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Network Management

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Promise of Telecom

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Basic infrastructure that provides:

- voice + FAX + Internet

That promises:

- Widespread access to knowledge
- reduce have/have-not divide by leap-frogging

$\Rightarrow$ must be affordable and reliable

Network “Storms”

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- Rapid escalation of cascading failures

Example:

Noise on a link

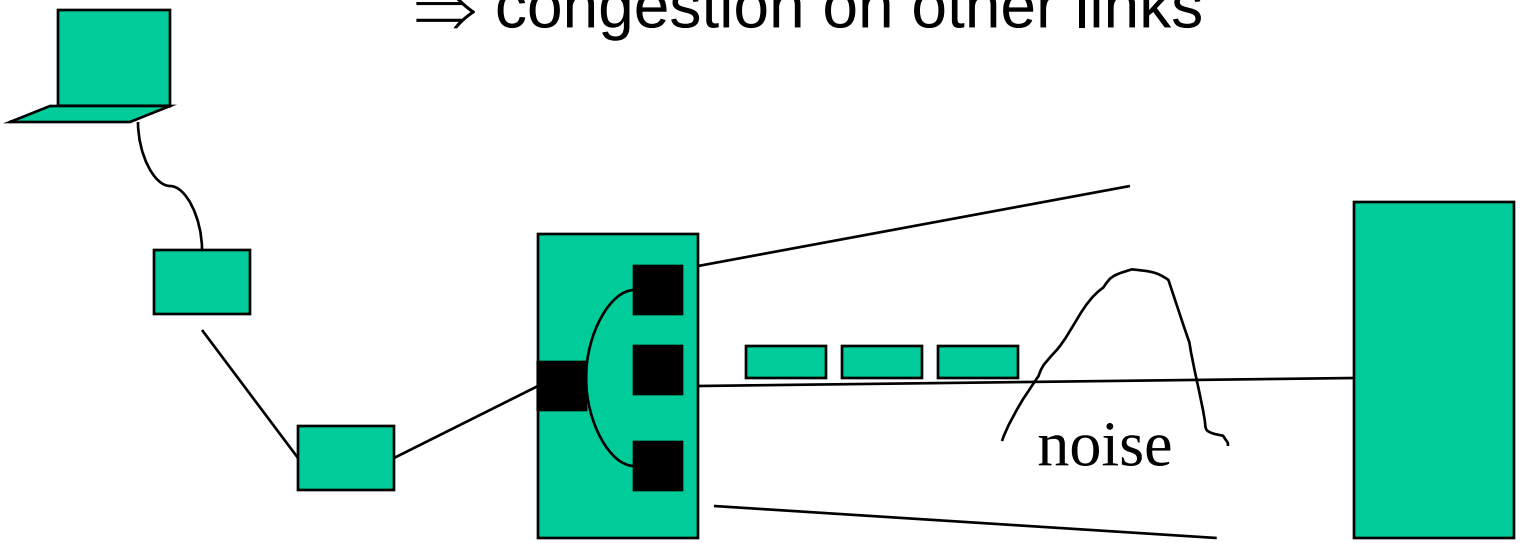
⇒ packet loss

⇒ link-level ARQ

⇒ queue buildup

⇒ source retransmits

⇒ congestion on other links



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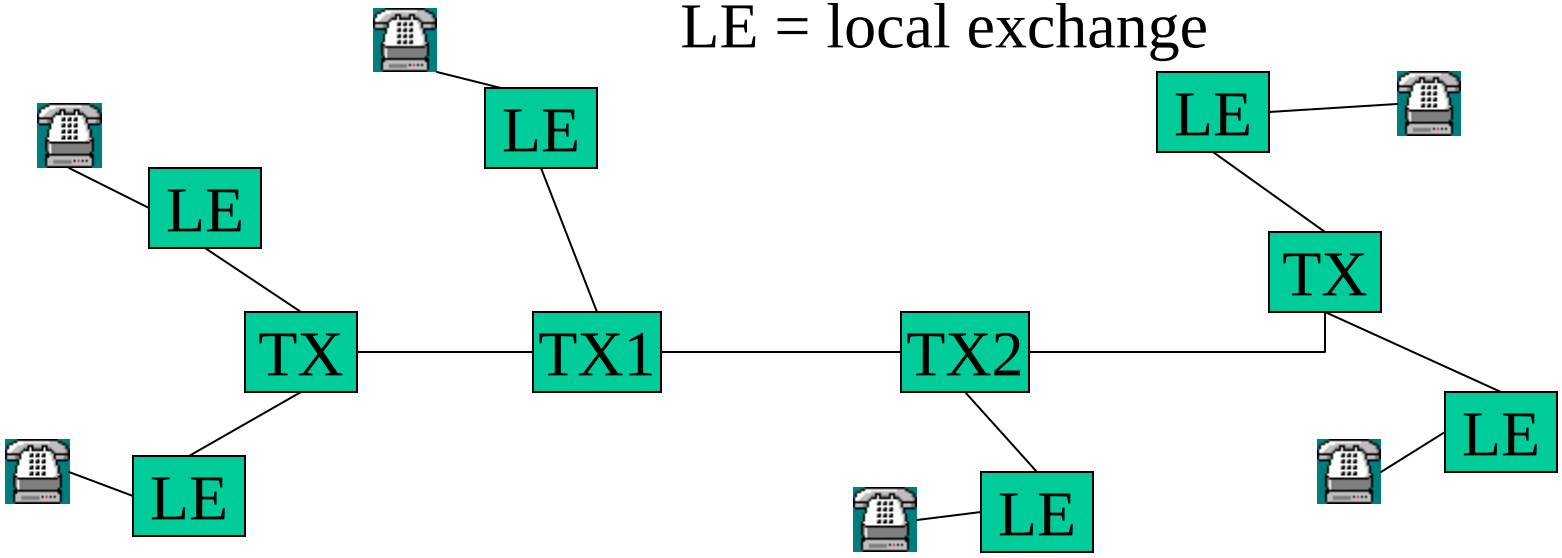
TX = trunk exchange
LE = local exchange



