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College of Science

Network Management System for Public Services

A Thesis
Submitted to college of Science, Al-Nahrain University in partial fulfillment of the requirements for the Degree of Master of Science in Computer Science

BY

HAIDER MAJEED JABER AL-BAKRY

(B. Sc. 2003)

Supervisor

DR. LOAY E. GEORGE

Safar 1428 **February 2007**

بسم الله الرحمن الرحيم

((وَأَن لَّيْسَ لِلإِنسَٰنِ
إِلاَّ مَا سَعَىٰ))

صدق الله العلي العظيم

النجم٣٩

Supervisor Certification

I certify that this thesis was prepared under our supervision at the Department of Computer Science/College of Science/Al-Nahrain University, by **Haider Majeed Jaber** as partial fulfillment of the requirements for the degree of Master of Science in Computer Science.

Signature:
Name : **Dr. Loay E. George**
Title : **Assist. Prof.**
Date : / / **2006**

In view of the available recommendations, I forward this thesis for debate by the examination committee.

Signature:
Name : **Dr. Taha S. Bashaga**
Title : **Head of the department of Computer Science,**
Al-Nahrain University.
Date : / / **2006**

Certification of the Examination Committee

We chairman and members of the examination committee, certify that we have studies this thesis "**Network Management System for Public Services**" presented by the student **Haider Majeed Jaber** and examined her in its contents and that we have found it worthy to be accepted for the degree of Master of Science in Computer Science.

Signature:
Name: **Dr. Kader H. AL-Shara**
Title : **Assist. Prof.**
Date : **/ /2007**

(Chairman)

Signature:
Name: **Dr.Kamal M. Abood**
Title : **Assist. Prof.**
Date : **/ /2007**

(Member)

Signature:
Name: **Dr. Sawsan K. Thamer**
Title : **Lecturer**
Date : **/ /2007**

(Member)

Signature:
Name: **Dr. Loay E. George**
Title : **Assist. Prof.**
Date : **/ /2007**

(Supervisor)

Approved by the Dean of the Collage of Science, Al-Nahrain University.

Signature:
Name: **Dr. LAITH ABDUL AZIZ AL-ANI**
Title : **Assist. Prof**.
Date : **/ /2007**

(Dean of Collage of Science)

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Signature:
Name: **Dr. Kader H. AL-Shara**
Title : **Assist. Prof.**
Date :20/ 3 /2007

(Chairman)

Signature: Kamal
Name: **Dr.Kamal M. Abood**
Title : **Assist. Prof.**
Date :20/ 3 /2007

(Member)

Signature:
Name: **Dr. Sawsan K. Thamer**
Title : **Lecturer**
Date : 20/ 3 /2007

(Member)

Signature:
Name: **Dr. Loay E. George**
Title : **Assist. Prof.**
Date : 20/ 3 /2007

(Supervisor)

Approved by the Dean of the Collage of Science, Al-Nahrain University.

Signature:
Name: **Dr. LAITH ABDUL AZIZ AL-ANI**
Title : **Assist. Prof.**
Date : / /2007

(Dean of Collage of Science)

DEDICATED TO

MY PARENTS …
MY SISTER …
MY BROTHERS …

To everyone
Taught me a letter

Haider

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Haider

ABSTRACT

Due to the expansion of the data transmission capabilities, it is utilized to make many services easier, efficient, and more controlled. The public services are more effective if they have online data transmission to get faster request servicing, maintenance, and control.

This project is concerned with designing and implementing a dedicated network management system prototype. Also, it concerned with building the necessary application software tools which may needed for managing public services (electricity, water, medical help alarm, police monitoring, and fire monitoring). It toke into consideration that the distributed system must be reliable, real time, secure, and scalable. The project tried to achieve these considerations on two levels, the first is by suggesting system layout and hardware that may provide an acceptable solution, and the second is by the applications and protocols designed.

This thesis shows the layout of the system that composed of four major parts: *customer's agent*, *service provider*, *zone center*, and *primary center*. The geographic area covered by the system was divided into regions called *zones*; each zone contains customers and may contain service providers. Each zone is controlled by network management station called *zone center* that monitor and receive alarms from the agents and send it to the appropriate nearest (estimated) available service provider. All the zone centers are controlled by one primary network management station called *primary center*. The primary center monitors and connects all zone centers together, and plays as a backup station in case of shutting down one of the zone centers.

The project suggests the connection media to be used (for example, using Power Line Communication (PLC) to connect the customers with zone center, because the power line infrastructure is already exist), using cluster of computers in each center, and distributed backup places to achieve maximal possible reliability with good performance. The designed system uses the Internet Protocol version 6 (IPv6) as the network protocol to support addressing huge number of customers, quality of service, support the anycast message type (which decrease the difficulty of building clusters), and the facility of leaving the unused options to increase performance. Also, the Simple Network Management Protocol version 2 (SNMPv2) was utilized because it is simple in development and takes low bandwidth, and it was adopted to achieve more security.

In this project a distributed database was established, and the two problems: data synchronization and the way of data storage to achieve an acceptable performance within the multi-threaded system were handled. The project prototype was established by using Microsoft Visual Basic .NET 2003 which depends on the .NET framework that supports the multi-threaded system with good utilization.

List of Abbreviations

API	Application Programming Interfaces
ARIN	American Registry for Internet Numbers
ARP	Address Resolution Protocol
ASP	Active Server Pages
ATM	Asynchronous Transfer Mode
BER	Basic Encoding Rules
CAN	Campus Area Network
CBC-DES	Cipher Block Chaining mode to the Data Encryption Standard
CCITT	The Comité Consultative Internationale de Telegraphique et Telephonique
CIDR	Classless Inter Domain Routing
CIMOM	Common Information Model Object Manager
CLR	Common Language Runtime
CLS	Common Language Specification
CMIP	Common Management Information Protocol
CMIS	Common Management Information Service
CMIS/CMIP	Common Management Information Service/Common Management Information Protocol
CTS	Common Type System
DBMS	Database Management System
DES	Data Encryption Standard
DHCP	Dynamic Host Configuration Protocol
DMTF	Desktop Management Task Force
FDDI	Fiber Distributed Data Transfer
FTP	File Transfer Protocol
GIS	Geographic Information System
GPS	Global Positioning System
HV/MV	High Voltage/ Medium Voltage
HE	Head End
HMAC	Hashing for Message Authentication

HMAC-MD5-128	Hash Message Authentication Code key with Message Digest Code with output of 128-bit
HT Technology	Hyper-Threading Technology
HTTP	Hyper Text Transfer Protocol
IAB	Internet Architecture Board
IANA	Internet Assigned Number Authority
ICMPv6	Internet Control Message Protocol for IPv6
IESG	Internet Engineering Steering Group
IETF	Internet Engineering Task Force
InterNIC	Internet Network Information Center
IPng	IP Next Generation
IPv4	Internet Protocol-version 4
IPv6	Internet Protocol version 6
ISO	The International Organization for Standardization
ISP	Internet Service Provider
ITU-T	Telecommunication Standardization Sector of the International Telecommunication Union
JMX	Java Management Extension
LANs	Local Area Networks
LV	low-voltage
MA	Mobile agent
MAC	Media Access Control
MAN	Metropolitan Area Network
MAU	Media Access Unit
MBeans	Manageable Beans
MD5	Message Digest 5
MIB	Management Information Base
MSIL	Microsoft Intermediate Language
MV/LV	medium-voltage/low-voltage
NAT	Network Address Translating
NMS	Network Management System
OID	Object Identifier
OSI	Open Systems Interconnection
PAN	Personal Area Networ
PAL	Personal Alert Link

PDU	Protocol Data Unit
PLC	Powerline communication
PPP	Point to Point Protocol
QoS	Quality of Service
RAN	Residential Area Networ
RMON	Remote Network Monitoring
RFC	Request For Comment
SHA-1	Secure Hash Algorithm 1
SLA	Site Level Aggregator
SMI	Structure of Management Information
SMTP	Simple Mail Transfer Protocol
SNMP	Simple Network Management Protocol
SNMPv1	Simple Network Management Protocol version 1
SNMPv2	Simple Network Management Protocol version 2
SNMPv3	Simple Network Management Protocol version 3
SRENA	Secure Remote Emergency Network Administration
TCP	Transmission Control Protocol
TMN	Telecommunications Management Network
UDP	User Datagram Protocol
UML	Unified Modeling Language
USM	User-Based Security Model
VACM	View-Based Access Control Model
WAN	Wide Area Network
WBEM	Web-Based Enterprise Management
WBM	Web-based management
xmlCIM	Extensible Markup Language Common Information Model

List of Contents

Subject **Page No.**

Subject **Page No.**

CHAPTER ONE

CHAPTER ONE
GENERAL INTRODUCTION

1.1 Preface

The expansion of the data transmission capabilities is utilized to make many services easier, efficient, and more controlled. The public services (like electricity measurements, water measurements, medical help alarm, police monitoring, and fire monitoring) are more effective if they have online data transmission to get faster request servicing, maintenance, and control. These operations must be under control and monitoring to ensure their best performance. The network control, configuring, and monitoring tasks are called *Network Management* which is established by a *Network Management System (NMS)*, such system try to make the management of devices and data flow in the network system easy to maintain [MEL98].

Network management is the task of monitoring, configuring and maintaining a network environment. Network management can be divided into a number of areas such as fault management, performance management, configurations management, security management and accounting management. Fault management detect, isolate, notify, and correct faults encountered in the network, while performance management means the collection of network traffic analysis task to keep the data throughput overall network elements is close to its designed correspondence. Configurations management consists of tasks such as installation, administration and configure network components. Security management control access to services with the purpose of protecting sensitive information from unauthorized access. Accounting Management is concerned with the allocation of resources within a networked system and charging for their services [TER02].

Central to the theme of network management are the two concepts: "*manager*" and "*agent*". The model of manager/agent is based on the Client/Server model. The Client/Server model consists of the concept that the client request a service from the server and the server respond with the appropriate respond upon the service requested. Sometimes the same node contains the server and the client.

In the network management system, the agent is the server that provides information about the devices it monitor and the manager is the client that request services (get or set information about the device or other information). The responsibility of the manager (it also called network management station or network management center) is to monitor and control the agents. An agent is a software component residing in a networked appliance that is responsible for monitoring and controlling the environment in which it operates. This includes any device connected to the network through a network interface that can be reached by the network management station. A single network management station can manage a variety of agents [MEL98].

Network management can be implemented by utilizing various models based on their type and size. Basically, there are two management models that can be used, they are centralized management and distributed management. Centralized management enables the centralization of management control and responsibility in one location. This is ideal for systems that are limited in size or geographically isolated. Distributed management enables the distribution of management control and responsibility. Distributed models provide management for large geographically distributed systems; they are also beneficial when the critical network resources must be conserved [MEL98]. Usually, the management in the distributed model is organized as multi-level managers, where the mid-level managers are responsible of their own domain, but whose manage those managers is the manager of managers which control and monitor those managers and synchronize their work if needed.

There are many standards protocols to define how to exchange data and alarms between the agent and manager in the network management system (like Common Management Information Protocol (CMIP), Simple Network Management Protocol (SNMP), and Remote Monitoring (RMON)).

Each of the manager and agent holds database. The agent holds monitoring information about the device it monitors. The manager stores information about each device it responsible of (for example location, device status, alarms received, maintenance information, etc) and other information (for example customers account, authorities, etc) needed. The data stored in the database are either permanent (for example, information about the devices connected in the system) or temporary for a period of time until expired (for example, alarms are expired after a period of time).

1.2 Literature Survey

- **Pras 1995 [PRA95]:** In his Ph.D. thesis (named "*Network Management Architectures*"), he analyzed the two primary network architectures: OSI and TMN Management architectures which are defined by ISO and ITU-T respectively. Also, he analyzed the Internet Management represented by SNMP (which was defined by IETF). He compared between them and proposed alternate network management architecture based on the concepts of OSI architecture, and he solved most the problems in the architectures discussed.

- **Sandlund 2001 [SAN01]:** In his M.Sc. thesis (entitled "*Network management using WBEM - Web-Based Enterprise Management*"), he evaluated the different parts that make up the WBEM standard and found that WBEM is extremely versatile and generalized standard that can be applied in almost any area of network management. Also, he compared between the WBEM and SNMP and noticed that the SNMP has better performance than WBEM. He built a prototype of a WBEM access module for NMS to see if his theoretical conclusions hold up. The results of his work showed that WBEM will most likely have a large impact on how network management is performed and most NMS systems have to consider the support of WBEM. But he also showed that on a network with limited bandwidth, WBEM might not be an ideal choice for the manager.
- **OutPost Sentinel Company 2002 [SER02]:** Had built *Secure Remote Emergency Network Administration* (SRENA) system, which was designed to monitor and manage servers and intelligent devices both locally (through TCP/IP) and remotely out of network. The system uses Simple Network Management Protocol (SNMP) to monitor and control the fire alarm devices.
- **Terlegård 2002 [TER02]:** In his M.Sc. thesis (named "*Design of a Secure Network Management System*"), he designed a new NMS that deals with devices that support standard protocols (like SNMP and CMIP) by making an intermediate layer which work as a translator between the standard protocol and his new protocol. This thesis concerned to make a new protocol with more flexibility and security.
- **Uzuner 2002[UZU02]:** In his Ph.D. thesis (entitled "*Integrated Network Management Systems*"), he attempted to find a universally applicable metric which measures the costs of complexity and

establishing principles for making network architecture decisions (such as choice of topology and infrastructure) based on market value and service provider strategy. He built a simulation system to test the studied architecture.

- **Lee and Hsu 2004 [LEE04]:** Had presented an object-oriented approach to achieve the systematical design and implementation of SNMP agents for remote monitoring and control systems. They applied standard Unified Modeling Language (UML) and Petri-net model on the system to achieve both qualitative and quantitative analysis for the system's dynamic behavior. The developed system has been used successfully in a mobile switching center of Taiwan Cellular Corporation for the remote monitoring and control, through the Internet, of its environmental conditions, including the temperature, humidity, power, and security, with a total 316 sensors and 140 actuators.
- **PAV Data Systems Ltd [PAV05]:** Had built *NIMBUS Network Management System*, which is a graphical user interface application that has central site comprising of a single application server, running Microsoft Windows NT4 or 2000. The client's sensors monitored through PSTN or GSM. It responses to fire and security alarms.
- **TelleAlarm Group Company [PAL05]:** Had introduced *PAL Medical alert system* where PAL stands for Personal Alert Link. It is a Medical Monitoring Center responds to device panic buttons distributed in the customer places. When an alert comes to the Medical Monitoring Center, the operator calls the customer to confirm the alert, if he didn't answer then and according to the medical history of the customer, the operator dispatches the necessary assistance. The alarms sent by wireless connection.

1.3 Aim of Thesis

The aim of this thesis is to design and build a dedicated network management system. Also, it concerned with building the necessary application software tools which may needed for managing public services (electricity, water, medical help alarm, police monitoring, and fire monitoring). It toke into consideration that the distributed system must be reliable, real time, secure, and scalable.

The services are scheduled according to their priorities, to give the most important service the privilege to be served first. For example, if water is cut off and fire happen the priority is to the fire alarm to be sent first and served first. The system must provide statistics and reports that give the manager an overall description about the system performance, the type of alarms occur frequently, the time that the alarm spent to be received by the manager, the time spent to send the alarm to service provider, the places with large number of alarms, and the time varying load on specific service providers. Those reports and statistics will help the manager to decide how to improve the system performance, if it is needed, and let him to assess the future occurrence of some problems.

1.4 Thesis Outline

- **Chapter Two**

  This chapter concerned with the definition of network system, its models, its protocols, and specifically make some highlights on the future Internet Protocol (IPv6). Then define the Network Management System, its concept, its protocols and architectures. Also describes the Power Line Communication (PLC) and the .NET framework.

- **Chapter Three**

This chapter introduces the design of the network management system for public services (electricity power measurement and maintenance, water measurement and maintenance, medical help alarm, fire monitoring, and security monitoring) and its necessary application software tools.

- **Chapter Four**

This chapter introduces the time diagrams of the main operations in the system and estimations for response and validation time.

- **Chapter Five**

This chapter introduces the conclusions and the suggested future work.

CHAPTER TWO

CHAPTER TWO

NETWORK PROTOCOLS AND MANGEMENT

2.1 Introduction

A computer network is an interconnected system of computing devices that provides shared economical access to computer services. Networks are important since they provide several benefits such as resource sharing, saving money, etc.

Networks can be divided into Local Area Networks (LANs), Metropolitan Area Networks (MANs), and Wide Area Networks (WANs), each network type has its own characteristics, technologies, speeds, and niches. LANs cover a building and operate at high speeds. MANs cover a city (for example, the cable television system) which is now used by many people to access the internet. WANs cover country or continent. LANs and MANs are unswitched (i.e. do not have routers); WANs are switched. Networks can be interconnected to form internetworks. [TAN03]

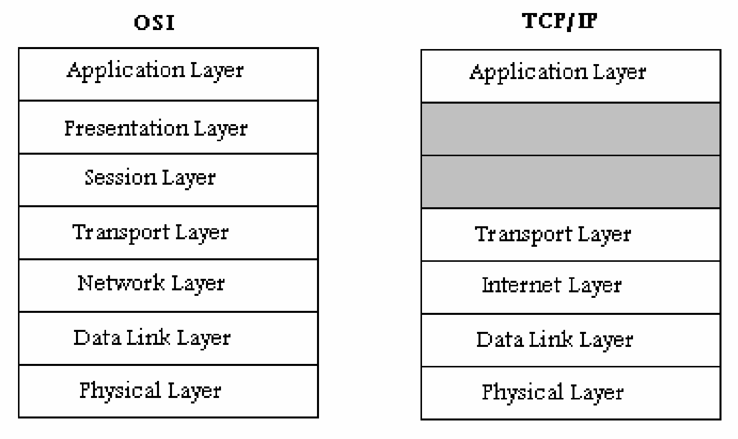
Computers can be connected in several topologies like bus, star, and ring. For more information see appendix A.

2.2 Network Models

A Network model also referred to as protocol suits reflects the design or architecture to accomplish communication between different systems. A network model usually consists of layers. Each layer of a model represents specific functionality. [Hel00]

There are two important network models: (1) International Standard Organization/Open System Interconnection (ISO/OSI) model and (2) Transmission Control Protocol/Internet Protocol (TCP/IP) model. The protocols associated with ISO/OSI model are rarely used any more while the protocols of the TCP/IP model are widely used [TAN03]. TCP/IP works in a very similar manner to OSI model in that it takes a layered approach to provide network services [Hel00]. The OSI has 7-layers but the

TCP/IP has 5-layers as shown in the Figure (2.1). Only the TCP/IP layers are introduced in the following section.



OSI	TCP/IP
Application Layer	Application Layer
Presentation Layer	
Session Layer	
Transport Layer	Transport Layer
Network Layer	Internet Layer
Data Link Layer	Data Link Layer
Physical Layer	Physical Layer

Fig.(2.1) OSI and TCP/IP layers

2.3 TCP/IP Layers

As shown in Figure (2.1) the TCP/IP model consists of the following five layers:

1. **Application Layer**: The application layer is responsible for supporting network applications. The application layer includes many protocols, including Hyper Text Transfer Protocol (HTTP) to support the Web, Simple Mail Transfer Protocol (SMTP) to support electronic mail, and File Transfer Protocol (FTP) to support file transfer [KUR01].

2. **Transport Layer**: The transport layer provides the service of transporting application-layer messages between the client and server sides of an application. In the Internet there are two transport protocols, Transmission Control Protocol (TCP) and User Datagram Protocol (UDP), either of which can transport application-layer messages. TCP provides a connection-oriented service to its applications. This service includes guaranteed delivery of application-layer messages to the destination and flow control (that is, sender/receiver speeds matching). TCP also segments long messages into shorter segments, and provides a congestion control mechanism, so that a source throttles its transmission rate when the network is congested.

The UDP protocol provides its applications a connectionless service [KUR01]. It does not do flow control, error control, or retransmission upon receipt of a bad segment. Both TCP and UDP have in its header the source and destination port numbers. The two ports serve to identify the end points within the source and destination machines. The port number is 16-bit integer. (i.e. Ports are numbered 1 through 65535). Port numbers below 1024 are called well-known ports and are reserved standard services. For example, any process wishes to establish a connection to a host to transfer a file using FTP can connect to the destination host's port 21 to contact its FTP daemon [TAN03].

3. **Internet Layer**: Its job is to permit hosts to inject packets into any network, and have them travel independently to the destination (potentially on a different network). They may even arrive in a different order than they were sent; it is the job of higher layers to rearrange them (if in-order delivery is desired). Note that "internet" is used here in a generic sense, even though this layer is present in the Internet.

   The job of the Internet layer is analogous to the mail system. A person can drop a sequence of international letters into a mail box in one country, and with a little luck most of them will be delivered to the correct address in the destination country. Probably the letters will travel through one or more international mail gateways along the way, but this is transparent to the users. Furthermore, each country (i.e. each network) has its own stamps, preferred envelope sizes, and the delivery rules are hidden from the users.

   The internet layer defines an official packet format and protocol called IP (Internet Protocol). The job of the internet layer is to deliver IP packets where they are supposed to go. Packet routing is clearly the major issue here, as is avoiding congestion [TAN03].

   Different versions of Internet Protocols have been evolved; the widely deployed version is Internet Protocol-version 4 (more commonly known as IPv4), and Internet Protocol version 6 (IPv6) which had been proposed to replace IPv4 in upcoming years [KUR01].

4. **Data Link Layers [KUR01]**: The services provided at the link layer depend on the specific link-layer protocol that is employed over the link. For example, some protocols provide reliable delivery on a link basis. (That is, from transmitting node, over one link, to receiving node). Note that this reliable delivery service is different from the reliable delivery service of TCP, which provides reliable delivery from one end system to another. Examples of link layers include Ethernet and Point to Point Protocol (PPP); in some contexts, Asynchronous Transfer Mode (ATM) and frame relay can be considered as link layers.

5. **Physical Layer [KUR01]**: While the job of the link layer is to move entire frames from one network element to an adjacent network element, the job of the physical layer is to move the individual bits within the frame from one node to the next. The protocols in this layer are again link dependent, and further depend on the actual transmission media of the link (for example; twisted-pair copper wire, single-mode fiber optics). For example, Ethernet has many physical layer protocols: one for twisted-pair copper wire, another for coaxial cable, another for fiber, and so on.

2.4 The Future IP, IPv6

In the early 1990s, the Internet Engineering Task Force (IETF) began an effort to develop a successor to the IPv4 protocol. The prime motivation for this effort was the realization that the 32-bit IP address space was begun to be used up with new networks and IP nodes being attached to the Internet (and being allocated unique IP addresses) at a high rate. To respond to this need for a large IP address space, a new IP protocol (i.e. IPv6) was developed. The designers of IPv6 also took this opportunity to increase and enhance the aspects of IPv4, based on the accumulated operational experience with IPv4 [KUR01].

The two leaders of the IETF's Address Lifetime Expectations working group estimated that the IPv4 addresses would exhausted in 2005 and 2018, respectively [SOL96]. In 1996, the American Registry for Internet

Numbers (ARIN) reported that all of the IPv4 class A addresses had been assigned, 62 percent of the class B addresses had been assigned, and 37 percent of the class C addresses had been assigned [ARN96] (for more information on classes see Appendix C). Although these estimates and numbers suggested that a considerable amount of time might be left until the IPv4 address space became exhausted, it was realized that a considerable time would be needed to deploy a new technology on such an extensive scale, and for this reason the "*IP Next Generation*" (*IPng*) effort was begun [BRA96].

The small range of IPv4 addresses is the main reason to develop a new protocol but not the only one. The following are the major goals to develop a new protocol [TAN03]:

1. Support billion of hosts.
2. Reduce the size of the routing tables.
3. Simplify the protocol, to allow routers to process packets faster.
4. Provide better security (authentication and privacy) than IPv4.
5. Pay more attention to type of service, particularly for real-time data.
6. Aid multicasting by allowing scopes to be specified.
7. Make it possible for host to roam without changing.
8. Allow the protocol to evolve in the future.

The advent of the IPv6 initiative doesn't mean that the technologies will exhaust the capabilities of the current Internet technology (i.e. IPv4). However, there are still compelling reasons to begin adopting IPv6 as soon as possible. However, this process has its challenges, and as essential to any evolution of Internet technology, there are requirements for seamless compatibility with IPv4, especially with regards to a manageable migration, which would allow us to take the advantage of the power of IPv6, without forcing the entire Internet to upgrade simultaneously [GON98].

The IPv6 features are the following:

1. New Header Format

The IPv6 header has a new format that is designed to minimize header overhead. This is achieved by moving both nonessential fields and option fields to extension headers that are placed after the IPv6 header. The streamlined IPv6 header provides more efficient processing at intermediate routers.

IPv4 headers and IPv6 headers are not interoperable, and the IPv6 protocol is not backward compatible with the IPv4 protocol. A host or router must use an implementation of both IPv4 and IPv6 in order to recognize and process both header formats. The new IPv6 header is only twice as large as the IPv4 header, even though IPv6 addresses are four times as large as IPv4 addresses [IPF02].

Figure (2.2) shows IPv6 header format. The *Version* is a 4-bit size field that identifies the version of the IP in use, and for IPv6 packet this field is set to 6 [KUR01].

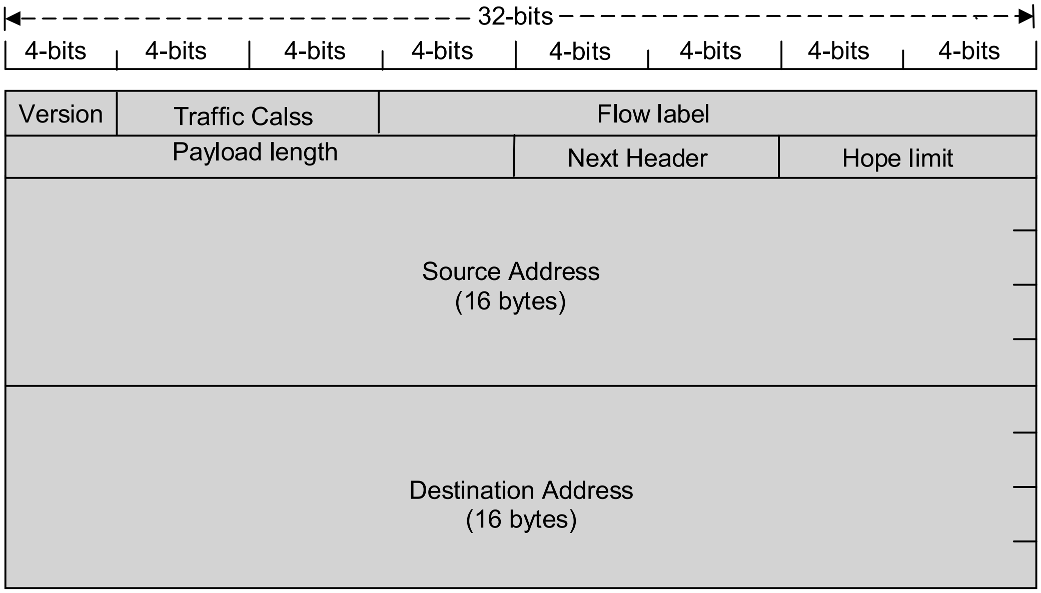


Fig.(2.2) IPv6 Header Format

The *Traffic Class* is an 8-bit field which is used to distinguish between packets with different real-time delivery requirements. It specifies the priority level for the packet where the larger value means the greater priority [TAN03].

The *Flow Label* is a 20-bits field; it allows a source to label a sequence of packets, for which it request special handling by an IPv6 router within the network. These packets would be on a route to a particular unicast or multicast destination. A real-time service, such as video, might use flow labeling. The combination of the source address and a non-zero flow label identifies a flow, packets that do not belong to a flow carry a flow label of zero.

The *Payload Length* field is a 16-bit unsigned integer; it defines the length of the tag following the header in octets. The IPv6 protocol specifies that the link be able to handle packets as large as 576 bytes. This means a payload could be as large as 536 bytes (576 bytes minus 40 bytes for the header). IPv6 can carry a payload as large as 65,535 bytes. IPv6 supports fragmentation of large packets if a link can not handle a packet of that size, IPv6 reassembles the fragmented packet at the destination.

A value of zero in this field indicates that the payload length is carried in a Jumbo Payload hop-by-hop option. The option in the Hop-by-Hop header can handle payloads in excess of 65,535 bytes.

The *Next Header* is an 8-bit field; it identifies the type of header that immediately follows the IPv6 header. Such a header could be an Authentication Header, an Encapsulation Security Header, a Routing Header, or the combination of all of them. Intermediate nodes on the packets path do not process the information of this header field. This field uses the same values as the IPv4 protocol field which are listed in RFC-1700 (for more information see Appendix D) [KUR01].

The *Hop Limit* field is an 8-bit unsigned integer; it identifies the number of hops the packet can transverse from its source to its destination. Each node that processes the packet, decrements the value of this field by one. If the hop limit is zero, the node discards the packet and returns an error message. Unlike IPv4, IPv6 nodes are not required to enforce maximum packet lifetime, this is the reason why the "Time to Live" field of IPv4 was renamed "Hop Limit" in IPv6.

The *Source Address* field contains the 128-bit address of the initial sender of the packet. The *Destination Address* field contains the 128-bit address of the intended recipient of the packet [KUR01].

2. Large Address Space [IPF02]

IPv6 has 128-bit (16-byte) source and destination addresses. Although 128 bits can provide over 3.4×10^{38} possible combinations, the large address space of IPv6 has been designed to allow for multiple levels of subnetting and address allocation from the Internet backbone to the individual subnets within an organization.

Although only a small percentage of possible addresses are currently allocated for use by hosts, there are plenty of addresses available for future use. With a much larger number of available addresses, address-conservation techniques, such as the deployment of Network Address Translating (NAT) (for more information see Appendix C), are no longer necessary.

3. Hierarchical Addressing and Routing Infrastructure

IPv6 global addresses used on the IPv6 portion of the Internet are designed to create an efficient, hierarchical, and summarizable routing infrastructure that addresses the common occurrence of multiple levels of Internet service providers. On the IPv6 Internet, backbone routers have much smaller routing tables [IPF02].

As shown in Figure (2.3), the first 3 address bits (*Format Prefix*) indicate what type of address follows (unicast, multicast, etc.). The next 13 bits are allocated to the various *Top Level Aggregators* around the world. Eight bits are reserved for future use, and the following 24 bits (*Next level aggregators*) are allocated to the next lower level of providers and subscribers [PER99].

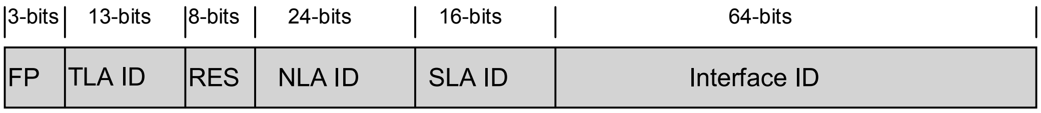


Fig.(2.3) IPv6 Address Format

Next level aggregators can divide the NLA address field to create their own hierarchy. For example, NLA1 can assign address range to NLA2 and NLA2 can assign smaller address range within its range to NLA3 and so on. This is accomplished by the further subdivision of the 24-bit NLA field (as shown in Figure (2.4)).

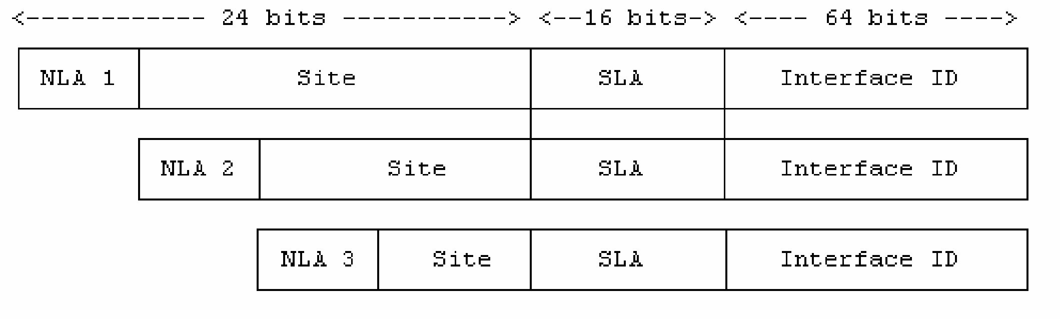


Fig.(2.4) Subdividing the NLA Address Space

Following the NLA ID are fields for subscriber site networking information: *Site Level Aggregator (SLA)* and *Interface Identifier*. Typically, service providers supply subscribers with blocks of contiguous addresses, which are then used by individual organizations to create their own local address hierarchy and identify subnets and hosts. The 16-bit SLA field supports up to 65,535 individual subnets. The 64-bit Interface ID, which is used to identify an IPv6 interface on a network link, will typically be derived from the installed Media Access Control (MAC) address. Large sites are expected to get an entire SLA. [PER99]

4. Stateless and Stateful Address Configuration [IPF02]

To simplify host configuration, IPv6 supports both stateful address configuration (i.e. address configuration in the presence of a DHCP server) and stateless address configuration (address configuration in the absence of a DHCP server). With stateless address configuration, hosts on a link automatically configure themselves with IPv6 addresses for the link (link-local addresses) and with addresses that are derived from prefixes advertised by local routers. Even in the absence of a router, hosts on the same link can automatically configure themselves with link-local addresses and communicate without manual configuration.

5. Built-In Security [IPF02]

Support for IPSec is an IPv6 protocol suite requirement. This requirement provides a standards-based solution for network security needs, and promotes interoperability between different IPv6 implementations.

6. Better Support for Quality of Service (QoS) [IPF02]

New fields in the IPv6 header define how traffic is handled and identified. Traffic identification, by using the "*Flow Label*" field in the IPv6 header, allows routers to identify and provide special handling for packets that belong to a flow. A flow is a series of packets between a source and destination. Because the traffic is identified in the IPv6 header, support for QoS can be easily achieved even when the packet payload is encrypted with IPSec.

7. New Protocol for Neighboring Node Interaction [IPF02]

The *Neighbor Discovery* protocol for IPv6 is a series of *Internet Control Message Protocol for IPv6 (ICMPv6)* messages that manage the interaction of neighboring nodes (that is, nodes on the same link). Neighbor Discovery replaces Address Resolution Protocol (ARP), ICMPv4 Router Discovery, and ICMPv4 redirect messages with efficient multicast and unicast messages and provides additional functionality.

8. Extensibility [IPF02]

IPv6 can be extended for new features by adding extension headers after the IPv6 header. Unlike the IPv4 header, which can only support 40 bytes of options, the size of IPv6 extension headers is only constrained by the size of the IPv6 packet.

2.5 IPv6 Addressing

The IPv6 addressing scheme more closely accommodates different user types, because it is based on the demographic nature of the served community. Additionally, IPv6 addressing provides the necessary compatibility and interoperability with today's IPv4 network architecture. This ability of IPv6 to coexist indefinitely with IPv4 in both host computers and routers, helps to preserve the world's enormous investment in TCP/IP[GON98].

2.5.1 IPv6 Address Allocation Management [GON98]

As the Internet transitions to IPv6, the plan for distributed allocation and assignment of the IPv4 address space, established in RFC-1466 (For more information see Appendix D), forms a base for the distributed allocation and assignment of the IPv6 address space.

The IPv6 address space must be managed for the good of the Internet community. The Internet community recognizes that good management requires at least some central authority over the delegation and allocation of the address space. Therefore, the Internet community has delegated the responsibility for the management of the IPv6 address space to the Internet Assigned Number Authority (IANA.). The IANA is the principal registry for the IPv6 address space. As representatives of the Internet community, the Internet Architecture Board (IAB) and the Internet Engineering Steering Group (IESG) provide advice to the IANA from time-to-time about management of the IPv6 address space.

The IANA carries out address allocation management with an element of central authority over the delegation to regional registries. These regional registries make specific address allocations to network service providers and other subregional registries.

The IANA delegates to regional registries the task of making specific address allocations to network service providers and other subregional registries. Individuals and organizations that need IP addresses obtain them from their internet service provider. The IANA serves as the default registry in cases where no delegated registration authority has been identified.

2.5.2 IANA Responsibilities

The IANA is responsible for the development of:

1. A plan for assignment of IPv6 addresses.
2. A method for the automatic allocation of IPv6 addresses to registries, ISPs, organizations, and individuals that already hold IPv4 address.
3. A set of procedures for mediation and appeals concerning the delegation and revocation of IP address space assignments.

