Customer-Implemented Networking Campus Solution

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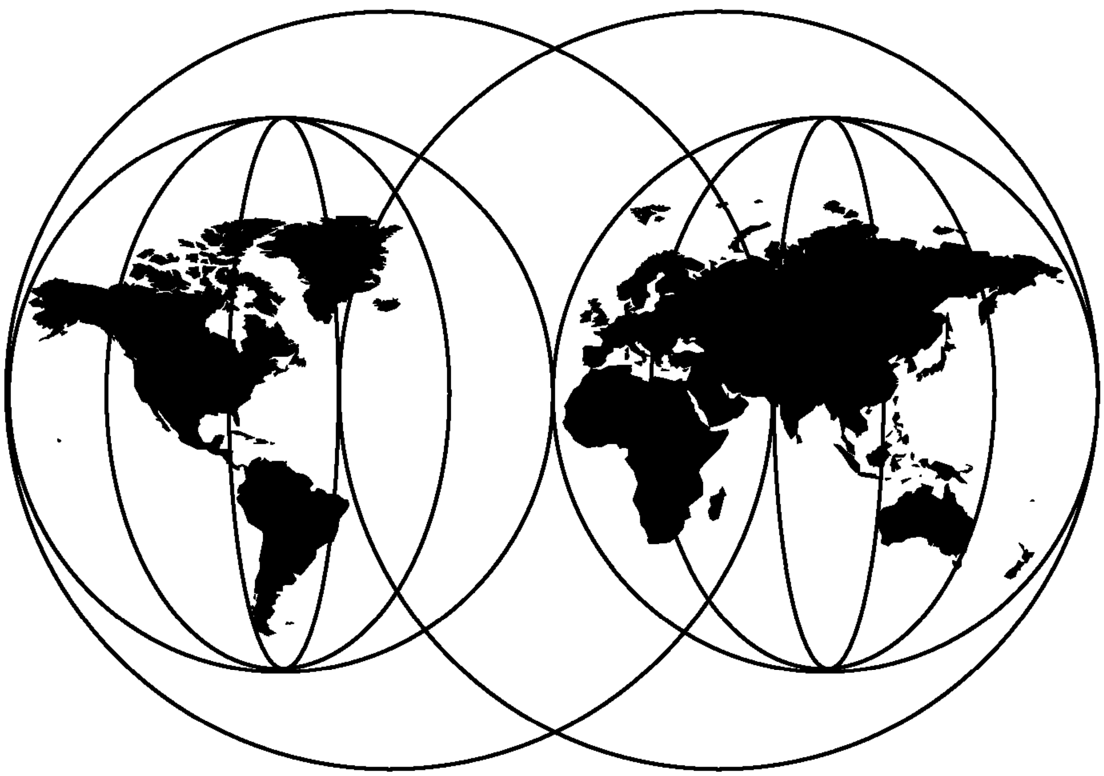

International Technical Support Organization

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Customer-Implemented Networking Campus Solution

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Take Note!

Before using this information and the product it supports, be sure to read the general information in Appendix D, “Special Notices” on page 117.

First Edition (January 1999)

This edition applies to Version 1, Release 1.1 of Multiprotocol Switched Services (MSS) and Version 3 8260 CPSW microcode.

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Contents

Preface

This redbook discusses ATM as a core campus network in a large university environment. This book will assist you in understanding the issues involved in designing and implementing an ATM campus network.

This redbook documents the experiences of the Florida International University during the implementation of their ATM core and various issues encountered, taking you through all the stages from motivation for the ATM technology through design of the network, to implementation and various issues encountered during these stages.

The ATM products used in this design are 8260s, MSS(8210 and 8260 blade) 8285s, 8273s, 8274s and 8271s. There is an emphasis on the use of the MSS in this network design. Configuration procedures are provided for the MSS, which can be used to help build other customer environments.

Some knowledge of LAN architecture, ATM technology, switching and bridging is assumed. This book does not define topics such as LANE, LECS, CIP, ATM physical signalling, UNI, etc.

The Team That Wrote This Redbook

This redbook was produced by a team of specialists from around the world working at the International Technical Support Organization, Raleigh Center.

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Chapter 1. Introduction

This redbook shows how a switched ATM network was successfully introduced into the Florida International University campus. The installation experiences, sample configurations and lessons learned will assist those involved with or contemplating similar large installations and migrations.

Florida International University recognizes the key role that computer networks and new digital technologies can play in providing cost-effective learning, teaching, and administrative functions that are more people centered. The university has a vision of how they want to deploy information technology to transform and enhance the core processes of the university and they are vigorously following a strategic plan involving industry business partners, including IBM, to assist them in making this vision a reality.

One of the cornerstones required to implement this strategy is a reliable ATM campus network. Twelve months after placing the first order for ATM switches from IBM, they are well down the path of a phased implementation plan for installing an ATM network that will not only carry their traditional LAN traffic but will also enable the implementation of new multimedia applications.

Florida International University currently has an enrollment of about 30,000 students and is located on two separate campuses. The main campus is known as ″University Park″ and the remote campus as ″North Campus″. The two campuses are located 30 miles apart. Ultimately the ATM network will service the two FIU campuses and another two associated campuses in the South Florida region. A long-term goal is to be able to provide high-quality, interactive video teaching modules directly into residences or places of work via an external service provider.

This redbook records the FIU network as it was during December 1997. The PNNI migration was carried out during the summer of 1998. The network was reviewed later during December 1998 once FIU had implemented PNNI.

1.1 The ATM Network

The layout of each campus consists of a number of buildings housing the different colleges, faculty, administrative departments, library, residential and social areas. Initially the ATM network at FIU consists of six IBM 8260 switches located in different buildings and interconnected with 155-Mbps multimode fiber optic links. The ATM network using ATM Forum-compliant LAN Emulation (LANE) is configured to support a number of virtual Ethernet LANs and interfaces to the previously existing Ethernet network via a 155-Mbps ATM connection to a Cisco 7513 router. As required, workstations with 25-Mbps ATM adapters are being rolled out and connected to the ATM backbone with IBM 8285 ATM workgroup switches. There are currently 18 IBM 8285 workgroup switches installed supporting approximately 400 ATM workstations.

TCI, which is a public telecommunications service provider, supplies a 155-Mbps ATM connection between the two campuses. TCI has implemented a public wide area ATM network using IBM 2220 Nways switches.

The function of the ATM network at Florida International University is to provide a high-speed digital network capable of carrying real-time multimedia traffic to enable new innovative and efficient methods of learning and teaching and at the same time interface with and carry the traffic from their existing data and voice networks.

This redbook describes the motivations for installing the ATM backbone network, some of the planning considerations, the migration steps to date, details of the current configuration, and a discussion of some of the considerations involved in planning for future migration phases of the network, and the factors that have contributed to the successful implementation.

A list of the equipment used to build the network is provided, together with samples of their relevant configurations as they were at a particular time. The details of the code levels and configuration parameters are supplied because they are examples of a working ATM network that has been tried and tested in the field with a large number of users, not because they represent the definitive release levels of code or configuration parameters to be used to implement such a network.

Chapter 2. Network Design Prior to the ATM Campus Network Installation

Prior to the installation of the ATM network equipment, the university had in place a large campus data network made up of Ethernet switches, bridges and routers servicing 4500 workstations and servers in different buildings on the two campuses. This network is referred to as the *legacy* network in this redbook. The legacy network, due to the large investment in its equipment, continues today to coexist and interoperate with the new ATM network.

The university network is made up of a campus-wide core network and multiple building backbone networks. The core network consists of the main cross-connect equipment and the communication links used to interconnect all the buildings across the campus. A building backbone network is contained within a building. It includes the horizontal cabling on the different floors and the vertical cabling within the risers between the floors. In addition the workgroup switches, hubs into which the workstations are concentrated, telecommunications closets and the intermediate cross-connect equipment form part of the building backbone network.

Before the installation of the ATM network the University Park campus had been cabled with multiple pairs of multimode and some single-mode fiber links. These fiber links were carrying 100-Mbps Fast Ethernet traffic. See Figure 1 on page 4 for a plan showing the layout of the buildings on the campus and the fiber links between them. The number appearing next to the link in the figure indicates the number of fibers in that link.

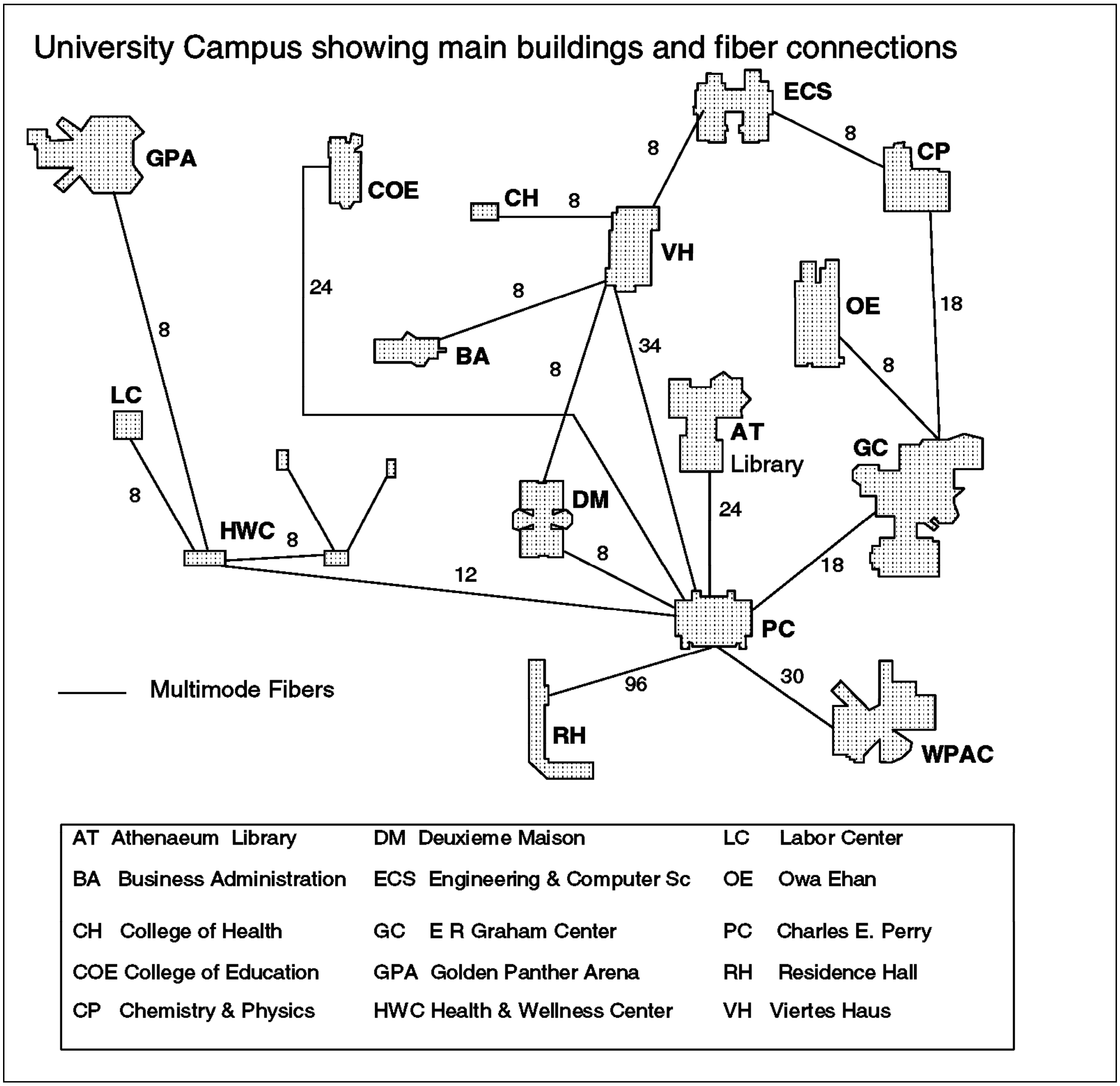


Figure 1. Geographic Layout of University Park

The core network consisted of a central Cisco 7513 router connected to a large Catalyst 5000 switch, which was the main cross-connect device into which the backbone LANs in the different buildings were connected. The routers, switch and the backbone in the buildings were all interconnected with fiber links. The central router provided the connectivity to North Campus and the College of Engineering and Applied Sciences (CEAS), which is located a short distance away from the main campus. The 10-Mbps link to North Campus is provided by a telecommunications service provider. The connection to the CEAS is via a 100-Mbps FDDI link. The central router also provided other wide area connections such as a T1 link to the Internet and connectivity to a set of terminal servers for dial-up users.

The servers were clustered around two Catalyst switches. The UNIX-based servers on the one switch and the PC-based servers on the other. The servers included a Web server, mail server, news server, network file server, domain name server and a number of administration and departmental servers.

Figure 2 on page 6 shows a simplified graphical representation of the physical network connections. The different buildings with their backbone networks are depicted by a box with a two or three-letter building mnemonic in it.

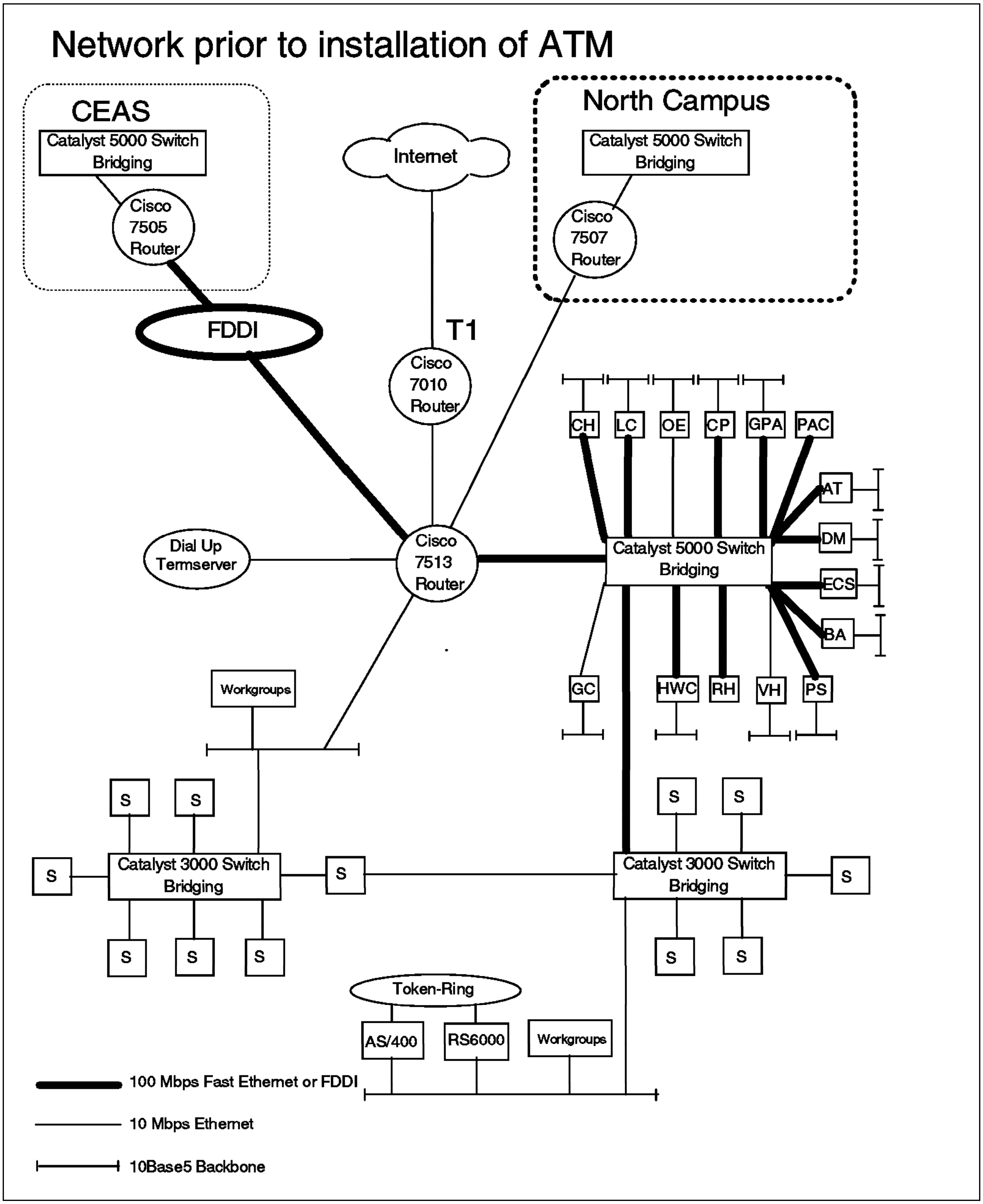


Figure 2. FIU Legacy Network

A building backbone would typically have a Cisco Catalyst 5000 Fast Ethernet switch as an intermediate cross-connect device interfacing with the core network via a multimode fiber link. On the different floors there would be a number of telecommunications closets each with a workgroup switch or hub to which the workstations were connected with Category 5 UTP cabling. The workgroup switches were in turn connected to the building intermediate cross-connect switch with multimode fiber. Figure 3 on page 7 shows a typical building backbone design.

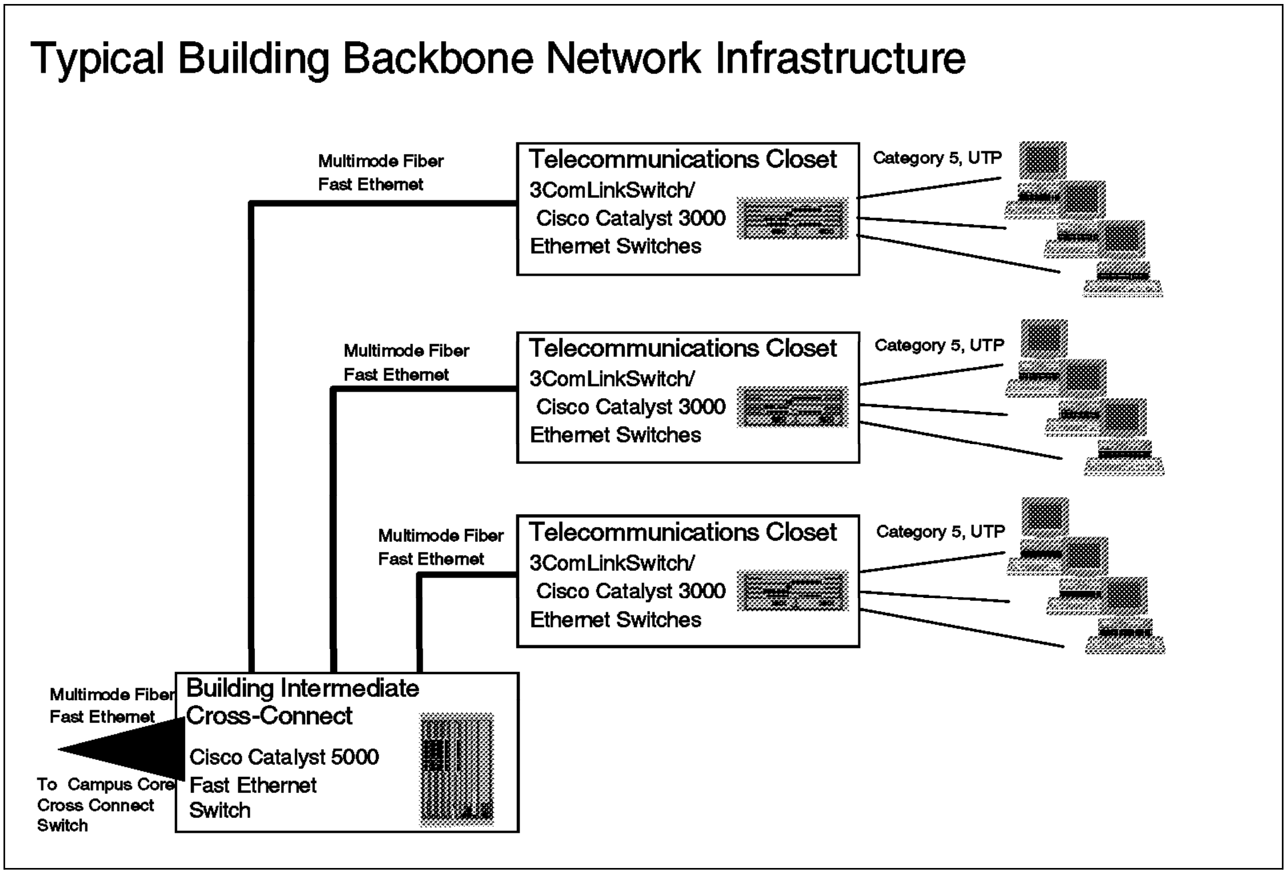


Figure 3. Building Backbone Structure

The LAN protocol was all 100-Mbps Fast Ethernet on the fiber links and 10-Mbps Ethernet on the Category 5 UTP links. There was a small token-ring segment with less than 50 users and servers.

The network protocols supported were predominantly TCP/IP but also Decnet, LAT, AppleTalk, NetBIOS and IPX. The Catalyst switches bridge all protocols and the Cisco routers were set up to route TCP/IP and Decnet and to bridge the other protocols.

There were about 40 different IP networks implemented across the campus-wide switched/bridged LAN infrastructure at University Park. The IP networks were typically dedicated to departments within buildings. The central Cisco router had multiple IP addresses on its Fast Ethernet interface and performed the routing between the different IP networks. The central router also routed the IP traffic between the University Park network, the CEAS network, the North Campus network and the Internet. The TCP/IP routers made use of RIP I to maintain their routing tables.

A central Cabletron Spectrum SNMP management station was used to manage the network.

The volume of traffic across the core network was sufficient to keep the 100-Mbps Fast Ethernet, on average 10% of the maximum throughput.

The legacy network with its Fast Ethernet LAN and central router was unable to transmit full-motion video and sound of a sufficient quality to enable Florida International University to realize their vision of using digital technology in the changing environment of learning and teaching. See Chapter 3, “Customer Requirements” on page 9 for a further discussion of the goals of the university and the requirements of their network.

Chapter 3. Customer Requirements

Florida International University, like many other large institutions, is faced with the requirement to be able to service an increasing number of potential customers, in their case students, with a higher quality product but with decreasing funding. The university is looking towards technology to provide a new cost-effective process and delivery mechanism. The student population, which is currently about 30,000, is expected to reach 50,000 by the year 2008. With this rate of growth, the university does not foresee that it will have the infrastructure or the funding to be able to deliver education in the traditional way.

3.1 Infrastructure

Florida International University has identified four technological components that are required to establish the infrastructure for it to be able to fulfill its vision for enhancing the scholarly environment of its students, faculty and staff and for providing education in a cost-efficient manner but on a far larger scale in the years to come.

1. High-speed communication networks accessible in all campus buildings and also accessible from private residences through new services offered by telecommunications companies.
2. A multimedia information server with huge storage capacity able to deliver multiple independent simultaneous information streams in the same way that communications companies are beginning to deliver video on-demand to individual homes today.
3. An inexpensive access device such as a network computer to enable users to access the information.
4. Sophisticated instructional software to produce the digital material and control the environment along with the educational content.

An ATM network implemented with IBM ATM switches and IBM Multiprotocol Switched Services (MSS) software has been installed and is in the process of being extended to fulfill the first requirement. Further network requirements are discussed later in this chapter. First, let us examine the second requirement in a little more detail as this will give us an insight into the new types of multimedia applications the network is required to support.

3.2 The Digital Library

The university is in the process of using digital technology to build an information repository, called the *digital library*, and plans to increasingly use the network as a conduit for research, teaching and administration, making this repository of information simultaneously accessible to a much larger number of potential students both on and off campus. An IBM RISC System/6000 SP2 with four nodes and eight 155-Mbps ATM ports has been purchased as a platform on which to implement the digital library. The IBM Digital Library software was selected to contain materials such as digitized lectures, voice and music recordings, musical score sheets, as well as data, video and text-based library materials. A user of the library should be able to use the network to download visual images, play, pause, rewind or fast forward a full-motion video clip, perform catalog searches or read text with hyperlinks to related information objects. One of the advantages of a digital library together with a high-speed network with guaranteed quality of service is that a single digital copy can be shared simultaneously by multiple users in different locations.

Currently the Florida International University has a number of digital objects in its library. These include:

- A collection of 200,000 architectural photographs and images.
- The Goodsell Collection, which represents over four decades of recent Latin American and Caribbean history. This is made up of digitized video recordings captured from 16mm film and VHS tape, recorded speeches and text.
- The Everglades Project, which is a unique collection of published books, reports, archives, pamphlets, aerial photos, maps and other data relating to the Everglades ecosystem.
- The Wolfsonian Museum, a collection of visual images of the art objects housed in the Wolfsonian Museum in Miami.
- The FIU College of Engineering and Design is preparing courses for the Asynchronous Learning Network, which is a Web-based course accessible to remote students studying at their own pace. Currently these courses are housed on Web servers accessible via Web browsers across the network.

To support the digital library, the network needs to be able to deliver in addition to data, good quality multimedia including high-resolution images and full-motion video and voice. The new generation of students is familiar with the responsiveness of electronic games on a stand-alone PC and the quality of images obtained from a CD and video available on a TV screen from recorded cassettes, and would expect at least the equivalent responsiveness and quality from an educational system. Today the video clips in the digital library are encoded using MPEG-1, but the plan is to use MPEG-2 for better quality in the future.

3.3 Distance Learning

There is a requirement for a network that is capable of delivering high-quality asynchronous learning programs that enable students to pursue their studies in their own time. Today 56% of the students at FIU are part time, and the university foresees that this trend will increase. Part-time students are constrained by family and work responsibilities and often have to interrupt studies to fulfill other obligations. These students will benefit from the technologies that support an on-demand, time and place-independent delivery of personalized instruction.

A reliable high-speed network could be used as a conduit for academic staff to be able to make their research work and teaching materials available to others without having to first go through a publisher. Revenue could still be earned from the intellectual content contained in this type of electronic material, as it is possible to be able to levy a charge to users each time they access this type of information.

There are administrative motivators driving the requirement for an ATM network capable of delivering multimedia services such as videoconferencing. The university, which is geographically dispersed, finds that teleconferencing is critical to address the efficient management of multiple campuses and would like to be able to do this over one integrated network.

3.4 Prerequisites

The network needs to be standard-compliant and scalable. The campus network consists of equipment from multiple vendors and is in a constant state of evolution and growth with the new equipment having to coexist with the old. The university network needs to interface with public wide area networks in a seamless way. These public networks include the Internet as we know it today and possibly higher speed versions of the Internet running over ATM in the future. The equipment that the university is installing in the core and backbone networks must be able to scale up to meet growing requirements without reaching some limit that may force all the infrastructure to be replaced.

The network should have high reliability and availability characteristics. The university is increasingly dependent on the network for its day-to-day functioning and so the network has to be maintained in an operational state throughout the migration phases and during an outage of some of the network components. The IBM implementation of servers in the MSS and hardware in the 8260 switches enables complete redundancy of the key components.

The network should enable the university to take advantage of new lower cost higher bandwidth services being offered by service providers. For example, the 155-Mbps ATM service between the two campuses costs 32% less per month than the dedicated link that was providing 10 Mbps in the past.

Chapter 4. High-Level Design

Florida International University has implemented an ATM network making use of IBM′s Switched Virtual Networking (SVN) strategy to meet their network requirements. SVN is an extension of IBM′s ATM strategy and combines the virtues of ATM switching, LAN switching, bridging, routing and other switched services. The ATM network provides scaleability, quality of service support and multivendor standards. The implementation of the ATM Forum LAN Emulation specification over the ATM network provides for the interoperability of the network with the legacy network. The ATM campus network at Florida International University is designed to be implemented in phases, co-existing with the legacy network while enabling the implementation of new applications requiring quality of service such as full-motion video and voice.

4.1 The Core Network

The design of the ATM network consists of a campus-wide core network that interconnects building backbone networks and the wide area links to remote campuses. The core network is implemented with IBM 8260 ATM switches interconnected with fiber optic links. The long term intention is to interconnect the IBM 8260 core switches in a meshed topology, to provide redundancy in case one of the fiber links is lost. In the initial phases the core network has been interconnected in a star topology using the existing fiber optic links radiating out from the PC building. The bandwidth on the links between the ATM switches can be scaled up in multiples of 155 Mbps or 622 Mbps, by aggregating more fibers into the link between two IBM 8260s, as the growth in traffic volumes require. Connected to the core is a router with an ATM interface and multiple Ethernet interfaces. The purpose of this router is to route data traffic from the legacy network to devices on the ATM network, and vice versa.

4.2 Building Backbone

A building backbone network would typically consist of a number of workgroup concentrators in the telecommunications closets on the different floors connected to an IBM 8260 ATM switch acting as a cross-connect device. In some buildings this cross-connect device may be the IBM 8260 switch that forms part of the core network. The work group concentrators are connected to the cross-connect ATM switch with fiber optic cables supporting transmission speeds of 155 Mbps. The workgroup concentrators in the telecommunications closets are a combination of IBM 8285 ATM switches supporting 25-Mbps links to workstations with ATM adapters and Ethernet switches with an ATM uplink to the building cross-connect switch and ports supporting category 5 cabling to legacy Ethernet workstations and servers. This mix of work group concentrators in the telecommunications closet enables ATM workstations to be installed and supported where required while connectivity to legacy workstations and servers over the ATM network will be maintained during the migration phases.

See Figure 4 on page 14 for a generic view of the physical connectivity.

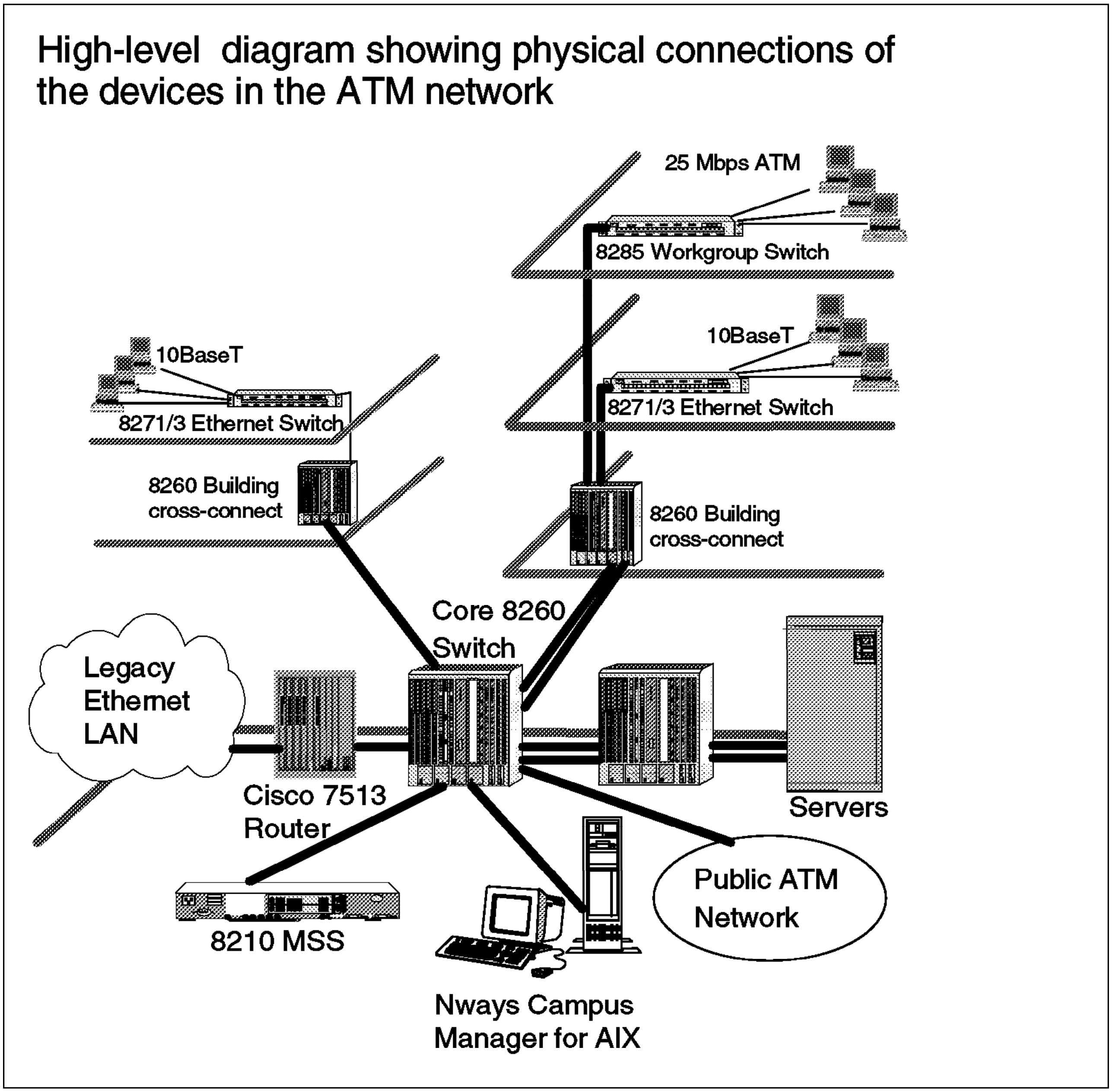


Figure 4. High-Level Design of ATM Network

4.3 Migration

ATM Forum-compliant LAN Emulation over ATM is used to provide a seamless interface between the ATM network and existing client/server applications that use traditional LAN protocols such as TCP/IP. LAN Emulation enables the ATM network to appear like an Ethernet LAN to the endstations. The high-speed ATM core network can be used while still protecting the current investment in software and hardware.

The university network design includes a number of virtual LANs or Emulated LANs (ELANs) implemented over the ATM network using LAN Emulation. The logical design of the ELAN network is based upon the traditional real LAN design. Each department or building may have a number of ELANs and all these departmental ELANs are connected to a central or core ELAN with a virtual router. The reason for creating unique ELANs for each department is purely administrative, since on the ATM network the end users are no longer limited by geographical location as to which LAN they can join. The reason for multiple ELANs per department is either because there is some administrative reason for separating the users within a department or because there are more than 254 users in that department and class C IP address masking is being used. The core ELAN only has the virtual routers attached to it; it does not have any end-user clients or servers other than the management server. The conceptual role of the core ELAN is similar to that of area 0 in an OSPF network. The implementation of the ELANs and virtual routers between the ELANs is provided by the IBM Multiprotocol Switched Services (MSS) software executing on either a stand-alone IBM 8210 server or an MSS server blade in the IBM 8260 hub.

4.4 Redundancy

High availability is ensured by providing redundant hardware components in the core IBM 8260 switches and by making use of the unique redundancy features of the IBM MSS software. Each of the 8260 switches has redundant power supplies and backup CPSWs. The MSS functions are all implemented with a primary and a backup instance. The primary and backup instance are each on different hardware platforms, either an MSS module in the IBM 8260 or an external IBM 8210. The redundancy functions will be implemented so that each MSS module will provide primary functions for one part of the network and backup functions for another part of the network. This will enable all available MSS hardware to be productively deployed all the time.

4.5 Strategy

The ATM network design is flexible and scaleable. This has been demonstrated by the successful installation of a number of phases to date and there are further phases still to be implemented as the availability of funds and requirements dictate. The implementation strategy of the design is as follows:

- To install the ATM network where it is required to be able to enable the new multimedia applications
- To install the ATM network into new buildings where there is no network infrastructure
- To install the ATM network where it will lead to cost savings such as over public service provider links

In a number of the buildings, the legacy network may continue to exist along with the ATM network for many years to come. The following chapters present the solution design and implementation phases in more detail.

Chapter 5. Solution Design

This chapter discusses the initial network design.

5.1 Building Names

The following acronyms are used to describe the buildings at FIU that make up the core network:

PC Charles Perry - Administration

LIB Library

COE College of Education

OE Owa Ehan

CEAS College of Engineering and Applied Science

ECS Engineering & Computer Science

NC North Campus

5.2 Device Names

The following are the device names of the IBM 8260 hubs and the MSS servers used in this document.

- 8260 Intelligent Hub

  PC205-8260 8260 located in the PC building (Core Concentrator), 2nd floor

  PC504-8260 8260 located in the PC building, 5th floor

  LIB-8260 8260 located in the library

  COE-8260 8260 located in the COE building

  OE-8260 8260 located in the OE building

  ACI-8260 8260 located at the North Campus

- Multiprotocol Switched Services

  PC205-MSS-8210 Primary MSS, located in the PC building 2nd floor

  PC205-MSS-8260 Backup MSS, located in the PC building 2nd floor

  PC504-MSS-8260 MSS located in the PC building 5th floor

  COE-MSS-8260 MSS located at the COE building

  ACI-MSS-8260 MSS located at the North Campus

5.3 FIU Network Design

The design discussed in this section is the design of the network as implemented during phases 1 to 5. This design has continued to evolve due to the availability of new functions and limitations of the original design becoming apparent during implementation. The evolution of the design is discussed in Chapter 7, “Solution Design Considerations” on page 65. The network design is discussed at three layers: the physical, the ATM and the network layer.