- Trunk line fails
  - alarms at TX1 and TX2
- Call failure rate exceeds threshold at several LEs
  - alarms at many LEs

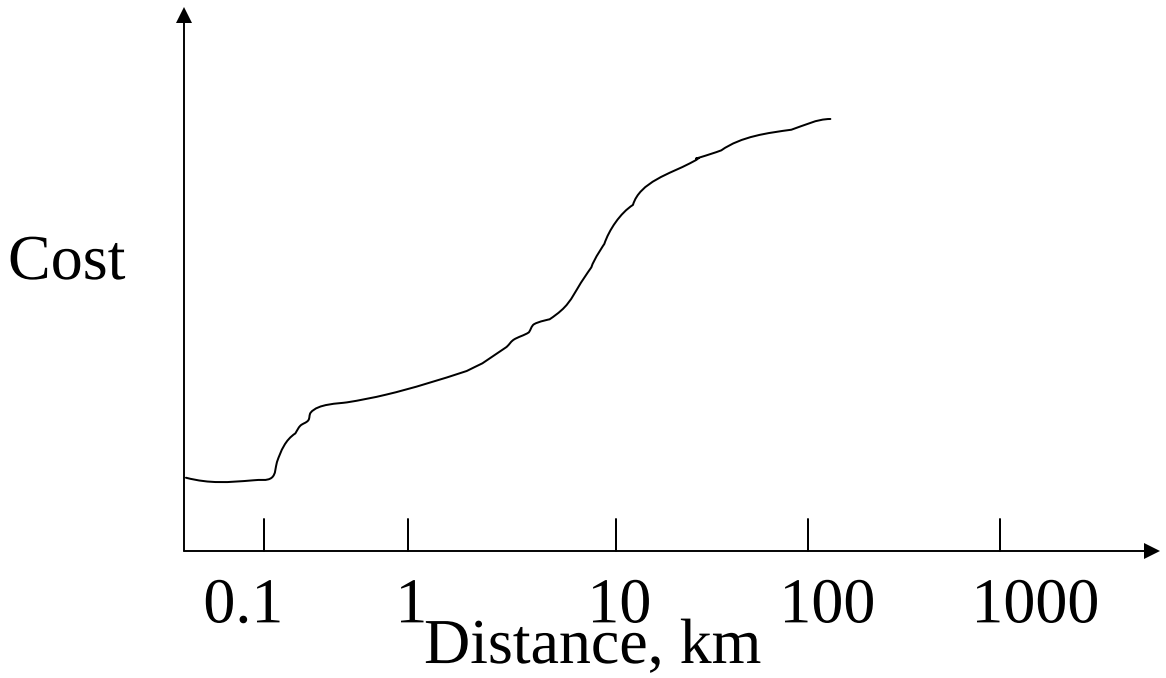
⇒ alarms at many LEs

- LE operator ignores alarms
- network operator sees long list of alarms, important ones may be missed

⇒ need integrated network management system

- only relevant alarms to the right person

Affordability



Cost of bandwidth increases with distance
=> install minimal required capacity including growth factor

Network Management

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Why?

Manage — monitor and control— heterogeneous, graphically-distributed elements

What?

Configuration	identify and control managed objects
Faults	detect, isolate, repair
Accounting	charges for resource usage
	limits on resource usage
Security	protect access to objects
	authentication, manage keys, logs
Performance	gather statistics
	analyze and plan

F C A P S

Basics

- Standards
  - Standards organizations
  - Protocol standards of transport layers
  - Protocol standards of management (application) layer
- Management Models
- Language

