Chapter 6 Network Management

Topics covered:
Network management standards & models. ISO Functional areas of management. Proactive vs. Reactive management. Network management tools and systems. SNMP architecture & operations.

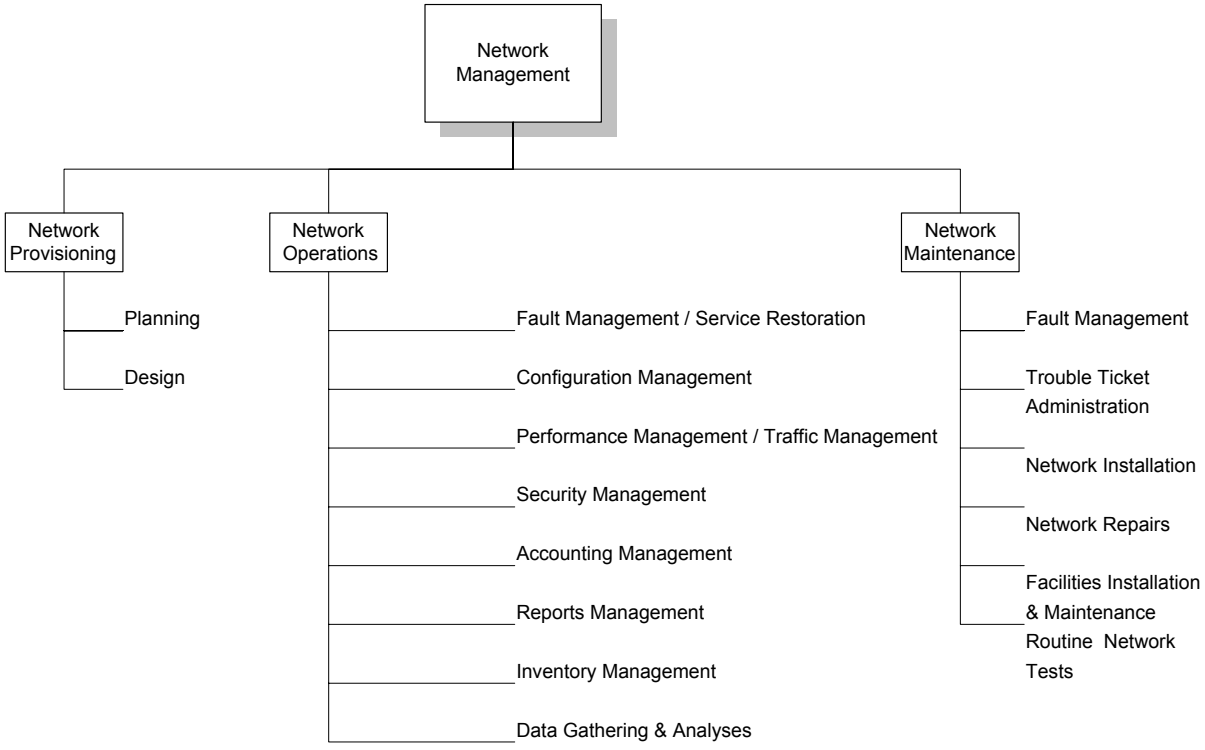
Note: Most of the information in this chapter is taken from [1], and accompanying slides that are © Mani Subramanian 2000

6.1 Introduction

- Network Management is the management of the network resources comprising nodes (e.g., hubs, switches, routers) and links (e.g., connectivity between two nodes).

- System Management is the management of systems and system resources in the network.

- Network Management can also be defined as OAM&P (Operations, Administration, Maintenance, and Provisioning) of network and services.



I Network Management Functional Groupings

- Common Network Problems

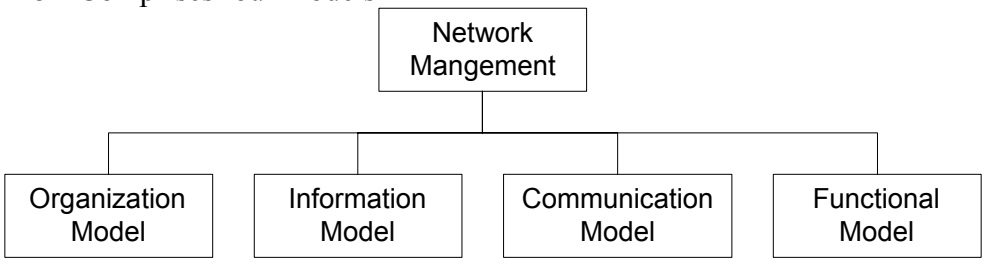
  - Loss of connectivity
  - Duplicate IP address
  - Intermittent problems
  - Network configuration issues
  - Non-problems
  - Performance problems

6.2 Network Management Standards

- NM Standards:
  - OSI/CMIP: Common Management Information Protocol
  - SNMP/Internet: Simple Network Management Protocol (IETF)
  - TMN: Telecommunications Management Network (ITU-T)
  - IEEE standards
  - Web-based Management
- SNMP is the most widely used
- SNMP and CMIP:
  - Use polling methodology → additional load on the network
  - Requires dedicated workstations for the NMS (Network Management System)

6.3 Network Management Model

- OSI Network Management Architecture and Model
  - Most superior of all models
  - Comprises four models



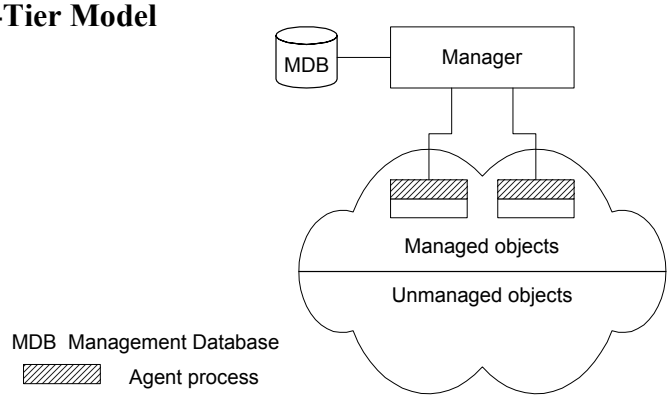
OSI Network Management Model

- SNMP Network Management Architecture and Model:
    - Not defined explicitly.
    - The first 3 models are similar to the OSI models.
    - Addresses the functional model in terms of operations, administration, and security.