2.5.3 IPv6 Addressing Model

Technically IPv6 addresses are 128-bit identifiers for interfaces and sets of interfaces. This is equivalent to an IPv4 address space squared twice (the IPv4 address size is 32-bit) which is very large number of addresses. It should be noted however that the size of the address is less important than its structure [GON98]. The emerging IPv6 protocols define three types of addresses:

1. **Unicast Addresses [UNI02]:** identify a single interface within the scope of the type of unicast address. With the appropriate unicast routing topology, packets addressed to a unicast address are delivered to a single interface. The following types of addresses are unicast IPv6 addresses:

    a. *Aggregatable Global Unicast Addresses:* Which are equivalent to public IPv4 addresses. They are globally routable and reachable on the IPv6 portion of the Internet known as the 6bone (IPv6 backbone). Aggregatable global unicast addresses are also known as global addresses

    b. *Link-Local Addresses:* Which are used between on-link neighbors and for Neighbor Discovery processes

c. *Site-Local Addresses:* Which are used between nodes that communicate with other nodes in the same site.

d. *Special Addresses:* The special IPv6 addresses are: (1) the unspecified address (0:0:0:0:0:0:0:0 or ::), which is used only to indicate the absence of an address. It is equivalent to the IPv4 unspecified address of 0.0.0.0, and (2) the loopback address (0:0:0:0:0:0:0:1 or ::1) which is used to identify a loopback interface, enabling a node to send packets to itself. It is equivalent to the IPv4 loopback address of 127.0.0.1

e. *Compatibility Addresses:* To aid in the migration from IPv4 to IPv6 and facilitate the coexistence of both types of hosts. Like IPv4-compatible address, IPv4-mapped address, and 6to4 address.

2. **Anycast Addresses [GON98]:** which are a new kind of address. An anycast address is an identifier (a single value) assigned to a more than one interface. The set of interfaces assigned an anycast address typically belong to more than one computer. It can be used in clustering and avoiding replications.

   When you send a packet to an anycast address, the routing protocol currently in use delivers the packet to the nearest interface identified by that address. The nearest interface is determined according to the particular routing protocol's measure of distance.

3. **Multicast Addresses [GON98]:** whose format allows for possibly trillions of multicast group codes. A multicast address is an identifier for a set of interfaces that typically belong to different nodes. Each multicast group code identifies two or more packet recipients. In addition, a particular multicast address can be confined to a single system, restricted within a specific site, associated with a particular network link, or distributed worldwide. When you send a packet to a multicast address, the protocol delivers the packet to all interfaces identified by that address.

IPv6 does not have broadcast addresses. The new IPv6 multicast addresses supersede broadcast addresses that used in IPv4. Table (2.1) shows how IPv6 differentiates between these types.

Table (2.1) IPv6 address types representation

Allocation	Binary prefix	Ex: (first 16 bit)
Global unicast	001	2xxx or 3xxx
Link-local unicast	1111 1110 10	FE8x … FEBx
Site-local unicast	1111 1110 11	FECx … FEFx
IPv4-compatible unicast	000…0 (96 zero bits)	Complete IP: 0:0:0:0:0:0:n:n:n:n
Multicast	1111 1111	FFxx
Reserved	0000 010	04xx or 05xx

IPv6 use the same model for subnets as IPv4; a subnet can be associated with only one link, and multiple subnets can be assigned to the same link.

2.5.4 Text Representations of IPv6 Addresses [GON98]

Traditionally IPv4 addresses are represented by using dotted decimal notation; each 32-bit address is divided into four 8-bit sections and a decimal number between 0 and 255 represents each section (for example 192.168.95.143).

The 128-bit IPv6 address uses different method to represent the address. In fact, there are three forms for representing IPv6 address as text strings:

1. **The preferred form:** it is the full IPv6 address in hexadecimal values. As defined in RFC-1884, the preferred form is X:X:X:X:X:X:X:X;

where X represent the hexadecimal values of the eight 16-bit pieces of the address. For example, an IPv6 address could have the following form:

FEDC:BA98:7654:3210:FFFF:CD91:5664:6743

A colon separates each section and four hexadecimal numbers represent each 16-bit section. Sometimes a 16-bit section contains leading zeros. It is not necessary to include the leading zeros in an individual field, but there must be at least one numeral in every field in the text representation of an address; as shown in the following simplified example of IPv6 address:

1080:0:0:0:8:800:200C:417A

2. **The compressed form**: in this form the zero strings are substituted with a special syntax to compress the zeros. This form uses double colons (::) to indicate multiple groups of 16-bit zeros. You can use the double colon (::) only once in an address. For example you can further simplify the address (1080:0:0:0:8:800:200C:417A) to be (1080::8:800:200C:417A).

   The double colon can also be used to compress the leading or trailing zeros in an address. This form shows the simplification of some IPv6 addresses using the double colon.

3. **The mixed form:** it is convenient to use for mixed environments of IPv4 and IPv6 nodes. This form takes the representation of X:X:X:X:X:X:D.D.D.D. The Xs represent the hexadecimal values of the six high-order 16-bit pieces of the address. The Ds represent the standard IPv4 decimal value representation of the four low-order 8-bit pieces of the address. This form shows some representative mixed form addresses in both a simplified and compressed form (for example, 1080::8:800:192.168.95.143).

2.5.5 IPv6 Address Prefixes [GON98]

IPv6, like IPv4 can have an address prefix. For our purposes, and IPv6 address prefix is defined as an IPv6 address and some indication of the leftmost contiguous significant bits within this address portion. The representation of an IPv6 address prefix is similar to the way IPv4 addresses prefixes are written in Classless Inter Domain Routing (CIDR) notation.

The user can write the IPv6 address by using any of the address forms described previously (preferred, compressed, or mixed) with one difference: "if the written address ends in a double colon (::), you can omit the trailing double colon".

The prefix-length is a decimal value. It specifies the number of leftmost contiguous bits of the address that comprise the prefix. The following examples show various legal representations for the 60-bit prefix 12AB00000000CD3 :

12AB:0000:0000:CD30:0000:0000:0000:0000/60
12AB::CD30:0:0:0:0/60
12AB:0:0:CD30::/60
12AB:0:0:CD30/60

2.6 IPv6 Transition Technologies [IPT04]

The migration of IPv4 to IPv6 will not happen overnight. Rather, there will be a period of transition when both protocols are in use over the same infrastructure. To address this, the designers of IPv6 have created technologies and types of addresses so that nodes can communicate with each other in a mixed environment, even if they are separated by an IPv4 infrastructure.

To coexist with an IPv4 infrastructure and to provide an eventual transition to an IPv6-only infrastructure, the following mechanisms are used:

1. **Dual Stack**: The dual stack contains a separate implementation of TCP and UDP, and the process in the application layer can communicate to

TCP/UDP of IPv6 or IPv4. The dual stack implementation can communicate over IPv4, IPv6, or IPv6 tunneled in IPv4.

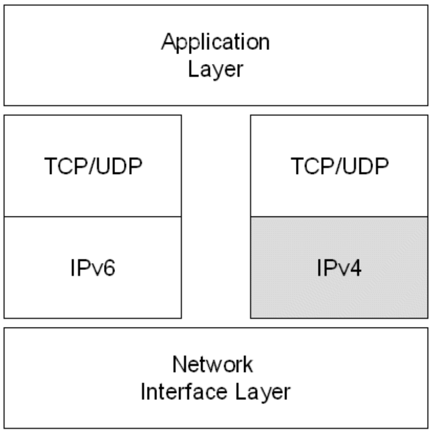


Fig.(2.5) A Dual Stack Layer Architecture

2. **IPv6 over IPv4 tunneling**: IPv6 over IPv4 tunneling is the encapsulation of IPv6 packets with an IPv4 header so that IPv6 packets can be sent over an IPv4 infrastructure.

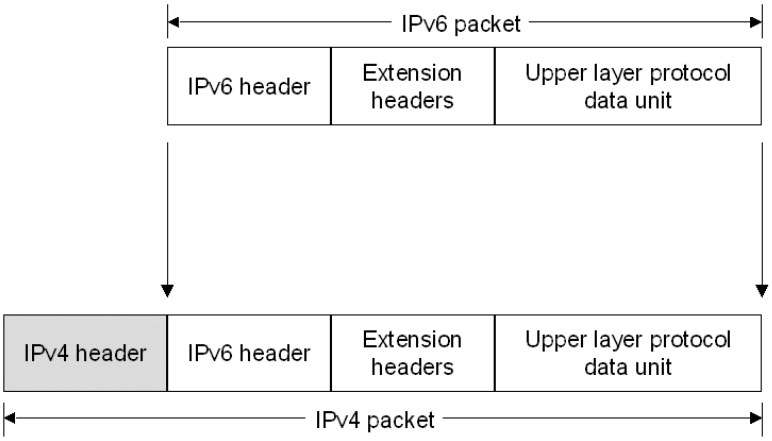


Fig.(2.6) IPv6 over IPv4 Tunneling

3. **DNS infrastructure**: A Domain Name System (DNS) infrastructure is needed for successful coexistence, because of the prevalent use of names (rather than addresses) to refer to network resources. Upgrading the DNS infrastructure consists of populating the DNS servers with records to support IPv6 name-to-address and address-to-name resolutions. After the addresses are obtained using a DNS name query,

the sending node must select which addresses are used for communication.

2.7 Network Management

The early 1980s saw tremendous expansion in the area of network deployment. As companies realized the cost benefits and productivity gains created by network technology, they began to add networks and expand existing networks almost as rapidly as new network technologies and products were introduced. By the mid-1980s, certain companies were experiencing growing pains from deploying many different (and sometimes incompatible) network technologies.

The problems associated with network expansion affect both day-to-day network operation management and strategic network growth planning. Each new network technology requires its own set of experts. In the early 1980s, the staffing requirements alone for managing large, heterogeneous networks created a crisis for many organizations. An urgent need arose for automated network management (including what is typically called network capacity planning) integrated across diverse environments [CIS02].

Network management includes the deployment, integration, and coordination of hardware, software, and human elements to monitor, test, poll, configure, analyze, evaluate, and control the network and element resources to meet the real-time, operational performance, and quality of service requirements at a reasonable cost [SYD96]. In other words, network management is the ability to monitor, control, and plan the resources and components of computer systems and networks. Network management is not an easy task and cannot be accomplished effectively by using manual techniques alone. So, network managers rely on a variety of tools to ensure that system and network operates and provides reliable service. Systems and network management is not only important, it is a big business [MEL98].

The main goals of the network management are [MEL98]:

1. **Keeping networks running:** systems and networks must be operational to accomplish the needed task.
2. **Maintaining Network Performance:** Simply initiating an operational network is not sufficient. A network must also perform at some minimally acceptable level of quality. A major responsibility of network management is to provide an acceptable level of performance level, or Quality of Service (QoS). If a performance problem exists, it must be pinpointed and resolved in a timely manner.
3. **Reducing the Cost of Ownership:** Simply purchasing network equipment and installing it is quite inexpensive compared to the longer-term cost of managing and maintaining it. Network management can be divided into two main categories, *reactive* and *proactive* management. In terms of the reduction of owner-ship costs, reactive management is much more expensive. This is true because when a network fails, it frequently needs to be fixed immediately and at any cost. While fault and performance management are important, they are primarily used in a reactive manner. When there is a fault in a system, you react to it by identifying the problem and eliminating it. When performance reaches an unacceptable level, you react to it by finding the source of the problem and fixing it. While reactive management is required, proactive management keeps these problems from happening in the first place. In doing so, proactive management promotes the reduction of ownership costs. Proactive management allows a network to be properly planned and built, thus avoiding expensive crisis scenarios.

So to achieve those goals, an NMS typically includes tools for gathering data on network elements, tools for data storage, analysis and prediction, tools for configuration and control of network elements, and tools for performance and system planning management.

2.7.1. Network Management Architectures

The structure that all network management architectures use is basically the same. The main components are [TERL02]:

1. **Managed Device:** managed devices run software that enables them to send alerts, be configured and monitored. Managed devices can be anything on a network that has the ability to run an agent. More and more devices are nowadays running agents (for example, there are washing machines running agents). This means that managed devices can be routers, switches, printers, servers, workstations, mobile phones, microwave ovens, DVDs and so on. And if they have agents, they can be managed.

2. **Agents:** agents are software running on a device. They mostly act as servers, responding to requests about their status, but they can also send alarms when they want to warn about something. As the years go by, agents will get more and more sophisticated and the picture of them just behaving as servers is changing slowly. Often the manufacturer of the managed device provides agents to their products.

3. **Network Management Protocols:** Protocols describe the way the systems (hardware or software) can communicate. If people speak different languages they do not understand each other. If two devices communicate by using different protocols they will not understand each other. So if a management application wants to manage a device, the manager application and the agent on the device have to use the same protocol. Applications are easy to develop, but the agents are often static and knows only one protocol. That makes the choice of protocol critical for both the application and the agent. There are several network management protocols: Common Management Information Service/Common Management Information Protocol (CMIS/CMIP), Simple Network Management Protocol (SNMP), Remote Monitoring (RMON), Web-Based Management (WBM), Web-Based Enterprise Management (WBEM), Java Management Extension (JMX), and Mobile agents.

4. **Managers:** Manager is the application that gets information from agents and informs the network engineers of the status of the network and

performs the necessary operations needed to increase performance and decrease faults.

There are several organizations have developed services, protocols and architectures for network management. The three most important organizations are:

1. The International Organization for Standardization (ISO).
2. The Comité Consultative Internationale de Telegraphique et Telephonique (CCITT); this organization is nowadays called the Telecommunication Standardization Sector of the International Telecommunication Union (ITU-T).
3. The Internet Engineering Task Force (IETF).

ISO was the first who started, as part of its "*Open Systems Interconnection*" *(OSI)* program, the development of an architecture for network management. The first proposals for such an architecture appeared during the early 1980; nowadays a large number of standards exist for the architecture as well as for network management services and protocols (for example, Common Management Information Service/Common Management Information Protocol (CMIS/CMIP)).

Initially the aim of ISO was to define management standards for datacom networks; development of management standards for telecom networks was left to CCITT. In 1985 CCITT started the development of such management standards; these standards have become known as the "*Telecommunications Management Network*" *(TMN)* recommendations. Originally these recommendations were self standing, but during the 1988-1992 study period they have been rewritten to include the ideas of OSI management. Nowadays OSI management and TMN can be seen as each others complements [PRA95].

Looking back at the last decade it may be concluded that the growth of the Internet has played a decisive role in the development of network management protocols. Initially the Internet Architecture Board (IAB) intended to apply the OSI management approach, but at the time the size of the Internet reached a level at which management became indispensable, OSI management groups were still busy with discussing the OSI management framework. Since implementations of OSI management were not expected to appear soon, the IAB requested the IETF (the organization who is responsible for the development of Internet protocols) to define an ad hoc management protocol. The "*Simple Network Management Protocol*" (*SNMP*) was completed within a year and soon many manufacturers started the production of SNMP compliant systems. Although the SNMP has some deficiencies, it has become the de facto standard for management of datacom networks. In 1993 an attempt was made to tackle these deficiencies and an improved version of SNMP (SNMPv2) appeared.

The ISO and IUT-T have many common concepts between them but they still have differences in fundamental philosophy (for example, the IUT-T group prefer to use a separate network for the transfer of management information. An interesting difference between the IETF and ISO is that the IETF takes a more pragmatic and result driven approach than ISO. In the IETF it is for instance unusual to spend much time on architectural discussions; people prefer to use their time on the development of protocols and implementations. This different attitude explains why no special standards have been defined for the Internet management architecture; only protocols and MIBs have been standardized [PRA95].

Each of these architectures is based on the concept of manager-agent concept. Network management can be implemented by utilizing various models based on their type and size. Basically, there are two management models that can be used, they are centralized management and distributed management. Centralized management enables the centralization of management control and responsibility in one location where a top-level manager is responsible of mid-level managers that in turn responsible of one or many agents. This is ideal for systems that are limited in size or geographically isolated. Distributed management enables the distribution of management control and responsibility. Distributed models provide management for large geographically distributed systems; they are also beneficial when the critical network resources must be conserved [MEL98]. The distributed management can be one of the following types:

1. *Weekly distributed*
2. *Strongly Distributed*
3. *Cooperative*

If the managers (both top-level and mid-level) are approximately as many as the agents, it is called cooperative management. The weakly and strongly distributed management are between the centralized and the cooperative management. Table (2.2) describes how this classification is made in numbers; *m* is the number of managers, *n* is the total number of elements (top- and mid-level managers and agents) [TERL02].

Table (2.2) Classification of network management models by numbers

Classification Rule	Class Model
$1 = m$	Centralized Management
$1 < m << n$	Weakly Distributed Management
$1 << m < n$	Strongly Distributed Management
$m \cong n$	Cooperative Management

Figure (2.7) illustrates the differences of among models in another way, with (a) centralized, (b) weakly distributed, (c) strongly distributed, (d) cooperative management.

The weakly distributed management systems typically use strictly vertical delegation of tasks (i.e. the managers, only delegate tasks to managers who are in a level below them). In strongly distributed and cooperative management the mid-level managers, also, delegate tasks to each other on the same level, so there is no clean hierarchy. Dynamic delegation of management tasks is possible with weakly distributed management, but is more convenient and efficient with strongly distributed or cooperative management.

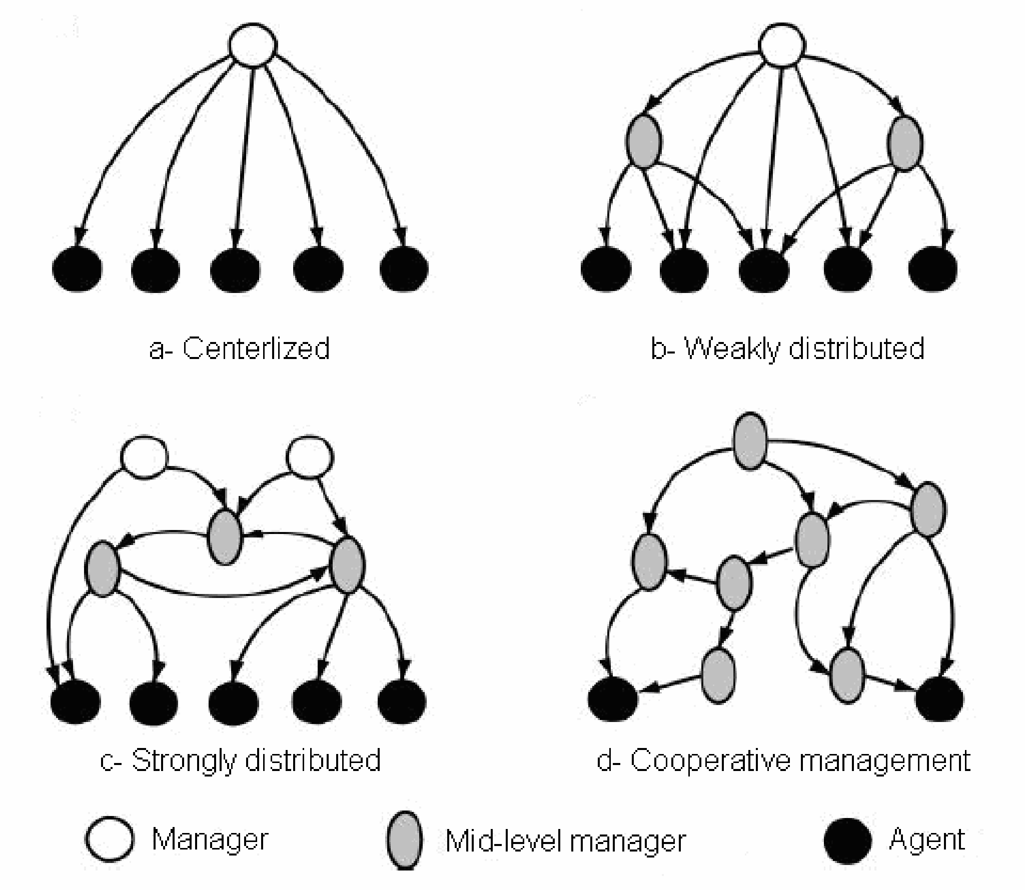


Fig. (2.7) Network Management models

2.7.2. Area of Network Management

Network management can be broken down into five functional areas according to *OSI* management. Each area defines a discrete domain of management with specific needs. Depending on the network to be managed, a specific area may be emphasized or de-emphasized.

1. **Fault Management:** whenever a service or network device fails, the management system shall detect the fault, find the cause and report the failure. In some cases the management system can also restore the service automatically, but most often a network operator has to fix the fault manually. The goal of fault management is to increase the network reliability, discover failures as quickly as possible so a network operator can fix the problem, hopefully even before the network's users notices there is a problem [TERL02]. Through *active monitoring* and *event*

notification, faults can be detected and isolated. Active monitoring is achieved by *polling* for information from managed components, see Figure (2.8). When the retrieved information exceeds some predetermined threshold, a fault condition can be detected. Although polling can be effective, it requires network bandwidth that is wasted when no faults are present. Polling also becomes difficult when dealing with a large network where many components need to be queried.

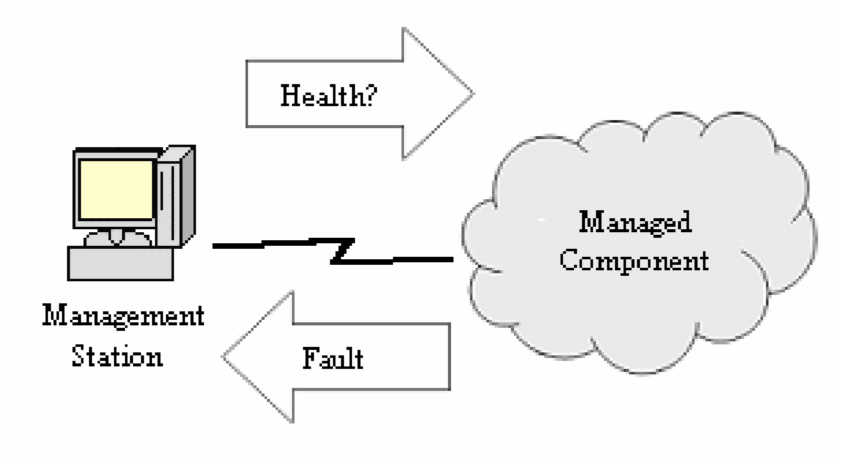


Fig (2.8) Fault detection via polling

An alternate approach to polling is event notification. Event notification enables a networked agent to notify a manager when a fault has occurred, see Figure (2.9). This saves network bandwidth since communication occurs only when a fault is present. Event notification by itself may not catch all errors because when a network component crashes it may not have the opportunity to notify someone [MEL98].

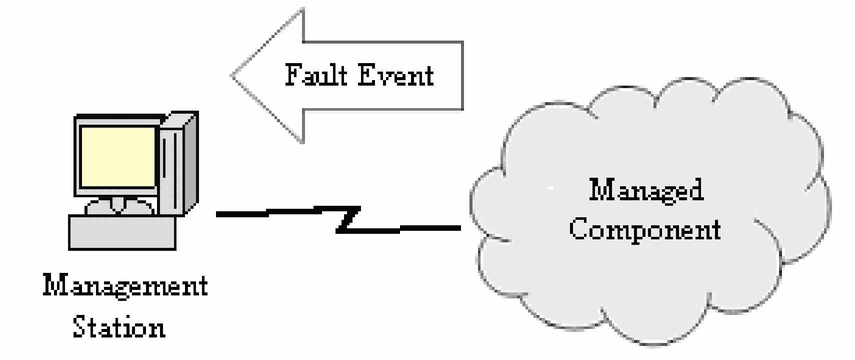


Fig. (2.9) Fault detection via event notification

The solution is to mix both approaches and have low frequency polling with event notification. In the event a networked component dies without notifying someone, the low-frequency poll cycle will report the error. Since polling is performed only at a low frequency, unnecessary network traffic is not introduced. In the event a notification is received, the polling frequency for that managed component may be increased. This technique is also known as *notification-based polling* [MEL98].

2. **Performance Management:** performance management is needed to optimize the QoS. Performance management is an important area of management in which both short- and long-term performance can be evaluated. Short-term analysis may determine immediately noticeable conditions, while longer-term analysis helps to shed light on conditions that happen slowly over time [MEL98].
3. **Configuration Management:** configuration management deals with updating, changing, and modifying resources within the network. Configuration of networked components is primarily performed when the component is first installed. Configuration also may be a result of fault management where faults are corrected through configuration changes. Through configuration, specific components of a network may be gracefully shutdown or turned on. Since configuration may change the attributes and behavior of a device, secure configuration is of primary concern [MEL98].
4. **Accounting Management:** Accounting management is concerned with the allocation of resources within a networked system and charging for their services. This type of management includes the collection of usage information from networked components and the creation of accurate billing information. Today, many Internet Service Providers (ISPs) use this form of management to determine how much to bill clients who use their Internet services. Accounting management is typically performed as a low priority task while other management tasks such as fault management take precedence. As more and more people become connected to the Internet and share key network resources, accounting

management will come to play a bigger role. Another important area of accounting management is asset management and the inventory of networked components. This enables the automatic creation of inventory lists of networked equipment. When dealing with large systems, this can be particularly useful [MEL98].

5. **Security Management:** Security management provides for the protection of resources within a system or network. Security becomes more important with increased connectivity. Security management is closely related to fault and configuration management since configuration of important devices must be secure. Security management can be divided into two areas: *management of the security of a network* and *management using secure protocols*. Management of the security of a network includes managing and configuring passwords on servers so that unauthorized access is prohibited. Management using secure protocols includes making sure that management of agents is performed using protocols that prevent unauthenticated access [MEL98].

2.7.3. Network Management Protocols

There are many protocols to define how to exchange data and alarms between the agent and manager in the network management system: Common Management Information Service/Common Management Information Protocol (CMIS/CMIP), Simple Network Management Protocol (SNMP), Remote Monitoring (RMON), Web-Based Management (WBM), Web-Based Enterprise Management (WBEM), Java Management Extension (JMX), and Mobile agents.

1. **SNMP**: Simple Network Management Protocol (SNMP) is by far the most popular system and network management protocol. More devices and systems are managed with SNMP than with any other management protocol. This is true because SNMP is quite small and inexpensive to deploy. That is, it can be implemented in devices with minimal memory and CPU resources. This is in contrast to the Open Systems

Interconnection (OSI) management protocols, which are complex and thus more expensive to deploy. SNMP was developed to provide basic, easy-to-implement network management tool for the Transport Control Protocol/Internet Protocol (TCP/IP) suite of protocols. This includes a framework of operation and a representation of management information within the framework. The Structure of Management Information (SMI) allows for the definition of Management Information Bases (MIBs). MIBs are analogous to database schemas. A managed entity, also known as an agent, includes one or more MIBs that define what information is manageable. This includes a standard set of management information resources that are part of the SNMP framework, as well as vendor-specific management information that enables a vendor to specify their device specific information. The ability to define a custom MIB allows SNMP management to be extended to meet a particular need of a vendor's device [MEL98]. The first version of this protocol (SNMPv1) had some deficiencies that fixed in the second version (SNMPv2). Also, a new SMI and MIB (SMIv2 and MIB-II) had been developed. But the security in the SNMPv2 was also weak, so the SNMPv3 had been developed with stronger security [KUR01].

2. **CMIS/CMIP**: The ISO and the CCITT have worked together to create a network management standard for the Open Systems Interconnection (OSI) environment. The result is the Common Management Information Service (CMIS) and the Common Management Information Protocol (CMIP), which implements CMIS. The OSI system management standard is a large and complex platform. Due to its complexity and size, a simpler scheme was introduced, SNMP. Nevertheless, CMIS and CMIP have found usage in the telecommunications industry [MEL98].

3. **RMON**: Remote Network Monitoring (RMON) is an addition to the SNMP standards (SMI, MIB, and SNMP) [RFC1747]. It defines a remote monitoring MIB that supplements MIB-II and provides the network engineers with lots of useful information that MIB-II does not provide. The information in the RMON MIB can be accessed by using

the ordinary SNMP operations. An SNMP-enabled device can, with MIB-II, learn about the traffic in and out of the device, but can not learn about the traffic on the LAN as a whole. An RMON agent monitors the network in *promiscuous* mode, that is it analyzes every packet on the LAN, not only the traffic meant for itself. The captured traffic can be used for statistics, checking performance etc. The monitor can also store packets or partial packets for later analysis. Filters can be used to drop packets, based on their content or type, allowing the monitor to ignore irrelevant traffic. As a monitor only can see packets in its own Ethernet LAN, there has to be an RMON device in each subnetwork. The monitor can be a standalone device whose whole purpose is to monitor and analyze traffic. RMON introduces a feature called action invocation. SNMP provides no specific mechanism for issuing a command to an agent to perform an action. The only capabilities of SNMP are to read and set managed objects. RMON uses the SNMP Set operation to issue a command. RMON specifies a number of objects that, if the values of them are changed, triggers a certain action. Another version of RMON were developed, RMON2. It is an extension to RMON. Both use MIB-II, but RMON uses SMIv1 and RMON2 uses SMIv2. RMON works on Link layer and below, while RMON2 operates on Network (IP) layer and above. This adds lots of new information that can be used by a network management system [TERL02].

4. **WBM**: In Web-based management (WBM), Web servers are embedded in the network devices. One can use a Web browser to browse the configuration and status of the device and also to configure it. Web servers are more intelligent than SNMP agents and can be more sophisticated. WBM uses a centralized model and suits for small offices, whose management requirements are not that big [TERL02].

5. **WBEM**: There are many standards for managing networks: SNMP, CMIP, WBM etc. Web-based Enterprise Management (WBEM) is an initiative by Desktop Management Task Force (DMTF) trying to integrate all these standards. This makes the protocol used transparent to the management applications. A client can send requests to any agent,

using the same protocol with all the agents, the Extensible Markup Language Common Information Model (xmlCIM) protocol. The client communicates with the Common Information Model Object Manager (CIMOM), which then transforms the request to the agent-specific protocol. When CIMOM receives messages from the clients, it uses the information from CIM schema to determine which protocol the managed object belongs to and switches the message to that protocol provider [TERL02].

6. **JMX**: Java Management Extensions (JMX) defines an architecture, APIs and the services for network management in the Java programming language. JMX runs on most Java-enabled devices. For a device to be Java-enabled, it needs to run a Java Virtual Machine that can interpret Java bytecode. Almost anything can be managed using JMX: applications, services or devices. For something to be manageable it needs to embed a managed object server and make some of its functionality available as one or several Manageable Beans (MBeans) registered in the object server. JMX provides a standard way to enable manageability for any Java based application, service or device [TERL02].
7. **Mobile Agent**: Mobile agents (MAs) are programs that can be dispatched by a client for execution on a remote server. Mobile agents are not an implementation or protocol; it is an infrastructure or framework. To implement mobile agents you can use any protocol and any programming language, the choice is up to the programmer. There are a couple of implementations of the mobile agents framework, for instance *Aglets* from IBM, *Tryllian* and *Grasshopper* [TERL02].

2.8 SNMP

The Simple Network Management Protocol (SNMP) was developed to provide a basic, easy-to-implement network management tool for the Transport Control Protocol/Internet Protocol (TCP/IP) suite of protocols. SNMP is more than just a protocol. It is a collection of specifications that are used for network management. SNMP includes the actual protocol, the definition of managed information, and other related components. The SNMP management model is based on the notion of an SNMP manager and an SNMP agent where an agent is "managed" by a manager. Agents typically instrument components in a network or system and provide this information to a manager that requests the information. The simplicity of SNMP is mostly appreciated by these agents, which frequently have limited computing resources [MEL98]. There are three versions of SNMP: SNMPv1, SNMpv2, and SNMPv3. The three versions have a common which is the Management Information Base (MIB) that is a definition of the information accessible on a device through a network management protocol. The information consists of managed objects and every managed object has a value which can be read or set [TERL02].

2.8.1 MIB

Network management stations execute management applications which monitor and control network elements. Network elements are devices such as hosts, routers, terminal servers, etc., which are monitored and controlled through access to their management information. Management information is viewed as a collection of managed objects, residing in a virtual information store, termed the Management Information Base (MIB). Collections of related objects are defined in MIB modules. These modules are written using a subset of OSI's Abstract Syntax Notation One (ASN.1), termed the Structure of Management Information (SMI) [RFC1450].

Each type of object (termed an object type) has a name, a syntax, and an encoding. The name is represented uniquely as an Object Identifier (OID). An OID is an administratively assigned name. The syntax for an object type defines the abstract data structure corresponding to that object type. For example, the structure of a given object type might be an INTEGER or OCTET STRING [RFC1155]. Table (2.3) shows the primitive types of an ASN.1.

Table (2.3) ASN.1 Data Types

Type	Description
INTEGER	An integer value (32-bit). It is on of the ASN.1 primitive types.
OCTET STRING	A data type that can hold zero or more octets. An octet is an 8-bit wide value. Octets can be used to store ASCII strings or binary encoded information. It is on of the ASN.1 primitive types.
NULL	A data type that has no value. Null is used to denote a value that contains no value or has yet to be initialized. It is on of the ASN.1 primitive types.
OBJECT IDENTIFIER	A data type that holds an object identifier for an MIB object. Object identifiers are stored using "dotted integer representation". It is on of the ASN.1 primitive types.
SEQUENCE	A data type that represents an ordered list of zero or more elements. Sequence allows definition of lists of other ASN.l data types. It is on of the ASN.1 primitive types.

In order to provide useful management information, more data types are required. Using the primitive data types, more useful data types may be constructed. The data types are defined with standard MIB definitions. The SMI defines a set of rules to describe management information using the ASN.l syntax. This allows management information to be defined independent of a particular implementation. SMI types are defined using ASN.l. The SMI definitions include a set of rules for the designing MIBs including data types, see Table (2.4).

The object type definition in the MIB consists of five fields [RFC1155]:

1. *OBJECT*: A textual name, termed the OBJECT DESCRIPTOR, for the object type, along with its corresponding OBJECT IDENTIFIER.
2. *Syntax*: The abstract syntax for the object type. This must resolve to an instance of the ASN.1 (or SMI) type.

3. *Definition*: A textual description of the semantics of the object type.
4. *Max-Access*: One of *read-only*, *read-write*, *write-only*, or *not-accessible*.
5. *Status*: One of *mandatory*, *optional*, or *obsolete*.

An example of an object definition is shown in Figure (2.10).

Table (2.4) SMI Data Types

Type	Description
IpAddress	Representation of an Internet Protocol address.
Counter32	Representation of a non-negative data type used for counting. Internally, this is a 32-bit value. It may increase monotonically until a maximum value is reached, when it will wrap back to a 0 value.
Counter64	Representation of a non-negative data type used for counting. Internally, this is a 64-bit value. It may increase monotonically until a maximum value is reached, when it will wrap back to a 0 value. (Available in SNMP version 2 and 3 only)
Gauge32	Representation of a non-negative data type used for gauging. Internally, this is a 32-bit value. Its value may increase or decrease. If the value exceeds the maximum value then it latches to the maximum value. If the value later drops below the maximum value then the actual value thereafter can change.
TimeTicks	Representation of a non-negative data type used for the relative time representation. TimeTicks are measured in hundredths of a second relative to some time (typically time since reboot).
Unsigned32	Representation of a data type used when a signed integer will not suffice. Internally, this is a 32-bit value.

```
  myMIBObject OBJECT-TYPE
          S YNTAX                  INTEGER
          MAX-ACCESS              read-write
          STATUS                   manadtory
          DESCRIPTION
                        "An example of MIB object"
 ::= { myobjects 1 )
```

Fig. (2.10) example of Managed Object Definition

The notation after the "::=" in Figure (2.10), identifies the OID of the object. The *myobjects* is an a previously defined object and has an OID and the *myobjects* also until we get the object that has no specified parent.

OIDs enable the identification of managed objects to be accessed, referenced, or modified. An OID is a sequence of unsigned integers that define a traversal order in an MIB tree. The tree consists of a root and a set of subnodes in which each node in the tree has its own unique identifier and label [MEL98]. Figure (2.11) shows a part of the current registered OIDs tree.

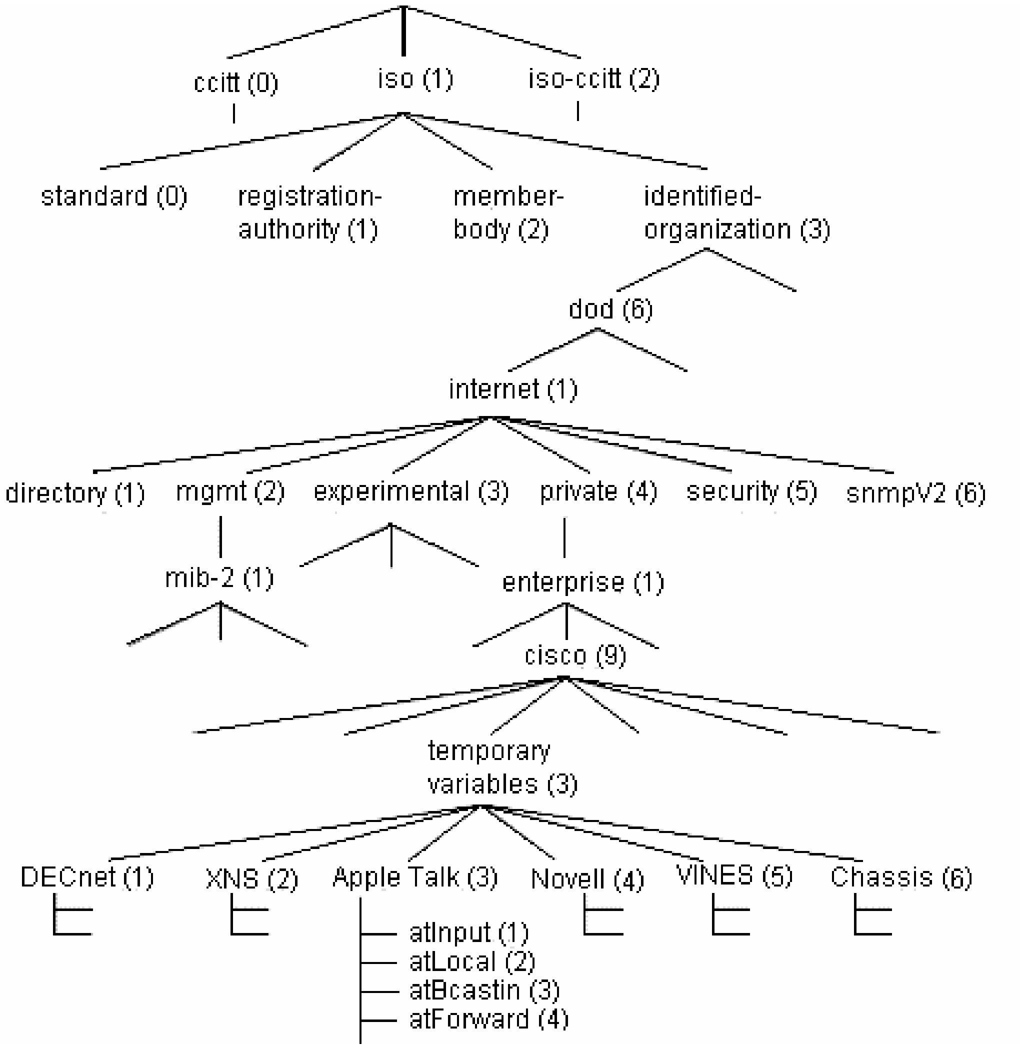


Fig. (2.11) part of the current OID tree

So, the OID of *atInput* is "1.3.6.1.4.1.9.3.3.1". The *experimental* subtree is dedicated for adding the objects of researches.