Table 3.1 Network Management Standards

Standard	Salient Points
OSI / CMIP	■ International standard (ISO / OSI) ■ Management of data communications network - LAN and WAN ■ Deals with all 7 layers ■ Most complete ■ Object oriented ■ Well structured and layered ■ Consumes large resource in implementation
SNMP / Internet	■ Industry standard (IETF) ■ Originally intended for management of Internet components, currently adopted for WAN and telecommunication systems ■ Easy to implement ■ Most widely implemented
TMN	■ International standard (ITU-T) ■ Management of telecommunications network ■ Based on OSI network management framework ■ Addresses both network and administrative aspects of management
IEEE	■ IEEE standards adopted internationally ■ Addresses LAN and MAN management ■ Adopts OSI standards significantly ■ Deals with first two layers of OSI RM
Web-based Management	■ Web-Based Enterprise Management (WBEM) ■ Java Management Extensions (JMX)

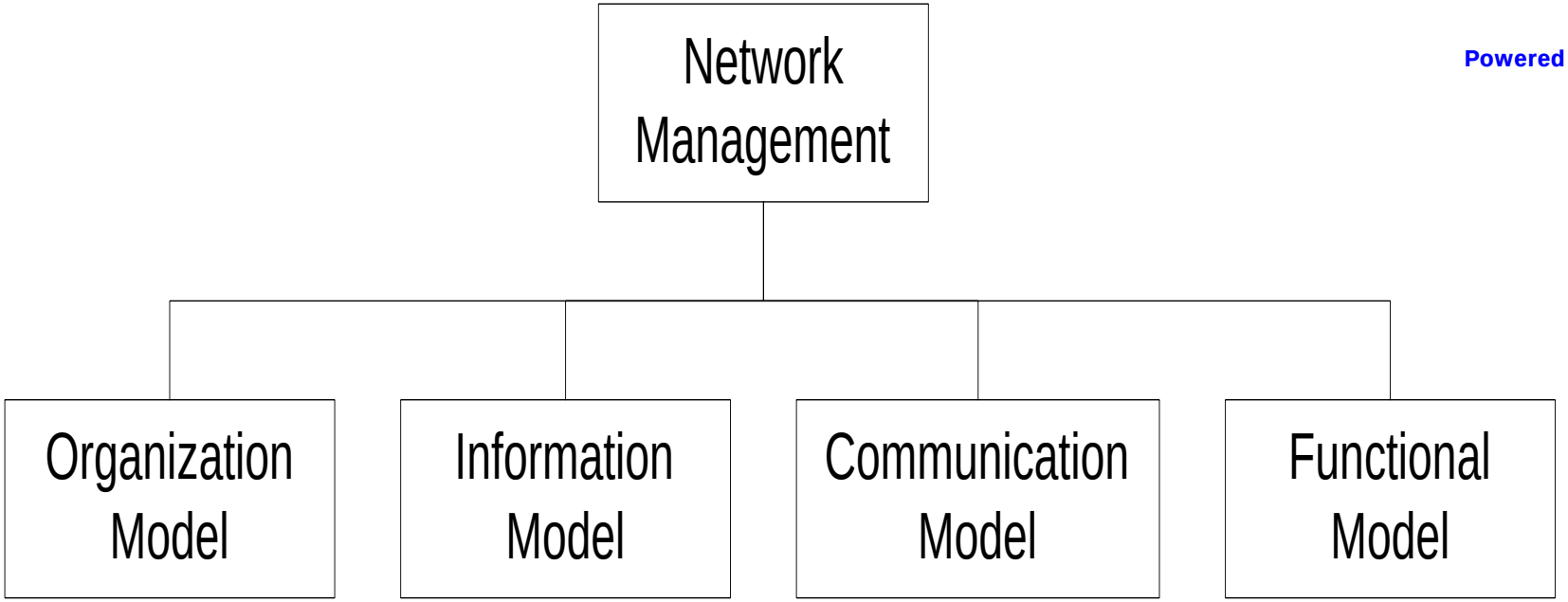


Figure 3.1 OSI Network Management Model

OSI Network Management Model

- Organization
  - Network management components
  - Functions of components
  - Relationships
- Information
  - Structure of management information (SMI)
    - Syntax and semantics
  - Management information base (MIB)
    - Organization of management information
  - Object-oriented

OSI Network Management Model

- Communication
  - Transfer syntax with bi-directional messages
  - Transfer structure (PDU)
- Functions
  - Application functions
    - Configure components
    - Monitor components
    - Measure performance
    - Secure information
    - Usage accounting

Protocol

messages (PDUs) for operations and notifications

Data representation

ASN.1:

encodes as a sequence of bytes

machine-independent

Standards

SNMP

simple network management protocol

- widely used in IP networks

CMIP

common management information protocol

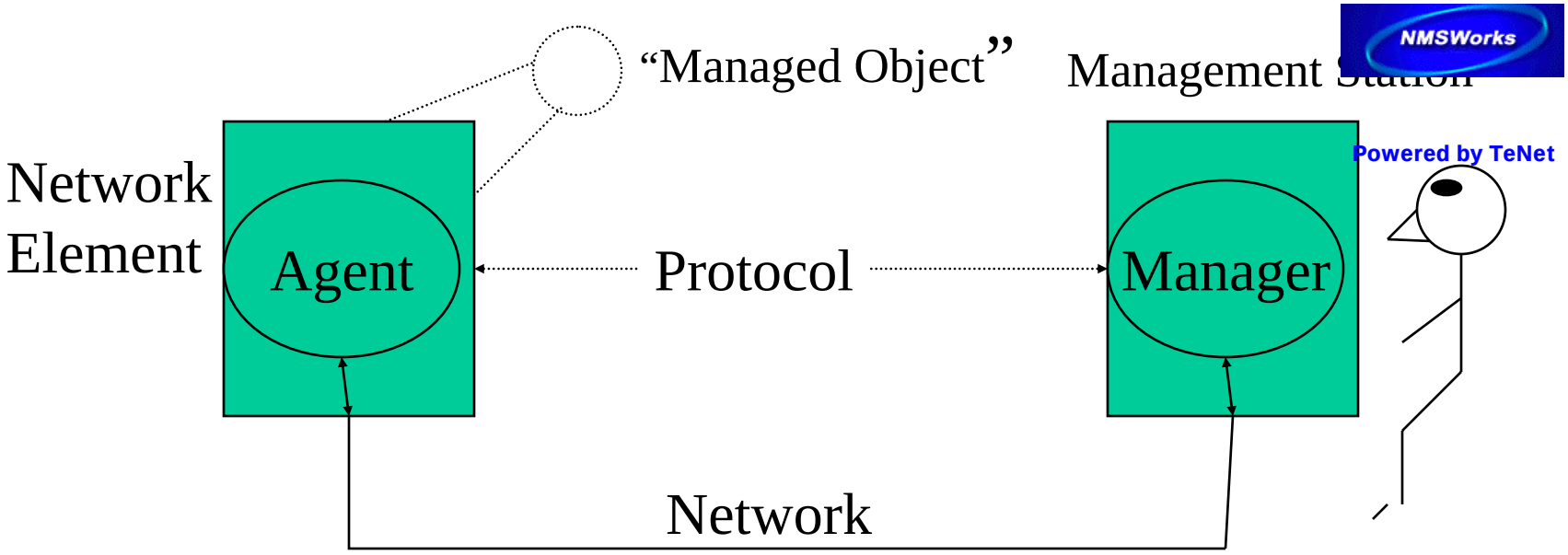
- based on OSI stack
- used in TMN (telecom management network)

SNMP Network Management Model

- Organization
  - Same as OSI model
- Information
  - Same as OSI, but scalar
- Communication
  - Messages less complex than OSI
  - Transfer structure (PDU)
- Functions
  - Application functions
    - Operations
    - Administration
    - Security

TMN Architecture

- Addresses management of telecommunication networks
- Based on OSI model
- Superstructure on OSI network
- Addresses network, service, and business management