6.3.1 Organization Model

- Describes components of network management and their relationship
- Defines the terms: object, agent and manager
- Manager
    - Manages the managed elements
    - Sends requests to agents
    - Monitors alarms
    - Houses applications
    - Provides user interface
- Agent
    - Gathers information from objects
    - Configures parameters of objects
    - Responds to managers' requests
    - Generates alarms and sends them to managers
- Managed object
    - Network element that is managed
    - Houses management agent
    - All objects are either managed or unmanaged

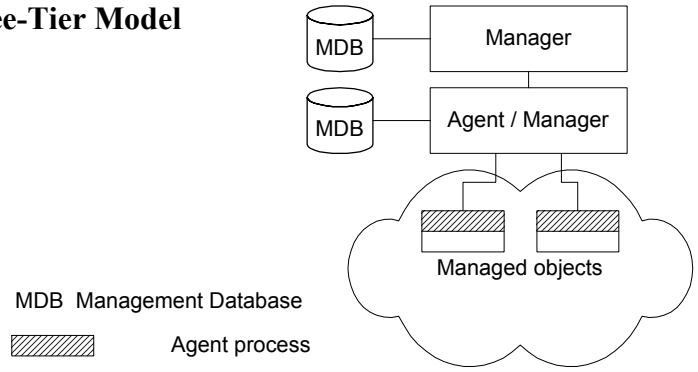
❖ **Two-Tier Model**



Two-Tier Network Mangement Organization Model

- Agent built into network element
  - Example: Managed hub, managed router
- A manager can manage multiple elements
  - Example: Switched hub, ATM switch
- MDB is a physical database
- Unmanaged objects are network elements that are not managed - both physical (unmanaged hub) and logical (passive elements)

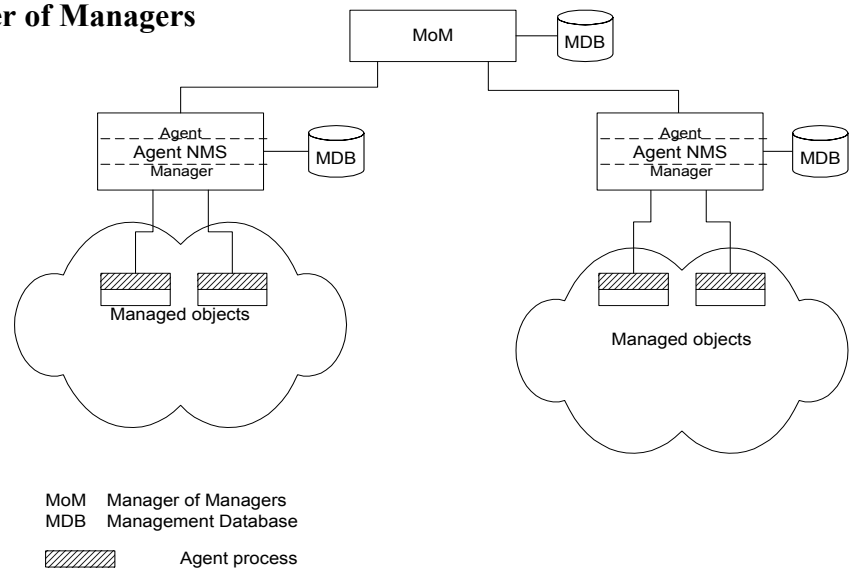
❖ Three-Tier Model



Three-Tier Network Mangement Organization Model

- Middle layer plays the dual role
  - Agent to the top-level manager
  - Manager to the managed objects
- Example of middle level: Remote monitoring agent (RMON)

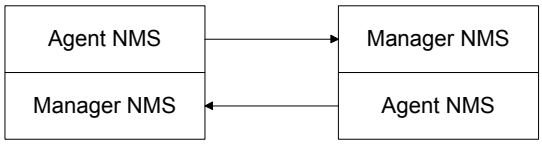
❖ Manager of Managers



Network Mangement Organization Model with MoM

- Agent NMS manages the domain
- MoM presents integrated view of domains
- Domain may be geographical, administrative, vendor-specific products, etc.

❖ **Peer NMSs**



Dual Role of Management Process

- Dual role of both NMSs
- Network management system acts as peers
- Notice that the manager and agent functions are processes and not systems

6.3.2 Information Model

- Concerned with the structure and the storage of information. Similar to information stored in the library (e.g., ISBN)
- Specifies the information base to describe managed objects and their relationships
- The **Structure of Management Information (SMI)** defines for a managed object:
  - Syntax
  - Semantics
  - plus additional information such as status

  Example

  sysDescr: { system 1 }

Syntax:	OCTET STRING
Definition:	"A textual description of the entity."
Access:	read-only
Status:	mandatory

- **Management Information Base (MIB)**
  - Information base contains information about objects
  - Organized by grouping of related objects
  - Defines relationship between objects
  - It is NOT a physical database. It is a ***virtual* database** that is compiled into management module

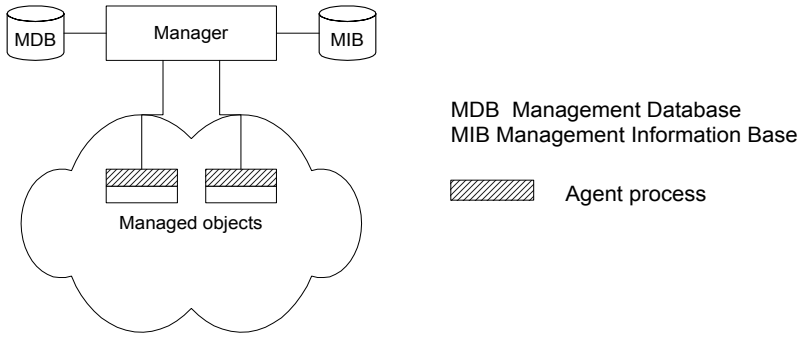
- **MIB View and Access of an Object**
  - A managed object has many attributes - its information base
  - There are several operations that can be performed on the objects
  - A user (manager) can view and perform only certain operations on the object by invoking the management agent
  - The view of the object attributes that the agent perceives is the **MIB view**
  - The operation that a user can perform is the MIB access