2.8.2 SNMPv1

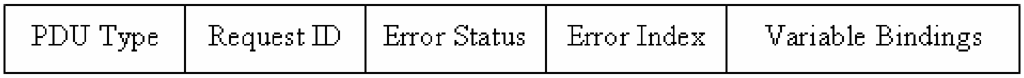
Communication among protocol entities is accomplished by the exchange of messages, each of which is entirely and independently represented within a single UDP datagram using the Basic Encoding Rules (BER) of Abstract Syntax Notation One (ASN.1). A message consists of a *version* identifier, an SNMP *community* name, and a *Protocol Data Unit (PDU)*, as shown in Figure (2.12). A protocol entity receives messages at UDP port 161 on the host with which it is associated for all messages except for those which report traps (i.e., all messages except those which contain the Trap-PDU). Messages which report traps should be received on UDP port 162 for further processing. An implementation of this protocol need not accept messages whose length exceeds 484 octets (Octets is an 8-bit wide value; Octets can be used to store ASCII strings or binary encoded information). However, it is recommended that implementations support larger datagrams whenever feasible. It is mandatory that all implementations of the SNMP support the five PDUs: *GetRequest-PDU*, *GetNextRequest-PDU*, *GetResponse-PDU*, *SetRequest-PDU*, and *Trap-PDU* [RFC1157]. The SNMP message in ASN.1 notation is defined in Appendix B.

Version	Community	PDU

Fig. (2.12) SNMPv1 Message

When an agent picks up an SNMP request message (GetRequest), the message is passed to the SNMP protocol engine where is it decoded and processed. The engine decodes the message to determine its type and the exact information being requested. If the request is authorized, the request is processed and a response (GetResponse) is generated to the manager that issued the request. The manager can request message by using GetRequest and then by using GetNextRequest message to get the next MIB. The manager can parse the MIBs of an agent by sending GetRequest message first, then repeatedly send GetNextRequest message until no MIB remain. When the agent needs to report a trap (for example, an unauthenticated message had been received) to the manager it uses trap message [MEL98].

The *Version* field, shown in Figure (2.12), determines the version of the SNMP message (it contains 0 for SNMPv1). The *Community* field is an OCTET STRING determines the community that the sender belongs to. The agent checks if the community in the message is the same community of it then the message is authenticated. The *PDU* field shown in Figure (2.13), is implemented by all PDUs except the Trap-PDU.



PDU Type	Request ID	Error Status	Error Index	Variable Bindings

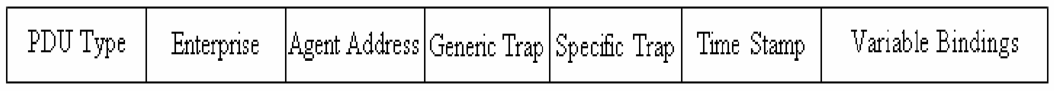
Fig. (2.13) SNMPv1 Request/Response PDU

The *PDU type* indicates the type of the PDU. *RequestID* is used to distinguish among outstanding requests. By use of the RequestID, an SNMP manager can correlate incoming responses with outstanding requests. In cases where an unreliable datagram service is being used, the RequestID also provides a simple means of identifying messages duplicated by the network.

A non-zero instance of *ErrorStatus* is used to indicate that an exception occurred while processing a request. In these cases, *ErrorIndex* may provide additional information by indicating which variable in the variable bindings caused the exception [RFC1157].

The term variable refers to an instance of a managed object. A variable binding, or VarBind, refers to the pairing of the name of a variable to the variable's value. The *VariableBindings* is a simple list of variable names and corresponding values. Some PDUs are concerned only with the name of a variable and not its value (the GetRequest-PDU and the GetNextRequest-PDU). In this case, the value portion of the binding is ignored by the protocol entity (agent or manager). However, the value portion must still have valid ASN.1 syntax and encoding. It is recommended that the ASN.1 value NULL be used for the value portion of such bindings.

The Trap-PDU is shown in Figure (2.14).



PDU Type	Enterprise	Agent Address	Generic Trap	Specific Trap	Time Stamp	Variable Bindings

Fig. (2.14) Trap-PDU

Enterprise field is an object identifier for a group, which indicates the type of object that generated the trap. *Agent address* is the IP address of the SNMP agent that generated the trap. *Generic Trap* is a code value specifying one of a number of predefined generic trap types (for example, authentication failure which is equal 4). *Specific Trap* is a code value indicating an implementation-specific trap type. *Time Stamp* is the amount of time since the SNMP entity sending this message last initialized or reinitialized [RFC1157].

2.8.3 SNMPv2

The lack of many good features in SNMPv1 resulted in a work on SNMPv2. For SNMPv2, security is still based on community names and the system architecture is essentially the same as for version 1. Further, version 2 is not backward compatible with version 1. SNMPv2 defines a new operation, GetBulk. Its purpose is to retrieve portions of a table. This is similar to walking through a table with repeated GetNext commands. SNMPv2 also introduces Inform messages, which is similar to traps. The problem with traps though, is that they are unreliable (UDP is unreliable). Inform can be seen as an SNMPv2 trap that can be retransmitted if it does not get acknowledged. SNMPv2 added new capabilities to the SNMP protocol. In January 1996, RFC-1902 updated SMI to be used with SNMPv2, SMIv2. Another MIB was also added; it was named MIB-II and is located in the 1.3.6.1.2.1-branch [TERL02]. SNMPv2 provides several advantages over SNMPv1, including [RFC2570]:

1. Expanded data types (for example, 64 bit counter).

2. Improved efficiency and performance (get-bulk operator).
3. Confirmed event notification (inform operator).
4. Richer error handling (errors and exceptions).
5. Improved sets, especially row creation and deletion.
6. Fine tuning of the data definition language.

RFC-1445 [RFC1445] and RFC-1446 [RFC1446] describe an administrative and a security model to be used with SNMPv2. RFC-1446 specified the following two principal threats to be protected in SNMPv2:

1. **Modification of Information**: The SNMPv2 protocol provides the means for management stations to interrogate and to manipulate the value of objects in a managed agent. The modification threat is the danger that some party may alter in-transit messages generated by an authorized party in such a way as to effect unauthorized management operations, including falsifying the value of an object.
2. **Masquerade**: The SNMPv2 administrative model includes an access control model. Access control necessarily depends on knowledge of the origin of a message. The masquerade threat is the danger that management operations not authorized for some party may be attempted by that party by assuming the identity of another party that has the appropriate authorizations.

And RFC-1446 specified two secondary threats [RFC1446]:

1. **Message Stream Modification**: The SNMPv2 protocol is based upon a connectionless transport service which may operate over any subnetwork service. The re-ordering, delay or replay of messages can and does occur through the natural operation of many such subnetwork services. The message stream modification threat is the danger that messages may be maliciously re-ordered, delayed or replayed to an extent which is greater than can occur through the natural operation of a subnetwork service, in order to produce an effect on the unauthorized management operations.

2. **Disclosure**: The disclosure threat is the danger of eavesdropping on the exchanges between managed agents and a management station. Protecting against the disclosure threat may also be required as a matter of local policy.

It suggests solving these threats by applying Message Digest 5 (MD5) to provide an authentication mechanism and the Data Encryption Standard (DES) to support data confidentiality.

2.8.4 SNMPv3

SNMPv3 address two major areas, administration and security. Another major goal was to have a modular architecture. For instance if new security protocols are developed, they are now easy to add without having to release a new version of the protocol. What was called managers and agents in SNMPv1 are now called entities [TERL02].

2.8.4.1 SNMPv3 Architecture [RFC2571]

The SNMPv3 entity constructed from two parts (as shown Figure 2.15):

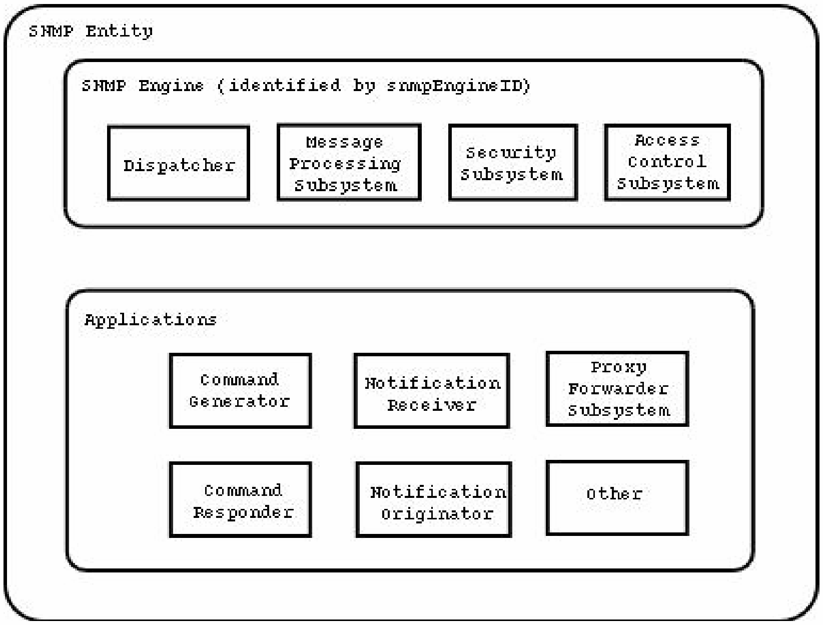


Fig. (2.15) SNMPv3 Entity

1. **SNMP engine**: An SNMP engine provides services for sending and receiving messages, authenticating and encrypting messages, and controlling access to managed objects. There is a one-to-one association between an SNMP engine and the SNMP entity which contains it.

   The engine contains:

   a. *Dispatcher*: There is only one Dispatcher in an SNMP engine. It allows for concurrent support of multiple versions of SNMP messages in the SNMP engine.

   b. *Message Processing Subsystem*: it is responsible for preparing messages for sending, and extracting data from received messages. The Message Processing Subsystem potentially contains multiple Message Processing Models. The Message Processing Models defines the format of a particular version of an SNMP message and coordinates the preparation and extraction of each such version-specific message format. For example, SNMPv3 Message Processing Model, SNMPv2 Message Processing Model, SNMPv1 Message Processing Model, and any other.

   c. *Security Subsystem*: it provides security services such as the authentication and privacy of messages and potentially contains multiple Security Models. For example, *User-Based Security Model (USM)*.

   d. *Access Control Subsystem*: provides authorization services by means of one or more Access Control Models. For example, *View-Based Access Control Model (VACM)*.

   For each SNMP engine, there is a unique snmpEngineID within an administrative domain. Since there is a one-to-one association between SNMP engines and SNMP entities, it also uniquely and unambiguously identifies the SNMP entity within that administrative domain. Note that it is possible for SNMP entities in different administrative domains to have the same value for snmpEngineID.

2. **Applications**: There are several types of applications, including:
    a. *Command Generators*: which monitor and manipulate management data.
    b. *Command Responders*: which provide access to management data.
    c. *Notification Originators*: which initiate asynchronous messages.
    d. *Notification Receivers*: which process asynchronous messages.
    e. *Proxy Forwarders*: which forward messages between entities.

    These applications make use of the services provided by the SNMP engine.

An SNMP entity containing one or more command generator and/or notification receiver applications (along with their associated SNMP engine) has traditionally been called an SNMP manager. And the SNMP entity containing one or more command responder and/or notification originator applications (along with their associated SNMP engine) has traditionally been called an SNMP agent.

2.8.4.2 SNMPv3 Message Format [RFC2572]

The SNMP message structure for version 3 has been changed to accommodate the use of a security model, the format is shown in Figure (2.16).

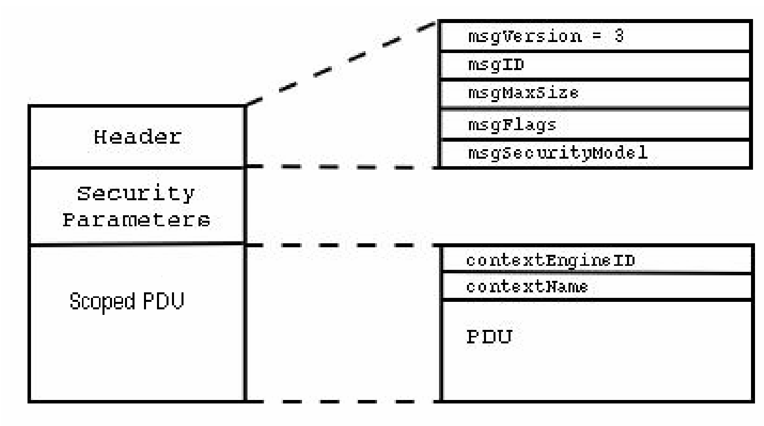


Fig. (2.16) SNMPv3 Message Format

The *msgVersion* field is set to SNMPv3(3) and identifies the message as an SNMP version 3 Message.

The *msgID* is used between two SNMP entities to coordinate request messages and responses, and to coordinate the processing of the message by different subsystem models within the architecture. A msgID in a response must be same as the msgID received in the request.

The *msgMaxSize* field of the message conveys the maximum message size supported by the sender of the message. The msgFlags field of the message contains several bit fields which control processing of the message. For instance, two bits of the msgFlags are used to specify whether or not the message has been authenticated and whether or not it has been encrypted.

The SNMPv3 supports the concurrent existence of multiple Security Models to provide security services for SNMPv3 messages. The *msgSecurityModel* field in an SNMPv3 Message identifies which Security Model was used by the sender to generate the message and therefore which security model must be used by the receiver to perform security processing for the message.

The *msgSecurityParameters* is an octet string that contains the security model specific data. This data is defined by and used only by the security model specified by the msgSecurityModel.

The *scopedPDU* contains the normal PDU and information for identifying the administratively unique context for processing the PDU. The context is a collection of management information accessible by an SNMP entity. Where, an item of management information may exist in more than one context. An SNMP entity potentially has access to many contexts.

2.8.4.3 SNMPv3 Security

Security is normally applied at two different stages: in the transmission/receipt of messages, and in the processing of the contents of messages. The security can be achieved by authentication, encryption, and timeliness checking. The default security model for the SNMPv3 is User-based Security Model (USM) [RFC2571].

The USM specifies the use of the Message Digest 5 (MD5) and Secure Hash Algorithm 1 (SHA-1) algorithms for authenticating SNMPv3 messages. These algorithms are used to create unique fixed sized message digests, also called digital signatures or fingerprints, of a variable length message. MD5 creates a digest of 128 bits (16 bytes) and SHA-1 creates a digest of 160 bits (20 bytes). Both MD5 and SHA-1 cannot be used directly as a message authentication code because they do not use secret keys as input to derivate the computed message digest. This is why the Keyed Hashing for Message Authentication (HMAC) algorithm in combination with MD5 and SHA-1 is used for computing message digests. The HMAC algorithm defines a procedure for appending a secret key to the data and then computing the MD5 or SHA-1 message digest. This guarantees that parties who wish to compute identical message digests for the same block of data must share a common secret key.

The USM specifies the use of the Cipher Block Chaining mode to the Data Encryption Standard (CBC-DES) algorithm for encrypting and decrypting SNMPv3 messages. The scope of the encryption only covers the scopedPDU which contains the PDU and context data used by the View-based Access Control Module (VACM). The DES algorithm takes three inputs. These inputs are the data to be encrypted, a 56 bit secret key, and a 56 bit randomly generated salt which is used to ensure that two different initialization vectors are used for two different data inputs encrypted with the same secret key. For two parties to use encryption during communication, each must share a secret privacy key as well as the salt used to derivate the initialization vector. The secret privacy keys are stored in the User Table (in each entity, there exist a table contains the names of the users and their information, for example: authentication method, authentication key, privacy method, and privacy key), and the salt is transmitted with the message [DAV00].

The USM also supports message timeliness and limited replay protection which is the provision of the property that a message whose generation time is outside of a specified time window is not accepted. The timeliness check is only performed if authentication is applied to the message [RFC2572].

2.8.4.4 Access Control [RFC2575]

The Access Control Subsystem of an SNMP engine has the responsibility for checking whether a specific type of access (read, write, notify) to a particular object is allowed.

Access Control occurs (either implicitly or explicitly) in an SNMP entity when processing SNMP retrieval or modification request messages from an SNMP entity. For example a Command Responder application applies Access Control when processing requests that it received from a Command Generator application.

Access Control, also, occurs in an SNMP entity when an SNMP notification message is generated (by a Notification Originator application). The default SNMPv3 access control model is the View-based Access Control Model (VACM), which defines a set of services that an application (such as a Command Responder or a Notification Originator application) can use for checking access rights. It is the responsibility of the application to make the proper service calls for access checking.

2.9 Power Line Communication (PLC)

Digital communications over powerlines is an old idea that dates back to the early 1920s. For some decades, the omnipresent power grid has been used for low-speed data communications. Many different standardized or proprietary systems have been used for the transmission of control and management signals (e.g. remote meter reading) by power supply companies. However, the powerline has largely been dismissed as being too noisy and unpredictable to be useful as a practical high-speed communication channel [SAR04].

A significant change occurred when the last monopolies were ended by 1998. In the same time, major advances in the fields of modulation, coding and detection enabled the design of efficient broadband communication systems over powerlines. The idea of exploiting the low-voltage (LV) power grid to provide broadband Internet access to residential customers has been proposed as an alternative to the other classical 'last-mile solutions' such as ADSL, cable modems, or wireless access systems. LV powerline communication (PLC) networks have a tree-like topology, with a PLC modem installed at the medium-voltage/low-voltage (MV/LV) transformer and providing connectivity to all premises in the neighborhood. The architecture of the LV PLC network has to be optimized for the special characteristics of the distribution grid, which changes from one geographic area to another, considering the number of households per transformer and the distance from the transformer to the customer premises. When larger distances are involved, as it is the case in European topologies, intermediate repeaters are typically needed to regenerate the signal from the head-end and provide adequate coverage in every customer outlet.

Also, there is growing interest in the prospects of reusing in-building powerline cables to provide a broadband LAN within the home or office. The major advantage offered by powerline-based home networks is the availability of an existing infrastructure of wires and wall outlets, so new cable installation is not required. The user can employ home networking devices for connecting several computers, sharing printers, or sharing a broadband Internet connection [SAR04].

Another important field of research is the use of the MV network for communication purposes. It can be used as a backbone to connect the low voltage transformer stations to the Internet if the conventional backbone networks, like fiber optic cables, are missing. MV lines have their own characteristics for communication: they are typically less noisy, and have fewer branches and taps than LV lines, so the environment is less hostile for communications and longer distances can be achieved. The problem with MV lines is that special couplers are needed for injecting the signal in the line to ensure that the mains voltage does not damage the equipment.

There are three components to make a connection through power lines [SAR04]:

1. **Head End**: it is the key component in a power grid topology. The HE is the master of the other units in the network. As a master the Head End coordinates the frequency and timeslots from the individual customer modems to maintain a smooth stream of packets in the dense spectrum of the power grid. The Head End also enables the WAN connection to the ISP where the Internet connects to the power grid.
2. **Intermediate Repeater**: it is used to extend the coverage offered by power-line communication. Installed with the secondary switchboard or in a metering unit, a riser or in a street-side cubicle, a repeater is required when there is a significant distance between the server modem and the customer modem. It is of two types: point to point or point to multipoint.
3. **Customer modem:** is used to connect the end-user to the electrical network thereby creating a data link. The modem is connected directly to an electrical socket at the customer location.

The speed of the PLC modems reaches 47Mbps and some companies announced of coming faster PLCs.

2.10 .NET Framework

The .NET Framework is the next generation of Microsoft's platform for developing component-based software. It provides fundamental advances in runtime services for application software. It also supports development of applications that can be free of dependencies on hardware, operating system, and language compiler [GIA02].

The .NET Framework encompasses the following:

1. **A new way to expose operating system and other Application Programming Interfaces (APIs):** for years, the set of Windows functionality that was available to developers and the way that functionality was invoked were dependent on the language environment being used. For example, the Windows operating system provides the ability to create windows (obviously). Yet, the way this feature was invoked from a C++ program was dramatically different from the way it was invoked from a Visual Basic program. With .NET, the way that operating system services are invoked is uniform across all languages (including code embedded in ASP.NET pages). This portion of .NET is commonly referred to as the .NET Framework class library.

2. **A new infrastructure for managing application execution:** to provide a number of sophisticated new operating-system services (including code-level security, cross-language class inheritance, cross-language type compatibility, and hardware and operating-system independency), Microsoft had developed a new runtime environment known as the Common Language Runtime (CLR). The CLR includes the Common Type System (CTS), for cross-language type compatibility, and the Common Language Specification (CLS), for ensuring that third-party libraries can be used from all .NET-enabled languages. To support hardware and operating-system independence, Microsoft developed the Microsoft Intermediate Language (MSIL, or just IL). IL is a CPU-independent machine language-style instruction set into which .NET Framework programs are compiled. IL programs are compiled to the actual machine language on the target platform prior to execution (known as just-in-time, or JIT, compiling). IL is never interpreted.

3. **A new web server paradigm:** to support high-capacity web sites, Microsoft has replaced its Active Server Pages (ASP) technology with ASP.NET. While developers who are used to classic ASP will find ASP.NET familiar on the surface, the underlying engine is different, and far more features are supported. One difference is that ASP.NET web page code is now compiled rather than interpreted; this feature is greatly increasing execution speed.

4. **A new focus on distributed-application architecture:** Visual Studio .NET provides top-notch tools for creating and consuming web services (vendor-independent software services) that can be invoked over the Internet.

5. **Building multi-threading into .NET applications is a powerful tool for the developer:** It empowers applications that demand high scalability, such as enterprise applications, as well as desktop applications that need to process more than one task at the same time. In order to enable multi-threading technology, Intel developed Hyper-Threading Technology (HT Technology) for the Pentium® 4 processor on the desktop and the Intel® Xeon™ processor for workstations and servers. These platforms make a particularly good choice for the deployment of threaded .NET solutions. The coming trend of parallelism in hardware is that of multi-core processors, which will make multi-threading even more important. Intel has announced planes to introduce the first versions of both the Itanium® processor and the Pentium 4 processor, that have multiple processor cores on a single die, in 2005. These introductions will be followed in 2006 by the first multi-core Intel Xeon processors and Intel Xeon processors MP. As these and other advances make hardware platforms ever more parallel in nature, the stage is set for software threading to deliver ever-larger performance gains. Software makers that gear up for this advance now, stand to gain a competitive advantage as this trend continues.

CHAPTER THREE

CHAPTER THREE
NETWORK MANAGEMENT SYSTEM DESIGN

3.1 Introduction

This chapter is dedicated to introduce the design of the network management system for public services (electricity power measurement and maintenance, water flow measurement and maintenance, medical help alarm, fire monitoring, and security monitoring) and its necessary application software tools. This system was implemented using Visual Basic .NET 2003.

3.2 System Objectives

1. Designing and building network management system for public services.
2. Designing and building software tools that manage these public services.
3. The system must be reliable, secure, extendable and easy to use.

3.3 System Considerations

1. The network traffic must be minimum.
2. The alerts must be sent to the service provider to be served, as fast as possible.
3. The alerts must have priorities.
4. The system must consider false alarms.
5. The database must be distributed, and efficiently work in multi-threaded system.
6. The addresses of services providers and customers' buildings must be easy to maintain.
7. Keeps the technologies used as standard as possible.

3.4 System Layout

Figure (3.1) shows the layout of the system.

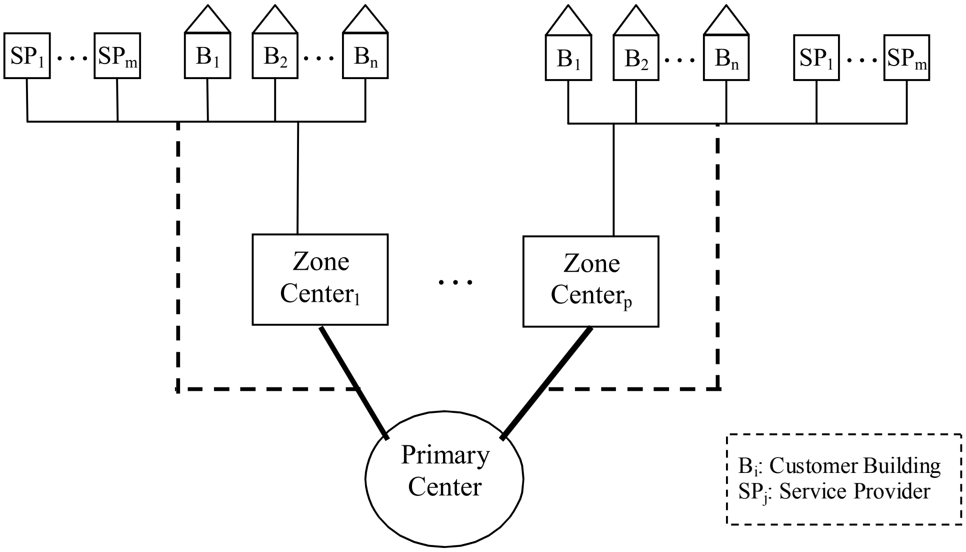


Fig.(3.1) System Configuration

The system is composed of one primary center that monitors multi zone centers, and each zone center monitors and controls a group of customers' buildings and service providers. In each customer building, an agent exists to collect information from sensors and meters established in customer building to provide a specific service (for example, smoke sensors give indication to the agent when a fire in the building is happening). The agent sends alerts to the zone center (that responsible to monitor the information sent from the building agent) or receives orders from it. The zone center analyzes the information received and does the necessary actions. The service provider receives service requests from the zone center and replies the answer with acceptance or refusal. The primary center monitors the operation (reaction) of the zone centers and hold any communication needed among the zone centers.

Each zone center monitor and control a group of buildings called *zone*. The zone is specified according to two factors:

1. *Geographical factor*: the area covered by the one zone should be as large as possible to hold a specific number such that the network infrastructure establishment and maintenance is feasible and proportional with the importance of the supported public service.
2. *Capacity factor*: The number of customers covered within the zone is important, it should be not small (because this will make the infrastructure infeasible), and too large (because this may cause some operational failures due to network overload).

3.5 Hardware Requirements

The hardware requirements are grouped into four sets. The first set is concerned with hardware needed at the customers' buildings; the second set is for zone center building; the third set is for primary center building; and the last set is for the network media.

3.5.1 Customer's Building Hardware

To monitor and then provide the services requested by the customer, the customer's building must contain sensors and meters. The considered sensors in this project are classified into three major types according to the provided service:

1. Smoke sensors to provide fire monitoring service.
2. Security sensors to provide security alarm service.
3. Water sensors to monitor the water flow, and consequently detect the cut of the water from the pipes (water service).

To read the measurements of the electricity and water, electrometers and water meters are needed for each service respectively. All these devices are connected to the agent's device that collects data from them and do the necessary operations related to storing data or sending alarms to the zone center.

The medic help alarm service is achieved by using a panic button in the building that is pressed when medic help is needed. The panic button could be exists in every room in the building or specific places according to the need of the customer.

In case that the sensors couldn't detect a problem happened, manual alarms can be raised by pushing the required button. The manual buttons are: (1) Fire Alarm, (2) Security Break Alarm, (3) Electricity Maintenance, (4) Water Maintenance, (5) Fire Devices Maintenance, and (6) Security Devices Maintenance. The Fire Alarm and the security Break Alarm buttons can be distributed in the house as needed like the Medic Help button.

Also, a liquid crystal display (LCD) devices are provided for displaying the electricity meter reading, water flow, and other devices status with a *Control* button to display the required information. Also, there are speakers (if demanded) to announce the customer when critical alerts happened.

3.5.2 Service Provider Hardware

The main job of the service provider software is receiving requests from the zone center. The number of orders that the service provider can serve is the factor that specifies the hardware needed. But, basically the service provider must provide reliability and availability to its services. To achieve that, the service provider software is put on a *cluster* of fast nodes (computers). When one node is breakdown the others are ready to monitor and control the agents. Also, the cluster configuration provides load balancing between the nodes.

3.5.3 Zone Center Hardware

The main jobs of the zone center are monitoring and controlling large number of customers. The zone center must provide reliability and availability to its services. To achieve that, two strategies have been taken into consideration:

1. The zone center system software is put on a *cluster* of fast nodes (computers). When one node is breakdown the others are ready to monitor and control the agents. Also, the cluster configuration provides load balancing between the nodes.
2. When the whole zone center break down, the primary center takes the responsibility of its functionality until it reruns again.

3.5.4 Primary Center Hardware

The jobs of primary center are monitoring and controlling a number of zone centers, and provides a backup to them in case of break down one of them. So, the primary center must provide reliability and availability to its service. This can be achieved by using cluster of fast nodes to hold the primary center system software.

3.5.5 Connection Media

This system is designed to cover a large geographical area with large number of customers. To suggest the suitable connection media that can achieve minimum cost with acceptable performance with scalability, a set of connections with different features must be established:

1. *Connection between customer's building and zone center*. This connection holds the transfer of alarms (from the agent in the Customer's building to the zone center), requests (from zone center to the agent) and their responds. The average size of messages transferred through this connection is 158 byte. The number of connections of this type is equal to the number of customers' buildings, which is very large.

   The large number of the connections of this type causes the construction of totally new infrastructure to cost very much. Even using wireless connections with this large number of connections with the existence of mobile networks and wireless internet service providers could generate large interference. So, the existing wired connection is the most suitable key in respect with cost. Usually the existing public networks are the unleased telephone lines (most of the existing telephone lines are unleased) and the electricity power lines. In the sense of the low bandwidth need, these two types of networks are suitable. But using the telephone lines (that are unleased connections) would cause problems, such as: (a) opening connection could be slow which in turn affects the time of alert notification, (b) when the telephone line is in use by the customer and it is needed to send an alert then the customer call must be closed unless the telephone central is supporting this capability, and (c) how the agent knows if the telephone call is from the manager (zone center) directed to it or it is for the customer from a friend; if the agent depends on the caller number (not all the telephone centrals supports that) then this number must be stored in the agent connection list and when it is needed to be replaced then it must be replaced by all agents.

   The other option is the electricity power lines. The devices needed to communicate through the electricity power lines are described in chapter two; they are the Head End, Intermediate Repeater, and Customer Modem. The customer modem would be setup in the customer's building, the intermediate repeater in the transformers or in a dedicated box in case of long distance between the transformers and the customer's building, and the Head End is put in the HV/MV transformers.

Last thing is the media connecting between the zone center and the Head End. The Head End collects data from relatively large number of agents. So, the zone is partitioned into sub zones, each one is supplied with Head End to avoid bottleneck problems and to increase the reliability. The media connecting the Head Ends and the zone center is suggested to be fiber optics and wireless for backing up.

2. *Connection between zone center and service provider*. This connection holds transfer of alarms (from the zone center to the service provider) and keeps information about the state of the service provider. Some statistical information may be delivered from the service provider to the zone center. This connection does not necessarily need to be high bandwidth because *usually* the amount of information transferred through it is small. The size of the messages transferred through this connection is 105 byte in average. The number of connections of this type equal to the number of service providers, which is, relatively, very small in comparison with the number of customers' buildings.

   The connection between zone center and the service provider could be achieved mainly by wireless connection because the wireless satisfies the needs of this type, and it is less expensive than others like twisted pair or optical fiber, or by unleased telephone lines. The backup connection is the electricity power lines, which is utilized only for alerts and states.

3. *Connection between zone center and primary center*. This connection holds the transfer of synchronization information, backup data, reports (from the zone center to the primary center), and disaster warnings. This connection needs to be high bandwidth because the amount of information is relatively large. The size of the messages transferred through this connection is 105…>100 Mbyte (in average 100 Mbyte). This large size is caused by the large backup files transferred between the zone center and the primary center. The distance between the primary center and the zone center could be long distance. The number of connections of this type is equal to the number of zone centers. The Optical Fiber is a suitable media could be installed and the wireless for the backup. The use of the wireless as a backup and not as primary connection is due to its instability in very bad weather and insecure. For very long distances, the Internet Satellite connection could be used with tunneling support, like Virtual Private Network (VPN) for secure connection.
4. *Connection between primary center and each zone*. This connection is needed to make the primary center capable of monitoring and controlling the zone in case the zone center was break down. The connection could be used temporarily until the zone center rerun again.

   This connection is used to connect the primary center with the Head Ends of the zone. The type of this connection depends on the average time of repairing the zone center. Unleased telephone lines could be used if the zone center repairing process requires little time that not affects the performance of the system. The wireless medium is suitable for this type of connection for long repairing process. Another strategy could be adopted which is installing unleased telephone lines but when the zone center breaks down and long time needed for repairing then the wireless should installed temporarily.

3.6 System Capacity Estimation

The calculation of the number of customers or service providers that each zone center can handle depends on many factors, the most effective factors are: (1) software capability, (2) zone center computers speed and capacity, (3) the transmission rate of the connection between agent or service provider and the zone center, and (4) the speed and capacity of the agent device or the service provider computers. The software in this thesis is designed to provide large capability and scalability where *in each zone* the zone center software can handle 2^{32}-1 (=4,294,967,295) agent and 2^{16}-1 (=65535) service provider at maximum. But the performance is depending on the other factors (Hardware factors). Because of the development of computers with high speed and large capacity, the second and the fourth factors are neglected during this estimation. So, the calculations depend on the third factor (connection media) only which is specified in section 3.5.5. The equations (3.1-2) are used to estimate the average number of nodes (agents or service providers) can be handled by the zone center depending on the usage of the connection media and its transmission rate:

$$N_S = \frac{R}{L} \qquad \text{......... (3.1)}$$

$$N_T = \frac{N_S}{r} \qquad \text{......... (3.2)}$$

Where R is the transmission rate of the communication channel,

L is the average length of the message transmitted between the node and the zone center,

N_S is the average number of nodes that use the communication channel at the same time,

r is the rate of the nodes (agent or service provider) that use the communication channel at the same time,

and N_T is the total number of nodes connected to the zone center by the same connection.

The average number of agents and service providers that can be handled by each zone center is defined in the following sections.

3.5.1 Agents Number Estimation

There are two main types of messages transferred between zone center and agent which are request messages and trap messages. The request messages must be replied with at least one response message. The trap messages are sent at least 5-times. After receiving trap message, the zone center send two request messages and responded by two response messages. The size of the request messages is 140 byte (in average) including the header size of the data link, network (IPv6), and transport layers (UDP). The response messages have the same size. The size of trap messages is 178 byte. If it is supposed that one trap and one request message per month are transferred between the zone center and each agent then the average size of message is calculated as follow:

$$AverageMessageSize(L) = \frac{2\times 140 + (5\times 178 + 4\times 140)}{2+5+4}$$

$$= 157.27 \approx 158 \quad byte$$

If it is assumed that one from every 15 agent in the same sub zone is sending or receiving message at the same time. Thus:

$$r = \frac{1}{15}$$

According to section 3.5.5, the power lines are the suitable communication media between zone center and agents. It is assumed that

ILEVO (LR1000, LR1100, LR120, and LR100) modems are used (see [ILV05]). The following calculations depend on equations (3.1-2):

$$R = 36 \quad Mbps$$

$$N_S = \frac{36 \times 2^{20}}{158 \times 8} = 29864.51 \approx 29865 \text{ agent}$$

$$N_T = \frac{29865}{\frac{1}{15}} = 447975$$ agent (maximum total number of agents in each sub zone that can be controlled by zone center)

Note that this number is calculated according to the maximum performance of the hardware used (according to the manufacturer) but even if this number is divided by two (=223987) then it still acceptable.