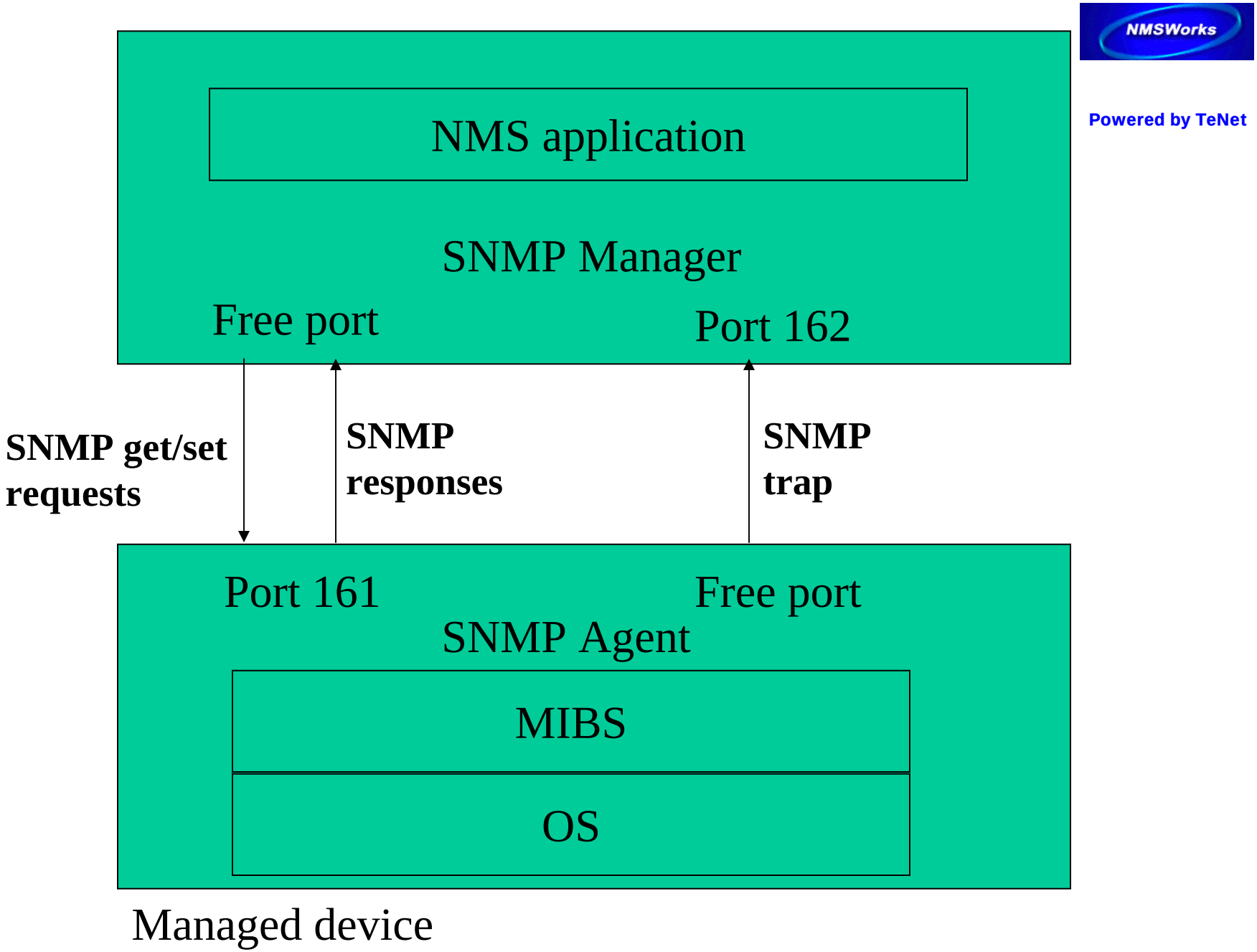
Object

- attributes - name, uptime, load,…
- operations - create/delete, get, set, actions. (reboot,…)
- notifications - unusual events (load > threshold,…)
- behaviour - how it reacts to operations

MIB or MOL = collection of managed objects

management information base

managed object library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NMS application
SNMP Manager
Free port
Port 162
SNMP get/set requests
SNMP responses
SNMP trap
Port 161
Free port
SNMP Agent
MIBS
OS
Managed device

Two-Tier Model

- Agent built into network element
  Example: Managed hub, managed router
- An agent 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)

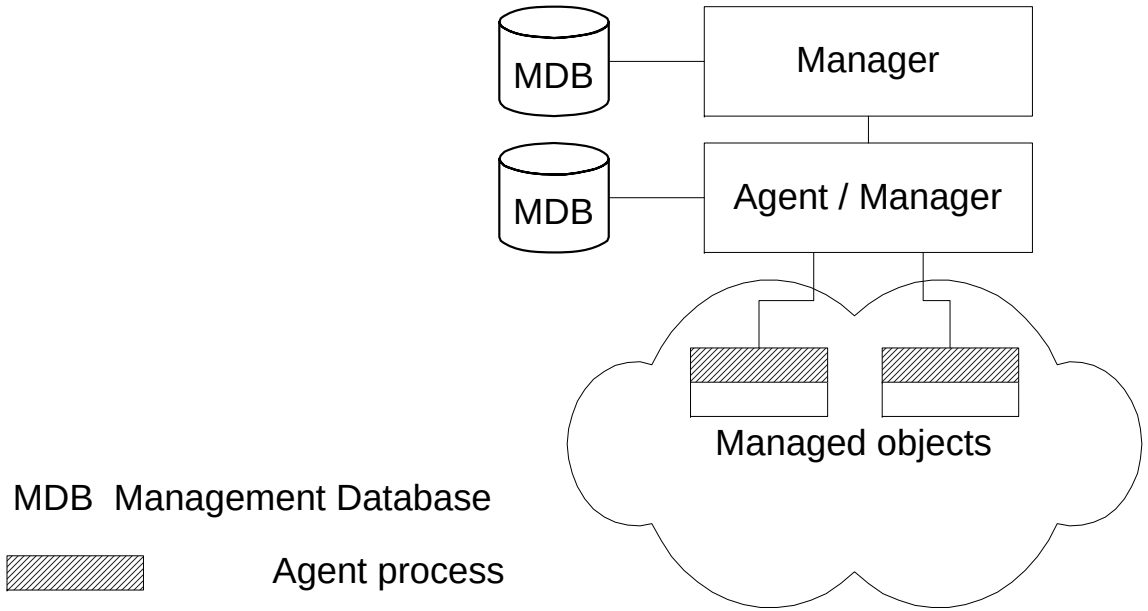

Figure 3.3 Three-Tier Network Mangement Organization Model

Three-Tier 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)