1. Physical Layer Design

   The PC building is the collapse point for all the existing campus fiber. This physical structure ultimately dictated the initial star design using the PC building as the concentrating building. The physical design is a star-wired core of 8260 switches using 155-Mbps connections. Some connections required multiple 155-Mbps links. PC205-8260 is the central core switch for two reasons. The PC building is a physical fiber concentrator and the PC building would contain all or most of the high-performance servers. PC205-8260 connects with double 155-Mbps connections to the LIB-8260, PC504-8260 and COE-8260. The OE, ECS and the connection to the legacy LAN have single 155-Mbps connections. The North Campus will be connected to a WAN ATM service provider with a 155-Mbps link. See Figure 5 for the physical network design. Each building has a combination of ATM and Ethernet workgroup switches forming the backbone of the building.

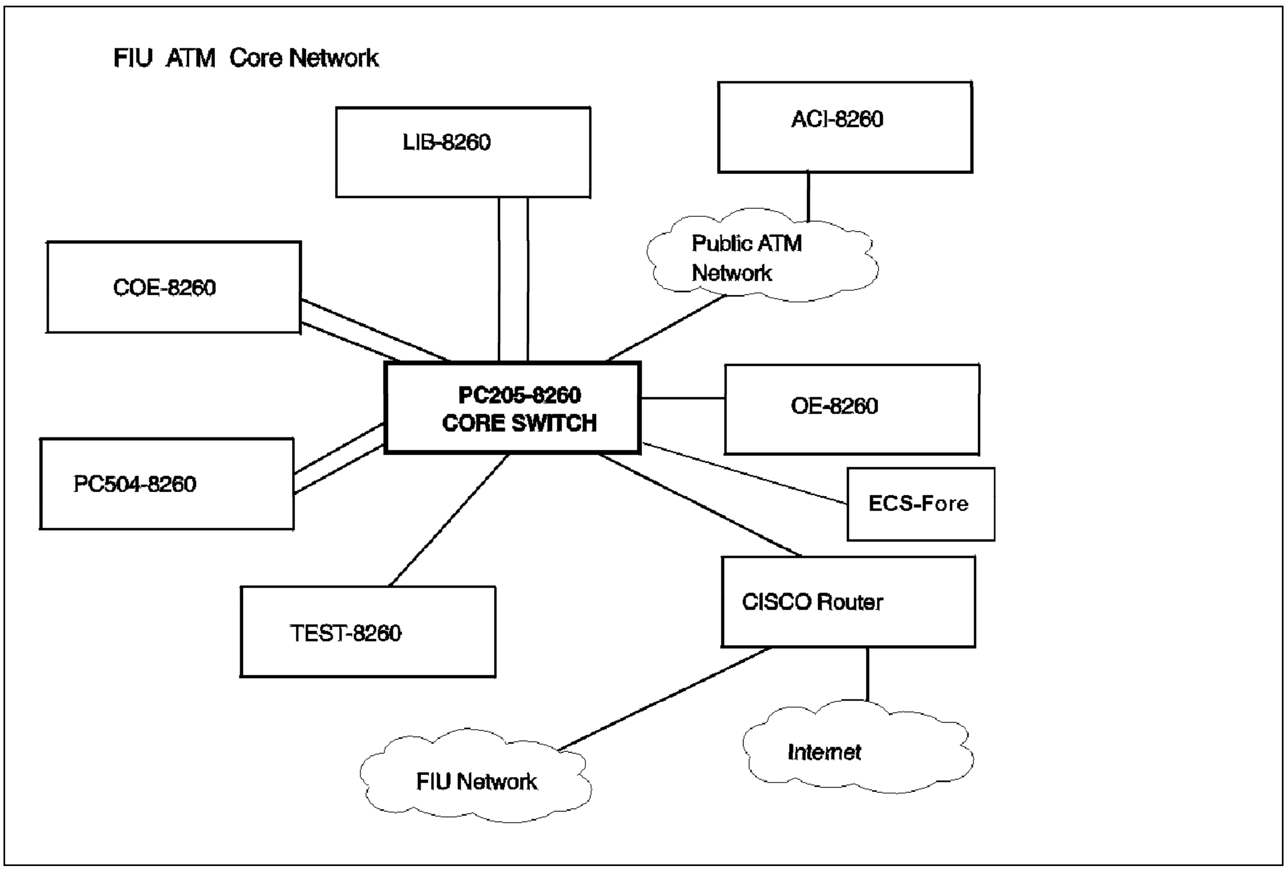


Figure 5. Physical Layer Design

2. ATM Layer Design

   On this level the network is structured into four clusters. See Figure 6 on page 19 for a cluster representation of the network design. Refer to Chapter 7, “Solution Design Considerations” on page 65 for the discussion on the limitations of this design.

   Cluster 01: OE, COE, PC205 and PC504
   Cluster 02: North Campus
   Cluster 03: LIB
   Cluster 09: Computer Science

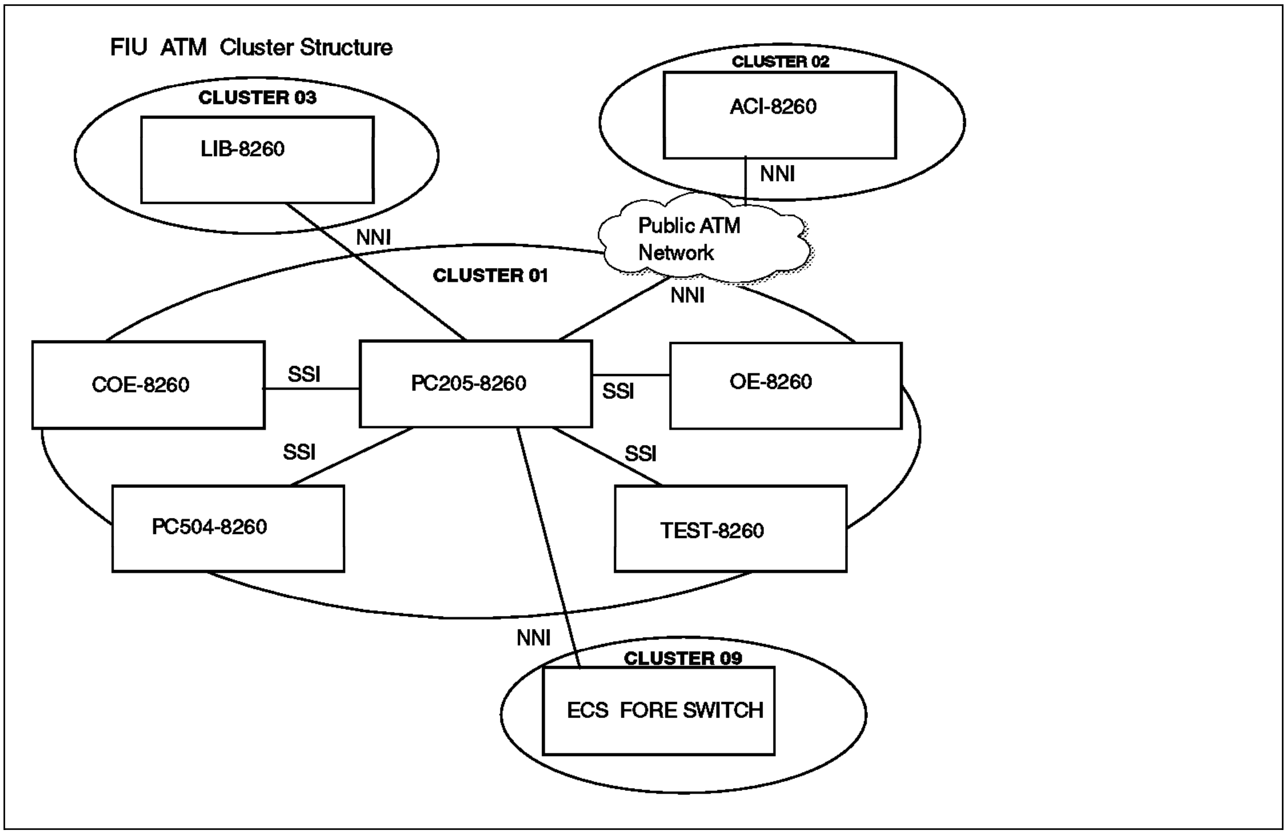


Figure 6. ATM Layer Design

3. Network Layer Design

   The FIU network is predominantly an IP network that is segmented via subnets. IP subnets are assigned to buildings/departments. The introduction of ATM and MSS has made it possible to maintain this subnet structure with a high degree of flexibility. Each ELAN represents an IP subnet. The ELAN names have subnets associated with them. There are one or more ELANs defined per building. In addition to the localized ELANs per building, there are two other ELANs defined. One is used for routing between the MSSs and the other is used for bridging nonroutable protocols between the ATM network and the legacy network. The policy to join an ELAN is by ELAN name. More ELANs will be created as additional buildings join the ATM network. Figure 7 on page 20 shows how the ELANs are interconnected.

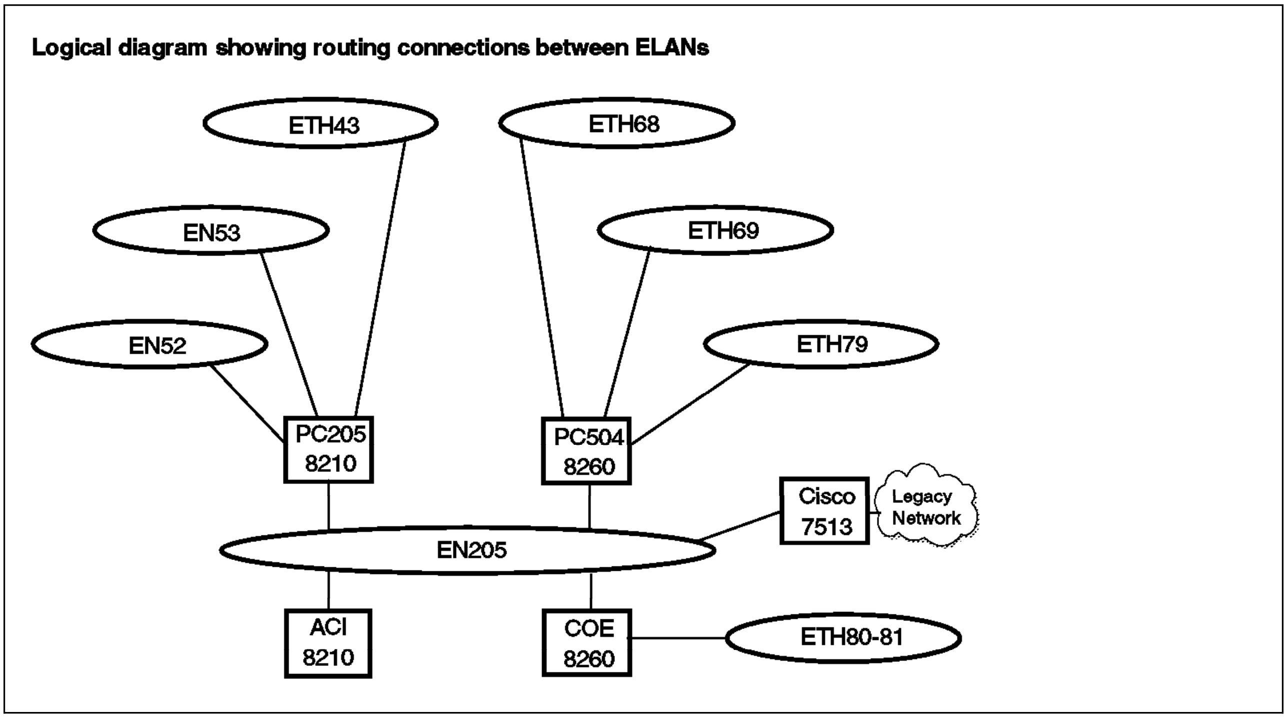


Figure 7. Network Layer Design

5.4 Description of the ELANs

This section lists and describes the function of each ELAN defined on the various MSSs.

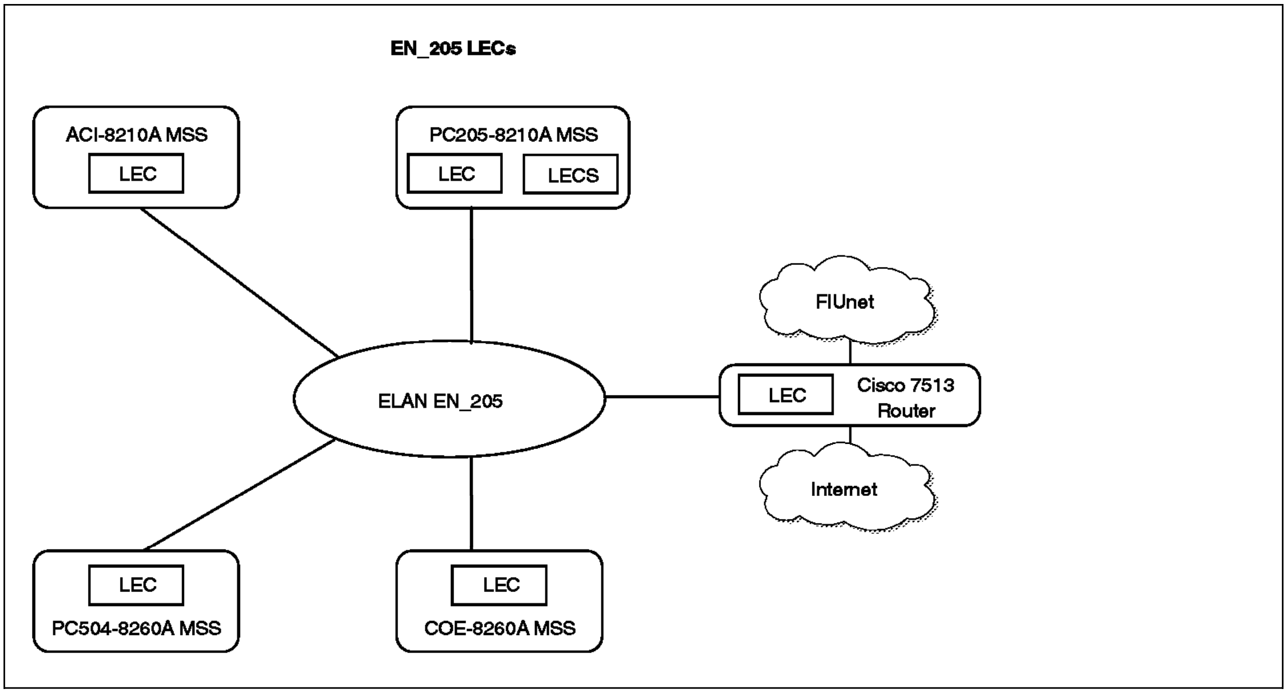


Figure 8. ELAN EN_205 and MSS Connectivity

The following list describes the ELANs created in the FIU network:

- EN_205: Subnet 205.x

  MSSs join this ELAN.

  EN_205 was created as the core ELAN. All data being routed between the MSSs traverses this ELAN. The only devices attached to this ELAN are MSSs and the Cisco 7513 router which connects the ATM network to the legacy network. The primary LES-BUS for this ELAN is defined on the PC205-MSS-8210.

  Figure 8 on page 20 shows the MSSs are connected to this ELAN.

- ETH_43: Subnet 43.x

  Devices at the OE building will join this ELAN. This ELAN is defined on the PC205-MSS-8210.

- EN_52: Subnet 52.x

  Devices at the library will join this ELAN. This ELAN is used for devices that do not access the Internet (printers, etc.). This ELAN is defined on the PC205-MSS-8210.

- EN_53: Subnet 53.x

  Devices at the library will join this ELAN. This ELAN is used by devices that have access to the Internet. The authorization is done on the Cisco 7010. This ELAN is defined on the PC205-MSS-8210.

- ETH68 and ETH69: Subnet 68.x, 69.x

  Both these ELANS were created to interface with the SP2 server. The SP2 has four nodes each with two ATM ports. Each group of two ports per node, which are routing interfaces, need to join separate ELANs. Both ELANS are defined on the PC504-MSS-8260.

- ETH79: Subnet 79.x

  Devices throughout the campus join this ELAN. This ELAN is used by the legacy LAN and the ATM LAN. It is used to bridge protocols not being routed (DECnet, IPX, etc.) to the legacy network. The bridging mechanism is handled by the 8274. This mechanism is discussed later during Phase 4. This ELAN is defined on the PC504-MSS-8260.

- ETH80-81: Subnets 80.x, 81.x

  Devices at the COE building join this ELAN. This ELAN is defined on the COE-MSS-8260. The 80.x and 81.x subnets were both created on the same interface because at this time the 8271 code level (V2.3) restricted the number of ATM clients to one, so it was not possible for the switch to join multiple ELANS. In order to maintain the two subnets, both 80.x and 81.x were defined on the same interface. The 8271 code level V2.5.1 and onwards does allow for multiple ATM clients to be configured.

Figure 7 on page 20 represents the logical connectivity of the ELANS, with EN_205 as the core ELAN.

5.5 Classical IP and the Management Subnet

The Classical IP network is used purely for management purposes. All ATM devices except 8271s have interfaces to this subnet and can be managed via IP and SNMP. 8271s, which do not support CIP, each belong to an ELAN together with the devices that connect to the 8271. The ATM devices are initially given minimum parameters to join the network, such as an IP address and an ATM address. All further configuration is done remotely from the management station, using telnet to access the command line interface or with the MSS by using the Configuration Program. Figure 9 shows how the devices are attached to the management network.

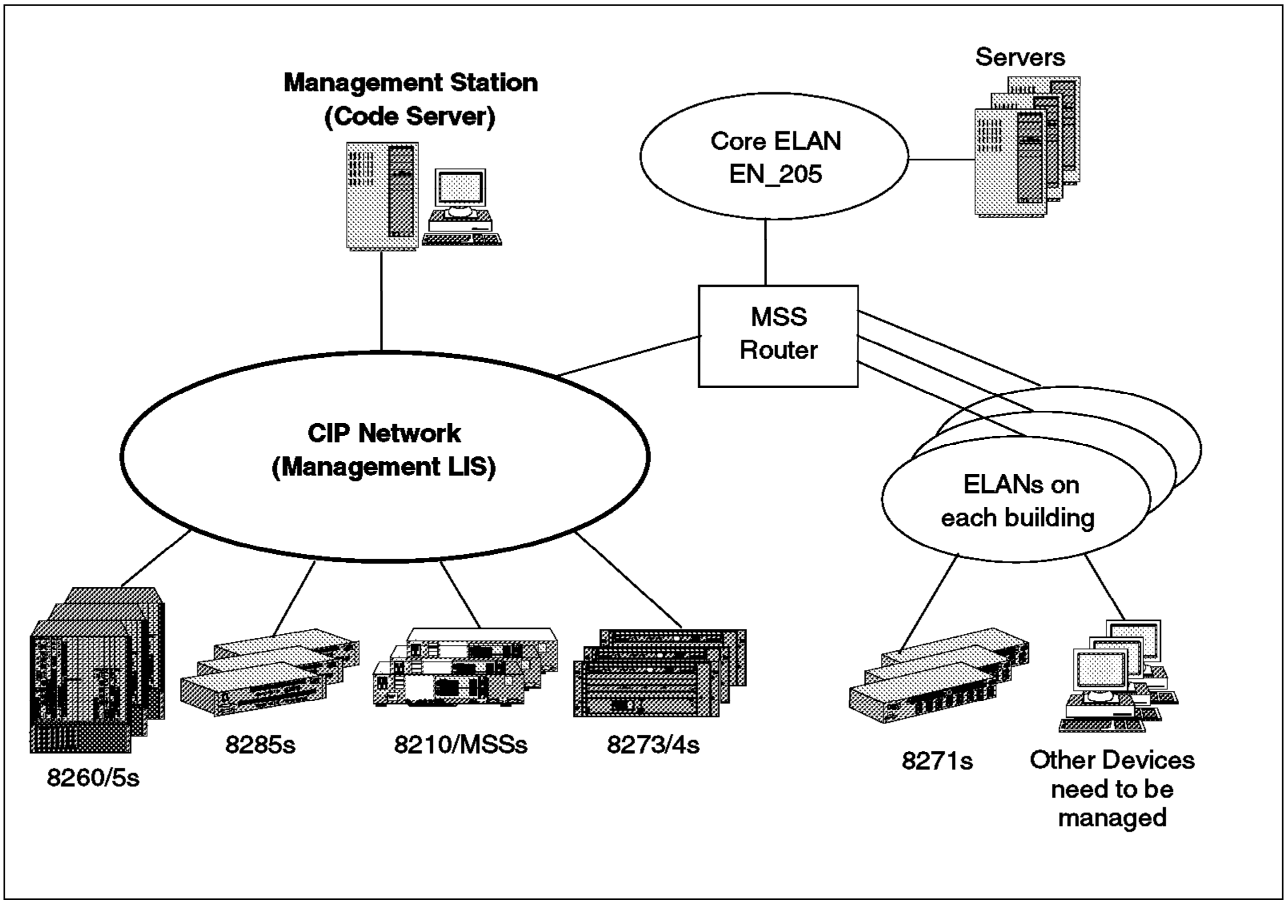


Figure 9. CIP Network and Management Scheme

5.6 Method Used to Document the Configurations of the MSSs

Initially all the MSSs were configured via the command line. Later the customer used the Configuration Program, which provides an easy-to-use interface for the configuration, download and upload of configurations. FIU is using the Configuration Program Version 1 R1.1 on a Windows 95 platform and on the AIX platform.

FIU devised an effective method to document the configuration of the MSSs. This method is an extension of the parameter overview in the redbook *Understanding and Using the MSS Server Release 1.0*, SG24-4915 (see Chapter 11). Each component LECS, ARP server, LEC and LES-BUS is represented in box format with all the relevant information available at a glance. This provides an easy way to document all the parameters before the configuration is started. The configuration can be entered from this chart. Changes can also be documented in this manner. Using the box representation together with a logical view of the relationships between the ELANS and the MSSs provides an effective tool for understanding and designing the connectivity of the ELANS. This method of representing the MSS configuration is used for each implementation phase of the network design. Figure 10 on page 24 shows how each entity of the MSS can be represented in this format. An explanation of each component represented follows the diagram.

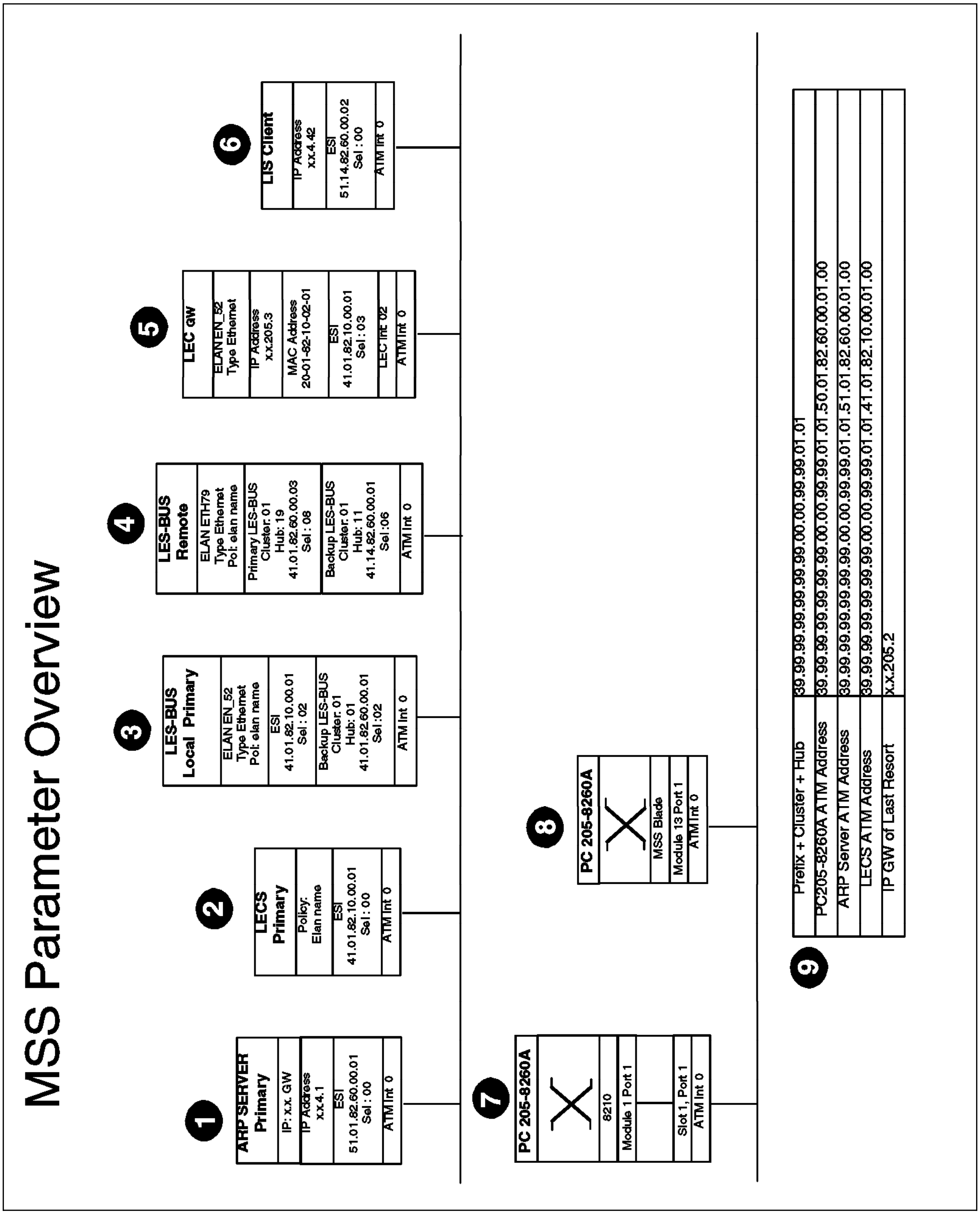


Figure 10. Parameter Overview Showing All Components of the MSS

The following list relates to the numbers identified in Figure 10. The definitions for each entity is listed below the numbered item.

1. ARP Server

The ARP server is identified as primary.
Default GW address for the classical IP subnet.
ARP server IP address.
The ESI, Selector byte.
The ATM interface, in this case 0. In the case of an 8210 this could be 0 or 1 depending on how many ATM UFCs are installed.

2. LECS

   The LECS is identified as primary.
   The policy by which the LECS assigns LECs to ELANs.
   The LECS′s ESI and selector byte.
   ATM interface number.

3. LES-BUS Local Primary

   The ELAN name, type, policy.
   The ESI and Selector byte.
   The cluster, hub, ESI, selector of the backup LES-BUS if backup is remote.
   ATM interface number.

4. LES-BUS Remote

   ELAN name, type, policy.
   Cluster, hub, ESI, selector byte of the primary LES-BUS.
   Cluster, hub, ESI, selector byte of the backup LES-BUS.
   ATM Interface Number.

5. LEC GW

   ELAN name that the LEC joins and the type.
   IP address of LEC.
   MAC address of LEC.
   ESI, selector byte of LEC.
   ATM interface.

6. LIS client

   IP address of LIS client.
   ESI, selector of LIS client.
   ATM interface.

7. MSS 8210 connection into 8260

   Name of the 8260 that the 8210 connects to.
   Module #, Port # of the 8260.
   Slot #, Port # of the 8210.
   ATM interface number of MSS.

8. MSS blade connection to 8260

   Module #, Port # of the 8260 that the blade slots into.
   Name of the 8260 that the blade slots into.
   8260 port connection to the adjacent 8260.

9. List of ATM addresses

   Prefix, Cluster #, Hub # of the 8260 that the MSS connects to.
   8260 ATM address.
   ARP Server ATM address.
   LECS WKA address.
   IP address of last resort.

5.7 Routing

Currently the only protocol being routed over ATM is IP. The virtual routers on the MSSs handle the routing between ELANs. It is important to note that the MSSs handle all the routing at the ATM side of the network. The MSSs are the routers at the ATM side of the network. MSS V1.1 has the capability of routing AppleTalk. This new MSS feature will be implemented in the near future.

5.8 Bridging

Bridging is used to take care of protocols not being routed. The design isolates these protocols to ELAN ETH79. An 8274 is configured to handle the bridging between ETH79 and the legacy network. Figure 11 shows this connectivity. The configuration of this bridging function is described in more detail later in phase 4.

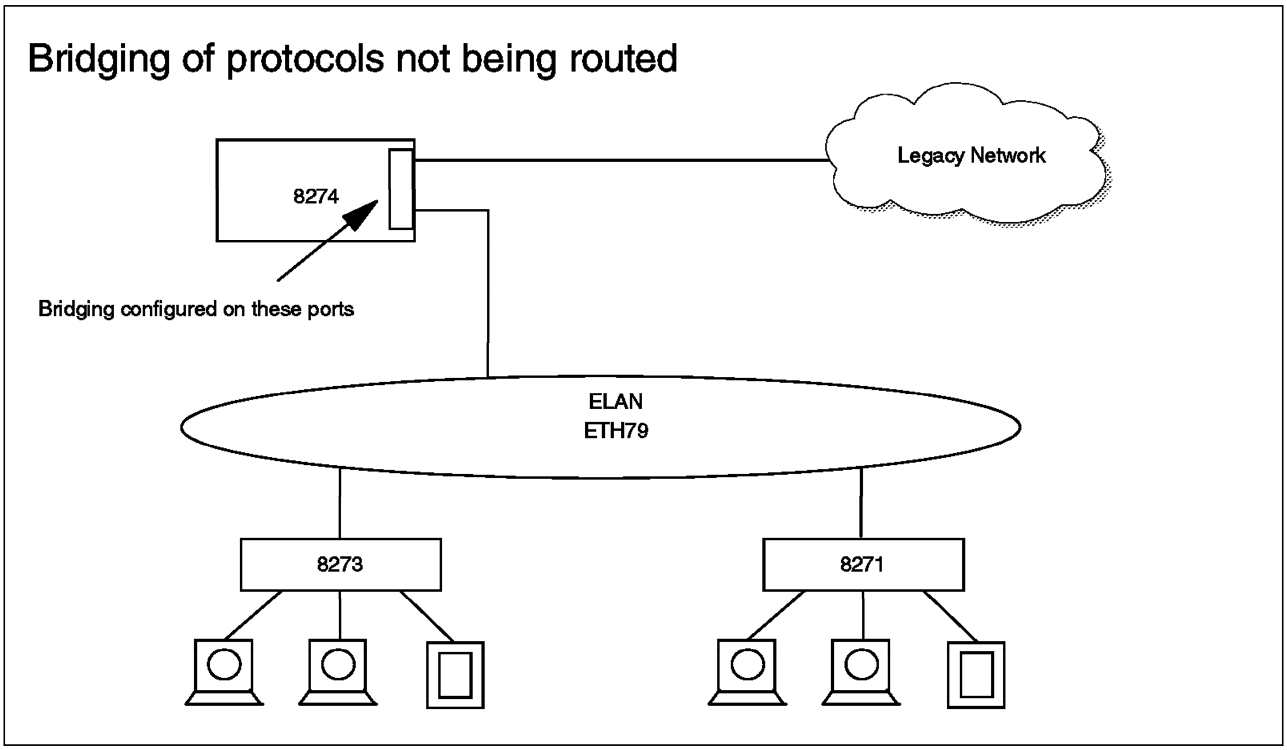


Figure 11. Bridging of Protocols Not Being Routed between the Legacy and ATM Networks

5.9 The Core Network

The core network comprises all the 8260s in their star configuration. The PC205-8260 is the core concentrator. Each 8260 will have a core link to the PC205-8260. The 8260s in each building will be the cross connectors for the building backbone.

5.10 Broadcast Management

The Broadcast Manager (BCM) intercepts broadcast and multicast frames intended for the BUS. It then converts broadcast frames into unicast frames and transmits the frames directly to the destination clients. BCM functions independently for each ELAN. BCM is enabled on each ELAN. BCM supports IP, IPX and NetBIOS. Broadcast Management is enabled to minimize the amount of traffic sent over the ELANs. This function is also useful over the WAN between North Campus and University Park.

To illustrate the effectiveness of the BCM, an IBM networking specialist carried out an analysis of the impact of BCM on broadcasts within various ELANS. The EN_205s LES BCM did not reduce any broadcasts. The reason for this is that EN_205 only has routers attached to it. RIP is the predominant protocol on EN_205. The BCM has no ARP broadcasts to manage.

ELAN EN_53 on the other hand has many user devices attached to it. Each end-user device is ARPing for the MSS gateway and the local IP servers. With BCM enabled, EN_53 showed a reduction of broadcasts by 40 - 50%. This is a significant reduction of broadcasts.

5.11 Redundancy

The nature of the service provided, the number of users and the 24-hour usage period demand that the FIU network be highly reliable. To ensure the reliability of the network the following features have been embedded into the design. At the time that phase one was implemented, the MSSs were at code level V1.0. The redundancy features described in the following sections are using MSS V1.0 functionality.

5.11.1 Device Redundancy

Each 8260 has redundant power supplies installed. ATM switch redundancy is achieved by installing two CPSWs in each 8260. One is set up as active and the other as passive. The active CPSW updates the passive CPSW by keeping a configuration table updated. See *8260 ATM Product Architecture*, SG24-2110 for more information on CPSW redundancy. MSS redundancy is achieved by installing initially two and later more MSSs throughout the network. The PC205-MSS-8210 will perform the primary MSS function and the PC-205-MSS-8260 will act as the backup MSS. The redundancy of the various components of the MSS are discussed below.

5.11.2 ARP Server

As implemented in MSS V1.0, there is no way to identify the ARP server as primary or backup. Whichever one registers its ATM address first becomes the active one. To route between the CIP and the ELANs the ARP server must be on the same MSS as the gateway for the ELANs. Here we call the primary ARP server the one defined on the PC205-MSS-8210. The backup ARP server (an identical copy of the server on PC205-MSS-8210) is defined on PC205-MSS-8260. The backup keeps trying to register its ATM address (every ten seconds). If the primary does fail, the backup is able to register its address. When the primary becomes active, it will then try to register it′s ATM address. The only way to force the primary to become active again is to power off the backup. The problem with this is that there is a need for manual intervention. It is also difficult to keep track of which ARP server is active. MSS V1.0 forces the primary LECS and ARP server to exist on the same physical 8260 as the backup LECS and ARP server. This is the reason why the PC205-MSS-8210 and the PC205-MSS-8260 are on the same physical 8260.

5.11.3 Default Gateway

As implemented in MSS V1.0, the default gateway (DGW) on the LEC is manually configured to join that ELAN. This implies that the LEC resides on the same MSS as the LES-BUS for that ELAN. The redundant default gateway (RDGW) resides on the same MSS as the backup LES-BUS. The RDGW is manually configured to join the backup LES-BUS. These LECs have the same IP address. When the primary fails, the backup LES-BUS takes over and the RDGW is able to register and take over as the DGW for that ELAN.

5.11.4 LECS

Generally, LECS redundancy is not considered on MSS but on the ATM switches. There are three methods, ILMI, well-known address (WKA) and LECS PVC, defined on the ATM Forum to provide the LECS address to LECs dynamically. The ATM switch maintains the information to handle the request from LECs to appropriate LECS.

Prior to V3, 8260/8285 supports multiple LECS addresses registration for ILMI LECS address by using multiple set lan_emul configuration_server definitions, but it supports only one LECS address for the WKA. FIU defined the LECS address which exists on the building as the first entry and another LECS address as the second. The second LECS must have the LES-BUS instances (local or remote) defined in order to reach them. In addition, V3 code now supports multiple WKA LECS addresses by dynamic WKA LECS address resolution based on the WKA address registration from the LECSs.

5.11.5 LES-BUS

As implemented in MSS V1.0, the primary LES-BUS is defined as the primary and the backup LES-BUS is defined as the backup. When the primary fails the backup will register its address. When the primary recovers the backup will deregister its ATM address and the primary will register its own ATM address.

5.11.6 New Features with MSS V1.1

MSS V1.1 provides several enhancements for redundancy functions. The following sections describe these functions, which are implemented in FIU as well.

5.11.6.1 ARP Server

MSS V1.1 supports redundant ARP servers and redundant default gateways for logical IP subnets (LISs). Limited support for ARP server redundancy was provided in MSS V1. Limitations of MSS V1 ARP server redundancy support are (1) both the primary and the backup ARP server must be attached to the same switch, (2) the user has no configuration control over which ARP server is the primary and which is the backup (that is, the first one to power up and register with the switch is the primary), and (3) the MSS servers hosting the primary and backup ARP servers cannot be performing IP routing. Although the first limitation is still present in MSS V1.1, the other two limitations have been removed. For more detail, please refer to *Understanding and Using MSS Release 1.1* (SG24-2115-00).

FIU implements CIP only for the management purpose. There is only one LIS network and it does not need routing. FIU uses redundant ARP servers on the buildings (that is, on the buildings that have two or more MSSs connected to the same switch).