3.5.2 Service Providers Number Estimation

There is more than one type of messages transferred between zone center and service provider. The status messages sent at least every five minutes for monitoring purposes. The size of the status messages is 105 byte including the header size of the data link, network (IPv6), and transport layers (UDP). Other types of messages excluding the report messages approximately have the same size. The report messages that assumed to be requested every one or more months have different sizes. The following calculations would assume that for each month there is one report request of size 105 and report response of size 1000 byte (which is approximately 50 records). Thus, for one month (30 days, 24 hours per day, and 60 minutes per hour), there are at least 8640 status request and also 8640 status response. Then, the average length is calculated as follows:

$$AverageMessageSize(L) = \frac{8640 \times 2 \times 105 + 1 \times 1000 + 1 \times 105}{8640 * 2 + 2}$$

$$= 105.05 \approx 105 \quad byte$$

It is assumed that all the service providers in the same zone (or sub zone) are transmitting data at the same time. Thus:

$$r = \frac{1}{1} = 1$$

According to section 3.5.5, the wireless media or unleased telephone lines are the suitable connection media between zone center and service providers. The following calculations depend on equations (3.1-2):

1. Wireless: if the Cisco Aironet® 350 series [CIS06] (which is built on 802.11b standard with transmission rate of 11Mbps and there is faster and there are faster products) are used then:

$$R = 11 \quad Mbps$$

$N_S = \frac{11 \times 2^{20}}{105 \times 8} = 13731.35 \approx 13732$ service provider

$N_T = \frac{13732}{1} = 13732$ service provider (maximum total number of service providers service provider in each sub zone that can be controlled by zone center)

Note that this number is calculated according to the maximum performance of the hardware used (according to the manufacturer) but even if this number is divided by two (=6866) then it still acceptable.

2. Unleased Telephone Lines:

$$R = 56 \quad Kbps$$

$N_S = \frac{11 \times 2^{10}}{105 \times 8} = 13.41 \approx 14$ service provider

$N_T = \frac{14}{1} = 14$ service provider (maximum total number of service providers service provider in each sub zone that can be controlled by zone center)

The system administrator can decide whether this number of service providers is suitable or not taking in consideration that these calculations assume that all the service providers are transmitting and receiving data at the same time. This thesis suggests using the wireless connection to provide acceptable performance.

3.7 System Description

The time zone is unified in all components even if the large geographical area covered by the system has different time zones. The main components of the system are:

1. Agent component.
2. Zone Center Management component.
3. Primary Center Management component.
4. Services Providers components.

The SNMP protocol used in this system is SNMPv2 as basis with some changes. The established system uses the SNMPv2 as basis rather than SNMPv3 due to the complexity of the SNMPv3 and its need to wide bandwidth and time consuming.

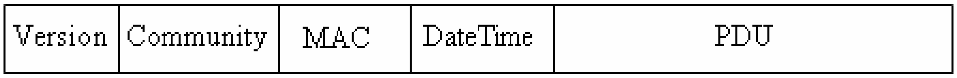
The used protocol has different authentication technique, time delay protection, message redirection protection, confidentiality, and an additional community. The authentication in the original SNMPv2 depends on the community name only which is a plain text and can be exploited easily. In the used protocol, it depends on Hash Message Authentication Code key with Message Digest Code (whose output is 128-bit; HMAC-MD5-128) algorithm for authentication. The time delay protection depends on the time that the message sent by the agent, where if the time difference between the receiving time and the sending time is larger than 2 seconds (default) then the message is considered delayed. The interceptor can not get a message and change the time because the HMAC-MD5-128 works on the whole message including the time which means any change on the time would make the MAC code invalid and the message would considered as unauthenticated. To protect the message from redirection to another destination, the IPv6 address of the destination would be included in the generation of the MAC code.

There is no confidentiality in the original SNMPv2, but the established system uses the Triple DES algorithm for encryption of specific messages and for local security.

The communities used are:

1. *Public*: This community can only read the MIBs and not allowed to write them.
2. *Power*: This community can read and write the MIBs.
3. *Administrators*: This community has the same privileges of Power in addition to the ability to change the keys of authentication and encryption. The requests sent to and responded by this community are always encrypted.

The format of the protocol is shown in Figure (3.2). The *Version* field holds 21 to refer to this new format. The *Community* field would be one of the communities mentioned before. The *MAC* field contains the result of the HMAC-MD5-128 method, where the input is the whole message concatenated with the destination IPv6 address with MAC field set to Null. The encryption is performed on the fields: MAC, DateTime, and PDU, where the PDU is the same definition as the SNMPv2. The MAC and DateTime fields are represented using the BER with type *octet string* of length 16 and *counter32*, respectively.



Version	Community	MAC	DateTime	PDU

Fig.(3.2) New Message Format

3.7.1 Agent Component

This component is an SNMP proxy which monitors the sensors, meters, and PLC interfaces, and send alarms to the zone center (SNMP manager part) when needed, and responds to requests from the zone center. It assigned IPv6 address according to its location as would be explained in the Zone Center Manager. It consists of the following modules (as shown in Figure 3.3):

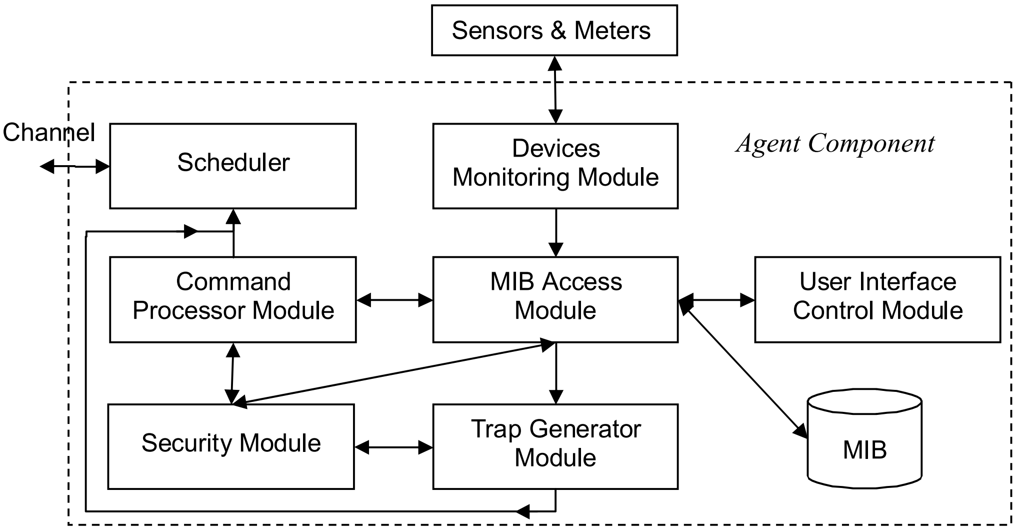


Fig.(3.3) Agent Component Modules

1. *Devices Monitoring Module*: This module is concerned with monitoring the sensors and meters periodically every one second, and send the status of the devices to the MIB Access Module to update the MIB. The one second is enough to be online with any change of device's status. The type and number of meters and sensors to be monitored are configured when the agent installed.

2. *MIB Access Module*: This module is responsible for reading and updating the MIBs, and orders the Trap Generator Module to generate specific traps according to the *changed* MIB. There are two types of

MIBs: (1) MIB that changing it doesn't require generating traps; (2) MIB that changing it requires generating trap(s). For example, changing the electricity measurement MIB doesn't need to generate trap but changing electrometer response to *not responding* would need to generate trap. Also, changing one MIB could cause more than one trap, for example, fire alarm would cause to generate fire, security, and medical alarms because if a fire happened it may need medical support to deal with injuries, and it may need police officers to control the area.

Also, the MIB Access module is responsible of authorizing the community and the access rights of the MIBs. For example, if an authenticated request, issued from a community *Public*, to change the number of times the trap must be sent, and *Public* has the authorization of *read-only* then the MIB Access Module return an error to the Command Processor Module. Another error situation may occur when the *Power* community has the authorization of *read-write* but the MIB is set as *not-accessible* which means it can not be read or write. Some of the MIBs are encrypted to give local security to these MIBs. When the MIB Access Module needs to access an encrypted MIB, it sends the MIB data with the *key* to the Security Module for encryption or decryption.

3. *Trap Generator Module*: This module is responsible of the generation of the trap and sending it to the Scheduler to be sent to the manager (zone center). The trap message is sent using UDP protocol which is unreliable, so the trap message is sent many times (default value = 5) every 5-minutes for the non high priority traps, and every 30 seconds for high priority traps until *set* request is received, then the MIB service of the trapped service is changed to off, or the sensors status returned normal in case of fire alarm only because changing, for example, the

security sensor's status could be caused by the intruder. If one of the previous conditions not occurs for the high priority traps then a warning message would be displayed on the LCD device. The authentication failures, the start and the shutdown traps are sent once (i.e. just the first five times) and don't send again. The time interval between one trap and another is set to 500 milliseconds to give enough time to change the status of the network. Signature needed to authenticate the trap at the manager is generated by the Security Module.

Sometimes, the user may press a manual alarm button accidentally or a false alarm is generated from one of the sensors then a trap is sent to the zone center. Phone call to the zone center by the customer is the only way to discard the alarm. The zone center would check the identity of the caller before discarding the alert request by turning off the trap.

The traps have different priorities as follow (from the highest to the lowest):

a. Fire, medical, police traps.
b. Authentication failures trap (which is generated when number of unauthenticated messages had been received), agent start trap, agent shutdown trap, and changing key trap.
c. Maintenance traps.

Also the alarms have higher priorities than the requests and responses issued by the manager. The priorities are implemented in two ways. *First*, the Trap Generator would generate the highest priority alarm, and the Scheduler sends it first. *Second*, the packet handling the alarm has higher priority which means that the device receives this packet and will serve it first.

4. *User Interface Control Module*: This module handles the user (customer). The customer can only see the readings and sensors' status through the LCD in addition to the ability of pressing the manual alarm buttons when needed. When the customer needs to see some information, he should press the Control button one or more times until the needed information are displayed. For example, if he need to see the status of the security sensors, he should press the Control button one or more times until the security sensors status are displayed, each time he press the Control button some information about the specific device is shown. When the user press a manual alarm button, the User Interface Control module sends a request to the MIB Access module to update the MIB, then the MIB Access Module issues a command to the Trap Generator module to send a trap.

5. *Command Processor Module*: This module is the responsible of processing the requests and responding to them if needed. When the Command Processor module get a request for reading or setting MIBs, it sends the message to the Security module to check the authenticity of the community (by sending the source IPv6 address and the message with MAC field set to NULL to the Security model), and then if it is authenticated it checks the validity of the message time. It validates the time if the period between the time of receiving the message and the time specified in the DateTime field is less than the specified period in the MIB (the default is 2 seconds). If the time is valid then the Command Processor issues the MIB Access module to do the required operation and then send the response of the request to the Scheduler to be sent to the requester. If not authenticated or time is invalid then the Command Processor issues to the MIB Access module a command to increment the authentication failures MIB value, then the MIB access

module generates an authentication failure trap. Also, it does the same for the encrypted message.

6. *Scheduler*: It manages the reception of requests, the sending of responses, and the sending of traps. It controls the number of requests to be served to avoid degradation of the agent performance from serving a lot of requests at same time. Also, it is responsible of granting the priorities of sending and serving. For example, the traps (in general) have higher priorities than responses, so the Scheduler will send them before sending the responses; in addition to the priority set in the IPv6 packet header which makes the devices serve them before the lower priorities packets.

7. *Security Module*: It is responsible of the security methods used for authentication and encryption/decryption processes. HMAC-MD5-128 algorithm is used for authentication, and Triple DES algorithm for encryption/decryption. HMAC-MD5-128 and Triple DES are used because they don't require a lot of resources, relatively fast, and provides enough security. The keys used are five, three of them for authenticating each community with HMAC-MD5-128 (each one is 128-bit). The other two keys are used for encryption/decryption (each one is 192-bits), one key is for local encryption and the other for encrypting messages (this key is only used with the Administrators community). The main reason for the ability to encrypt messages is providing secure connection to change the keys. In addition to encrypting the message the way of sending the key provide more security in case the encryption is broken. The method used for sending the key is that the zone center applies the following function before sending the result:

$$Key_s = Key_n \oplus MD5(Key_o) \qquad \text{.........} \ (3.3)$$

Where Key_n is the new key with 128-bits,

Key_o is the old key with 128-bits,

Key_s is the key to be sent,

and $\oplus$ is the XOR bitwise operation

The agent would extract the new key by the following function:

$$Key_n = Key_s \oplus MD5(Key_o) \qquad \text{.........} \ (3.4)$$

8. *MIB Database*: It holds all the MIBs values used in the agent for storing the states of the sensors and meters, readings, authentication and encryption keys, addresses, and history. Some of the MIBs are encrypted to provide local security and they checked as encrypted by setting the first word in the Description part of the MIB object to be "Encrypted". The system uses MIB-II standards. The IDs of the MIBs objects are under the ISO(1).Organization(3).DoD(6).Internet(1) .Experimental(3).PubMgmt(17) tree (or simply 1.3.6.1.3.17) which is a branch of the experimental tree. The enterprise that uses this system could register its own tree with IANA. To see the used MIB definitions see Appendix E.

3.7.2 Zone Center Management Component

This component is responsible of monitoring and controlling the agents and requesting the needed service from the nearest available service provider. Also, it is responsible of getting the electricity and the water readings of the customers. It communicates with the primary center to synchronize information and to request or provide the services needed in the case of disaster situations. The zone center is composed of following parts:

1. *SNMP Manager*: It is responsible of getting information from agents, configuring them, and redirects some of their traps to Service Providers Manager. It uses the same version of SNMP protocol in the agents (which is the modified one that described earlier). It composes of the following Modules: Trap Processor, Request Processor, Readings Collector, and Security Module. Figure (3.4) shows the SNMP Manager Modules.

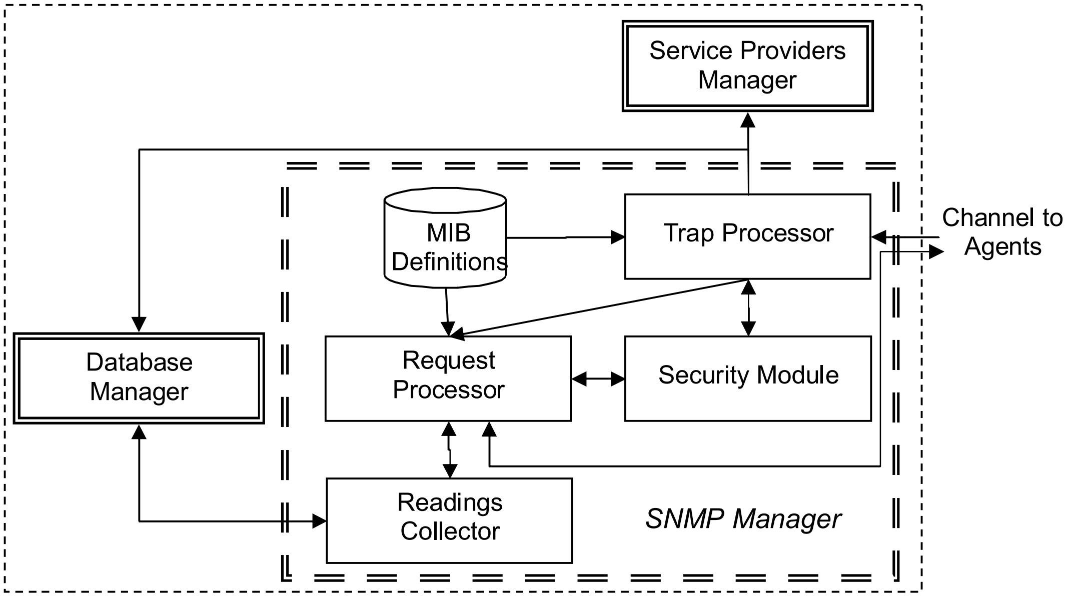


Fig.(3.4) SNMP Manager Layout

The *Trap Listener* is responsible of receiving the traps from the agents and sends them to the Service Providers Manager or to the Request Processor during time synchronization process. It records the history of the traps received through the Database Manager. When the Trap Processor receives a trap that needed to be stopped, it requests from the Request Processor to send *set* request to the agent to stop sending that trap which means to the agent the trap was received. The Trap Processor has protection against processing a huge number of traps that could hang the system or fall down its performance by pending and not processing more traps than the maximum number of the traps specified. Also, it does not accept traps from addresses not registered as an agent in the Database. The Trap Processor checks if the MIB that generates the trap is valid by checking it at the MIB Definitions.

The *Request Processor* is responsible of sending requests and receiving responses to and from the agents. It uses the MIB definitions to specify the MIBs used by the agents. Also, it is responsible of synchronizing the time with the agent in case of sending request without receiving response but an Authentication Failure by time trap had been received from the same agent and by the same MIB which mean that the request sent has not the same time as the agent, and then the agent needs to be synchronized. Algorithm (3.1) describes how the synchronization achieved.

```
ALGORITHM (3.1): TimeSynchronization
INPUT:
        Time of sending request (T1);
        Time of receiving Authentication Failure trap (T2);
        DateTime field value in the received Authentication Failure trap (DT);
        and agent address (Addr)
OUTPUT:
        Fail OR Success
Procedure:
        Step 1: set RCount = 0
        Step 2: set DTagent = T2 - T1 + DT
                Step 3: if RCount = 5 then return Fail
        Step 4: set DTc = current DateTime + $\lceil (T2 - T1) /2 \rceil$
        Step 5: send set request for DateTime MIB of value DTc with DateTime field
                of DTagent to the address Addr, and set T1 = current DateTime
        Step 6: if response received then return Success
        Step 7: increment RCount
        Step 8: if Authentication Failure trap by time from Addr had been received
                then set T2 = current DateTime,
                set DT = DateTime field value of the trap,
                and goto Step 2
        Step 9: Else if wait time is expired then goto Step 3
```

This algorithm depends on the trap received from the agent to guess the time at the agent to validate the time of the request. It is achieved by calculating the time difference between sending the request and receiving the trap to achieve the time interval to be added to the time of sending the trap (DateTime field value in the trap) to achieve approximately the time of receiving the next request by the agent in its time. If the response to the request not received but an Authentication Failure trap by time received or the wait time for receiving either response or request had been expired then the algorithm repeat the same process until the response received or it will repeated for 5 times. If the algorithm fails to synchronize the time it notifies the manager to treat this problem.

The *Readings Collector* is responsible of getting the electricity and water measurements from agents through the Command Processor and stores them in the database through the Database Manager. The process of reading all the measurements must be accomplished in maximum of two months (default value). To avoid using the whole bandwidth of the lines for reading, the process of reading agents are accomplished by partitioning the agents into groups and each group are read in a separated time interval. The time interval is three minutes which give acceptable time for sending the requests and receiving them. The agents are partitioned according to the following equations:

$$totMinutes = totDays * 24 * 60 \qquad \ldots\ldots\ldots \ (3.4)$$

$$SpareTime = 0.2 * totMinutes \qquad \ldots\ldots\ldots \ (3.5)$$

$$GAgents = \left\lceil \frac{no\_agents}{\frac{totMinutes - SpareTime}{SepInterval}} \right\rceil \qquad \ldots\ldots\ldots \ (3.6)$$

Where totDays is total number of days in the period to read all the electricity and water meters,

24 is the number of hours in the day,
60 is the number of minutes in the hour,
totMinutes is total number of minutes in the period,
SpareTime is spare time for the unexpected failures during reading meters,
SepInterval is the time interval that separates the reading of groups,
and GAgents is the maximum number of the agents in each group.

The spare time is used in case of failures in reading some meters, and it is 20% from the whole period of reading the all the meters which gives the ability of 20% failures to be treated. The agents in the groups are chosen to avoid as possible being in the same region as in the same street number. This strategy could balance the load on wires and provides a way of continuous monitoring of all streets. It is accomplished by using Algorithm (3.2) which make benefit of the mapping from building address to IPv6 address that explained in the *Registration* part.

```
ALGORITHM (3.2): GenerateGroup
INPUT:
        Sorted list of agent IPv6 addresses started with index 0 (SortedL);
        Number of items in SortedL (N);
        Maximum number of agents in group (Max);
        and Start index (Start)
OUTPUT:
        List of agent addresses represents the group;
        Last index
Procedure:
        Step 1: if Max-1 < Start then return empty list and Start as last index
        Step 2: set GroupL as empty list of IPv6 addresses
        Step 3: set Gn = 0
        Step 4: if Start >= N or Gn >= N then return GroupL and Start as last index
        Step 5: get SortedL[Start] item and put it in T
        Step 6: add T to GroupL
        Step 7: increment Start
        Step 8: increment Gn
        Step 9: goto Step 4
```

The parameter list *SortedL* in Algorithm (3.2) is generated using Algorithm (3.3) by calling it each time a new customer need to be added. Actually Algorithm (3.3) is part of the Database Manager.

```
ALGORITHM (3.3): SortforGrouping
INPUT:
        List of sorted agent IPv6 addresses started with index 0 (SortedL);
        Number of items in SortedL (N);
        and newIPv6 address (newIPv6)
OUTPUT:
        List of sorted agent addresses
Procedure:
        Step 1: if N = 0 then add newIPv6 to SortedL and return SortedL
        Step 2: set RevIPv6 = the reverse of newIPv6 in bit level
        Step 3: set Counter = 0
        Step 4: set TmpRev = the reverse of SortedL[Counter] in bit level
        Step 5: if RevIPv6 >TmpRev then goto Step 8
        Step 6: increment Counter
        Step 7: if Counter < N then goto 4
        Step 8: shift the items in SortedL up from the index Counter
        Step 9: set SortedL[Counter] = newIPv6
```

2. *Registration*: It is responsible of registering service providers and customers and their needed services. It stores these information by sending them to the Database Manager part. It is responsible only for the service providers and customers in the zone under the responsibility of zone center. The information needed for registering the customer are: (1) *customer name* which is 60 character length of five fields; (2) *address* which is composed of *city name* of 30 character length, *sector number* of 4 digits length, *street number* of 3 digits length, and *building number* with length of 6 digits; and (3) *services requested* which are electricity power measurement (essential service) and maintenance, water measurement and maintenance, medical help alarm, fire monitoring, security monitoring, and intermediate device. If the

intermediate device had been chosen, it assumes to be not a customer but an intermediate device connecting customer (for example, repeater).

The information needed for registering service provider are: (1) *service provider name* which is 50 character length; (2) *address* which is the same as needed to register customer in addition to *Latitude* which is composed of 3 digits degree, 2 digits minutes, and 3 digits seconds, and *Longitude* which is composed of 3 digits degree, 2 digits minutes, and 3 digits seconds; (3) *services provided* which are electricity power maintenance, water maintenance, ambulance station, fire station, and police station; and (4) *IPv6 addresses* that would be assigned to the service provider. Each sector number has reference point assigned by its longitude and latitude. The latitude and longitude is needed to find the nearest service provider to customer. For both the agent and the service provider, the IPv6 address is build automatically from the building address as shown in Figure (3.5).

76-bits	8-bits	14-bits	10-bits	20-bits
Enterprise Network Address	City	Sector	Street	Building Number

Fig.(3.5) The building address mapping to IPv6 address

The *Enterprise Network* field is the network address reserved by the enterprise that uses this system and the other fields represent the building address.

3. *Service Providers Manager*: It is responsible of monitoring and requesting services from the nearest available service provider to the customer in addition to serving requests from the primary center. Also, it is responsible of requesting reports from the service providers. It composes of the following modules: Service Providers Monitor, Service

Requester, and Primary Center Server. Figure (3.6) shows the modules of the Service Providers Manager.

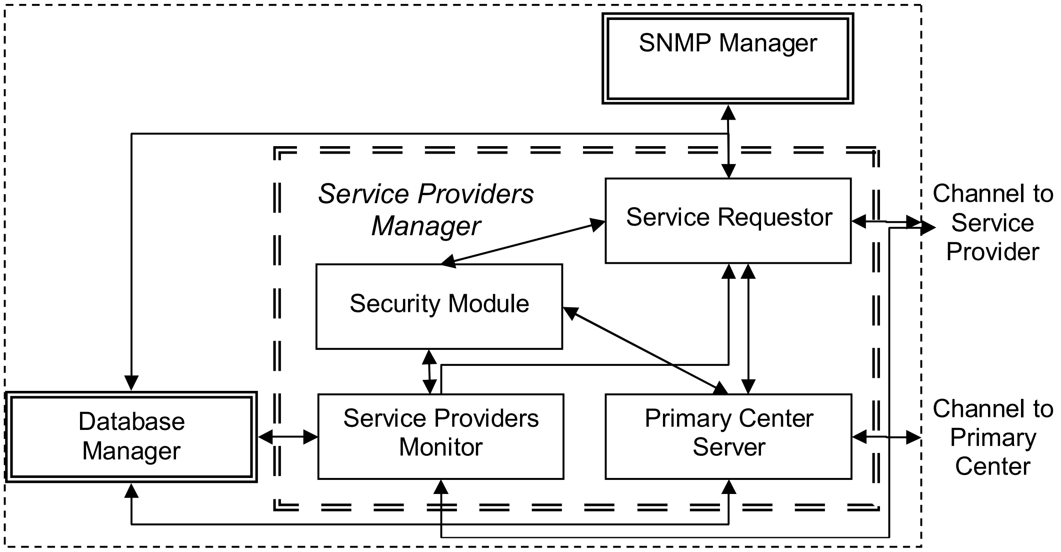

SNMP Manager
Service Providers Manager
Service Requestor
Channel to Service Provider
Security Module
Database Manager
Service Providers Monitor
Primary Center Server
Channel to Primary Center

Fig.(3.6) Service Providers Manager Modules

The *Service Providers Monitor* sends request to the service provider every 5-minute to get its status to ensure that the service provider is working, and to know if it is available for requests or not. If the service provider does not respond, another request sent and so on until 5 times. If it does not respond, the service provider monitor alerts the operator of this service provider showing its information if needed. The status is stored using the Database Manager. Also, the service providers monitor accepts *support* requests from service provider to get support from other service providers. After receiving support request, the service providers monitor makes the service provider state unavailable and directs the request to the service requester.

When the SNMP Manager receives a trap from an agent, it sends the appropriate request to the *Service Requester* which in turn sends the request to the appropriate nearest available service provider. The Service Requester retrieves the information needed for this operation from the Database

Manager. Finding the nearest service provider depends on two factors: (1) the mathematical subtraction between part of IPv6 addresses of the agent and the service provider (the city, sector, and street fields) which gives an indication of how far is the distance between them from the aspect of the urban planning; (2) the distance between the sector of the agent and the service provider by using the latitude and longitude of them. These two factors help the Service Providers Manager to make a good estimation about the nearest service provider. The following equations calculate the required to be used in nearest distance decision (for details about equation 3.13 see appendix F):

$$\begin{aligned} UrbanDist = {} & (AgentIPv6 \;>>\; 20)\;\&\;0FFFFFFFFh \\ & -(SPIPv6 \;>>\; 20)\;\&\;0FFFFFFFFh \end{aligned} \qquad \ldots\ldots\ldots (3.8)$$

$$Lat = LatD + \frac{LatM}{60} + \frac{LatS}{3600} \qquad \ldots\ldots\ldots (3.9)$$

$$Lon = LonD + \frac{LonM}{60} + \frac{LonS}{3600} \qquad \ldots\ldots\ldots (3.10)$$

$$ScalLat = \frac{6378 \times \pi}{180}, \qquad 6378 \text{ is earth's radius} \qquad \ldots\ldots\ldots (3.11)$$

$$ScalLon = \frac{2\pi \times 6378 \times \cos(LatC)}{360} \qquad \ldots\ldots\ldots (3.12)$$

$$Dist = \sqrt{\begin{aligned}&(Lat1 - Lat2)^2 \times ScalLat^2 \\ &+ (Lon1 - Lon2)^2 \times ScalLon^2\end{aligned}} \qquad \ldots\ldots\ldots (3.13)$$

$$FinalDist = UrbanDist \times Dist \qquad \ldots\ldots\ldots (3.14)$$

Where AgentIPv6 is the IPv6 address of the agent,

SPIPv6 is the IPv6 address of the service provider,

UrbanDist is the distance between the service provider and the agent in aspect of the urban planning,

(*LatD, LatM, LatS*) are the latitude elements extracted from the latitude format (DD° MM′ SS.SS″),

(*LonD, LonM, LonS*) are the longitude elements extracted from the longitude format (DDD° MM′ SS.SS″), *Lat1*and *Lat2* are the latitude of the sector and the service provider respectively (extracted from DD˚ MM′ SS.SS″),

*Lon1*and *Lon2* are the longitude of the sector and the service provider respectively (extracted from DDD˚ MM′ SS.SS″),

ScalLat is the scale factor of the latitude,

ScalLon is the scale factor of the longitude,

LatC is the Latitude of the center in the region that the system work in.

Dist is the distance between the SP and the agent calculated from lat. & lon.

and *FinalDist* is the distance that the comparison use it

After the Service Requester found the nearest available service provider (the "available" according to the last check by the Service Providers Monitor) then it sends request to the service provider. The service provider sends a response (either acceptance or refusal) according to its current status. If the response is refusal then the Service Requester should get the next nearest available one and so on. If all of the service providers available in the zone are not available then it commands the Primary Center Server part to send the request to the primary center for sending the request to other neighbor zones. Algorithm (3.4) describes how the Service Providers Manager finds the nearest available service provider to the customer. Equations (3.9) and (3.10) are calculated and stored in the Database at the initial stages of the registration of the service provider, while Equation (3.11) is calculated and treated as constant.

Also, the Service Requester is responsible of requesting reports from the service provider on its history which contains information about the accepted requests, if they are served or not, when, and other details.

The Primary Center Server is responsible of sending requests to the primary center to get help from other zones. Also, it receives requests from the primary center to serve other zones. In addition to that, it sends reports about the center to the primary center when demanded.

```
ALGORITHM (3.4): NearestAvailableSP
INPUT:
        Agent IPv6 address (AgentIPv6);
        List of available service providers' IPv6 addresses started (SPL);
        List of the Lat and Lon for each service provider in SPL (LatLon);
        Number of items in SPL (N);
        and primary center IPv6 address (PrimeIPv6)
OUTPUT:
        Success or Fail
Procedure:
        Step 1: extract the city and sectors from AgentIPv6 then get its Lat and Lon
                from the Database Manager and put them on Lat1 and Lon1,
                repectively
        Step 2: set DistL to empty list
        Step 3: for each service provider's IPv6 address (SPAdd) in SPL do
            Step 3.1: get its Lat and Lon from LatLon then put them in Lat2 and Lon2,
                      respectively
            Step 3.2: calculate equations 3.8 and 3.13 then 3.14 to add FinalDist by sort
                      (ascending order) to DistL list with indication to its item in SPL
        Step 4: if DistL is empty then goto Step 14
        Step 5: remove the first item from DistL and put it in NearSP
        Step 6: set Hopes = 0
        Step 7: send request to the service provider that NearSP belongs to
        Step 8: get response from the service provider and put it in Stat
        Step 9: increment Hopes
        Step 10: if Stat is fail and Hopes <5 then goto step 7
        Step 11: if Stat is fail then notify the operator and goto Step 4
        Step 12: if Stat is refused then set it as unavailable at the Database Manager
                and goto Step 4
        Step 13: if Stat is accepted then return Success
        Step 14: send the request to the Primary Center Server
```

The last module is the Security Module which consists of encryption and authentication routines to be used in the transmission between the Service Providers Manager, the service providers, and the primary center. Triple DES algorithm is used for encryption and HMAC-MD5-128 is used for authentication. All the transmissions add the time stamp to messages (i.e. sending with the message the date and time to protect them from delay, and add the destination IPv6 address to protect them from redirecting the messages. Also it uses the same technique as used by the SNMP manager in exchanging keys.

4. *Electricity Measurements Displayer*: It is responsible of displaying the electricity readings collected from agents. It issues reports about the customers' meters readings in every two months and shows which meters were not read yet because of failure in reading or waiting for its time.

5. *Water Measurements Displayer*: It is responsible of displaying the water readings collected from agents. It shows reports about the customers' meters readings in every two months and shows which meters were not read yet because of failure in reading or waiting for its time.

6. *Database Manager*: It manages the system's data storage and manipulation. The Database Manager is responsible of backing up the registered customers, service providers, and other information. Also, it manages synchronization of the data shared between zone center and other parts of the system to keep the distributed data integrity valid (for example, synchronizing the registered customers with primary center or within the same center). The Database Manager is composed of three modules: *Data Manipulator module*, *Backup module*, and *Synchronization module*. The Data Manipulator module is responsible of how to store the data, read the data, and thus serve requests from other parts of the system. The involved data are structured into the tables shown in Tables (3.1-20). Note that the field (or fields) with bold font is the primary key for the table. The history tables are needed as statistical information and could refer to the cause of failures, degradation of performance, and intruding operations to the system.

Table (3.1) SectorInfo

Field Name	Size (Byte)	Description
Sector	**2**	**Sector number.**
Lat	4	The latitude represented by float number.
Lon	4	The longitude represented by float number.

Table (3.2) Cities (replica table from the primary center)

Field Name	Size (Byte)	Description
City_Id	**4**	**Holds the ID that refers to city.**
CityName	30	It holds the name of the city.

Table (3.3) Customers

Field Name	Size (Byte)	Description
Cust_Id	**4**	**Holds the ID that refers to customer.**
Name1	12	It holds the first name of the customer.
Name2	12	It holds the second name of the customer.
Name3	12	It holds the third name of the customer.
Name4	12	It holds the fourth name of the customer.
Name5	12	It holds the fifth name of the customer.
City_Id	1	Holds the city number that the customer in. Foreign Key to Cities.
Sector	2	Sector number.
Street_Build	4	The least significant 20-bits for building number, 10-bits for street number, and the rest are unused.
Services	1	It refers to the services requested by the customer. One bit for each service.
Status	1	Describes the status of the services of customer, is the service suspended or not. Each bit refers to a service.
Regist-Date	8	It holds the date and time of the registration.

Table (3.4) Cust_Status_History

Field Name	Size (Byte)	Description
Cust_Id	**4**	**Refers to the customer. Foreign Key to Customers.**
ChangeDate	**8**	**The Date and Time that the status had been changed.**
Status	1	Describes the status of the services of customer, is the service suspended or not. Each bit refers to a service.
Comment	100	It can be a description of the cause of status change. It could be changed due to punishment or failure.

Table (3.5) Cust_Registration_History

Field Name	Size (Byte)	Description
Cust_Id	**4**	**Refers to the customer. Foreign Key to Customers.**
Reg-Services	**1**	**Describes the services requested by customer. Each bit refers to a service.**
Reg_Date	8	The Date and Time that the service requested by the customer.

Table (3.6) Electricity_Readings

Field Name	Size (Byte)	Description
Cust_Id	**4**	**Refers to the customer. Foreign Key to Customers.**
ERead_Date	**8**	**The Date and Time that the reading occurs.**
Elect_Reading	4	Holds the value read from the electricity meter at the customer’s building.

Table (3.7) Water_Readings

Field Name	Size (Byte)	Description
Cust_Id	**4**	**Refers to the customer. Foreign Key to Customers.**
WRead_Date	**8**	**The Date and Time that the reading occurs.**
Water_Reading	4	Holds the value read from the Water meter at the customer’s building.

Table (3.8) Readings_Fail (for one time)

Field Name	Size (Byte)	Description
Cust_Id	**4**	**Refers to the customer. Foreign Key to Customers.**
Fail_Date	**8**	**The Date and Time that the reading failed.**
Readings_Faild	1	Specifies which one has been failed, the electricity, water, or both.

Table (3.9) Readings_Fail_History (for all times)

Field Name	Size (Byte)	Description
Cust_Id	**4**	**Refers to the customer. Foreign Key to Customers.**
Fail_Date	**8**	**The Date and Time that the reading failed.**
Readings_Faild	1	Specifies which one has been failed, the electricity, water, or both.

Table (3.10) ServiceProviders

Field Name	Size (Byte)	Description
SP_Id	**2**	**Holds the ID that refers to service provider (SP).**
SPName	50	It holds the name of the SP.
City_Id	1	Holds the city number that the SP in. Foreign Key to Cities.
Sector	2	Sector number.
Street_Build	4	The least significant 20-bits for building number, 10-bits for street number, and the rest are unused.
Lat	4	The latitude represented by float number.
Lon	4	The longitude represented by float number.
Services	1	It refers to the services provided by the SP. One bit for each service.
Status	1	Describes the status of the services of SP, is the service suspended or not. Each bit refers to a service.
Regist-Date	8	It holds the date and time of the registration.

Table (3.11) SP_Status_History

Field Name	Size (Byte)	Description
SP_Id	**2**	**Refers to the service provider. Foreign Key to ServiceProviders.**
ChangeDate	**8**	**The Date and Time that the status had been changed.**
Status	1	Describes the status of the services supported by the service provider, is the service suspended or not. Each bit refers to a service.
Comment	100	It can be a description of the cause of status change.

Table (3.12) SP_Registration_History

Field Name	Size (Byte)	Description
SP_Id	**2**	**Refers to the SP. Foreign Key to ServiceProviders.**
Reg-Services	**1**	**Describes the services newly provided by SP. Each bit refers to a service.**
Reg_Date	8	The Date and Time that the service registered for the SP.

Table (3.13) SP_IP_Addresses

Field Name	Size (Byte)	Description
SP_Id	**2**	**Refers to the SP. Foreign Key to ServiceProviders.**
IPv6	**16**	**The assigned IPv6 address.**
Assign_Date	8	The Date and Time that the IPv6 assigned to the SP.