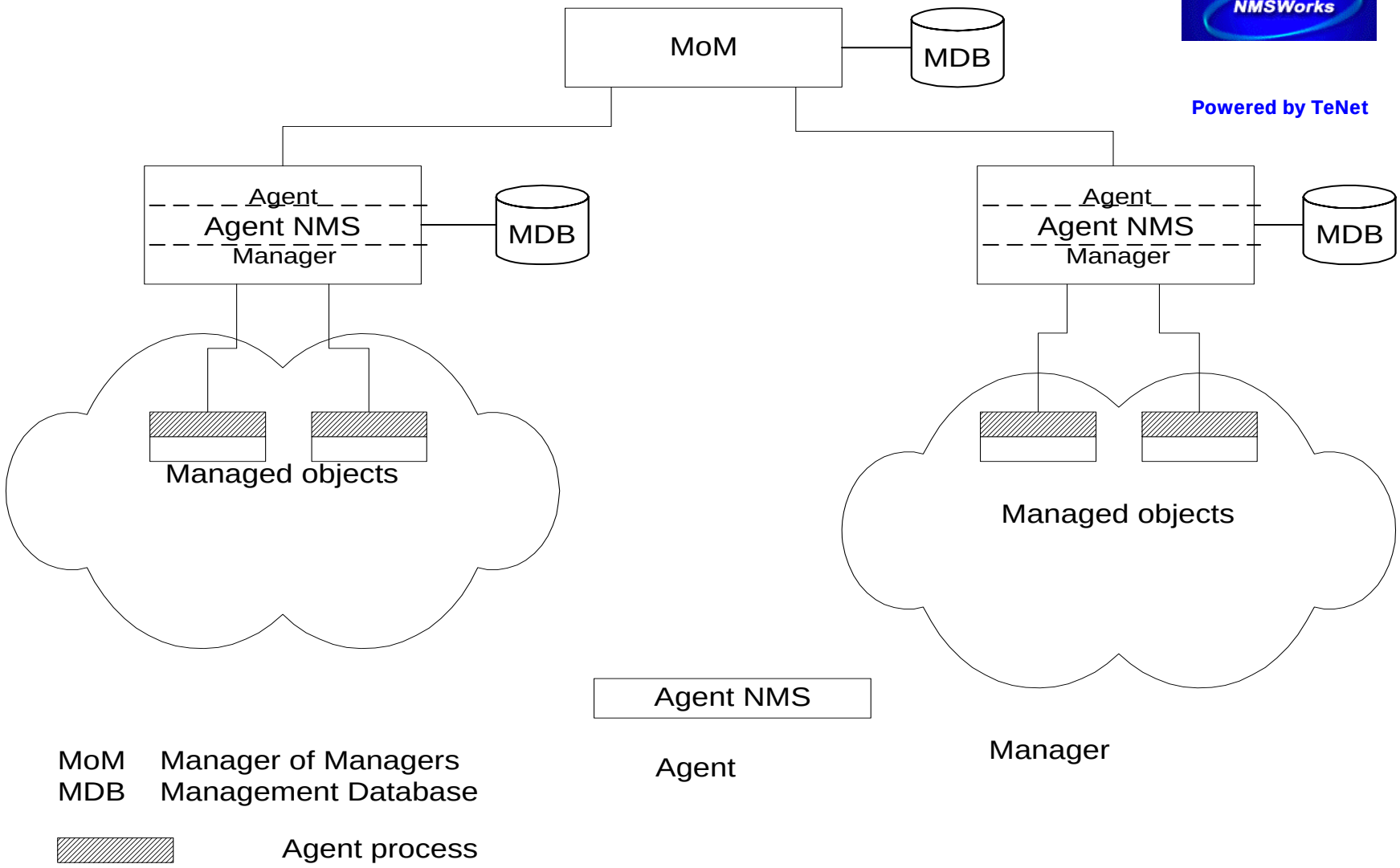

Figure 3.4 Network Mangement Organization Model with MoM

Manager of Managers

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

Peer NMSs

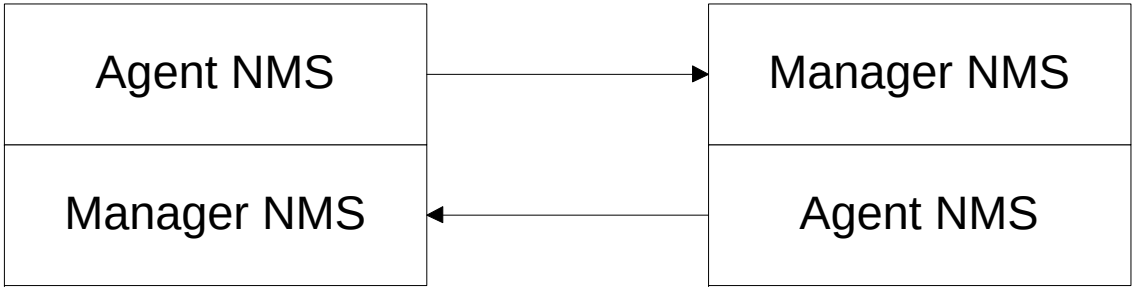


Figure 3.5 Dual Role of Management Process

- Dual role of both NMSs
- Network management system acts as peers
- Dumbbell architecture discussed in Chapter 1
- Notice that the manager and agent functions are processes and not systems

Structure of Management Information (SMI)

- 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

Structure of Management Information (SMI)

Agent names:

DNS — domain naming system

e.g. lantana.tenet.res.in

cordect53.hfcl.co.in

Object names:

Hierachical naming tree

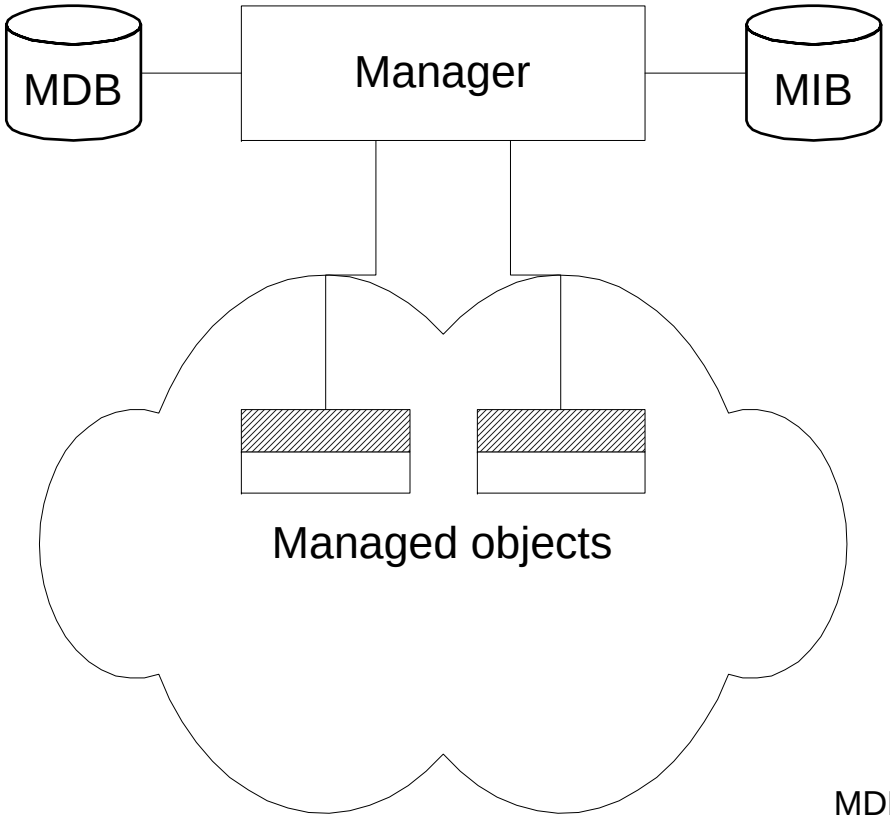
globally unique

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



MDB Management Database
MIB Management Information Base

Agent process

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

Managed Object

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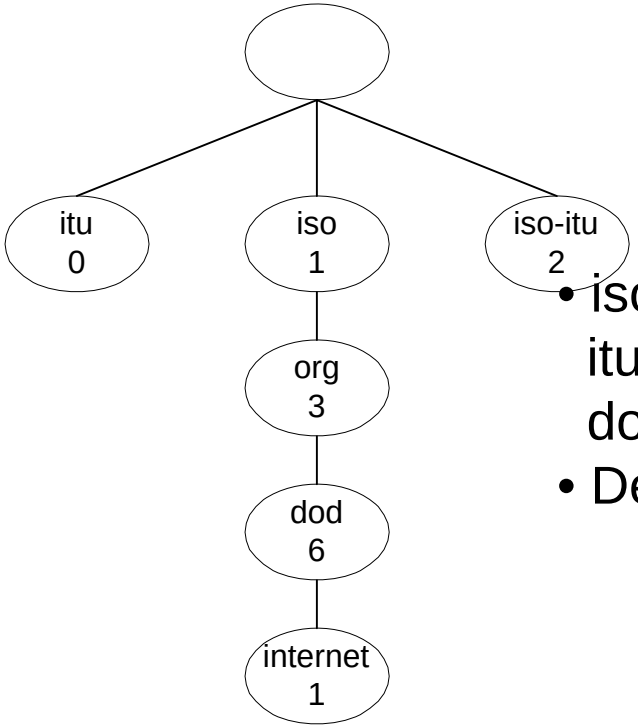
- Managed objects can be
  - Network elements (hardware, system)
    - hubs, bridges, routers, transmission facilities
  - Software (non-physical)
    - programs, algorithms
  - Administrative information
    - contact person, name of group of objects (IP group)

OSI Management Information Tree



- iso International Standards Organization
  itu International Telecommunications Union
  dod Department of Defense
- Designation:
  - iso 1
  - org 1.3
  - dod 1.3.6
  - internet 1.3.6.1

Figure 3.8 **OSI Management Information Tree**

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

Figure 3.10(a) 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

Figure 3.10 (b) OSI Perspective

Figure 3.10 Packet Counter As Example of Managed Object

ASN.1

Abstract Syntax Notation 1
ISO 8824, X.208

Abstract syntax = language for describing information objects

ASN.1= language for describing abstract syntaxes

BER= basic encoding rules for transfer of information objects
ISO 8825, X.209

ASN.1— Basic Encoding Rules (BER)