5.11.6.2 Default Gateway Redundancy

MSS V1.1 allows for the default gateway redundancy for an ELAN to be defined on a separate MSS. This makes it possible to implement a more flexible redundancy design. Also the workload on the MSSs can be more evenly distributed. The redundant default gateway function and redundant LES/BUS function were tested in July/97. These test scenarios using the new redundancy functions are discussed in 6.6, "Phase 6: LES-BUS/Default Gateway/Redundancy" on page 58 and the current implementation is in 8.5, "New Method of Documenting the MSS Configuration" on page 82.

Chapter 6. Installation of the Network

This chapter describes the phases and implementation of the FIU network.

To understand how the FIU network grew to what it is today, we have split the growth into various phases. These phases signify major growth or design considerations. At each phase we discuss the issues encountered.

The phases are as follows:

Phase 1 ATM Core and Library Backbone

Phase 2 ATM Core and College of Education (COE) Backbone

Phase 3 ATM Core and OE Backbone

Phase 4 PC504/8274/Catalyst3000/SP2 Connectivity

Phase 5 ATM WAN Link to ACI (North Campus)

Phase 6 LES-BUS/Default Gateway/Redundancy

Phase 7 DM Infrastructure Project

Phase 8 PNNI Migration (CPSW V3, 8285 Upgrade)

6.1 Phase 1: ATM Core and Library Backbone (Starting January 97)

The goal of phase one is to provide a core link between the library and the PC205 building and implement an ATM backbone infrastructure at the library. The PC 205-8260 would be the core switch with two 155-Mbps connections to the library 8260. The backbone at the library consists of nine 8285s, each with a single 155-Mbps link to the library 8260, and six 8273s each with a single 155-Mbps link to the library 8260. The ATM 25-Mbps PCs connected to the 8285s and the 10-Mbps Ethernet PCs connected through the 8273s now have access to the ATM servers located in the library and they have access to all other servers located on the legacy FIU network. The 25-Mbps PCs are non-proxy LECs on EN_53, while the 8273s are proxy LECs on EN_53 working on behalf of the 10-Mbps Ethernet PCs. Figure 12 shows the physical connections of the network while Figure 13 on page 33 shows the logical representation of the ELANs in the FIU network.

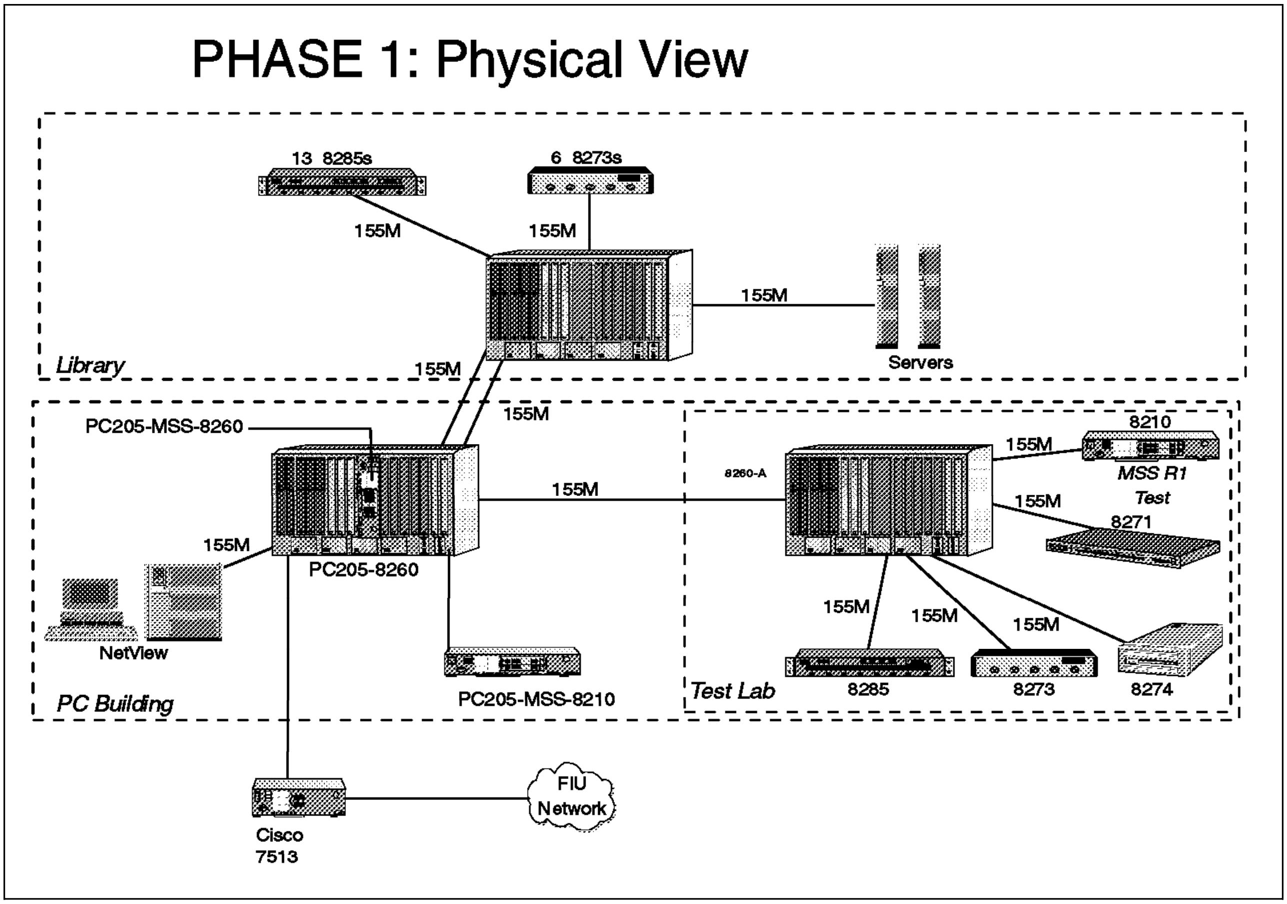


Figure 12. Physical View

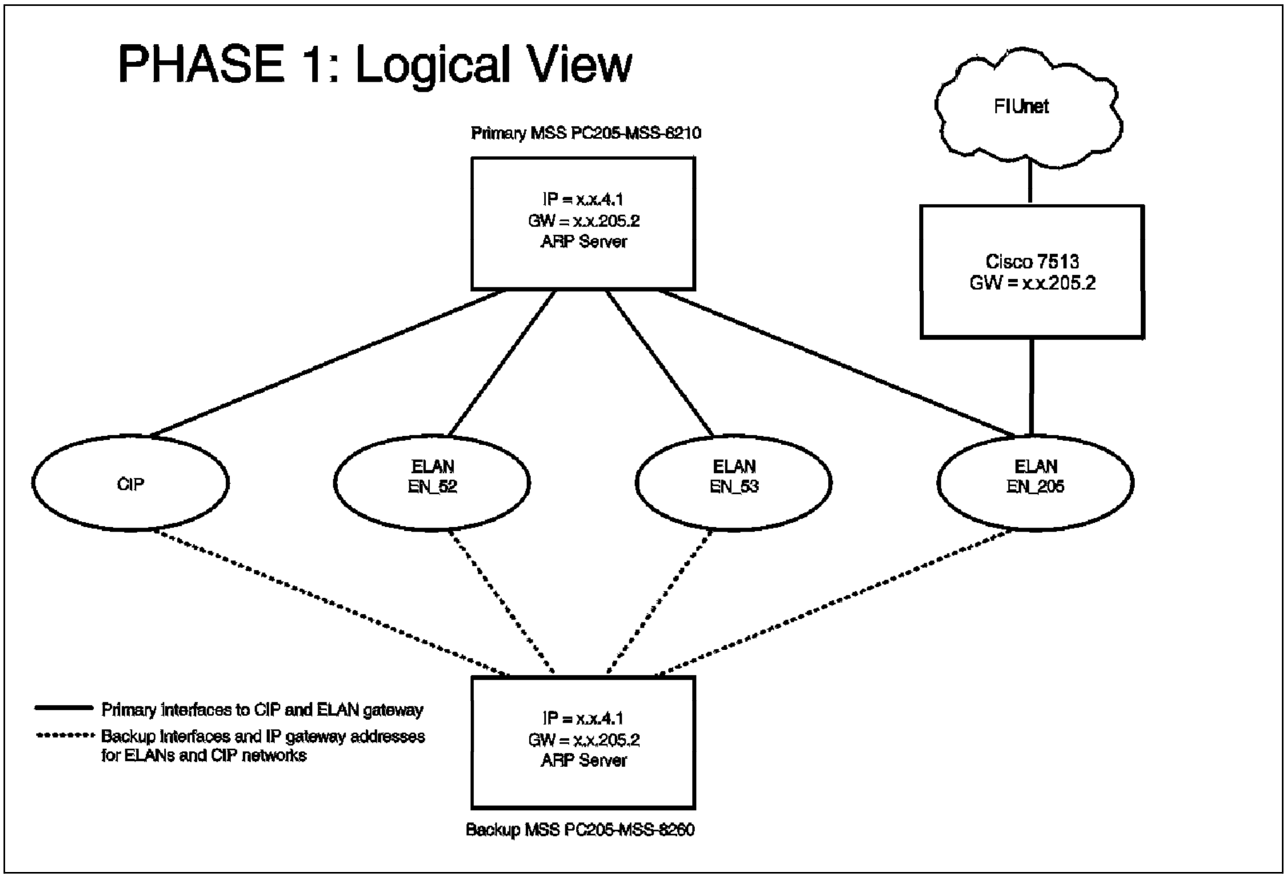


Figure 13. Logical View

Using the same structure as Figure 10 on page 24, Figure 14 on page 34 shows the configuration of the primary MSS while Figure 15 on page 35 shows the configuration of the backup MSS.

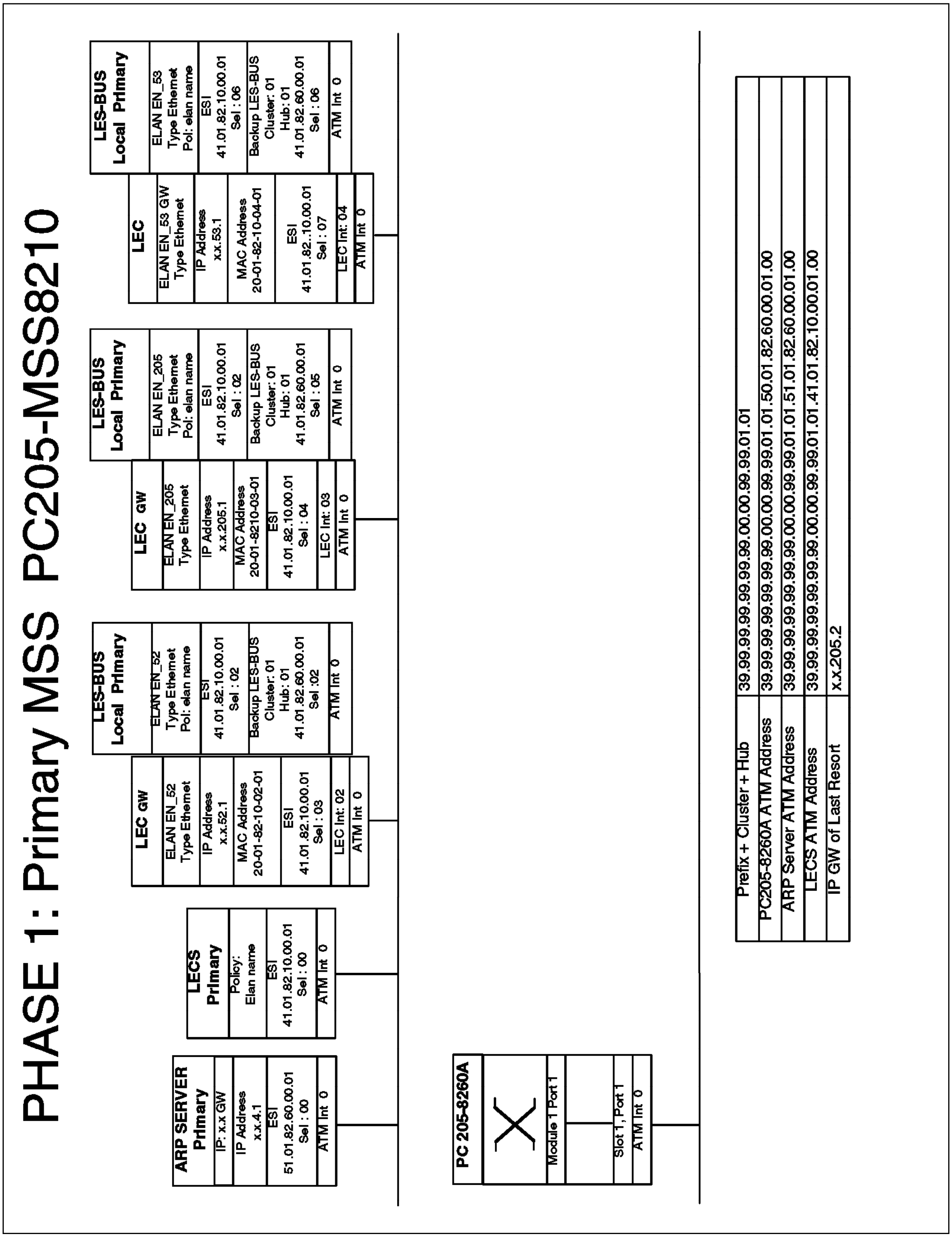


Figure 14. MSS Configuration (Primary)

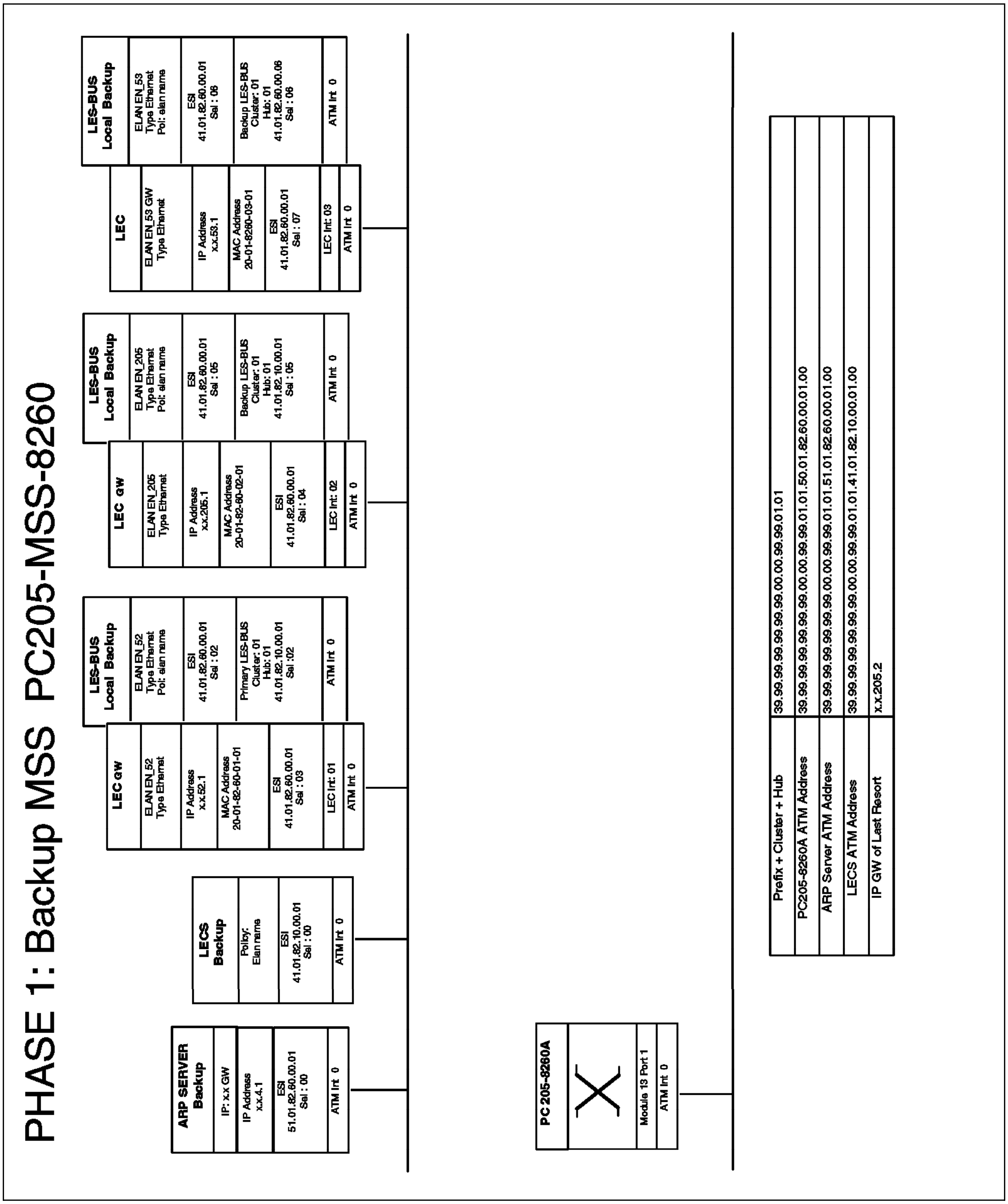


Figure 15. MSS Configuration (Backup)

6.1.1 Equipment Used

The library requires one 8260, nine 8285s and six 8273s. The PC building requires one 8260, one MSS-8210 and one MSS-8260 blade. The workstations and servers at the library use IBM 25-Mbps and Interphase 155-Mbps ATM NICs respectively.

6.1.2 Levels of Code

Phase one was implemented using the microcode levels on the 8260 and MSS described below.

MSS Release 1.0

CPSW Boot EEPROM version: V2.5.0

Flash EEPROM version: V2.5.1

Flash EEPROM backup version: V2.3.0

Operational FPGA version: B50

ATM Modules Operational FPGA version: B50

8285 Boot EEPROM version: V1.5.0

Flash EEPROM version: V1.5.0

Flash EEPROM backup version: V1.3.0

Operational FPGA version: C30

8273 V2.0

8274 V2.0

6.1.3 The Test Environment

This test environment was a crucial factor in the successful migration toward ATM. The test bed was used to configure and test the 8260 with basic connectivity to the following products: 8260, 8210, 8285, 8271, 8273 and 8274. This environment made it possible for the customers to familiarize themselves with the products and also to test the connectivity of the various products. The test bed was invaluable in testing the migration plan for configuring new functions available in MSS Version 1.1, especially the PNNI functionality.

After the MSS and the Cisco 7513 were configured and working, some of the unique redundancy features of the MSS and 8260 were tested. The dual CPSW redundancy was tested by removing the active CPSW module from the PC205-8260. The backup CPSW then became active and the sessions recovered after a short down time. The sessions were broken because the SVCs needed to be rebuilt. The users experienced a short (less than a few minutes) delay. The PC205-MSS-8210 was then turned off to test the redundant MSS features. Since FIU was at that stage using MSS V1.0 the redundancy function was not automatic as it is now with MSS V1.1. FIU had to manually enable the 8260 slot that the backup MSS was using. Only then would it come up and serve as the backup ARP server, LECS, LES-BUS and gateway functions. The user sessions were broken because they were connected through the MSS LEC gateway and these SVCs were broken and needed to be rebuilt. The users experienced a temporary delay.

The redundant fiber links were also tested between the LIB-8260 and the PC205-8260 by removing one of them. The SVCs that were using that fiber were torn down and automatically re-built over the remaining fiber. These tests were performed using the test bed before the library 8260 was installed.

6.1.4 Steps Taken to Achieve This Goal

The following configuration steps need to be carried out in order to create this network as depicted in Figure 12 on page 32 and Figure 13 on page 33. Figure 14 on page 34 shows the parameter overview used to enter the parameters.

The PC205-MSS-8210 was implemented to provide all the primary ELAN services and CIP functions. A second MSS was implemented on the PC205-8260 to be a backup for the PC-MSS-8210. It provided a backup for the ARP server, the LECS, the LES-BUS pairs and the default gateways for the ELANs. The ARP server is the CIP gateway. The ARP server and LECS are set up identically to the MSS on the PC205-MSS-8210. In this manner only one ARP server and one LECS can be active at any one time. Step 4 on page 36 shows the configuration procedures necessary to create the backup ARP server, LECS, LES-BUSs and gateways.

Step 6 lists the configuration steps required to implement each 8285 at the library. The 155-Mbps UFC is used to link each 8285 to the library 8260. The UFCs are configured as an SSI link (same cluster) with 155-Mbps bandwidth. Each 8285 is configured with the address of the LECS using the set lan_emulation configuration_server command, which points the LEC to the LECS in the PC205-MSS-8210. This LECS is also acting as the well-known address (WKA). Most 25-Mbps clients use the ILMI process to learn the address of this LECS. The Interphase NICs use the well-known address to get the LECS address.

The configuration steps were as follows:

1. Configure PC205 8260 CPSW as follows:
   a. Configure the ATM interface of the CPSW.
   b. Set the ATM address.
   c. Set the ATM address of the ARP server.
   d. Set the IP address.
   e. Set the default gateway.
   f. Set the LECS as the well-known address.
   g. Set the logical link (this is needed between clusters) to cluster 03, library.
2. Configure the PC205-MSS-8210 (primary):
   a. Configure the ATM interface of the PC205-MSS-8210:
      1) Add the necessary ESIs.
   b. Configure the LIS client and ARP server:
      1) Configure IP on the ATM interface.
      2) Configure the LIS client as an ARP server/client.
   c. Configure the LECS:
      1) Configure the LECS with a locally administered ESI address.
      2) For each ELAN do the following:
         a) Add the ELAN definition to the LECS.

        b) Configure the ELAN definition and set the policy value.

    3) Define priorities for LECS general policies

  d. Configure LES-BUS pairs for each ELAN.

  e. Configure LECs:

    1) For each LEC to be defined do the following:

        a) Add a LEC as a logical interface.

        b) Configure the logical interface.

        c) Assign an IP address to the LEC.

3. Configure PC205 8260 CPSW:

    a. Configure the ATM interface of the CPSW (port that connects to PC205-MSS-8260).

4. Configure PC205-MSS-8260 (the backup MSS):

    a. Configure the ATM interface of the PC205-MSS-8260.

    b. Configure the LIS client and ARP server (identical configuration as the ARP server on PC205-MSS-8210):

        1) Configure IP on the ATM interface.

        2) Configure the LIS client as an ARP server/client.

    c. Configure the LECS (identical configuration to the LECS on PC205-MSS-8210):

        1) Configure the LECS with a locally administered ESI address.

        2) For each ELAN do the following (local backup):

            a) Add the ELAN definition to the LECS.

            b) Configure the ELAN definition and set the policy value.

        3) Define priorities for LECS general policies.

    d. Configure LES-BUS pairs for each ELAN.

    e. Configure LECs:

        1) For each LEC to be defined do the following:

            a) Add a LEC as a logical interface.

            b) Configure the logical interface.

            c) Assign an IP address to the LEC.

5. Configure the LIB8260 (the port that connects the PC205-8260 blade):

    a. Configure the ATM interface of the CPSW:

        1) Set the ATM address.

        2) Set the ATM address of the ARP server.

        3) Set the IP address.

        4) Set the default gateway.

        5) Set the LECS as the well-known address.

        6) Set logical link (this is needed between clusters) to cluster 01, PC205.

6. Configure each 8285 as follows:

a. Configure the ATM interface of the 8285.

b. Set the ATM address.

c. Set the ATM address of the ARP server.

d. Set the IP address.

e. Set the default gateway.

f. Set the LECS as the well-known address.

7. Configure the 8273s.

8. Connect the Cisco 7513 to the ATM network:

   a. Configure port on PC205-8260 for Cisco 7513

   b. Configure Cisco ATM interface to join ELAN_205

9. Upgrade PCs at the library to ATM NICs:

   a. Install 25-Mbps ATM adapters in PCs

   b. PCs (Windows 95) configured to join EN_53 ELAN

6.2 Phase 2: ATM Core and College of Education (COE) Backbone

Our goal is to provide a core link to the education building (new building) and implement a switched backbone at the education building. The COE 8260 is linked to the PC205 core switch with two 155-Mbps links. The backbone at the COE consists of six 8285s each with a 155-Mbps link to the COE 8260, and four 8271s, each with a 155-Mbps link to the COE 8260.

At this stage distributed MSS functionality is introduced. ELAN ETH80-81 is primary on COE-MSS-8260 and backup on PC205-MSS-8210. A second LECS is defined on the COE-MSS. This LECS allowed the 25-Mbps LECs and the 8271 LECs in the education building to join the ETH80-81 ELAN in the COE-MSS. The COE LECS also has knowledge of the EN_205 ELAN so that its local gateway (LEC) to EN_205 can join the EN_205 core ELAN. If we do not let the COE LECS know about the EN_205 LES, then we would have to hard code the ATM address of the EN_205 LES in the COE-MSS gateway (LEC). We would have to pick the primary PC205-MSS-8210 ATM address of the LES (41.01.82.10.00.01/02) or the backup PC205-MSS-8260 address of EN_205 LES 41.01.82.60.00.01/05), but not both since their ESIs are different. This would not allow us to take advantage of the MSS redundancy in the PC205 building.

In steps 2e and 2f on page 43, we set two LECSs addresses on the CPSW of the PC205-8260: first the PC205-MSS-8210 as the active WKA and the LECS on the COE-MSS-8260 as the inactive WKA. This ensures that if the COE-MSS fails, then the LECS on the PC205-MSS would allow COE LECs to join the ETH80-81 ELAN. The same goes for the 8285s at the COE which are set up in section 7f and 7g on page 43. Figure 16 on page 40 shows the physical connection of the COE building to the ATM network, while Figure 17 on page 40 shows the logical representation of the additional switch.

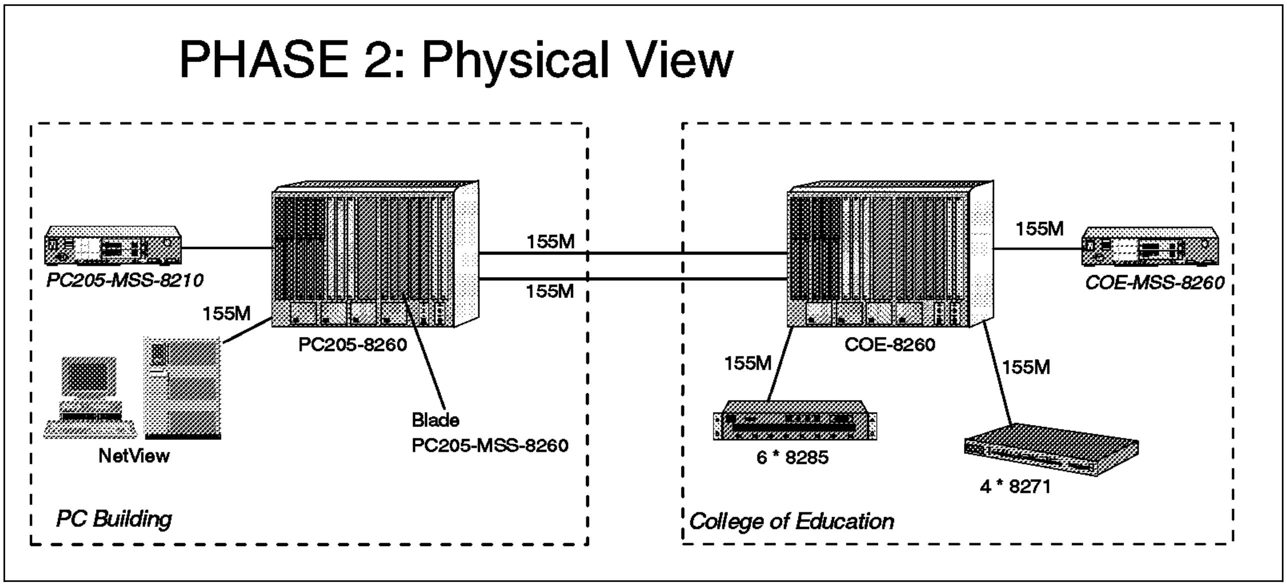


Figure 16. Physical View

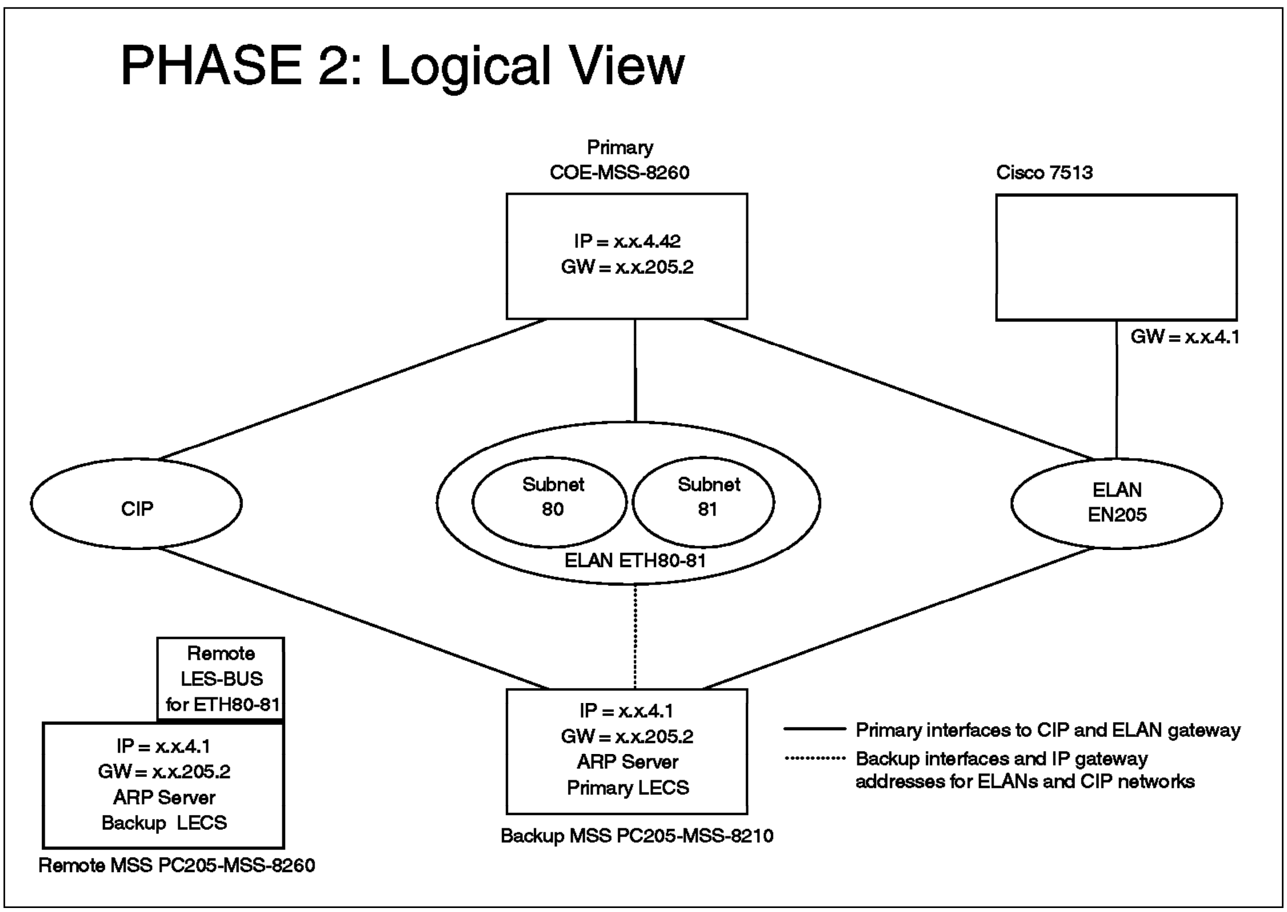


Figure 17. Logical View of ELANS ETH80 and ETH81

Figure 18 on page 41 shows the configuration of the MSS added in the COE building and Figure 19 on page 42 shows the changes necessary to the MSSs in the original core backbone.

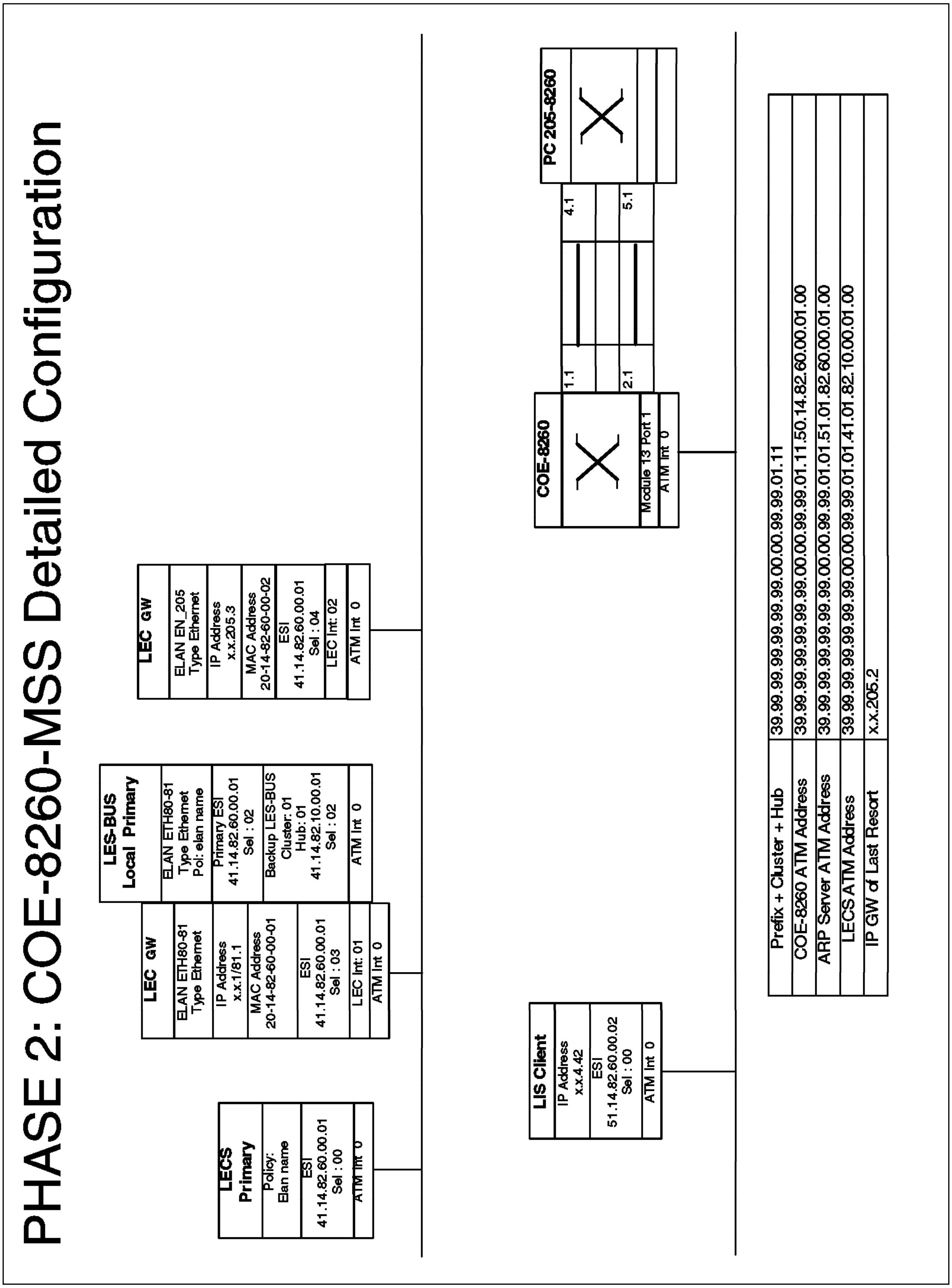


Figure 18. COE-MSS-8260 Configuration

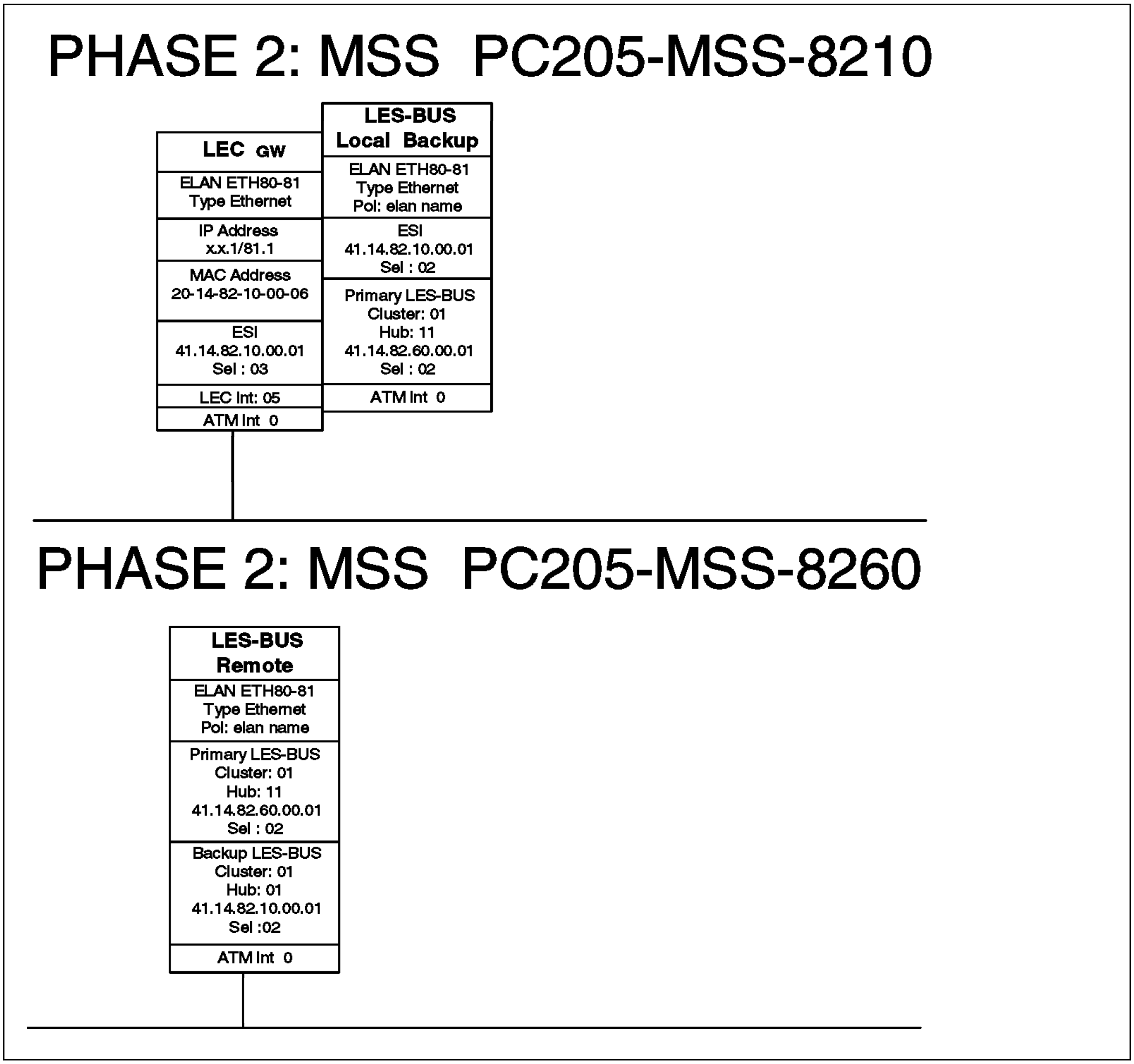


Figure 19. PC205-MSS-8210 and PC205-MSS-8260 Configuration

6.2.1 Equipment Used

The COE requires one 8260 A17, one MSS-8260-blade, six 8285s and four 8271s.