Table (3.14) Traps (All customers' Traps)

Field Name	Size (Byte)	Description
Cust_Id	**4**	**Refers to the customer. Foreign Key to Customers.**
Trap_Date	**8**	**The Date and Time that the Trap occurs.**
Trap_MIB	**2**	**Specifies the MIB that generates the trap.**
Trap_Datagram	60	It contains the trap datagram that had been received.

Table (3.15) Customer_Alarms (only the customers' services alarms)

Field Name	Size (Byte)	Description
Cust_Id	**4**	**Refers to the customer. Foreign Key to Customers.**
Alarm_Date	**8**	**The Date and Time that the alarm occurs.**
Alarm_Type	**2**	**Specifies the type of the alarm. Each bit refers to specific alarm.**
To_SP	2	It specifies the service provider that requested to serve this alarm. If it is 0 then it is either not served yet or served by the primary center. Foreign Key to ServiceProviders.
Status	1	It specifies the status of serving the alarm. It is not served yet, served by other zone center, or served by To_SP service provider.

Table (3.16) Intermediate_Devices

Field Name	Size (Byte)	Description
IDev_Id	**4**	**Holds the ID that refers to Intermediate Device (IDev).**
IDev_IPv6	16	It holds the IPv6 address of the device
City_Id	1	Holds the city number that the SP in. Foreign Key to Cities.
Sector	2	Sector number.
Street	2	Street number.
IDev_Type	1	Type of the IDev.

Table (3.17) IDev_Traps

Field Name	Size (Byte)	Description
IDev_Id	**4**	**Refers to the customer. Foreign Key to Customers.**
Trap_Date	**8**	**The Date and Time that the Trap occurs.**
Trap_MIB	**2**	**Specifies the MIB that generates the trap.**
Trap_Datagram	100	It contains the trap datagram that had been received.

Table (3.18) Network_Prefix

Field Name	Size (Byte)	Description
Net_Prefix	16	Holds the network prefix of the network where each IP address in the system could has the same one.

Table (3.19) Servers_Addresses

Field Name	Size (Byte)	Description
Serv_IPv6	**16**	**Holds the IPv6 address of the server.**
Type	**1**	**It specifies the type of the server that it is one of the following: Primary Center, within the cluster, data server, or backup.**
Bckup_duration	2	Specifies the number of days until making another backup.
Last_Backup	8	Specifies the date and time of the last backup.

Table (3.20) Files_Checksum

Field Name	Size (Byte)	Description
File_Name	**20**	**It specifies the file name.**
Checksum	8	It holds the checksum of the file contents using MD5 algorithm with 64-bit output (the original algorithm output is 128-bit but by XORing the two halves of it, the output with be 64-bit).
Changed	1	In data server, it specifies if the file had been changed or not which in turn identifies the validity of the Checksum field. In ordinal server, it refers to the changed tables in the data server.

The *Files_Checksum* table is containing the checksum of all the files and whether the calculated checksum is valid or not. Thus, it is valuable to the synchronization process to specify whether the replicated data on the remote machine is the same or not, without unnecessary calculation to the checksum.

Also, the data manipulator has index tables to index the tables according to specific fields. Each table has an index table according to the primary key of the table and other index tables according to other fields. Some of the index tables are shown in Tables (3.21-24).

Table (3.21) Customers_index_Name (Sorted by name1,name2, name3,name4, and name5)

Field Name	Size (Byte)	Description
Cust_Id	4	It specifies the customer id in Customers table.
Record_Idx	4	It specifies the physical record number of the customer in the table.

Table (3.22) SP_index_Name (Sorted by name)

Field Name	Size (Byte)	Description
SP_Id	4	It specifies the SP id in ServiceProviders table.
Record_Idx	4	It specifies the physical record number of the customer in the table.

Table (3.23) Customers_index_IPv6 (Sorted by City_id, Sector, and Street_Build)

Field Name	Size (Byte)	Description
Cust_Id	4	It specifies the customer id in Customers table.
Record_Idx	4	It specifies the physical record number of the customer in the table.

Table (3.24) Customers_index_RIPv6 (Sorted by the reverse of IPv6 address)

Field Name	Size (Byte)	Description
Cust_Id	4	It specifies the customer id in Customers table.
Record_Idx	4	It specifies the physical record number of the customer in the table.

All the tables are physically stored in one or more files according to table's number of records and size to: (1) simplify the operation of synchronization, (2) decrease the size of data needed a new checksum due to a change and thus increase the speed, and (3) gives better performance by making more than one thread to write data on one table but in different files. Each table has header that contains information about the table which are:

SizeOfRecord: is two bytes positive integer that contains the size of the record in the table.

TotalRecords: is four bytes positive integer that contains the total number of records without the deleted ones.

LastFileNoOfRecs: is two bytes positive integer that contains the Number of records in the last file.

MaxNoOfRecsInFiles: is the maximum number of records allowed in one file.

NumberOfFiles: is two bytes positive integer that contains the number of files contains the data of the table.

LastTimeBackup: is eight bytes that contains the Date and Time of the last time that this table is backed up.

LastTimeClean: is eight bytes that contains the Date and Time of the last time that cleaned from deleted records.

Each record in the table has an additional physical attribute field that indicates the status of the record. It is one byte length contains, *state* (unused, used, or deleted) and *access permission* (locked or unlocked). The state indicates that the record has not correct values (unused), has correct values (used), or has previously correct values but deleted. The access permission ensures that the record can not be processed (read or write) by more than one thread to ensure the integrity of the table. Locking file or record by one thread makes other threads waiting. The waiting state to the threads can be either by infinite looping (or even timed looping that is loop for specific time and return fail when expired) or by sleeping the thread until the table is unlocked or for specific time. The first way would use most of its time quantum in checking, but the second could give its time quantum to other threads that need processing and do not need that specific file which provide better utilization of the CPU. But both ways could make one (or more) thread either starved (i.e.

the file or record is locked each time the thread check for it) or returned with fail in case of time expire. This problem is happened due to the relatively large number of threads need to access the file or record and each time the starved thread check for the file lock, another thread reach its time quantum and locks the file before the starved thread reaches its next time quantum and so on.

For example, T1, T2, T3, T4 are threads want to access the same file (F). T1 was started and locked F and its time quantum expired. Then, T2 started and check for F and find that F is locked so, it sleeps for one time quantum, T1 reaches its time quantum and use the file F and complete then unlock it. When T1 time quantum is expired, T3 is started and wants to access F so; it locks F. T3's time quantum has expired. When T2 reaches its next time quantum, it checks for F and find that it locked then it sleep again. So when T3 reaches its time quantum and unlock F then its time is expired, T4 started and lock F, and so on. Thus, the threads accessing files must be managed to avoid the starvation. The management is achieved by creating queue for each file locked by a thread. When thread wants to lock a file, it sends request to thread management object which in turn create queue for that file to hold the waiting threads. Each thread wants to lock the file (i.e. to read or write on file) sends request to the thread management object then the thread management to checks if this file has a waiting queue. If not it creates waiting queue for that file and permit locking the file to the requesting thread. If the waiting queue exists, the thread management object adds the requesting thread to the waiting queue and reply with deny. When the thread receives deny reply, it go into sleep state. But when it receives permission to lock, it locks the file and do process its process then when completed it unlock the file and send unlock request to the thread management object. When the thread management object receives the unlock request, it gets the first thread in the queue and wake it up to process the file. So, in this way the threads can not be starved unless that there are a large number of higher priority threads waiting.

The Backup module is responsible of backing up the data in the backup servers (specified in the Servers table) after a specified duration. Also, it is responsible of exporting data that is not necessary after a period of time which are the history information, the customers, and the service providers that are suspended for a long time. This process could be run every 6-months or one year according to the enterprise policy and the performance notification of the system. The backup servers are preferred to be in multiple buildings to avoid the loss of all the information.

The synchronization module is responsible of the process of assuring that all the replicas of the tables in other servers are same. The cluster is composed of one *data server* which holds all the original tables and ordinal servers that contains a read only replica of the tables. Any change on the original tables would generate a notification message to all the servers in the cluster about the changed table. Then each server received the notification message would change the *changed* field of the files (belong to the table) in the *Files_Checksum* table and activate the synchronization process of that table in two cases either when requesting data from the table or when the synchronization timer activated. The timer activated every 30-minute to check all the tables with the data server.

The field "*changed*" in the *Files_Checksum* table plays different roles in data server than others ordinal servers in the cluster, where in ordinal server, it refers to the change of the contents of the original files, but in the data server it refers that the checksum is invalid. Algorithm (3.5) shows how to synchronize a table.

```
ALGORITHM (3.5): SynchonizeTable
INPUT:
    Table name (TableName);
    List of files names (FNameL)
    List of files checksum (ChksumL);
    Number of items in ChksumL (N);
    and data server IPv6 address (ServIPv6)
OUTPUT:
    Success or Fail
Procedure:
    Step 1: get from the data server the number of files and put it in OriginN
    Step 2: get the list of original files names and checksum from the data server and put
            it in OFNameL and OChksunL, respectively
    Step 3: if no response then repeats Step 1 until getting the lists or repeated five times
    Step 4: if no response then return Fail
    Step 5: if N equal OriginalN then goto Step 7
    Step 6: for each item FX in list FNameL and not exist in list OFNameL do
         Step 6.1: get FX from the data server and its checksum then put them in a
                   temporary place
         Step 6.2: if no response then repeats Step 6.1 until getting the file or repeated
                   five times
         Step 6.3: if no response then return Fail.
    Step 7: for each item X in list ChksumL and Y with in list OChksumL with the same
            names in FNameL and OFNameL do
         Step 7.1: if X not equal Y then
             Step 7.1.1: get its file from the data server and its checksum then put them
                         in a temporary place
             Step 7.1.2: if no response then repeats Step 7.1.1 until getting the file or
                         repeated five times
             Step 7.1.3: if no response then return Fail.
    Step 8: delete all local files belong to the table with name not exist in FNameL
    Step 9: replace all the old files by the new files and update their checksums
    Step 10: return Success
```

7. *Tools*: It is a collection of programs can be used to help the manager to test connections, change settings of agents, and time synchronizing. The Tester tool test connection by sending a specified number of application layer messages to the destination and waits for respond for each one. The time between sending one the messages is specified. If the respond does not come after a specified time, it sends another one and so on. If no respond had been received for all the messages it is considered as not responding. If a respond received, the tool calculates the speed of sending message and receiving its respond. The speed is calculated by dividing the difference between the sending and the receiving time by 2 then divides the result by the size of the message (see equation 3.15).

$$\text{Speed} = \frac{(\mathrm{Re}cieveTime - SendTime)/2}{MessageSize} \quad bps \qquad \ldots (3.15)$$

Another tool is the MIB browser that shows the MIBs in the agents and gives the capability of changing their values. It is supported by the MIB definitions in the agent to provide ability to change the values of the MIBs. It provides two ways in browsing the MIBs. The first is by writing the OID of the MIB and then send the request and receive the value of the MIB. The second is graphical tree that is built by sending sequence of Get-Next requests until the end of the tree then display it in graphical tree.

The Time Synchronizer tool synchronizes the time between the server and a specified agent or service provider. It uses Algorithm (3.1) to accomplish its target.

3.7.3 Primary Center Management Component

It monitors and controls the zone centers, and connects them in case of requesting service. It is composed of four modules (as shown in Figure 3.7):

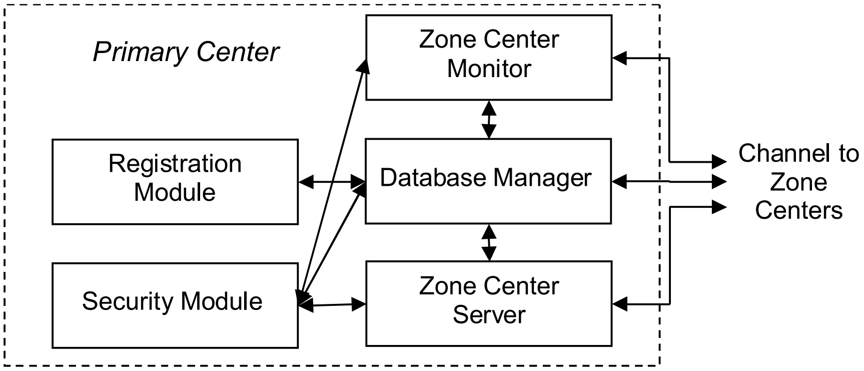


Fig.(3.7) Primary Center Management Modules

1. *Zone Centers Monitor*: which monitors the zone centers to ensure that it is working by sending message to be responded every 5-minute. It responsible of requesting reports under demand from zone center about the customers' information, service provider information, alarms received, and alarms served.
2. *Zone Center Server*: it responsible of redirecting the alarms from zone center to another. When the zone center couldn't find an available service provider, it sends the request to the primary zone. This request is received by this module then implement algorithm (3.6) which is like Algorithm (3.4) but with difference that in replace of the service providers addresses and positions (latitude and longitude), the center position is taken. When the nearest center is found then the request would be sent to it to found the nearest available service provider, while if it is not found it returns with fail acknowledgement to make the primary center continue searching.

```
ALGORITHM (3.6): NearestZoneCenter
INPUT:
        Source zone cnter (ZC)
        Request info (ReqInfo);
        List of zone centers (ZCL);
        List of the Lat and Lon for each zone center in ZCL (LatLon);
        and Number of items in ZCL (N);
OUTPUT:
        Success or Fail
Procedure:
        Step 1: get the Lat and Lon of the sector from ReqInfo and put them on Lat1
                and Lon1, repectively
        Step 2: set DistL to empty list
        Step 3: for each zone center's IPV6 address (ZCAdd) in ZCL and not equal to
                ZC do
            Step 3.1: get its Lat and Lon from LatLon then put them in Lat2 and Lon2,
                      respectively
            Step 3.2: calculate equations 3.8 and 3.13 then 3.14 to add FinalDist by sort
                      (ascending order) to DistL list with indication to its item in ZCL
        Step 4: if DistL is empty then return Fail
        Step 5: remove the first item from DistL and put it in NearZC
        Step 6: set Hopes = 0
        Step 7: send request to the NearZC
        Step 8: get response from the NearZC and put it in Stat
        Step 9: increment Hopes
        Step 10: if Stat is fail and Hopes <5 then goto step 7
        Step 11: if Stat is fail then notify the operator and goto Step 4
        Step 12: if Stat is unavailable then set it as unavailable at the Database
                 Manager and goto Step 4
        Step 13: if Stat is accepted then return Success
        Step 14: return fail
```

3. *Registration Module*: it responsible of registering the zone centers and cities. The information needed for registering zone center are:(1) *zone center name* which is 50 character length; (2) *address* which is the same as needed to the service provider (described in section 3.7.2 in the registration part); (3) *Controlled Region* that described by a list of cities and sectors; and (4) *IPv6 addresses* that would be assigned to the zone center.

4. *Database Manager*: this module like that established in the Zone center except that it has some different tables. Some of them are shown in the Tables (3.25-30).

Table (3.25) ZoneCenters

Field Name	Size (Byte)	Description
ZC_Id	**2**	**Holds the ID that refers to Zone Center.**
ZCName	50	It holds the name of the SP.
City_Id	1	Holds the city number that the zone center in. Foreign Key to Cities.
Sector	2	Sector number.
Street_Build	4	The least significant 20-bits for building number, 10-bits for street, and the rest are unused.
Lat	4	The latitude represented by float number.
Lon	4	The longitude represented by float number.
Status	1	Describes the status of the zone center: suspended or active
Regist-Date	8	It holds the date and time of the registration.

Table (3.26) Cities

Field Name	Size (Byte)	Description
City_Id	**4**	**Holds the ID that refers to city.**
CityName	30	It holds the name of the city.

Table (3.27) ZC_IP_Addresses

Field Name	Size (Byte)	Description
SP_Id	**2**	**Refers to the SP. Foreign Key to ServiceProviders.**
IPv6	**16**	**The assigned IPv6 address.**
Assign_Date	8	The Date and Time that the IPv6 assigned to the zone center

Table (3.28) ZC_Status_History

Field Name	Size (Byte)	Description
ZC_Id	**2**	**Refers to the zone center. Foreign Key to ZoneCenters.**
ChangeDate	**8**	**The Date and Time that the status had been changed.**
Status	1	Describes the status of the zone center: suspended or active
Comment	100	It can be a description of the cause of status change.

Table (3.29) ZoneCenterRequest

Field Name	Size (Byte)	Description
ZC _Id	**2**	**Refers to the zone center. Foreign Key to Customers.**
Request_Date	**8**	**The Date and Time that the request received.**
To_ZC	2	It specifies the zone center that served the requested. If it is 0 then it is not served yet. Foreign Key to ZoneCenters.

Table (3.30) Files_Checksum

Field Name	Size (Byte)	Description
File_Name	**20**	**It specifies the file name.**
Checksum	8	It holds the checksum of the file contents using MD5 algorithm with 64-bit output
Changed	1	In data server, it specifies if the file had been changed or not which in turn identifies the validity of the Checksum field. In ordinal server, it refers to the changed tables in the data server.

5. *Security Module*: is like the security module described in section 3.7.2.

There is another part of primary center management it is the backup zone center manager which works only when one of the zone centers shutdown. Activating this part is accomplished by: (1) executing it as another process and makes the latest backup data sent from that zone center as its initial data, (2) activating the connection between the primary center and the zone, and (3) assign the same IPv6 address of the zone center to it with updating to route tables in routers. The backup zone center manager is a copy of the zone center manager that explained in section 3.7.2.

3.7.4 Service Providers Component

All the service providers management applications have the same general properties, and because the aim of thesis is concerned with the network management so, the detailed information of each service would not discussed. Thus all of them have the same application but their names are different. The management application of the service provider is composed of the following modules (see Figure 3.8):

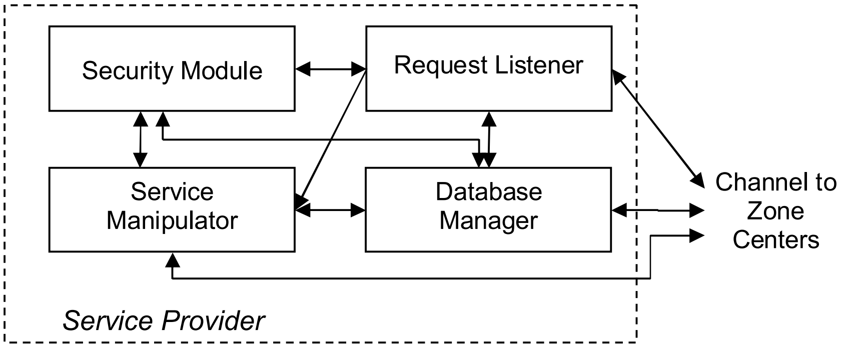


Fig.(3.8) Service Provider Management Modules

1. *Request Listener*: is responsible of receiving requests and responding them. The requests are either serving an alarm or statistical information about the accomplished services and those not yet accomplished. If it is an alarm this module saves the request in the database through Database Manager and sends it to the Service Manipulator. The Service Manipulator returns answer to the Request Listener as accept or refuse the request. In turn, the Request Listener returns the answer to the Zone Center. When the request asks for information, the Request Listener retrieves it from the Database Manager and sends it to the zone center.

2. *Service Manipulator*: it receives alarm request from the Request Listener to send cars for serving specific building, the request added to the database and set as waiting state then it decides the answer of the request either manually or automatically, stores it in the database, and returns it. Manually means it only accepted or refused by the dispatcher. The dispatcher can configure the application to either auto-refuse or auto-serve state. The auto-refuse makes the Service Manipulator refuses all the requests automatically. The auto-serve accepts the request when there are minimum number of cars (which is specified by the dispatcher) ready to serve request, and refuses if not enough. The automatic answer helps the dispatcher to be faster in answer to the zone center and simplify the refusing of all incoming requests when needed. If the request accepted, it transferred to the serving state and waits for the dispatcher to end serving the request and returning the cars to the station. Sometimes, service needs more cars than sent to serve (for example, very big fire within street that has closed buildings), thus the dispatcher can send more cars to help, but if the station does not has the needed available number of cars then the dispatcher send support request to the zone center. Another option is the simulation state which is only for tests situations that work as auto-serve with auto completion which means that when the request completed the service manipulator set a random time within range specified for the completion of the service, and decreases the number of cars stored in the database by the minimum number of cars needed to serve request. When the time is expired, it increases the number of cars in the database and set the request as completed.
3. *Database Manager*: this module is like the one in the Zone center except it has different tables. Tables (3.31-37) showing some of them.

Table (3.31) Cities

Field Name	Size (Byte)	Description
City_Id	**4**	**Holds the ID that refers to city.**
CityName	30	It holds the name of the city.

Table (3.32) Cars

Field Name	Size (Byte)	Description
Cars_Total	1	Holds the total number of cars in the station.
Cars_Available	1	Number of cars ready to serve.
Cars_Out	1	Number of cars is out of duty.

Table (3.33) Cars-AddRemove

Field Name	Size (Byte)	Description
Cars_No	1	Number of cars added or removed.
Op_Type	1	Holds the type of the operation. 0→ Add, 1→ Remove
Op_Date	8	It is the Date and Time of operation.

Table (3.34) Requests

Field Name	Size (Byte)	Description
Req_Id	**4**	**Holds number to identify the request.**
City_Id	1	Holds the city number that the zone center in. Foreign Key to Cities.
Sector	2	Sector number.
Street_Build	4	The least significant 20-bits for building number, 10-bits for street, and the rest are unused.
Req_Status	1	Describes the status of the request is Waiting, Serving, or Served.
Request-Date	8	It holds the date and time of the request.
Cars_Sent	1	It is the number of cars sent to serve the request.
Help_Cars	1	It is the numbers of cars requested from the zone center.

Table (3.35) Refused-Requests

Field Name	Size (Byte)	Description
Request-Date	8	It holds the date and time of the request.
City_Id	1	Holds the city number that the zone center in. Foreign Key to Cities.
Sector	2	Sector number.
Street_Build	4	The least significant 20-bits for building number, 10-bits for street, and the rest are unused.

Table (3.36) Cars-Out

Field Name	Size (Byte)	Description
Req_Id	4	Holds request id. If it is nonzero then it refers to Requests table, but if it is zero then it is out of duty not to serve.
Out_Date	8	It is the Date and Time that it is out.
Cars_No	1	Number of cars is out at this time.
Description	50	A comment for why is out.

Table (3.37) Cars-Return

Field Name	Size (Byte)	Description
Req_Id	4	Holds request id. If it is nonzero then it refers to Requests table, but if it is zero then it was out of duty not to serve.
Return_Date	8	It is the Date and Time that it is out.
Cars_No	1	Number of cars is returned at this time.

Table (3.38) IPs

Field Name	Size (Byte)	Description
IPv6	**16**	**IPv6 Address.**

CHAPTER FOUR

CHAPTER FOUR
System Implementation

4.1 Introduction

This chapter introduces the time diagrams for some of the main operations in the project and estimations for response and validation time.

4.2 Time Diagrams

This section would show the time diagrams of four main operations, *trap notifications*, *read measurements*, *service provider monitoring*, and *zone center monitoring*. For each operation, three situations are described by the time diagram: (1) Successful operation, (2) Fail by not receiving the request, and (3) Fail by not receiving the response. The fail situations could be caused by many factors, the two main factors are: high congestion and cut in the communication medium.

Figure (4.1) shows the time diagram of successful trap notification operation.

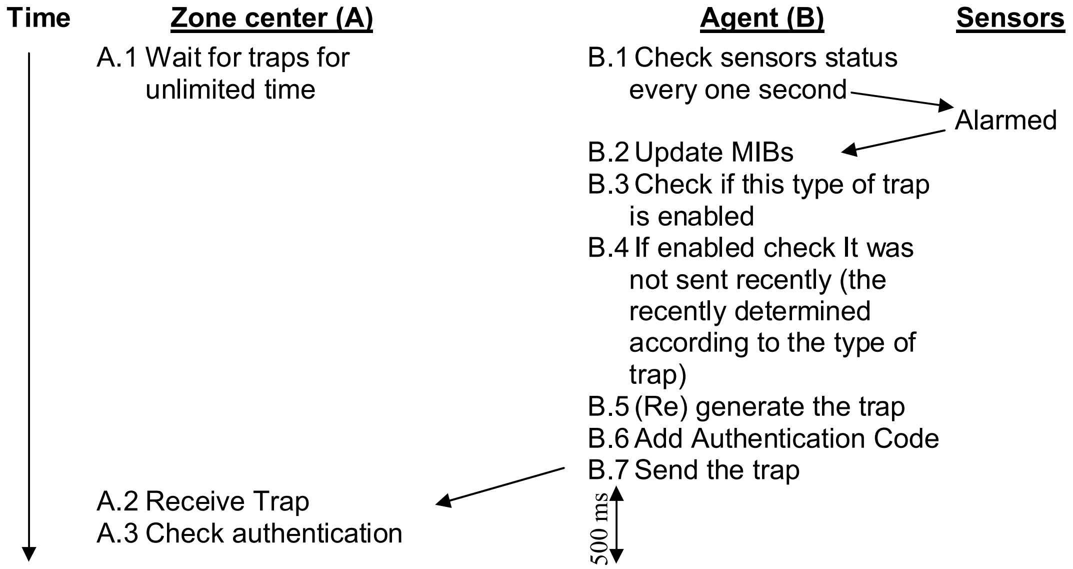
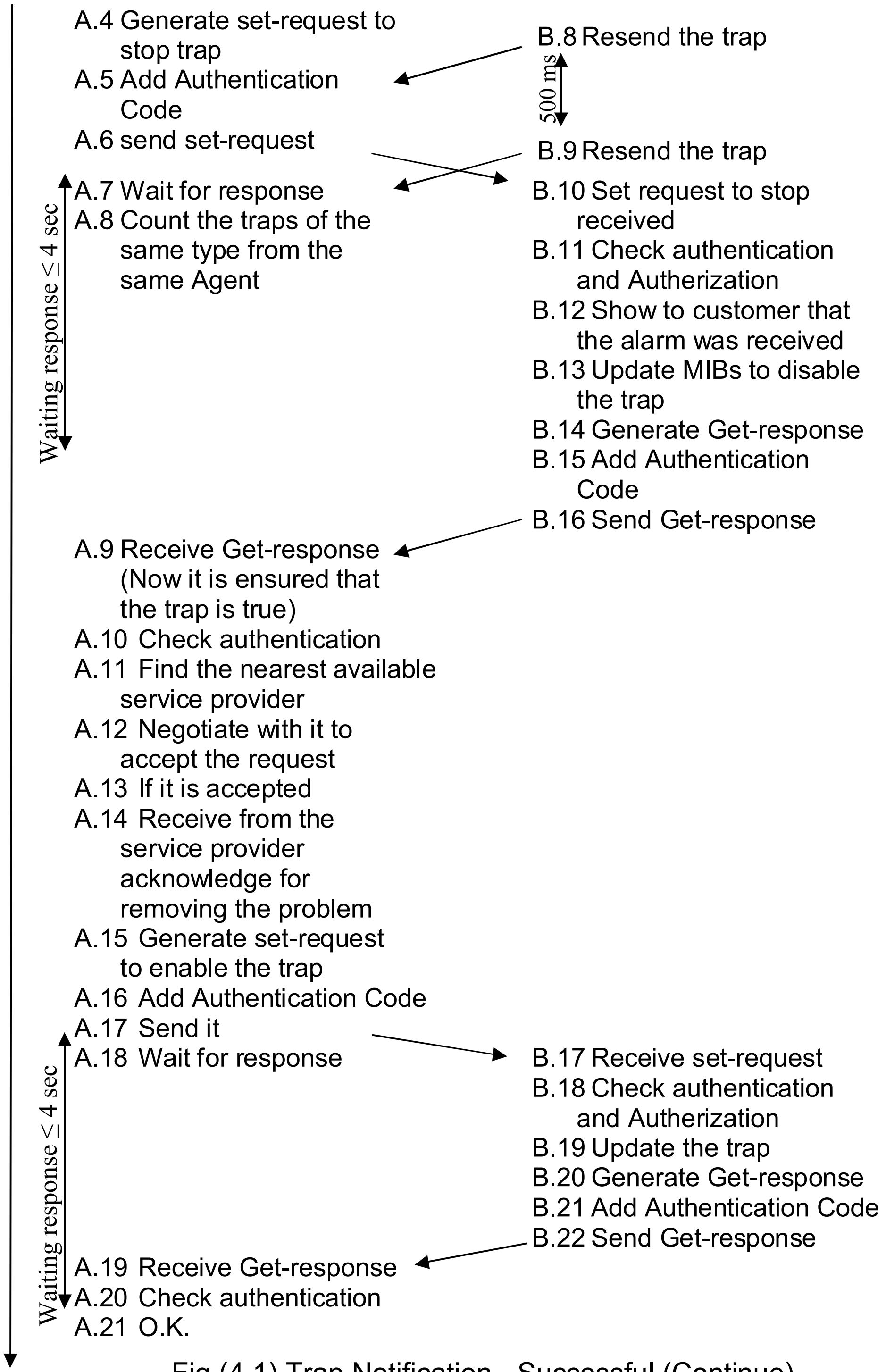

Time
Zone center (A)
Agent (B)
Sensors
A.1 Wait for traps for unlimited time
B.1 Check sensors status every one second
Alarmed
B.2 Update MIBs
B.3 Check if this type of trap is enabled
B.4 If enabled check It was not sent recently (the recently determined according to the type of trap)
B.5 (Re) generate the trap
B.6 Add Authentication Code
B.7 Send the trap
A.2 Receive Trap
A.3 Check authentication
500 ms

Fig.(4.1) Trap Notification - Successful



A.4 Generate set-request to stop trap
A.5 Add Authentication Code
A.6 send set-request
A.7 Wait for response
A.8 Count the traps of the same type from the same Agent

B.8 Resend the trap
B.9 Resend the trap
B.10 Set request to stop received
B.11 Check authentication and Autherization
B.12 Show to customer that the alarm was received
B.13 Update MIBs to disable the trap
B.14 Generate Get-response
B.15 Add Authentication Code
B.16 Send Get-response

A.9 Receive Get-response (Now it is ensured that the trap is true)
A.10 Check authentication
A.11 Find the nearest available service provider
A.12 Negotiate with it to accept the request
A.13 If it is accepted
A.14 Receive from the service provider acknowledge for removing the problem
A.15 Generate set-request to enable the trap
A.16 Add Authentication Code
A.17 Send it
A.18 Wait for response

B.17 Receive set-request
B.18 Check authentication and Autherization
B.19 Update the trap
B.20 Generate Get-response
B.21 Add Authentication Code
B.22 Send Get-response

A.19 Receive Get-response
A.20 Check authentication
A.21 O.K.

Fig.(4.1) Trap Notification - Successful (Continue)

Figure (4.2) shows the time diagram of failed trap notification operation because the trap is not received by the zone center. Figure (4.3) shows the time diagram of trap notification operation with partial fail with stopping the trap from continuous sending.

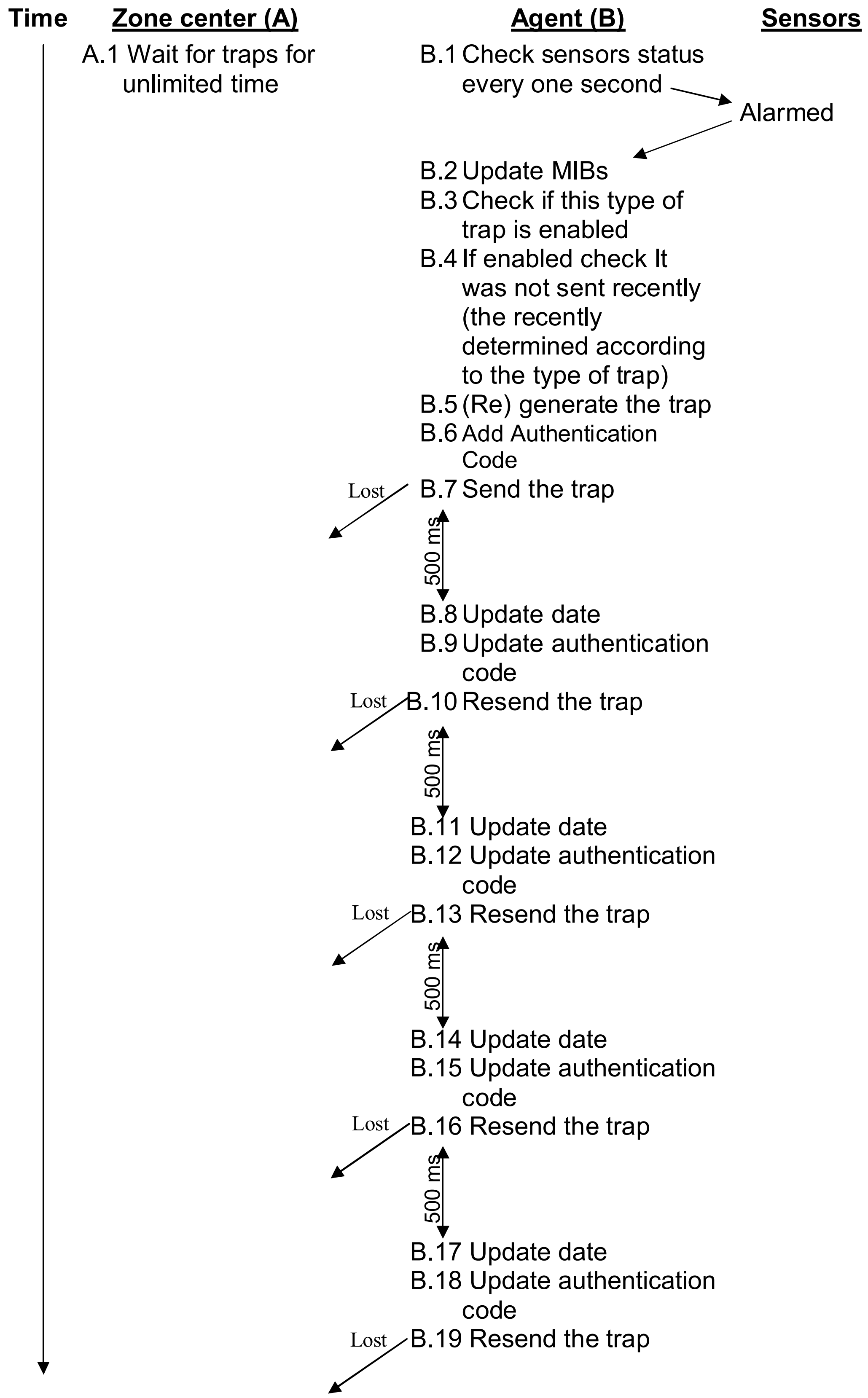
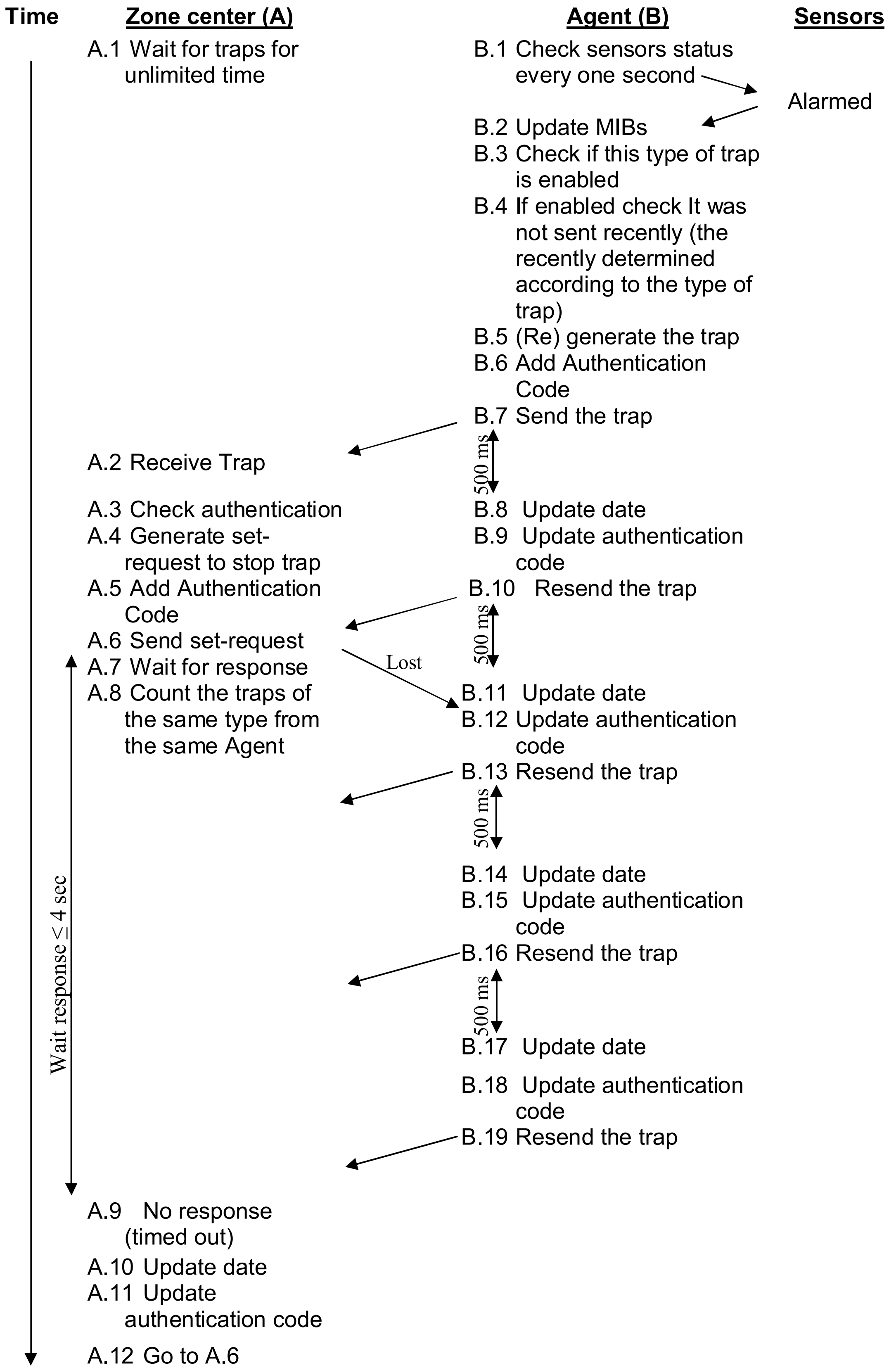

