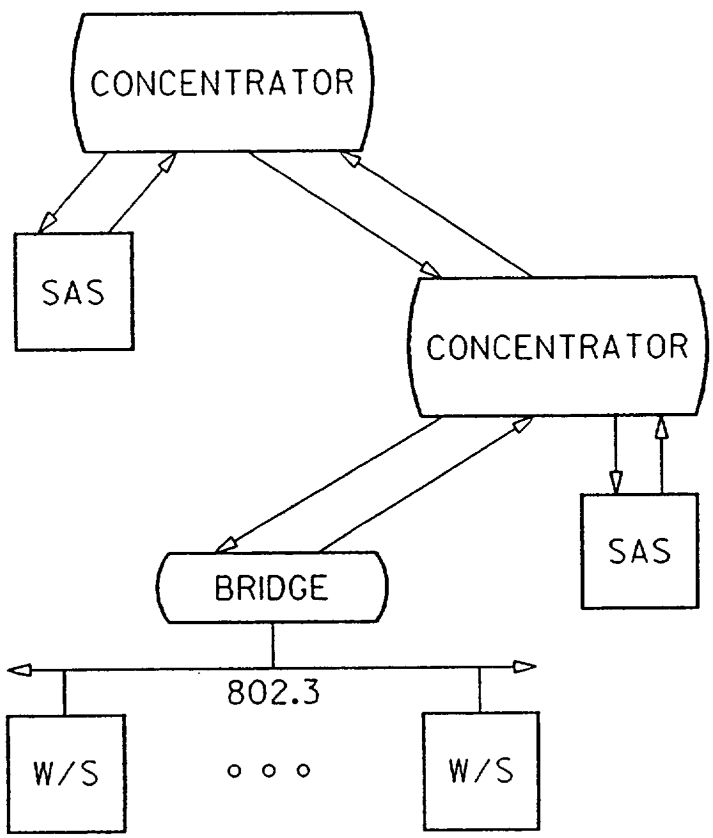

Figure 5. Tree of Concentrators

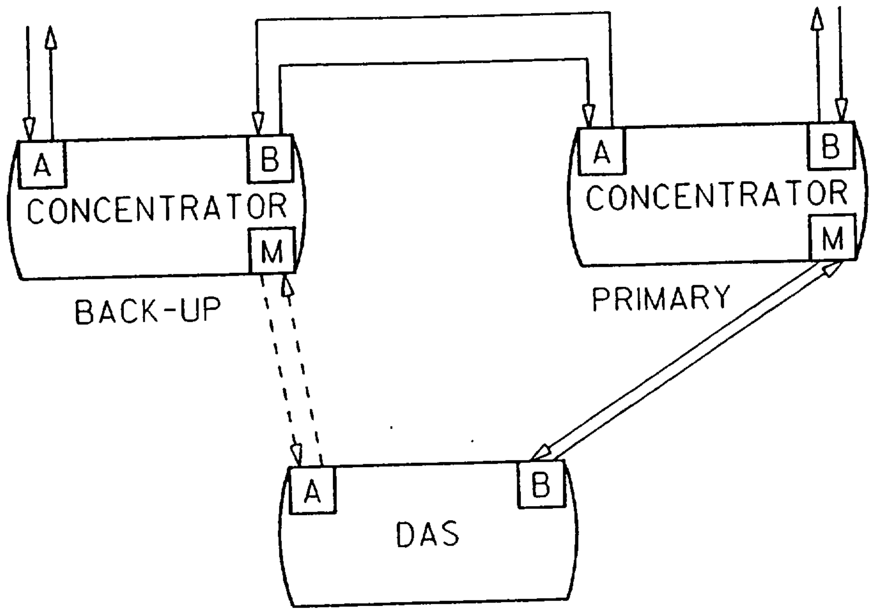

