MULTI-AREA DATA COMMUNICATION NETWORK DESIGN (DCN) FOR MANAGING TELECOMMUNICATIONS' SYNCHRONOUS DIGITAL HEIRARCHY (SDH) NETWORK ELEMENTS

EBENEBE, CHIKA FELICITAS

M.ENG./SEET/2006/1519

DEPARTMENT OF ELECTRICAL & COMPUTER ENGINEERING,

FEDERAL UNIVERSITY OF TECHNOLOGY MINNA,

NIGER STATE.

JANUARY, 2011

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DECLARATION

I, **EBENEBE CHIKA FELICITAS**, hereby declare that this work titled **Multi- Area Data Communication Network Design for Managing Tele-communications' SDH Network Elements,** was done by me in partial fulfillment of the requirements for the award of M.Eng in Communication Engineering in the department of Electrical and Computer Engineering, Federal University of Technology, Minna.

10/4/11

Ebenebe Chika Felicitas

Signature & Date

CERTIFICATION

This thesis titled Multi-Area Data Communication Network Design for Managing Telecommunications' SDH Network Elements by Ebenebe Chika Felicitas (M.Eng/SEET/2006/2010) meets the regulations governing the award of the degree of M.Eng of the Federal university of Technology, Minna and is approved for its contribution to scientific knowledge and literary presentation.

12/4/2011
Signature &Date

Engr. Dr. Y.A Adediran
Supervisor

April 12, 2011
Signature &Date

Engr. A.G. Raji
Head of Department
Electrical and Computer Engineering

3/5/11
Signature &Date

Engr. Prof. M. S Abolarin
Dean SEET

Signature &Date 1/8/2011

Prof. (Mrs.) S. N. Zubairu
Dean Postgraduate School

DEDICATION

This project is dedicated to my entire family.

ACKNOWLEDGEMENTS

To God be the glory that this project work came to a reality. I owe a lot of gratitude to my family, who has been very supportive during this program.

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I cannot forget the endless prayers and love of my lovely husband: Tom Best and children: Felicitas, Henry and Claire who went through the program with me. Also to my dearest mother: Ezeh Victoria, I say I love and appreciate you. You are always there for me.

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ABSTRACT

In order to find out the best possible way to manage the Synchronous Digital Hierarchy (SDH) Network Elements (NEs) and withstand frequent link failures among SDH vendors, surveys were conducted to determine which is the most protection standard. The standard, that in the event of failure along the primary (active) path, all the NEs (Network Elements) in the region can still be managed through the secondary (resilience) path. The survey reveals that IN BAND which utilizes the same backbone bandwidth, on which the vendor traffic is also present, is the most vulnerable. A separate bandwidth independent of the vendor's traffic route can be provided by the vendor or leased from a third party to assemble the OUT OF BAND DCN solution. Frequent site isolation scenarios where both east and west directions are lost, OUT OF BAND management, which is the creation of the resilience path, would still permit full access to each NE on the extraneous DCN and this allows full fault diagnosis, alarm reporting and reduction of operational cost.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

ABBREVIATIONS

ACSE:	Association Control Service Element
AD	Adaptation Device
AE	Application Entity
AE DCF	Automatic Encapsulating Data Communication Function
AP	Application Process
ARP	Address Resolution Protocol
ASON	Automatic Switched Optical Network
ASTN	Automatic Switched Transport Network
ATM	Asynchronous Transfer Mode
BIS	Boundary Intermediate System
LSR	Bidirectional Line Switched Ring
allC	Call Controller
C	Connection Controller
CCI	Connection Controller Interface
CIT	Craft Interface Terminal
CLNP	ConnectionLess Network layer Protocol
LNS	ConnectionLess Network layer Service
MISE	Common Management Information Service Element

CMISE	Common Management Information Service Element
CO	Central Office
COMMS OH	General Management Communications Overhead
DAP	Directory Access Protocol
DCC	Data Communication Channel
DCE	Data Communications Equipment
DCN	Data Communications Network
DF	Don't Fragment
DIB	Directory Information Base
DIT	Directory Information Tree
DN	Distinguished Name
DSA	Directory System Agent
DS-n	Digital Signal
DUA	Directory User Agent
ECC	Embedded Control Channel
ECC	Embedded Control Channel
EMF	Equipment Management Function
EMS	Element Management System
ES	End System
ES-IS	End System to Intermediate System protocol

ES	End System
ESH	End System Hello (ISO 9542)
FTAM	File Transfer Access and Management
FTP	File Transfer Protocol
GCC	General Communication Channel
GNE	Gateway Network Element
GRE	Generic Routing Encapsulation
HDLC	High Level Data Link Control
ICMP	Internet Control Message Protocol
ID	Identifier
IDRP	Inter
IEEE	Institute of Electrical and Electronic Engineers
In-IS	Integrated Intermediate System
IP	Internet Protocol
IPCP	Internet Protocol Control Protocol
IPv4	Internet Protocol Version 4
IPv6	Internet Protocol Version 6
IS	Intermediate System
IS-IS	Intermediate System to Intermediate System protocol
ISDN	Integrated Services Digital Network

ISH	Intermediate System Hello (ISO 9542)
ISO	International Organization for Standardization
IWF	Interworking Function
Kbps	Kilo
L1	Level 1 Routing
L2	Level 2 Routing
LAN	Local Area Network
LAPB	Link Access Procedure Balanced
LAPD	Link Access Procedure for the D channel
LCN	Local Communication Network
LDAP	Lightweight Directory Access Protocol
LLC	Logical Link Control
LNC	Local Naming Context
LSDB	Link State Data Base
LSP	Link State PDU
LSP	Link State Protocol Data Unit
MAC	Media Access Control
Mbps	Mega
MCF	Message Communication Function
MCN	Management Communication Network

MD	Mediation Device
MTU	Maximum Transmission Unit
NARSE	Network Address Resolution Service Element
NE	Network Element
NEF	Network Element Function
NEM	Network Element Manager
NET	Network Entity Title
NIST	National Institute of Standards and Technology
NLPID	Network Layer Protocol Identifier
NLR	Network Layer Relay
NMS	Network Management System
NOC	Network Operation Centre
NPDU	Network Protocol Data Unit
NSAP	Network Service Access Point
OAM	Operations, Administration and Maintenance
ODUk	Optical Channel Data Unit
OOS	OTM Overhead Signal
OS	Operations System
OSC	Optical Supervisory Channel
OSI	Open Systems Interconnect

OSIE	Open Systems Interconnect Environment
OSINLCP	OSI Network Layer Control Protocol
OSPF	Open Shortest Path First
OSS	Operations Support System
OTM	Optical Transport Module
OTN	Optical Transport Network
OTUk	Optical Channel Transport Unit
PDIS	Partition Designated Intermediate System
PDU	Protocol Data Unit
PPP	Point
PS	Packet Switch
PVC	Permanent Virtual Circuit
RA	Registration Agent
RBOC	Regional Bell Operating Company
RDN	Relative Distinguished Name
RFC	Request For Comment
RM	Registration Manager
SCN	Signalling Communication Network
SDCC	Section Data Communications Channel
SDH	Synchronous Digital Hierarchy

SDS	SONET Directory Service
SID	System Identifier
SIF	SONET Interoperability Forum
SNCr	SubNetwork Controller
SNDCF	SubNetwork Dependent Convergence Functions
SONET	Synchronous Optical NETwork
SP	Segmentation Permitted
SPF	Shortest Path First
SVC	Switched Virtual Circuit
T5 NE	with a TARP processor and a DUA+RA function reserved to its own use
T5GW	System having a TARP processor and a DUA+RA function and capable of acting on behalf of TARP NEs
TARP	TID Address Resolution Protocol
TCP	Transmission Control Protocol
TDM	Time Division Multiplexing
Telco	Telecommunications Company
TF	Translation Function
TID	Target IDentifier
TLV	Type Length Value
TMN	Telecommunication Management Network

TNE	Transport Network Element
TPDU	Transport Protocol Data Unit
TPn	Transport Protocol type n=0..4
UL	Upper Layers
UNI	User
UPSR	Unidirectional Path Switched Ring
WAN	Wide Area Network
WS	Work Station
WSF	Work Station Function
xMS X	Management Subnetwork

CHAPTER ONE

1.0 INTRODUCTION

1.1 Data Communications

Data Communications is therefore the transfer of data or information between a source and a receiver. In other words, it is the exchange of data (in form of 0s and 1s) between two devices via some form of transmission *medium*. Data Communication is interested in the transfer of data, the method of transfer and the preservation of the data during the transfer process. As shown in Figure 1.1, a data communication system comprises a source, medium and the destination or receiver.

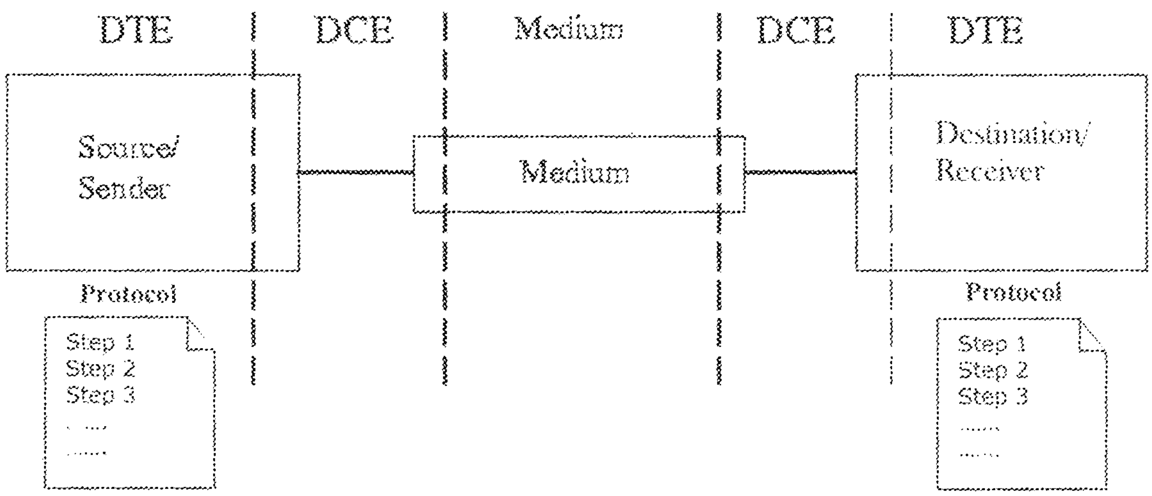


Figure 1.1: Data Communication Components

The Source/Sender transmits data. Examples include computers, synchronous transport modules level N (STM-N), Base Transceiver Station (BTS).

The Medium is the communications stream through which the data is being transmitted. Examples include Microwave, Fiber Optic Line, and Infra-red.

The Destination is the receiver of the data transmitted. Examples include printers, STM-N, Computers, Fax Machines, GSM handsets, BTS

DCE (Data Communication Equipment) is the interface between the Source and the Medium, and also between the Medium and the Destination. It is a physical piece of equipment. Examples are cables.

DTE (Data Terminal Equipment) is the Telecommunication name given to the Source and Receiver's equipment.

The purpose of Data Communications is to provide the rules and regulations that allow the source and destination to share resources irrespective of location and platform. These rules and regulations are called protocols and standards.

The effectiveness of a data communication system depends on three fundamental characteristics:

1. **Delivery**: The system must deliver data to the correct destination. Data must be received by the intended device or user and only by that device or user.
2. **Accuracy**: The system must deliver data accurately. Data that have been altered in the transmission and left uncorrected are unusable.
3. **Timeliness**: The system must deliver data in timely manner. Data delivered late are useless.

1.2 Data Communications Network (DCN)

Data Communications Network (DCN) is the network deployed by a telecommunication company (Telco) or service provider that contain all the cabling, network management (NM) stations, switches, network elements and other necessary equipment for delivering and managing services to the service providers' customers.

DCN represents an implementation of Open System Interconnect (OSI) layers 1 to 3, which may include any relevant International Telecommunications Union Telecommunications sector (ITU-T) or International Standard Organization (ISO) standards for layers 1 to 3. The DCN is therefore responsible for providing compatible communication at the network layer (Layer 3), data-link layer (Layer 2), and physical layer (Layer 1) of the OSI model as shown in Fig 1.2. DCN is aware of Layer 1, Layer 2, and Layer 3 protocols and is transparent to upper-layer protocols used by the applications for which it transports.

DCN provides Layer 1, Layer 2 and Layer 3 functionalities and, therefore, consists of routing/switching functionality interconnected via links. These links can be implemented over various interfaces, including Wide Area Network (WAN) interfaces (E1 Controller interface), Local Area Network (LAN) interfaces (Ethernet interface), and Embedded Control Channels (ECCs).

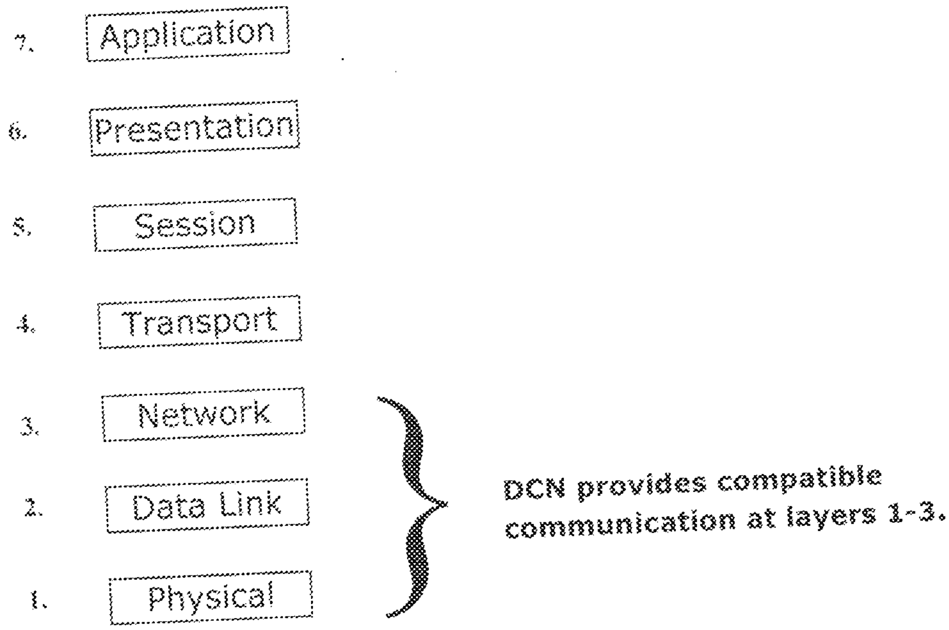


Figure 1.2: OSI Model and DCN functional layers.

In addition to providing compatible communication at physical, data-link and network layers, other DCN functionalities include quality of service, information transfer rate, and diversity of routing to support specific operational requirements of the distributed communications supported across the DCN. As will be discussed later, DCN provides the link between the service network (the network element) and the Network Management System (NMS). The network elements can be located at the customer premises, whereas the NMS can be located at the provider's Network Operations Center (NOC).

1.3 Data Communications Network Management

Data Communications Network Management enables telecommunications companies to achieve the following functions from their respective NOCs:

- Creation of the complete network view;
- Creation of dedicated paths through the network to support the QoS demands of end users;

• Modification of routing tables;

• Monitoring of link utilization;

• Optimizing network performance;

• Detection of faults;

• Updating of firmware.

Using the right protocols, DCN also helps management network operators in planning, provisioning, installing, maintaining, operating, and administering telecommunications networks and services.

1.4 Multi Area feature: Cisco release 12.x(y)T

Designing a Data Communication Network with many OSI areas implies having many L2 IS that are capable of routing data between different areas, at least one L2 IS per area is needed. With routers, it is recommended to assign them the L2 routing capability. With the new Cisco software it is possible to have the architecture depicted in Figure 1.3. In this case, the router is equipped with several interfaces acting as L1 IS in different areas and it is configured as a unique L2 IS for all of its interfaces. This reduces the number of routers.

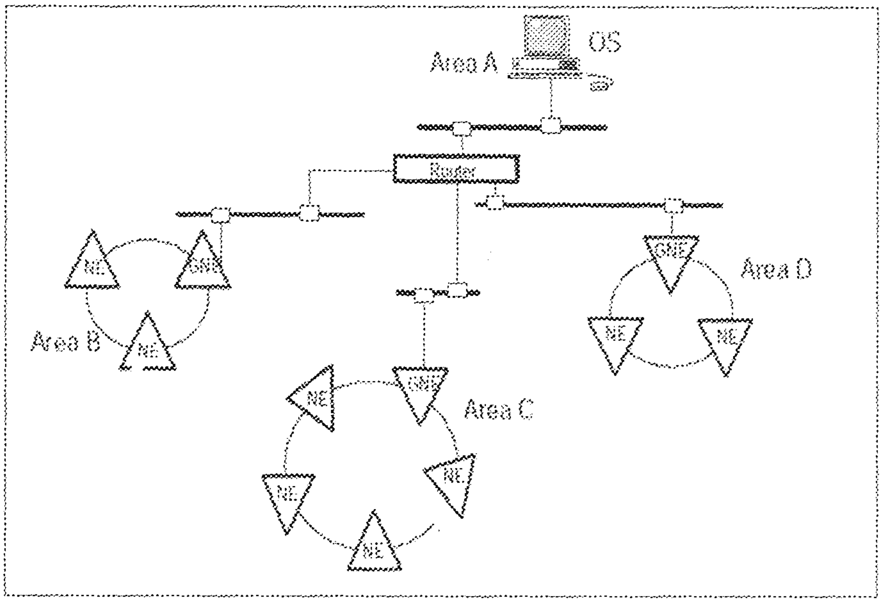


Figure 1.3: Router implementing the concept of Multi-Area

1.5. DCN Configuration Examples with Associated Problems

Example 1

Figure 1.4 shows an example on how to configure a network composed of two rings of ADMs. Configuration 1 of the figure is based on splitting of the network into 3 areas. This configuration is working but it is characterized by a single point of failure because if either Gateway Network Element (GNE) A or G fails, then the whole subtended ring will be unreachable by the OS.