- **Management Data Base / Information Base**

  - Distinction between MDB and MIB
    - MDB physical database; e.g., Oracle, Sybase
    - MIB virtual database; schema compiled into management software

  - An NMS can automatically discover a managed object, such as a hub, when added to the network

  - The NMS can identify the new object as hub only after the MIB schema of the hub is compiled into NMS software



Network Configuration with Data and Information Base

- **Managed Objects can be:**

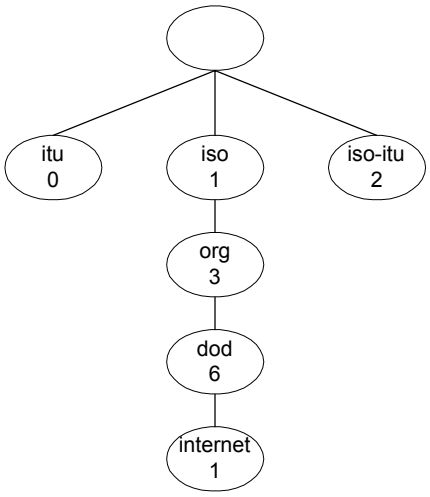
  - Network elements (hardware, system): hubs, bridges, routers, transmission facilities

  - Software (non-physical): programs, algorithms

  - Administrative information: contact person, name of group of objects (IP group)

6.3.2.1 Management Information Tree (MIT)

- Managed objects are uniquely defined by a tree structure specified by the OSI model.



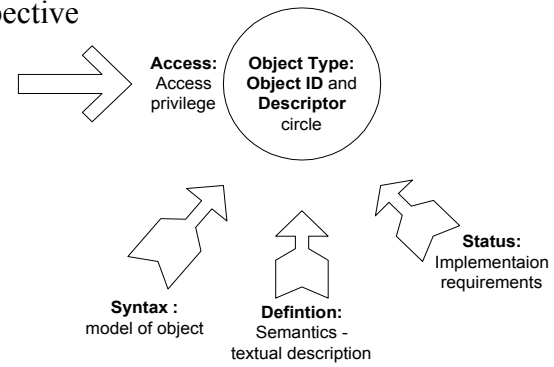
OSI Management Information Tree

- Each node is a managed object (e.g., the Internet is designated as 1.3.6.1)

  → All Internet-managed objects start with 1.3.6.1

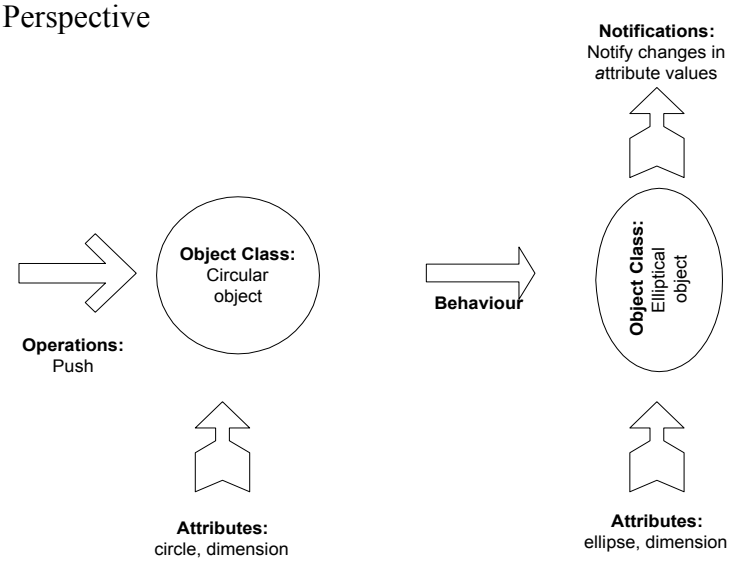
6.3.2.2 Managed Objects

- Internet Perspective



a) Internet Perspective

- OSI Perspective



OSI Perspective

- Comparison of Internet and OSI specifications for the object "Packet Counter"

Characteristics	Example
Object type	PktCounter
Syntax	Counter
Access	Read-only
Status	Mandatory
Description	Counts number of packets

Internet Perspective

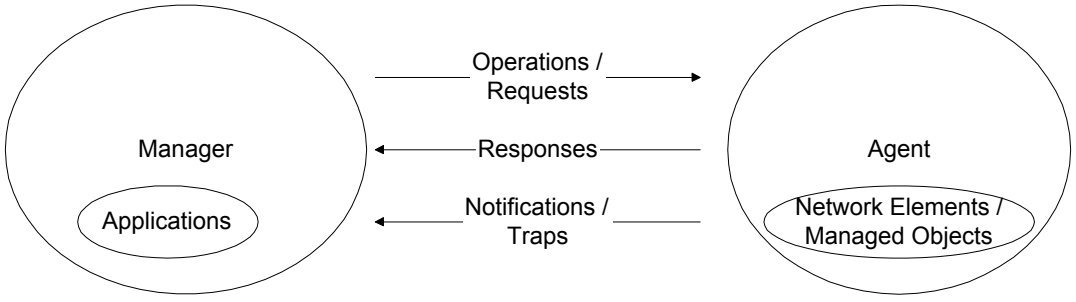
Characteristics	Example
Object class	Packet Counter
Attributes	Single-valued
Operations	get, set
Behavior	Retrieves or resets values
Notifications	Generates notifications on new value