6.2.2 Levels of Code

At this stage the microcode levels of the installed equipment have not changed. Note the addition of the 8271 and its level to the list of equipment and levels.

MSS Release 1.1

CPSW Boot EEPROM version: V2.5.0

Flash EEPROM version: V2.5.1

Flash EEPROM backup version: V2.3.0

Operational FPGA version: B50

ATM Modules Operational FPGA version: B50

8285 Boot EEPROM version: V1.5.0

Flash EEPROM version: V1.5.0

Flash EEPROM backup version: V1.3.0

Operational FPGA version: C30

8271 HW rev 1.5, SW V3.5.2

6.2.3 Steps Taken to Achieve This Goal

When the primary LECS fails on the PC205-MSS-8210, the backup LECS on PC205-MSS-8260 needs to know where the primary LES-BUS for ETH80-81 resides. Hence we create a remote instance for the LES-BUS. This is done in step 6.

The configuration steps were as follows:

1. Configure the PC205-8260 CPSW as follows:
    a. Configure the ATM interface of the CPSW (ports which connect to COE-8260).
2. Configure COE 8260 CPSW as follows:
    a. Set the ATM address.
    b. Set the ATM address of the ARP server.
    c. Set the IP address.
    d. Set the default gateway.
    e. Set the LECS of PC205-MSS-8210 as the active well-known address.
    f. Set the LECS of COE-MSS-8260 as the inactive well-known address.
    g. Configure the ATM interface of the CPSW (ports that connect to PC205-8260).
3. Configure the COE-MSS-8260:
    a. Configure the ATM interface of the COE-MSS-8260:
        1) Add the necessary ESIs.
    b. Configure the LIS client on the COE-MSS-8260:
        1) Configure IP on the ATM interface.
        2) Configure the LIS client as an ARP client.
    c. Configure the LECS 41.14.82.60.00.01 (new LECS added):
        1) Configure the LECS with a locally administered ESI address.
        2) For ELAN ETH80-81 do the following:
            a) Add the ELAN definition to the LECS.
            b) Configure the ELAN definition and set the policy value.
        3) Define priority for LECS general policies.
    d. Configure the LES-BUS pair for ELAN ETH80-81.
    e. Configure LEC (for ETH80-81 and EN_205).

        For each LEC to be defined do the following:

        1) Add a LEC as a logical interface.
        2) Configure the logical interface.
        3) Assign an IP address to the LEC.

4. Configure the PC205-MSS-8210 with redundancy for ELAN ETH80-81.
   a. Configure the LES-BUS pair.
   b. Configure LECs:
        1) Add a LEC as a logical interface.
        2) Configure the logical interface.
        3) Assign two IP addresses to the LEC.
5. Configure the PC205-MSS-8260 with redundancy for ELAN ETH80-81.
6. Configure the LES-BUS pair (remote LES-BUS).
7. Implement the 8285s at the COE.

   The 155-Mbps UFC is used to link each 8285 to the COE 8260. The UFCs are configured as an SSI link with 155-Mbps bandwidth. The 8285 is configured with a WKA LECS (the LECS defined on the PC205-MSS-8210) address.
8. Configure 8285 as follows:
   a. Configure the ATM interface of the 8285.
   b. Set the ATM address.
   c. Set the ATM address of the ARP server.
   d. Set the IP address.
   e. Set the default gateway.
   f. Set the LECS of PC205-MSS-8210 as the active well-known address.
   g. Set the LECS of COE-MSS-8260 as the inactive well-known address.

   The 8271s connect to the COE-8260 via the 155-Mbps UFC. At this stage the 8271s join only one ELAN. Later when ELAN ETH79 is defined, each 8271 will be configured with two LECs to join ELANs ETH80-81 and ETH79.
9. Configure the 8271s at the COE:
   a. Set the IP address.
   b. Configure non-Ethernet ports.
   c. Define the LEC (for ETH80-81).
   d. Assign ports to the LEC.

6.2.4 Issues Encountered during This Phase

Performance was bad from the beginning. Lengthy investigation pointed toward a faulty serial or modem port on the MSS, receiving traps, causing the MSS to reboot intermittently. (In response, Level 3 support built a PTF.) This issue stalled the implementation of the solution considerably.

A number of MAC workstations were implemented. Problems with ATM drivers for the MAC operating system stopped the MAC workstations from being connected via ATM. The driver issue is resolved and AppleTalk routing has been implemented to allow connectivity to the rest of the campus.

6.3 Phase 3: ATM Core and OE Backbone

Our goal is to provide a core link to the OE building and implement a switched backbone infrastructure at the OE building and link it to the ATM core network. The OE 8260 is linked to the PC205 core switch with one 155-Mbps link. The backbone at the OE consists of eight 8271s each with a 155-Mbps link to the OE 8260. Figure 20 shows the physical connection of the OE building to the network while Figure 21 on page 46 shows the logical view with the addition of ELAN ETH_43. In the logical diagram it can be seen that this was FIU′s first implementatiuon of MSS 1.1 redundant default gateway function.

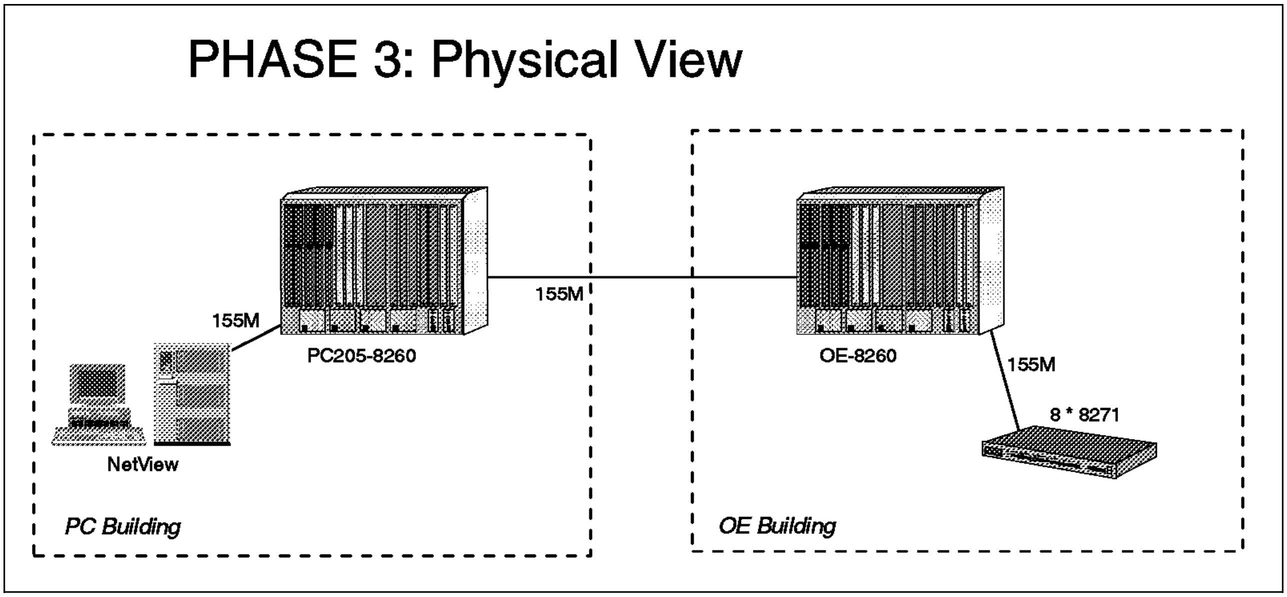


Figure 20. Physical View

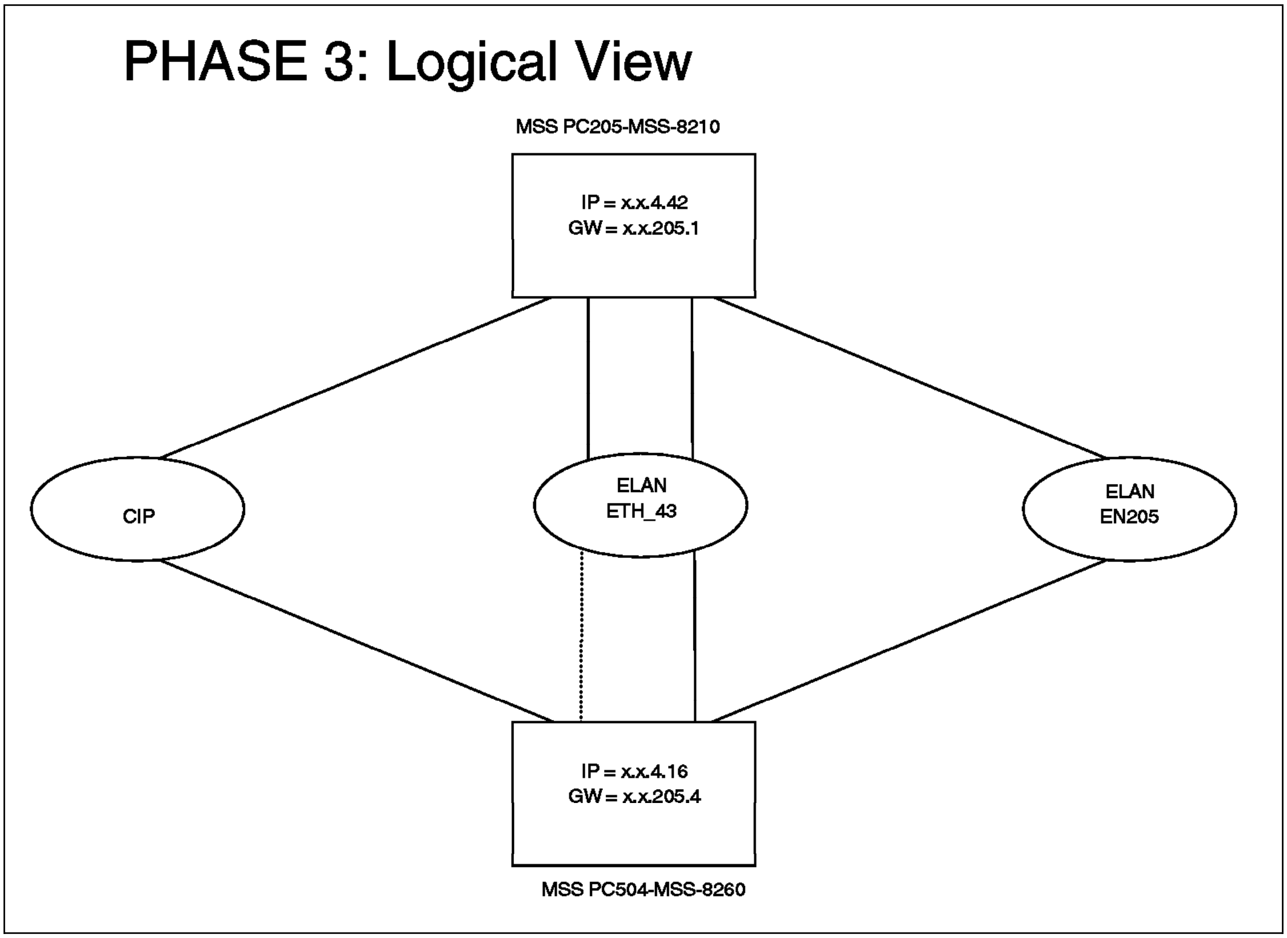


Figure 21. Logical View

Figure 22 on page 47 shows the additional configuration parameters used on MSS PC205_MSS_8210 and PC504_MSS_8260 to support the additions in phase three.

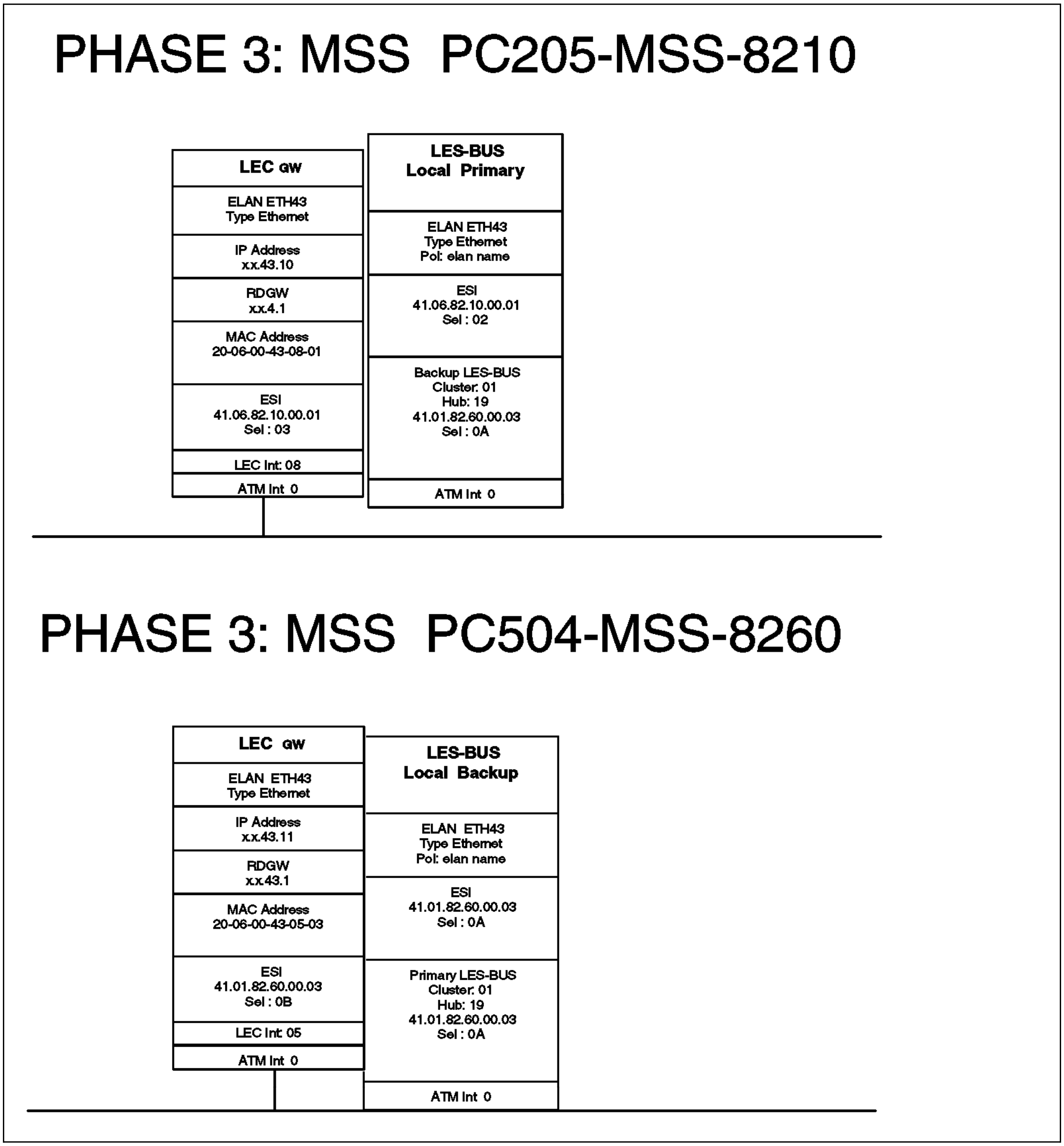


Figure 22. MSS Configuration

6.3.1 Equipment Used

The OE building requirements are one 8260 A10 and eight 8271s.

6.3.2 Levels of Code

The microcode levels have remained the same in phase three and are listed below.

MSS Release 1.1

CPSW Boot EEPROM version: V2.5.0

Flash EEPROM version: V2.5.1

Flash EEPROM backup version: V2.3.0

Operational FPGA version: B50

ATM Modules Operational FPGA version: B50

8285 Boot EEPROM version: V1.5.0

Flash EEPROM version: V1.5.0

Flash EEPROM backup version: V1.3.0

Operational FPGA version: C30

8271 HW rev 1.5, SW V3.5.2

6.3.3 Steps Taken to Achieve This Goal

Connect the PC205 8260 to the OE building 8260 (core link). Here the design makes use of one 155-Mbps fiber link between the PC205 8260 and the OE-8260. MSS V1.1 gateway redundancy is introduced at this stage. The ELAN ETH43 has the primary LES-BUS on PC205-MSS-8210. The LEC for ETH43 is defined on PC205-MSS-8210 with a PDGW and an NRI. The backup LES-BUS is defined on PC504-MSS-8210. The LEC for the backup LES-BUS is configured with the RDGW and an NRI. Steps 3 and 4 detail the configuration.

1. Configure PC205 8260 CPSW as follows:

   Configure the ATM interface of the CPSW (ports that connect to OE-8260).

2. Configure OE 8260 CPSW as follows:

   a. Set the ATM address.

   b. Set the ATM address of the ARP server.

   c. Set IP address.

   d. Set the default gateway.

   e. Set the LECS well-known address.

   f. Configure the ATM interface of the CPSW (ports that connect to PC205-8260).

3. Configure PC205-MSS-8210:

   a. Configure the LECS.

   b. Add the ELAN ETH43 definition to the LECS (primary).

   c. Configure the ELAN definition and set the policy value under LECS.

   d. Configure the LES.

   e. Configure the LES-BUS pair for ETH43:

      1) Enable redundancy for LES-BUS (primary).

   f. Configure the LEC (for ETH43) with V1.1 Redundant Gateway.

g. Add a LEC as a logical interface.

h. Configure the logical interface.

i. Assign an IP address to the LEC (NRI rip receive).

j. Configure the PDGW.

4. Configure PC504-MSS-8260. (This step is completed during next phase.)

   a. Configure the LECS.

   b. Add the ELAN ETH43 definition to the LECS (backup).

   c. Configure the ELAN definition and set policy value.

   d. Configure the LES.

   e. Configure the LES-BUS pair for ETH43:

      1) Enable redundancy on LES-BUS (backup).

   f. Configure the LEC (for ETH43) with V1.1 Redundant Gateway.

   g. Add a LEC as a logical interface.

   h. Configure the logical interface.

   i. Assign an IP address to the LEC (NRI) unique address to step 3j (NRI rip receive).

5. Configure the 8271s at the OE building:

   a. Set the IP address.

   b. Configure non-Ethernet ports.

   c. Define the LEC (for ETH43).

   d. Assign ports to the LEC.

6.3.4 Issues Encountered during This Phase

The Cabletron hub had 20 MAC workstations attached to it. The plan was to connect all the MAC workstations to the 8271 switches. The problem was that the AppleTalk and LAT network could not be seen. The hub with all the MAC workstations was kept separated from the ATM network. This is the point where the problem with protocols not being routed was discovered. The solution was to introduce the ETH79 ELAN so that the 8274 could be used to bridge unrouted protocols between the legacy LAN and the ATM network.

6.4 Phase 4: PC504/8274/Catalyst 3000/SP2 Connectivity

Our goal is to provide a core link to the PC504 (5th floor of the PC building), connect the SP2 to ATM and implement the bridging of protocols not being routed. The PC 504 8260 is linked to the PC205 core switch with two 155-Mbps links. The SP2 is linked to the PC504 8260 with eight 155-Mbps links. The 8274 is connected to the PC504 8260 with a single 155-Mbps link. The Cisco is connected to the 8274 with a single 10-Mbps link. This 10-Mbps link will be upgraded at a later stage.

Figure 23 on page 50 and Figure 24 on page 51 show the physical and logical views of the network with the additional equipment of phase four.

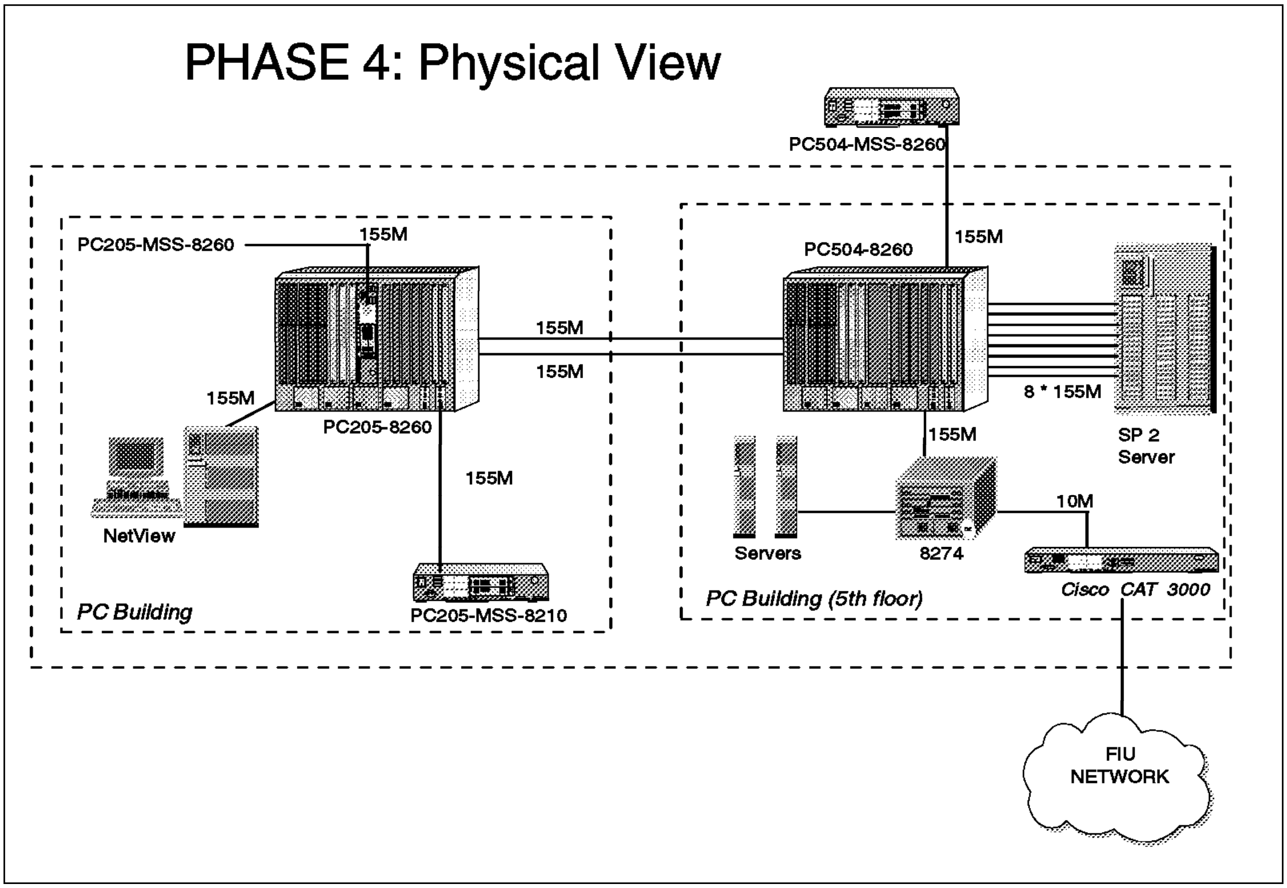


Figure 23. Physical View

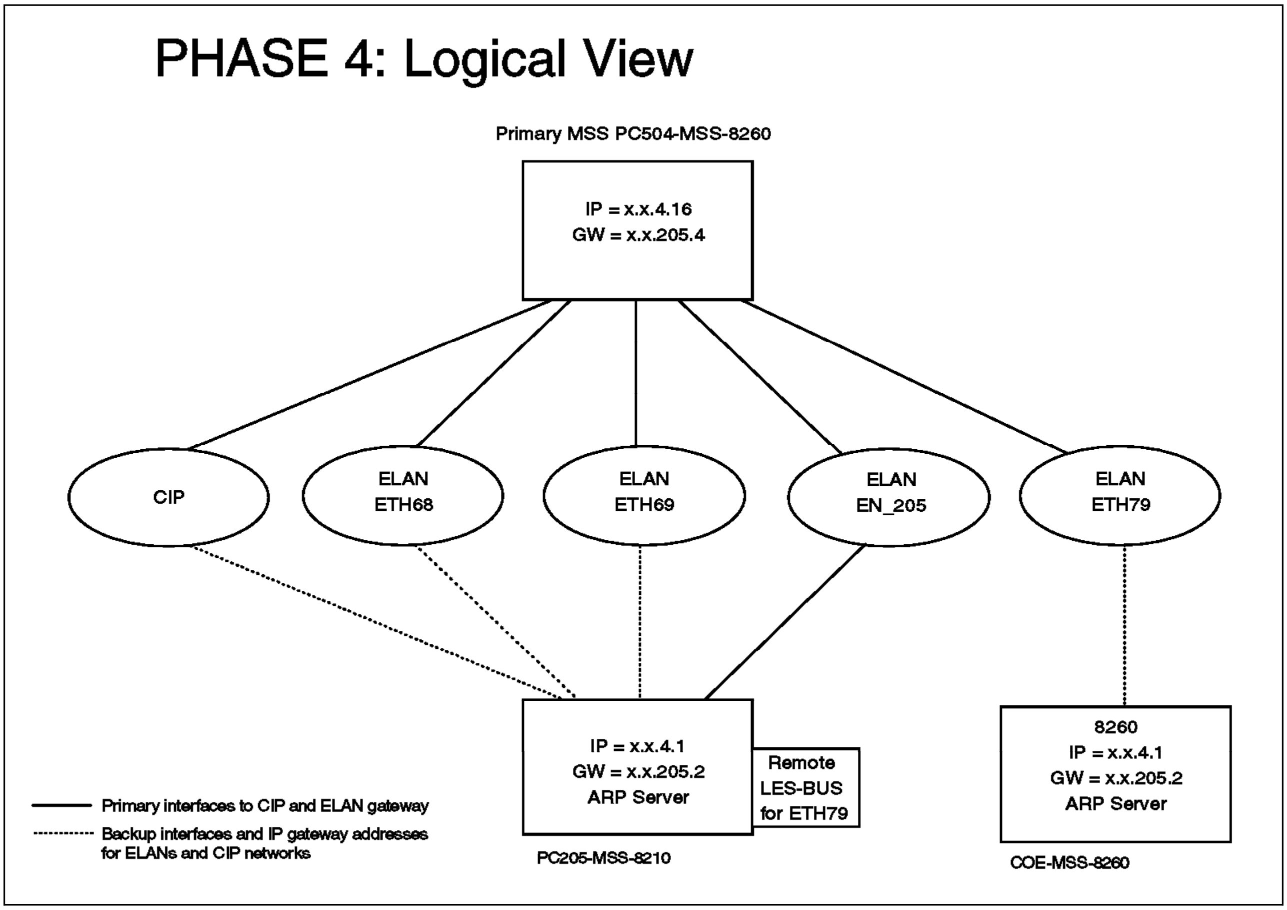


Figure 24. Logical View

Figure 25 on page 52 and Figure 26 on page 53 show the configuration changes to the MSSs needed to support the additional requirements of phase four.

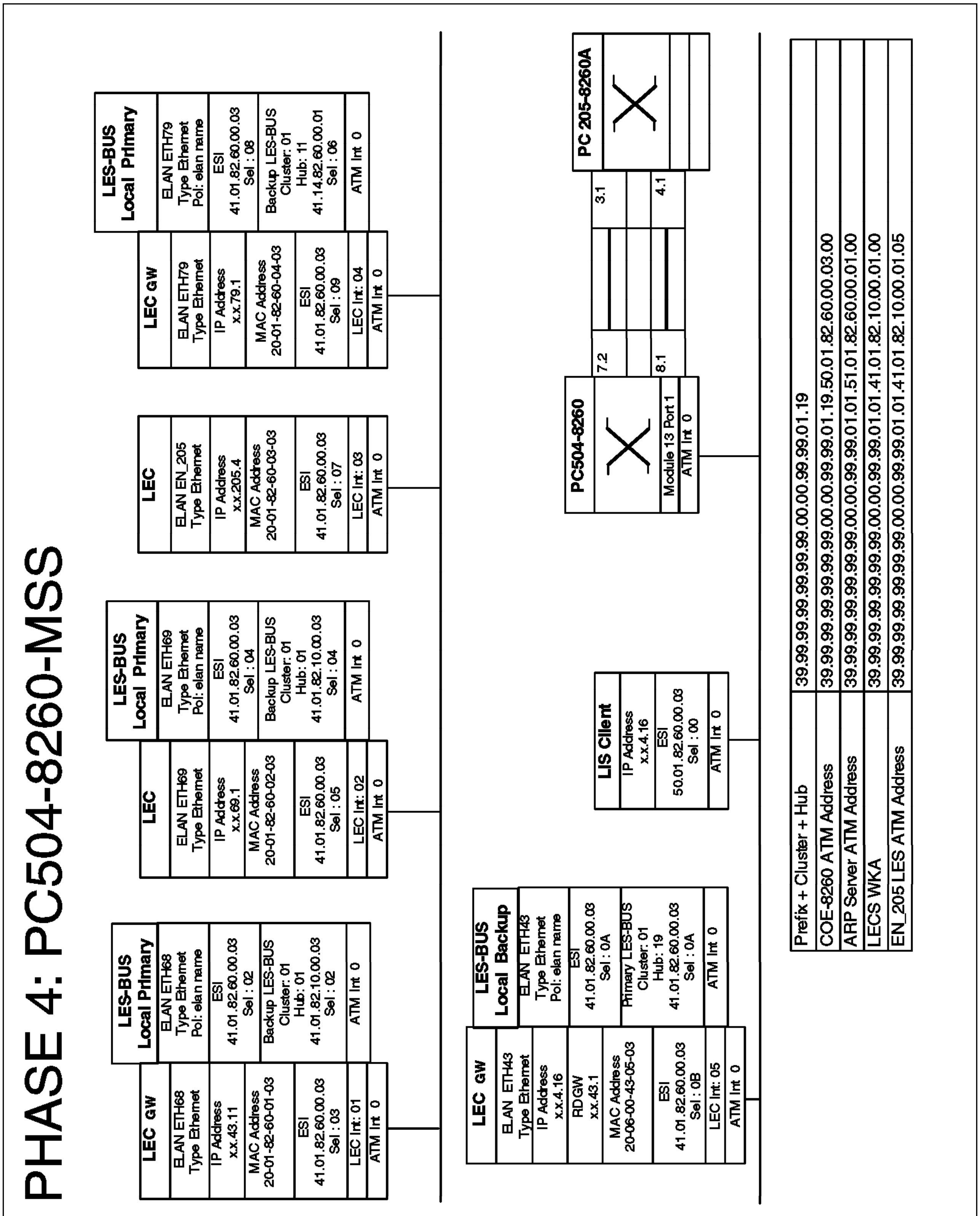


Figure 25. MSS Configuration PC504-MSS-8260

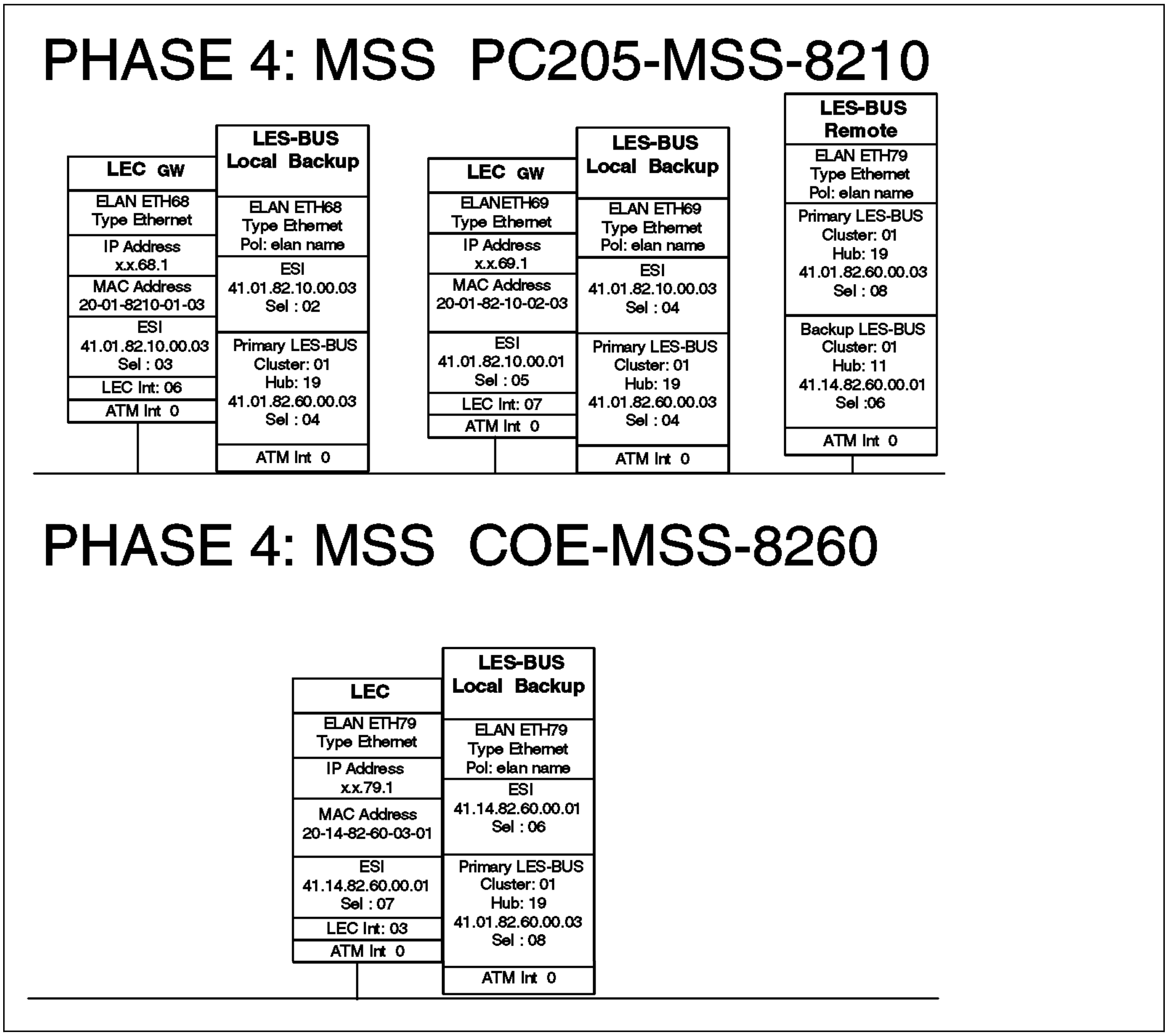


Figure 26. MSS Configuration PC205-MSS-8260 and COE-MSS-8260

6.4.1 Equipment Used

The PC504 requires one 8260 A17, one MSS-8260 blade, one 8274 and one SP2 server with ATM adapters.