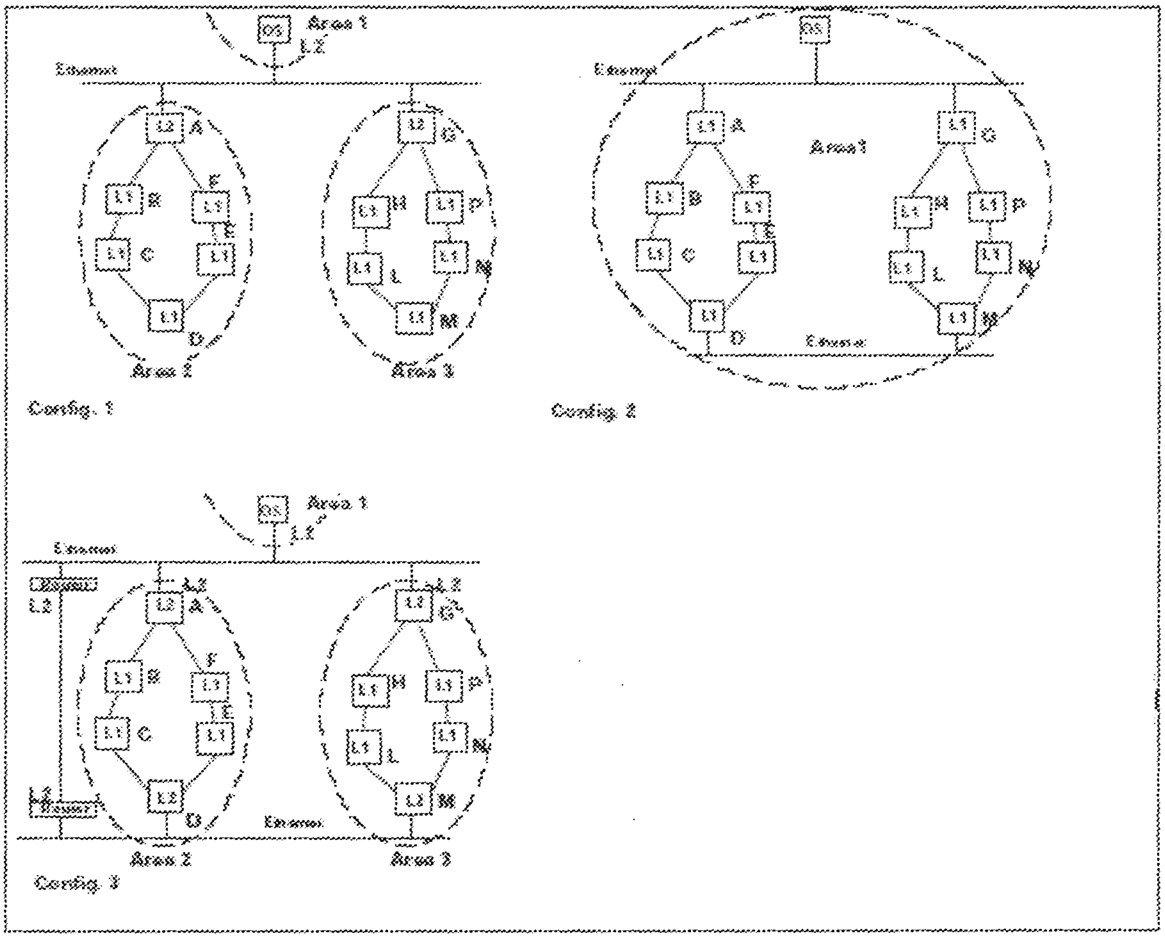


Figure 1.4: Simple Network Configuration Examples.

Configuration 2 aims at introducing the "double GNE" feature in the network. This is based on the fact that the number of NEs in the network is small enough to have only one area. In this topology, if GNE A fails, then the packets addressed to the ring subtended to GNE A will be reachable by passing through GNE G and its ring. However, this configuration has its associated problem - the load, in terms of packets per second, which charges the remaining GNE (GNE G in the example). This configuration could be completed by adding a router-to-router connection between the two LANs: goal of this connection is to unload the GNEs from part of the traffic, since half of the traffic will flow through the direct router-to-router link. Globacom Nigeria, for instance, uses configuration 2 at the moment.

Configuration 3 is supposed to provide the "double GNE" feature in the network while keeping two different areas. The router is absolutely mandatory in order to keep connected the Level 2 backbone. This solution, despite working under normal conditions, presents a single point of failure represented by the link interconnecting the two routers, or any of the two routers. If this link fails, then the level 2 backbone is partitioned and the lower part of the network (Network Elements C, E, D, L, N and M in the example) won't be reachable any more by the NMS!

Example 2

Figure 1.5 shows an example on how an operator may try to obtain a more reliable Telecommunication Management Network (TMN). However while doing so, he obtains an improper configuration. The two Add-Drop Multiplexer (ADM) rings with their gateway NEs are attached to the same 802.3 LAN. ADM rings are configured as two different areas. In addition, to increase reliability, the rings are connected through a DCC channel on an existing Synchronous Transport Module (STM) link between nodes D and M (DL2 link). Moreover, to further increase reliability and reduce path lengths, nodes A and D are interconnected via additional X.25 link (link DL1).

Now, assume that the X.25 link fails. This causes the partition of the level 2 backbone and the impossibility to exchange L2 PDUs between the partitioned L2 backbone composed of nodes D and M and the L2 backbone composed of nodes A and G. In such situation, even though it may seem at a first sight that the connectivity between the NMS and the NEs is guaranteed, due to the IS-IS mechanism, Network Elements C, D, E, L, N and M cannot reach the NMS anymore. These NEs refer to the nearest L2 ISs (that is the NEs D and M) to route management packets towards the NMS, but these L2 ISs have no knowledge on how to reach the routing subdomain of the OS. Therefore, all packets addressed to the NMS will get lost!

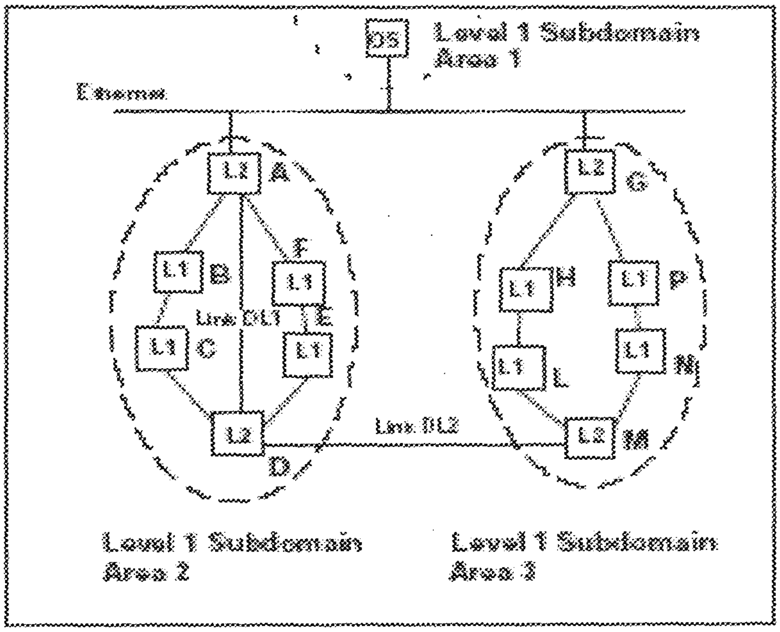


Figure 1.5: A Badly Configured Network

A right design for this network would require either the introduction of an additional link in order to avoid the partition of the level 2 backbone as a consequence of a single link failure (e.g. link between NEs M and G), or merging the level 1 subdomains into one, or disabling of the DCC channel on the STM DL2 link and configuring M as L1.

As a second scenario which can be examined on the same topology let us consider a failure of the DL2 link. Due to the fact that NE M is not connected to any outside routing subdomain anymore, it loses its role of the "reference L2 IS" for its subdomain. Therefore, all the NEs of the second ring would still be able to talk to the NMS referring to the NE G as the reference L2 IS. The same applies in case of a simultaneous failure of links DL1 and DL2.

It can therefore be concluded that particular care must be taken in order to avoid a situation in which a single link failure generates a partition into subdomains which are composed of two or more L2 ISs belonging to two or more separate level 1 subdomains.

Example 3

Consider the topology depicted in Figure 1.6. Assume the SDH ring to be too large to be configured as only one area for either IS-IS or performance reasons. The need therefore arises to split the transmission ring into several logical DCN rings making use of extra equipment (routers or bridges). Moreover assume NEs 1 and 38 to be co-located in the same station where the NMS is.

For example, the SDH ring can be split into two areas (Areas 1 and 2) and another area allocated for the Operations System (OS). In such a topology the area boundary NEs (1, 17, 18 and 38) shall be interconnected by a Level 2 backbone either using bridges or routers.

First, consider the use of routers to create DCN logical rings. The first ring is identified by NEs 1 to 17 and by routers B and C, all pertaining to the same area (Area 2). The second ring is identified by NEs 18 to 38 and by routers A and D all pertaining to the same area (Area 1). Let all the NEs be configured as L1 ISs and then disable DCC channels between NEs 1-38 and 17-18.

Interconnect the routers using a 2 Mbps (E1) link hopefully derived from the same SDH ring. The level 2 backbone is composed from all the routers and is intrinsically protected by its ring topology. Such a DCN topology is protected against every kind of single failure within the network.

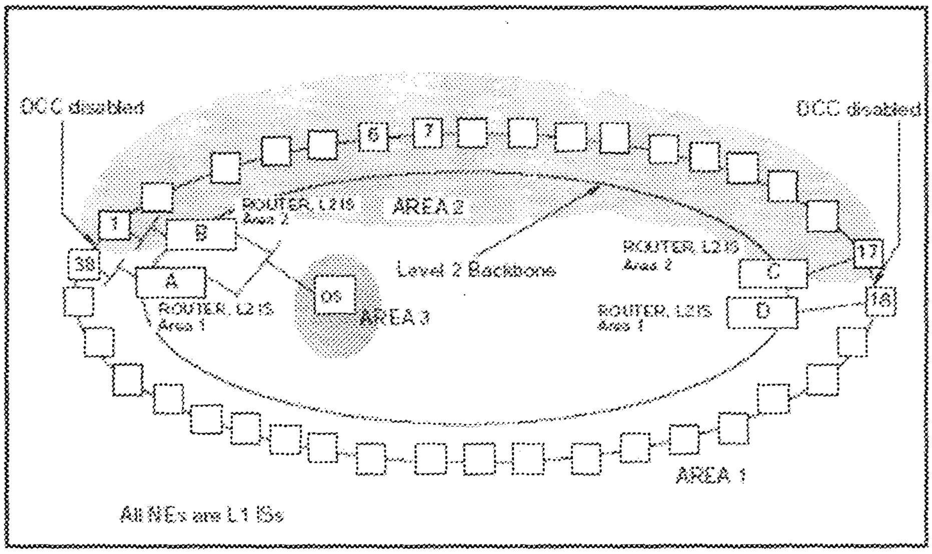


Figure 1.6: Partitioning of large SDH network into smaller Logical DCN ring using routers.

Consider the following possible network failures:

- The link between NE 6 and NE 7 fails.

  Then the messages addressed to NEs from 7 to 17 go through router B and C (which pertain to area 2 and therefore know the internal routing of this area)

- Router A fails.

  Then the messages addressed to NEs from 18 to 38 go through router B, C and D and then enter the SDH DCN network through NE 18.

- Router C fails.

  1. The NEs pertaining to area 2 do not recognize the router D as a possible reference L2 system and they refer to only router B reconfiguring the ring in a linear topology.

- Links connecting router C to B and C to D fail.

  The NEs pertaining to area 2 do not recognize the router C as a possible reference L2 system (because it is not connected to other areas anymore) and they refer to only router B reconfiguring the ring in a linear topology.

1.6 Statement of the Problem

The example illustrated by Figure 1.7 deals with a generic architecture suitable to design a multi-area DCN network. The idea is to build a level 2 backbone redundant to a single failure, and to organize the different areas in such a way that each area has two, or more, different L2 ISs and GNEs. Care is taken to avoid having too many NEs behind the same GNE. This structure is depicted in the config 1 of Figure 1.7. The Network Elements indicated in the picture are actually routers configured as L2 ISs. All the NEs, except routers, are configured as L1 ISs.

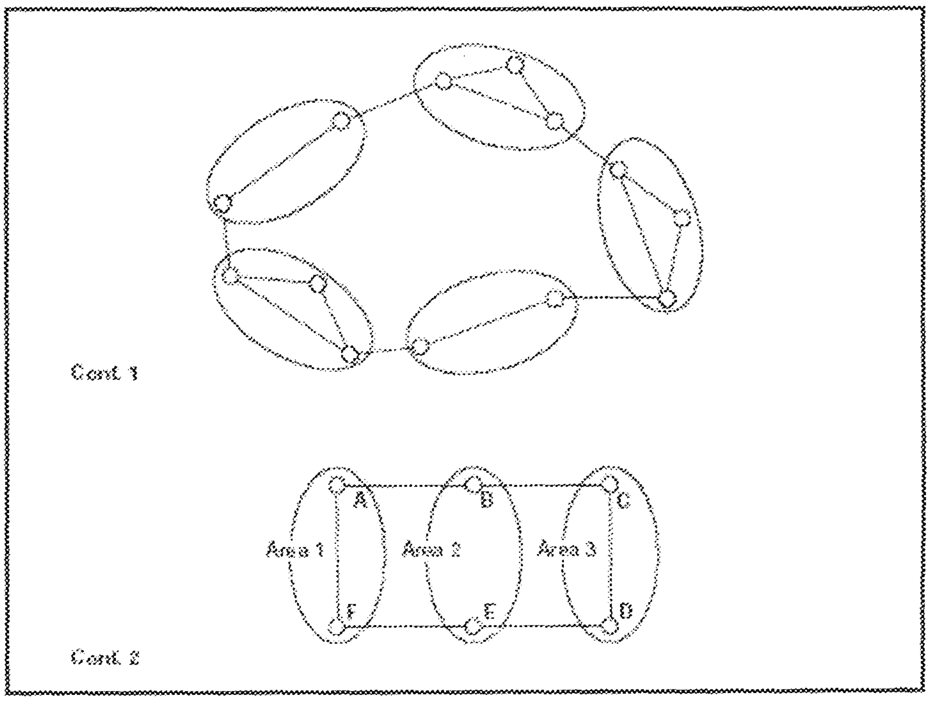


Figure 1.7: Generic architecture for multi-area network

The failure of any inter-area connection is recovered by the L2 backbone ring structure. Any failure of a router within an area is recovered by the other router(s) of the same area. The idea of having more than two routers within the same area is justified by the fact that, in case of failure of either one router or one GNE, the total traffic load will be handled by the remaining entry points. Having only one access point to the area could over-charge the GNE.

It is worth noting that Config 2 of Figure 1.7 is not really optimized. Actually, during the normal working condition (that is in presence of no failures in the network) the network is working properly. Suppose now that Area 2 is based on a linear SDH structure and that a failure occurs between B and E. Then, Area 2 will be partitioned into two subdomains. The NMS, wherever it is located, will be able to reach only partially the Area 2, up to the failed link exactly. To avoid such condition, it is necessary to connect routers B and E via an external point-to-point link. Conclusion of this mis-configured network is that L2 ISs pertaining to the same area shall always be directly connected to each other.

As SDH rings grow in size and number, the service provider needs to deploy higher bandwidth and more scalable Data Communications Networks to manage SDH network elements. The challenge is to provide this support over a common infrastructure and create a seamless network of networks that can manage the network through a single Data Communications Network utility. This work shall focus on the design of such a utility that will provide the required SDH management platform capable of withstanding failures.

The design presented in this write up, is aimed at helping Telcos avoid such loop-holes in the design of their DCN architecture, thus guiding them to:

- properly connect their SDH network elements to a router-based network using the Open System Interconnection (OSI) protocol:
- have a simplified Data Communications Network that reduces equipment costs;
- implement resilience network that will help them manage their network even in the event of failure of an NE or link;
- scale their network without imparting service.

1.7 Objectives

This project shall:

1. Describe Data Communications Network components and routing method to be used.

2. Identify reference architectures, including points of interface with the LAN and DCC portions of the Data Communications Network.

3. Provide guidelines for Data Communications Network design and router placement, as well as describe the interaction between WAN OSI routers, the DCC, and LAN routers.

4. Provide guidelines for routing area management, including guidelines for assigning OSI routing areas and OSI routing domains.

5. Assess the need for OSI inter-domain routing; and define requirements for the use of the OSI inter-domain routing protocol in SDH NEs and stand-alone routers.

6. Provide guidelines for Data Communications Network parameter provisioning.

1.8 Scope of the Project

Data Communications Network (DCN) is the network deployed by Telephone Companies (Telcos) that contain all the cabling, network management (NM) stations, switches, routers, network elements and other necessary equipment for delivering and managing services to the Telco's customers. The DCN is an out-of-band network, and it does not transit the same bandwidth segment used by services such as voice and its associated in-band signaling. It does, however, share the same transport equipment and interfaces with switching equipment.

SDH has become the transport technology of choice for Telecommunication companies, like Globacom, MTN, ZAIN and other carriers to meet the demand for bandwidth and new services. The growth of SDH and the increasing demands for both existing time-division multiplexing (TDM) and new packet-based data services necessitates better and more scalable DCNs for network operations and management connectivity between network elements and their respective OSSs. As SDH rings grow in both size and number, the service provider needs to deploy higher bandwidth and more scalable DCN network\s to manage SDH network elements. DCN transports network management traffic between network elements and their respective OSS, making them a vital link between the service network and the network operations center (NOC).

This project shall focus on designing architecture for scaling the OSI DCN. It shall describe Cisco network solutions for transporting data between Synchronous Digital Hierarchy

(SDH) and the Operations Support System (OSS) in a data communications network (DCN).

The solution presented in this work will help any telecommunication company connect their SDH network elements to a router- based network using the Open System Interconnection (OSI) protocol, which simplifies the DCN and reduces equipment costs. Multiple OSI/IS-IS area support per router - allows multiple level-1 areas (such as Areas *0066*, *0070*, *0074*, and *0078* shown in figure 4.2), to be supported in a single router. Here, multiple IS-IS instances are defined, each with a separate area address. Individual interfaces on the router are then assigned to different instances (level-1 areas). A single Level 2 area continues to exist to provide access to the backbone. The router provides connectivity between level-1 areas local to the router. This feature replaces several routers with one and saves central office space and reduces cost for the Telco.

This project recommends the use of OSI-based protocol for the SDH network elements' ring network management. Our challenge in this project is to provide this management support over a common infrastructure and create a seamless network of networks that can manage the network through a single DCN utility – against failures.

The DCN shall be designed by segmenting the network into regions and regions into autonomous systems called areas. The DCN shall in this case, provide the link between the service network and the Network Operations Center, thus enabling the surveillance and the status of the support network. It shall also support Operations, Administration, Maintenance and Provisioning (OAM&P) functions.

The entire SDH Data Communications Network (DCC, LAN and WAN) shall be included in this work. The scope of protocols to be considered for the DCC and LAN is limited to the OSI protocols.

This work shall present the recommended Cisco architecture for building the OSI network. The method of implementing and scaling an OSI network shall be included with configuration examples. Specific Cisco IOS software features such as Intermediate System-to-Intermediate System (IS-IS), multi-areas and VLAN support for International Standards Organization Connectionless Network Service (ISO CLNS) shall be described. However, because of the unavailability of the right simulation software that has the E1 (WAN) interface features, this design couldn't be simulated using Cisco simulation engine, but was rather tested on a live network.

Furthermore, the resilience shall be discussed and applied to backup the primary links against failures. The management of the SDH NEs shall take place at the NMS terminal at the NOC. However, configuration of the NMS servers and terminals are outside the scope of this project.

Note: in this project, when nothing is specified the word NE refers to ADMs, WDMs, and SDH Radio equipments.

1.9 Methodology

For clarity, the network model shall be built on the Nigerian geographical map. The Telecommunication DCN shall be designed by segmenting the network into regions, and regions into autonomous systems called areas within the boundaries of the Nigerian map, touching the cities and villages.

For simplicity and time, this work shall focus on only one region, the Port Harcourt (PHC) region. This PHC region model shall be a template to implement DCN across all other regions.

To illustrate resilience, a design without ideal protection shall be presented. Then another design with protection shall be illustrated. The difference shall be compared by inducing failures at some points in the network, and then observe the recovery through the secondary path.

The designed DCN shall provide the link between the service network and the Network Operations Centre (NOC), to enable the surveillance and the monitoring of the status of the network. It shall also support Operations, Administration, Maintenance, and Provisioning (OAM&P) functions.