OSI Perspective

Packet Counter As Example of Managed Object

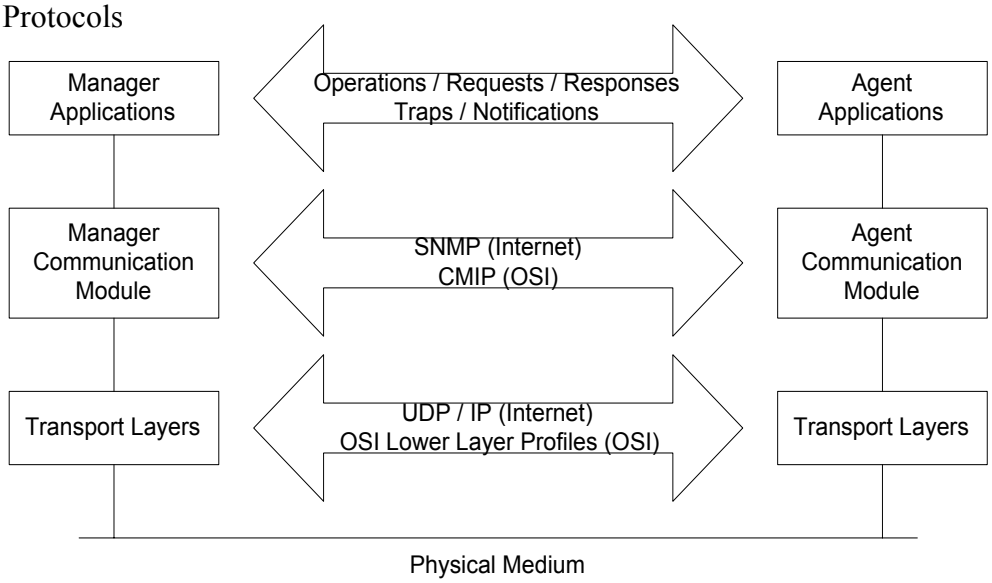
6.3.3 Communication Model

- Addresses the way information is exchanged between systems (agents/managers)



Management Message Communication Model

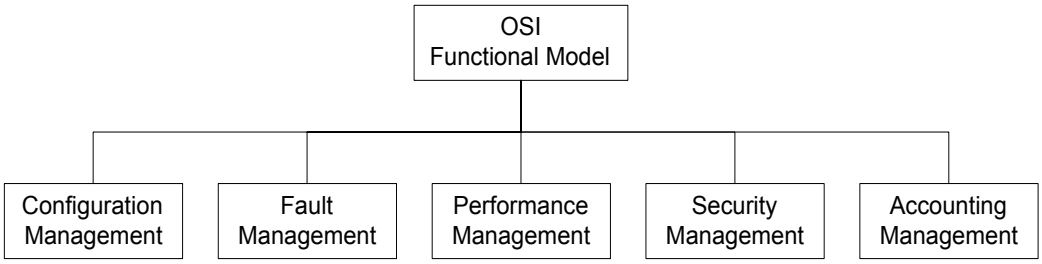
- Transfer Protocols



Management Communication Transfer Protocols

6.3.4 Functional Model

- Addresses the user-oriented applications
- Formally specified in the OSI model as follows:



6.3.4.1 Configuration Management (CM)

- Basic functionality
  - Set and change network configuration and component parameters
  - Set up alarm thresholds
- Network Provisioning
- Inventory Management
  - Equipment
  - Facilities
  - Database Considerations
- Network Topology

- **Network Provisioning / Circuit Provisioning**

    - Provisioning of network resources
        - Design
        - Installation and maintenance

    - Circuit-switched network

    - Packet-switched network

    - ATM networks

- **Network Topology**

    - Manual

    - Auto-discovery by NMS using
        - Broadcast *ping*
        - ARP table in devices

    - Mapping of network
        - Layout
        - Layering

    - Views
        - Physical
        - Logical

6.3.4.2 Fault Management (FM)

- Summary
    - Detection and isolation of failures in network
    - Trouble ticket administration

- Fault is a failure of a network component

- Results in loss of connectivity

- Fault management involves a 5-step process:
    - Fault detection
        - Polling
        - Traps: *linkDown, egpNeighborLoss*
    - Fault location
        - Detect all components failed and trace down the tree topology to the source

        - Fault isolation by network and SNMP tools
        - Use artificial intelligence / correlation techniques
    - Restoration of service (has higher priority)
    - Identification of root cause of the problem
    - Problem resolution (trouble ticket generation)

6.3.4.3 Performance Management (PM)

- Summary
    - Monitor performance of network

- Tools (e.g., analyzers)
- Performance Metrics
- Data Monitoring
- Problem Isolation
- Performance Statistics

➢ **Performance Metrics**

- Macro-level
    - Throughput
    - Response time
    - Availability
    - Reliability

- Micro-level
    - Bandwidth
    - Utilization
    - Error rate
    - Peak load
    - Average load

➢ **Data Monitoring and Problem Isolation**

- Data monitoring
    - Normal behavior
    - Abnormal behavior (e.g., excessive collisions, high packet loss, etc)
    - Set up traps (e.g., parameters in alarm group in RMON on object identifier of interest)
    - Set up alarms for criticality
    - Manual and automatic clearing of alarms

- Problem isolation
    - Manual mode using network and SNMP tools
    - Problems in multiple components needs tracking down the topology
    - Automated mode using correlation technology

- **Performance Statistics**

  - Traffic statistics

  - Error statistics

  - Used in
    - QoS tracking
    - Performance tuning
    - Validation of SLA (Service Level Agreement)
    - Trend analysis
    - Facility planning
    - Functional accounting

6.3.4.4 Security Management (SM)

- Summary
  - Authentication
  - Authorization
  - Encryption

- Security threats
  - Modification of information
  - Masquerade
  - Message stream modification
  - Disclosure

- Secure communication
  - Integrity protection
  - Authentication validation

- Policies and Procedures

- Resources to prevent security breaches
  - Firewalls (e.g., packet filtering using a TCP/UDP port address)
  - Cryptography
  - Authentication (e.g., data integrity & data origin)
  - Authorization (e.g., read, read-write, no-access)

6.3.4.5 Accounting Management (AM)

- Summary
  - Functional accounting of network usage

- Least developed
- Usage of resources
- Identification of hidden cost of IT usage
- Functional accounting
- Business application