6.4.2 Levels of Code

Once again the levels of microcode have essentially remained the same; one exception is the addition of the 8274. Its software level is listed below:

MSS Release 1.1

CPSW Boot EEPROM version: V2.5.0

Flash EEPROM version: V2.5.1

Flash EEPROM backup version: V2.3.0

Operational FPGA version: B50

ATM Modules Operational FPGA version: B50

8274	V2.0

6.4.3 Bridging of Non-Routed Protocols

Phase three exposes the issue of communicating non-routed protocols between the ATM network and the legacy network. AppleTalk is routable with MSS V1.1 and will be implemented at a later stage. ETH79 was created for the NRP. Devices using NRP join this ELAN. The 8274 RouteSwitch is used as a bridge between the ATM network (ETH79) and the legacy LAN. Using this technique ETH79 is used to contain broadcasts associated with NRP.

6.4.4 Steps Taken to Achieve This Goal

Connect the PC205 8260 to the PC504 8260 (core link). Here the design makes use of two 155-Mbps fiber links between the PC205 8260 and the PC504 8260. The PC504 8260 will become part of cluster 1.

1. Configure PC205 8260 CPSW as follows:

   Configure the ATM interface of the CPSW (ports that connect to PC504-8260).

2. Configure PC504 8260 CPSW as follows:

   a. Set the ATM address.

   b. Set the ATM address of ARP server.

   c. Set the IP address.

   d. Set the default gateway.

   e. Set the LECS well-known address.

   f. Configure the ATM interface of the CPSW (ports that connect to PC205-8260).

3. Configure the PC504-MSS-8260:

   a. Configure the ATM interface of the PC504-MSS-8260.

      1) Add the necessary ESIs.

   b. Configure the LIS client on the PC504-MSS-8260:

      1) Configure IP on the ATM interface.

      2) Configure the LIS client.

   c. Configure the LECS on PC504-MSS-8260 with ETH68, ETH69 and ETH79 local primary:

      1) For each ELAN do the following:

         a) Add the ELAN definition to the LECS.

         b) Configure the ELAN definition and set the policy value.

   d. Configure LES-BUS pairs on PC504-MSS-8260 for ETH68, ETH69 and ETH79 all local primary.

   e. Configure LECs for ETH68, ETH69, ETH79 and EN_205.

      For each LEC to be defined do the following:

      1) Add a LEC as a logical interface.

      2) Configure the logical interface.

      3) Assign an IP address to the LEC.

4. Configure the LECS on PC205-MSS-8210 with ETH68 and ETH69 local backup.

   For each ELAN do the following:

   a. Add the ELAN definition to the LECS.
   b. Configure the ELAN definition and set the policy value.
   c. Configure a remote LES-BUS pair for ELAN ETH79.

5. Configure the LECS on the COE-MSS-8260 (with ETH79 local backup):

   a. Add the ELAN definition to the LECS.
   b. Configure the ELAN definition and set the policy value.
   c. Configure the LES-BUS pair for ETH79.
   d. Configure the client for ELAN ETH79.
   e. Add a LEC as a logical interface.
   f. Configure the logical interface.
   g. Assign an IP address to the LEC.

   Connect the 8274 to the PC504 8260. One 155-Mbps fiber link must be installed between the PC504 8260 and the 8274. The ATM client on the 8274 is configured to join ELAN ETH79. Connect the Catalyst to 8274 using a 10-Mbps Ethernet connection. Configure bridging on all ports of the 8274. A number of servers were attached to the 8274. This was done to lighten the load of the Catalyst 3000.

6. Connect the SP2 box to the PC504 8260. The SP2 has four nodes each with two ATM links per node. The two interfaces on each node must join separate ELANS. ELANS ETH68 and ETH 69 were created for this purpose.

   a. Configure the PC504 8260 with eight UNI connections.
   b. Connect the SP2 server to those eight links.
   c. Configure node 1 on the SP2, one client to join ETH68 and one joins ETH69.
   d. Configure node 2 on the SP2, one client to join ETH68 and one joins ETH69.
   e. Configure node 3 on the SP2, one client to join ETH68 and one joins ETH69.
   f. Configure node 4 on the SP2, one client to join ETH68 and one joins ETH69.

7. Configure the 8274:

   a. Configure PC504-8260 (port connecting to the 8274).
   b. Configure the ATM port on the 8274.
   c. Configure bridging.

See Appendix C, "Configuration Steps for the 8274" on page 113 for details on the 8274 configuration.

6.5 Phase 5: ATM WAN Link to ACI (North Campus)

The goal of this phase is to connect the South Campus (University Park) to the North Campus with an ATM WAN link. Both links to the WAN will be 155-Mbps NNI. Figure 27 shows the physical view of the wide area connection while Figure 28 shows the logical additions.

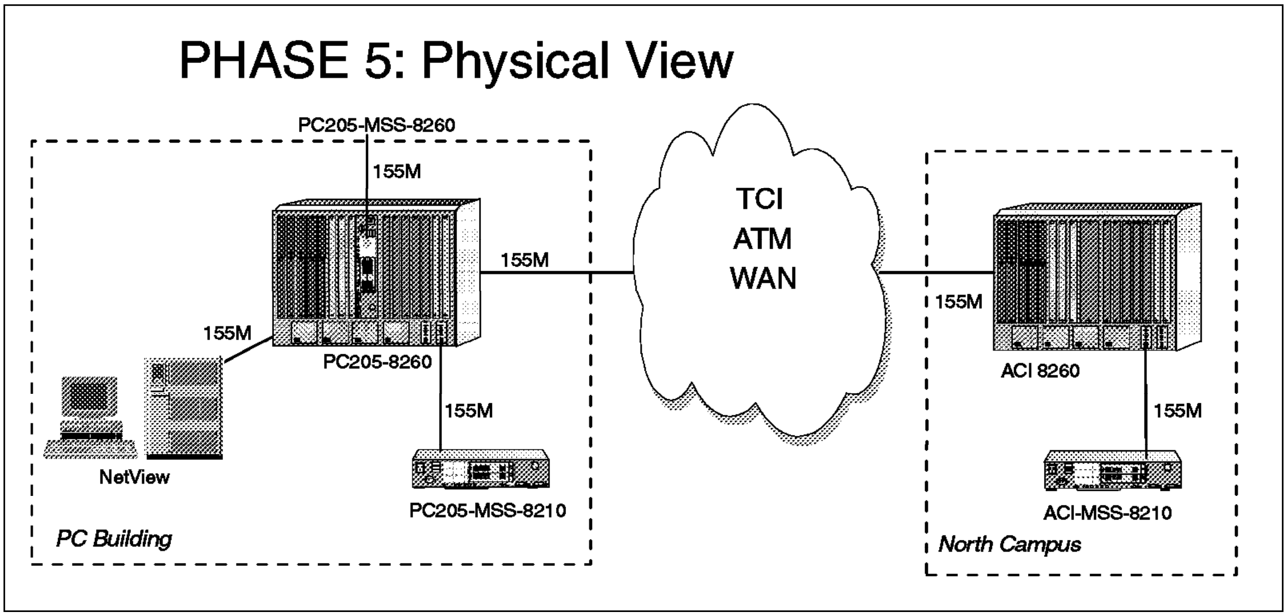


Figure 27. Physical View

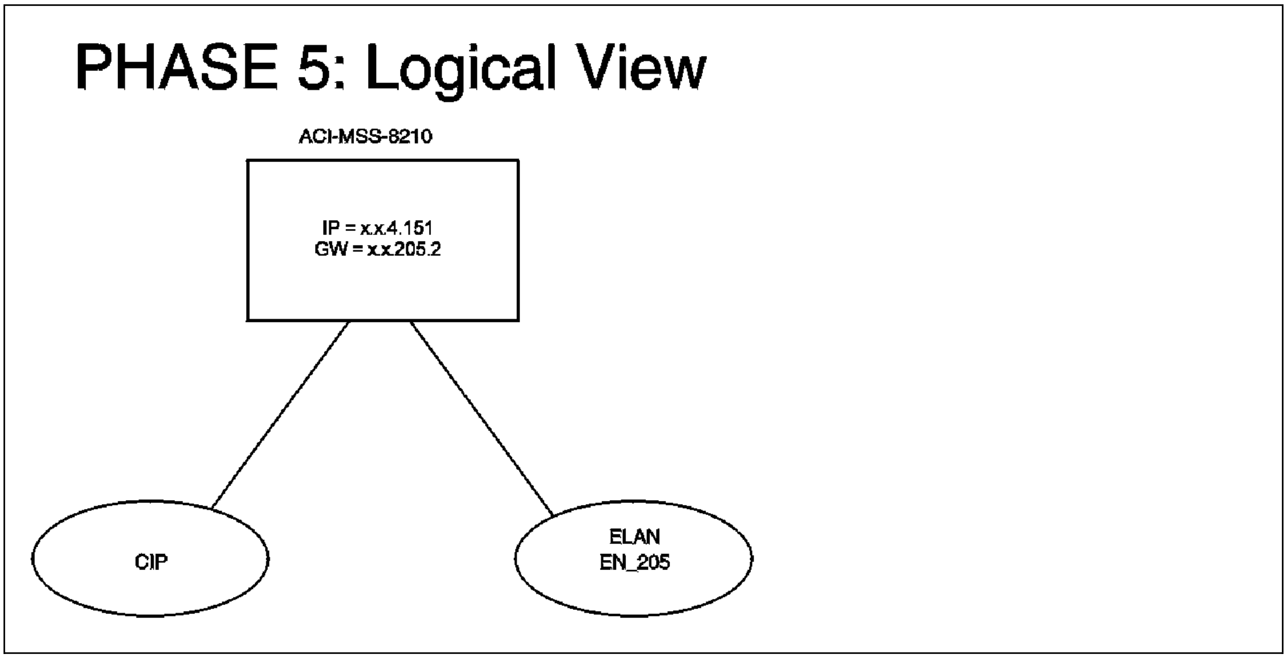
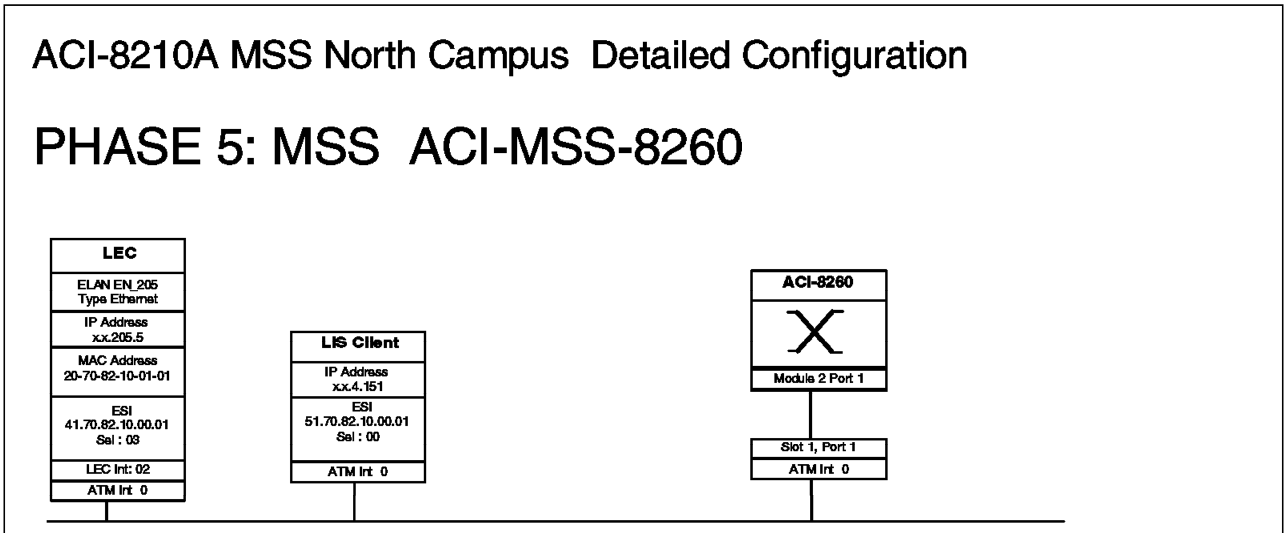


Figure 28. Logical View

Figure 29 on page 57 shows the configuration steps added to support the phase five wide area link.



Prefix + Cluster + Hub	39.99.99.99.99.99.99.00.00.99.99.02.20
ACI-8260A ATM Address	39.99.99.99.99.99.99.00.00.99.99.02.20.50.70.82.60.00.01.00
ARP Server ATM Address	39.99.99.99.99.99.99.00.00.99.99.01.01.51.01.82.60.00.01.00
LECS WKA	39.99.99.99.99.99.99.00.00.99.99.01.01.41.01.82.10.00.01.00
EN_205 LES ATM Address	39.99.99.99.99.99.99.00.00.99.99.01.01.41.01.82.10.00.01.05

Figure 29. MSS Configuration

6.5.1 Equipment Used

The requirements for the North Campus were an 8260 A17 and an MSS blade. TCI will provide the WAN link.

6.5.2 Levels of Code

The list below shows the level of microcode used in the equipment for phase five:

MSS Release 1.1

CPSW Boot EEPROM version: V2.5.0

Flash EEPROM version: V2.5.1

Flash EEPROM backup version: V2.3.0

Operational FPGA version: B50

ATM Modules Operational FPGA version: B50

6.5.3 Steps Taken to Achieve This Goal

In planning for the wide area link FIU put the following requirements to TCI:

1. From FIU′s perspective TCI′s ATM WAN must be a virtual pipe.
2. FIU should not have to be concerned about TCI′s ATM addressing scheme.
3. TCI is able to offer 155 Mbps over the wide area.
4. It is a simple procedure of connecting the link.

Once the agreement was made between FIU and the provider, TCI, the steps outlined below were implemented to set up the link.

1. Configure PC205 8260 CPSW as follows:
    a. Configure the ATM interface of the CPSW (port that connects to the TCI WAN) NNI connection.
2. Configure ACI 8260 CPSW as follows:
    a. Set the ATM address.
    b. Set the ATM address of the ARP server.
    c. Set the IP address.
    d. Set the default gateway.
    e. Set the LECS well-known address.
    f. Configure the ATM interface of the CPSW (port that connects to the TCI WAN) NNI connection.
3. Configure ACI-MSS-8260:
    a. Configure the ATM interface of the ACI-MSS-8260:
        1) Add the necessary ESIs.
    b. Configure the LIS client on the ACI-MSS-8260:
        1) Configure IP on the ATM interface.
        2) Configure the LIS client.
    c. Configure a LEC for EN_205:
        1) Add a LEC as a logical interface.
        2) Configure the logical interface.
        3) Assign an IP address to the LEC.

6.6 Phase 6: LES-BUS/Default Gateway/Redundancy

Our goal is to test redundancy for the default gateway and the LES_BUS pairs using MSS V1.1 features. Figure 30 on page 59 shows the logical representation of the redundant default gateways.

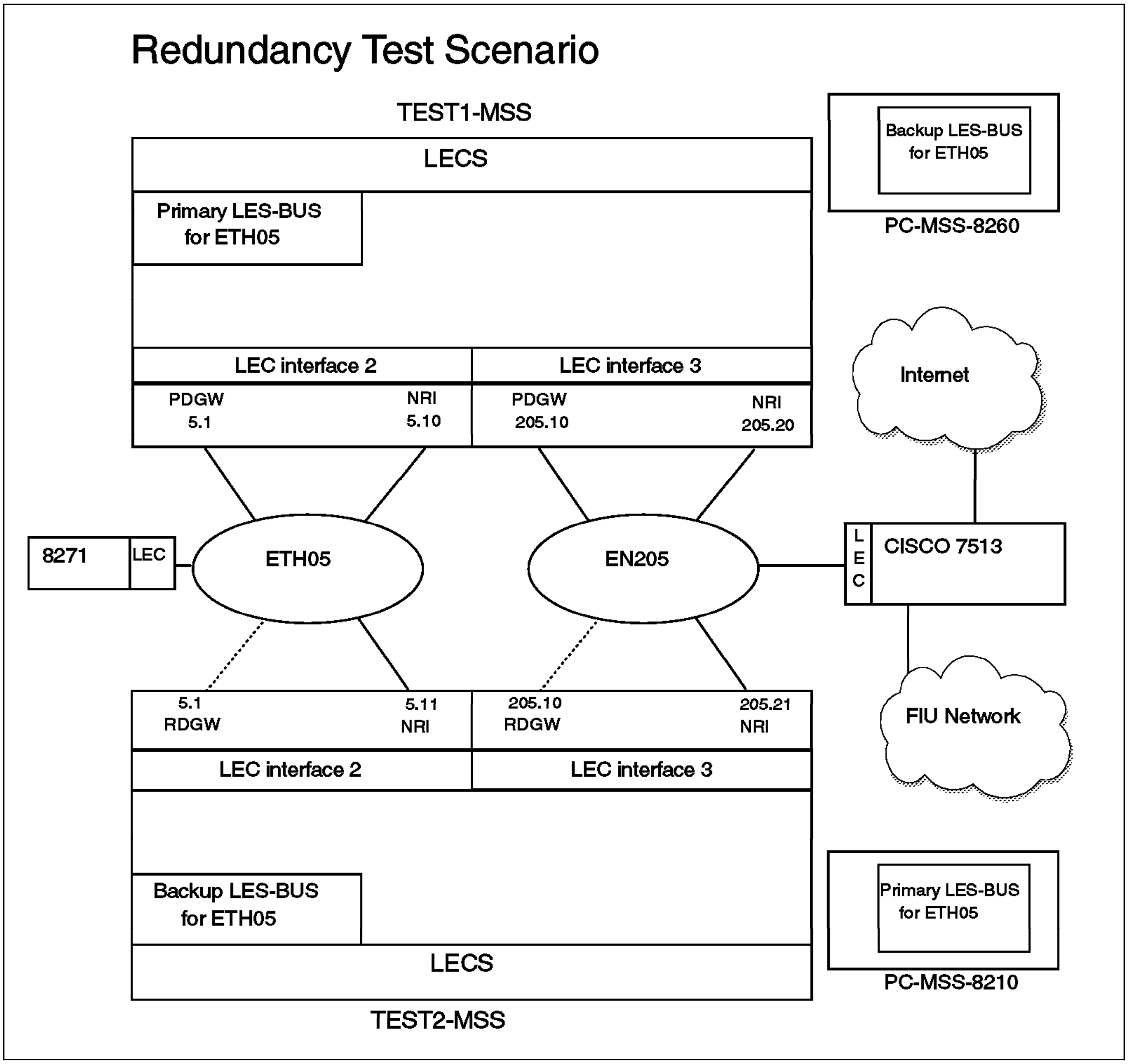


Figure 30. Logical View

6.6.1 Equipment Used

In this scenario the 8260 A17, MSS 8210, the MSS 8260 and an 8271 were used.

6.6.2 Levels of Code

Levels in this phase may depend on the implementation of PNNI. If the prior phase is implemented, then the CPSWs will be at least at Version 3 and the MSS will be at least at Version 2.

6.6.3 LES-BUS Redundancy and the Redundant Default Gateway

The current redundancy design makes use of MSS V1.0 functionality. With MSS V1.0 the LEC or GW could only register one MAC address with the LES and hence only one IP address. Therefore, only one of the primary or backup gateways could be active at any one time.

With MSS V1.1, a LEC is able to register multiple MAC addresses with the LES and an IP address is associated with the extra MAC address. This enables an improved method of providing a redundant default gateway. The extra interface on the backup LEC is able to gather routing information, while the primary is still active.

To implement this enhancement to default gateway redundancy, two IP, MAC address pairs are associated with each LEC. On the LEC representing the primary gateway the one IP address is the default gateway and is called the primary default gateway (PDGW). The other IP address is a normal routing interface (NRI). On the LEC representing the backup default gateway the one IP address is an NRI and the other IP address is the same as the PDGW and is called the RDGW. Only one of these can function as the DGW at any one time, since they share the same IP address.

The NRI interface on the primary LEC has a different IP address than the NRI on the backup LEC and both must be registered with the LES. RIP receive is enabled on the NRI interfaces on both the primary and the backup LECs so that both maintain current routing information. This minimizes the time taken for the backup to learn the routing information if the primary gateway fails. Both the primary and the backup gateway try to register their DGW IP address with the LES. If the primary is unable to register the gateway address with the LES because the backup has already registered the gateway address, it will request that the backup deregister the default gateway address. See Chapter 9 of *Understanding and Using MSS Release 1.1 and 2.0*, SG24-2115, for a detailed description of this function.

FIU has designed and implemented a test scenario that shows the flexibility of the MSS V1.1 RDGW function. The scenario shows how to implement the MSS V1.1 version of RDGW. This functionality was put to the test with positive results. (In addition, the network is unaware of change.)

Three functions are illustrated in this test scenario:

1. RDGW as discussed above with an active interface learning network topology.
2. The DGW for an ELAN is defined on a separate MSS from where the LES-BUS is defined.
3. Redundant LECS and distributed LECS functions.

As shown in Figure 30 on page 59 the TEST1-MSS has the primary LES-BUS for ETH05. The LEC on ETH05 is configured to be the PDGW. The backup LES-BUS for ETH05 is defined on TEST2-MSS. This LEC on ETH05 is configured with the RDGW, which does not become active until the primary fails.

The PDGW for EN_205 is defined on TEST1-MSS and the RDGW is defined on TEST2-MSS. Both the PDGW and the RDGW share the same MAC address and the same IP address. The same MAC address is necessary on both these gateways to ensure that ARP entries cached at endstations remain valid after a failure.

The primary LES-BUS for EN_205 is defined on PC205-MSS-8210. Therefore we need to define a remote LES-BUS for EN_205 on both the TEST1-MSS and TEST2-MSS. Each MSS needs to know the location of the primary and backup LES-BUS for EN_205.

When TEST1-MSS is up, we are able to route between EN_205 and ETH05. When TEST1-MSS fails, the backup LEC′s second MAC is able to register and assumes the DGW address and function. The same procedure occurs for ETH05. The DGW function is lost for only a brief moment. Users will be unaware of this disruption. Figure 31 on page 62 shows a more detailed representation of these definitions.

To carry out the test, a workstation connected to the 8271 established a session with the Internet via the Cisco router. The TEST1 would route between the ETH05 and the EN_205 to get to the Cisco router. When TEST1-MSS fails, the RDGW interface of the LECs for ETH05 and EN_205 both become active on TEST2-MSS. The current network topology is obtained from the NRI of the LECs that have been actively exchanging network topology.

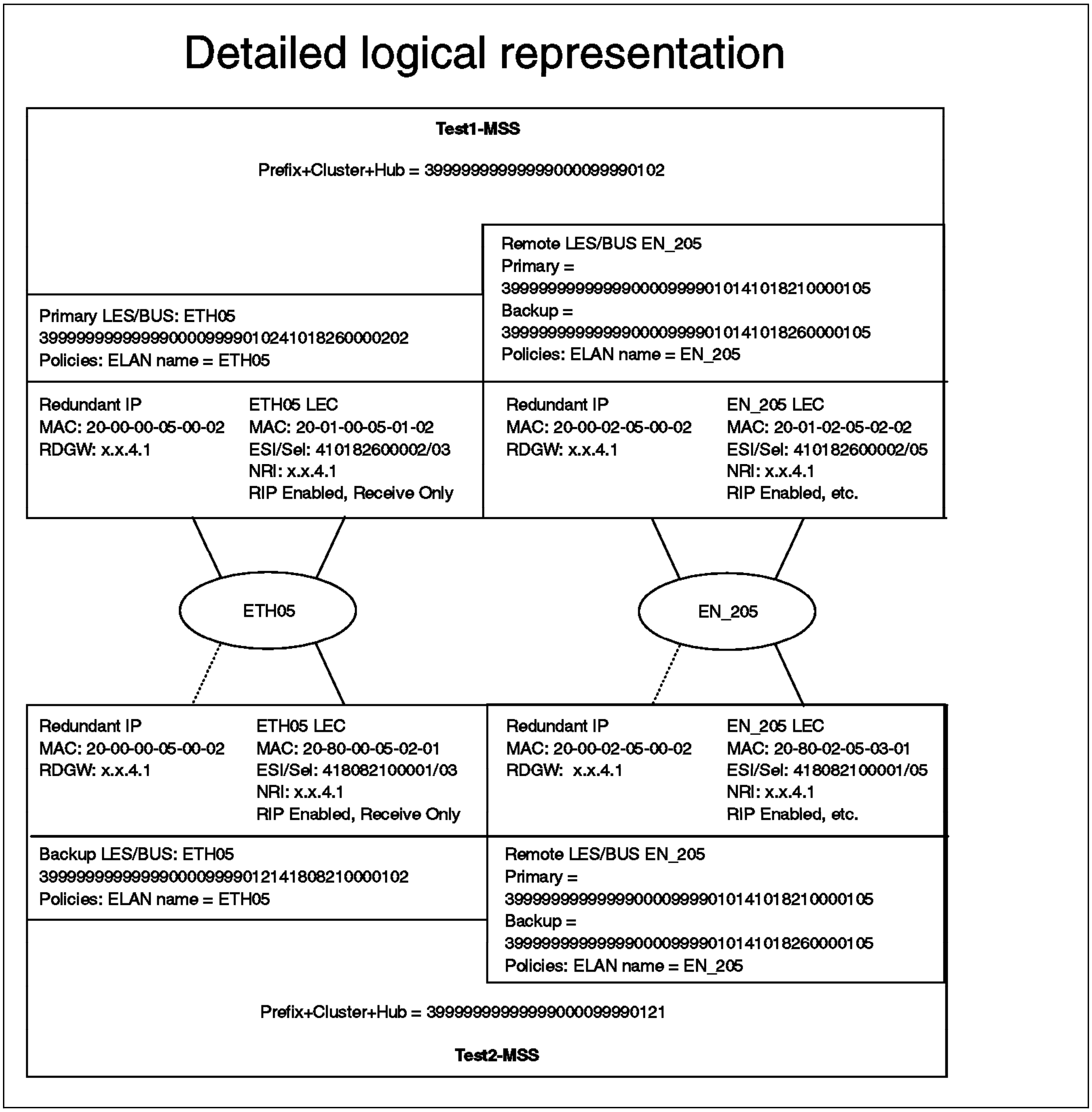


Figure 31. Logical View Showing Detailed MSS Configuration

6.7 Phase 7: Deuxieme Maison (DM) Infrastructure Project

Our goal is to provide a backbone link and implement a switched infrastructure at the DM building.

6.7.1 Equipment Used

The following products will be installed at the DM building: one 8260 A17, one MSS and six 3Com SuperStacks.

6.7.2 Levels of Code

Levels in this phase may depend on the implementation of PNNI. If the prior phase is implemented, then the CPSWs will be at least at Version 3 and the MSS will be at least at Version 2.

6.7.3 Steps Taken to Achieve This Goal

This stage of the project has not been completed yet. Hopefully PNNI would have been implemented by the time this stage is started. Since we do not know, the configuration steps are not described in detail.

1. Connect the PC205 8265 to the DM 8260 (core link). Hopefully by this stage FIU will have implemented PNNI.
2. Configure DM-MSS-8210.
3. Configure 8271s.
4. Connect Cat 3000.
5. Connect the 3Com superstacks.

Chapter 7. Solution Design Considerations

The implementation of the network design revealed certain issues that caused the design to be reviewed. These issues are discussed at the physical, ATM and the network layer.

- **Physical Layer Design:**

  The star network design does not provide the redundant links needed to ensure the high availability that the FIU network demands. The reliability is focused on the central core switch (PC205). The network design cannot be determined by the physical layout of the existing fiber on the South Campus. New fiber will be installed in order to provide a meshed design with more redundant links. The reviewed physical design will spread the core out to three or four major buildings around the campus. The plan is to incorporate the PC, LIB, GC and possibly the dormitories into the core network. These four buildings will be linked with 155-Mbps links and possibly grow to 622 Mbps (see Figure 32). The core switches will be connected with redundant links. This meshed core topology optimizes performance and increases availability. Each building backbone switch will have 155-Mbps links to two of the core switches, creating a higher degree of resilience than the star configuration.

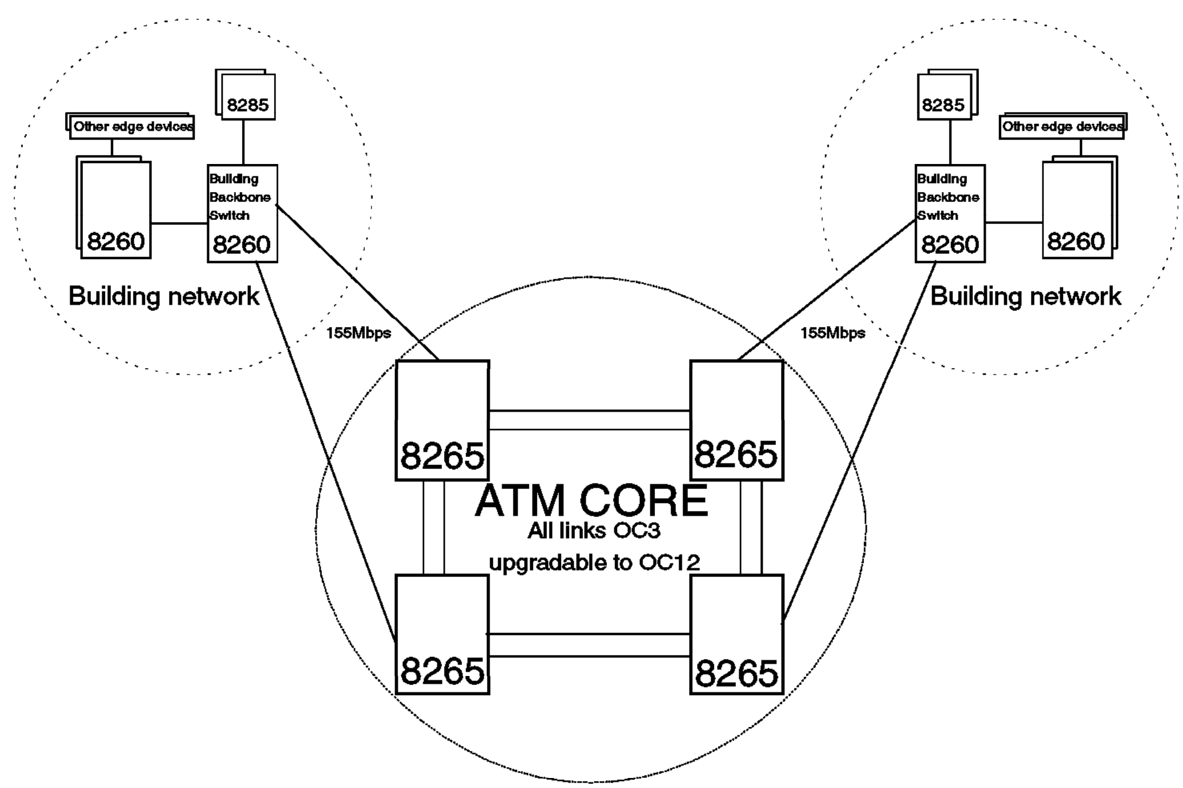


Figure 32. The Reviewed Core Network Design

- **ATM Layer Design:**

  The cluster model used initially proved to be inadequate due to the size of the FIU network. The SSI protocol used to connect switches within a cluster allowed a maximum of 15 switches per cluster. SSI is also an IBM proprietary method of connecting switches. The NNI links used to interconnect clusters require static routes to be defined manually.

  The reviewed design makes use of various new features of the CPSW V3 and MSS V1.1. The PNNI implementation groups nodes or switches into peer groups or what we previously referred to in the NNI - SSI implementation as clusters. The PNNI control point allows for up to 50 switches in a single peer group using LANE applications. PNNI is an ATM Forum standard, with support for many redundancy and QoS functions. Peer groups can be structured in a hierarchical fashion. One possible PNNI design is to have the core switches in one peer group and each building in their separate peer groups. The final PNNI design using peer groups and PNNI Hierarchy has yet to be established. This design will take into account the issues surrounding the FIU network being used as a multiservice network. (See Chapter 9, "Future Plans" on page 85 for a list of additional services to run on the ATM network).

- **Network Layer Design:**

  The only changes in this area will be the introduction of new features available with MSS V1.1. These new features include Super ELANs, QoS for LANE clients, redundant default gateway for ELANs, Classical IP redundancy enhancements for the ARP server, and IP gateway redundancy for CIP subnets.

  This reviewed network design allows the MSS functionality to be more evenly and more widely distributed throughout the network. Figure 33 on page 67 shows a possible combination of distributing the MSS function across the network. The workload and the redundancy is evenly distributed among the MSSs.

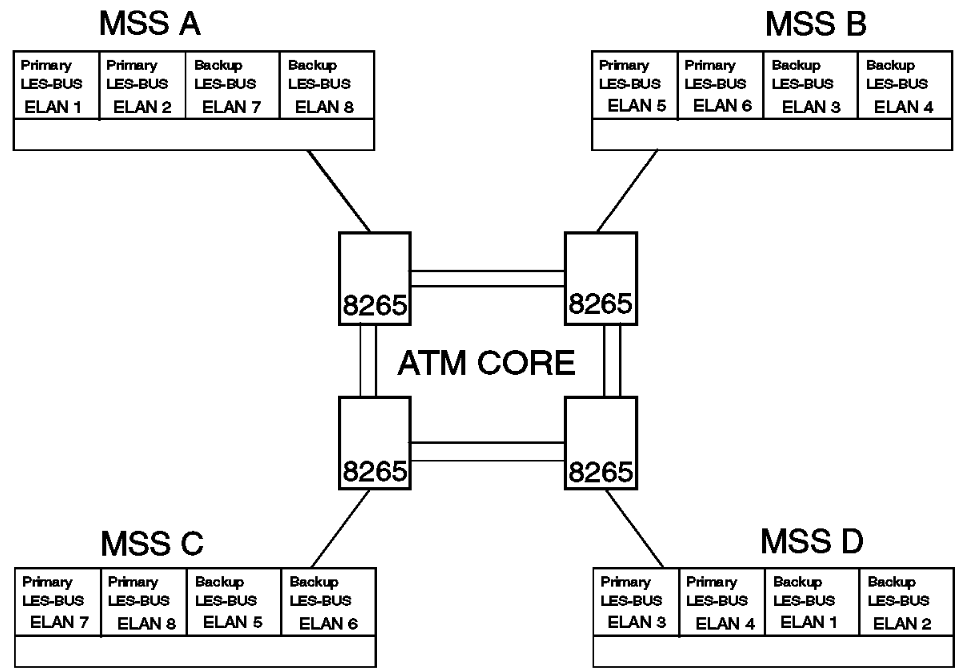


Figure 33. Distributed MSS Functionality

7.1 Product-Related Issues

The following were some of the product-related issues considered:

1. SSI and the number of switches in a cluster.

   The IBM documentation implies that 25 switches is the maximum number of switches allowed in a cluster. It was found that when the number of switches in Cluster 01 reached 15, users would lose sessions or not be able to connect at all. At this stage the library, the COE and the OE were all part of one cluster. This cluster needed to be split into two in order to resolve this. The library was separated into its own cluster.

2. Bandwidth throughput of the CPSW on the 8260 (212 Mbps on an ATM switch module).

   Using two I/O cards in a media module implies that each I/O card is capable of 106 Mbps at the same time. If one I/O card is receiving or transmitting at a rate of less than 212 - 155 = 57 Mbps, then the second will be capable of 155 Mbps. If not, then the second will be capable of transmitting at (212-X) Mbps, where X is the transmission rate of the first port. This is certainly a consideration if both ports are transmitting at maximum throughput, where it will be necessary to use a second media module to handle the throughput.

3. Faulty serial port on MSS 8210 MSS rebooted itself every now and again.

At that time the backup MSS was not providing backup for the whole network. This caused areas of the network to be down until the 8210 was rebooted. After much investigation, preventing progress of the project, IBM found that the serial or modem port caused the MSS to reboot when it received a certain signal. IBM development produced a PTF that solved this problem. The customer was delayed considerably.

4. Devices shipped with back-level code.

   8260 A-17 ATM modules were delivered with back-level microcode incompatible with the CPSW code. This forced the customer to upgrade the code themselves before the ATM modules could be used. Also 8285 expansion unit modules were shipped with incompatible FPGA microcode. This caused considerable delays in the implementation of the network.

5. The Interphase and the Adaptec 155-Mbps ATM adapters were chosen for the servers. Adaptec adapters were dismissed due to three out of five adapters having the same MAC address.

Chapter 8. PNNI Solution Design

This chapter gives an overview of the PNNI control point and then discusses the FIU PNNI network design and the migration steps taken to enable the switches to support PNNI.

8.1 Overview of the PNNI Control Point

The IBM PNNI Control Point is a standard-compliant implementation of the ATM Forums PNNI 1.0 protocol (ATM Forum Specification af-pnni-0055.000 March 1996), with value-added features that make the IBM implementation superior to that found in competitive products, but which do not adversely impact interoperability. The original release of the control point supported a single PNNI peer group. Multiple peer groups can be interconnected using the ATM Forums IISP protocol.