Time
Zone center (A)
Agent (B)
Sensors
A.1 Wait for traps for unlimited time
B.1 Check sensors status every one second
Alarmed
B.2 Update MIBs
B.3 Check if this type of trap is enabled
B.4 If enabled check It was not sent recently (the recently determined according to the type of trap)
B.5 (Re) generate the trap
B.6 Add Authentication Code
Lost
B.7 Send the trap
500 ms
B.8 Update date
B.9 Update authentication code
Lost
B.10 Resend the trap
500 ms
B.11 Update date
B.12 Update authentication code
Lost
B.13 Resend the trap
500 ms
B.14 Update date
B.15 Update authentication code
Lost
B.16 Resend the trap
500 ms
B.17 Update date
B.18 Update authentication code
Lost
B.19 Resend the trap

Fig.(4.2) Trap Notification - Fail: First Case



A.1 Wait for traps for unlimited time

B.1 Check sensors status every one second

B.2 Update MIBs

B.3 Check if this type of trap is enabled

B.4 If enabled check It was not sent recently (the recently determined according to the type of trap)

B.5 (Re) generate the trap

B.6 Add Authentication Code

B.7 Send the trap

A.2 Receive Trap

A.3 Check authentication

A.4 Generate set-request to stop trap

A.5 Add Authentication Code

A.6 Send set-request

A.7 Wait for response

A.8 Count the traps of the same type from the same Agent

B.8 Update date

B.9 Update authentication code

B.10 Resend the trap

B.11 Update date

B.12 Update authentication code

B.13 Resend the trap

B.14 Update date

B.15 Update authentication code

B.16 Resend the trap

B.17 Update date

B.18 Update authentication code

B.19 Resend the trap

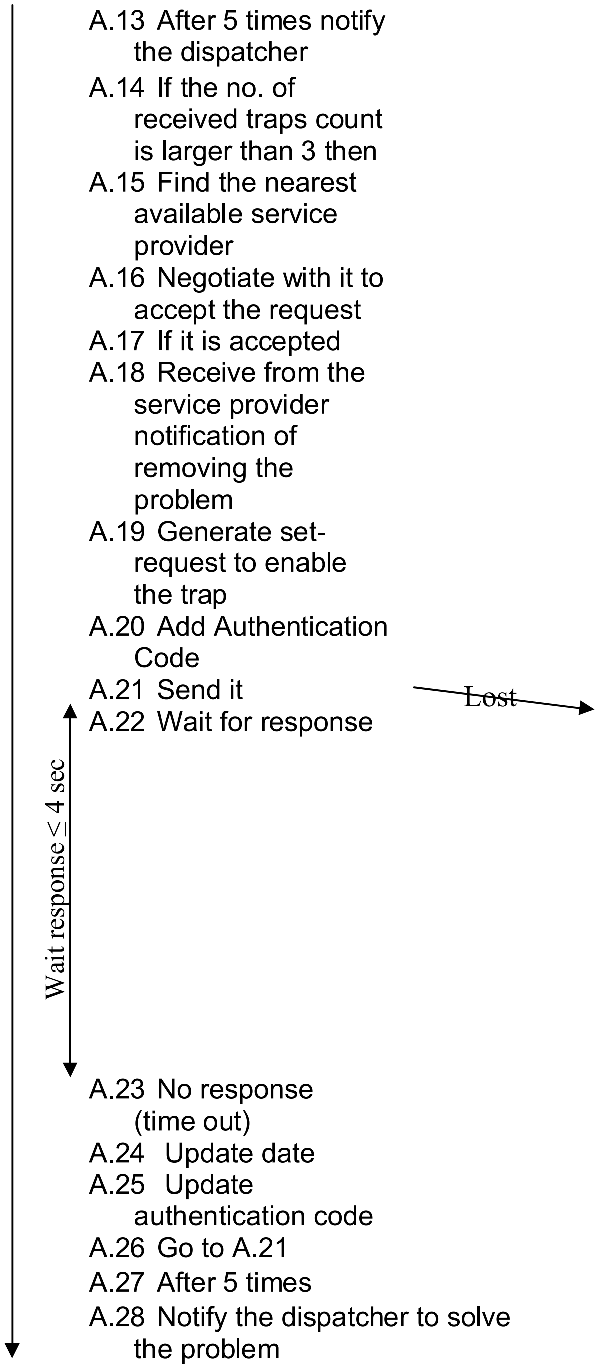
A.9 No response (timed out)

A.10 Update date

A.11 Update authentication code

A.12 Go to A.6

Fig.(4.3) Trap Notification - Fail: Second Case



A.13 After 5 times notify the dispatcher

A.14 If the no. of received traps count is larger than 3 then

A.15 Find the nearest available service provider

A.16 Negotiate with it to accept the request

A.17 If it is accepted

A.18 Receive from the service provider notification of removing the problem

A.19 Generate set-request to enable the trap

A.20 Add Authentication Code

A.21 Send it

A.22 Wait for response

A.23 No response (time out)

A.24 Update date

A.25 Update authentication code

A.26 Go to A.21

A.27 After 5 times

A.28 Notify the dispatcher to solve the problem

Fig.(4.3) Trap Notification - Fail: Second Case (Continue)

Figure (4.4) shows the time diagram of successful reading measurements operation and figure (4.5) shows the time diagram of failed reading measurements operation because the request is not received by the agent. Figure (4.6) shows the time diagram of failed reading measurements operation because the response is not received by the agent.

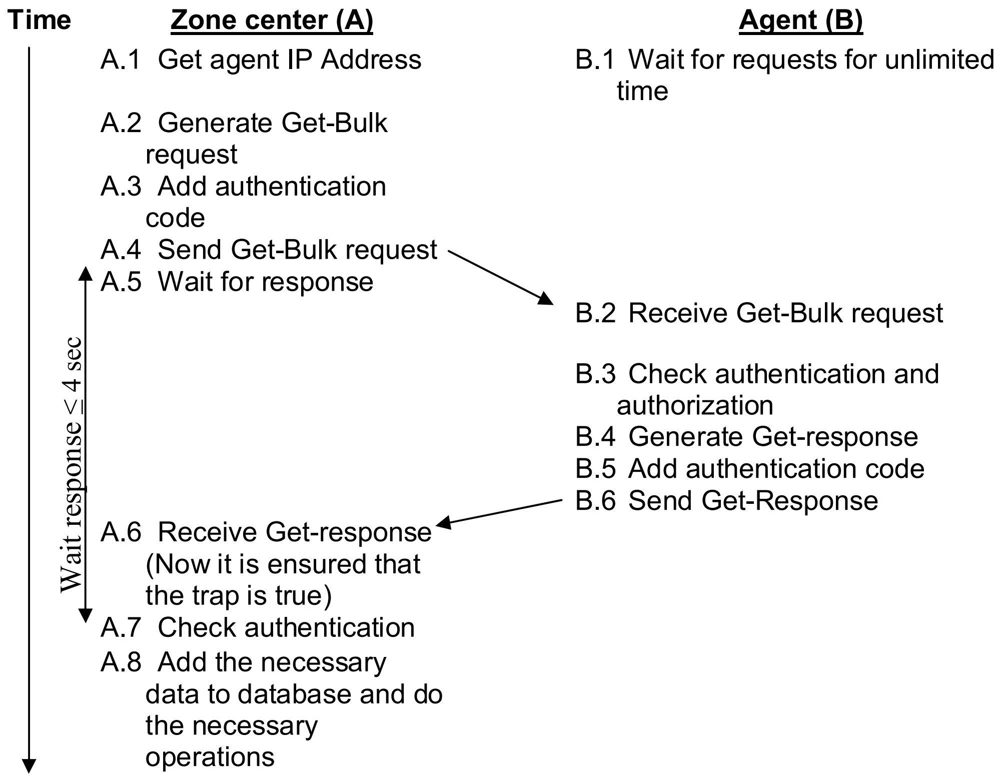

Time
Zone center (A)
Agent (B)
A.1 Get agent IP Address
B.1 Wait for requests for unlimited time
A.2 Generate Get-Bulk request
A.3 Add authentication code
A.4 Send Get-Bulk request
A.5 Wait for response
B.2 Receive Get-Bulk request
Wait response ≤ 4 sec
B.3 Check authentication and authorization
B.4 Generate Get-response
B.5 Add authentication code
B.6 Send Get-Response
A.6 Receive Get-response (Now it is ensured that the trap is true)
A.7 Check authentication
A.8 Add the necessary data to database and do the necessary operations

Fig.(4.4) Reading Measurements – Successful

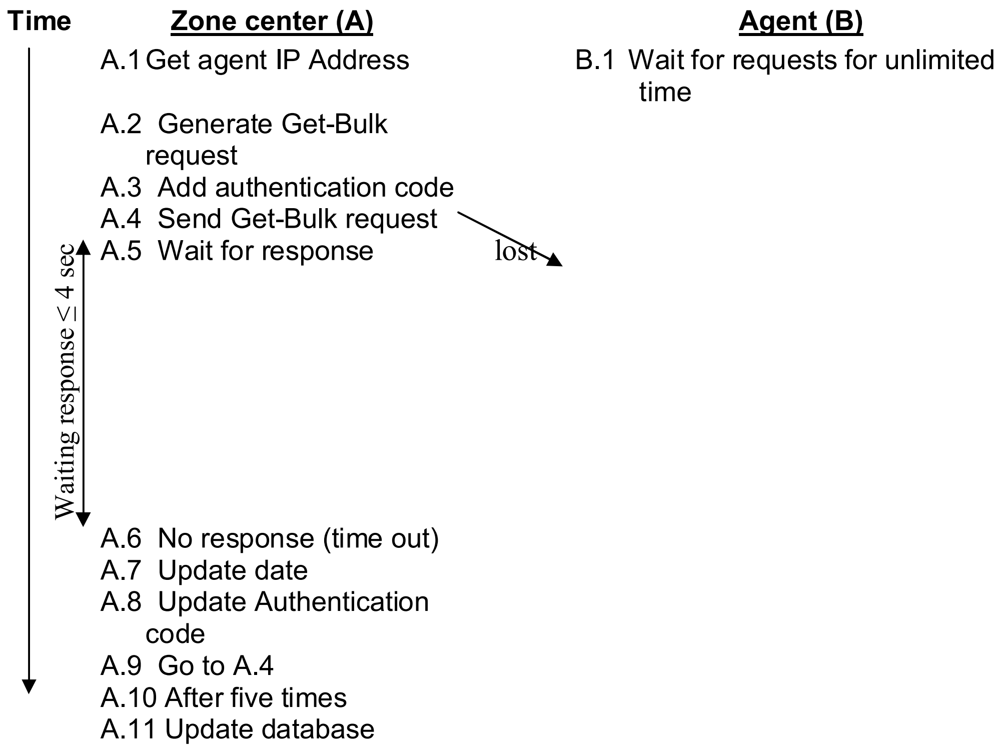

Time
Zone center (A)
Agent (B)
A.1 Get agent IP Address
B.1 Wait for requests for unlimited time
A.2 Generate Get-Bulk request
A.3 Add authentication code
A.4 Send Get-Bulk request
A.5 Wait for response
lost
Waiting response ≤ 4 sec
A.6 No response (time out)
A.7 Update date
A.8 Update Authentication code
A.9 Go to A.4
A.10 After five times
A.11 Update database

Fig.(4.5) Reading Measurements – Fail: First Case

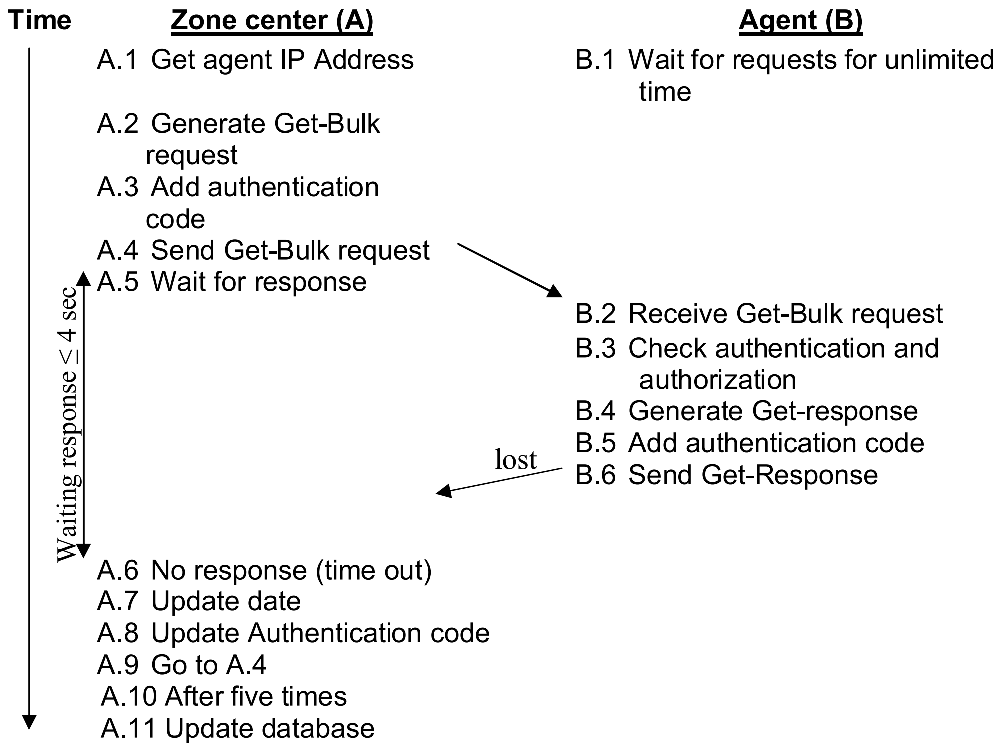

Time
Zone center (A)
Agent (B)
A.1 Get agent IP Address
B.1 Wait for requests for unlimited time
A.2 Generate Get-Bulk request
A.3 Add authentication code
A.4 Send Get-Bulk request
A.5 Wait for response
B.2 Receive Get-Bulk request
B.3 Check authentication and authorization
B.4 Generate Get-response
B.5 Add authentication code
lost
B.6 Send Get-Response
Waiting response ≤ 4 sec
A.6 No response (time out)
A.7 Update date
A.8 Update Authentication code
A.9 Go to A.4
A.10 After five times
A.11 Update database

Fig.(4.6) Reading Measurements - Fail: Second Case

Figure (4.7) shows the time diagram of successful service provider minitoring operation.

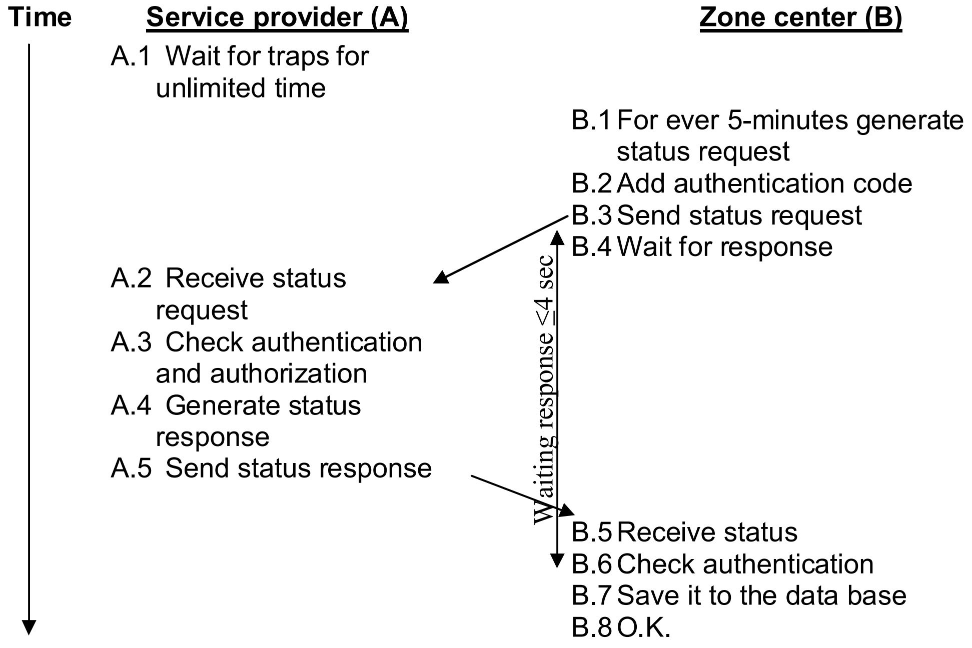
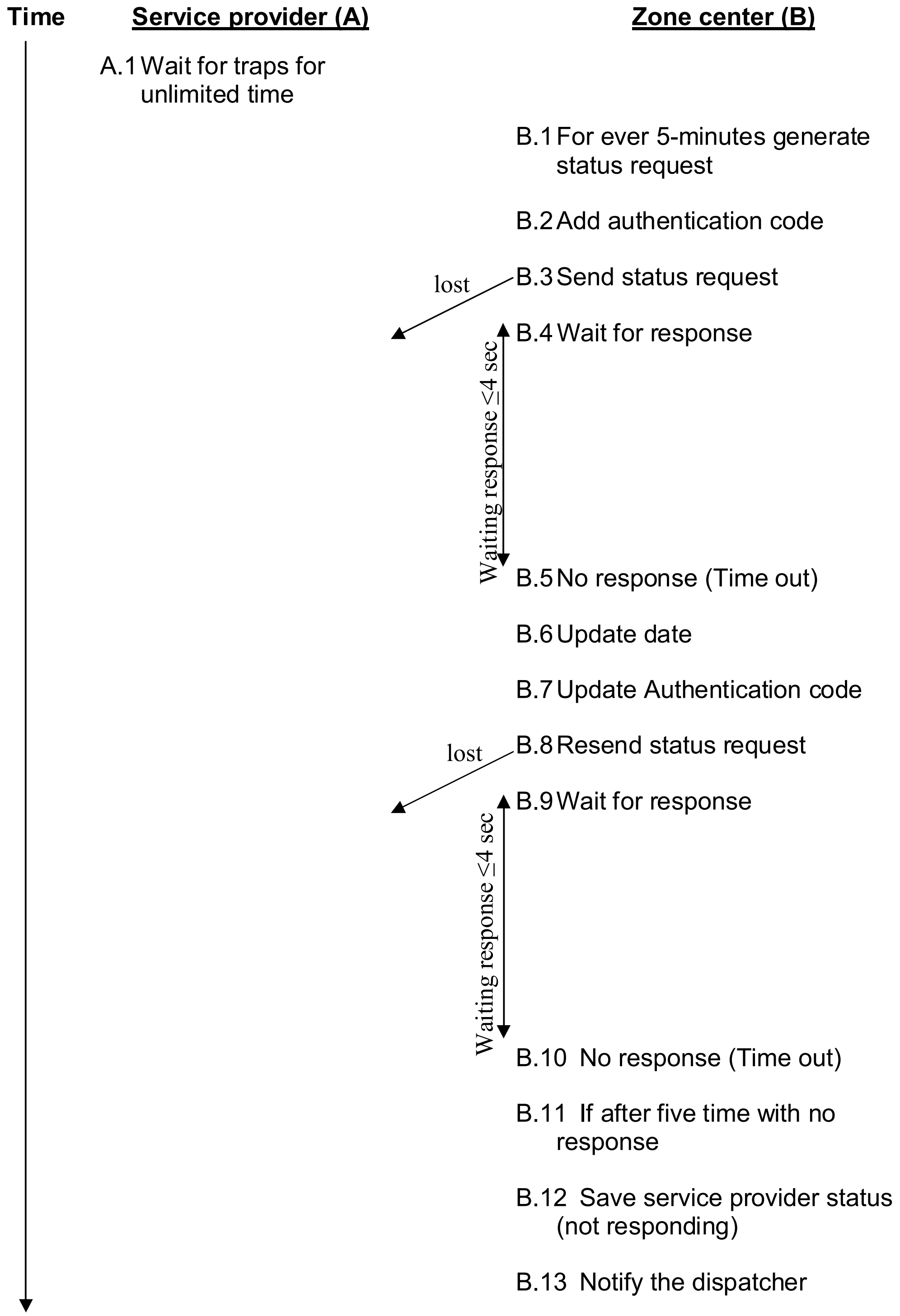

Time
Service provider (A)
Zone center (B)
A.1 Wait for traps for unlimited time
B.1 For ever 5-minutes generate status request
B.2 Add authentication code
B.3 Send status request
B.4 Wait for response
A.2 Receive status request
A.3 Check authentication and authorization
A.4 Generate status response
A.5 Send status response
Waiting response ≤4 sec
B.5 Receive status
B.6 Check authentication
B.7 Save it to the data base
B.8 O.K.

Fig.(4.7) Monitoring Service Provider - Successful

Figure (4.8) shows the time diagram of failed service provider monitoring operation because the request is not received by he service provider.



A.1 Wait for traps for unlimited time

B.1 For ever 5-minutes generate status request

B.2 Add authentication code

B.3 Send status request

B.4 Wait for response

B.5 No response (Time out)

B.6 Update date

B.7 Update Authentication code

B.8 Resend status request

B.9 Wait for response

B.10 No response (Time out)

B.11 If after five time with no response

B.12 Save service provider status (not responding)

B.13 Notify the dispatcher

Fig.(4.8) Monitoring Service Provider – Fail: First Case

Figure (4.9) shows the time diagram of failed service provider monitoring operation because the response is not received by the zone center.

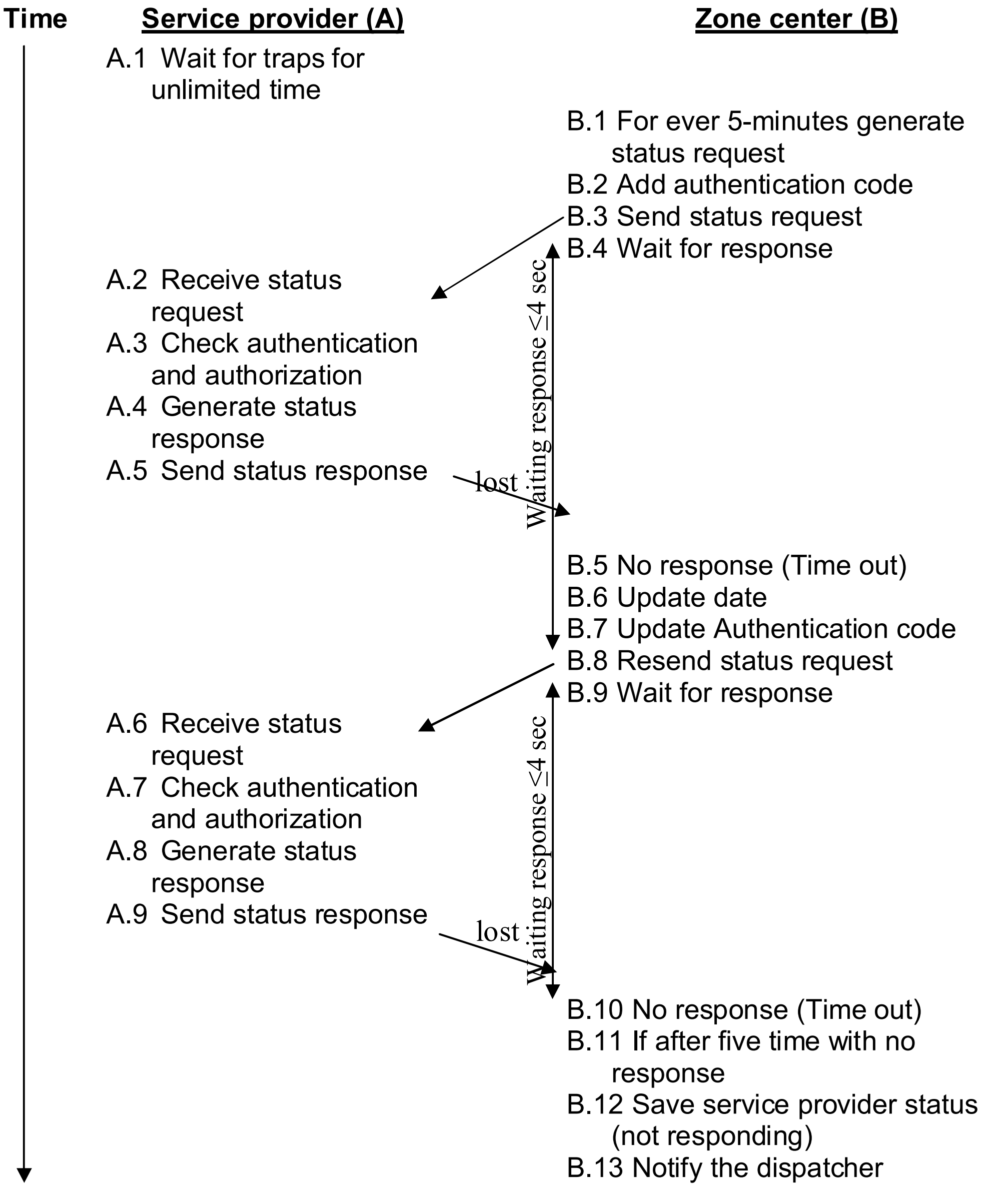
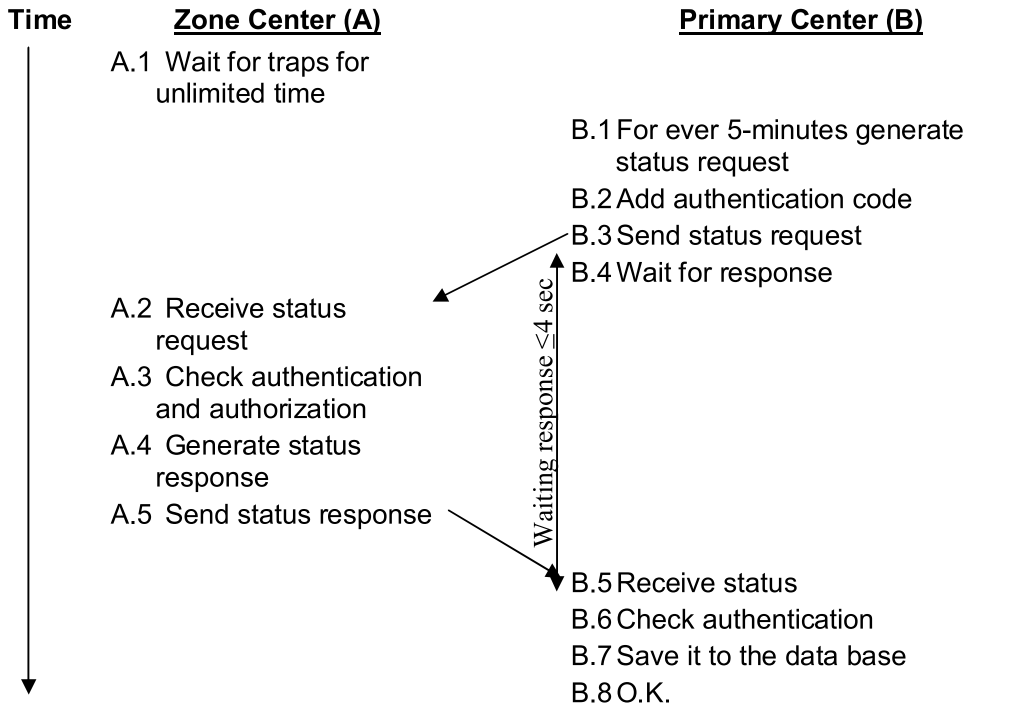

Time
Service provider (A)
Zone center (B)
A.1 Wait for traps for unlimited time
B.1 For ever 5-minutes generate status request
B.2 Add authentication code
B.3 Send status request
B.4 Wait for response
A.2 Receive status request
A.3 Check authentication and authorization
A.4 Generate status response
A.5 Send status response
Waiting response ≤4 sec
lost
B.5 No response (Time out)
B.6 Update date
B.7 Update Authentication code
B.8 Resend status request
B.9 Wait for response
A.6 Receive status request
A.7 Check authentication and authorization
A.8 Generate status response
A.9 Send status response
Waiting response ≤4 sec
lost
B.10 No response (Time out)
B.11 If after five time with no response
B.12 Save service provider status (not responding)
B.13 Notify the dispatcher

Fig.(4.9) Monitoring Service Provider – Fail: Second Case

Figure (4.10) shows the time diagram of successful zone center monitoring operation and figure (4.11) shows the time diagram of failed zone center monitoring operation because the request is not received by the zone center.



Zone Center (A)

A.1 Wait for traps for unlimited time

A.2 Receive status request

A.3 Check authentication and authorization

A.4 Generate status response

A.5 Send status response

Primary Center (B)

B.1 For ever 5-minutes generate status request

B.2 Add authentication code

B.3 Send status request

B.4 Wait for response

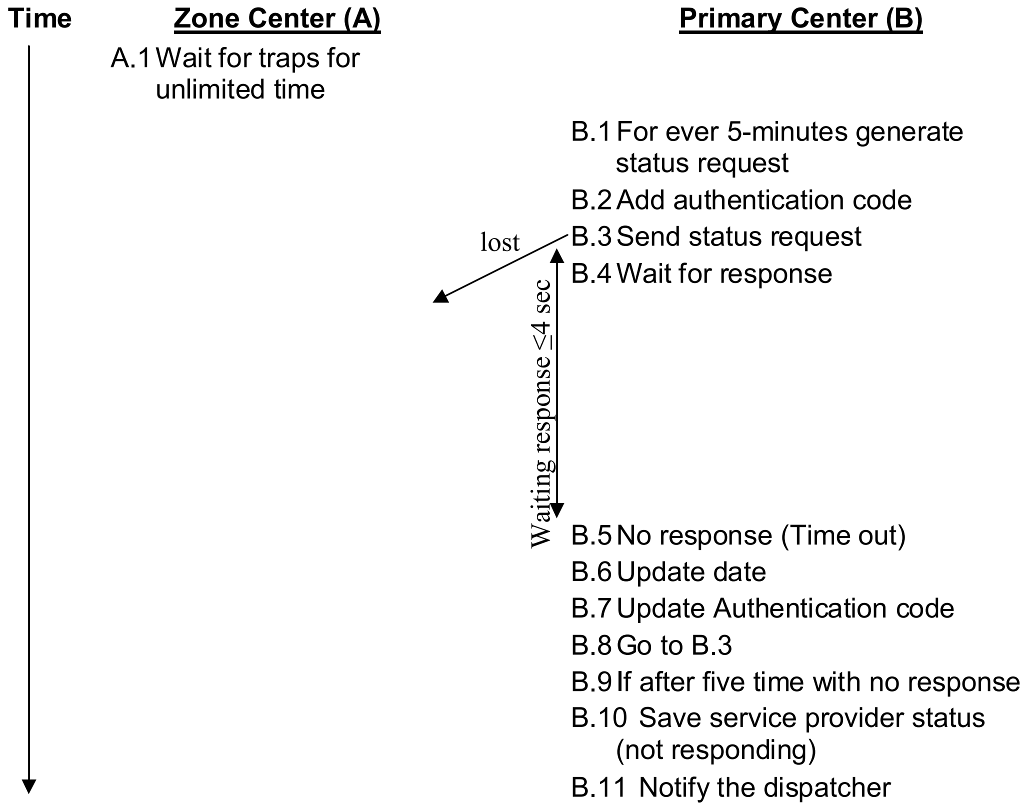
B.5 Receive status

B.6 Check authentication

B.7 Save it to the data base

B.8 O.K.

Fig.(4.10) Monitoring Zone Center – Successful



Zone Center (A)

A.1 Wait for traps for unlimited time

Primary Center (B)

B.1 For ever 5-minutes generate status request

B.2 Add authentication code

B.3 Send status request

B.4 Wait for response

B.5 No response (Time out)

B.6 Update date

B.7 Update Authentication code

B.8 Go to B.3

B.9 If after five time with no response

B.10 Save service provider status (not responding)

B.11 Notify the dispatcher

Fig.(4.11) Monitoring Zone Center – Fail: First Case

Figure (4.12) shows the time diagram of failed zone center monitoring operation because the response is not received by the primary center.

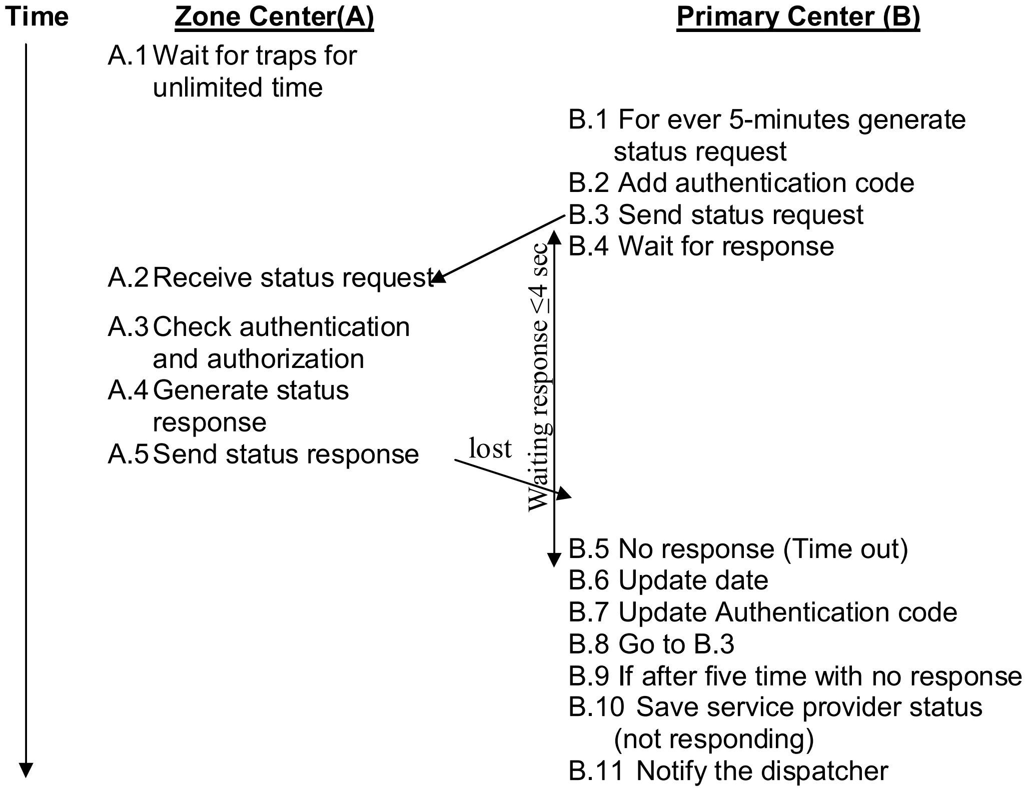

Time
Zone Center(A)
Primary Center (B)
A.1 Wait for traps for unlimited time
B.1 For ever 5-minutes generate status request
B.2 Add authentication code
B.3 Send status request
B.4 Wait for response
A.2 Receive status request
A.3 Check authentication and authorization
A.4 Generate status response
A.5 Send status response
lost
Waiting response ≤4 sec
B.5 No response (Time out)
B.6 Update date
B.7 Update Authentication code
B.8 Go to B.3
B.9 If after five time with no response
B.10 Save service provider status (not responding)
B.11 Notify the dispatcher

Fig.(4.12) Monitoring Zone Center – Fail: Second Case

4.3 Time Estimations

This section estimates the response wait time and the maximum time for validating the message between the zone center and the agent. In general, the time needed for sending message and receiving it at destination is calculated as follow [KUR01]:

$$TD = \frac{L}{R} \qquad \text{………} \ (4.1)$$

$$PRD = \frac{Dis\tan ce}{Speed} \qquad \text{………} \ (4.2)$$

$$Send\_\mathrm{Re}cv = PD_S + QD_S + TD + PRD + RD + QD_R \ \text{………} \ (4.3)$$

Where R is the transmission rate of the communication channel,

L is the average length of the message transmitted between the two nodes,

TD is the time needed for transmitting the message,

Distance is the distance of the channel,

Speed is the speed of the channel (for wire is $2*10^8$),

PRD is the propagation delay of the channel is the time needed for transmitting the message,

RD is the time needed for receiving the message,

PD_S is the time delay due to message processing at the sender

QD_S is the time delay caused by waiting the message in the queue for sending,

and QD_R is the time delay caused by waiting the message in the queue for receiving.