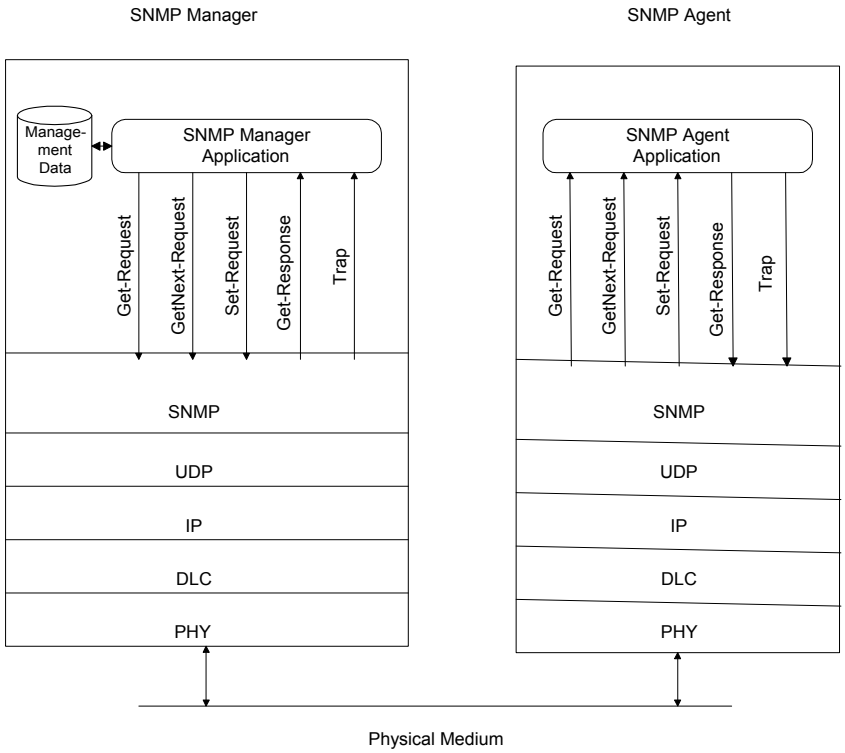
6.4 SNMPv1: Communication Model

An SNMP-based Network Management System consists of 3 main elements:

-
-
-

6.4.1 SNMP Architecture

- Five SNMP messages, three from manager and two from agent.

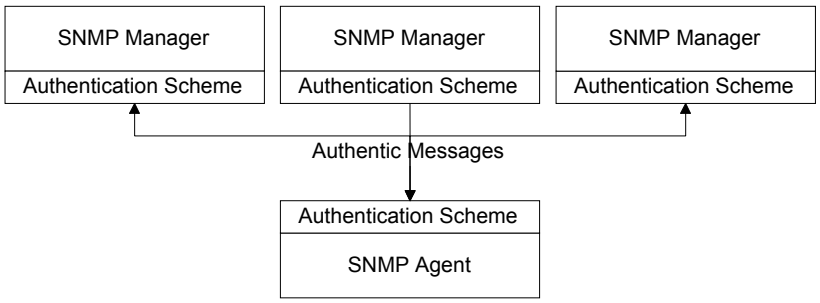


SNMP Network Management Architecture

6.4.2 Administrative Model

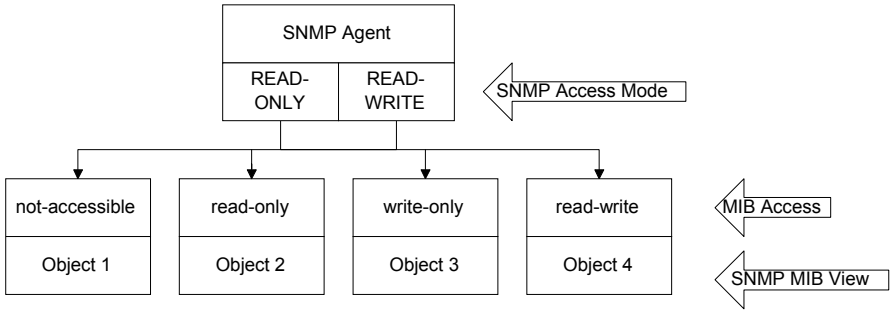
- Based on community profile and policy
- SNMP Entities:
    - SNMP application entities
      - Reside in management stations and network elements
      - Manager and agent
    - SNMP protocol entities
      - Communication processes (PDU handlers)
      - Peer processes that support application entities

6.4.2.1 SNMP Community



- Security in SNMPv1 is community-based
- Authentication scheme is a filter module in manager and agent (e.g., common community name)
- Community: Pairing of two application entities
- Community name: String of octets
- Two applications in the same community communicate with each other
- Application could have multiple community names
- Communication is not secured in SNMPv1 - no encryption

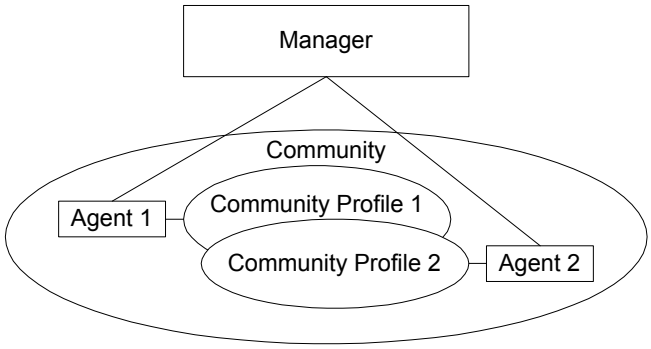
6.4.2.2 SNMP Community Profile



- SNMP MIB view
  - An agent is programmed to view only a subset of managed objects of a network element
- SNMP access mode
  - Each community name is assigned an access mode: read-only and read-write
- Community profile: SNMP MIB view + SNMP access mode
- Operations on an object determined by community profile and the access mode of the managed object
- Total of four access privileges
- Some objects, such as table and table entry are non-accessible
- Most objects available for the public community are read-only.