8.1.1 PNNI Routing

PNNI routing is based on the well-known link-state routing technique similar to OSPF. In addition to the basic link-state mechanism, PNNI includes two key extensions that make it suitable for use in today′s communication environment:

1. Support for quality of service (QoS) routing, which is required for applications with real-time requirements.
2. A hierarchy mechanism to allow scalability to large worldwide networks. Use of a single routing protocol for the entire network, as opposed to the Internet strategy of using different protocols at different levels (for example, OSPF, BGP and EGP), is advantageous for supporting end-to-end QoS routing, and also to reduce the configuration associated with multiple levels of routing.

8.1.2 PNNI Signaling

PNNI includes a signaling protocol for the establishment and takedown of point-to-point and point-to-multipoint connections.

8.1.3 Crankback

Crankback creates the ability to reroute a call on an alternate path in case of failure. It is possible that a node in the path from the connection source to the destination may not have sufficient resources to support the requested connection. This could occur, for example, if the topology information used to compute a path is not up-to-date due to the delay between a change in available resources at a node and the distribution of updated topology information to all other nodes in a peer group. Crankback ensures that if there is any path that can support the requirements of an application, it will likely be found.

8.1.4 PNNI Hierarchy Introduction

PNNI supports a hierarchy mechanism that allows groups of switches to be clustered, and then clusters of switches to be further clustered, and so on. In PNNI terminology these clusters are called peer groups. At the bottom level of the PNNI hierarchy, a peer group is a cluster of real switches. At the next higher level of hierarchy, each lower-level peer group is represented by a logical group node. Thus a peer group at this higher level is a cluster of logical group nodes. Each peer group elects a leader from its switches or logical group nodes to be the peer group leader. The peer group leader creates the logical group node that represents the peer group. In this way the amount of topology information is significantly reduced by the hierarchy. Extremely large networks can be built using this functionality

8.2 Planning and Installation of PNNI

This section describes FIU′s design and implementation of PNNI.

To understand how the PNNI structure evolved to what it is today, we first describe the network prior to PNNI (that is, the Cluster Model using NNI and SSI), second we describe the issues surrounding the migration and thirdly we layout the steps taken to allow the switches to participate in the PNNI network.

8.2.1 FIU PNNI Design

A design that would take advantage of the various features of PNNI would have all the switches in the meshed core members of one peer group. FIU will be using the ATM network as a multiservice network. What services will be included and how the technology can best be utilized will be dealt with at a later stage. One of the decisions will be whether to do away with IISP to join the peer groups or to use PNNI hierarchy. For now we discuss the enablement of the network to support PNNI. Please note that the upgrading of the network does not require a hardware forklift. The upgrade is done via software, except for the 8285s which needed a 4MB memory upgrade in order to support the new level of code.

8.2.2 Network prior to PNNI

Since the completion of Phase 5 (December 97) the DM building has been added to the network as a separate cluster. Figure 34 on page 71 shows the stage at which the FIU network was prior to the PNNI migration. The figure shows five seperate clusters. The rationale behind the method of migration is to smoothly migrate one building at a time without affecting the connectivity in the rest of the network. With that in mind each building backbone switch in cluster one needed to be migrated to its own peer group. This was done one building at a time and at the same time the code was upgraded, first in the building backbone switch and second in the remaining switches in the now new peer group. The building that already existed in its own cluster only needed the code upgrades and the PNNI definitions.

8.2.3 Equipment Used

The devices involved in the PNNI migration were 8260 A17s, 8265 and 8285s.

8.2.4 Levels of Code

The code levels prior to PNNI migration were as follows:

CPSW Boot EEPROM version: V2.5.0

Flash EEPROM version: V2.5.1

Flash EEPROM backup version: V2.3.0

Operational FPGA version: B50

ATM Modules Operational FPGA version: B50

8285 Boot EEPROM version: V1.5.0

Flash EEPROM version: V1.5.0

Flash EEPROM backup version: V1.3.0

Operational FPGA version: C30

All control points (CPSWs) will have to be upgraded to Version 3 in order to support PNNI in the network.

8.3 FIU PNNI Implementation

Figure 34 shows the physical topology of the network using the IBM SSI/Cluster design. This shows that five switches are in cluster one and the other four buildings are in their own clusters. In order to maintain availability on campus throughout the conversion to PNNI, the switches in each cluster were ultimately divided into eight separate peer groups. This allowed each building to be converted one at a time.

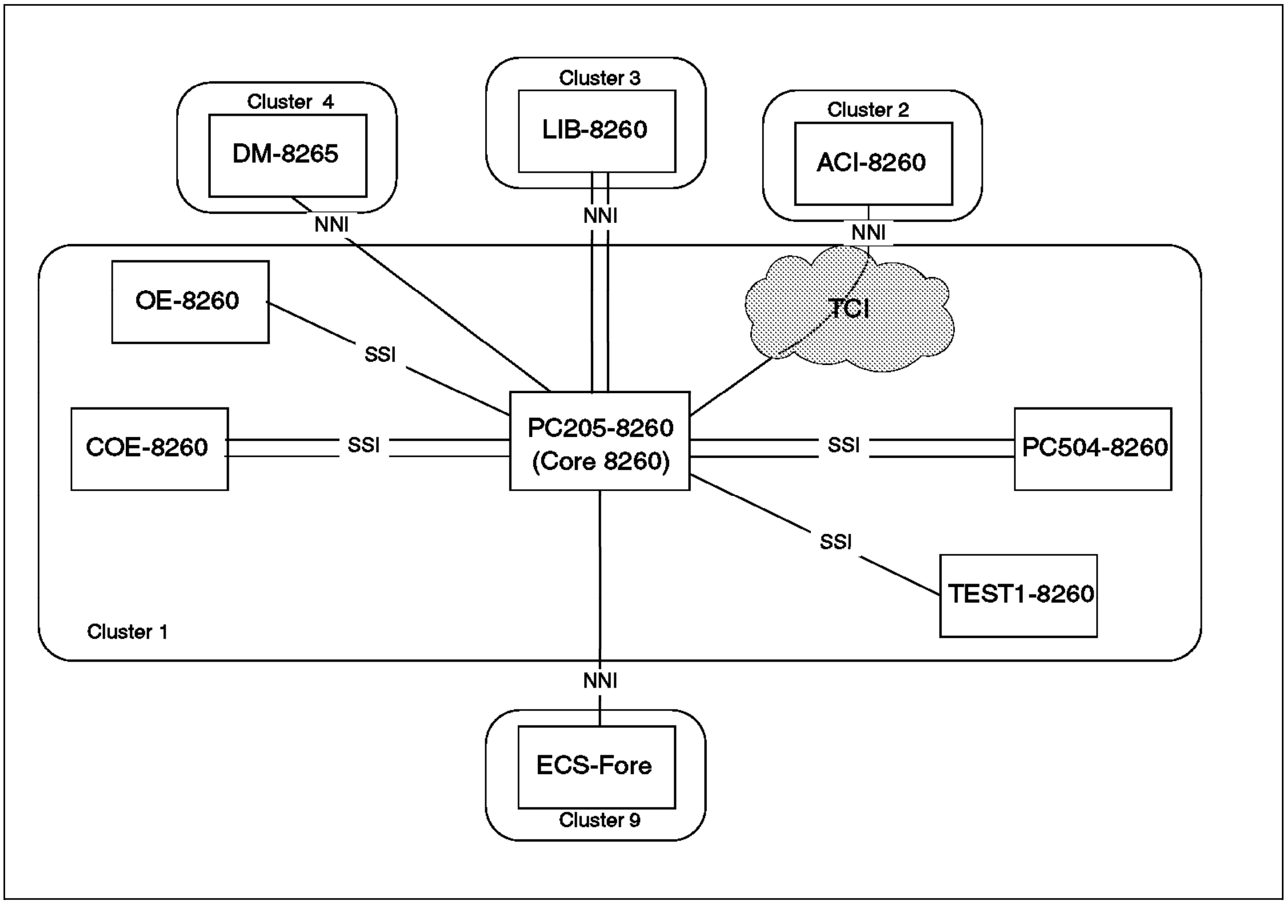


Figure 34. FIU ATM Physical Topology Using IBM SSI/Cluster (before PNNI)

The migration plan had four basic steps. Figure 35 on page 72 shows two basic connections that the buildings used to connect to the core switch, before converting to PNNI. The detailed steps for the migration begin at 8.3.1, “Step 1: Loading PNNI Code to Every Switch” on page 74.

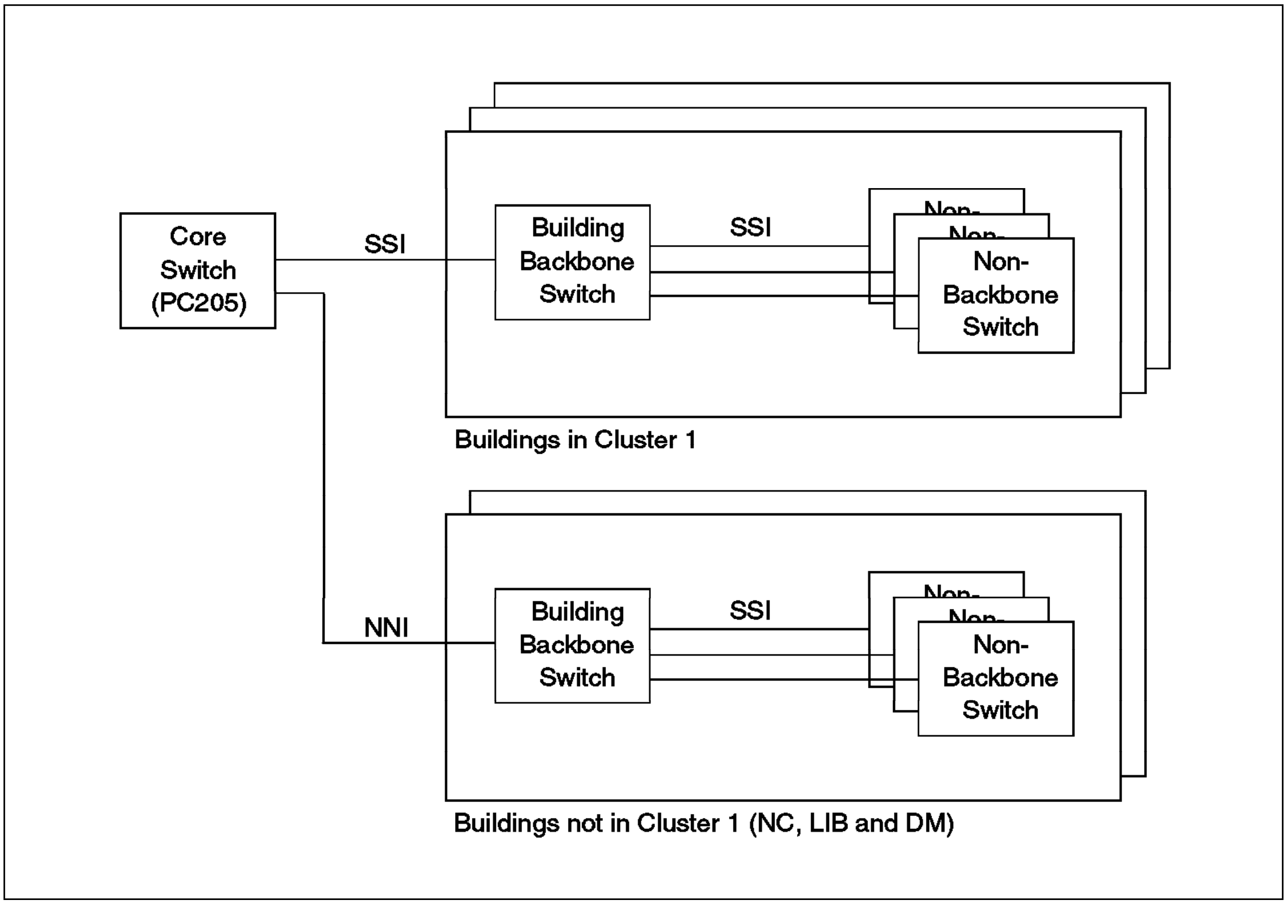


Figure 35. The Structure of ATM Network

1. **Step One: Loading PNNI Code to Every Switch**

   At first, load PNNI(V3) code to every switch in the ATM network. The operational and FPGA codes are stored on backup flash and the boot codes are loaded in non-migration mode. This step is done before the following steps so as to decrease the workload and time spent on the following steps.

2. **Step Two: Upgrading Building Backbone Switch**

   Step two and step three are coupled and performed at each building. Step two is performed before step three in order to regain connectivity to the core before upgrading the remaining switches. This procedure makes it easy to switch to the previous configuration in case problems are encountered.

   At this stage, the ATM address of the building backbone switch belonging to that cluster must change to reflect the new peer group. The buildings already in unique clusters do not need to change the ATM address and just become a new peer group.

   The building backbone switch connects to the core using IISP. On this step, the core switch also needs to change the port configuration connected to the building backbone switch.

3. **Step Three: Upgrading Non-Backbone Switches**

   As mentioned above, this step is performed just after step two has been completed. These devices could be 8260s, 8265s and 8285s.

4. **Step Four: Upgrading the Core Switch**

Finally, upgrade the core switch and PC504-8260 which are in the same cluster. After which all other switches in the network are PNNI-capable.

Figure 36 shows the PNNI migration steps described above.

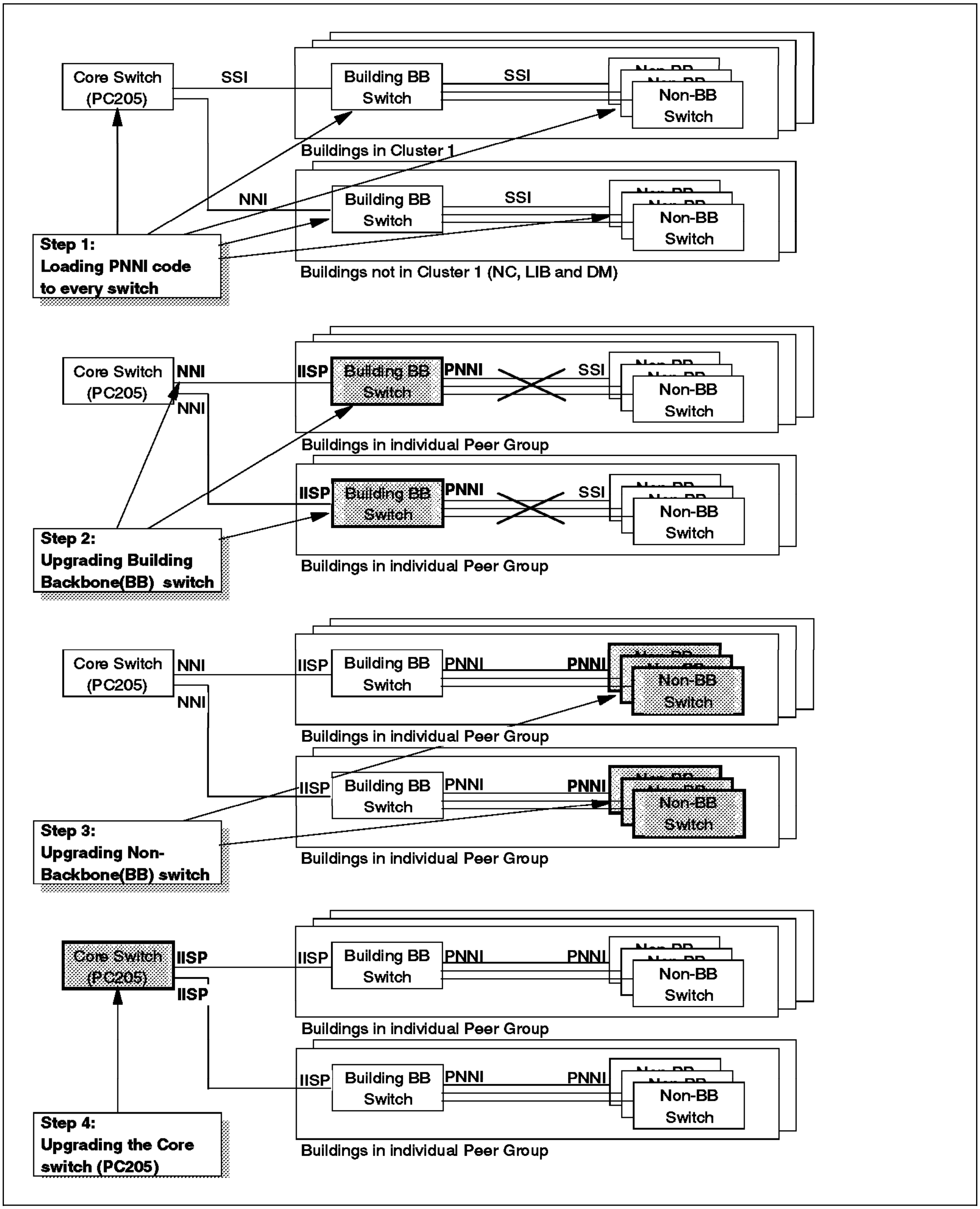


Figure 36. PNNI Migration Steps

8.3.1 Step 1: Loading PNNI Code to Every Switch

At this step, PNNI code should be just loaded and not activated. The operational and FPGA codes are stored on backup flash and the boot code is loaded in non-migration mode.

- Install the 4MB memory upgrade into each 8285.

  In order to support PNNI code, 8260s need 16MB and 8285s need 8MB memory. At the time, all 8260s installed in FIU had enough memory but all 8285s only had standard 4MB memory.

- Load the new PNNI code(V3) in backup mode into each ATM switch in the network.

8.3.2 Step 2: Upgrading Building Backbone Switch

This step upgrades the ATM switch attached to the core switch. This step is done first to ensure building connectivity back to the core before upgrading any other building switches.

- Swap the code in the building backbone 8260/8265 that connects to the core (PC205).

- Set the ATM address for the unique peer group/hub number.

  The default PNNI configuration that is used in FIU defines the byte 12 as the peer group number and byte 13 as the hub number. In the following example, xx and yy should be peer group and hub number.

  ```
  >set pnni node_0 atm_address:
  39.99.99.99.99.99.99.00.00.99.99.xx.yy.....
  >show future_pnni node_0
  >commit pnni
  ```

- Set port(s) on each building backbone switch connected to core switch (PC205) to VOID.

  In this step, FIU has implemented one or more IISP links between a peer group and the core cluster. In order to enable communication between peer groups, we need to define IISP links between the peer groups that need to communicate. This implementation needs to have multiple VPCs on a single ATM port. In order to do so, the port should be defined as VOID and each IISP link defined as VPC_LINK related to the VOID port.

  Below is an example of the commands needed to accomplish this step

  – Set ports to VOID:

    ```
    >set port x.x disable
    >set port x.x enable void
    ```

  – Set VPC_LINKs:

    ```
    >set vpc_link x.x 0 enable iisp user bandwidth:51666 signalling_version_3_0
    >set vpc_link x.x 1 enable iisp user bandwidth:51666 signalling_version_3_0
    >set vpc_link x.x 2 enable iisp user bandwidth:51666 signalling_version_3_0
    ```

  – Set reachable addresses:

    ```
    >set reachable_address x.x 96 39.99.99.99.99.99.99.00.00.99.99.01 vpi:0
    >set reachable_address x.x 96 39.99.99.99.99.99.99.00.00.99.99.03 vpi:1
    >set reachable_address x.x 96 39.99.99.99.99.99.99.00.00.99.99.04 vpi:2
    ```

    Figure 37 on page 75 shows the physical and logical image of the network with VOID port and VPC_LINKs.

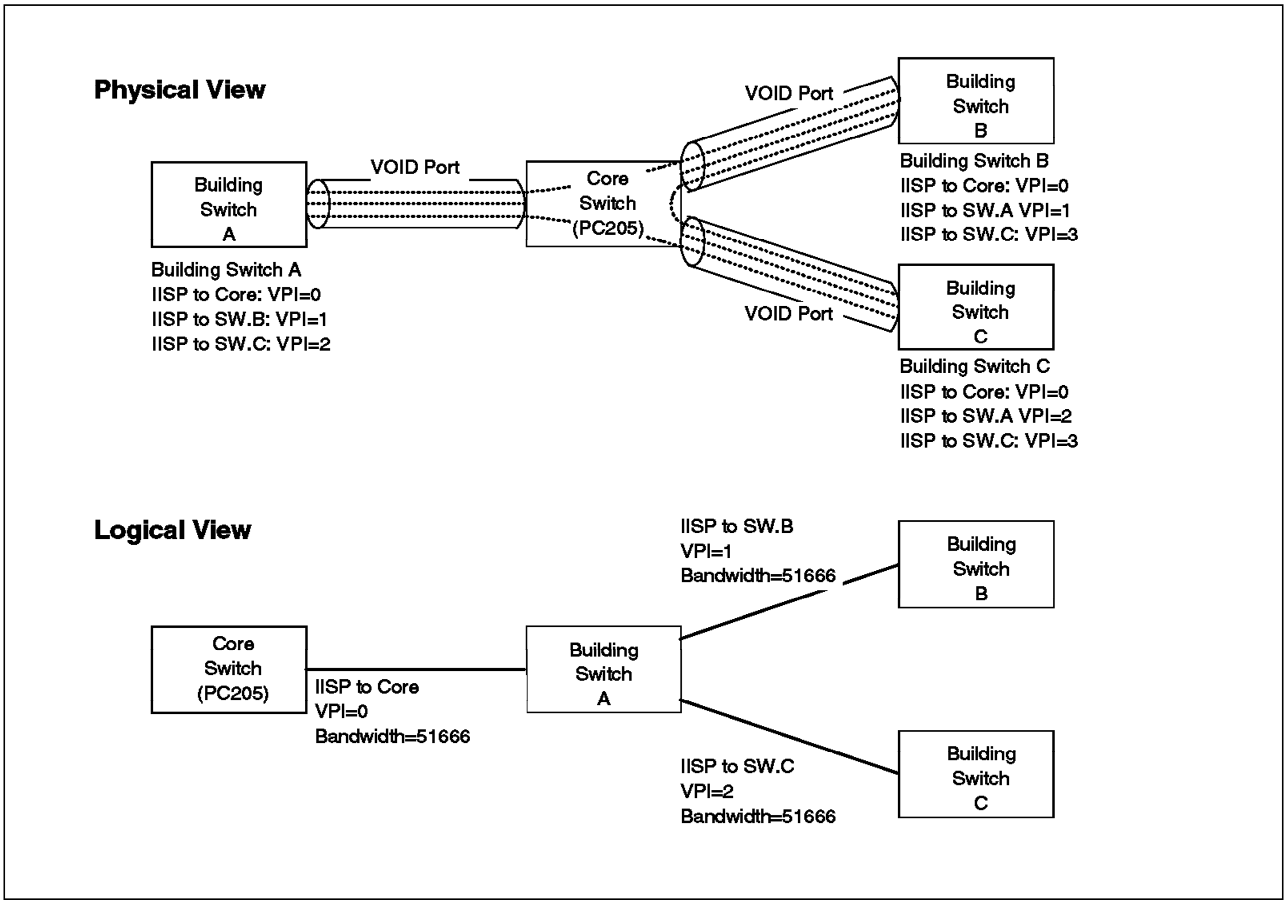


Figure 37. Physical and Logical Image of VOID/VPC_LINK

- On the core switch (PC205), change the connecting port(s) to NNI links and add a logical link for all switches except for North Campus, Library and DM. These buildings are already separate networks.
- Verify connectivity to the core switch (PC205) using CIP ping and the following command:

  ```
  >show reachable_address all
  ```

- Set the LECS address on the building backbone 8260/8265 so that LECs can ILMI for the address of their LES-BUSs. The following command is used to set the address:

  ```
  >set lan_emul configuration_server 39.99.99.99.xx...
  ```

  To verify the correctness, use the following command.

  ```
  >show lan_emul configuration_server
  ```

8.3.3 Step 3: Upgrading Non-Backbone Switches

With connectivity to the core established in the last step, this step upgrades any ATM switches not directly connected to the core.

- Swap the code of all non-backbone switches (8260, 8265, 8285) in the building being upgraded.
- After completing the swap, the SSI port will become a disabled PNNI port, therefore the ports need to be enabled. The following command is used to enable these ports:

```
>set port x.x enable pnni
```

- Set the ATM address to match the peer group address defined in the building backbone 8260/8265. The following command is used to change the address:

```
>set pnni node_0 atm_address:
39.99.99.99.99.99.99.00.00.99.99.xx.yy.....
>show future_pnni node_0
>commit pnni
```

- Verify connectivity to the core switch (PC205) using CIP ping and the following command:

```
>show reachable_address all
```

- Set the LECS address on the non-backbone 8260/8285s so that LECs can ILMI for the address of their LES-BUSs. The following command is used to set the address:

```
>set lan_emul configuration_server 39.99.99.99.xx...
```

To verify the correctness, use the following command:

```
>show lan_emul configuration_server
```

Figure 38 shows the physical topology of the network at the end of step three. This shows that two switches (core and PC504), which are in the same building, remain in cluster one and the other six buildings are in their own peer groups.

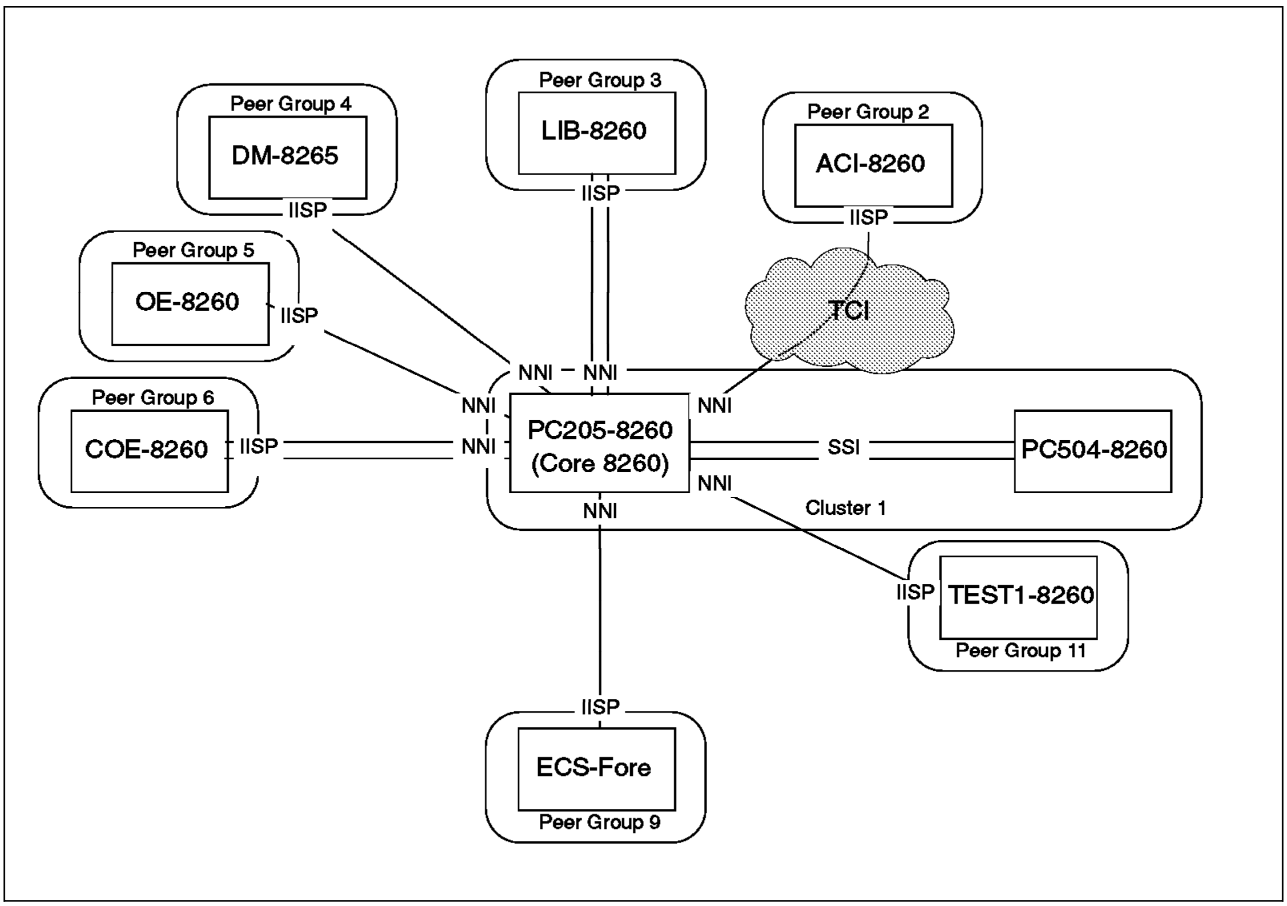


Figure 38. FIU ATM Physical Topology after Step 3

8.3.4 Step 4: Upgrading the Core Switch (PC205)

In this step, the core switch (PC205) is upgraded. In addition, the building switches in the PC building (PC504 and 8285s connect to PC504) are upgraded in order to complete the migration.

- Swap code in the core 8265 to V3:
- Check the ATM address:

  `>show pnni node:0`

- After completing the swap, the NNI port will become a disabled IISP port, therefore the ports need to be enabled. The following command is used to enable these ports:

  `>set port x.x enable iisp`

- After the code swap, logical link and static route definitions are deleted, so new reachable addresses must be entered. The following command is used to set addresses:

  `>set reachable_address x.x 96 39.99.99.99.xx...`

  (This is done for each peer group/building.)

- For each building backbone switch that attaches to the core its connecting port must change from VOID to IISP and delete the vpc_links, with the exception of North Campus. Reachable addresses also need to be re-entered.
- Verification: The following commands were used to verify connectivity to the remote building switches.
  - Verify connectivity to all the peer groups using CIP pings.
  - Use `show reachable_address all` command
  - Use `show pnni neighbor` command

Figure 39 on page 78 shows the physical topology of the network after the migration of the ATM Forum Standard IISP/PNNI design. This shows that only two switches remain in peer group one and the other seven buildings are in their own peer groups.

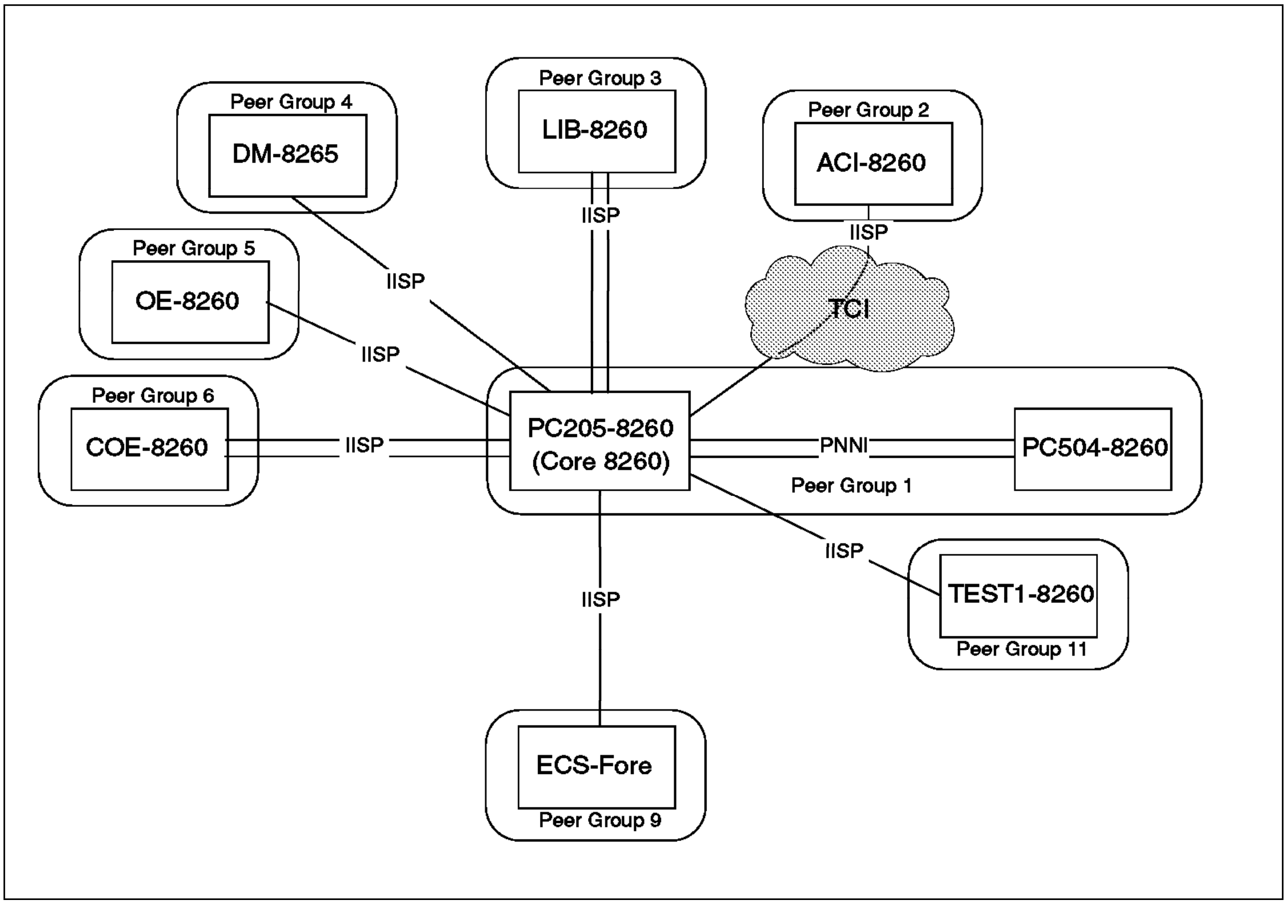


Figure 39. FIU ATM Physical Topology Using PNNI

8.3.5 Consideration

The migration steps were planned and performed by considering various factors. From FIU′s experience, the following considerations would be applied to the other cases migrating from V2 to V3 codes:

- **From Edge to Core Migration**

  By migrating the core switch first, all building backbone switches need to change the definitions at the same time. FIU decided to migrate each building first because it allowed migration to be staged and the disruption to the backbone to be minimized.

- **Multiple IISP Links Design vs. Single IISP Link Design**

  Initially, as shown in 8.3.2, "Step 2: Upgrading Building Backbone Switch" on page 74, FIU used VOID ports to have individual IISP links for each cluster/peer group that needed connectivity. This approach required definitions to specify every link to be reached and divide the bandwidth of physical links into each link. This initial configuration method was necessary because of the migration from Version 2 to Version 3. FIU and IBM realized that this required more definition than was necessary and took the approach that each building backbone switch has only one IISP link to the core switch and sends all frames to the core using the reachable address definition.

In this configuration, the core switch becomes the intermediate node to transfer traffics between buildings. Figure 40 on page 79 shows the image of single IISP link.

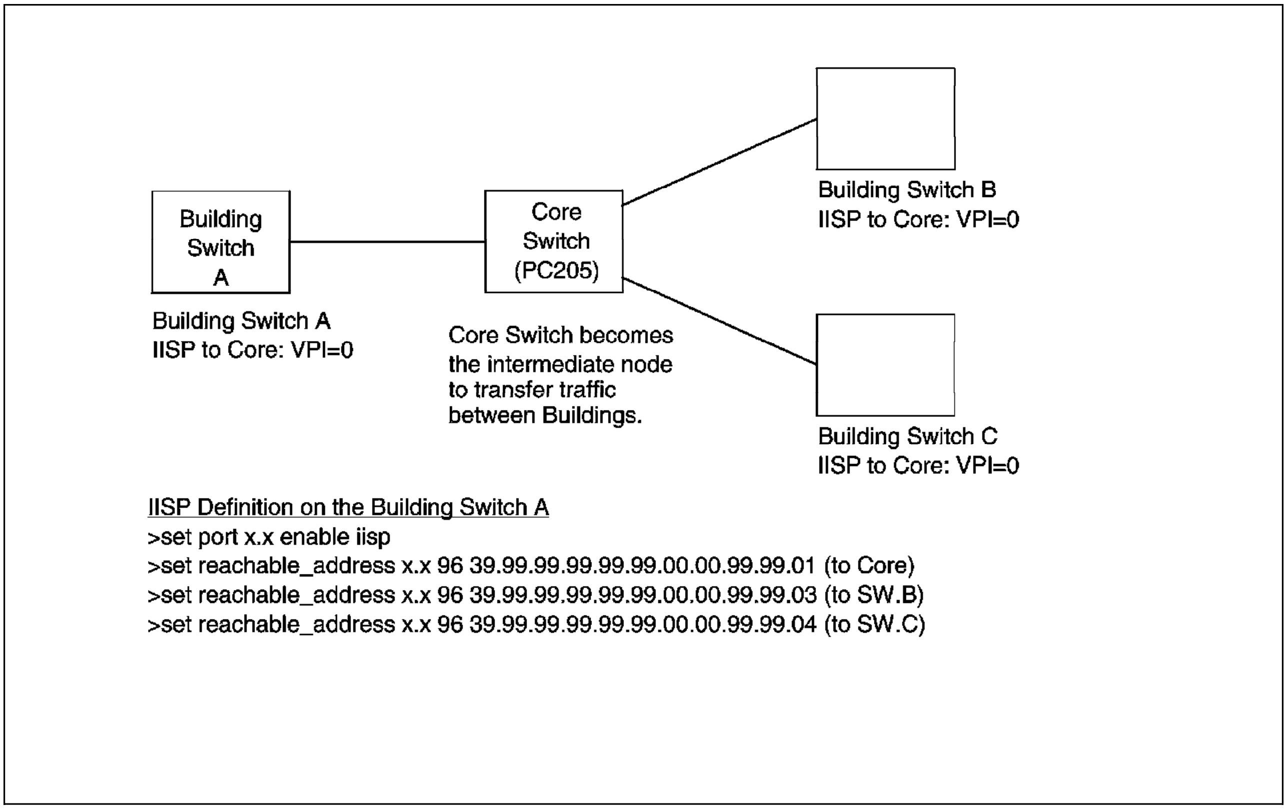


Figure 40. Image of Single IISP Link Design

8.4 Current Network (As of 12/98)

This section describes the changes made after the PNNI migration steps have been completed and shows the current PNNI network in FIU as of 12/98.