The processing delay queue and queue delay is specific to the specifications of the computers used and the load at that time. The computers used to estimate the time have the following descriptions:

- C.P.U. Speed is 2.0GHz with 512 KB cashe,
- R.A.M. capacity is 256MB,
- Bus speed is 100 MHz,
- and IDE H.D.D. with 5200rpm.

The average *PD* and *QD* estimated is 200ms, and it is taken in average for both the agent and zone center.

The connection suggested in chapter three between agents and one center is PLC and ILEVO [ILV05] is taken as a sample product. Then:

$$RD = TD = \frac{158*8}{36*2^{20}} = 3.35*10^{-5} \quad Sec$$

The ILEVO modems have maximum levels of four (i.e. the Head End, customer modem, and two intermediate repeaters) and maximum distance between each two nodes is 400m. the Head End modem is connected to the zone center by another channel that supposed to have the same properties. Then, there are three nodes between the zone center and the agent; each node is receiving messages from previous one and sending them to the next one. Thus, equation (4.3) is multiplied by 5.

$$PRD = \frac{400}{2*10^{8}} = 0.2*10^{-5}\ Sec$$

$$\begin{aligned} Send\_\mathrm{Re}cv &= (200*10^{-3} + 3.35*10^{-5} + 0.2*10^{-5} + 3.35*10^{-5} + 200*10^{-3})*5 \\ &\approx 2\ Sec \end{aligned}$$

So, the time needed for validating a message is 2 seconds. The time needed to wait for response is the double which is 4 seconds. These values can be changed by the administrator according to the state of the system.

CHAPTER FIVE

CHAPTER FIVE
Conclusions and Suggestions

5.1 Conclusions

The proposed system should cover a large area and huge number of customers, this require a complicated analysis for determining the aspects of the network capable to connect the distributed parts of the system. In this thesis it had been shown, analytically, that the PLC communication is suitable for connecting a large number of customers with the zone center. Taking into consideration that a low cost PLC communication technology is already exists, and offers enough bandwidth for the transmission of traps and reading data from the agents. Also, in this project some suggestions about other connections between the parts of the system have been discussed and implemented.

During the designing, implementation and testing phases a lot of remarks have been issued; the following are some of them:

1. The distribution of the system parts needs to be handled by using simple and reliable techniques, and some fast decision making rules should be used because the system covers large geographical area and need real-time reception of the alarms by the service providers.

2. Building a dedicated distributed DBMS specific to the system requirements, that is simpler and faster than the existed commercial DBMS, in order to speed up the system performance, and to simplify the interaction between the system parts and the DBMS.

3. The multi-threaded programming improves the system capability of receiving, processing, and sending data in concurrent way, but it adds more complexity in managing the threads, especially in processing data.

4. The systems cover very large geographical area may face the problem of different time zones. This problem is solved by setting all the parts of the system referenced to the same time. Therefore, an automatic synchronization between the distributed system components is very necessary. This synchronization was handled by implementing algorithm (3.1).

5. The use of two simple criteria for estimating the nearest service provider (SP) to the service requester (SR) is necessary to get better estimation results than using one of the formulas. By using only the distance between customer's sector and the service provider as a criteria may not express the actual distance should be passed on roads to move between SP and SR. And by using only the urban map for the estimating the distance may not lead the nearest also. So, as an average both formulas together could give better results than using only one.

6. By using simplified formula (even less accurate) for determining the distance between customer's sector and the service provider had speed up the process of estimating the nearest service provider, without losing significant accuracy. The determination of the exact distance is not target, the actual target is the comparison between the distances and thus a highly accurate distance formula is not necessary, its low computational load should be considered as an important requirement.

5.2 Suggestions for Future Work

In the following some conducted suggestions for future work are given to enhance the project and make it more effective:

1. Giving the facility of direct communications among the zone centers, and not necessarily through the primary center. This will improve the system reliability and become more efficient.

2. Enhance the way of estimating the nearest service provider by using Geographic Information System (GIS) technology supported by Global Positioning System (GPS).

3. Adding other tools to help the administrator to allocate the factors that might cause decrease in the system performance. If the utilized tools use different mechanisms, they would let the administrator to see the problem in different ways and then he might make faster diagnosis. For example, ping utility, and trace route utility that can detect all the devices between the zone center and agent or service provider.

4. Enhance the backup operation by backuping only the new data and compressing it if needed to decrease the size of transferred data.

5. Using a graphical mapping tool that can easily show the positions of customers and service providers.

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REFRENCES

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APPENDIXES

APPENDIX A

Network Topologies [JAY06]

The word topology comes from the Greek word “topos”, which means “place”. Topology is the description of the physical layout of a place. In networking, it means the pictorial layout of a network, including hosts, other devices, and lines that connect them.

Networks can be defined by protocol (for example, an IP network or AppleTalk network), by the physical and logical connections (such as ring or star topology), or by geography (for example, a local, metropolitan, or wide area network).

In spite of the specific criteria used to move data between devices or LAN segments, network infrastructures, in general, follow a hierarchy that extends from the physical layer up through the end-user application.

A.1 Architecture-Based Network Topologies

Topologies are logical arrangements and need not be physically cabled as shown in topology diagrams. Following are examples of the various architecture-based network topologies:

1. Bus topology
2. Tree topology
3. Ring topology
4. Single-star topology
5. Hierarchical-star topology
6. Wireless topology
7. Point-to-point topology
8. Mesh topology

LANs are interconnected using routers. Based on a packet's destination IP address, the packet travels from router to router until it reaches its last destination router, which usually happens to be inside an office building or campus. Then it must hop out of the router's cloud and look at the wall plates and ports to find its destination host. This stage requires making the transition from the destination host's IP address to the host's physical address, also called the media access control (MAC) address. The transition is done via hubs and switches. All hosts, printers, servers, and other devices in a LAN must have a NIC with a unique MAC address. In short, The IP address gets the message over the routers to the neighborhood, and the MAC address gets the message over the hub or switch to the host.

A.1.1. Bus Topology

A bus topology is a linear architecture where hosts or devices are cabled directly to a line. All signals propagate the length of the medium and are received by all devices. Each device has a unique identity and can recognize (and accept) signals intended for it. In the early days of networking, bus topologies were common. A fat coaxial cable called thicknet ran through the building. All hosts tapped directly into the cable, which seemed like the network backbone. This is shown in Figure (A1).

As technology developed, a thinner coaxial cable called thinnet was introduced. It was cheaper, easier to work with, and less bulky. The topology and all its trouble remained the same, however. If any part of the network broke down, a number of hosts connected along the cable lost their LAN links. Bus topologies were hard to manage. Adding taps for additional hosts was a lot of manual work. Someone had to crawl into the plenum, find the coaxial cable, make a tap, connect a new cable to the tap, and drop it for the device. The bus topology has given way to star topology, implemented using hubs and switches. This has provided network architects with a lot of flexibility in configuring logical and physical layouts.

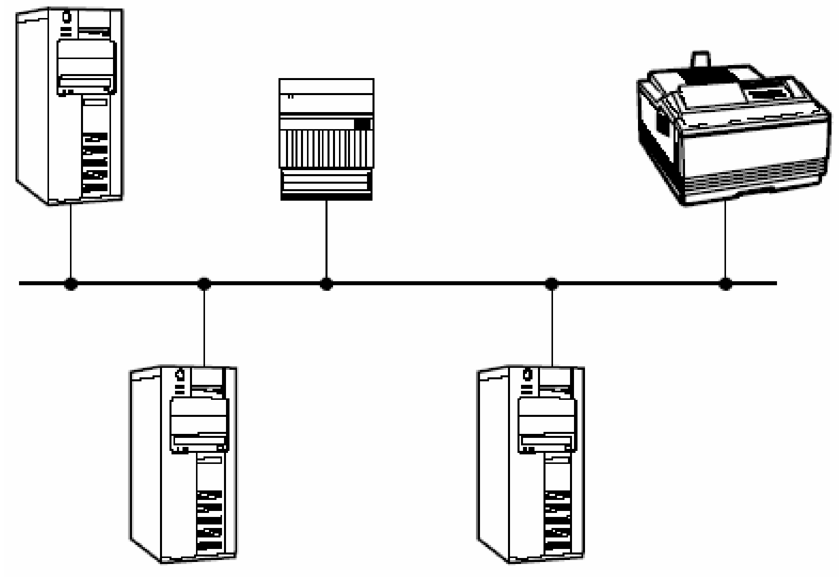


Fig. (A1) Bus Topology

A.1.2. Tree Topology

A tree topology is similar to bus topology except that tree networks contain branches with multiple nodes. As in bus topology, all signals traverse the entire bus length. The advantage is that it requires less cabling than ring or star topology. However, if any device is broken, the sequence is disrupted and the entire network goes down. Therefore, bus or tree topologies are not used today.

A.1.3. Ring Topology

A ring topology includes two or more devices attached along the same signal path, forming a closed loop or ring, as shown in Figure A2. A controlling device, called a media access unit (MAU), manages the unidirectional flow of all packets along the ring. Each node in the ring acts like a repeater. Each node has a receiver on the incoming cable and transmitter on the outgoing cable. FDDI and Token Rings are implementations of ring topology.

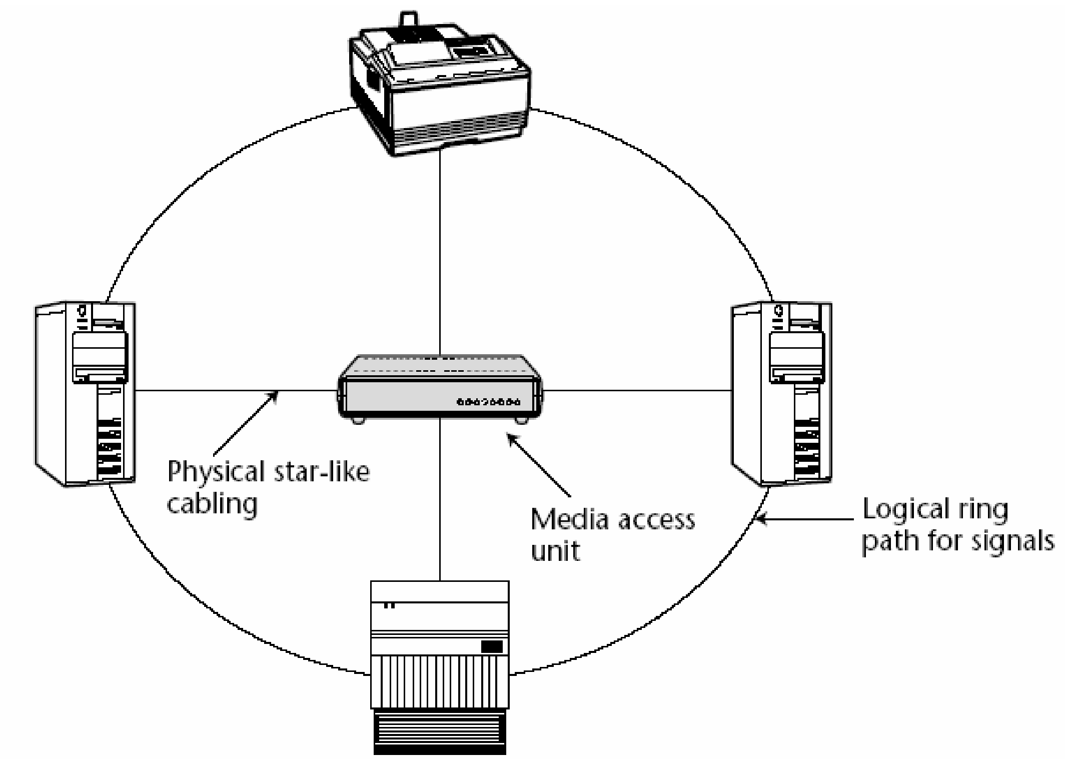


Fig. (A2) Ring Topology

A.1.4. Single-Star Topology

A star topology consists of a backbone or central transmission device, to which a number of network lines can be attached. Each line provides a port for attaching a host or device. The transmission device acts like a network concentration point, as shown in Figure (A3).

A star topology is set up using one or more hubs or switches, which have ports for network cables. Following are some advantages of the star topology:

1. *Modular design*: It is easier to set up and manage many small segments, as opposed to a large number of interconnected hosts. Adding a host is as easy as plugging a telephone-type connector into a hub or switch.
2. *Increased reliability*: Failures are localized within a segment.
3. *Improved performance*: User traffic within a segment does not impact others.

A single-star topology uses one hub or switch to form a LAN. This setup is common in small office networks or home networks.

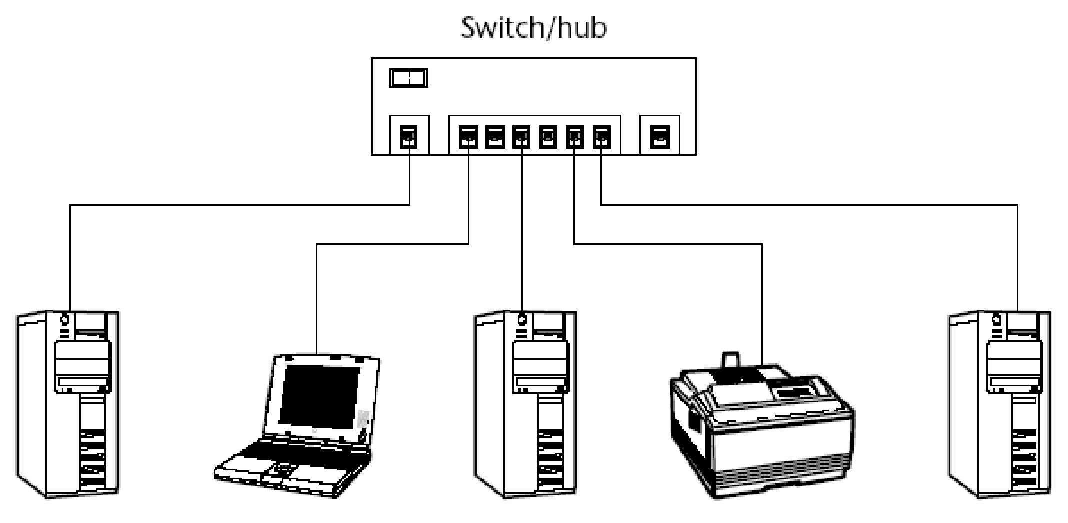


Fig. (A3) Single-Star Topology

A.1.5. Hierarchical-Star Topology

In a hierarchical-star topology, outlying hubs and switches are connected to a master switch (Figure A4). This allows a far greater number of hosts to be connected to the network than is possible with a single hub or switch. There is Physical star-like cabling media access unit logical ring path for signals. Also, there is no need to lay many long cables to connect distant hosts. This topology is closely tied to the geographical or building layout. Each floor can have a single hub or switch, which is connected to the master switch.

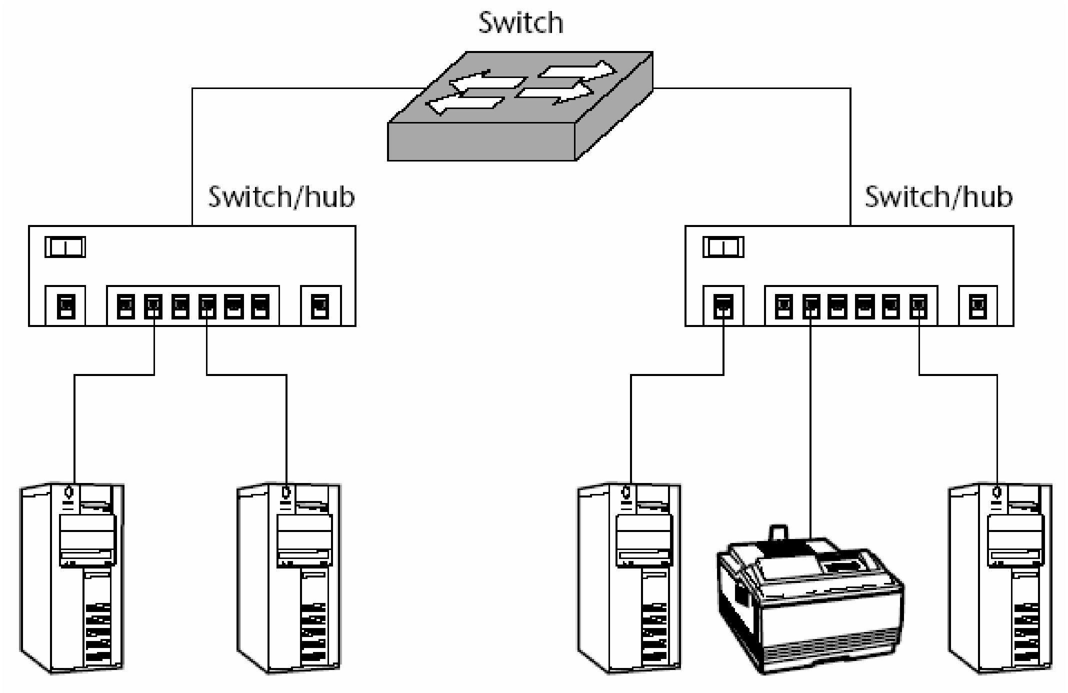


Fig. (A4) Hierarchical-Star Topology

A.1.6. Wireless Topology

A wireless topology has geographical areas that are divided into cells. Each cell has a wireless repeater. A mobile device attaches to the network via the cell's repeater. If the device is moved from one cell to another, it maintains network connection via another cell's wireless repeater. Figure (A5) shows three cells with wireless repeaters and devices such as laptop computers and mobile telephones.

A.1.7. Point-to-Point Topology

A point-to-point topology includes two devices that are directly attached using a point-to-point connection. Figure (A6) shows the point-to-point topology.

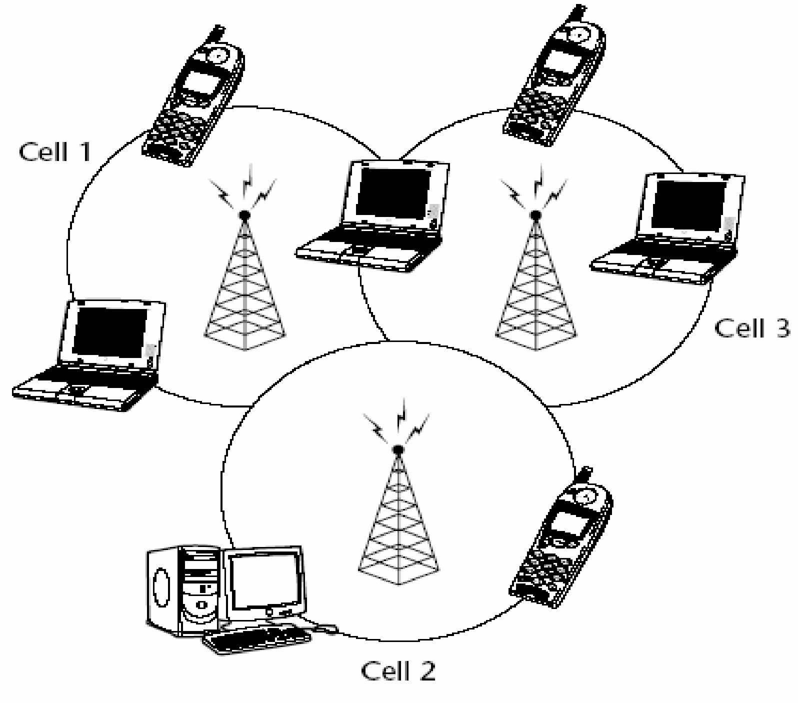


Fig. (A5) Wireless Topology

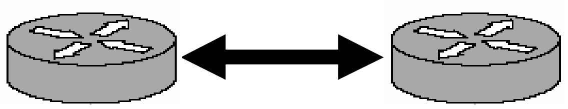


Fig. (A6) Point-to-Point Topology

A.1.8. Meshed Topology

A meshed topology includes several point-to-point connections between devices. There are three types of meshes (Figure A7 shows two mesh types):

1. *Fully meshed topology*: All nodes have physical or virtual circuits to every other node in the network.
2. *Partially meshed topology*: All nodes are connected to a few other nodes but not to all other nodes.
3. *Hybrid topology*: Some parts of the topology are fully meshed and the rest of the topology has nodes connected to one or two other nodes.

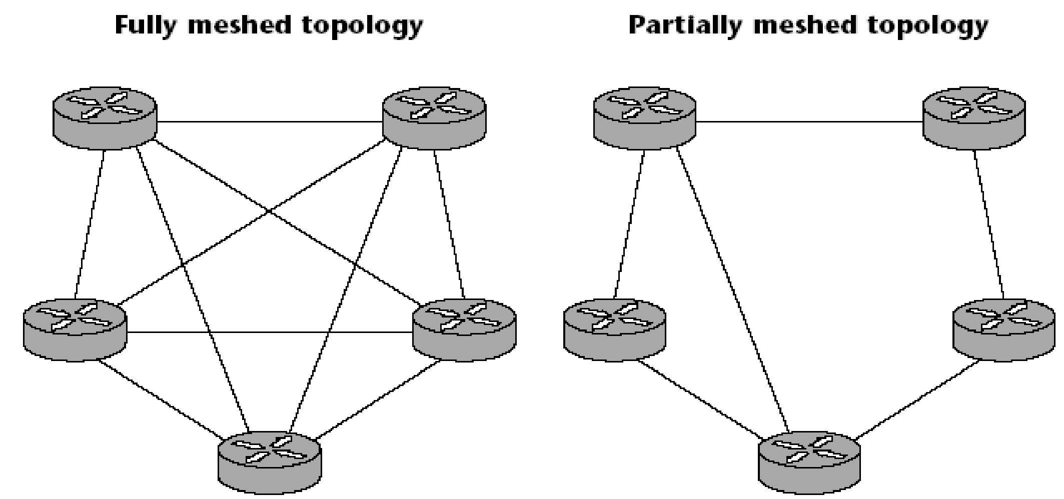


Fig. (A7) Fully and partially meshed topologies

At first inspection, a fully meshed topology seems like the way it should always be done. It has high availability because of redundant paths and high throughput because of load balancing and one-hop links between any two points. Fewer hops make it faster. Despite these advantages, meshing must be used selectively because of its high complexity and cost.

Each mesh link uses ports that could otherwise be used for networks or hosts. The denser the mesh, the more often devices have to broadcast their services and changes, thus eating into payload bandwidth. Dense meshes make it difficult to pinpoint a bad link or device. A misconfigured device will broadcast indiscriminate messages to devices farther from the source. For all these reasons, only backbones and core layers are fully meshed. Access and distribution layers are partially meshed.

A.2 Distance-Based Network Topologies

A topology is a physical arrangement of nodes within a network. A topology map represents each node and the media and links between them. Network topologies can be classified by the type of mesh (star, bus) or by the distance they span. There are three distance-based topologies.

A.2.1. Local Area Network (LAN)

LANs are small networks that are limited to the confines of a building, office, or small campus. They are made up of PCs, workstations, servers, printers, and so on and are often connected with copper or fiber links. The distinction between a LAN segments and a LAN is often blurred. ALAN segment is the basic building block and consists of a number of hosts, servers, and so on, connected by hub or switch. A collection of individual segments within a small office or building is a LAN. The Internet is a collection of many thousands of LANs. Although a LAN is limited to a small area, it can be extended geographically via MANs or WANs. See Figure (A8).

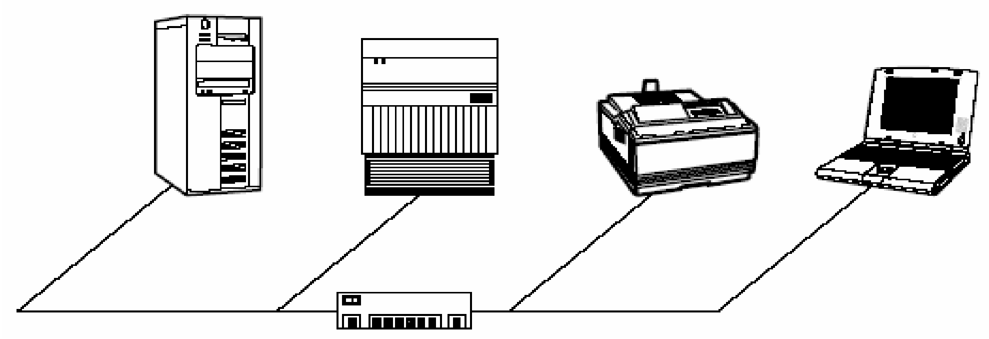


Fig. (A8) LAN

A.2.2. Metropolitan Area Network (MAN)

MANs are high-speed networks that extend LANs across a metropolitan area or city. They generally span an area up to 100 kilometers in diameter. MANs are used where there is a need to extend the reach of LANs to further distance but not far enough to necessitate the use of WANs. They have several LANs interconnected by a high-speed, fiber-optic backbone. Required services and equipment can be contracted from service providers, or you can lease the fiber cabling from the service provider and build your own private MAN. MANs are typically architected using point-to-point or ring topology, and speeds range up to several gigabits per second.

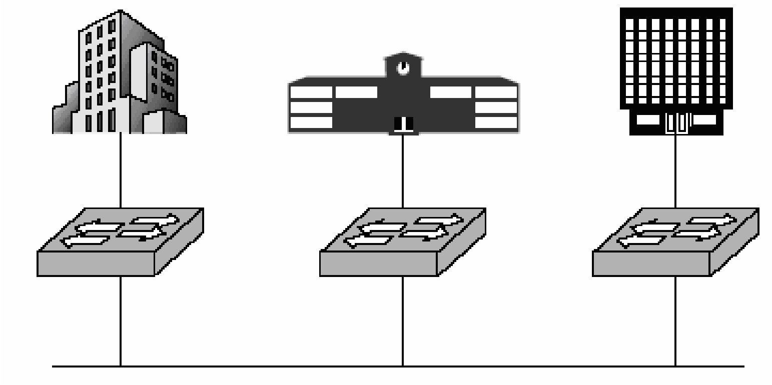


Fig. (A9) MAN

A.2.3. Wide Area Network (WAN)

WANs connect networks or resources beyond the reach of MANs. As shown in Figure (A10), WANs connect MANs in different geographical locations and usually provide a conduit to the Internet. WAN links should not be confused with network backbones. WAN links connect distant sites, but a network or campus backbone is a high-speed (fast Ethernet, fiber-optic) link between neighboring LANs. WANs are made up of geographically separated network equipment that are owned by telecommunications or network service providers. Each customer can lease an end-to-end connection with some guarantee of uptime and service levels. The service comes with a bill, the amount of which depends on the speed of the line, service level agreement, distance covered, and the level of competition among providers in the area. WAN links are intercity telecommunications links on intercontinent links strung across the ocean floors.

Fig. (A10) WAN

Beside the above broad networks, there are several other acronyms that you will hear:

1. *Campus Area Network (CAN)*: A campus is a building or group of buildings within a corporate campus that is connected to form one enterprise network. It consists of several interconnected LANs. It spans over a small geographical area and is usually owned and managed by one organization.
2. *Residential Area Network (RAN)*: This is a LAN within a home, consisting of a modem and one or more hosts. It may also have a router, switch, or hub.
3. *Personal Area Network (PAN)*: This is the set of devices that a person can carry and is part of a wireless network. Common devices include a cellular or mobile telephone, pager, and navigation system (typically satellite-based) within an automobile.

APPENDIX B

SNMP Message

The following sections describe the SNMP version 1 and 3 formats. The sign "--" indicates that the text following the sign is comment.

B.1 SNMPv1 [RFC1157]

```
SNMPv1 DEFINITIONS ::= BEGIN

    IMPORTS
       ObjectName, ObjectSyntax, NetworkAddress, IpAddress, TimeTicks
          FROM RFC1155-SMI;

       -- top-level message

      Message ::=
           SEQUENCE {
               version                  -- version-1
                 INTEGER {
                    version-1(0)
                 },

               community                -- community name
                 OCTET STRING,

               data                     -- e.g., PDUs if trivial
                 ANY                    -- authentication is being used
            }

       -- protocol data units

      PDUs ::=
            CHOICE {
               get-request
                   GetRequest-PDU,

               get-next-request
                   GetNextRequest-PDU,

               get-response
                   GetResponse-PDU,

               set-request
                   SetRequest-PDU,

               trap
                   Trap-PDU
            }
```

```
-- PDUs

GetRequest-PDU ::=
    [0]
        IMPLICIT PDU

GetNextRequest-PDU ::=
    [1]
        IMPLICIT PDU

GetResponse-PDU ::=
    [2]
        IMPLICIT PDU

SetRequest-PDU ::=
    [3]
        IMPLICIT PDU

PDU ::=
      SEQUENCE {
          request-id
            INTEGER,
          error-status          -- sometimes ignored
            INTEGER {
              noError(0),
              tooBig(1),
              noSuchName(2),
              badValue(3),
              readOnly(4),
              genErr(5)
            },

          error-index           -- sometimes ignored
            INTEGER,

          variable-bindings     -- values are sometimes ignored
            VarBindList
      }

Trap-PDU ::=
    [4]
      IMPLICIT SEQUENCE {
          enterprise            -- type of object generating
                                -- trap, see sysObjectID in [5]

            OBJECT IDENTIFIER,
          agent-addr            -- address of object generating
            NetworkAddress,     -- trap

          generic-trap          -- generic trap type
            INTEGER {
              coldStart(0),
              warmStart(1),
                    linkDown(2),
                    linkUp(3),
                    authenticationFailure(4),
                    egpNeighborLoss(5),
                    enterpriseSpecific(6)
                  },

                specific-trap          -- specific code, present even
                  INTEGER,             -- if generic-trap is not enterpriseSpecific

                time-stamp             -- time elapsed between the last
                  TimeTicks,           -- (re)initialization of the network
                                       -- entity and the generation of the trap

                variable-bindings      -- "interesting" information
                  VarBindList
            }

     -- variable bindings

      VarBind ::=
          SEQUENCE {
            name
                ObjectName,
            value
                ObjectSyntax
          }
      VarBindList ::=
          SEQUENCE OF
            VarBind
END
```

B.2 SNMPv3 [RFC2572]

```
SNMPv3MessageSyntax DEFINITIONS IMPLICIT TAGS ::= BEGIN

      SNMPv3Message ::= SEQUENCE {
          msgVersion INTEGER ( 0 .. 2147483647 ),  -- the value 3 is used for snmpv3
          msgGlobalData HeaderData,                 -- administrative parameters
          msgSecurityParameters OCTET STRING,       -- security model-specific
                                                    -- parameters format defined by
                                                    -- Security Model

          msgData  ScopedPduData
      }

      HeaderData ::= SEQUENCE {
          msgID      INTEGER (0..2147483647),
          msgMaxSize INTEGER (484..2147483647),
          msgFlags   OCTET STRING (SIZE(1)),
              --  .... ...1   authFlag
              --  .... ..1.   privFlag
              --  .... .1..   reportableFlag
              --              Please observe:
              --  .... ..00   is OK, means noAuthNoPriv
              --  .... ..01   is OK, means authNoPriv
              --  .... ..10   reserved, MUST NOT be used.
              --  .... ..11   is OK, means authPriv

          msgSecurityModel INTEGER (1..2147483647)
      }

      ScopedPduData ::= CHOICE {
          plaintext    ScopedPDU,
          encryptedPDU OCTET STRING  -- encrypted scopedPDU value
      }

      ScopedPDU ::= SEQUENCE {
          contextEngineID  OCTET STRING,
          contextName      OCTET STRING,
          data             ANY -- e.g., PDUs as defined in [RFC3416]
      }
END
```

APPENDIX C

Internet Protocol Version 4

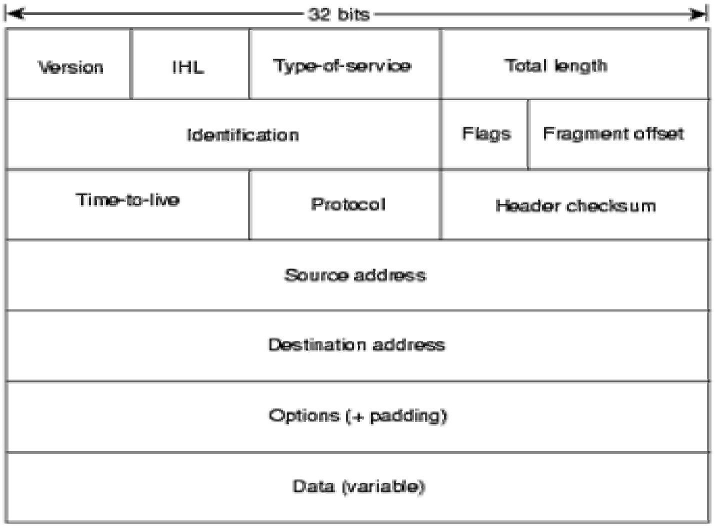
(IPv4)

C.1 Internet Protocol (IP) [CIS02]

The Internet Protocol (IP) is a network-layer (Layer 3) protocol that contains addressing information and some control information that enables packets to be routed. IP is documented in RFC 791 and is the primary network-layer protocol in the Internet protocol suite. Along with the Transmission Control Protocol (TCP), IP represents the heart of the Internet protocols. IP has two primary responsibilities: providing connectionless, best-effort delivery of datagrams through an inter-network; and providing fragmentation and reassembly of datagrams to support data links with different maximum-transmission unit (MTU) sizes.

C.2 IP Packet Format [CIS02]

An IP packet contains several types of information, as illustrated in Figure (C1).



32 bits

Version | IHL | Type-of-service | Total length

Identification | Flags | Fragment offset

Time-to-live | Protocol | Header checksum

Source address

Destination address

Options (+ padding)

Data (variable)

Fig.(C1) The IP packet fields

The *Version* field indicates the version of IP used. *IP Header Length* (IHL) field indicates the datagram header length in 32-bit words. *Type-of-Service* field specifies how an upper-layer protocol would like a current datagram to be handled, and assigns datagrams various levels of importance. *Total Length* field specifies the length, in bytes, of the entire IP packet, including the data and header. *Identification* field contains an integer that identifies the current datagram. This field is used to combine the datagram fragments to the original one. *Flags* field consists of a 3-bit field of which the two low-order (least-significant) bits control fragmentation of the IP datagram. The low-order bit specifies whether the packet can be fragmented. The middle bit specifies whether the packet is the last fragment in a series of fragmented packets. The third or high-order bit is not used. *Fragment Offset* field indicates the position of the fragment's data relative to the beginning of the data in the original datagram, which allows the destination IP process to properly reconstruct the original datagram. *Time-to-Live* field maintains a counter that gradually decrements down to zero, at which point the datagram is discarded. This keeps packets from looping endlessly. *Protocol* field indicates which upper-layer protocol receives incoming packets after IP processing is completed (for example, this field could refer to the TCP protocol to receive the packet). *Header Checksum* field helps to ensure IP header integrity. *Source Address* field specifies the sending node. *Destination Address* field specifies the receiving node. *Options* field allows IP to support various options, such as security. *Data* field contains upper-layer information.

C.3 IP Addressing [CIS02]

Each IP address has specific components and follows a basic format. These IP addresses can be subdivided and used to create addresses for subnetworks. Each host in a TCP/IP network is assigned a unique 32-bit logical address that is divided into two main parts: the network number and the host number. The network number identifies a network and must be assigned by the Internet Network Information Center (InterNIC) if the network is to be part of the Internet. An Internet Service Provider (ISP) can obtain blocks of network addresses from the InterNIC and can itself assign address space as necessary. The host number identifies a host on a network and is assigned by the local network administrator.

C.4 IP Address Format [CIS02]

The 32-bit IP address is grouped eight bits at a time, separated by dots, and represented in decimal format (known as dotted decimal notation). Each bit in the octet has a binary weight (128, 64, 32, 16, 8, 4, 2, 1). The minimum value for an octet is 0, and the maximum value for an octet is 255. Figure (C2) illustrates the basic format of an IP address.

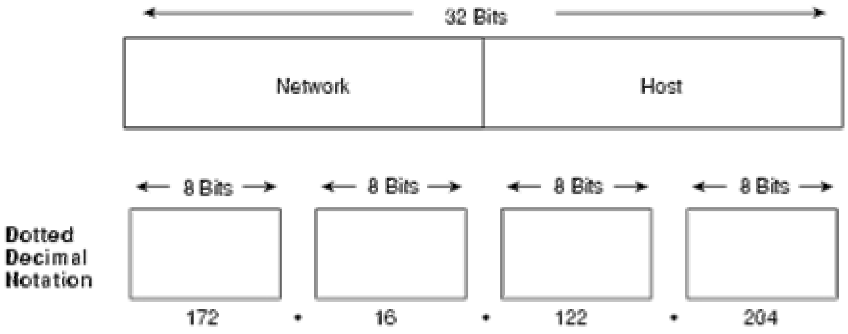


Fig.(C2) An IP address consists of 32 bits, grouped into four octets

C.5 IP Address Classes [CIS02]

IP addressing supports five different address classes: A, B, C, D, and E. Only classes A, B, and C are available for commercial use. The left-most (high-order) bits indicate the network class. Table (C1) provides reference information about the five IP address classes.