CHAPTER TWO

2.0 LITERATURE REVIEW

The importance of DCN management in SDH network cannot be over-emphasized. To achieve quality service delivery, increasing number of Telecommunicatio ns are deploying DCN, using the OSI protocol, to manage their SDH networks. With the right infrastructure and protocol, DCN quality criteria can be realized!

Forouzan (1998), shares with this idea when he stated that a Data Communications Network must meet performance, reliability and security criteria before being considered efficient and effective. In addition to scalability which drives a robust DCN, Cisco (2007) stated the following factors which underscore Telcos' need for DCN:

a. The use of IP and OSI-based intranets within the central office to facilitate communication between network elements and management stations is increasing.
b. "Intelligent" (feature-rich) network elements are requiring more frequent software version updates than their less feature-rich predecessors.
c. Software downloads to intelligent network elements across the management network are increasing bandwidth requirements.
d. As competition offers more alternatives, upgraded DCNs are offering the ability to remotely turn up services faster as demanded by their customers.

Generally, a good DCN design provides the link between the service network and the Network Management System (NMS). SIF (199 stated that a data communications network provides management communications capabilities between elements of a Telecommunication Management Network (TMN).

In its contribution, ITU-T (2000) underscores the importance of DCN to support management network operators in planning, provisioning, installing, maintaining, operating, and administering telecommunications networks and services.

To implement DCN to manage Telco's SDH network elements, OSI protocol stack is the ideal choice. Cisco (2004) states that a good Data Communications Network solution will help telecommunications companies connect their SDH network elements to a router-based network using the Open System Interconnection (OSI) protocol, which simplifies the DCN and reduces equipment costs.

SIF standards (1998) specify that SONET/SDH equipment support OSI protocols. As such, SONET/SDH equipment must support OSI router functionality. This includes routing OSI traffic between Data Communications Channels (DCCs), as Well as OSI traffic between the operations interfaces and the DCCs.

2.1 The LAPD

The LAPD (Link Access Protocol-Channel D), defined in ITU-T Q.920/921 (1993), is a Layer 2 protocol used for communication (not transmission) between two adjacent SDH equipment of same type. To access remote equipment from the local equipment, the LAPD of both equipment must be properly configured. As shown in figure 2.1, it is also proper during the DCN design to include the LAPD routing protocol. No two same adjacent SDH equipment, should have the same LAPD protocol on their communicating ports.

There are basically two LAPD roles in use, namely: *USER* and *NETWORK*. The following illustrates the principle of LAPD routing in same adjacent SDH equipments.

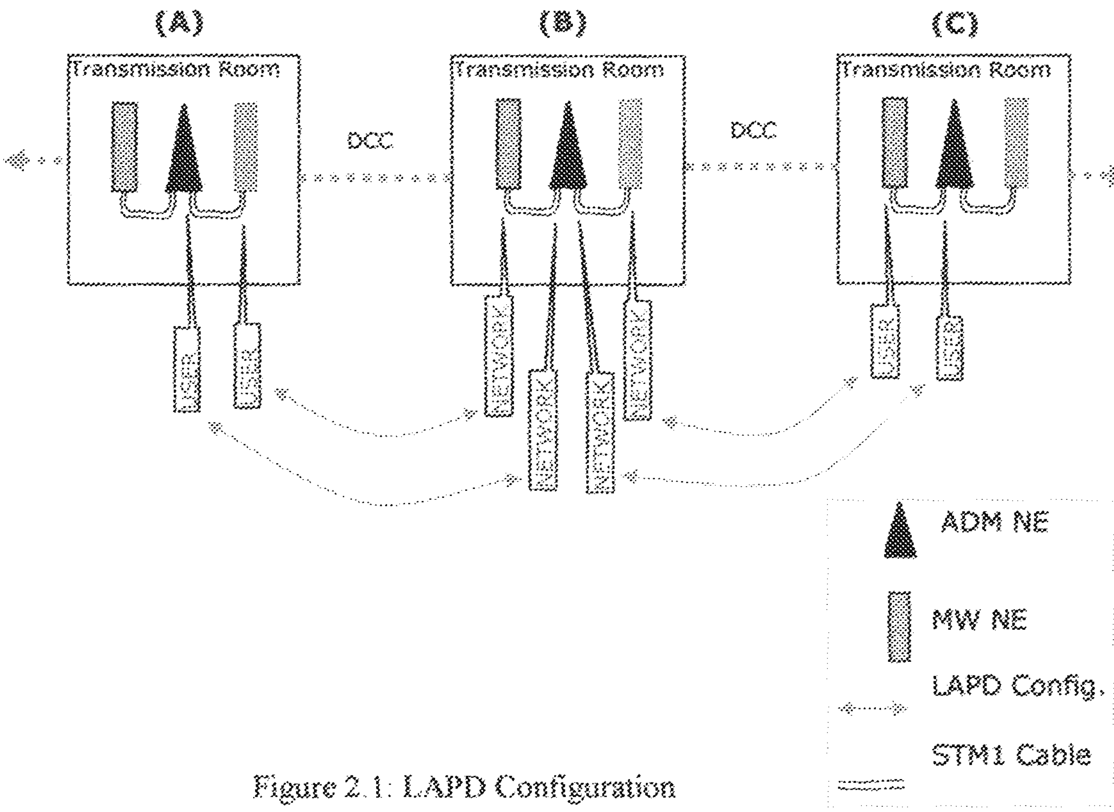


Figure 2.1: LAPD Configuration

In Alcatel-Lucent equipment, for instance, assigning same LAPD role to two adjacent ports of two same contiguous SDH equipment will trigger off *CSF* (communication Sub-system Failure) alarm on such ports! And the downstream NE cannot be seen when the *"show clns neighbour"* or *"show isis topology"* command is issued (described in chapter five) on the OSI router. Also the downstream NE cannot be supervised from the local Craft Terminal

(CT). The LAPD configuration applies to electrical (EIS) and optical interfaces (OPS). In plate I the ports marked *E* and *O* are examples of electrical and optical interfaces respectively.

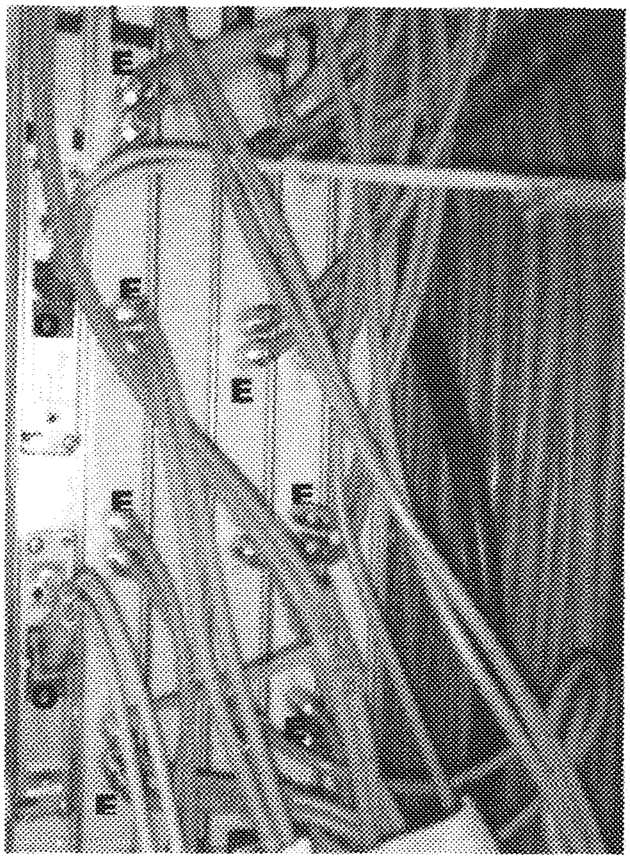


Plate I: SDH Interface NE

2.2 OSI and IS-IS Protocol

Intermediate System to Intermediate System (IS-IS) is an OSI level 3 routing protocol among intermediate Systems (ISs). IS-IS provides an automatic, reliable, efficient and distributed mechanism to keep updating a data communication network working with Connection Less Network layer Protocol (CLNP) network protocol in terms of routing tables. Therefore, the network operator shall not be aware of network topology when installing NEs and shall not be concerned with manual reconfiguring of the network in case of NE or link failures.

2.2.1 OSI Addresses

The OSI network address is referred to as a network service access point (NSAP). We shall use Alcatel-Lucent`s recommended ISO-DCC NSAP format defined in RFC 1629 (1994). As shown in table 2.1, the NSAP address is made of two adjacent parts:

- "Initial Domain Part" (IDP)
- "Domain Specific Part" (DSP).

The DSP is structured in the same way for both GOSIP V2 and ISO-DCC.

GOSIP V2: Government OSI Procurement Specification (*sometimes called Government Open Systems Interconnection Profile / Information Exchange Steering Committee*).

ISO-DCC: ISO Data Country Code

OSI: Open System Interconnection - ISO model for open network interconnection.

NSAP: Network Service Access Point – an OSI level 3 address.

Table 2.1: ISO DCC NSAP with a GOSIP V2 DSP format, RFC 1629 Section 4.2 (1994)

NSAP								
IDP		DSP						
AFI	IDI	VER	AUT	Reserved	Domain Id	Area Id	System ID	Sel
1 byte	2 bytes	1 bytes	3 bytes	2 bytes	2 bytes	2bytes	6 bytes	1 bytes
Example								
39	566F	80	000000	0000	1000	0004	0007723C505B	ID

AFI: the "Authority and Format Identifier" specifies the authority responsible for allocating the IDI number and its format. This field can get the following BCD values:

- 39 ISO-DCC format. The NSAP length is 20 bytes long.
- 47 GOSIP V2 format. The NSAP length is 20 bytes long.
- 49 Local format. No length is in principle pre-defined for this address format.

IDI: the "Initial Domain Identifier" defined in ISO/IEC 10589 (2002) international standard is, for ISO-DCC format, the country code (e.g. 566 for Nigeria, padded with all remaining bits set to one, resulting in an F hexadecimal, so having 566F).

VER: the "Version" identifies the DSP format. The value 80 identifies the GOSIP V2 format.

AUTH: The "Authority" field is supposed to be allocated to the network deployer by the ISO-DCC committee as an administrative authority identifier. Obviously this field is a constant for the whole network.

Reserved: According to GOSIP V2 format, the "Reserved" field shall be set to 0000.

Domain: The "Domain" field identifies the Routing Domain an NE is pertaining to. This field can be used by the network deployer to define different routing domains within its network.

The Area Address: Identifies the area the Network Element (NE) is pertaining to. This field can be used by the network deployer to define different areas within a single routing domain.

The system_id: This field, which is 6 bytes long, is also called the MAC address. It uniquely identifies a given NE within its area. It is strictly recommended to assign a system_id value to an NE which is also unique within the routing domain (all the areas pertaining to the specific network). Two NEs cannot have the same MAC address. In fact, the IS-IS protocol will fail and cannot know how to route packets if there are two NEs with the same System_id in the same area. Alcatel suggests assigning the 802.3 MAC address (worldwide unique Ethernet address) to this field in order to surely have a unique System ID value within the area.

Sel: This is called the selector field which identifies the user (or application) on top of network layer the packet is addressed to (e.g. the transport protocol).

2.2.2 The IS-IS Principles and Multi-Area Features of Routers

The IS-IS protocol provides a hierarchical mechanism to split the routing domain into areas. This protocol includes Level 1 Intermediate Systems (L1 IS) and Level 2 Intermediate Systems (L2 IS). L1 IS enables each NE to be aware of which is the best path to reach anyone else within its area and if any event occurs within its area (example: topological changes, failures ...). L2 IS enables intra-area routing in which each L2 IS is aware of which is the best path to reach any area within its routing domain by exchanging information (PDUs) of level 2. Protocol Data Unit (PDU) is the message exchanged between two peer-level protocol entities.

Articles from *ISO/IEC (2002)* support ConnectionLess Network layer Protocol (CLNP) as the network layer protocol. Therefore, the end-to-end path between two communicating entities (example, an OS and a managed NE) will support CLNP.

In this project, since OSI solutions shall be presented, the routing protocol shall be IS-IS. ITU-T (2007) specifies that the SDH network elements will act as routers to forward management traffic across the DCC. In OSI environments, IS-IS will be the routing protocol of choice.

ISO/IEC 10589 (2002) defines the IS-IS routing exchange protocol in order to create and maintain the routing tables used by Intermediate Systems to route CLNP packets. IS-IS operates by defining a two layers hierarchical architecture. This architecture identifies an intra-area routing, where the area is the lowest entity of the hierarchy, and an inter-area routing, in order to interconnect areas within the routing domain.

For DCN design considerations for OSI, the Bellcore and ITU standards recommend the use of the OSI protocol stack for the management of SDH network elements. Figure 2.3 shows the packet flow from the NMS/OSS to SDH network elements.

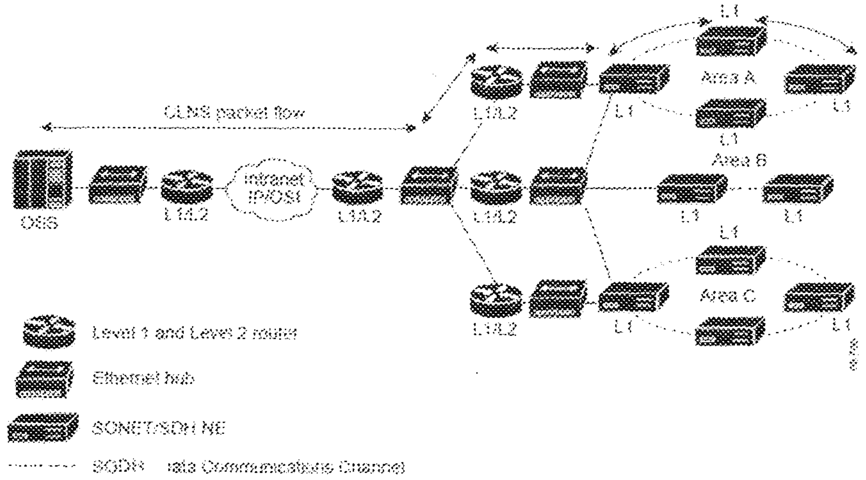


Figure 2.2: Packet Flow in a DCN Network. Cisco (2007)

2.3 The DCC

The SDH DCC is the physical path. The SDH network element and GNE are IS-IS Level 1 routers. According to Cisco (2007), the standalone routers in the DCN perform the IS-IS Level 2 function. Notice that the DCC has become part of the DCN. The performance of the DCN is determined by all of these components: L1/L2 Routers, Ethernet Hubs/Switches, SDH NEs, cabling, IOS software used.

SIF and Sharman (1998) were in unison when they agreed that since ISO 10589 (IS-IS) is a hierarchical layer three routing protocol, networks designed to carry CLNS traffic will work best when architected in a tiered design. With the inclusion of OSI routing at the SDH Section and Line DCCs it is important to use the DCC bandwidth efficiently. Keeping this in mind it is the SIF's desire to allow the Level 1 areas to grow in size as needed and also to not impact the size of the Level 2 routing tables. Where the Central Offices (COs) consist of several SDH rings this design allows for the NE's in the respective rings to be aggregated under the same OSI area. The routers function not only as a Level 1 area router but also as the necessary Level 2 router for communication outside the Central Office (CO) or between areas within the CO.

2.4 DCN Guidelines

The SIF (1998) and Bellcore (1995) agree with the following guidelines:

a. All SONET/SDH NEs in the same configuration with connected DCCs (e.g., a ring network) should reside in the same OSI routing area.

b. A GNE and at least one CO router should reside in the same routing area.

c. Data communications switching routers should not share a routing area with a CO router.

d. Redundancy should be provided through multiple switching routers in separate physical locations with different routing areas, and multiple CO routers and WAN links to every GNE, so no single point of failure exists in the data communications network.

e. SONET/SDH NEs deployed without a direct WAN interface should be accessible from a management system via more than one GNE (i.e., primary and secondary GNEs should be provided) to protect against single GNE point of failure.

f. As a starting point, OSI routing areas should be limited to 50 routing devices (all SONET/SDH NEs and all data communications routers), until experience validates the actual numbers (Note: some vendors' equipment may support a greater number of devices within an OSI routing area).

g. A GNE shall support L2 routing.

According to the Cisco (2007), to design a network based on the three-tiered architecture, answers to the following questions must be provided:

a. What is the number of SDH nodes in the network today?

b. What is the growth rate (number of nodes added per year) of the SDH network?

c. What is the size of the Level 1 OSI area that the routing engine can support? In other words, how many Level 1 routers can be in an area?

d. What is the size of the OSI domain that the Level 2 routing engine can support?

e. How many network elements does the service provider want to place in an area to start with? Does the service provider want to leave room for growth within an area?

f. How many central stations does the service provider have in the DCN?

g. Does the service provider want to support a single GNE or dual GNEs?

h. What is the average ring size?

i. How many rings can be aggregated into a single area?

CHAPTER THREE

3.0 MATERIALS AND METHODS

Consider the Nigerian map shown in figure 3.1. To provide good coverage of SDH network to the people of Nigeria, the service provider must design its SDH network to run on this map. This will enable at least the major cities to be covered. But before deploying their SDH network to these cities one of the major considerations will be how best to manage the SDH NEs after deployment. The purpose of this work is to provide the design solution to achieve the NEs management.

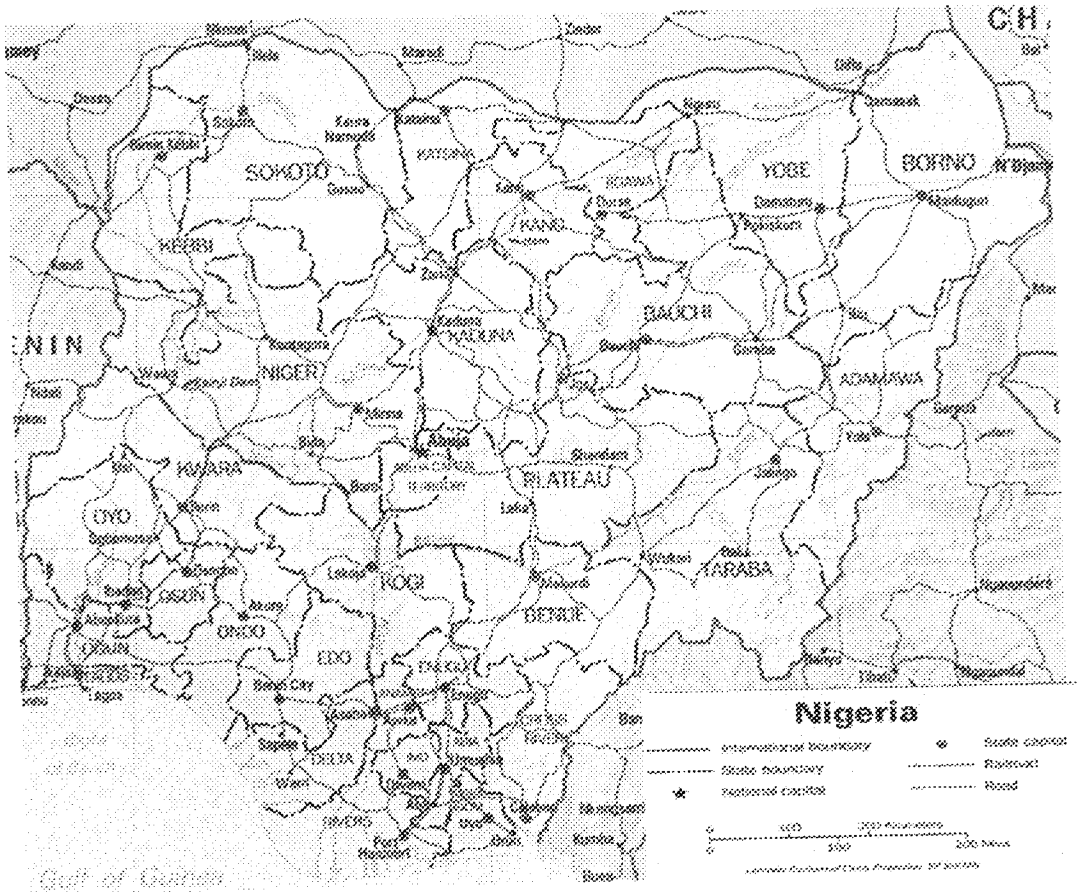


Figure 3.1: The Nigerian Map

Fundamental issues to address in the design are the routing performance of the IS-IS routers and the bandwidth on the DCC to achieve a multi-area implementation. The performance characteristics of all of the routers shall be taken into account, including the routing engine in the network element.