8.4.1 Building

After having completed the PNNI migration, the following buildings were added to the PNNI network:

BA Business Administration

RH Residence Hall

CEAS College of Engineering and Applied Science

Wolf Wolfsonian

Figure 41 on page 80 shows the physical topology of the current network, which implements the ATM Forum Standardized IISP/PNNI design. This shows that additional buildings were added into new peer groups, with the exception of the Wolfsonian, which was added to peer group one, and BA, which was added to peer group six. The result shows ten peer groups.

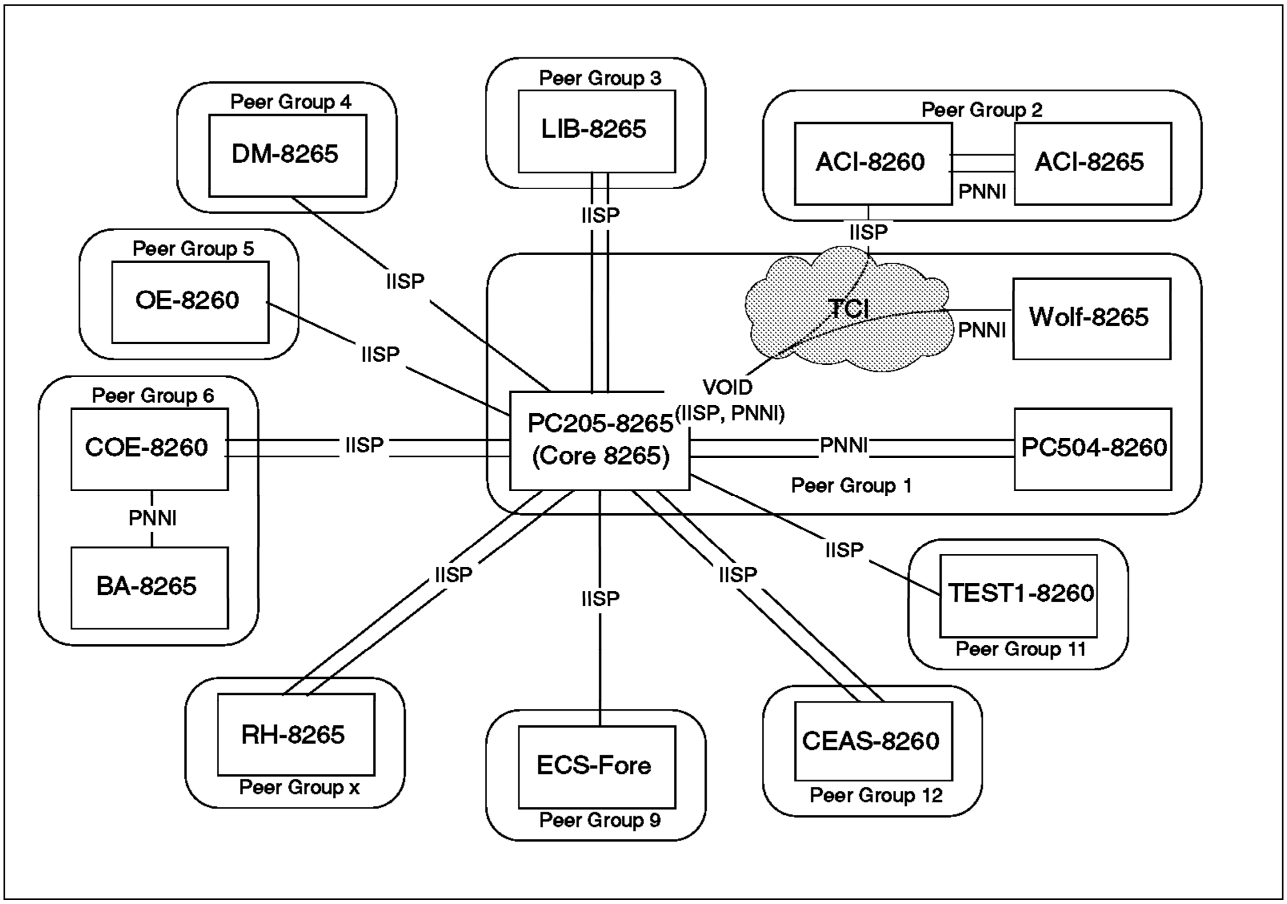


Figure 41. FIU ATM Physical Topology Using PNNI (As of 12/98)

8.4.2 Other Changes

The following are the other changes in the FIU network after PNNI migration:

- **Migrate the core switch from 8260 to 8265**

  This provided performance and capacity improvements to the core switch. 8265 relieves some of the product-related issues described in 7.1, "Product-Related Issues" on page 67.

  – Number of switches in a peer group

    The Release Note of PNNI code shows that the number of switches in the same peer group depends on the network topology and complexity. The peer group can have up to 100 nodes (assuming there are up to 200 foreign addresses and 500 links in the peer group). It relieves the restriction in the SSI network and provides more scalability to the PNNI network.

  – Bandwidth throughput of the CPSW on the 8265

    Each 8260 module supports up to 212 (256 x 53/64) Mbps bandwidth capacity. It only allows you to use full bandwidth on a port of the 155M module so that all ports on the module share the 212 Mbps bandwidth. We have to consider this restriction to define bandwidth on each port or logical link when using 8260 modules as well as 8285. 8265 and its modules support up to 636 (768 x 53/64) Mbps bandwidth capacity. It allows use of full bandwidth on every port of any 8265 module. Please note that 8260 modules still support up to 212 Mbps bandwidth capacity even if they are installed on an 8265.

- **Change the routing protocol from RIP to OSPF**

  In the initial phase, FIU implemented RIP as the routing protocol in the ATM network. They migrated it to OSPF for the following reasons:

  – Scalability

    The OSPF topology supports a hierarchical structure using *areas* and provides more scalability than RIP.

  – Broadcast frame reduction

    In the ATM network, the reduction of broadcast frames is one of the key design points to make the network traffic effective. As explained, the OSPF protocol does not need to send broadcast frames to support the explicit neighbor definition. In addition, it reduces the traffic regarding topology exchange between the nodes.

  – Improvement of route alternation

    With the effective topology exchange, the OSPF protocol detects the failure of a route and changes the topology database more rapidly than RIP. As a result, it reduces the time to switch a route from primary to secondary when needed. This provides flexible redundancy to the IP hosts connected to the ATM network in conjunction with the redundant default gateway function implemented in the MSS.

  Figure 42 on page 82 shows the OSPF network topology in FIU. You can see that the topology used in OSPF (area structure) is almost the same as the PNNI topology (peer group structure). The protocols they use for maintaining the topology are similar, although the implemented layers are different. The subnet name shown in this figure (for example, Subnet.A) stands for one or more actual subnet(s) implemented at FIU.

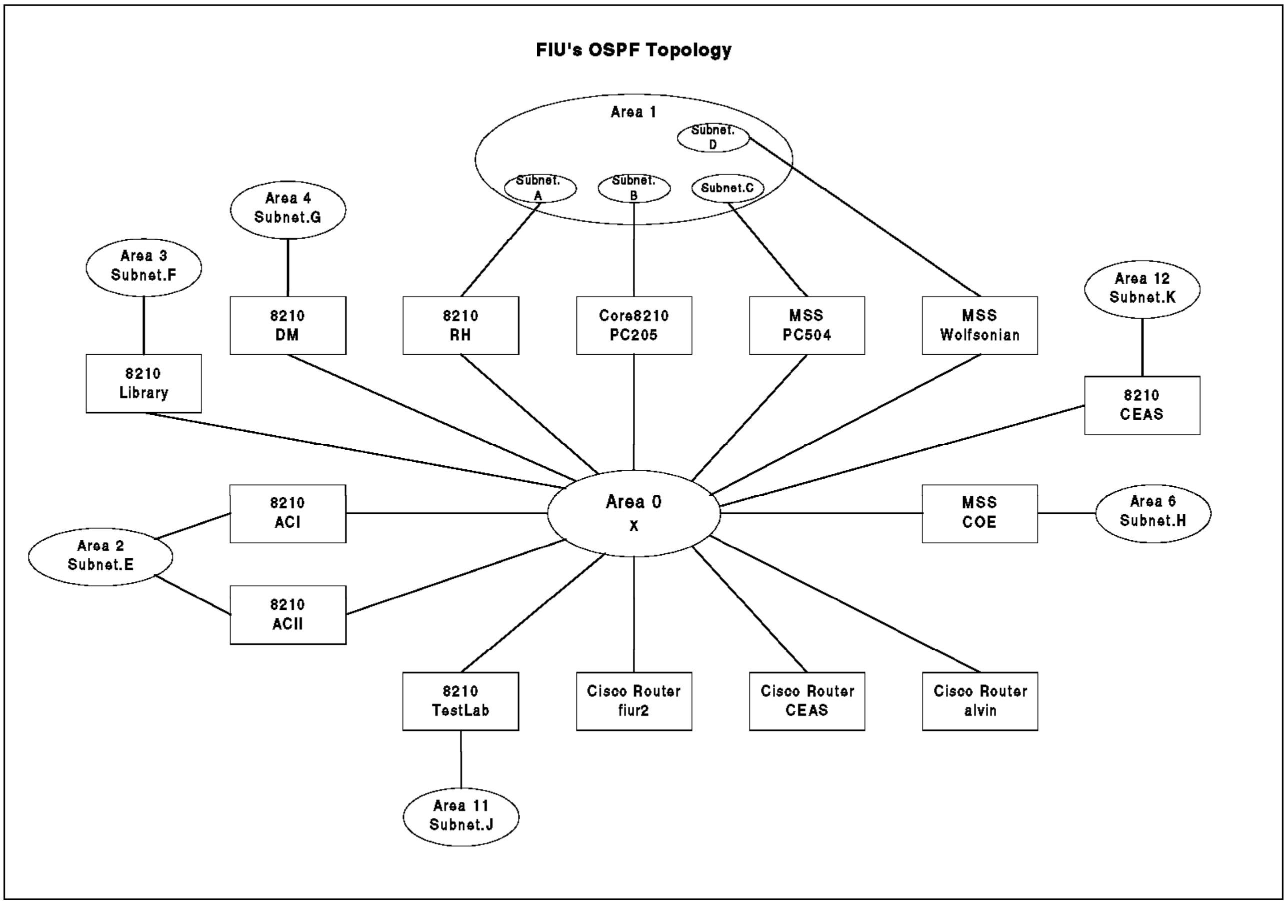


Figure 42. FIU OSPF Network Topology

8.5 New Method of Documenting the MSS Configuration

FIU has revised the method of documenting the MSS configuration. The new method combines the representation as described in 8.5.1, "Components of the Configuration Representation" and in Figure 30 on page 59.

8.5.1 Components of the Configuration Representation

Refer to Figure 43 on page 83 when reading the following list:

1. (A)&(L) This section identifies the MSS name as acii8210 and shows the LECS address that the clients will ILMI to retrieve their LES-BUS addresses.
2. (B)&(K) - Here the basic LES-BUS features are shown, the ELAN name and whether or not it is primary, backup or remote, the ESI and selector byte and the join by policy. If it is a remote LES-BUS, then the ESI/selector of the primary and backup LES-BUSs are shown.
3. (C)&(J) - These sections show the default gateway and LEC configuration. The default gateway is identified as primary (PDGW) or backup (BDGW). The normal routing interface (NRI) IP address is also given.
4. (E) - Indicates the connection from the PDGW to the ELAN.
5. (F)&(I) - Indicates the connection the from the primary and backup LECs to the ELAN.
6. (G) - The ELAN representation.

7. (H) - Indicates the BDGW's connection to the ELAN.

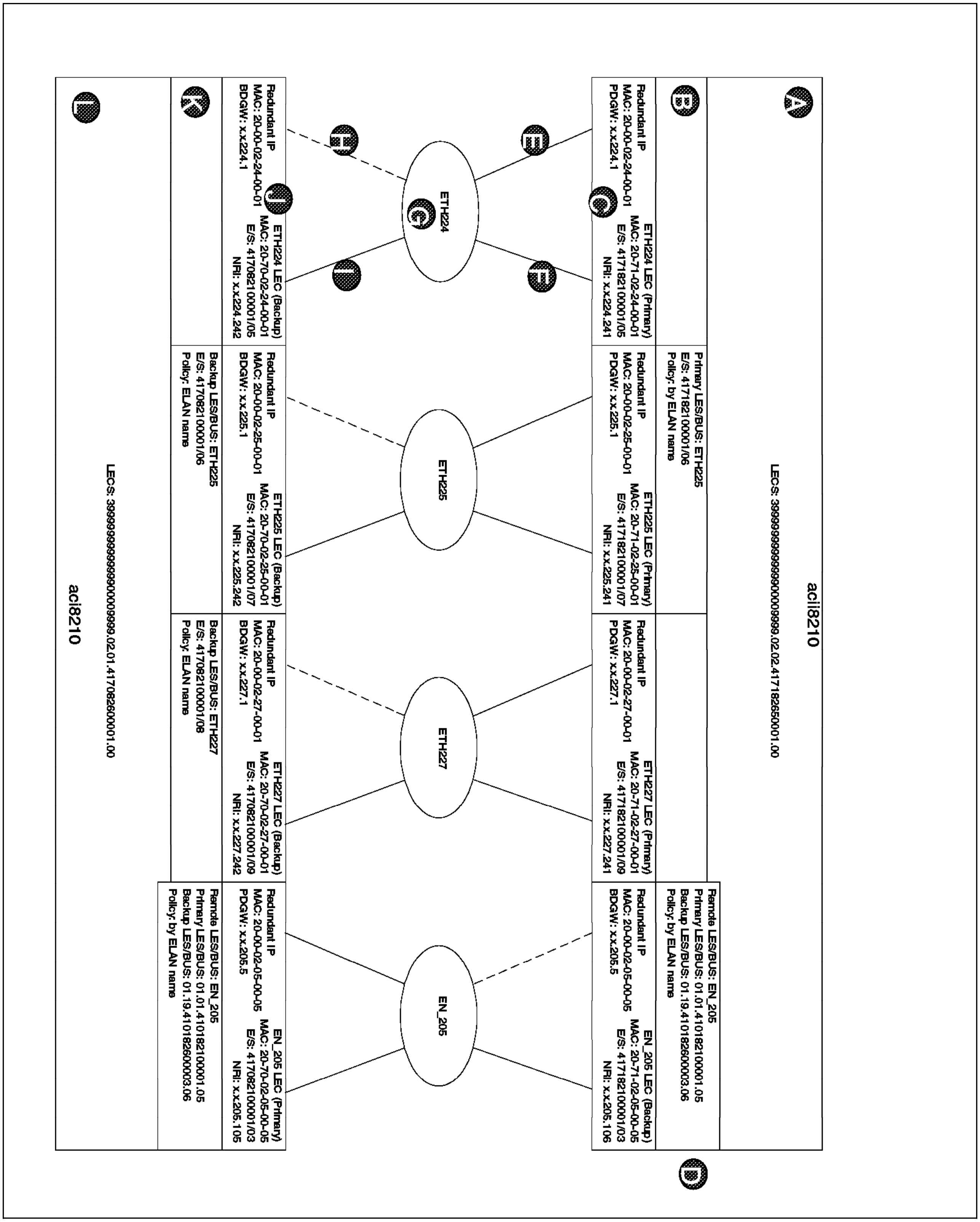


Figure 43. MSS Configuration

8.6 Videoconferencing at FIU

FIU has made use of the First Virtual Corporation (FVC) videoconferencing set of products.

To enable videoconferencing between the FIU and the North Campus, two video access nodes (VANs) were installed, one connected to the ACI8260 and one to the LIB8265. VANs provide true broadcast quality video using H.310 MPEG-2 over ATM. Figure 44 shows the generic view of the videoconferencing design.

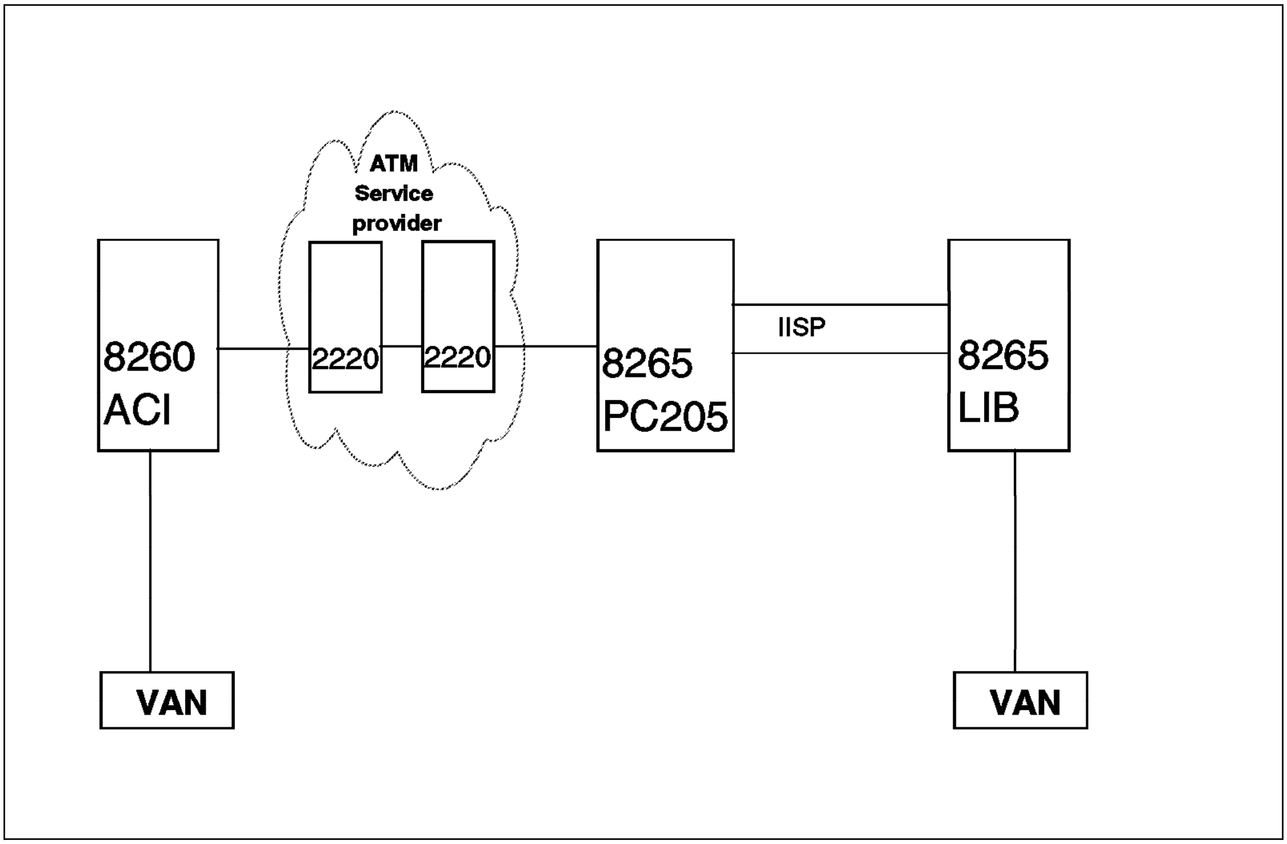


Figure 44. Generic Videoconferencing Design

Chapter 9. Future Plans

The network at FIU will continue to evolve and change. Listed here in this section is future possibilities and directions.

9.1 Network Management

The network management design has not been covered in this redbook. There is a network management station installed. FIU has given priority to other issues regarding the implementation of the solution. The management design uses NetView for AIX and Nways Campus manager for AIX. The hardware platform is an RS/6000. The traps and broadcasts associated with device management are restricted to this subnet. FIU plans to use the management more effectively as soon as their resources allow.

9.2 New Features of MSS

The implementation of PNNI is a key strategy of the revised network design. Once PNNI is fully implemented, FIU plans to make use of a number of new features of MSS V1.1. Four significant features that FIU plans to use are Next Hop Resolution Protocol (NHRP), Super ELANs, MPOA, and Quality of Service (QoS) for LANE. (Now QoS can be configured with MSS V1.1.) Since the FIU network is predominantly an IP network, the introduction of NHRP will improve network performance by eliminating router hops. See *Understanding and Using MSS Release 1.1 and 2.0*, SG24-2115 for a detailed discussion on both NHRP and Super ELANS.

9.3 Migration to a Meshed Core

As discussed in Chapter 7, there is a need to migrate from the current physical star wired design with PC205-8260 at the center to a meshed network where the PC205, PC504 and one or two other switches form the core network. This growth is dependent on more fiber being added underground to allow these meshed connections.

FIU is in the process of planning the network infrastructure to support all the services that FIU plans to offer. FIU will be working with IBM at IBM′s International Networking center, participating in briefings. The objective is to position IBMs technology and integrate this technology into FIUs network design, mapping the technical solutions to FIUs specific objectives and requirements. The ATM backbone at FIU will be used as a multiservice network. The emphasis is on creating a scalable, high availability network. Some of the additional services that will be utilizing the network are MPEG2 over ATM, an energy management system, a security system, SNA over ATM, and Voice over ATM.

9.4 Device Upgrades

The core 8260 hubs will be replaced by 8265s. Two 8265s have been ordered to replace the PC205-8260 and the PC504-8260. The reason for this upgrade is the higher port availability and higher bandwidth capacity of the 8265. The PC205-8260 is fully populated with all ports occupied.

The 155 Mbps from the PC205 to the PC504 and the LIB-8260 will be upgraded to 622 Mbps when the traffic volume warrants this growth.

9.5 Videoconferencing

FIU plans to expand on the videoconferencing that is currently installed. This is a strategic feature of their education strategy. FIU has installed the First Virtual videoconferencing products. This functionality will be used between FIU and the remote campuses, for example, North Campus. FIU will be using more FVC technologies to provide other services that demand high-quality broadcasting such as distance learning.

9.6 Voice over ATM

FIU plans to introduce Voice over ATM by the end of 1999. The North and South campuses will have ATM-enabled PABXs installed. Initially Voice over ATM will be used between North and South campuses. With the enablement of PNNI crankback, voice quality will ensure FIU is a participant of the Internet2 project.

9.7 Internet2 Project

Internet2 is a collaborative effort by over 100 U.S. research universities government and industry partners to create the broadband application, engineering and network management tools that will enable advanced research and education.

FIU is a participant of the Internet2 Project. The university community has joined together with government and industry partners to accelerate the next stage of Internet development in academia. The aim of the Internet2 project is to:

- Create and sustain a leading edge network capability for the national research community.
- Direct network development efforts to enable a new generation of applications to fully exploit the capabilities of broadband network media integration, interactivity and real-time collaboration.
- Integrate the work of Internet2 with on-going efforts to improve production Internet services for all members of the academic community.

Chapter 10. Conclusion

The design and implementation of a network of this scale is affected by many factors. Likewise the success of such an installation requires the cohesion of various disciplines.

10.1 The Customer′s Contribution

FIU made a strategic decision to implement ATM. This decision was made at a high executive level. Consequently all the staff involved in the implementation were committed to make the project work. The technical staff at FIU showed a strong willingness to understand and implement the new technology.

The technical staff understands the FIU network and know what they want to do with it. This has been extremely beneficial to the design and implementation of this solution. The technical staff at FIU attended a week long MSS bootcamp. This enabled them to take over configuration of the products much quicker than some other customers.

The test bed environment proved to be an essential tool for the technical staff at FIU to familiarize themselves with the technology and to test various aspects of the technology. FIU demonstrated a great deal of patience when product-related issues prevented progress of the implementation.

10.2 IBM′s Contribution

Skilled resources were made available on-site to assist with the planning and implementation of the network. The implementation of the network is an on-going timely process. From the time the implementation began there was a considerable advancement in the code levels and hardware available in this technology. IBM proved its commitment to protect the customer′s investment in earlier ATM implementations. It is not necessary for the customer to replace hardware in order to take advantage of new features. IBM has also shown its commitment to moving away from an IBM ATM implementation to developing a standard-compliant ATM implementation. As a whole the IBM team worked well together with the customer to successfully design and install the solution.

Clearly a project of this nature involves many aspects from both the customer and the vendor. A number of issues encountered during the implementation of the network could have been avoided with proper planning. Commitment from the customer, technical skill, excellent products, etc., are not the only answer. The successful coordination of all the aspects of this project proved to be a vital part of this project. This coordination is provided by a competent project management team.

10.3 The Test Bed Environment

The value of the test bed cannot be over-emphasized. The availability of a test environment to test various concepts is an absolute must, especially for a network of this scale. Either a customer′s test bed or IBM Raleigh′s proof of concept test bed is a requirement to test new concepts such as MSS V1.1 redundancy and PNNI migration.

10.4 Summary

ATM is a relatively new technology that is continuously developing. The issues encountered have slowed the implementation of FIU′s network to some degree. Developing technologies are nothing new to FIU as they are continuously breaking barriers in distance learning and education on-demand techniques.

There is no doubt that the open architecture of IBM′s ATM product set is a worthy solution that can lay the foundation for the challenging and innovative asynchronous learning methods that FIU is offering students.

Appendix A. Configuration Examples for the CPSW

The configuration examples that follow are used as a guide to configure components of the 8260 CPSWs on the network. Every configuration example that was used during the implementation of the network is documented below. The examples do not build a network but show how each component is configured.

A.1 CPSW Version 1 and Version 2

The following are commands used to configure the CPSWs in the 8260, 8265 and 8285 at versions one and two.

1. Setting the ATM address:

```
8260>set device atm_address
Enter ATM address:  ##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.# #.##.##.##.##

This call will reset the ATM subsystem

Are you sure? (Y/N) y
```

2. Setting the ARP server ATM address:

```
8260>set device arp_server
Enter ATM address:  ##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.# #.##.##.##.##

ATM address set
```

3. Setting the IP address:

```
8260>set device ip_address
Enter network atm
Enter parameter:  ###.###.###.###
Enter subnet mask: ###.###.###.###

IP address and mask set
```

4. Setting the default gateway:

```
8260>set device default_gateway
Enter parameter:  ###.###.###.###

Entry set
8260>
```

5. Configuring the ATM interface of the CPSW:

```
8260>set port 1.1 enable ilmi_forced_sig_3_0
```

6. Setting the LECS Active Well-Known Address

```
8260>set lan_emulation Configuration_server active_wka
Enter ATM address : ##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.# #.##.##.##.##

Entry set.
8260>
```

7. Setting the LECS inactive well-known address:

```
8260>set lan_emulation Configuration_server inactive_wka
Enter ATM address : ##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.# #.##.##.##.##

Entry set.
8260>
```

8. Setting the logical link:

```
8260>set logical_link
Enter virtual Path Identifier: #
Enter ATM Cluster Network: #
Enter Parameter: network_side or user_side
Enter signalling type: 3.0
Enter traffic type: any
Enter bandwidth in kpbs: 85
Logical link set
```

A.2 CPSW Version 3

The following are commands used to configure the CPSWs in the 8260, 8265 and 8285 at versions three.

1. Setting the ATM address:

```
8260> set pnni node_0 atm_address:
Enter ATM address : ##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##
To activate issue COMMIT after your last 'set pnni...' entry.
To cancel all changes since previous COMMIT, issue UNCOMMIT.

8260> commit pnni
COMMIT execution will first SAVE pnni configuration updates then RESET Hub..
Are you sure ? (Y/N) Y
```

2. Setting the ARP server ATM address:

```
8260> set device arp_server
Enter ATM address:  ##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.# #.##.##.##.##

ATM address set
```

3. Setting the IP address:

```
8260> set device ip_address
Enter network atm
Enter parameter:  ###.###.###.###
Enter subnet mask: ###.###.###.###
IP address and mask set
```

4. Setting the default gateway:

```
8260> set device default_gateway
Enter parameter:  ###.###.###.###
Default gateway set
```

5. Setting the ILMI LECS address:

```
8260> set lan_emul configuration_server
Enter ATM address : ##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.# #.##.##.##.##
Entry set.
```

6. Configuring the ATM interface of the CPSW:

- UNI:

```
8260> set port 1.1 enable uni signalling_version:auto
1.01:Port set
```

- IISP:

```
8260> set port 1.1 enable iisp network bandwidth_nni:######
signalling_version:sign_3_0
1.01:Port set
```

- PNNI:

```
8260> set port 1.1 enable pnni
1.01:Port set
```

7. Setting the reachable address:

```
8260> set reachable address 1.1
Enter prefix length: 96
Enter reachable address : ##.##.##.##.##.##.##.##.##.##.##.##.##
Entry set.
```

8. Verifying connectivity:

- Showing PNNI neighbor information:

```
8260> show pnni neighbor
------ Neighbors of Node 0------
60.A0.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##:Full
    Port 1.01 vpi=0
```

- Showing the reachable address:

```
8260_HUB2> show reachable_address all
Port  Len Address                                                Active Idx
-------------------------------------------------------------------------
1.01   96 ##.##.##.##.##.##.##.##.##.##.##.##.  .  .  .  .  .  .   Y   1
1.02  152 ##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.## Y Dyn
1.02  152 47.00.79.00.00.00.00.00.00.00.00.00.00.00.A0.3E.00.00.01 Y Dyn
```

Appendix B. Configuration Steps and Configuration Listings for the MSS

This section gives the configuration commands necessary to configure each component of the MSS. At the end of each section the results of the commands entered for each MSS are displayed. The results displayed reflect the network as at the end of Phase 5. This snapshot of the network was taken at the end of November 1997.

B.1 Configure the ATM Interface of the MSS

Figure 45 shows the command used to configure the ESI on an MSS.

```
Config>network 0
ATM user configuration
ATM Config>interface
ATM interface configuration
ATM Interface Config>set uni 3.0
ATM Interface Config>add esi
ESI in 00.00.00.00.00.00 form []? ##.##.##.##.##.##
ATM Interface Config>exit
ATM Config>exit
Config>
```

Figure 45. MSS ESI Command

The following list shows the ESIs configured on the various MSSs in the FIU network.

PC205-8210-MSS

```
ATM Interface Config>li esi
          ESI        Enabled
  -----------------  -------
  41.01.82.10.00.01      YES
  41.01.82.10.00.03      YES
  41.01.82.60.00.01      YES
  41.06.82.10.00.01      YES
  41.14.82.10.00.01      YES
  51.01.82.60.00.01      YES
```

PC205-8260-MSS

```
TM Interface Config>li esi
         ESI        Enabled
 -----------------  -------
 41.01.82.10.00.01      YES
 41.01.82.10.00.03      YES
 41.01.82.60.00.01      YES
 41.06.82.10.00.01      YES
 41.14.82.10.00.01      YES
 51.01.82.60.00.01      YES
```

COE-8260-MSS

```
ATM Interface Config>li esi
```

```
        ESI         Enabled
 -----------------  -------
 41.14.82.60.00.01      YES
 51.14.82.60.00.02      YES
```

PC504-8260-MSS

```
ATM Interface Config>li esi

        ESI         Enabled
 -----------------  -------
 41.01.82.60.00.03      YES
 51.01.82.60.00.03      YES
```

ACI-8210-MSS

```
ATM Interface Config>li esi
        ESI         Enabled
 -----------------  -------
 41.70.82.10.00.01      YES
 51.70.82.10.00.01      YES
```

B.2 Configure the LIS Client and ARP Server

The next three steps describe the necessary configuration for the ARP server and LIS client.

B.2.1 Configure IP on the ATM Interface

Figure 46 shows the command to add an IP address.

```
Config>protocol ip
Internet protocol user configuration
IP config>add address
Which net is this address for [0]? 0
New address [0.0.0.0]? ###.###.###.###
Address mask [255.255.0.0]? ###.###.###.###
IP config>exit
Config>
```

Figure 46. Adding an IP Address

The list below shows the configured IP interfaces and addresses on the MSSs in the FIU network.

PC205-8210-MSS

```
IP config>list ip
Interface addresses
IP addresses for each interface:
   intf  0   x.x.4.1       255.255.255.0    Local wire broadcast, fill

RIP default origination: disabled
  Per-interface address flags:
     intf  0   x.x.4.1       RIP disabled for this interface
```

PC205-8260-MSS

```
IP config>li all
```

```
Interface addresses
IP addresses for each interface:
   intf  0   x.x.4.1       255.255.255.0    Local wire broadcast, fill
```

COE-8260-MSS

```
IP config>li all
Interface addresses
IP addresses for each interface:
   intf  0   x.x.4.42      255.255.255.0    Local wire broadcast, fill

RIP default origination: disabled
  Per-interface address flags:
     intf  0   x.x.4.42      RIP disabled for this interface
```

PC504-8260-MSS

```
IP config>li all
Interface addresses
IP addresses for each interface:
   intf  0   131.94.4.16      255.255.255.0    Local wire broadcast, fill

RIP default origination: disabled
  Per-interface address flags:
     intf  0   131.94.4.16      RIP disabled for this interface
```

ACI-8210-MSS

```
IP config>li all
Interface addresses
IP addresses for each interface:
   intf  0   131.94.4.151     255.255.255.0    Local wire broadcast, fill

RIP default origination: disabled
  Per-interface address flags:
     intf  0   131.94.4.151     RIP disabled for this interface
```

B.2.2 Configure the LIS Client to Be Client and Server

Figure 47 on page 96 shows the command to configure a LIS client along with a LIS Server.

```
Config>protocol arp
ARP user configuration
ARP config>add atm-arp-client-configuration
Interface Number [0]? 0
Protocol [IP]?
Client IP Address [0.0.0.0]? ###.###.###.###
This client is also a server? [No]: yes
Refresh timeout (in minutes) [20]?
Enable auto-refresh? [Yes]:
Refresh by InAtmArp? [Yes]:
  (  1) Use burned in ESI
  (  2) ##.##.##.##.##.##
  (  3) ##.##.##.##.##.##
Select ESI [1]? 3
Use internally assigned selector? [Yes]: n
Selector Only, Range 00..FF [00]? 00
Validate PCR for best effort VCCs? [No]:
Maximum Reserved Bandwidth for incoming VCCs (Kbps) [0]?
Use Best Effort Service for Control VCCs? [Yes]:
Peak Cell Rate of outbound control VCCs (Kbps) [0]?
Sustained Cell Rate of outbound control VCCs (Kbps) [0]?
Use Best Effort Service for Data VCCs? [Yes]:
Peak Cell Rate of outbound Data VCCs (Kbps) [0]?
Sustained Cell Rate of outbound Data VCCs (Kbps) [0]?
Max SDU size (bytes) [9188]?
ARP config>exit
Config>
```

Figure 47. LIS Client/Server Configuration

The following shows the configuration of the two MSSs configured as ATM ARP servers.