Table (C1) Reference Information About the Five IP Address Classes

IP Address Class	Format	Purpose	High-Order Bit(s)	Address Range	No. Bits Net/Host	Max. Hosts
A	N.H.H.H[1]	Few large organizations	0	1.0.0.0 to 126.0.0.0	7/24	16,777, 214[2] (2^{24} - 2)
B	N.N.H.H	Medium-size organizations	10	128.1.0.0 to 191.254.0.0	14/16	65, 534 (2^{16} - 2)
C	N.N.N.H	Relatively small organizations	110	192.0.1.0 to 223.255.254.0	22/8	254 (2^{8} - 2)
D	N/A	Multicast groups (RFC 1112)	1110	224.0.0.0 to 239.255.255.255	N/A (not for commercial use)	N/A
E	N/A	Experimental	1111	240.0.0.0 to 254.255.255.255	N/A	N/A

[1] N = Network number, H = Host number.

[2] One address is reserved for the broadcast address, and one address is reserved for the network.

Figure (C3) illustrates the format of the commercial IP address classes. Note the high-order bits in each class.

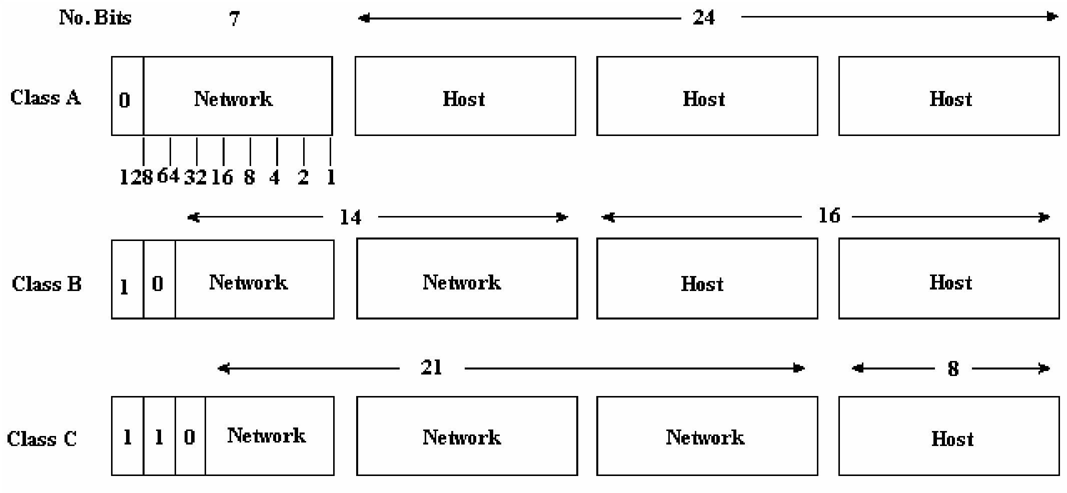


Fig.(C3) IP address formats A, B, and C are available for commercial use.

The class of address can be determined easily by examining the first octet of the address and mapping that value to a class range in the following table. In an IP address of 172.31.1.2, for example, the first octet is 172. Because 172 falls between 128 and 191, thus the address 172.31.1.2 is a Class B address. Figure (C4) summarizes the range of possible values for the first octet of each address class.

Table (C2) A range of possible values exists for the first octet of each address class

Address Class	First Octet in Decimal	High-Order bits
Class A	1-126	0
Class B	128-191	10
Class C	192-223	110
Class D	224-239	1110
Class E	240-254	11110

C.6 IP Subnet Addressing [CIS02]

IP networks can be divided into smaller networks called subnetworks (or subnets). Subnetting provides the network administrator with several benefits, including extra flexibility, more efficient use of network addresses, and the capability to contain broadcast traffic (a broadcast will not cross a router).

Subnets are under local administration. As such, the outside world sees an organization as a single network and has no detailed knowledge of the organization's internal structure.

A given network address can be broken up into many subnetworks. For example, 172.16.1.0, 172.16.2.0, 172.16.3.0, and 172.16.4.0 are all subnets within network 171.16.0.0.

C.7 Network Address Translation (NAT) [Sza01]

Network address translation is a network layer technique that protects the computers on the private network from Internet intruders by masking their IP addresses and can extends the number of computers in the network without registering new IPs. Connecting a network to the Internet without firewall protection of any kind implies computers in the network to use registered IP addresses so that they can communicate with other computers on the Internet. However, registered IP addresses are, by definition, visible through the Internet. This means that any user on the Internet can conceivably access your network's computers and, with a little ingenuity, access any resource. The results can be disastrous. Network address translation prevents this from happening by assigning unregistered IP addresses to the computers. These addresses fall into a range of addresses specifically designated for use on private networks. These addresses are not registered to any Internet user, and are therefore not visible from the Internet, so it can be safely deploying them on the network without limiting the users' access to Internet sites.

After assigning these private IP addresses to the computers on the network, outside users can't see these computers from the Internet. This means that an Internet server can't send packets to the private network, so the users can send traffic to the Internet but can't receive it.

To make normal Internet communications possible, the router that provides Internet access can use NAT. For example, when one of the computers on the private network attempts to access an Internet server using a Web browser, the Hypertext Transfer Protocol (HTTP) request packet should contain its own private IP address in the IP header's Source IP Address field. When this packet reaches the router, the NAT software substitutes its own registered IP address for the client computer's private address and sends the packet on to the designated server. When the server responds, it addresses its reply to the NAT router's IP address. The router then inserts the original client's private address into the Destination IP Address field and sends the packet on to the client system. All of the packets to and from the computers on the private network are processed in this manner, using the NAT router as an intermediary between the private network and the Internet. Because only the router's registered IP address is visible to the Internet, it is the only computer that is vulnerable to attack.

A popular security solution, NAT is implemented in numerous firewall products, ranging from high-end routers used on large corporate networks to inexpensive Internet connection-sharing solutions designed for home and small business networks. In fact, the Internet Connection Sharing (ICS) feature included with the latest versions of Windows is based on the principle of NAT.

Also, the NAT can be used to extend the number of computers in the network without registering new IPs by making the private network communicates with the Internet through one IP (or more). This facility serve the need of expanding networks without IP overhead costs resulted from registering IPs and solves the problem of limited number of available IPs but on the cost of performance. The degradation of performance is resulted from the translation process in sending and receiving.

APPENDIX D

Request for Comment (RFC)

The RFC is document specifies an Internet standards track protocol for the Internet community, and requests discussion and suggestions for improvements. The following are some of the RFCs:

SNMPv1
RFC 1157 - Simple Network Management Protocol
RFC 1155 - Structure of Management Information
RFC 1212 - Concise MIB Definitions
SNMPv2
RFC 1901 - Community-based SNMPv2
RFC 3416 - Protocol Operations for SNMPv2
RFC 3417 - Transport Mappings for SNMP
RFC 1908 - SNMPv1 and SNMPv2 Coexistence
SNMPv2 Data Definition
RFC 2578 - Structure of Management Information
RFC 2579 - Textual Conventions
RFC 2580 - Conformance Statements

SNMPv3
RFC 3411 - Architecture for SNMP Frameworks
RFC 3412 - Message Processing and Dispatching
RFC 3413 - SNMPv3 Applications
RFC 3414 - User-based Security Model
RFC 3415 - View-based Access Control Model

MIBs
RFC 1213 - Management Information Base II
RFC 1757 – Remote Network Monitoring MIB
RFC 3418 - MIB for SNMP
RFC 1573 - Evolution of the Interfaces Group of MIB-II
RFC 2011 - Internet Protocol MIB
RFC 2012 - Transmission Control Protocol MIB
RFC 2013 - User Datagram Protocol MIB

Authentication/Privacy
RFC 1321 - MD5 Message-Digest Algorithm
RFC 2104 - HMAC: Keyed-Hashing for Message Authentication
RFC 2786 - Diffie-Helman USM Key

APPENDIX E

Agent MIB Definitions

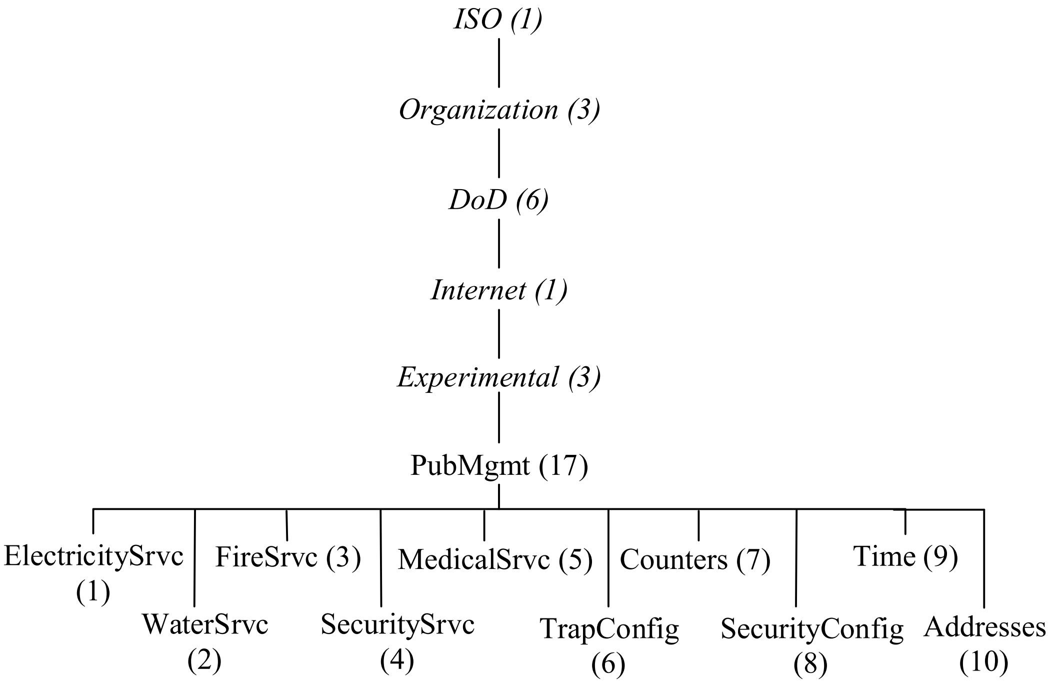


Fig.(E.1) Shows the OID tree of the MIBs

```
PubMgmt OBJECT IDENTIFIER ::= { ISO(1) Organization(3) DoD(6)
                                Internet(1) Experimental(3) 17 }

ElectricitySrvc OBJECT IDENTIFIER ::= { PubMgmt 1 }

  EService OBJECT-TYPE
        SYNTAX  INTEGER (SIZE (0..1))
        ACCESS  read-write
        STATUS  mandatory
        DESCRIPTION  " ; It shows if the electricity power measurement and
                     maintenance service is supported or not. 0--> Service Not
                     Supported, 1--> Service supported."
   ::= { ElectricitySrvc 1 }
  EMeasure OBJECT-TYPE
        SYNTAX  INTEGER (SIZE (0..2^32-1))
        ACCESS  read-only
        STATUS  optional
        DESCRIPTION  " ; It holds the electricity meter last reading."
   ::= { ElectricitySrvc 2 }

  EResponse OBJECT-TYPE
        SYNTAX  INTEGER (SIZE (2^32-2..2^32-1))
        ACCESS  read-only
        STATUS  optional
        DESCRIPTION  " ; It holds the condition of the electricity meter, if it is
                      responding or not."
   ::= { ElectricitySrvc 3 }

  EStopTrap OBJECT-TYPE
        SYNTAX  INTEGER (SIZE (0..1))
        ACCESS  read-write
        STATUS  optional
        DESCRIPTION  " ; It indicates whether to stop sending electricity traps or
                      not. 0 for send traps and 1 for don't send."
   ::= { ElectricitySrvc 4 }
```

WaterSrvc OBJECT IDENTIFIER ::= { PubMgmt 2 }

```
  WService OBJECT-TYPE
        SYNTAX  INTEGER (SIZE (0..1))
        ACCESS  read-write
        STATUS  mandatory
        DESCRIPTION  " ; It shows if the water flow measurement and
                      maintenance service is supported or not. 0--> Service Not
                      Supported, 1--> Service supported"
   ::= { WaterSrvc 1 }

  WMeasure OBJECT-TYPE
        SYNTAX  INTEGER (SIZE (0..2^32-1))
        ACCESS  read-only
        STATUS  optional
        DESCRIPTION  " ; It holds the water meter last reading."
   ::= { WaterSrvc 2 }
```

```
 WResponse OBJECT-TYPE
      SYNTAX  INTEGER (SIZE (2^32-2..2^32-1))
      ACCESS  read-only
      STATUS  optional
      DESCRIPTION  " ; It holds the condition of the water meter, if it is
                     responding or not."
  ::= { WaterSrvc 3 }

 WStopTrap OBJECT-TYPE
      SYNTAX  INTEGER (SIZE (0..1))
      ACCESS  read-write
      STATUS  optional
      DESCRIPTION  " ; It indicates whether to stop sending water traps or not.
                     0 for send traps and 1 for don't send."
  ::= { WaterSrvc 4 }

FireSrvc OBJECT IDENTIFIER ::= { PubMgmt 3 }

 FService OBJECT-TYPE
      SYNTAX  INTEGER (SIZE (0..1))
      ACCESS  read-write
      STATUS  mandatory
      DESCRIPTION   " ; It shows if the fire monitoring service is supported or
                     not. 0--> Service Not Supported, 1--> Service supported."
  ::= { FireSrvc 1 }

 FStatus OBJECT-TYPE
      SYNTAX  INTEGER (SIZE (0..2^32-1))
      ACCESS  read-only
      STATUS  optional
      DESCRIPTION  " ; It holds the fire sensors status. Each bit represents a
                     sensor."
  ::= { FireSrvc 2 }

 FResponse OBJECT-TYPE
      SYNTAX  INTEGER (SIZE (0..2^32-1))
      ACCESS  read-only
      STATUS  optional
      DESCRIPTION  " ; It holds the condition of the fire sensors, if it is
                     responding or not. Each bit represents a sensor; if its value
                     1 then it is responding else it is not responding."
  ::= { FireSrvc 3 }
 FPattren OBJECT-TYPE
      SYNTAX  INTEGER (SIZE (0..2^32-1))
      ACCESS  read-only
      STATUS  optional
      DESCRIPTION  " ; It identifies the number of sensors installed by
                     referring each bit to a sensor; if the bit value is 0 then it is
                     exist else it is empty."
  ::= { FireSrvc 4 }

 FStopTrap OBJECT-TYPE
      SYNTAX  INTEGER (SIZE (0..1))
      ACCESS  read-write
      STATUS  optional
      DESCRIPTION  " ; It indicates whether to stop sending fire traps or not. 0
                     for send traps and 1 for don't send."
  ::= { FireSrvc 5 }

 FMaintStopTrap OBJECT-TYPE
      SYNTAX  INTEGER (SIZE (0..1))
      ACCESS  read-write
      STATUS  optional
      DESCRIPTION  " ; It indicates whether to stop sending fire sensors
                     maintenance  traps or not. 0 for send traps and 1 for don't
                     send."
  ::= { FireSrvc 6 }

SecuritySrvc OBJECT IDENTIFIER ::= { PubMgmt 4 }

 SService OBJECT-TYPE
      SYNTAX  INTEGER (SIZE (0..1))
      ACCESS  read-write
      STATUS  mandatory
      DESCRIPTION   " ; It shows if the security service is supported or not. 0-
                     -> Service Not Supported, 1--> Service supported."
  ::= { SecuritySrvc 1 }

 SStatus OBJECT-TYPE
      SYNTAX  INTEGER (SIZE (0..2^32-1))
      ACCESS  read-only
      STATUS  optional
      DESCRIPTION  " ; It holds the security sensors status. Each bit
                     represents a sensor."
  ::= { SecuritySrvc 2 }
 SResponse OBJECT-TYPE
      SYNTAX  INTEGER (SIZE (0..2^32-1))
      ACCESS  read-only
      STATUS  optional
      DESCRIPTION  " ; It holds the condition of the security sensors, if it is
                     responding or not. Each bit represents a sensor; if its value
                     1 then it is responding else it is not responding."
  ::= { SecuritySrvc 3 }

 SPattren OBJECT-TYPE
      SYNTAX  INTEGER (SIZE (0..2^32-1))
      ACCESS  read-only
      STATUS  optional
      DESCRIPTION  " ; It identifies the number of sensors installed by
                     referring each bit to a sensor; if the bit value is 0 then it is
                     exist else it is empty."
  ::= { SecuritySrvc 4 }

 SStopTrap OBJECT-TYPE
      SYNTAX  INTEGER (SIZE (0..1))
      ACCESS  read-write
      STATUS  optional
      DESCRIPTION  " ; It indicates whether to stop sending security traps or
                     not. 0 for send traps and 1 for don't send."
  ::= { SecuritySrvc 5 }

 SMaintStopTrap OBJECT-TYPE
      SYNTAX  INTEGER (SIZE (0..1))
      ACCESS  read-write
      STATUS  optional
      DESCRIPTION  " ; It indicates whether to stop sending security sensors
                     maintenance traps or not. 0 for send and 1 for don't send."
  ::= { SecuritySrvc 6 }

MedicalSrvc OBJECT IDENTIFIER ::= { PubMgmt 5 }

 MStopTrap OBJECT-TYPE
      SYNTAX  INTEGER (SIZE (0..1))
      ACCESS  read-write
      STATUS  optional
      DESCRIPTION  " ; It indicates whether to stop sending medical help
                     traps or not. 0 for send traps and 1 for don't send."
  ::= { MedicalSrvc 1 }
```

TrapConfig OBJECT IDENTIFIER ::= { PubMgmt 6 }

```
 NoOfTimesToSendTraps OBJECT-TYPE
       SYNTAX  INTEGER (SIZE (1..255))
       ACCESS  read-write
       STATUS  mandatory
       DESCRIPTION   “ ; It is the number of times to send the traps to decrease
                        the possibility of not receiving the trap by the zone
                        center.”
   ::= { TrapConfig 1 }

 TimeDelayOfHighTraps OBJECT-TYPE
       SYNTAX  INTEGER (SIZE (1..2^15-1))
       ACCESS  read-write
       STATUS  mandatory
       DESCRIPTION   “ ; It is the delay time between sending a group of high
                        priority traps and another in seconds.”
   ::= { TrapConfig 2 }

 TimeDelayOfLowTraps OBJECT-TYPE
       SYNTAX  INTEGER (SIZE (1..2^15-1))
       ACCESS  read-write
       STATUS  mandatory
       DESCRIPTION   “ ; It is the delay time between sending a group of high
                        priority traps and another in seconds.”
   ::= { TrapConfig 3 }
```

Counters OBJECT IDENTIFIER ::= { PubMgmt 7 }

```
 NoOfTimesStarted OBJECT-TYPE
       SYNTAX  COUNTER16
       ACCESS  read-only
       STATUS  mandatory
       DESCRIPTION   “ ; It holds the number of times the agent started.”
   ::= { Counters 1 }

 NoOfTimesShutdown OBJECT-TYPE
       SYNTAX  COUNTER16
       ACCESS  read-only
       STATUS  mandatory
       DESCRIPTION   “ ; It holds the number of times the agent shut downed.”
   ::= { Counters 2 }
```

```
NoOfTimesAuthenticationFailure OBJECT-TYPE
      SYNTAX  COUNTER16
      ACCESS  read-only
      STATUS  mandatory
      DESCRIPTION   " ; It holds the number of times that received
                      unauthenticated message."
  ::= { Counters 3 }

NoOfTimesAuthenticationFailureByTime OBJECT-TYPE
      SYNTAX  COUNTER16
      ACCESS  read-only
      STATUS  mandatory
      DESCRIPTION   " ; It holds the number of times that received
                      unauthenticated message because of the time."
  ::= { Counters 4 }

NoOfTimesElectMaintTrap OBJECT-TYPE
      SYNTAX  COUNTER16
      ACCESS  read-only
      STATUS  mandatory
      DESCRIPTION   " ; It holds the number of times that a need to electricity
                      maintenance was detected and then generated electricity
                      maintenance trap."
  ::= { Counters 5 }

NoOfTimesElectMaintTrapManual OBJECT-TYPE
      SYNTAX  COUNTER16
      ACCESS  read-only
      STATUS  mandatory
      DESCRIPTION   "; It holds the number of times that a need to electricity
                      maintenance was manually requested and then an
                      electricity maintenance trap was generated."
  ::= { Counters 6 }

NoOfTimesWaterMaintTrap OBJECT-TYPE
      SYNTAX  COUNTER16
      ACCESS  read-only
      STATUS  mandatory
      DESCRIPTION   " ; It holds the number of times that a need to water
                      maintenance was detected and then generated water
                      maintenance trap."
  ::= { Counters 7 }
```

```
NoOfTimesWaterMaintTrapManual OBJECT-TYPE
      SYNTAX  COUNTER16
      ACCESS  read-only
      STATUS  mandatory
      DESCRIPTION   “; It holds the number of times that a need to water
                         maintenance was manually requested and then an water
                         maintenance trap was generated.”
  ::= { Counters 8 }

NoOfTimesFireTrap OBJECT-TYPE
      SYNTAX  COUNTER16
      ACCESS  read-only
      STATUS  mandatory
      DESCRIPTION   “ ; It holds the number of times that a fire was detected
                         and then generated fire trap.”
  ::= { Counters 9 }

NoOfTimesFireTrapManual OBJECT-TYPE
      SYNTAX  COUNTER16
      ACCESS  read-only
      STATUS  mandatory
      DESCRIPTION   “ ; It holds the number of times that a fire was detected
                         and then generated fire trap.”
  ::= { Counters 10 }

NoOfTimesFireMaintTrap OBJECT-TYPE
      SYNTAX  COUNTER16
      ACCESS  read-only
      STATUS  mandatory
      DESCRIPTION   “ ; It holds the number of times that a need to fire
                         sensors maintenance was detected and then generated fire
                         sensors maintenance trap.”
  ::= { Counters 11 }

NoOfTimesFireMaintTrapManual OBJECT-TYPE
      SYNTAX  COUNTER16
      ACCESS  read-only
      STATUS  mandatory
      DESCRIPTION   “ ; It holds the number of times that a need to fire
                         sensors maintenance was manually requested and then a
                         fire sensors maintenance trap was generated.”
  ::= { Counters 12 }
```

```
NoOfTimesSecurityTrap OBJECT-TYPE
      SYNTAX  COUNTER16
      ACCESS  read-only
      STATUS  mandatory
      DESCRIPTION   " ; It holds the number of times that a security break was
                    detected and then generated security break trap."
  ::= { Counters 13 }

NoOfTimesSecurityTrapManual OBJECT-TYPE
      SYNTAX  COUNTER16
      ACCESS  read-only
      STATUS  mandatory
      DESCRIPTION   " ; It holds the number of times that a security break was
                    detected and manually ordered to generate security break
                    trap."
  ::= { Counters 14 }

NoOfTimesSecuMaintTrap OBJECT-TYPE
      SYNTAX  COUNTER16
      ACCESS  read-only
      STATUS  mandatory
      DESCRIPTION   " ; It holds the number of times that a need to security
                    sensors maintenance was detected and then generated
                    security sensors maintenance trap."
  ::= { Counters 15 }

NoOfTimesSecuMaintTrapManual OBJECT-TYPE
      SYNTAX  COUNTER16
      ACCESS  read-only
      STATUS  mandatory
      DESCRIPTION   " ; It holds the number of times that a need to security
                    sensors maintenance was manually requested and then a
                    security sensors maintenance trap was generated."
  ::= { Counters 16 }

NoOfTimesMedicalTrapManual OBJECT-TYPE
      SYNTAX  COUNTER16
      ACCESS  read-only
      STATUS  mandatory
      DESCRIPTION   " ; It holds the number of times a medical support trap
                    was sent."
  ::= { Counters 17 }
```

```
NoOfTimesPUBLICKeyChange OBJECT-TYPE
      SYNTAX  COUNTER16
      ACCESS  read-only
      STATUS  mandatory
      DESCRIPTION   " ; It holds the number of times that received
                    unauthenticated message."
  ::= { Counters 18 }

NoOfTimesPOWERKeyChange OBJECT-TYPE
      SYNTAX  COUNTER16
      ACCESS  read-only
      STATUS  mandatory
      DESCRIPTION   = " ; It holds the number of times that the POWER
                    community key had been changed."
  ::= { Counters 19}

NoOfTimesADMINISTRATORKeyChange OBJECT-TYPE
      SYNTAX  COUNTER16
      ACCESS  read-only
      STATUS  mandatory
      DESCRIPTION   = " ; It holds the number of times that the
                    ADMINISTRATOR community key had been changed."
  ::= { Counters 20 }

NoOfTimesMessageKeyChange OBJECT-TYPE
      SYNTAX  COUNTER16
      ACCESS  read-only
      STATUS  mandatory
      DESCRIPTION   = " ; It holds the number of times that the message
                    encryption key had been changed."
  ::= { Counters 21 }

NoOfTimesLocalKeyChange OBJECT-TYPE
      SYNTAX  COUNTER16
      ACCESS  read-only
      STATUS  mandatory
      DESCRIPTION   = " ; It holds the number of times that the local key for
                    encryption had been changed."
  ::= { Counters 22 }
  NoOfTimesTimeChange OBJECT-TYPE
        SYNTAX  COUNTER16
        ACCESS  read-only
        STATUS  mandatory
        DESCRIPTION   = " ; It holds the number of times that the local Time
                          had been changed."
    ::= { Counters 23 }

  NoOfInvalidMessages OBJECT-TYPE
        SYNTAX  COUNTER16
        ACCESS  read-only
        STATUS  mandatory
        DESCRIPTION   = " ; It holds the number of times an invalid message
                          had been received."
    ::= { Counters 24 }

  NoOfIncompatibleVersion OBJECT-TYPE
        SYNTAX  COUNTER16
        ACCESS  read-only
        STATUS  mandatory
        DESCRIPTION   = " ; It holds the number of times a message with
                          incompatible version number had been received."
    ::= { Counters 24 }


SecurityConfig OBJECT IDENTIFIER ::= { PubMgmt 8 }

  PUBLICKey OBJECT-TYPE
        SYNTAX  OCTET STRING (SIZE (16))
        ACCESS  write-only
        STATUS  mandatory
        DESCRIPTION   "Encrypted; It holds the PUBLIC community key for
                          authentication."
    ::= { SecurityConfig 1 }

  POWERKey OBJECT-TYPE
        SYNTAX  OCTET STRING (SIZE (16))
        ACCESS  write-only
        STATUS  mandatory
        DESCRIPTION   "Encrypted; It holds the POWER community key for
                          authentication."
    ::= { SecurityConfig 2 }
```

```
 ADMINISTRATORKey OBJECT-TYPE
       SYNTAX  OCTET STRING (SIZE (16))
       ACCESS  write-only
       STATUS  mandatory
       DESCRIPTION   “Encrypted; It holds the ADMINISTRATOR
                      community key for authentication.”
   ::= { SecurityConfig 3 }

 MessageKey OBJECT-TYPE
       SYNTAX  OCTET STRING (SIZE (24))
       ACCESS  write-only
       STATUS  mandatory
       DESCRIPTION   “Encrypted; It holds the key for encrypting message.”
   ::= { SecurityConfig 4 }

 LocalKey OBJECT-TYPE
       SYNTAX  OCTET STRING (SIZE (24))
       ACCESS  write-only
       STATUS  mandatory
       DESCRIPTION   “Virtual; It holds the key for encrypting local data.”
   ::= { SecurityConfig 5 }

 ValidTimePeriod OBJECT-TYPE
       SYNTAX  INTEGER (SIZE (0..2^16))
       ACCESS  read-write
       STATUS  mandatory
       DESCRIPTION   “ ; The maximum time (in seconds) difference between
                      the receiving and the sending time of message to be stated
                      as a valid.”
   ::= { SecurityConfig 6 }
```

Time OBJECT IDENTIFIER ::= { PubMgmt 9 }

```
 LocalDateTime OBJECT-TYPE
       SYNTAX  OCTET STRING (SIZE (8))
       ACCESS  read-write
       STATUS  mandatory
       DESCRIPTION   “Virtual; It holds the local date and time of the agent.”
   ::= { Time 1 }
```

```
Addresses OBJECT IDENTIFIER ::= { PubMgmt 10 }

 LocalIPv6 OBJECT-TYPE
       SYNTAX  IPv6Address
       ACCESS  read-write
       STATUS  mandatory
       DESCRIPTION   " ; It holds the local IPv6 address and when changed the
                        agent restarts."
  ::= { Addresses 1 }

 ManagerIPv6 OBJECT-TYPE
       SYNTAX  IPv6Address
       ACCESS  read-write
       STATUS  mandatory
       DESCRIPTION   " ; It holds the Manager IPv6 address to send the trap to
                        it."
  ::= { Addresses 2 }
```

APPENDIX F

Distance Equation Derivation

The latitude and longitude lines specify the points on the earth. The earth are divided into 180 latitude lines with the “equator” (where 90 lines northern the equator and 90 lines southern equator) and 360 lines longitude lines with the “meridian” (where 180 lines eastern meridian and 180 lines western meridian). The points between the lines are specified by minutes and seconds of arc (i.e. not unit of time) northern or southern a specified latitude and minutes and seconds of arc eastern or western a specified longitude. If the earth is considered as a sphere and then the radius of earth is the radius of the equator R=6378 km. Figure (F1) shows the latitude and longitude lines.

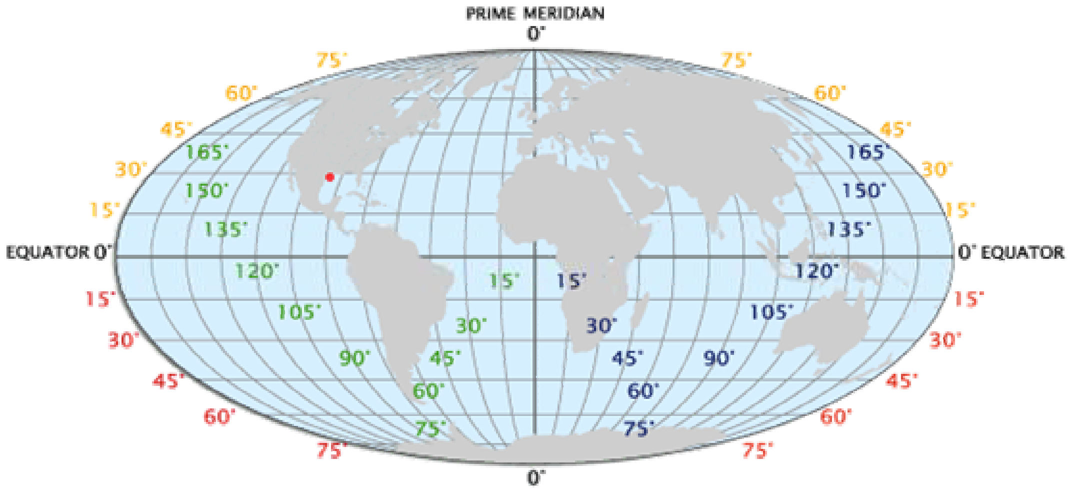


Fig.(F1) shows the latitude and longitude lines

Calculating the distance between two points (Lat1, Lon1) and (Lat2, Lon2) on the surface of earth is determined by the following equation:

$$\begin{aligned} Dist = \arccos(&\sin(Lat1) * \sin(Lat2) + \cos(Lat1) * \cos(Lon1) \\ &* \cos(Lat2) * \cos(Lon2) + \cos(Lat1) * \sin(Lon1) \\ &* \cos(Lat2) * \sin(Lon2)) * R \end{aligned} \quad \ldots\ldots\ldots(\text{F1})$$

OR can be simplified to:

$$\begin{aligned} Dist = \arccos(&\sin(Lat1) * \sin(Lat2) + \cos(Lat1) * \cos(Lat2) \\ &* \cos(Lon1 - Lon2)) * R \end{aligned} \quad \ldots\ldots\ldots(\text{F2})$$

Where *Lat* and *Lon* are in radians and *R* is the radius of the earth. The search operation could be slowed if it depends on this equation. Thus, simpler equation is needed to improve the search operation.

The following section shows the derivation of the distance between two points in specific region on earth.

First, determine each latitude degree in km. Because that there are 180 latitude lines, the earth is considered as a sphere, and the latitude line is a circle around the earth (that is the latitude line is cross each vertical circle around the earth with 2- points, see Figure F2) then:

$$180\,lat = \frac{2\pi R}{2} = \pi R$$

$$1\,lat = \frac{\pi R}{180} = 111.317 \quad {}^{km}\!/_{\deg ree}$$

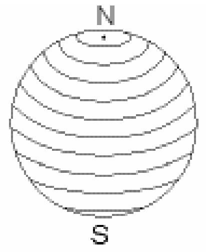


Fig.(F2) shows the latitude lines

Second, determine each longitude degree in km. The distance between the longitude lines in different latitude lines is varying because the longitude lines are closed to each other on going far away from the equator (see Figure F3). Thus, the longitude degree would be calculated according to specific latitude line. Therefore, the final equation would be specific to some region with center latitude (*Latc*).

$$360\,Lon = 2\pi\ r$$

Where r is radius of the latitude *Latc*. Then:

$$360\ Lon = 2\pi\ R\ \cos(Latc)$$

$$1\ Lon = \frac{2\pi\ R\ \cos(Latc)}{360} = scllon\ \left({}^{km}\!/_{\deg ree}\right) \qquad \text{………(F3)}$$

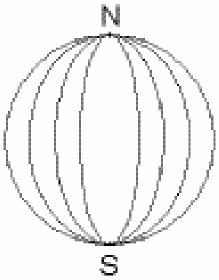


Fig.(F3) shows the longitude lines

Now, if the surface of the earth is considered as a plane then the distance between the two points can be calculated by using the normal distance formula, which is:

$$\text{Distance} = \sqrt{(Y1 - Y2)^2 + (X1 - X2)^2} \qquad \text{………(F4)}$$

Let *p1* is a point on region *a* (where the *Latc* is the latitude of the *a*'s center point) and composed of (*Lat1*, *Lon1*) and *p2* is a point on the same region and composed of (*Lat2*, *Lon2*) then:

$$D_x = (Lon2 - Lon1) * R_x \quad (km) \qquad \text{………(F5)}$$

$$D_y = (Lat1 - Lat2) * R_y \quad (km) \qquad \text{………(F6)}$$

$$Distance = \sqrt{D_y^2 + D_x^2}\ \ (km) \qquad \text{………(F7)}$$

$$Distance = \sqrt{\begin{matrix}(Lat1 - Lat2)^2 * sclllat^2 \\ + (Lon2 - Lon1)^2 * sclllon^2\end{matrix}} \quad (km) \qquad \ldots\ldots\ldots(F8)$$

The result of Equation (F8) is not accurate but it is faster than Equation (F2) and its accuracy is acceptable to the thesis need. Table (F1) shows the different in accuracy between the two equations. The specified region is Baghdad where the latitude of its center point is (33˚:20″:0′ N) which is equal in decimal degree to (33.333).

Table (F1) shows comparison between the two equations (F2) and (F8)

P1		**P2**		**F2 Result (km)**	**F8 Result (km)**	**Difference (km)**
Lat	*Lon*	*Lat*	*Lon*			
33.367	44.333	33.361	44.407	6.871	6.873	-0.002
33.361	44.407	33.365	44.264	13.309	13.313	-0.005
33.365	44.264	33.237	44.407	19.464	19.460	0.003
33.237	44.407	33.334	44.525	15.401	15.397	0.004
33.334	44.525	33.423	44.403	15.150	15.155	-0.005
33.333	*44.433*	*33.883*	*35.500*	*830.404*	*833.300*	*-2.896*

Table (F1) showed that the difference in meters between the two equations if it is calculated to points in Baghdad. But the last one is between Baghdad and Beirut so, the difference in kilometers because Equation (F8) is derived for Baghdad region.

[illegible]

[illegible]

[illegible] zones [illegible]

[illegible] network management station [illegible]

[illegible] zone center [illegible]

[illegible] primary center [illegible]

[illegible]

[illegible] cluster of computers [illegible]

!!»!!!!¿!! !! !!anycast!!¿!! !!!!!! !!!! !! !!!! !!!! !! !!

!¿!!!! !!! !! !!! !!!!!! !!!! !! !!!!! ! !!!! !!!! !!clusters!

!¿!!! » !!!!!¿!! !!!!! ! !! !!SNMPV2!!! !! !!! !!! ! !!!IPV6!!!

!!!!! !!! !!!!!!!!!! !!! !!¿! !!bandwidth!!!!!

!!!!»¿!» !!¿!! !!!! !!!!! !!!!!!!!

MS Visual !!!! !!!!! !!! !!!multi-threaded system!!! !!¿!!

multi-threaded !!! » !!! !»!! !!!Net frame work!!!!!!!! !! !!Basic net 2003

!!! ! !!!!! !!system

جمهورية العراق
وزارة التعليم العالي والبحث العلمي
جامعة النهرين
كلية العلوم

نظام إدارة الشبكات للخدمات العامة

رسالة مقدمة الى كلية العلوم، جامعة النهرين كجزء من متطلبات نيل
شهادة الماجستير في علوم الحاسوب

تقديم

حيدر مجيد جابر

(بكالوريوس ٢٠٠٣)

إشراف

د. لـــؤي ادوار جورج

شباط ٢٠٠٧ صفر ١٤٢٨