To achieve the design objective, first a multi-area DCN without ideal protection shall be designed. Then a design solution to protect the network shall be provided.

3.1 Design Steps

The outlined pseudo-code from steps 1 to 9 shall be followed as a guide:

1. Identifying the geographical spread of SDH stations on the Network Map;
2. Segmenting the spread of SDH Network into Regions;
3. Assigning each Region a Unique Name and Area Address;
4. Identifying the spread of NEs in each Region;
5. Segmenting the Regions into autonomous systems called OSI Areas;
6. Assigning each OSI Area a Unique Area Address;
7. Determining the Location of the DCN Rack;
8. Integrating Areas to the Region and Region to the NOC;
9. Designing the Resilience Route

These steps are summarily illustrated in figure 3.1, starting from bottom upward. In this figure, the packet leaves the NMS and is routed across the DCN by routers to the gateway network element (GNE). The GNE routes the packet from the Ethernet network onto the SDH DCC. The packet is routed around the designated OSI Area.

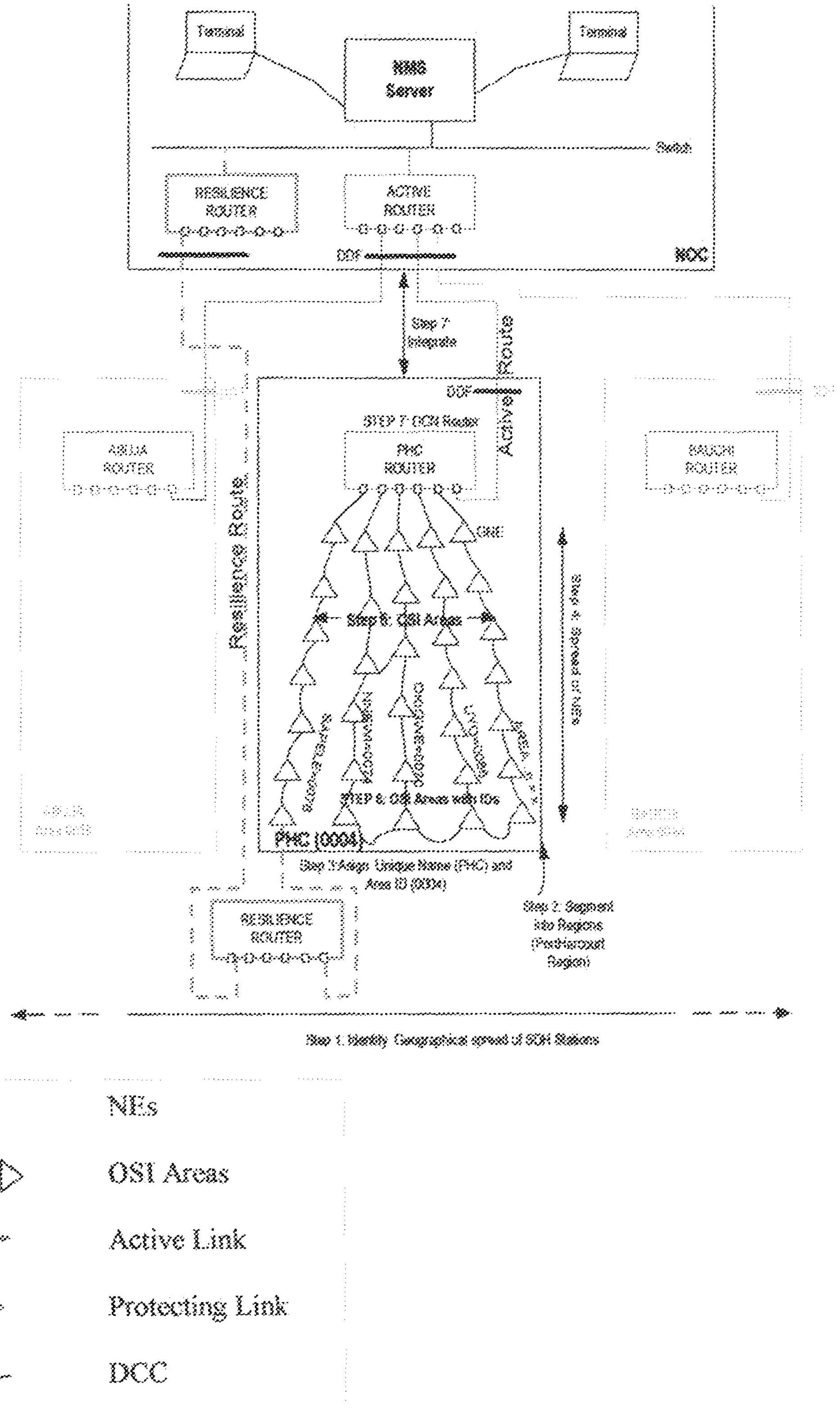


Figure 3.2: Design Flow (with Emphasis on PHC Region)

3.2 Identifying the Spread of SDH Stations on the Network map.

Every Telco must have the geographical map of the city or country of its operational jurisdiction. From the field survey report, the network can be planned and deployed based on this map. The map presented in figure 3.3 is a Nigerian map showing a hypothetical SDH network on it. It shows the location of SDH stations, MSC stations (COs) and the NOC. In the course of this design, this map shall be further segmented in order to achieve the goal of this work, which is to provide the design solution to achieve the NEs management even in the event of failures.

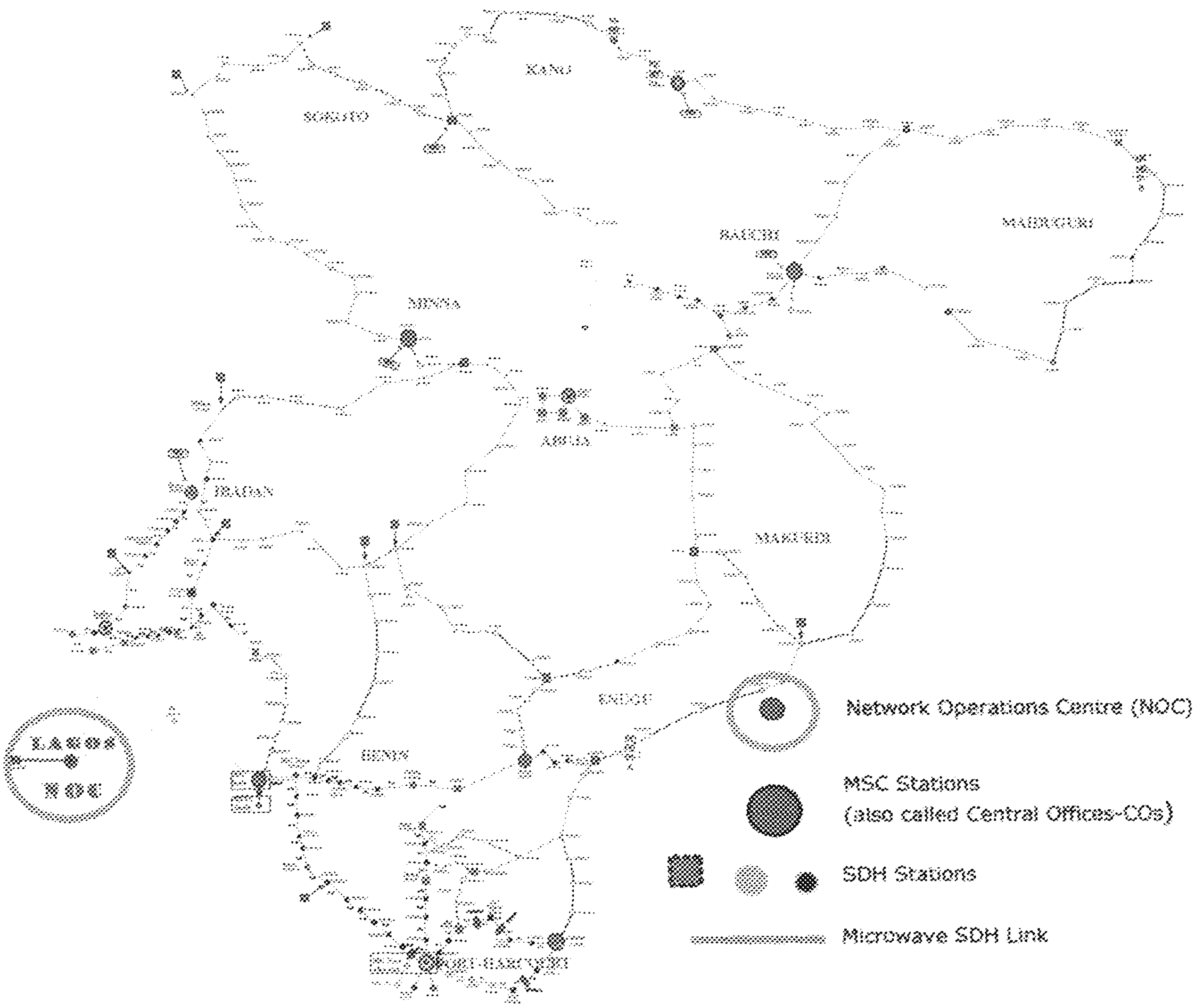


Figure 3.3: Spread of SDH Network

3.3 An SDH Station

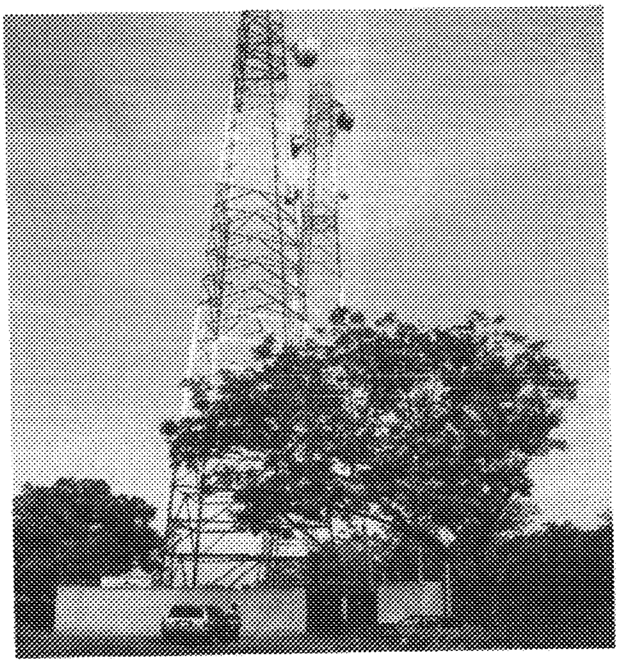


Plate II: A typical SDH Station

Plate II depicts a typical SDH station, showing antennas of SDH microwave radios. An SDH station can have one or more NEs such as radios, ADMs, WDMs, and so on. Sometimes a station can have two or more NEs of same type.

3.4 Segmenting the Spread of SDH Network into Regions

Having identified the spread of SDH stations, the next step is to segment the SDH network into regions. This is done by merging some cities together into regions, and collating their NEs - physically drawing area boundaries on the map. This is illustrated in the Hypothetical network shown in Figure 3.4. The four-digit area number (called Regional Area address) given to each region was arbitrarily assigned here, and must be unique throughout the network.

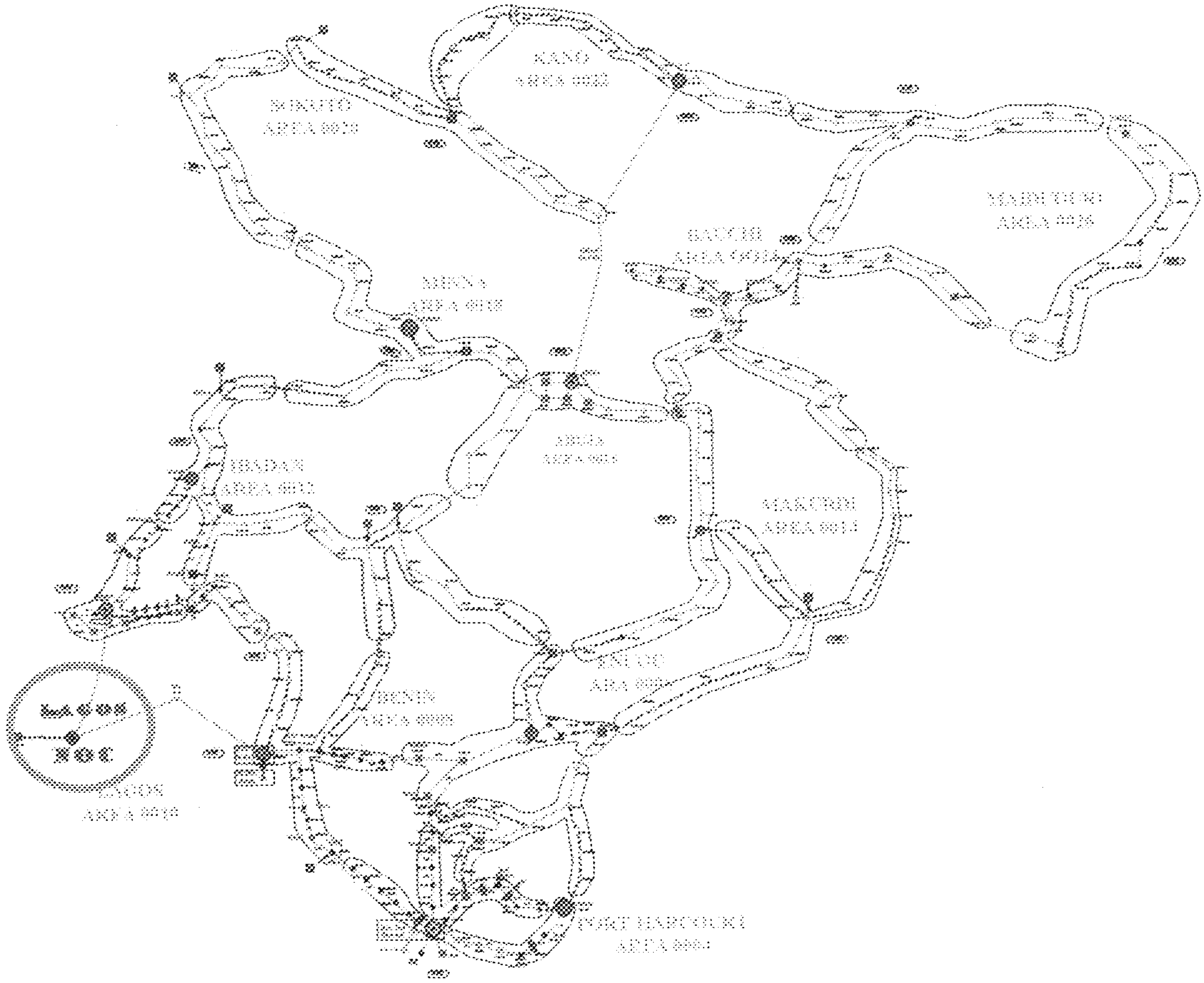


Figure 3.4: Segmenting SDH Network into Regions

3.5 Assigning each Region a Unique Name and Area Address

Table 3.1 depicts the summary of SDH network and constituent regions, taken from Figure 3.4.

Table 3.1: SDH Regions and Area Addresses

s/n	Region	Regions OSI Addresses	States/Cities Covered	Remark
1	Port-Harcourt	0004	PHC, Abia, Imo. Cross River, Bayesa, Delta, Akwa-Ibom, Anambra.	Some Parts of Delta and Anambra
2	Enugu	0006	Enugu, Anambra, Eboyi,	Some Part of Delta
3	Benin	0008	Edo, Delta, Ondo	Some Parts of Delta, Ondo
4	Lagos	0010	Lagos, Ogun,	
5	Ibadan	0012	Oyo, Osun, Kwara,	
6	Makurdi	0014	Benue, Kogi	
7	Abuja	0016	FCT, Nasarawa	
8	Minna	0018	Niger, FCT	
9	Sokoto	0020	Sokoto, Binin Kebi, Zamfara.	
10	Kano	0022	Kano, Kaduna,	
11	Bauchi	0024	Bauchi, Plateau,	
12	Maiduguri	0026	Borno, Gombe, Yola,	

From here on, we shall use the Port-Harcourt region as a model for all design and illustrations.

3.6 Identifying the Spread of NEs in each Region

Typical connection between the NEs in each SDH station is shown in figure 3.5a and figure 3.5b.

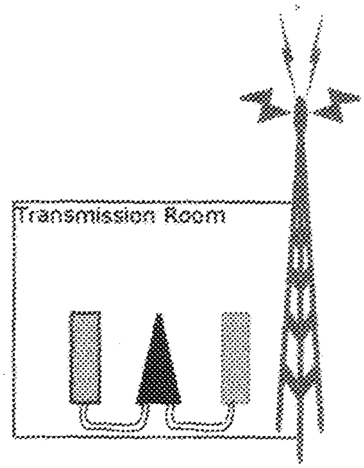


Figure 3.5a Radios Integrated with ADM

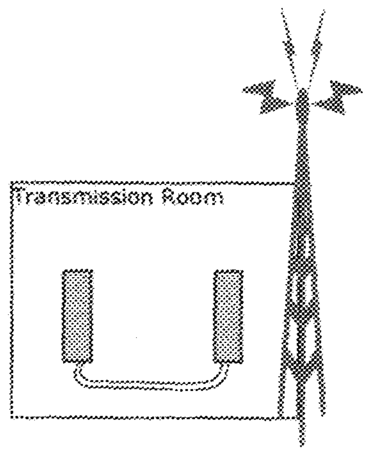


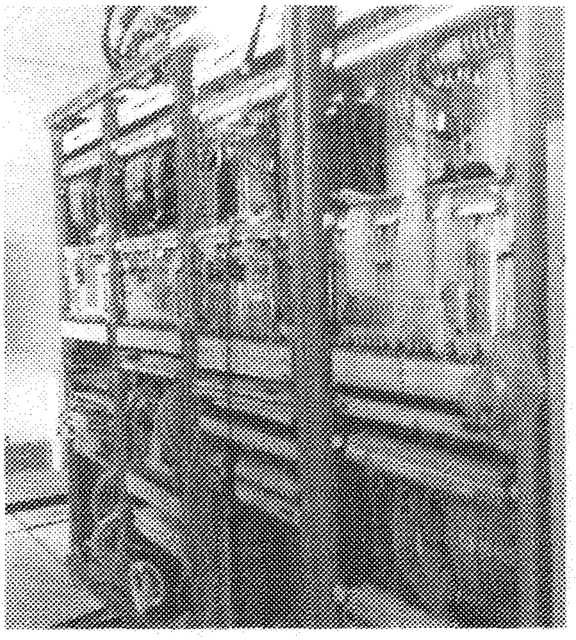
Figure 3.5b: Radios integrated back-back (i.e. without ADM)

Fig 3.5: Typical SDH Integration

In some transmission rooms there can be more than two SDH radios and ADMs. In this case the NEs should be properly integrated using the appropriate ports. A visit to the stations may be necessary to verify that the NEs are well integrated. Any NEs not integrated cannot be managed from the Remote Management system in the NOC.