PC205-8210-MSS

```
ARP config>li atm
ATM Arp Clients:
--------------------------------------------------
If: 0  Prot: 0  Addr: x.x.4.1       ESI: 51.01.82.60.00.01  Sel: 00
Server: yes  Refresh T/O: 20   AutoRefr: yes   By InArp: yes  Validate PC
Use Best Effort: yes/yes  (Control/Data)   Max B/W(kbps):      0
Cell Rate(kbps):  Peak:      0/     0      Sustained:      0/     0
Max SDU(bytes):   9188
--------------------------------------------------
If: 0  Prot: 7                        ESI: burned-in          Sel: auto
Refresh T/O: 5    AutoRefr: no    By InArp: yes  Validate PCR: no
Use Best Effort: yes  (Data)             Max B/W(kbps):      0
Cell Rate(kbps):  Peak: 155000           Sustained:      0
Max SDU(bytes):   9188
```

PC205-8260-MSS (Identical to PC205_8210_MSS)

```
ARP config>li atm
ATM Arp Clients:
--------------------------------------------------
If: 0  Prot: 0  Addr: x.x.4.1       ESI: 51.01.82.60.00.01  Sel: 00
Server: yes  Refresh T/O: 20   AutoRefr: yes   By InArp: yes  Validate PC
Use Best Effort: yes/yes  (Control/Data)   Max B/W(kbps):      0
Cell Rate(kbps):  Peak:      0/     0      Sustained:      0/     0
Max SDU(bytes):   9188
--------------------------------------------------
```

```
If: 0  Prot: 7                          ESI: burned-in          Sel: auto
Refresh T/O: 5    AutoRefr: no    By InArp: yes  Validate PCR: no
Use Best Effort: yes  (Data)             Max B/W(kbps):      0
Cell Rate(kbps):  Peak: 155000           Sustained:      0
Max SDU(bytes):   9188
```

B.2.3 Configure the LIS Client to Be a Client Only

Figure 48 shows the command to setup a LIS client on an MSS.

```
ARP config> add atm-arp-client-configuration
Interface Number [0]?
Protocol [IP]?
Client IP Address [0.0.0.0]? ###.###.###.###
This client is also a server? [No]:no
Refresh timeout (in minutes) [5]?
Enable auto-refresh? [No]:
Refresh by InAtmArp? [Yes]:
  (  1) Use burned in ESI
  (  2) ##.##.##.##.##.##
Select ESI [1]? 2
Use internally assigned selector? [Yes]: no
Selecto r Only, Range 00..FF [00]? 02
Validate PCR for best effort VCCs? [No]:
Maximum Reserved Bandwidth for incoming VCCs (Kbps) [0]?
Use Best Effort Service for Control VCCs? [Yes]:
Peak Cell Rate of outbound control VCCs (Kbps) [0]?
Sustained Cell Rate of outbound control VCCs (Kbps) [0]?
Use Best Effort Service for Data VCCs? [Yes]:
Peak Cell Rate of outbound Data VCCs (Kbps) [0]?
Sustained Cell Rate of outbound Data VCCs (Kbps) [0]?
Max SDU size (bytes) [9188]?
ARP config>
```

Figure 48. Creating a LIS Client

B.3 Configure the LECS

This section describes the steps necessary to setup the LECS environment used in the FIU network

B.3.1 Configure LECS with a Locally Administered ESI Address

In order to match configurations on the 8260 for LECS reachability the ESI needs to be set to a locally administered address. Figure 49 on page 98 shows the command issued on the MSS to set the laa(locally administered address).

```
Config>network 0
ATM user configuration
ATM Config>le-services
LAN Emulation Services user configuration
LE Services config>lecs
Lan Emulation Configuration Server configuration
LECS config>add
  (  1) Use burned in ESI
  (  2) ##.##.##.##.##.##
  (  3) ##.##.##.##.##.##
End system identifier [1]? 2
LECS added to configuration
Enable standard Error Logging System for LECS? [Yes]: yes
Standard ELS activated for LECS
LECS config>
```

Figure 49. Setting the ESI for the LECS

The following is the configured LAAs for the MSSs in the FIU network.

PC205_8210_MSS

```
LECS config>list
LECS Detailed Configuration
   Lecs is                                       Enabled
   ATM Device number:                            0
   ESI:                                          41.01.82.10.00.01
   Selector:                                     0x00
   Validate Best Effort PCR:                     No
   Configuration Direct Max Reserved BW (Kbps): 0
   Maximum number of simultaneous VCCs:          128
   Idle VCC Timeout (in seconds):                60
   Trace ATM address value: 00.00.00.00.00.00.00.00.00.00.00.00.00.00.00.
   Trace ATM address mask:  FF.FF.FF.FF.FF.FF.FF.FF.FF.FF.FF.FF.FF.FF.FF.
LECS config>
```

PC205_8260_MSS (Identical to PC205_8210_MSS)

```
LECS config>li ?
LECS Detailed Configuration
   Lecs is                                       Enabled
   ATM Device number:                            0
   ESI:                                          41.01.82.10.00.01
   Selector:                                     0x00
   Validate Best Effort PCR:                     No
   Configuration Direct Max Reserved BW (Kbps): 0
   Maximum number of simultaneous VCCs:          128
   Idle VCC Timeout (in seconds):                60
   Trace ATM address value: 00.00.00.00.00.00.00.00.00.00.00.00.00.00.00.
   Trace ATM address mask:  FF.FF.FF.FF.FF.FF.FF.FF.FF.FF.FF.FF.FF.FF.FF.
LECS config>
```

COE_8260_MSS

```
LECS config>list
LECS Detailed Configuration
   Lecs is                                       Enabled
   ATM Device number:                            0
   ESI:                                          41.14.82.60.00.01
   Selector:                                     0x00
```

```
   Validate Best Effort PCR:                    No
   Configuration Direct Max Reserved BW (Kbps): 0
   Maximum number of simultaneous VCCs:         128
   Idle VCC Timeout (in seconds):               60
   Trace ATM address value: 00.00.00.00.00.00.00.00.00.00.00.00.00.00.00.
   Trace ATM address mask:  FF.FF.FF.FF.FF.FF.FF.FF.FF.FF.FF.FF.FF.FF.FF.
LECS config>
```

B.3.2 Add ELAN elan_??? Definition to the LECS

In order for the LECs to join the defined ELANs by name the ELANs have to be entered into the LECSs database. Figure 50 shows the command used to add the ELANs to the LECS database on the MSS.

```
 LECS config>elan
 Configuration of ELANs for LECS
 LECS ELANs config>add
 Name of ELAN []? elan_???
 Type of ELAN
         (1) Ethernet
         (2) TokenRing

 Enter Selection:  [2]? 1
 Maximum frame size of ELAN
         (1) 1516
         (2) 4544
         (3) 9234
         (4) 18190

 Enter Selection:  [1]? 1
 ELAN 'elan_???' added


LECS ELANs config>li elan
ELAN Listing...
                             Name  Type  Packet Size  Enabled
=================================  ====  ===========  =======
                           EN_205  Ethe         1516      Yes
                            EN_52  Ethe         1516      Yes
                            EN_53  Ethe         1516      Yes
                            ETH43  Ethe         1516      Yes
                            ETH68  Ethe         1516      Yes
                            ETH69  Ethe         1516      Yes
                            ETH79  Ethe         1516      Yes
                         ETH80-81  Ethe         1516      Yes
LECS ELANs config>
```

Figure 50. Adding an ELAN to the LECS Database

B.3.3 Configure the LECS with a Local Primary LES for ELAN elan_??? and Set Policy Value

Figure 51 on page 100 shows the commands to add a LES and add it to the LECS database.

```
LECS ELANs config>select
  (  1) elan_???
Choice of ELAN [1]? 1
ELAN 'elan_???' selected for detailed configuration
Selected ELAN elan_???'>less add
  (  1) Local
  (  2) Remote
Primary LES is [1]? 1
  (  1) Unspecified
  (  2) Local
  (  3) Remote
Backup LES is  [0]? 3
If backup LES is remote, enter ATM address
         []? ##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##

Do the LESs utilize IBM LES redundancy?? [Yes]: yes
LES ATM address Local LES for: elan_???
    added to ELAN 'elan_???'
Selected ELAN elan_???'>policy add name
ATM address of LES for policy value(s)

        (1) Local LES for: ELAN_???

Enter Selection:  [1]? 1
ELAN name []? elan_???
ELAN name 'elan_???'
     bound to LES Local LES for: ELAN_???
Selection "ELAN name add" Complete
Selected ELAN elan_???'>exit
LECS ELANs config>
```

Figure 51. Adding the Local Primary LES to the LECS

The following shows the definitions for the local primary LES/BUS on MSS PC205_8210_MSS.

```
PC205_8210_MSS
LECS ELANs config>sel elan
Choice must be between 1 and 8
  (  1) EN_205
  (  2) EN_52
  (  3) EN_53
  (  4) ETH43
  (  5) ETH68
  (  6) ETH69
  (  7) ETH79
  (  8) ETH80-81
Choice of ELAN [1]? 1
ELAN 'EN_205' selected for detailed configuration
Selected ELAN 'EN_205'>les list
LESs for ELAN 'EN_205'
Enbld  LES ATM address
=====  ===========================================================
  Yes  Local LES for: EN_205
       Backup LES with IBM LES redundancy:
       39.99.99.99.99.99.99.00.00.99.99.01.01.41.01.82.60.00.01.05
Selected ELAN 'EN_205'>
```

```
Choice of ELAN [1]? 2
ELAN 'EN_52' selected for detailed configuration
Selected ELAN 'EN_52'>les list
LESs for ELAN 'EN_52'
Enbld  LES ATM address
=====  ==========================================================
  Yes  Local LES for: EN_52
       Backup LES with IBM LES redundancy:
       39.99.99.99.99.99.99.00.00.99.99.01.01.41.01.82.60.00.01.02
Selected ELAN 'EN_52'>

Choice of ELAN [1]? 3
ELAN 'EN_53' selected for detailed configuration
Selected ELAN 'EN_53'>les list
LESs for ELAN 'EN_53'
Enbld  LES ATM address
=====  ==========================================================
  Yes  Local LES for: EN_53
       Backup LES with IBM LES redundancy:
       39.99.99.99.99.99.99.00.00.99.99.01.01.41.01.82.60.00.01.06
Selected ELAN 'EN_53'>


Choice of ELAN [1]? 4
ELAN 'ETH43' selected for detailed configuration
Selected ELAN 'ETH43'>les li
LESs for ELAN 'ETH43'
Enbld  LES ATM address
=====  ==========================================================
  Yes  Local LES for: ETH43
       Backup LES with IBM LES redundancy:
       39.99.99.99.99.99.99.00.00.99.99.01.19.41.01.82.60.00.03.0A
Selected ELAN 'ETH43'>
```

B.3.4 Configure LECS with the LES Definition for Local Backup LES-BUS and Add Policy Value

In the previous section it showed the definitions for primary LES/BUS, this section outlines the backup LES/BUS configuration. Figure 52 on page 102 shows the commands issued on the MSS to configure the backup LES/BUSs to the LECS.

```
 LECS ELANs config>select
  (  1) elan_???
  (  2) elan_???
  (  3) elan_???
Choice of ELAN [1]? 3
 ELAN 'elan_???  ' selected for detailed configuration
Selected ELAN 'elan_???'>les add
 (  1) Local
 (  2) Remote
 Primary LES is [1]? 2
 If primary LES is remote, enter ATM address
        []? ##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##
(  1) Unspecified
  (  2) Local
  (  3) Remote
 Backup LES is  [0]? 2
 Do the LESs utilize IBM LES redundancy?? [Yes]: yes
 LES ATM address ##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##
  added to ELAN 'elan_???'
Selected ELAN 'elan_???'>policy add name
 ATM address of LES for policy value(s)
         (1) ##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##
Enter Selection:  [1]? 1
 ELAN name []? elan_???
ELAN name 'elan_???'
     bound to LES ##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##
Selection "ELAN name add" Complete
 Selected ELAN 'elan_???'>exit
LECS ELANs config>exit
 LECS  config>exit
 LE Services config>exit
```

Figure 52. Adding the Local Backup LES to the LECS

The following shows the definitions for the local backup LES/BUS on MSS PC205_8210_MSS.

```
PC205_8210_MSS
LECS ELANs config>sel elan
Choice must be between 1 and 8
  (  1) EN_205
  (  2) EN_52
  (  3) EN_53
  (  4) ETH43
  (  5) ETH68
  (  6) ETH69
  (  7) ETH79
  (  8) ETH80-81
Choice of ELAN [1]? 5
ELAN 'ETH68' selected for detailed configuration
Selected ELAN 'ETH68'>les li
LESs for ELAN 'ETH68'
Enbld  LES ATM address
=====  ============================================================
  Yes  39.99.99.99.99.99.99.00.00.99.99.01.19.41.01.82.60.00.03.02
       Backup LES with IBM LES redundancy:
       Local LES for: ETH68
Selected ELAN 'ETH68'>
```

```
Choice of ELAN [1]? 6
ELAN 'ETH69' selected for detailed configuration
Selected ELAN 'ETH69'>les li
LESs for ELAN 'ETH69'
Enbld  LES ATM address
=====  ===========================================================
  Yes  39.99.99.99.99.99.99.00.00.99.99.01.19.41.01.82.60.00.03.04
       Backup LES with IBM LES redundancy:
       Local LES for: ETH69
Selected ELAN 'ETH69'>

Choice of ELAN [1]? 8
ELAN 'ETH80-81' selected for detailed configuration
Selected ELAN 'ETH80-81'>les li
LESs for ELAN 'ETH80-81'
Enbld  LES ATM address
=====  ===========================================================
  Yes  39.99.99.99.99.99.99.00.00.99.99.01.11.41.14.82.60.00.01.02
       Backup LES with IBM LES redundancy:
       Local LES for: ETH80-81
Selected ELAN 'ETH80-81'>
```

B.3.5 Configure LECS with the LES Definition for Remote LES-BUS and Add Policy Value

The previous sections showed the definitions for primary and backup local LES/BUS, this section outlines the remote LES/BUS configuration. Figure 52 on page 102 shows the commands issued on the MSS to configure the remote LES/BUSs to the LECS.

```
LECS config>elan
Configuration of ELANs for LECS
LECS ELANs config>add
Name of ELAN []? elan_???
Type of ELAN
        (1) Ethernet
        (2) TokenRing

Enter S election:  [2]? 1
Maximum frame size of ELAN
        (1) 1516
        (2) 4544
        (3) 9234
        (4) 18190

Enter Selection:  [1]? 1
ELAN 'elan_???' added
Selection "ELAN addition" Complete
LECS ELANs config>select
  (  1) elan_???
Choice of ELAN [1]? 1
ELAN 'elan_???' selected for detailed configuration
Selected ELAN 'elan_???'> less add
  (  1) Local
  (  2) Remote
Primary LES is [1]? 2
If primary LES is remote, enter ATM address
         []? ##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##
(  1) Unspecified
  (  2) Local
  (  3) Remote
Backup LES is  [0]? 3
If backup LES is remote, enter ATM address
         []? ##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##
Do the LESs utilize IBM LES redundancy?? [Yes]:
LES ATM address ##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##
  added to ELAN 'elan_???'
Selected ELAN 'elan_???'>policy add name
ATM address of LES for policy value(s)

        (1) ##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##

Enter Selection:  [1]? 1
ELAN name []? elan_???
ELAN name 'elan_???'
     bound to LES ##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##
Selection "ELAN name add" Complete
Selected ELAN 'elan_???'>exit
LECS ELANs config>exit
```

Figure 53. Configuring the LECS with Remote ELAN Definitions

The following shows the definitions for the remote LES/BUS on MSS PC205_8210_MSS.

```
PC205_8210_MSS
LECS ELANs config>sel elan
Choice must be between 1 and 8
  (  1) EN_205
  (  2) EN_52
  (  3) EN_53
  (  4) ETH43
  (  5) ETH68
```

```
  (  6) ETH69
  (  7) ETH79
  (  8) ETH80-81
Choice of ELAN [1]? 7
ELAN 'ETH79' selected for detailed configuration
Selected ELAN 'ETH79'>les li
LESs for ELAN 'ETH79'
Enbld  LES ATM address
=====  ==========================================================
  Yes  39.99.99.99.99.99.99.00.00.99.99.01.19.41.01.82.60.00.03.08
       Backup LES with IBM LES redundancy:
       39.99.99.99.99.99.99.00.00.99.99.01.11.41.14.82.60.00.01.06
Selected ELAN 'ETH79'>
```

B.3.6 Define General Policies Priority for LECS

Policies are added to the LECS to allow LECs (clients) to easily join ELANs. In the FIU network the policy of join by elan name was configured. This set up eases the configuration of clients by only having to configure the elan name in the driver. Figure 54 shows the command entered on the MSS to configure polices on the LECS.

```
LECS config>policies
LECS POLICIES configuration
LECS POLICIES config>add
Priority of Policy [10]? 10
Policy type
        (1) byAtmAddr
        (2) byMacAddr
        (3) byRteDesc
        (4) byLanType
        (5) byPktSize
       (6) byElanNm

Enter Selection:  [1]? 6
Added policy 'byElanNm ' at priority 10
Selection "Add assignment policy" Complete
LECS POLICIES config>exit
LECS config>exit
LE Services config>
```

Figure 54. Configuring Policies on an LECS

The same configuration parameters are used on PC205_8210_MSS, PC205_8260_MSS and COE_8260_MSS

```
LECS config>policies
LECS POLICIES configuration
LECS POLICIES config>li all
Policy Listing...
Enabled  Priority  Type
=======  ========  ==========
    Yes        10  byElanNm
LECS POLICIES config>
```

B.4 Configure a LES-BUS Pair for ELAN elan_???

Once the LESs have been defined in the LECS database the ELANs themselves must be configured on the MSS. The following sections describe the commands and configurations in the FIU network.

B.4.1 Define the LES-BUS for elan_???

Figure 55 shows the command and configuration of a LES/BUS on the MSS.

```
LE Services config>les-bus
ELAN Name (ELANxx) []? elan_???
LES-BUS configuration
LES-BUS config for ELAN 'ELAN_???'>add
Turn on Standard Event Logging for LES [yes]yes
Select ELAN type
        (1) Token Ring
        (2) Ethernet

Enter Selection:  [1]? 2
Select ESI
        (1) Use burned in ESI
        (2) ##.##.##.##.##.##
        (3) ##.##.##.##.##.##

Enter Selection:  [1]? 2



Selector x00 is generally reserved for use by the LECS,
Selector x01 is generally reserved for use by the LECS Interface.

Enter selector (in hex) [2]?
Selection "Add LES-BUS" Complete
LES-BUS config for ELAN elan_???'>set bus-mode (must do this to enable bcm all)
BUS Mode
        (1) System
        (2) Adapter
        (3) Vcc-Splice
        (4) Exit (no-change)

Enter Selection:  [1]? 1
Selection "Set BUS Mode" Complete
LES-BUS config for ELAN elan_???'>enable bcm all
LES-BUS config for ELAN elan_???'>exit
LE Services config>exit
ATM Config>
```

Figure 55. Configuring a LES-BUS (ELAN)

B.4.2 Configure an ELAN for Redundancy

Redundancy of components is a critical piece of providing a reliable network. Figure 56 on page 107 shows the command to add a redundant LES-BUS to an MSS.

```
LES-BUS config for ELAN 'elan_???'> enable Redundancy protocol role
        (1) Primary LES-BUS
        (2) Backup LES-BUS

Enter Selection:  [1]?1

ATM address of backup les-bus []?
 ##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##.##
Selection "Enable Redundancy" Complete
LES-BUS config for ELAN 'elan_???'>
```

Figure 56. Defining a Redundant LES-BUS

Figure 57 shows the configured LES-BUSs on the PC205_8210_MSS.

```
LE Services config>li all
List of Configured LES-BUS(s)
ELAN Type  (E=Ethernet/802.3, T=Token Ring/802.5)
] Interface #
] ] Enabled                                          Max.
] ] ]                                                Frame   Redunda
] ] ] ELAN Name                 LES ESI       Sel    Size    Role
- - - ------------------------- ------------  ---    -----   -------
E 0 Y EN_205                    410182100001  x05     1516   Primary
E 0 Y EN_52                     410182100001  x02     1516   Primary
E 0 Y EN_53                     410182100001  x06     1516   Primary
E 0 Y ETH43                     410682100001  x02     1516   Primary
E 0 Y ETH68                     410182100003  x02     1516   Backup
E 0 Y ETH69                     410182100003  x04     1516   Backup
E 0 Y ETH80-81                  411482100001  x02     1516   Backup
LE Services config>
```

Figure 57. List of Configured ELANs

The example below is from PC205_8210_MSS and shows the configuration of one of the ELANs (EN_205), all of the other ELANs are identical with the exception of the selector byte, and in the case of ETH69 and ETH68 these are on a different MSS. See Figure 57 above.

```
LE Services config>les-bus
ELAN Name (ELANxx) []? EN_205
LES-BUS configuration
LES-BUS config for ELAN 'EN_205'>li all
LES-BUS Detailed Configuration
Name:  EN_205
   LES-BUS Enabled/Disabled:                  Enabled
   ATM Device number:                         0
   End System Identifier (ESI):               41.01.82.10.00.01
   Selector Byte:                             0x05
   ELAN Type:       (S2)                      Ethernet
   Max Frame Size:  (S3)                      1516
   Control Timeout: (S4)                      120
   Max Frame Age:   (S5)                      1
   LECID Range Minimum:                       1
   LECID Range Maximum:                       65279
   Validate Best Effort Peak Cell Rate (PCR): No
   Control Distribute VCC Traffic Type:       Best Effort VCC
   Control Distribute VCC PCR in Kbps:        155000
```

```
   Control Direct VCC Max Reserved Bandwidth:  0
   Multicast Forward VCC Traffic Type:         Best Effort VCC
   Multicast Forward VCC PCR in Kbps:          155000
   Multicast Send VCC MAX Reserved Bandwidth:  0
    -LES-BUS Options-
   BUS Mode:                                   System
   Security (LECS Validation of Joins):        Disabled
   Partition LE_ARP_REQUEST Forwarding Domain: Yes
   LE_ARP RESPONSE Destination:                One client
   Partition Unicast Frame Domain:             Yes
   Redundancy:                                 Enabled
   Redundancy Role:                            Primary LES-BUS
   ATM address of Backup LES-BUS:  3999999999999900009999010141018260000l
   ATM address trace filter value: 0000000000000000000000000000000000000000
   ATM address trace filter mask:  FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF
    -BUS Monitor Configuration-
   Monitor Host Usage of BUS:                  Enabled
   # Top Hosts to Record:                      10
   # Seconds in each sample interval:          10
   # Minutes between sample intervals:         30
   Frame sampling rate:                        1 out of 10
    -Broadcast Manager Configuration-
   IP BCM:                                     Enabled
   IPX BCM:                                    Enabled
   NetBIOS BCM:                                Enabled
   BCM IP Cache Aging Time:                    5
   BCM IPX Cache Aging Time:                   3
   BCM NetBIOS Cache Aging Time:               15
   BCM IPX Maximum Forwarding List:            50
   No BCM IPX Static Entries defined
LES-BUS config for ELAN 'EN_205'>
```

B.5 Define the LEC for ELAN elan_???

To eventually bridge and/or route between the ELANs, LECs must be configured in each of the ELANs. The following steps describe the configuration of LECs and adding and IP address to the configured LECs.

B.5.1 Add a LEC As a Logical Interface

Figure 58 shows the command step to add a LEC to an ELAN.

```
ATM Config>
ATM Config>le-client
ATM LAN Emulation Clients configuration
LE Client config>add ethernet forum-compliant
Added Emulated LAN as interface 1
LE Client config>
```

Figure 58. Configuring a LAN Emulation Client

The list below shows the LECs created on PC205_8210_MSS and the ELAN name and type they are attached to.

```
PC205_8210_MSS
LE Client config>li all
   ATM Forum Compliant Emulated LANs
-------------------------------------------------------
  Physical ATM interface number = 0
  LEC interface number = 2
  Emulated LAN type    = Ethernet Forum Compliant
  Emulated LAN name    = EN_52
-------------------------------------------------------
  Physical ATM interface number = 0
  LEC interface number = 3
  Emulated LAN type    = Ethernet Forum Compliant
  Emulated LAN name    = EN_205
-------------------------------------------------------
  Physical ATM interface number = 0
  LEC interface number = 4
  Emulated LAN type    = Ethernet Forum Compliant
  Emulated LAN name    = EN_53
-------------------------------------------------------
  Physical ATM interface number = 0
  LEC interface number = 5
  Emulated LAN type    = Ethernet Forum Compliant
  Emulated LAN name    = ETH80-81
-------------------------------------------------------
  Physical ATM interface number = 0
  LEC interface number = 6
  Emulated LAN type    = Ethernet Forum Compliant
  Emulated LAN name    = ETH68
-------------------------------------------------------
  Physical ATM interface number = 0
  LEC interface number = 7
  Emulated LAN type    = Ethernet Forum Compliant
  Emulated LAN name    = ETH69
-------------------------------------------------------
  Physical ATM interface number = 0
  LEC interface number = 8
  Emulated LAN type    = Ethernet Forum Compliant
  Emulated LAN name    = ETH43
No IBM Emulated LANs have been added to ATM interface 0

LE Client config>
```

B.5.2 Configure the Logical Interface

In order to effectively manage these LECs the next step shows how to assign or set the ATM ESI and the MAC address of the LECs.

```
LE Client config>config
Emulated LAN interface number [1]? 1
ATM LAN Emulation Client configuration
Ethernet Forum Compliant LEC Config>set elan-name
Assign emulated LAN name []? elan_???
Ethernet Forum Compliant LEC Config>set mac-address
MAC address [00.00.00.00.00.00]? ##.##.##.##.##.##
Ethernet Forum Compliant LEC Config>set esi-address
Select ESI
   (1) Use burned in ESI
   (2) ##.##.##.##.##.##
   (3) ##.##.##.##.##.##

Enter selection [1]? 2
Selector 0x2 is already in use on this interface
The selector has been changed to 0x3
Ethernet Forum Compliant LEC Config>exit
LE Client config>exit
ATM Config>exit
Config>
```

Figure 59. Setting the ESI and MAC Address on a LEC

Below is an example listing of one of the LECs. Note that it shows the LEC interface number, selector byte, Emulated LAN name, and LE Client MAC address. These will be unique in every LEC instance.

PC205_8210_MSS

```
LE Client config>con
Emulated LAN interface number [1]?2
ATM LAN Emulation Client configuration
Ethernet Forum Compliant LEC Config>list

                 ATM LEC Configuration

   Physical ATM interface number            = 0
   LEC interface number             = 2
   LECS auto configuration          = No

   C1: Primary ATM address
          ESI address               = 41.01.82.10.00.01
          Selector byte             = 0x3
   C2: Emulated LAN type            = Ethernet
   C3: Maximum frame size           = 1516
   C5: Emulated LAN name            = EN_52
   C6: LE Client MAC address        = 20.01.82.10.02.01
   C7: Control timeout              = 120
   C9: LE Server ATM address        = 39.99.99.99.99.99.99.00.00.99.99.01
  C10: Maximum unknown count        = 1
  C11: Maximum unknown time         = 1
  C12: VCC timeout period           = 1200
  C13: Maximum retry count          = 1
  C17: Aging time                   = 300
  C18: Forward delay time           = 15
  C20: LE ARP response time         = 1
  C21: Flush timeout                = 4
  C22: Path switch delay            = 6
  C24: Multicast send VCC type      = Best-Effort
  C25: Multicast send VCC avg rate  = 155000
  C26: Multicast send VCC peak rate = 155000
```

```
  C28: Connection completion timer  = 4

   LE ARP queue depth               = 5
   LE ARP cache size                = 125
   Best effort peak rate            = 155000
   Maximum config retries           = 3
   Packet trace                     = No
   NetWare IPX encapsulation        = ETHERNET_802.3
   IP Encapsulation                 = ETHER

Ethernet Forum Compliant LEC Config>
```

Table 1 shows the configuration parameters for the rest of the LECs.

Table 1. LEC Configuration Parameters

LEC Interface Number	Primary ESI	Selector Byte	ELAN Name	LEC MAC Address
2	41.01.82.10.00.01	0x3	EN_52	20.01.82.10.02.01
3	41.01.82.10.00.01	0x4	EN_205	20.01.82.10.03.01
4	41.01.82.10.00.01	0x7	EN_53	20.01.82.10.04.01
5	41.01.82.10.00.01	0x3	EN_53	20.01.82.10.02.06
6	41.01.82.10.00.03	0x3	ETH68	20.01.82.10.01.03
7	41.01.82.10.00.03	0x5	ETH69	20.01.82.10.02.03

B.5.3 Assign an IP Address to the LEC

For the different subnets in the FIU network to route to each other, IP addresses must be assigned to the LECs configured in the ELANs. Figure 60 shows the command entered on the MSS to configure an IP address on a LEC.

```
Config>protocol ip
Internet protocol user configuration
IP config>add address
Which net is this address for [0]? 1
New address [0.0.0.0]? ###.###.###.###
Address mask [255.255.0.0]? ###.###.###.###
IP config>exit
Config>
```

Figure 60. Configuring an IP Address on a LEC

The listing below shows the IP addresses used on the LECs in the FIU network.

```
Config>pro ip
Internet protocol user configuration
IP config>li all
Interface addresses
IP addresses for each interface:
   intf  0   131.94.4.1       255.255.255.0    Local wire broadcast, fill
   intf  1                                         IP disabled on this in
   intf  2   x.x.52.1      255.255.255.0    Local wire broadcast, fill
   intf  3   x.x.205.1     255.255.255.0    Local wire broadcast, fill
   intf  4   x.x.53.1      255.255.255.0    Local wire broadcast, fill
   intf  5   x.x.80.1      255.255.255.0    Local wire broadcast, fill
             x.x.81.1      255.255.255.0    Local wire broadcast, fill
```

```
intf  6   x.x.68.1      255.255.255.0    Local wire broadcast, fill
intf  7   x.x.69.1      255.255.255.0    Local wire broadcast, fill
intf  8   x.x.43.10     255.255.255.0    Local wire broadcast, fill
```

B.5.4 Configure the PDGW (IP, MAC Address and Primary/Backup)

Normally the LECs would point to one of the IP addresses in the last section as their default gateway. In order to provide backup and redundancy the MSS is configured for redundant default gateways. Figure 61 shows the command to enable the redundant gateway function.

```
IP config> add redundant default gateway
Which net is this Redundant Gateway for [0]? 3
IP address of Gateway [0.0.0.0]? ###.###.###.###
Address mask [255.255.0.0]? ###.###.###.###
MAC address [00.00.00.00.00.00]? ##.##.##.##.##
Is this the Primary Gateway? [No]: yes
IP config>
```

Figure 61. Configuring a Redundant IP Gateway

Appendix C. Configuration Steps for the 8274

This section gives the configuration commands necessary to configure the 8274 as used in the FIU network.

There are two groups defined on the 8274 Route Switch: the default group (group 1) and the CIP management group (group 2). All Ethernet ports are members of group 1. The LANE service defined on port 4.1 (virtual port #15) is also a member of group 1. This is to enable routing between the legacy LAN and the ATM network.

Group 2 is used for management via CIP. Group 2 can be added using the crgrp command under /VLAN. The IP address for group 2 can be configured using modvl under the /VLAN menu. Typing gp under the /VLAN menu will display the following:

```
/VLAN$APC-21>gp
Group                                 Network Address  Proto/
 ID         Group Description        (IP Subnet Mask)  Encaps
(:VLAN ID)                           or (IPX Node Addr)
===== ============================== =============== ========
    1 Default GROUP (#1)
    2 CIP Management Group           131.94.x.x        CIP /
                                          (ff.ff.ff.00)   1483
```

Figure 62. Group Descriptions

The CIP service defined on port 4.1 (virtual port #14) is the only member of group 2. This defines the CIP client. Services can be added using the cas (create a service) command under the /Interface/ATM menu. To verify the ATM LEC configuration, use the vas (view a service) command under the /Services menu. Figure 63 on page 114 shows the ATM services enabled on the 8274.

```
/Services$APC-21>vas
                          ATM Services

         Serv           Service             Service
Slot Port Num          Description            Type
==== ==== ==== ============================ =========
4    1    1    PTOP Bridging Service 1      PTOP Priv
4    1    2    Classical IP Service 2       CIP
4    1    3    LAN Emulation Service 3      LANE

                          ATM Services

          Serv VC    Oper

Slot Port Num  Typ  Status  SEL Groups      Conn VCI's/Addresses
==== ==== ==== === ======== === =========== ====================
4    1    1    PVC Enabled  N/A 1           100
4    1    2    SVC Enabled   02 2           4
4    1    3    SVC LANE Op.  03 1           303  304  305  306
                                           104
FDDI Services do not exist!
Frame-Relay Table empty !!
```

Figure 63. 8274 ATM Services

The ATM interface is configured as follows (Connection Type = SVC). The map (modify a port) command under the/Interface/ATM menu will allow the ATM port to be configured. To verify the ATM configuration use the vap command under the /Interface/ATM menu as shown in Figure 64.

```
/Interface/ATM$APC-21>vap
                         ATM Port Table
                                         Conn Tran   Media UNI Max  VCI
Slot Port      ATM Port Description      Type Type   Type  Typ VCC  bits
==== ==== ============================ ==== ====== ===== === ==== ====
4    1    ATM PORT                       SVC  STS3c  Multi Pri 1023 10
Slot Port Loopback Cfg Tx Clk Source
==== ==== ============ ============
4    1    NoLoop       LocalTiming
                                      End System   Sig Sig  ILMI   ILMI
Slot Port     ATM Network Prefix      Identifier   Ver VCI  Enable VCI
==== ==== ==========================  ============ === ==== ====== ====
4    1    39999999999999000099990119  0020da74e610 3.0 5    True   16
                                                        Status
                                                  -------------------
slot Port Tx Seg Sz Rx Seg Sz Tx Buff Sz Rx Buff Sz   Oper   SSCOP ILMI
==== ==== ========= ========= ========== ========== ======== ===== ====
4    1         8192      8192       4600       4600 Enabled   Up    Up
```

Figure 64. Viewing the ATM Port

To enable bridging between the all the other ports and the ATM network, the ATM port (port 4.1 (virtual port #15)) must be added group 1. The command addvp under the/VLAN menu will do this. Group assignment verification can be viewed using the via command under the /VLAN menu as shown in Figure 65 on page 115.

```
/VLAN$APC-21>via
                   GROUP Interface Attachments For All Interfaces
GROUP:                                       Service/                     Admin
Slot/Intf          Description               Instance          Protocol   Status
========== ================================ ============   ============ =======
    2.1 :* Management net via CIP           Rtr     /  1   CIP          Enabled
    1:3/1  Virtual port (#1)                Brg     /  1    Tns         Enabled
    1:3/2  Virtual port (#2)                Brg     /  1    Tns         Enabled
    1:3/3  Virtual port (#3)                Brg     /  1    Tns         Enabled
    1:3/4  Virtual port (#4)                Brg     /  1    Tns         Enabled
    1:3/5  Virtual port (#5)                Brg     /  1    Tns         Enabled
    1:3/6  Virtual port (#6)                Brg     /  1    Tns         Enabled
    1:3/7  Virtual port (#7)                Brg     /  1    Tns         Enabled
    1:3/8  Virtual port (#8)                Brg     /  1    Tns         Enabled
    1:3/9  Virtual port (#9)                Brg     /  1    Tns         Enabled
    1:3/10 Virtual port (#10)               Brg     /  1    Tns         Enabled
    1:3/11 Virtual port (#11)               Brg     /  1    Tns         Enabled
    1:3/12 Virtual port (#12)               Brg     /  1    Tns         Enabled
    1:4/1  Virtual port (#13)               Brg     /  1    Tns         Enabled
    1:4/1  Virtual port (#15)               Lne     /  1    Tns         Enabled
    2:4/1  Virtual port (#14)               CIP     /  1    Tns         Enabled
    1:5/1  Virtual port (#16)               Brg     /  1    Tns         Enabled
    1:5/2  Virtual port (#17)               Brg     /  1    Tns         Enabled
    1:6/1  Virtual port (#18)               Brg     /  1    Tns         Enabled
    1:6/2  Virtual port (#19)               Brg     /  1    Tns         Enabled
    1:7/1  Virtual port (#20)               Brg     /  1    Tns         Disabld
    1:7/2  Virtual port (#21)               Brg     /  1    Tns         Enabled
    1:8/1  Virtual port (#22)               Brg     /  1    Tns         Enabled
    1:8/2  Virtual port (#23)               Brg     /  1    Tns         Disabld
    1:9/1  Virtual port (#24)               Brg     /  1    Tns         Enabled
    1:9/2  Virtual port (#25)               Brg     /  1    Tns         Disabld
/VLAN$APC-21>
```

Figure 65. Viewing the Group Interfaces

Appendix D. Special Notices

This publication is intended to help customers, system engineers, service specialists and marketing specialists understand the issues involved during the design and implementation of a Campus ATM network. The information in this publication is not intended as the specification of any programming interfaces that are provided by the ATM products refered to in this redbook. See the PUBLICATIONS section of the IBM Programming Announcement for the various ATM products for more information about what publications are considered to be product documentation.

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Appendix E. Related Publications

The publications listed in this section are considered particularly suitable for a more detailed discussion of the topics covered in this redbook.

E.1 International Technical Support Organization Publications

For information on ordering these ITSO publications see "How to Get ITSO Redbooks" on page 121.

- *Understanding and Using the MSS Server Release 1.0*, SG24-4915
- *Understanding and Using MSS Release 1.1 and 2.0,*, SG24-2115
- *IBM ATM Workgroup Solutions: Implementing the 8285*, SG24-4817
- *Asynchronous Transfer Mode (ATM) Technical Overview*, SG24-4625
- *Campus ATM Design Guidelines*, SG24-5002
- *8260 ATM Product Architecture*, SG24-2110
- *IBM Nways RouteSwitch Implementation Guide*, SG24-4881

E.2 Redbooks on CD-ROMs

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Application Development Redbooks Collection	SBOF-7290	SK2T-8037

E.3 Other Publications

These publications are also relevant as further information sources:

- *IBM PNNI Control Point (Switched Network Services) White paper*
- *Advantages of Muliprotocol Switched Services White paper*
- *Switched Virtual Networking White paper*
- *ATM positioning in the LAN environment*

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