6.4.2.3 Access Policy

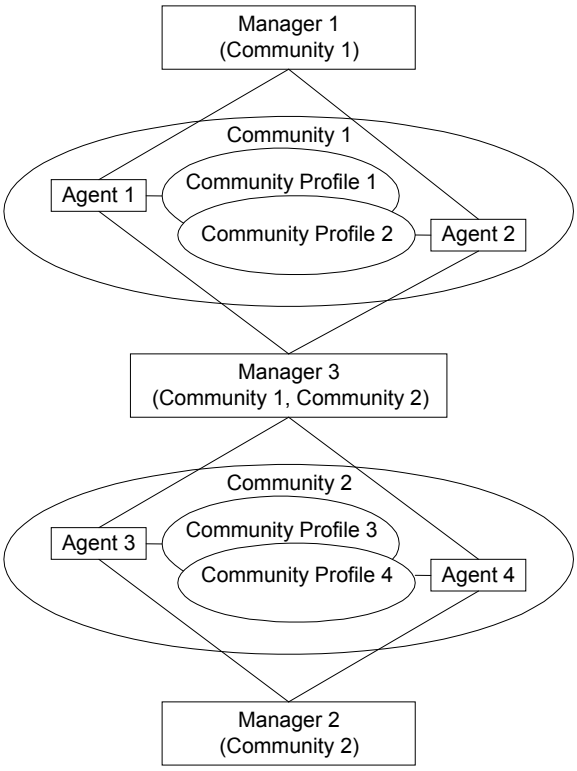
- The SNMP access policy defines the administrative model
- SNMP community paired with SNMP community profile is SNMP access policy



- Manager manages Community 1 and 2 network components via Agents 1 and 2
- Agent 1 has only view of Community Profile 1, e.g. Cisco components
- Agent 2 has only view of Community Profile 2, e.g. 3Com components
- Manager has total view of both Cisco and 3Com components

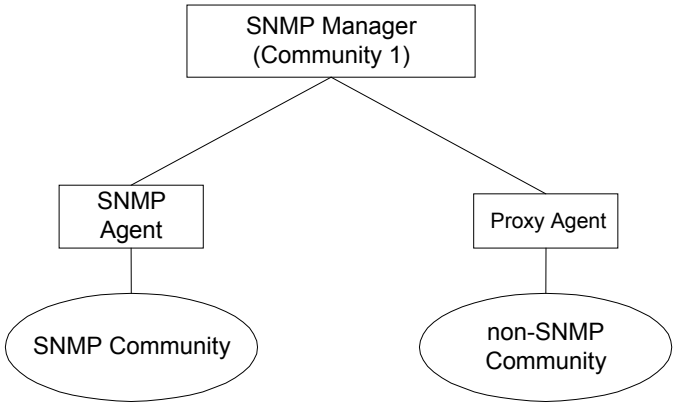
6.4.2.4 Generalized Administration Model

- Manager 1 manages community 1, manager 2 community 2, and manager 3 (MoM) both communities 1 and 2



SNMP Access Policy

6.4.2.5 Proxy Access Policy

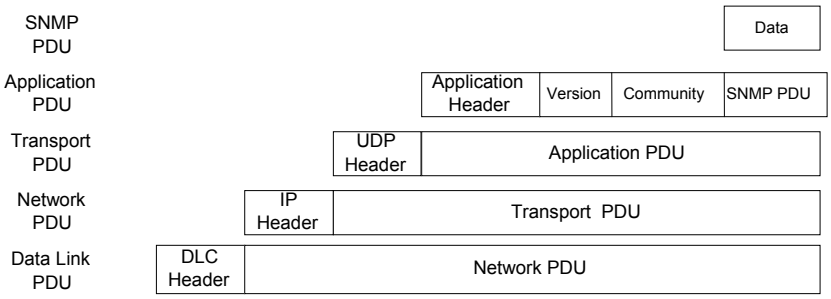


SNMP Proxy Access Policy

- Proxy agent enables non-SNMP community elements to be managed by an SNMP manager.
- An SNMP MIB is created to handle the non-SNMP objects

6.4.3 SNMP Protocol Specifications

6.4.3.1 Protocol Entities



Encapsulated SNMP Message

- Protocol entities support application entities
- Communication between remote peer processes
- Message consists of
  - Version identifier
  - Community name
  - Protocol Data Unit
- Message encapsulated and transmitted

6.4.3.2 Get and Set PDU

PDU Type	RequestID	Error Status	Error Index	VarBind 1 name	VarBind 1 value	...	VarBind n name	VarBind n value

Get and Set Type PDUs

- VarBindList: multiple instances of VarBind pairs
- PDU Type: enumerated INTEGER

```
get-request          [0]
get-next-request     [1]
set-request          [2]
get-response         [3]
trap                 [4]
```

- Error in Response

```
ErrorStatus ::=
INTEGER {
        noError(0)
        tooBig(1)
        noSuchName(2)
        badValue(3)
        readOnly(4)
        genErr(5)
}
```