3.6.1 ADM NEs

Plate IIIa and Plate IIIb depict a cross-section of Alcatel-Lucent ADM NEs deployed in an SDH station. Labelled interface (A) is the Ethernet ports which are our connection points with the Router. These interfaces must be **enabled** through the NE software in order to establish point-point connection with the router.



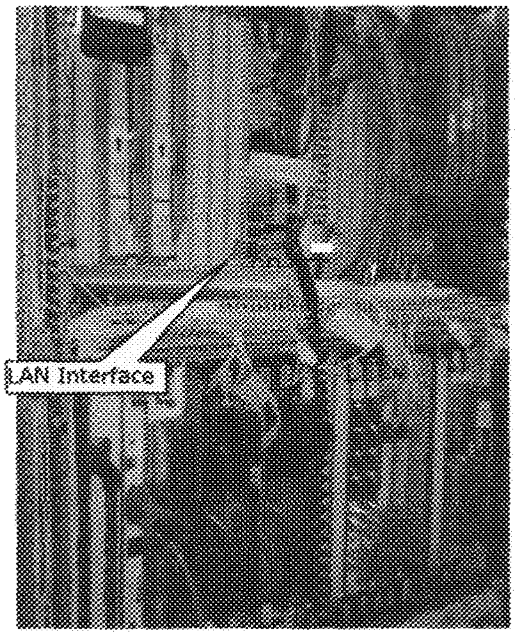
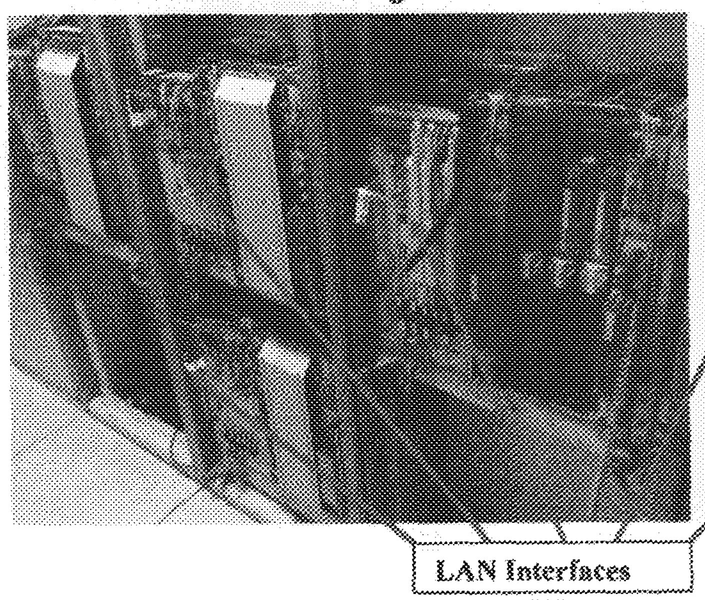


Plate IIIa Alcatel-Lucent ADM NEs

Plate IIIb: Alcatel-Lucent ADM shelf and LAN Interface

3.6.2 MW Radio NEs

Plate IVa and Plate IVb depict a cross-section of Alcatel-Lucent Radio (LSY and USY) NEs working in an SDH station. Labelled interfaces (shown with arrows) are the Ethernet ports which are the connection points to the DCN. These interfaces must also be **enabled** through the NE software.



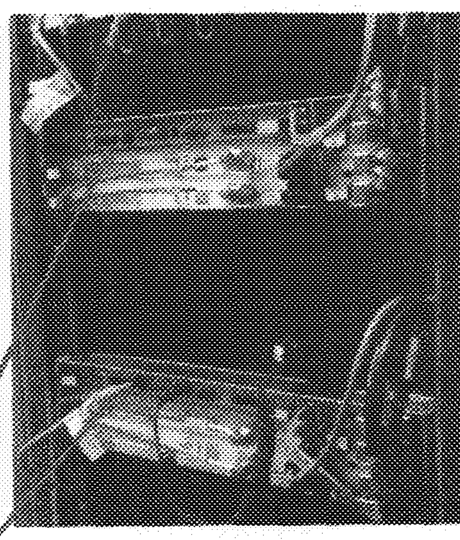


Plate IVa: Racks of Alcatel-Lucent MW (LSY) SDH Radios and LAN interfaces.

Plate IVb: A Rack of Alcatel-Lucent MW (USY) SDH Radios and LAN interfaces.

3.7 Segmenting SDH Regions into Autonomous Systems called OSI Areas.

Next is to segment the regions into *autonomous systems*, called OSI AREAS. Using the Port-Harcourt region (area 0004), this is illustrated in Figure 3.6. Other regions can be designed in a similar way.

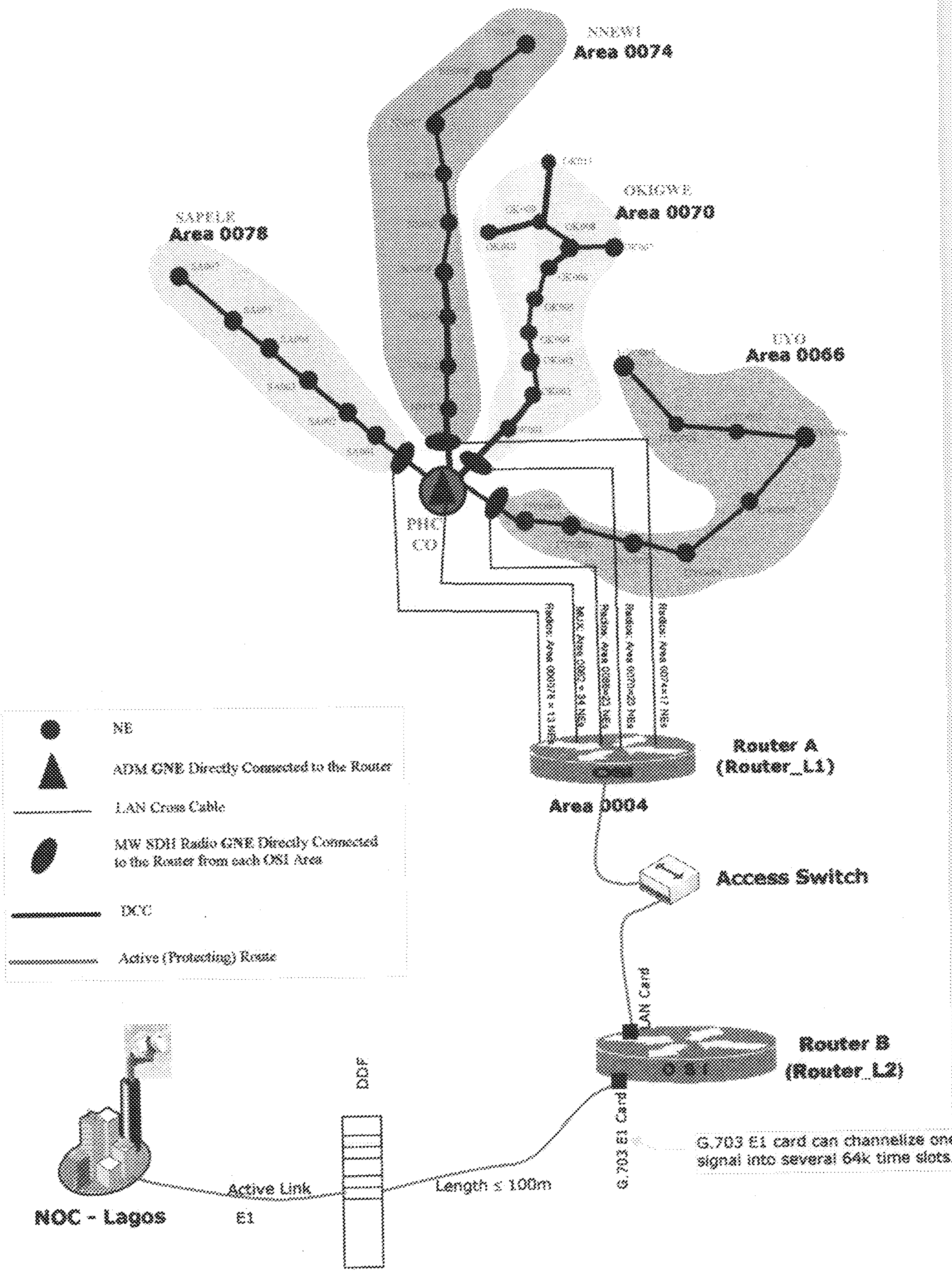


Figure 3.6: An SDH Region Segmented
into multi-Areas

Router A: This is the L1 Router. It is also called the **access** Router. Its function is to route packets within its domain (Areas 0078, 0074, 0070, 0066 & 0062) only.

Router B: This is the L2 Router. It is also called the **Gateway** Router. Its function is to route packets within its domain and also outside its domain – to NOC and to other regions.

3.8 Assigning each OSI Area a Unique Area Address

Table 3.2 Summarizes the number of NEs in this region.

Table 3.2: SDH Regional Network segmentation

Region ID	Regional Area ID	Areas in the Region	ID of OSI Areas in the Region	No. of NEs in each OSI Area	NE Type in Each OSI Area
		Sapele	0078	2 * 6 +1= 13	MW Radio
		Okigwe	0074	2 * 9 +1= 19	MW Radio
PHC	0004	Nnewi	0070	2 * 11+1= 23	MW Radio
		Uyo	0066	2 * 9+1= 19	MW Radio
		Adm	0062	35	ADM

The total number of NEs in each OSI area is calculated as follows:

At each station (represented by the symbol ●) there are two MW radios and one ADM. As illustrated in figure 3.5a. Hence, for OSI area 0078 in Figure 3.6, for instance, the total number of radios is: 6 * 2 = 12 (since there are 6 stations, each with 2 radios, in OSI Area 0078).

From Figure 3.6, one last radio at the MSC station (denoted by symbol ●) is directly connected to the Cisco router. This brings the total to 13 SDH radios. If each station has 1 ADM, the total number of ADM NEs is the number of stations in this region. Since there are 35 stations, therefore we have 35 ADM NEs.

It is important to know the total number of NEs expected in each OSI area so as to ensure that the "*show isis topology*" and "*show clns neighbour*" commands capture all the expected NEs. These commands shall be illustrated in Chapters 5. Every SDH NE in each station should be configured with proper OSI Area Address assigned during the design.

3.9 Determining the Location of the DCN Rack

For each region, DCN Rack should be provided to house the DCN equipment (Switch/Hub, L1 and L1/L2 routers). This rack should have a Top Rack Unit (TRU) with appropriate circuit breakers, as shown in Figure 3.7.

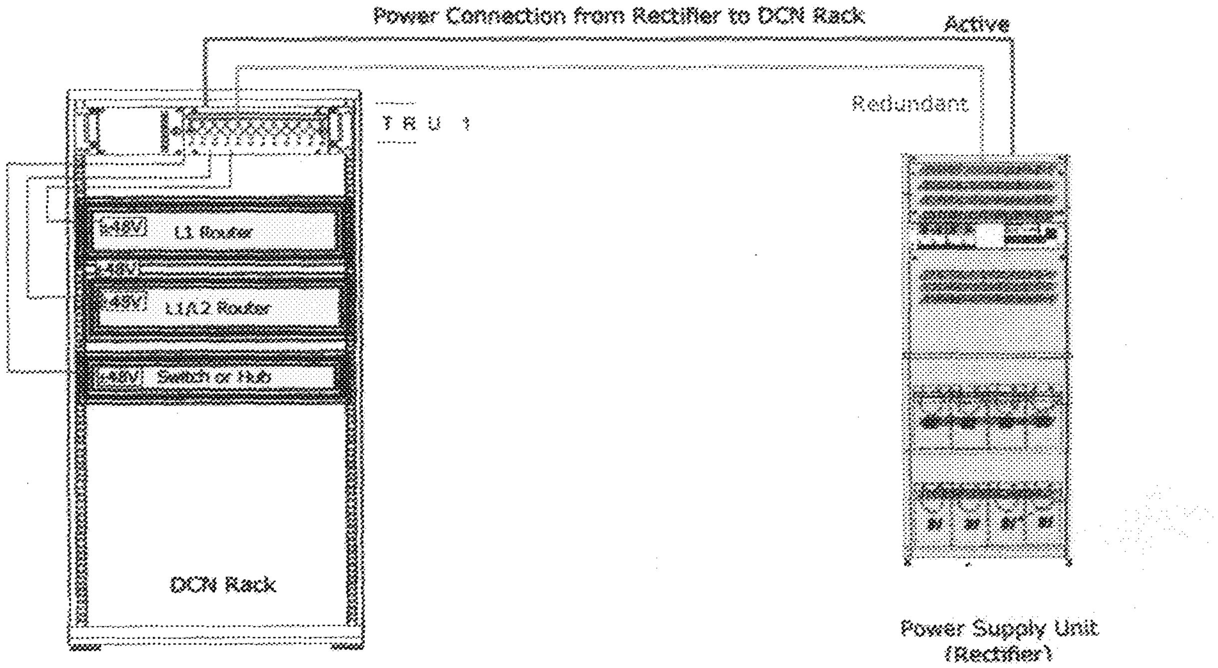


Figure 3.7: Power Connections

3.9.1 Power Consideration

As shown in Figure 3.7, each Cisco router should be powered from the TRU of the DCN rack. And the DCN Rack should in turn be powered from the rectifier, with a 1+1 protection. DC Cisco routers (2600, 3700 series) that use ±48V power supply (shown in Plate V) is recommended.

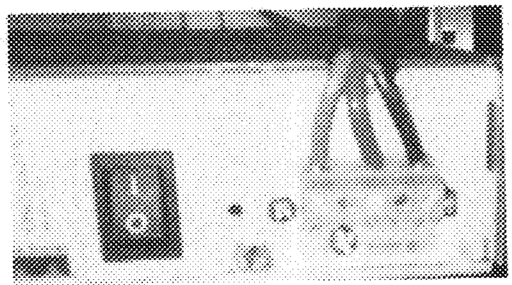


Plate V: ±48V Router Power Pack

3.9.2 DDF Consideration

The Digital Distribution Frame (DDF) shall connect the L1/L2 OSI router to the NOC through the router's E1 Controller Card (shown in plate VI). The position of the DCN rack with reference to the DDF is very crucial to this design. The distance between L1/L2 Router and DDF should not be more than *100 meters*. After the DCN rack has been properly located, the next step is to get the designated DDF ports (TX and RX) assigned for DCN integration. Information about these designated ports can be got from the telco's Transmission Planning team.

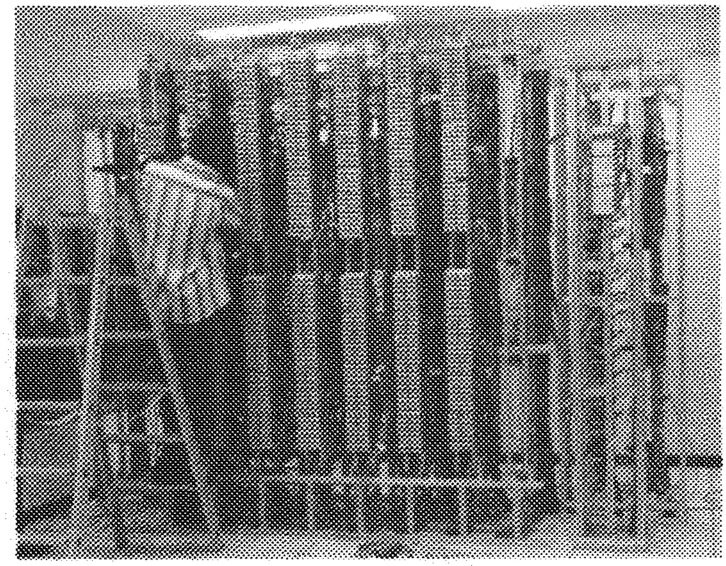


Plate VI: A Typical DDF Frame

3.10 Integrating from the NOC to PHC Region

The design in figure 3.8 shows the connections from the NOC to the PHC region. From the NOC, with this model, other regions not shown here (Abuja, Minna, Bauchi, …) can be integrated in the same way.

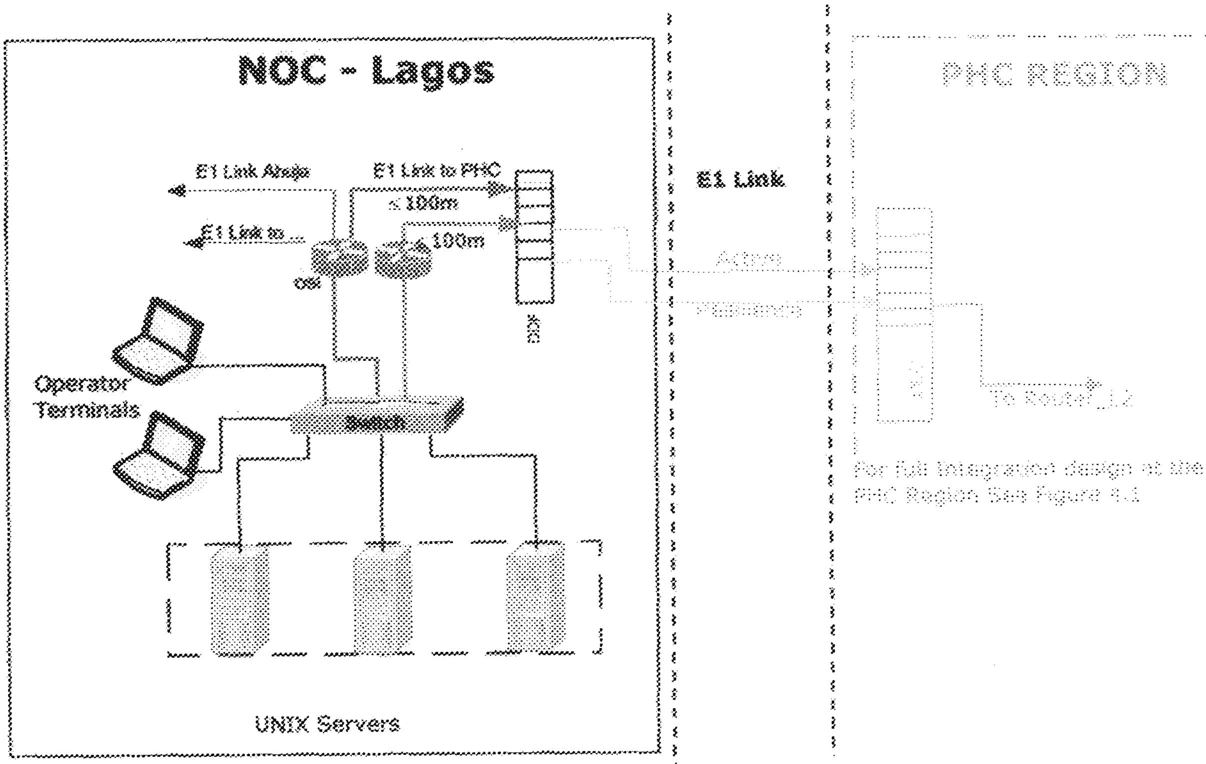


Figure 3.8: DCN Integration at the Network operations Centre (NOC)

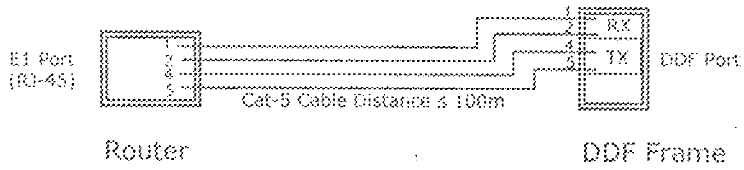


Figure 3.9: E1 to DDF Integration

3.11 LAN Cable Design

Tables 3.3, 3.4 and 3.5 show the pin-out assignments of the Cat-5 Straight, Cat-5 Cross and E1 cables respectively that will be used to implement this project.