Figure 6. Dual Homing

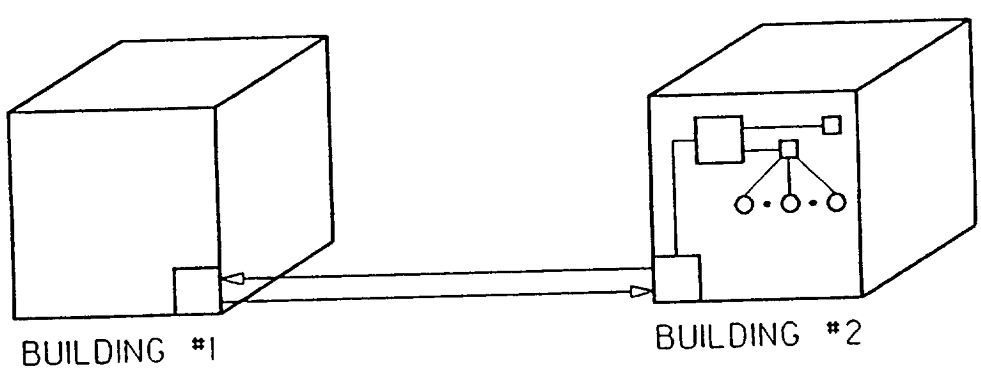

Figure 8. Wiring Topology

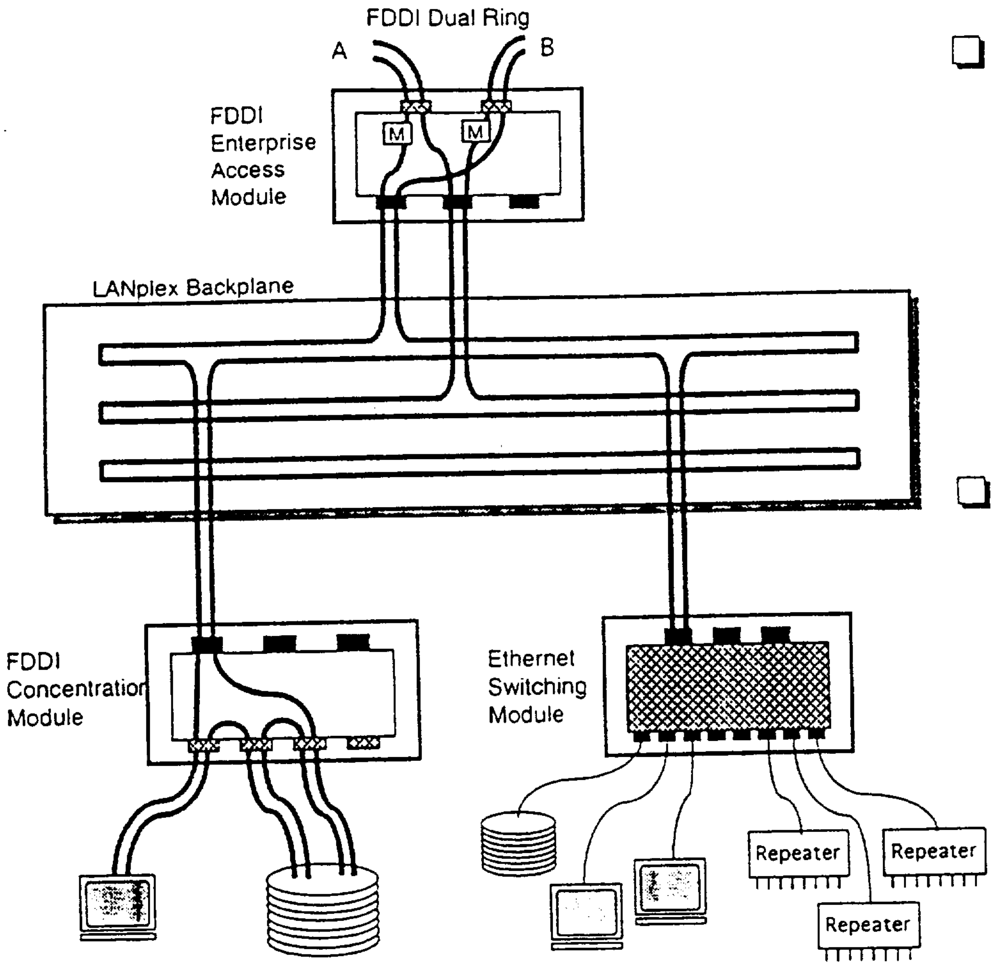