Error Index: No. of VarBind where the first error occurred

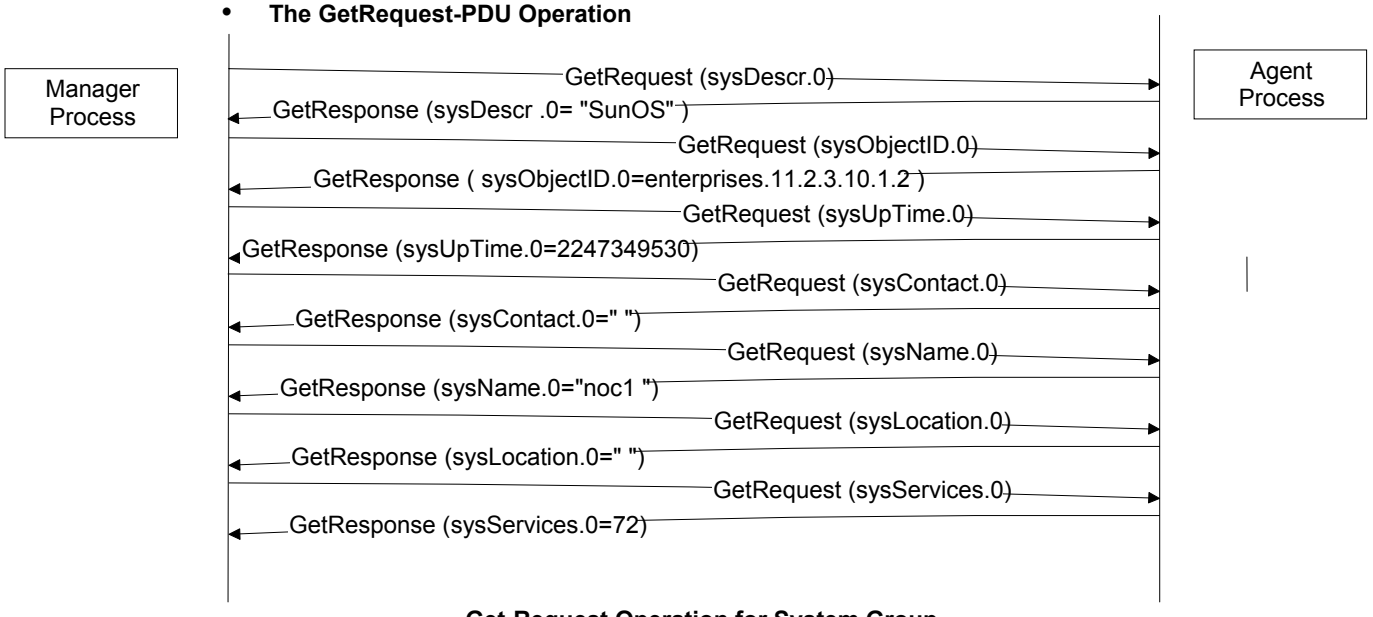
6.4.3.3 Trap PDU

PDU Type	Enterprise	Agent Address	Generic Trap Type	Specific Trap Type	Timestamp	VarBind 1 name	VarBind 1 value	...	VarBind n name	VarBind n value

- Enterprise and agent address pertain to the system generating the trap
- Seven generic traps specified by enumerated INTEGER
- The enterprise-specific trap is used by the private organizations to define their device-specific traps. If the Generic Trap type value is six, the trap is enterprise specific and is defined in a private MIB.
- Timestamp indicates elapsed time since last re-initialization