Table 3.3: Cat-5 Straight Cable Pin-Out

Polarity	Pin	Colour	Pin	Polarity
Tx+	1	White/Orange	1	Tx+
Tx -	2	Orange	2	Tx -
Rx+	3	White/Green	3	Rx+
	4	Blue	4	
	5	White/Blue	5	
Rx-	6	Green	6	Rx-
	7	White/Brown	7	
	8	Brown	8	

Table 3.4: Cat-5 Cross Cable Pin-Out

Colour	Polarity	Pin	Pin	Polarity	Colour
White/Orange	Tx+	1	3	Rx+	White/Green
Orange	Tx-	2	6	Rx-	Green
White/Green	Rx+	3	1	Tx+	White/Orange
Green	Rx-	6	2	Tx-	Orange
White/Blue		4	4		Blue
Blue		5	5		White/Blue
White/Brown		7	7		White/Brown
Brown		8	8		Brown

Table 3.5: E1 Cable Pin-Out

Colour	Polarity	Pin Number	Pin Number	Polarity	Colour
White/Orange	Tx+	1	2	Tx-	Orange
Orange	Tx-	2	1	Tx+	White/Orange
White/Green		3	3		White/Green
Blue	Rx-	4	5	Rx+	White/Blue
White/Blue	Rx+	5	4	Rx-	Blue
Green		6	6		Green
White/Brown		7	7		White/Brown
Brown		8	8		Brown

3.12 The Possible Failures

The design in figure 3.6 does not show any protection for the OSI areas or the NEs. Here, we shall extend this design to achieve ideal resilience for this entire region.

Dissecting figure 3.6, we can find the following problems:

Problem 1 - No alternative route from SA007 to Lagos Router: Imagine traffic cut at point A. From Router_L1, you cannot ping beyond SA001. Not only is that supervision of the NEs (SA002 to SA007) is no longer possible from the NMS (NOC) but also traffic addressed to these NEs from downstream will be lost. The diagram in figure 3.10 illustrates this point.

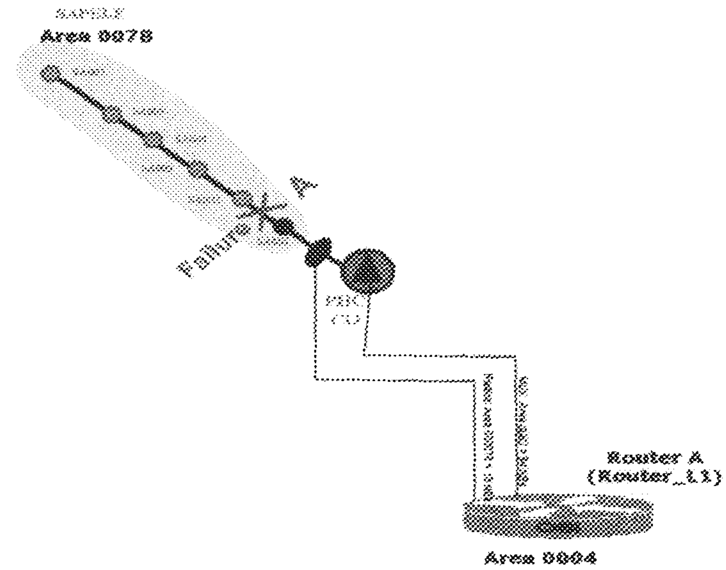


Figure 3.10: No Protection for NEs SA002 to SA007

Problem 2 - No alternative route from NN005 to OK010: If there is failure at point **B**, you cannot ping beyond the NE NN001 from Router_L1. Hence all the packets addressed to the NEs (NN002 to NN009) will be lost. And consequently these NEs cannot be reached from NMS (in the NOC) for management. This is shown in Figure 3.11.

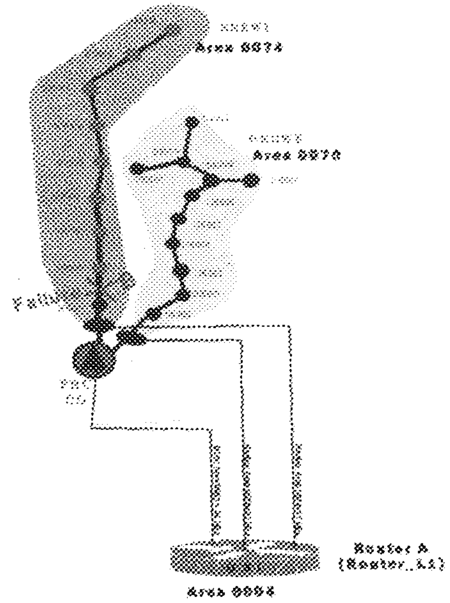


Figure 3.11: No Protection for NEs NN002 to NN009

Problem 3 - No alternative route from NN009 to OK011: As shown in figure 3.12, even if there is alternative link between NN005 and OK010, when there is traffic cut anywhere after NN005, all the packets addressed to the NEs (NN006 to NN009) will be lost. These NEs cannot be reached from the downstream and hence cannot be managed by the NMS.

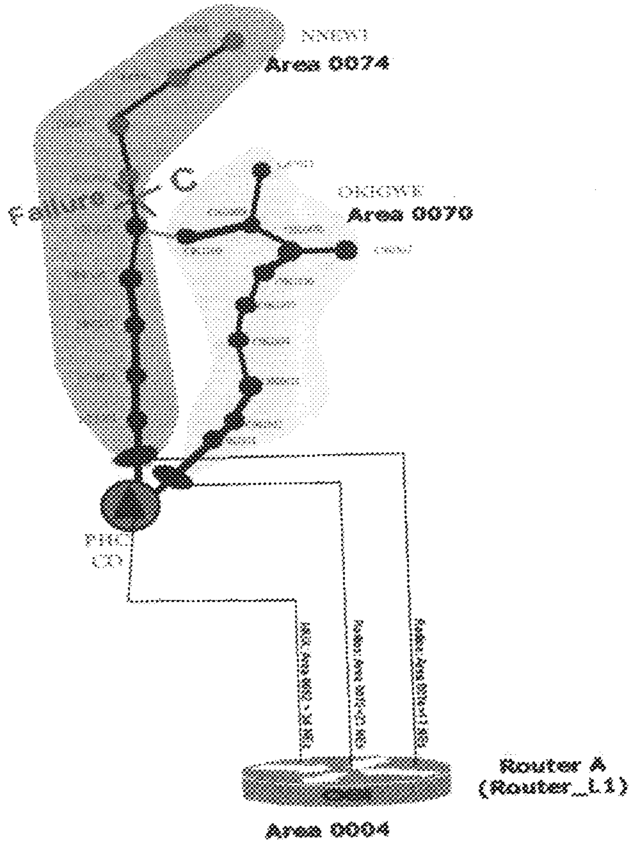


Figure 3.12: No Protection for NEs NN005 to NN009

Problem 4: No alternative route from OK003 to UYO009 – If there is failure anywhere after UYO001, all the packets addressed to the upstream NEs will be lost. Take for instance a cut at point **D**, you cannot ping NEs after UYO001. Consequently NEs UYO002 to UYU010 cannot be managed from NMS in The NOC. Figure 3.13 illustrates this scenario.

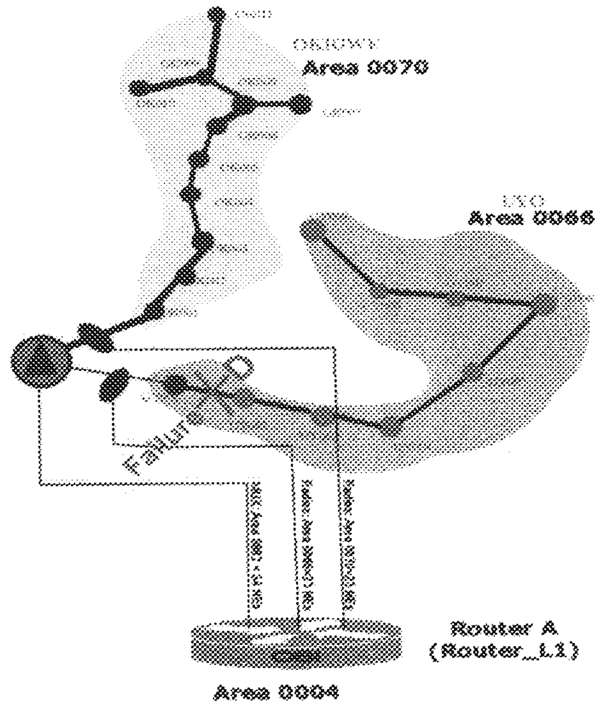


Figure 3.13: No Protection for NEs UYOO2 to UY009

3.13 The Resilience Design

By designing the resilience routes, shown in figure 3.14, we can withstand any form of network failure in this region. The key lies in making these connections:

1. SA007 to NOC - by lease line or through another network not running on the active link. The purpose of this connection is not only to protect the Sapele area but also to

protect the entire PHC region from failure. This link can be a lease line or another parallel link.

2. NN005 to OK010 - by DCC. The Purpose of this connection is to protect part of Nnewi and Okigwe Areas from failure.
3. NN009 to OK011 - by DCC. The Purpose of this connection is to protect the remaining part of Nnewi and Okigwe areas from failure.
4. OK003 to UYO009 - by DCC. This connection is necessary to protect the Uyo area from failure.

The design shown in figure 3.14 illustrates this resilience.

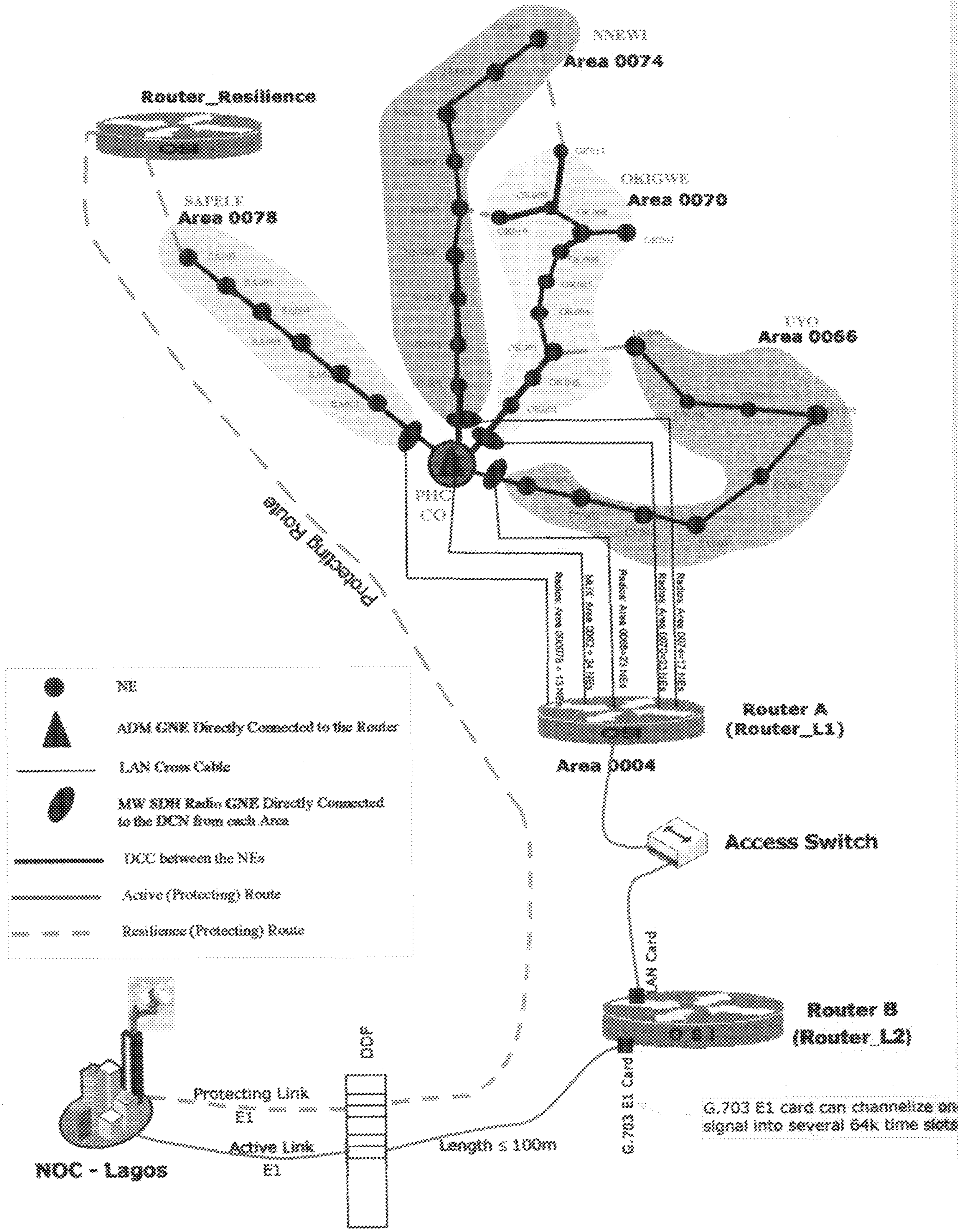


Figure 3.14: Multi-Area Design with Resilience Protection

3.14 Switching Criteria

The flowchart presented in figure 3.15 depicts typical switching criteria from primary route to resilience route and from resilience route to primary route. This criterion is followed each time the Network Management System (NMS) issues query to each region to know the reach-ability of the NEs in each area in the region.

Whenever there is a failure, with the help of DCN, the NMS looks for the least-cost alternative route to reach the downstream NEs. When the failure has been corrected, counter is transferred back to the primary route again. As long as all the NEs in the region is reachable through the primary route, the resilience route remains on standby mode.

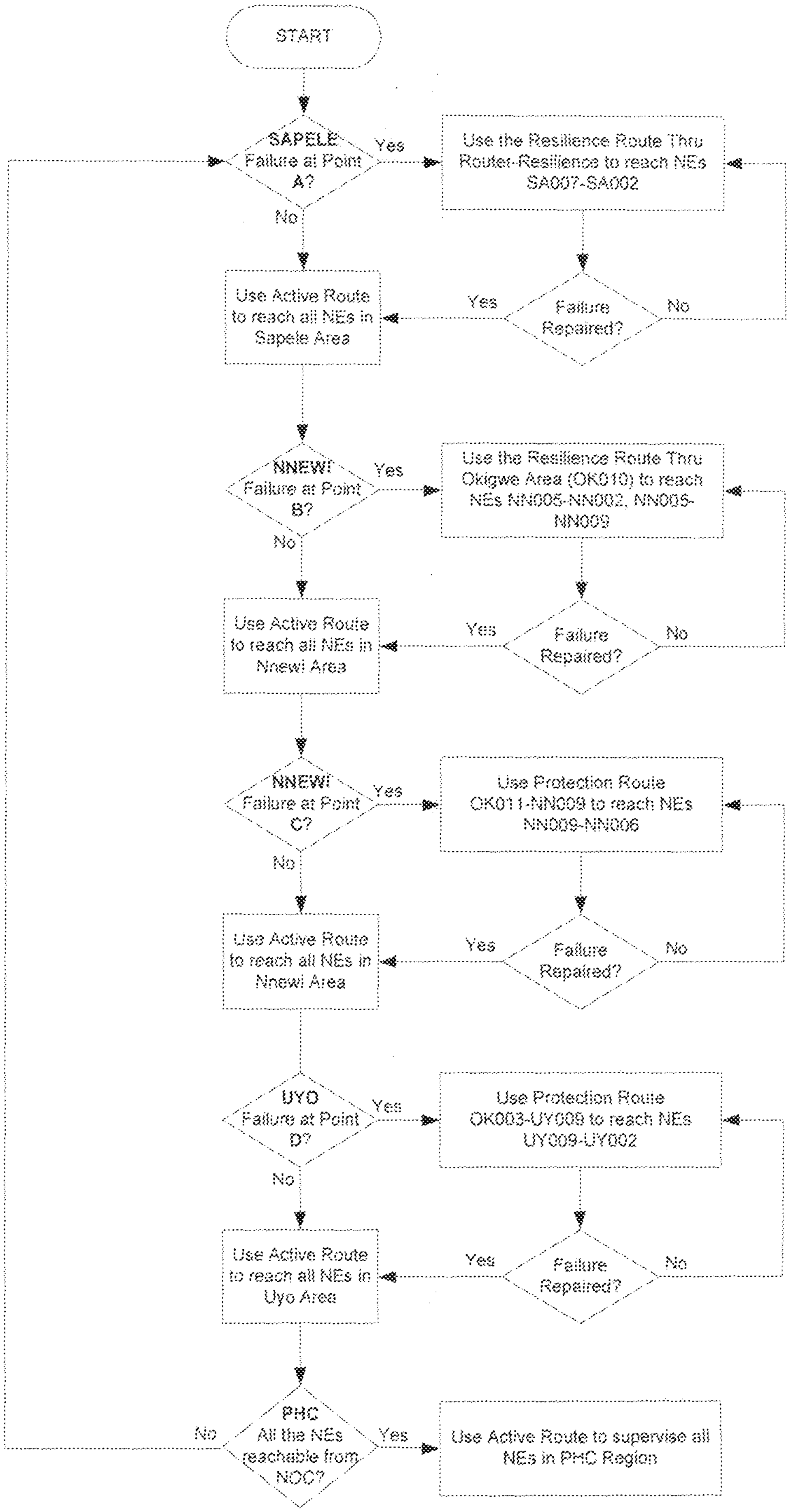


Figure 3.15: Switching Criteria

CHAPTER FOUR

4.0 RESULTS

In trying to implement a network it is important to first decide on an architecture which scales and is manageable. OSI networks must have an architecture that enables an easily controlled and administered numbering plan that scales well as the number of network elements in an administrative domain grow. The architecture must provide adequate performance as well as assured availability, driving device and link redundancy. Building on a solid architecture will allow for the network to be manageable. It will give the implementor the ability to add equipment, features, and services as necessary. And will generally allow for an equal distribution of access to the network, as well as, give a symmetric distribution of packet flow across the backbone transport. During the design and implementation phases we never wavered from this principle.