Figure 7. SYNERNETICS Intelligent Switch

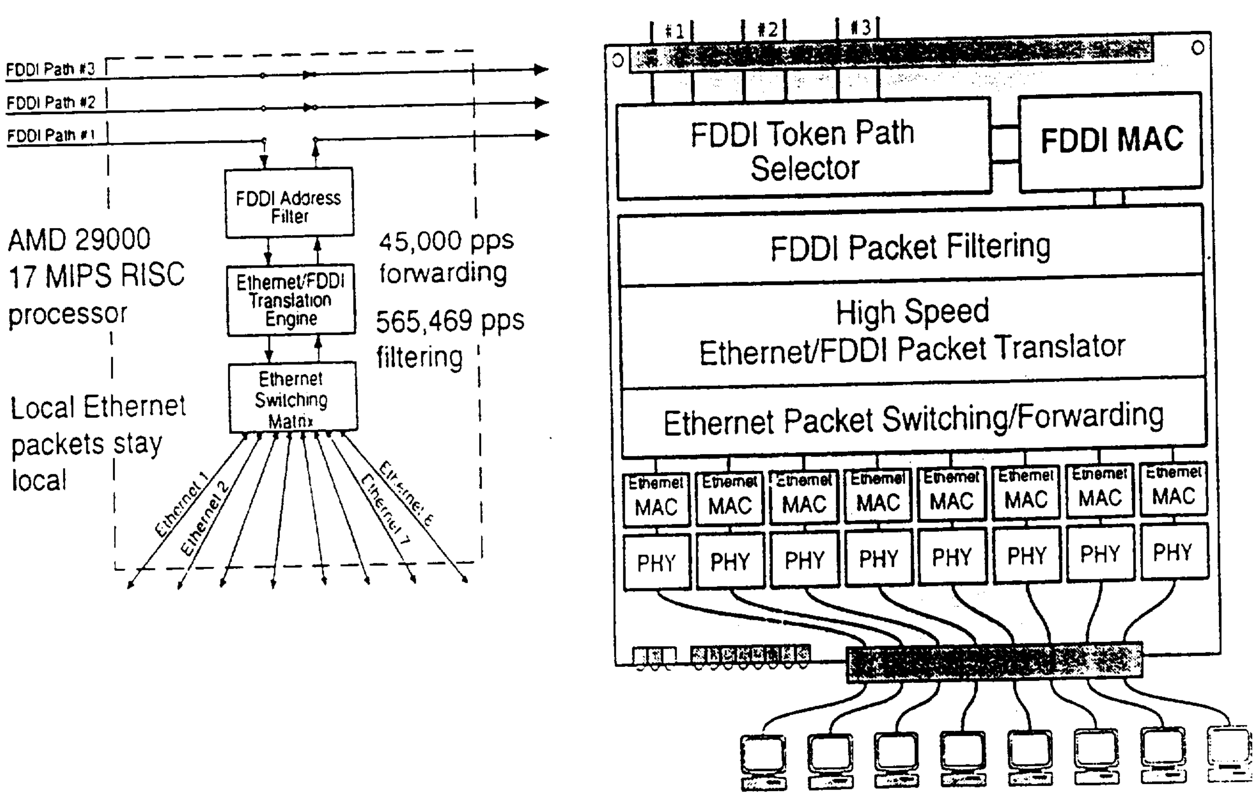

Figure 9. SYNERNETICS