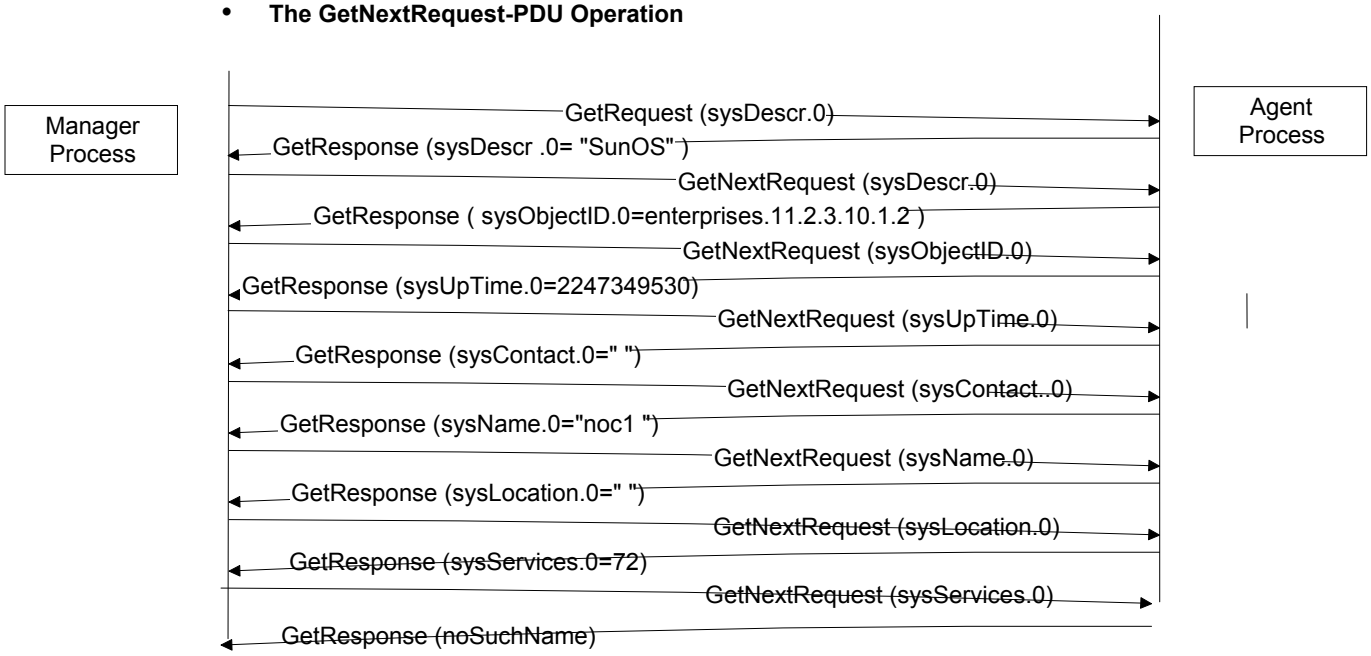
6.4.4 SNMP Operations

- **The GetRequest-PDU Operation**



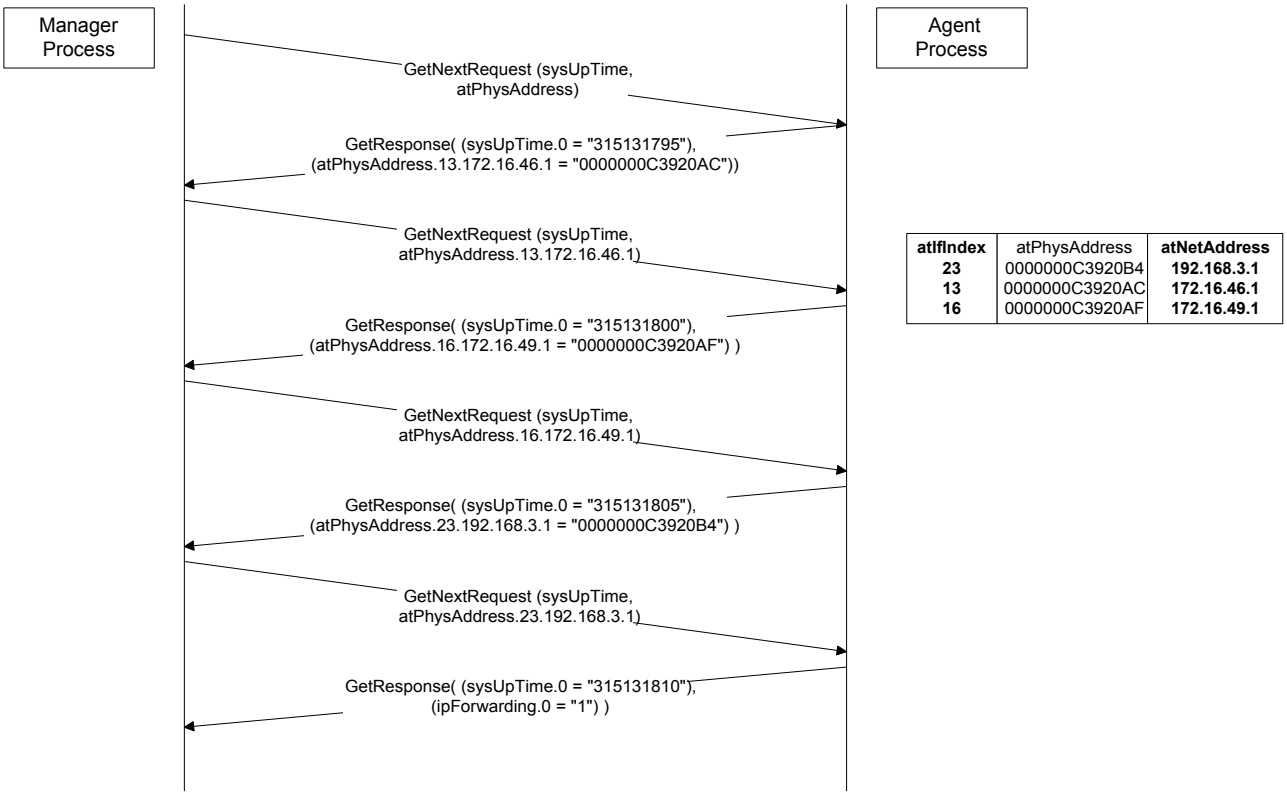
Get-Request Operation for System Group

- **The GetNextRequest-PDU Operation**



Get-Next-Request Operation for System Group

- **GetNextRequest with Indices (faster method)**
  - Uses Lexicographic Order to traverse the MIB subtree
  - A GetNextRequest Example with Indices

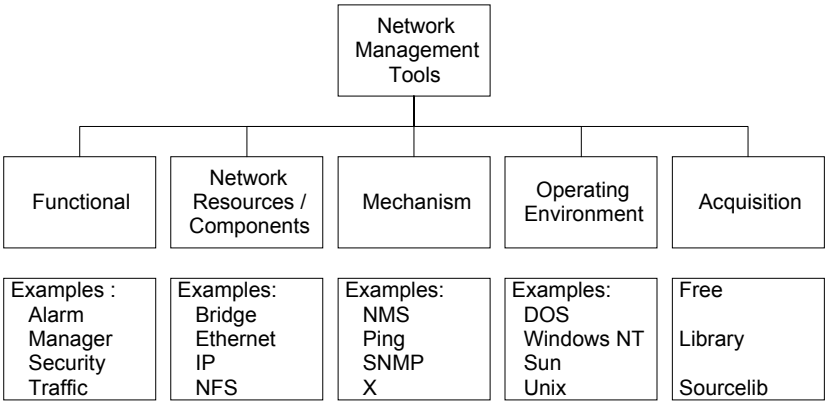


atIfIndex	atPhysAddress	atNetAddress
23	0000000C3920B4	192.168.3.1
13	0000000C3920AC	172.16.46.1
16	0000000C3920AF	172.16.49.1

GetNextRequest Example with Indices

6.5 SNMP Tools & Systems

6.5.1 Tools Catalog



NOC Tool Categories (RFC 1470)

6.5.2 Network Software Tools

- Status monitoring tools
- Traffic monitoring tools
- Route monitoring tools

6.5.2.1 Network Status Monitoring Tools

NAME	OPERATING SYSTEM	DESCRIPTION
Ifconfig	UNIX	Obtains and configures networking interface parameters and status
ping	UNIX Windows	Checks the status of node / host
nslookup	UNIX Windows NT	Looks up DNS for name/IP address translation
dig	UNIX	Queries DNS server
host	UNIX	Displays information on Internet hosts / domains

6.5.2.2 Network Traffic Monitoring Tools

Name	Operating System	Description
ping	UNIX Windows	Used for measuring roundtrip packet loss
bing	UNIX	Measures point-to-point bandwidth of a link
etherfind	UNIX	Inspects Ethernet packets
snoop	UNIX	Captures and inspects network packets
tcpdump	UNIX	Dumps traffic on a network
getethers	UNIX	Acquires all host addresses of an Ethernet LAN segment
iptrace	UNIX	Measures performance of gateways

6.5.2.3 Network Routing Tools

Name	Operating System	Description
netstat	UNIX	Displays the contents of various network-related data structures
arp rarp	UNIX, Windows 95/x/00NT	Displays and modifies the Internet-to Ethernet address translation tables
traceroute tracert	UNIX Windows	Traces route to a destination with routing delays

6.5.3 SNMP MIB Tools

- SNMP MIB Browsers
- SNMP command-line tools

6.5.3.1 SNMP MIB Browsers

- User friendly tools
- May have a GUI
- Specify hostname or IP address & request information on a specific MIB object, MIB group or entire MIB
- Response returns object id(s) and value(s)

6.5.3.2 SNMP Command-Line Tools

- snmpget
- snmpgetnext
- snmpset
- snmptrap
- snmpwalk
- snmpnetstat

6.6 References

1. "Network Management - Principles and Practice" by Mani Subramanian, 2000

2. "TCP/IP Illustrated, Volume 1 - The protocols" by Richard Stevens