4.1 Assigning Router Interfaces to Instances

On the Router_L1, the following Fast Ethernet Interfaces shall be used to connect to the various OSI Areas.

Interface 0/0 = Sapele Link

Interface 0/1 = Nnewi Link

Interface 1/0 = Okigwe Link

Interface 1/1 = Uyo Link

Interface 0/2 = ADM Link

Interface 2/0 = Hub (to Router L2)

On the Router_L2, the following interfaces shall be used:

Interface 2/0 = Hub (to Router L1)

Interface Serial 1/1:0 = DDF (to NOC)

These are clearly shown in plate VII.

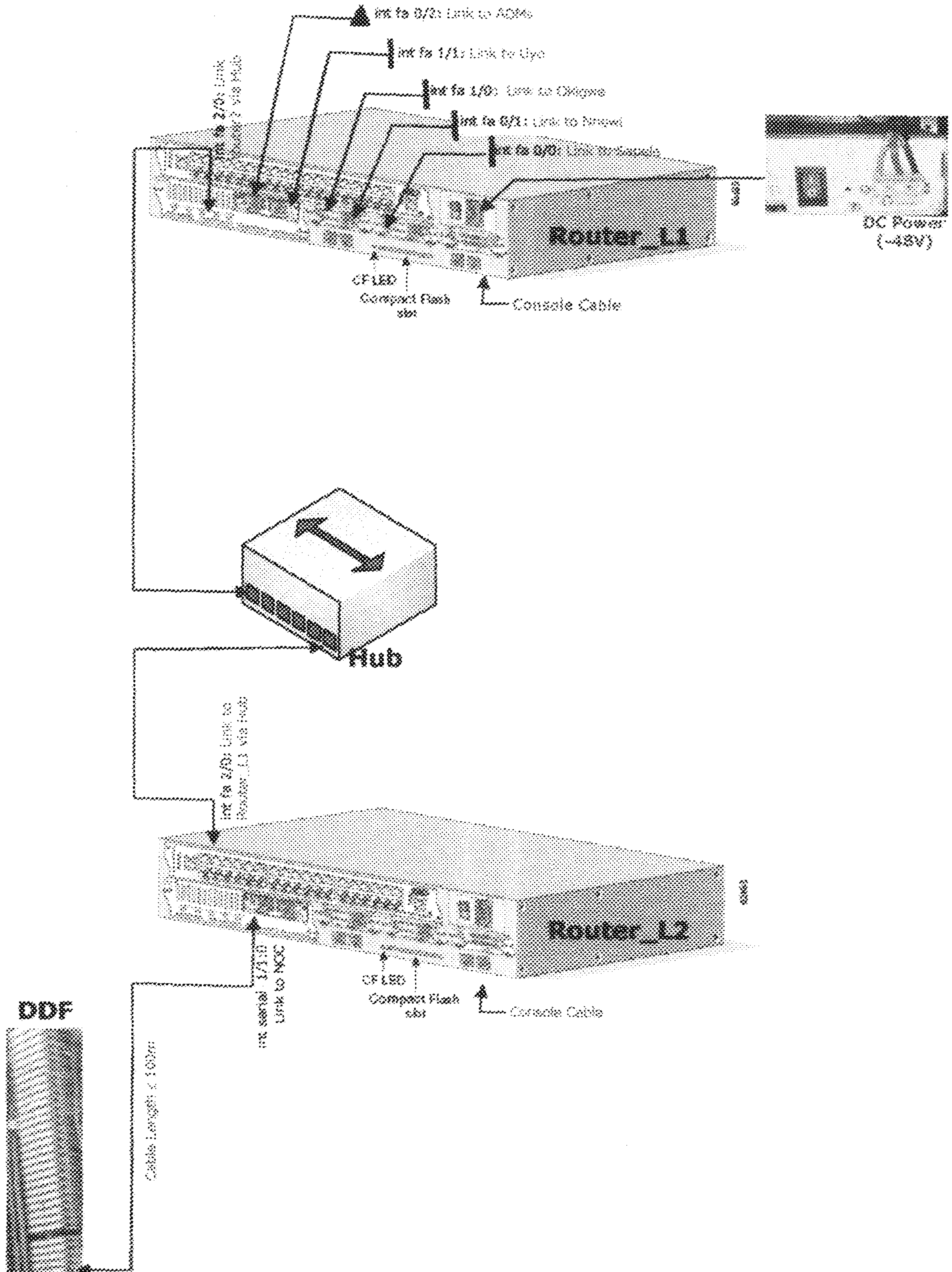


Plate VII: A typical Cisco 3725_DC Router showing designated interfaces for Router L1 and

4.2 IS-IS Multi-Area Connections

Using CAT-5 cables, the IS-IS multi-area connections are as shown in figure 4.1:

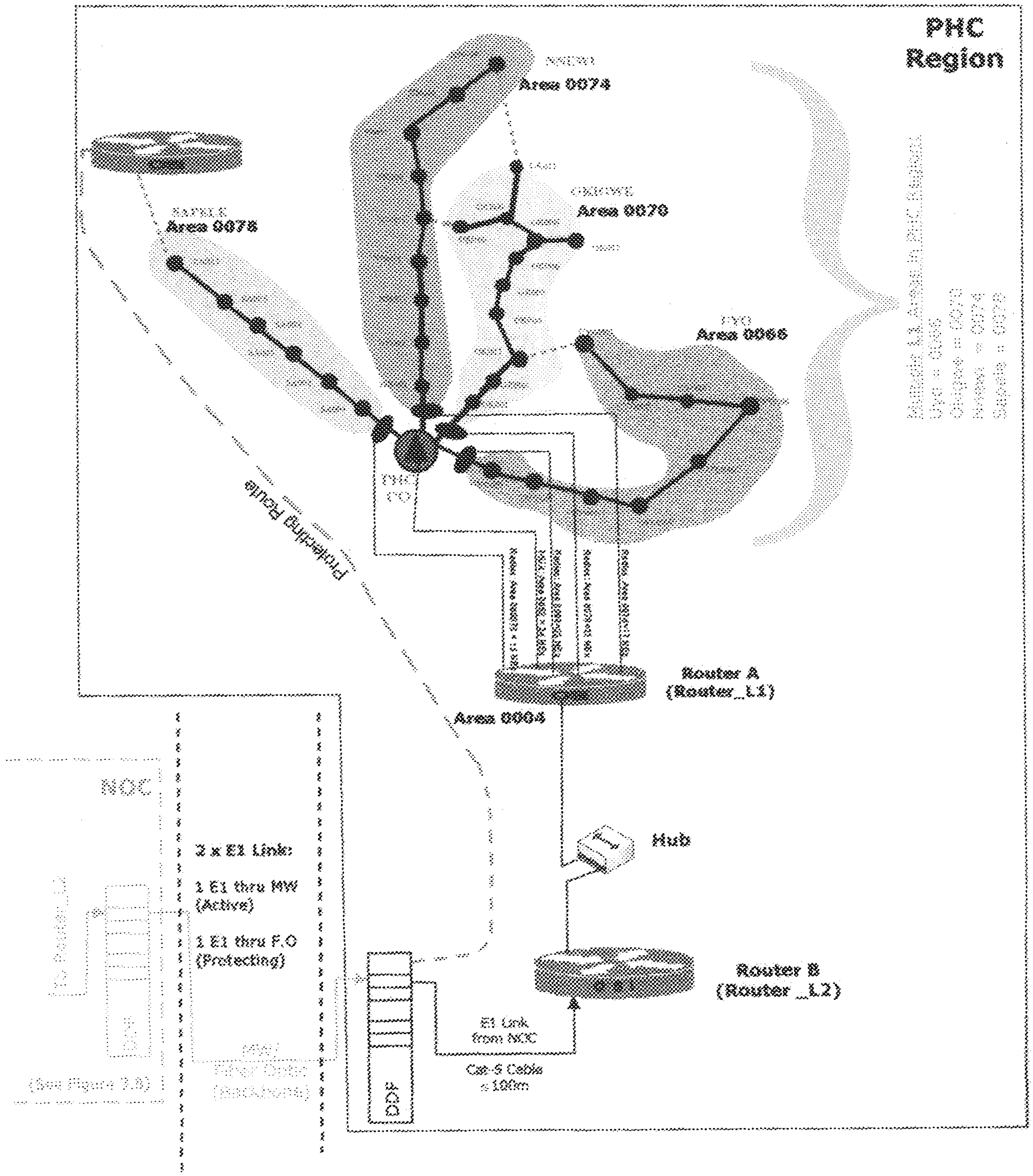


Figure 4.1: PHC Region – Physical Connecions for 4- Area IS-IS Model

Multiple OSI/IS-IS area support per router - allows multiple level-1 areas (such as Areas *0066, 0070, 0074*, and *0078* shown in Figure 4.1), to be supported in a single router. Here, multiple IS-IS instances are defined, each with a separate area address. Individual interfaces on the router are then assigned to different instances (level-1 areas). A single Level 2 area continues to exist to provide access to the backbone. The router provides connectivity between level-1 areas local to the router. This feature replaces several routers with one and saves central office space and reduces cost for the Telco.

Cisco IOS software is capable of supporting up to 12 instances (OSI Areas) in a single Cisco 3662-DC-CO router. Other considerations (resource constraints, especially CPU) may further limit the number of areas that may be supported in practice. Three instances can be supported in a Cisco 2600 Series router. In this project, Cisco 3725-DC router, which supports up to 50 instances, is used.

From our Port-Harcourt model shown in figure 4.1, for each OSI area, there is a GNE (represented with the symbol  for SDH Radios and  for ADMs). These GNEs are the gateway between the DCN and the in-band management channel, the DCC. These GNEs are respectively connected directly to corresponding Ethernet interfaces on the router, using LAN CAT-5 cross cables. And then, the corresponding Ethernet interfaces on the respective GNEs are enabled by software.

How the E1 link is structured and cross-connected hop by hop from the NOC (Lagos) to PHC (in our model) is outside the scope of this work.

4.3 IS-IS Multi-Area Configuration

4.3.1 Router_L1.

As stated in session 3.5, Router_L1 is the access router which function is to route OSI packets within its domain (PHC) only.

4.3.1.1 MAC Address

First, get the MAC address of Router_L1 Ethernet interface. To get this MAC address, we use the following command on the router's command line interface (CLI).

ROUTER_L1#*show interface fa[interface]* ↵

- where *interface* can be 0/0, 0/1, 1/1, 0/2, etc.

The number of IS-IS Level 1 processes supported depends upon the router platform. Each Level 1 IS-IS process must have a unique NSAP within an OSI area. The unique portion of the NSAP is the system identifier. The same unique system identifier must be used when creating multiple NSAPs on the Cisco 3725 router. In this example, the system identifier used is MAC address 0010.7bc7.ae40 from Ethernet port 0/1.

The MAC address is listed in the output of the *show interface* command, illustrated below (text bolded and encircled for the purpose of example):

ROUTER_L1# ***show interface fa0/1*** ↵

```
Ethernet0/0 is up, line protocol is up
Hardware is AmdP2, address is 0010.7bc7.ae40 (bia 0010.7bc7.ae40)
```

```
Internet address is 192.168.0.49/24
MTU 1500 bytes, BW 10000 Kbit, DLY 1000 usec,
reliability 255/255, txload 1/255, rxload 1/255
Encapsulation ARPA, loopback not set
Keepalive set (10 sec)
ARP type: ARPA, ARP Timeout 04:00:00
Last input 00:00:07, output 00:00:00, output hang never
Last clearing of "show interface" counters never
Input queue: 0/75/0/0 (size/max/drops/flushes); Total output drops: 0
Queueing strategy: fifo
Output queue: 0/40 (size/max)
5 minute input rate 0 bits/sec, 0 packets/sec
5 minute output rate 0 bits/sec, 0 packets/sec
4 packets input, 533 bytes, 0 no buffer
Received 3 broadcasts, 0 runts, 0 giants, 0 throttles
0 input errors, 0 CRC, 0 frame, 0 overrun, 0 ignored
0 input packets with dribble condition detected
11 packets output, 786 bytes, 0 underruns
0 output errors, 0 collisions, 4 interface resets
0 babbles, 0 late collision, 0 deferred
0 lost carrier, 0 no carrier
0 output buffer failures, 0 output buffers swapped out
```

In this project, we use **1000** as the Routing Domain number. The following example configures Router_L1, which is the access Router, to handle Level-1 (L1) functions for the four OSI areas:

39.566F.8000.0000.0000.1000.0062 → *ADMs*

39.566F.8000.0000.0000.1000.0066 → *Uyo*

39.566F.8000.0000.0000.1000.0070 → *Okigwe*

39.566F.8000.0000.0000.1000.0074 → *Nnewi*

39.566F.8000.0000.0000.1000.0078 → *Sapele*

4.3.1.2 NSAP Address

The corresponding NSAP addresses for the Cisco 3725-DC router_L1 are built with a unique system identifier and a network selector value of **00**. Remember, the chosen system identifier for this example is the MAC address obtained from the Ethernet interface 0/1, so the NSAP addresses for Cisco 3725-DC router_L1 for our respective areas are as follows:

39.566F.8000.0000.0000.1000.0062.0010.7bc7.ae40.00 → ADMs
39.566F.8000.0000.0000.1000.0066.0010.7bc7.ae40.00 → Uyo
39.566F.8000.0000.0000.1000.0070.0010.7bc7.ae40.00 → Okigwe
39.566F.8000.0000.0000.1000.0074.0010.7bc7.ae40.00 → Nnewi
39.566F.8000.0000.0000.1000.0078.0010.7bc7.ae40.00 → Sapele

4.3.1.3 Process Identifier

Each IS-IS process has an identifier. In the examples, the IS-IS process identifiers are named according to where the SDH Link is facing, as in section 4.3.1.2 (e.g: to Uyo, to Okigwe, To Nnewy, to Sapele). These names are used for clarity and maintenance purpose.

4.3.1.4 Configuration Steps

The following procedure shows the configuration steps for the IS-IS routing processes for the four areas in the PHC region:

ROUTER_L1#conf↵

ROUTER_L1(config)#router isis PHC↵

net 39.566F.8000.0000.0000.1000.0004.0010.7BC7.AE40.00↵

Configure the virtual interface as follows:

ROUTER_L1(config)#router ospf 10

ROUTER_L1(config)#router-id 3.3.3.2

ROUTER_L1(config)#log-adjacency-changes

ROUTER_L1(config)#area 4.4.4.254 virtual-link 3.3.3.1

ROUTER_L1(config)#network 10.103.32.0 0.0.0.255 area 4.4.4.254

ROUTER_L1(config)#network 192.168.0.0 0.0.255.255 area 0.0.0.0

ROUTER_L1(config)#network 0.0.0.0 255.255.255.255 area 0.0.0.0

ROUTER_L1(config)#router isis Link-To-Sapele↵

net 39.566F.8000.0000.0000.0001.0078.0010.7bc7.ae40.00 ↵

ROUTER_L1(config)#is-type level-1↵

ROUTER_L1(config)#log-adjacency↵

ROUTER_L1(config)#router isis Link-To-Nnewi↵

net 39.566F.8000.0000.0000.1000.0074.0010.7bc7.ae40.00 ↵

ROUTER_L1(config)#is-type level-1↵

ROUTER_L1(config)#log-adjacency↵

ROUTER_L1(config)#router isis Link-To-Okigwe↵

net 39.566F.8000.0000.0000.1000.0070.0010.7BC7.AE40.00 ↵

ROUTER_L1(config)#is-type level-1↵

ROUTER_L1(config)#log-adjacency↵

ROUTER_L1(config)#router isis Link-To-Uyo↵

net 39.566F.8000.0000.0000.1000.0066.0010.7BC7.AE40.00 ↵

ROUTER_L1(config)#is-type level-1↵

ROUTER_L1(config)#log-adjacency↵

ROUTER_L1(config)#router isis Link-ADMs↵

net 39.366F.8000.0000.0000.1000.0062.0010.7BC7.AE40.00 ↵

ROUTER_L1(config)#is-type level-1 ↵

ROUTER_L1(config)#log-adjacency↵

Save this configuration as follows:

ROUTER_L1(config)#ctrl+z ↵

ROUTER_L1#copy run sta ↵

Next, assign each IS-IS process to separate Ethernet interface on the router by configuring these interfaces thus:

ROUTER_L1(config)#int fa 2/0 ↵

ROUTER_L1(config)#clns router isis PHC ↵

ROUTER_L1(config)#int fa 0/0 ↵

ROUTER_L1(config)#clns router isis Link-To-Sapele ↵

ROUTER_L1(config)#int fa 0/1 ↵

ROUTER_L1(config)#clns router isis isis Link-To-Nnewi ↵

ROUTER_L1(config)#int fa 1/0 ↵

ROUTER_L1(config)#clns router isis isis Link-To-Okigwe ↵

ROUTER_L1(config)#int fa 1/1 ↵

ROUTER_L1(config)#clns router isis isis Link-To-Uyo ↵

ROUTER_L1(config)#int fa 0/2↵

ROUTER_L1(config)#clns router isis isis Link-To-ADMs ↵

Save the configuration:

ROUTER_L1(config)#CTRL+Z ↵

ROUTER_L1#copy run sta ↵

4.3.2 Router_L2

Router_L2 routes packets within and outside its domain (from PHC region to the NOC and vice-visa). The IS-IS process PHC is specified in the Cisco IOS software with the **is-type level-1-2** command, which is the Cisco IOS software default, but no **is-type** commands will be displayed in the configuration output. The PHC process will provide connectivity back to the IS-IS backbone. This process will be assigned to WAN (E1 Controller) interface (2/0) on our Router. There can be only one Level 2 IS-IS process, and each additional IS-IS process will be at Level 1. Each IS-IS process must be assigned to a separate Ethernet interface on the router. The configuration step for router-L2 is as follows:

ROUTER_L2#conf↵
ROUTER_L2(config)#controller E1 1/1↵
ROUTER_L2(config)#framing NO-CRC4↵
ROUTER_L2(config)#channel-group 0 timeslots 1↵
ROUTER_L2(config)# descrip **** Link to NOC *****↵

ROUTER_L2(config)#int serial 1/1:0 ↵
ROUTER_L2(config)#descrip **** Link to NOC ****↵
ROUTER_A_L2(config)#ip add 10.2.0.17 255.255.255.252↵
ROUTER_L2(config)#clns router isis PHC↵

ROUTER_L2(config)#router OSPF 10↵
ROUTER_L2(config)#router-id 192.168.2↵
ROUTER_L2(config)#log-adjacency-changes↵
ROUTER_L2(config)#network 192.168.204.8 0.0.0.0 area 0.0.0.0↵

ROUTER_L2(config)#network 0.0.0.0 255.255.255.255 area 0.0.0.0↵

ROUTER_L2(config)#router isis PHC↵

ROUTER_L2(config)#net 39.566f.8000.0000.0000.0001.0008.000b.fdc8.a580.00↵

ROUTER_L2(config)#is-type level-2-only↵

ROUTER_L2(config)#log-adjacency-changes↵

Connect the E1 interface (2/0) to the DDF using the cable configuration shown in Table 3.4. Connect the other interfaces to the respective NEs as shown in figure 4.1.

It is important to verify that the multi-area configuration is able to contact all the NEs in each area. Any of the following commands can be used to verify this. These commands also display the MAC address of each contacted NE.

ROUTER_L1(config)#show clns nei↵

ROUTER_L1(config)#show ip int brie↵

ROUTER_L1(config)#show isis topology↵

The results and evaluation of these commands are shown and discussed in Chapter Five.