Ethernet Switching Module

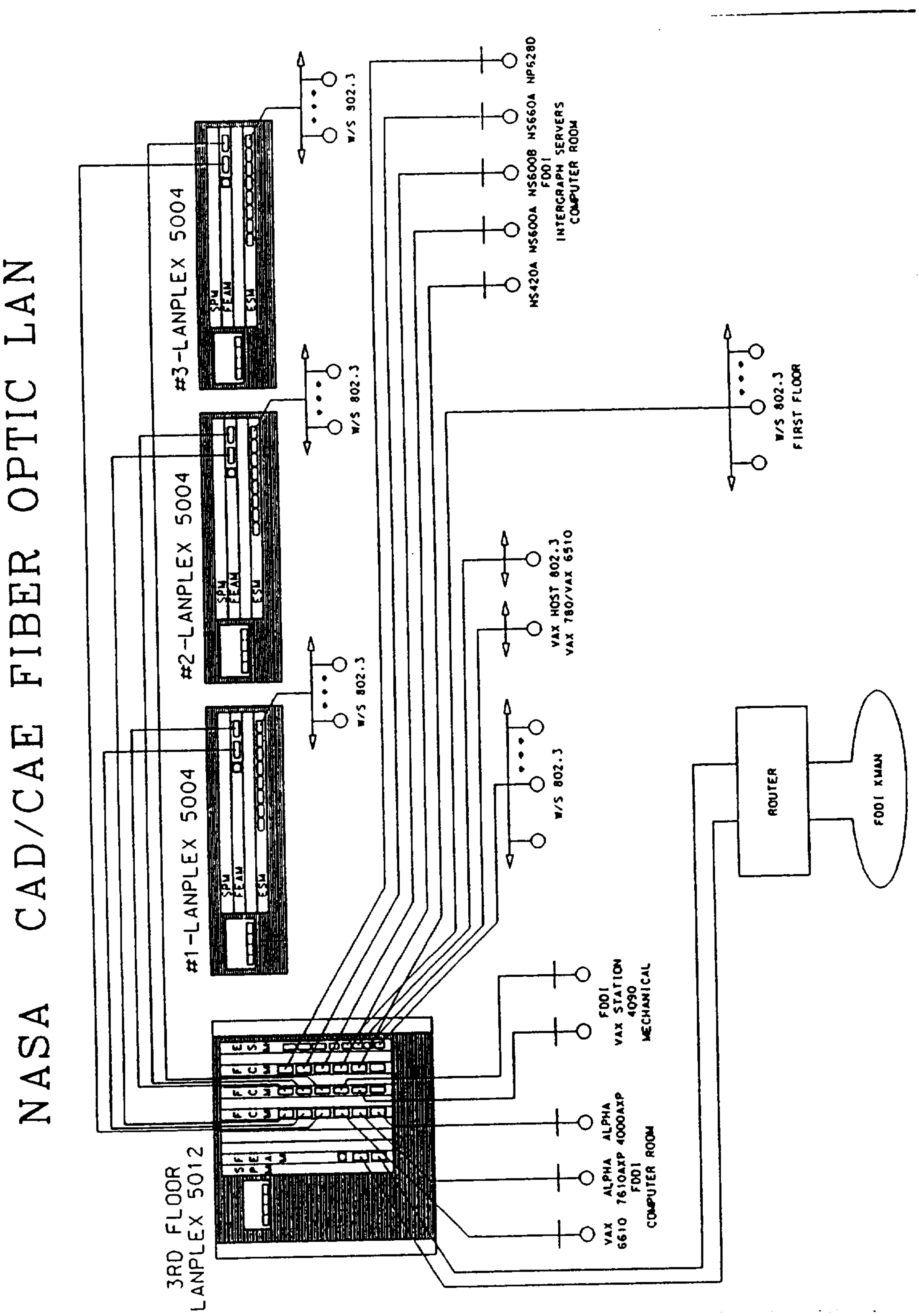

Figure 10. SYNERNETICS Generic FDDI/Ethernet LAN