CHAPTER FIVE

5.0 DISCUSSION, CONCLUSION& RECOMMENDATION

5.1 The ISIS Topology:

The IS-IS topology displays the paths to all intermediate systems. As shown below, the 'show ISIS Topology' is used to display a list of all connected NEs in each OSI area in the region.

Router_L1# show ISIS-top.↵

```
Area backbone:

IS-IS paths to level-1 routers
System Id          Metric     Next-Hop             Interface    SNPA
Router_L1          10       Router_L2              fa2/0       *HDLC*
Router_L1          --        NOC_Router_L2         fa2/0          *HDLC*

IS-IS path to level-2 routers
System Id         Metric      Next-Hop             Interface    SNPA
Router_L2          10       Router_L2          fa2/0        *HDLC*
Router_L2                    --

Link-SAPELE:

IS-IS paths to level-1 routers
System Id          Metric          Next-Hop            Interface      SNPA
0007.7BC7.AE40     10              0020.601A.45D9      Fa0/0           020.601a.45d9
0007.7220.8952     100             0020.601A.45D9      Fa0/0           0020.601a.45d9
0007.7222.896C     120             0020.601A.45D9      Fa0/0           0020.601a.45d9
0007.7224.E855     70              0020.601A.45D9      Fa0/0           0020.601a.45d9
0007.7230.FAF0     80              0020.601A.45D9      Fa0/0           0020.601a.45d9
0007.7265.75FA     140             0020.601A.45D9      Fa0/0           0020.601a.45d9
0007.772C.40EA     20              0020.601A.45D9      Fa0/0           0020.601a.45d9
0007.7110.8951     90              0020.601A.45D9      Fa0/0           0020.601a.45d9
0007.7753.2D6C     50              0020.601A.45D9      Fa0/0           0020.601a.45d9
0007.7724.5581     70              0020.601A.45D9      Fa0/0           0020.601a.45d9
0020.6060.2F2D     80              0020.601A.45D9      Fa0/0           0020.601a.45d9
0007.65BD.A3D2     130             0020.601A.45D9      Fa0/0           0020.601a.45d9
0020.6063.B4D2     140             0020.601A.45D9      Fa0/0           0020.601a.45d9
```

Link-NNEWI:

IS-IS paths to level-1 routers

System Id	Metric	Next-Hop	Interface	SNPA
0007.7251.427B	80	0007.7251.717A	Fa0/1	0007.7251.717a
0007.7236.DEC5	50	0007.7251.717A	Fa0/1	0007.7251.717a
0007.723C.6057	70	0007.7251.717A	Fa0/1	0007.7251.717a
0020.6017.B3A6	60	0007.7251.717A	Fa0/1	0007.7251.717a
0020.601A.70AB	30	0007.7251.717A	Fa0/1	0007.7251.717a
0020.601A.6804	80	0007.7251.717A	Fa0/1	0007.7251.717a
0020.6045.F463	130	0007.7251.717A	Fa0/1	0007.7251.717a
0020.6045.EA74	90	0007.7251.717A	Fa0/1	0007.7251.717a
0020.6045.ED12	40	0007.7251.717A	Fa0/1	0007.7251.717a
0007.7715.B77B	60	0007.7251.717A	Fa0/1	0007.7251.717a
0020.6056.5CD2	40	0007.7251.717A	Fa0/1	0007.7251.717a
0007.77C3.5075	70	0007.7251.717A	Fa0/1	0007.7251.717a
0020.6061.B3A8	60	0007.7251.717A	Fa0/1	0007.7251.717a
0020.606A.B03B	30	0007.7251.717A	Fa0/1	0007.7251.717a
0020.606A.4004	70	0007.7251.717A	Fa0/1	0007.7251.717a
0020.6065.3463	110	0007.7251.717A	Fa0/1	0007.7251.717a
0020.6064.AE74	120	0007.7251.717A	Fa0/1	0007.7251.717a
0020.606D.ED21	90	0007.7251.717A	Fa0/1	0007.7251.717a

Link-OKIGWE:

IS-IS paths to level-1 routers

System Id	Metric	Next-Hop	Interface	SNPA
0020.604A.815D	80	0020.604A.899C	Fa1/0	0020.604a.899c
0020.604A.985F	60	0020.604A.899C	Fa1/0	0020.604a.899c
0020.6059.9D9C	100	0020.604A.899C	Fa1/0	0020.604a.899c
0020.6059.9D9D	90	0020.604A.899C	Fa1/0	0020.604a.899c
0020.6059.9D9E	110	0020.604A.899C	Fa1/0	0020.604a.899c
0020.6059.9DDF	100	0020.604A.899C	Fa1/0	0020.604a.899c
0020.606E.66DF	110	0020.604A.899C	Fa1/0	0020.604a.899c
0020.606E.66EA	90	0020.604A.899C	Fa1/0	0020.604a.899c
0020.606E.6704	110	0020.604A.899C	Fa1/0	0020.604a.899c
0020.606E.6712	150	0020.604A.899C	Fa1/0	0020.604a.899c
0020.606E.6743	130	0020.604A.899C	Fa1/0	0020.604a.899c
0020.604D.51D5	70	0020.604A.899C	Fa1/0	0020.604a.899c
0020.604A.F985	50	0020.604A.899C	Fa1/0	0020.604a.899c
0020.605D.C34A	90	0020.604A.899C	Fa1/0	0020.604a.899c
0020.6050.9D92	30	0020.604A.899C	Fa1/0	0020.604a.899c
0020.6053.8008	20	0020.604A.899C	Fa1/0	0020.604a.899c
0020.605C.FF22	60	0020.604A.899C	Fa1/0	0020.604a.899c
0020.606E.62AF	100	0020.604A.899C	Fa1/0	0020.604a.899c
0020.606B.82EA	120	0020.604A.899C	Fa1/0	0020.604a.899c
0020.606E.4004	110	0020.604A.899C	Fa1/0	0020.604a.899c
0020.606D.1D12	150	0020.604A.899C	Fa1/0	0020.604a.899c
0020.606F.3473	140	0020.604A.899C	Fa1/0	0020.604a.899c

Link-UYO:

IS-IS paths to level-1 routers

System Id	Metric	Next-Hop	Interface	SNPA
0020.606E.8793	130	0020.606E.6947	Fa1/1	0020.606e.6947
0020.606E.7067	130	0020.606E.6947	Fa1/1	0020.606e.6947
0020.9F2D.2BFD	100	0020.606E.6947	Fa1/1	0020.606e.6947
0020.9F2D.9E72	30	0020.606E.6947	Fa1/1	0020.606e.6947
0020.9F2D.9DF2	30	0020.606E.6947	Fa1/1	0020.606e.6947
0020.9F2D.9AF3	30	0020.606E.6947	Fa1/1	0020.606e.6947
0020.606E.6212	150	0020.606E.6947	Fa1/1	0020.606e.6947
0020.606E.6943	130	0020.606E.6947	Fa1/1	0020.606e.6947
0020.606E.6343	30	0020.606E.6947	Fa1/1	0020.606e.6947
0020.606E.8793	140	0020.606E.6947	Fa1/1	0020.606e.6947
0020.606E.7067	90	0020.606E.6947	Fa1/1	0020.606e.6947
0007.772A.5BD4	120	0020.606E.6947	Fa1/1	0020.606e.6947
0020.602D.1E5F	130	0020.606E.6947	Fa1/1	0020.606e.6947
0020.601A.3D1E	70	0020.606E.6947	Fa1/1	0020.606e.6947
0020.60BA.8B22	50	0020.606E.6947	Fa1/1	0020.606e.6947
0020.606B.6343	60	0020.606E.6947	Fa1/1	0020.606e.6947
0020.606F.7A2D	130	0020.606E.6947	Fa1/1	0020.606e.6947
0020.606A.34F1	130	0020.606E.6947	Fa1/1	0020.606e.6947

Link-ADM:

IS-IS paths to level-1 routers

System Id	Metric	Next-Hop	Interface	SNPA
0020.606E.7695	130	0020.606E.6794	Fa0/2	0020.606e.6794
0020.606E.7A67	130	0020.606E.6794	Fa0/2	0020.606e.6794
0020.9F2D.2DFD	100	0020.606E.6794	Fa0/2	0020.606e.6794
0020.9F2D.9072	30	0020.606E.6794	Fa0/2	0020.606e.6794
0020.9F2D.9FF2	30	0020.606E.6794	Fa0/2	0020.606e.6794
0020.9F2D.9BF3	30	0020.606E.6794	Fa0/2	0020.606e.6794
0020.606E.6142	150	0020.606E.6794	Fa0/2	0020.606e.6794
0020.606E.6643	130	0020.606E.6794	Fa0/2	0020.606e.6794
0020.606E.6354	10	0020.606E.6794	Fa0/2	0020.606e.6794
0020.606A.6759	130	0020.606E.6794	Fa0/2	0020.606e.6794
0020.606C.67A5	120	0020.606E.6794	Fa0/2	0020.606e.6794
0020.602B.D2D2	100	0020.606E.6794	Fa0/2	0020.606e.6794
0020.602A.0055	30	0020.606E.6794	Fa0/2	0020.606e.6794
0007.772D.2A2F	30	0020.606E.6794	Fa0/2	0020.606e.6794
0020.9F2D.AAF3	30	0020.606E.6794	Fa0/2	0020.606e.6794
0007.606B.2416	130	0020.606E.6794	Fa0/2	0020.606e.6794
0020.606D.1834	130	0020.606E.6794	Fa0/2	0020.606e.6794
0007.7211.1EA2	110	0020.606E.6794	Fa0/2	0020.606e.6794
0007.7722.5966	130	0020.606E.6794	Fa0/2	0020.606e.6794
0007.7344.A667	130	0020.606E.6794	Fa0/2	0020.606e.6794
0020.606B.555A	100	0020.606E.6794	Fa0/2	0020.606e.6794
0020.606A.00B2	20	0020.606E.6794	Fa0/2	0020.606e.6794
0020.6066.C22F	30	0020.606E.6794	Fa0/2	0020.606e.6794
0020.606D.B93F	60	0020.606E.6794	Fa0/2	0020.606e.6794
0020.606E.1426	100	0020.606E.6794	Fa0/2	0020.606e.6794
0020.606E.3442	120	0020.606E.6794	Fa0/2	0020.606e.6794
0020.606F.99CA	110	0020.606E.6794	Fa0/2	0020.606e.6794
0020.606D.8234	120	0020.606E.6794	Fa0/2	0020.606e.6794
0020.606A.A767	130	0020.606E.6794	Fa0/2	0020.606e.6794
0020.606B.5890	120	0020.606E.6794	Fa0/2	0020.606e.6794
0020.6064.271B	130	0020.606E.6794	Fa0/2	0020.606e.6794
0020.606D.111B	50	0020.606E.6794	Fa0/2	0020.606e.6794

0007.7721.3F9B	60	0020.606E.6794	Fa0/2	0020.606e.6794
0007.7711.BA22	70	0020.606E.6794	Fa0/2	0020.606e.6794
0020.606D.2234	100	0020.606E.6794	Fa0/2	0020.606e.6794

Explanations

System ID: The system identifier of the neighbouring NE.

Metric: A relative cost for sending information over this interface.

Next-Hop: The system identifier of the next hop from the neighbouring system.

Interface: The interface over which the adjacency was established.

SNPA: The neighbour's MAC address on a broadcast network.

Evaluation of the Result of the 'show ISIS Topology'

Comparing this result with table 3.2, we can verify, by counting the total number of NEs in the 'system Id' field for each area, that all the NEs in each area in the region were all learned.

Total number of mw radion NEs under Sapele area = 13

Total number of mw radion NEs under Nnewi area = 19

Total number of mw radion NEs under Okigwe area = 23

Total number of mw radion NEs under Uyo area = 19

Total number of mw radion NEs under ADM area = 35

This result shows that the NEs in this region are able to be managed from the NOC.

Furthermore, the 'interface' field in each area in the 'show isis topology' matches the designated interfaces earlier specified in Plate VII and in section 4.3.1.4 respectively.

Initiating the 'show IS-IS topology' from the resilience path (Router_Resilience), instead of the the active path (Router_L1), the same number of NEs were learned, with only varying routing matric which is normal because of the route taking, thus:

Router_Resilience# show ISIS top↵

PHC Region:

IS-IS paths to level-1 routers

System Id	Metric	Next-Hop	Interface	SNPA
0007.7BC7.AE40	20	0020.601A.45D9	Fa1/1	0020.601a.45d9
0007.7220.8952	50	0020.601A.45D9	Fa1/1	0020.601a.45d9
0007.7222.896C	20	0020.601A.45D9	Fa1/1	0020.601a.45d9
0007.7224.E855	30	0020.601A.45D9	Fa1/1	0020.601a.45d9
0007.7230.FAF0	10	0020.601A.45D9	Fa1/1	0020.601a.45d9
0007.7265.75FA	40	0020.601A.45D9	Fa1/1	0020.601a.45d9
0007.772C.40EA	20	0020.601A.45D9	Fa1/1	0020.601a.45d9
0007.7110.8951	30	0020.601A.45D9	Fa1/1	0020.601a.45d9
0007.7753.2D6C	50	0020.601A.45D9	Fa1/1	0020.601a.45d9
0007.7724.5581	15	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.6060.2F2D	20	0020.601A.45D9	Fa1/1	0020.601a.45d9
0007.65BD.A3D2	60	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.6063.B4D2	50	0020.601A.45D9	Fa1/1	0020.601a.45d9
0007.7251.427B	90	0020.601A.45D9	Fa1/1	0020.601a.45d9
0007.7236.DEC5	70	0020.601A.45D9	Fa1/1	0020.601a.45d9
0007.723C.6057	70	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.6017.B3A6	80	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.601A.70A	130	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.601A.6804	100	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.6045.F463	100	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.6045.EA74	120	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.6045.ED12	130	0020.601A.45D9	Fa1/1	0020.601a.45d9
0007.7715.B77B	60	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.6066.5CD2	40	0020.601A.45D9	Fa1/1	0020.601a.45d9
0007.77C3.5075	70	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.6061.B3A8	6	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.606A.B03B	30	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.606A.4004	70	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.6065.3463	110	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.6064.AE74	120	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.606D.ED21	90	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.604A.815D	80	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.604A.985F	60	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.6059.9D9C	100	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.6059.9D9D	90	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.6059.9D9E	110	0020.601A.45D9	Fa1/1	0020.601a.45d9

0020.6059.9DDF	100	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.606E.66DF	110	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.606E.66EA	90	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.606E.6704	110	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.606E.6712	150	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.606E.6743	130	0020.601A.45D9	Fa1/1	0020.601a.45dd
0020.604D.51D5	70	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.604A.F985	50	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.605D.C34A	90	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.6050.9D92	30	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.6053.8008	20	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.605C.FF22	60	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.606E.62AF	100	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.606B.82EA	120	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.606E.4004	110	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.606D.1D12	150	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.606F.3473	140	0020.601A.45D9	Fa1/1	0020.601a.45d9

0020.606E.8793	130	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.606E.7067	130	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.9F2D.2BFD	100	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.9F2D.9E72	30	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.9F2D.9DF2	30	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.9F2D.9AF3	30	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.606E.6212	150	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.606E.6943	130	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.606E.6343	30	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.606E.8793	140	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.605E.7067	90	0020.601A.45D9	Fa1/1	0020.601a.45d9
0007.772A.5BD4	120	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.602D.1E5F	130	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.601A.3D1E	70	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.60BA.8B22	50	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.606B.6343	60	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.605F.7A2D	130	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.606A.34F1	130	0020.601A.45D9	Fa1/1	0020.601a.45d9

0020.606E.7695	130	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.606E.7A67	130	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.9F2D.2DFD	100	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.9F2D.9072	30	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.9F2D.9FF2	30	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.9F2D.9BF3	30	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.606E.6142	150	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.606E.6643	130	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.606E.6354	10	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.606A.6759	130	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.606C.67A5	120	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.602B.D2D2	100	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.602A.0055	30	0020.601A.45D9	Fa1/1	0020.601a.45d9
0007.772D.2A2F	30	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.9F2D.AAF3	30	0020.601A.45D9	Fa1/1	0020.601a.45d9
0007.606B.2416	130	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.606D.1834	130	0020.601A.45D9	Fa1/1	0020.601a.45d9
0007.7211.1EA2	110	0020.601A.45D9	Fa1/1	0020.601a.45d9
0007.7722.5966	130	0020.601A.45D9	Fa1/1	0020.601a.45d9
0007.7344.A667	130	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.606B.555A	100	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.606A.00B2	20	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.6066.C22F	30	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.606D.B93F	60	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.606E.1426	100	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.606E.3442	120	0020.601A.45D9	Fa1/1	0020.601a.45d9

0020.606F.99CA	110	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.606D.8234	120	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.606A.A767	130	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.606B.5890	120	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.6064.271B	130	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.606D.111B	50	0020.601A.45D9	Fa1/1	0020.601a.45d9
0007.7721.3F9B	60	0020.601A.45D9	Fa1/1	0020.601a.45d9
0007.7711.BA22	70	0020.601A.45D9	Fa1/1	0020.601a.45d9
0020.606D.2234	100	0020.601A.45D9	Fa1/1	0020.601a.45d9

5.2 Clns Neighbour Database

The show clns neighbour command displays information about Intermediate System-to-Intermediate System (IS-IS) neighbours and the areas to which they belong, verifying also that all expected adjacencies are up with all neighbours.

Router_L1# show clns nei↵

System Id	Interface	Area Name	State	Holdtime	Type	Protocol
0020.601A.45D9	fa0/0	SAPELE	Up	26	L1	IS-IS
0007.7251.717A	fa0/1	NNEWI	Up	26	L1	IS-IS
0020.604A.899C	Fa1/0	OKIGWE	Up	21	L1	IS-IS
0020.606E.6947	Fa1/1	UYO	Up	28	L1	IS-IS
0020.606E.6794	Fa0/2	ADM	Up	22	L1	IS-IS
0000.0000.0053	Fa2/0	ROUTER_L2	Up	23	L1L2	IS-IS

System Id: This field shows the MAC Addresses of the all the GNEs (that is the NEs directly connected to Router_L1).

Interface: this field shows the interface on the router_L1 where the GNE was learned.

Area Name: Indicates the area where each of the listed GNE belongs.

State: indicates the status of the adjacency, whether it is up (on) or down (off).

Holdtime: Number of seconds before this adjacency entry times out.

Type:

L1—Router adjacency for Level 1 routing only.

L1L2—Router adjacency for Level 1 and Level 2 routing.

L2—Router adjacency for Level 2 only.

Protocol: Indicates the protocol through which the adjacency was learned. In this case IS-IS.

5.2 Conclusion

From the displayed database results of the 'show IS-IS topology' and the 'show CLNS Neighbour' commands, all the NEs and their respective area were learned through both the active path and resilience paths. This means that in the event of failure along the primary (Active) path, all the NEs in the region can still be managed through the secondary (resilience) path. From this result, one can humbly say here that the objective of this project has been met.

5.3 Recommendations

Telecommunication industries should build a resilience management path into their existing management scheme, to enhance effective monitoring, reduce down time and drastically, reduce operational cost.

I also recommend that data communication syllabus be expanded to accommodate modern techniques applicable in Telecommunication industries. This will not only enrich the student's knowledge, but will also, prepare them for its application in the telecommunication Industries.

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