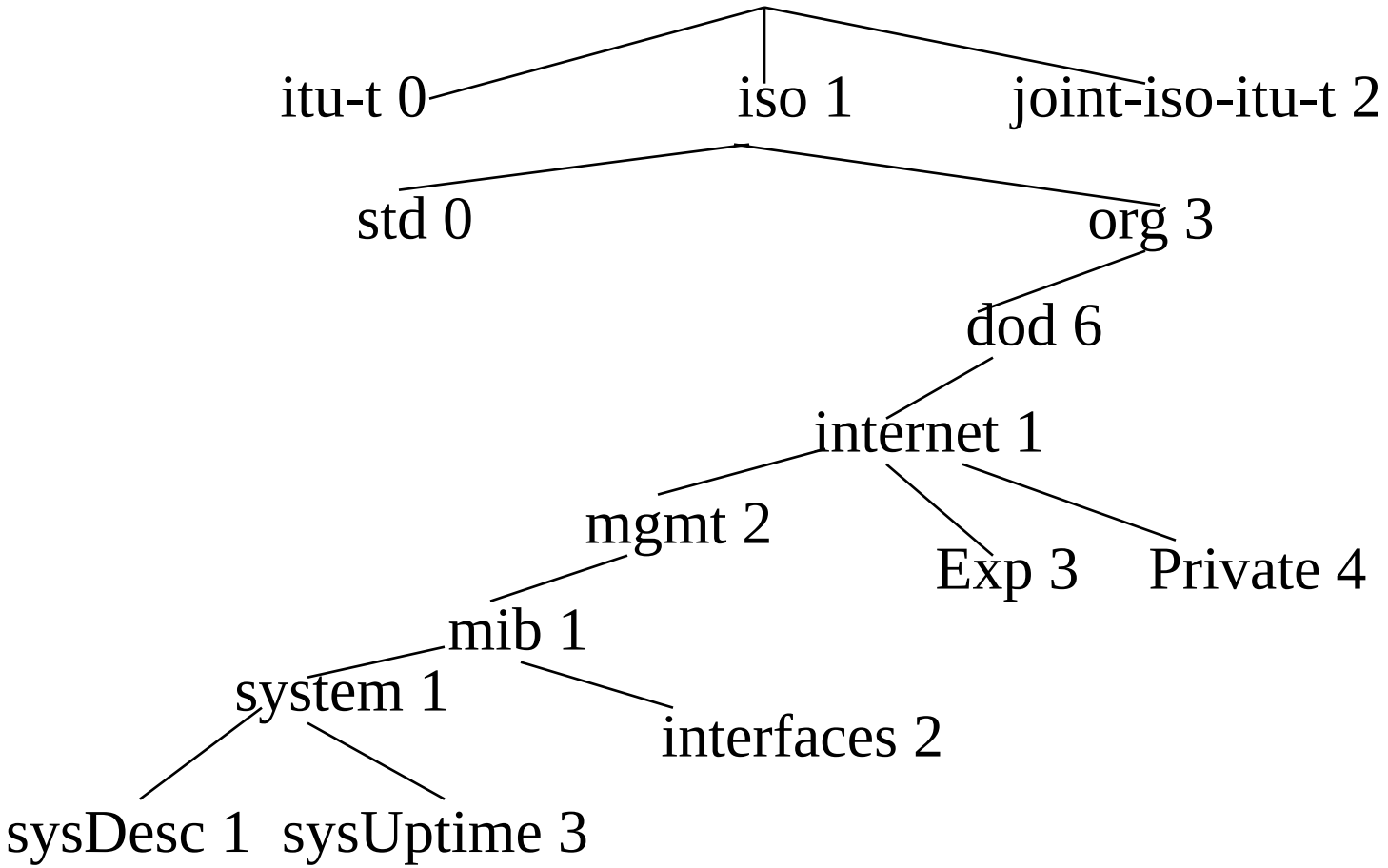
Example: 28510

M/c X: 0000 0001, 0001 1101
M/c Y: 1011 1000, 1000 0000, 0000 0000, 0000 0000

ASN.1: 0000 0001, 0000 0010, 0000 0001, 0001 1101
Integer Len = 2 1×2561 + 29×2560

- Identifier:

Class | p/c | Tag
p=primitive, c=constructed



Human-readable names:

{iso.reg.org.dod.internet.mgmt.mib.system.sysUptime}

{mib 1,3}

Used in PDUs: {1,3,6,1,2,1,1,3}

- Sub-tree of the registration hierarchy:
  MIB view/group/module
- Standard MIB views:

MIB-II:	all network elements
Ethernet MIB:	all Ethernet devices
FDDI MIB:	all FDDI devices
RMON MIB:	remote network monitoring

- Object Types:
  IP Address
  Time Ticks

Gauge	32-bit counter, no wraparound
Counter	0..232-1, with wraparound
Opaque	any octet string

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MIB-II Groups

system: overall information about the system

interfaces: about each of the interfaces from the system to a subnetwork

ip, icmp, tcp, udp, egp, snmp: related to the implementation and execution of each protocol on this system

dot3: information about the transmission schemes and access protocols at each system interface

system Group (mib-2 1)

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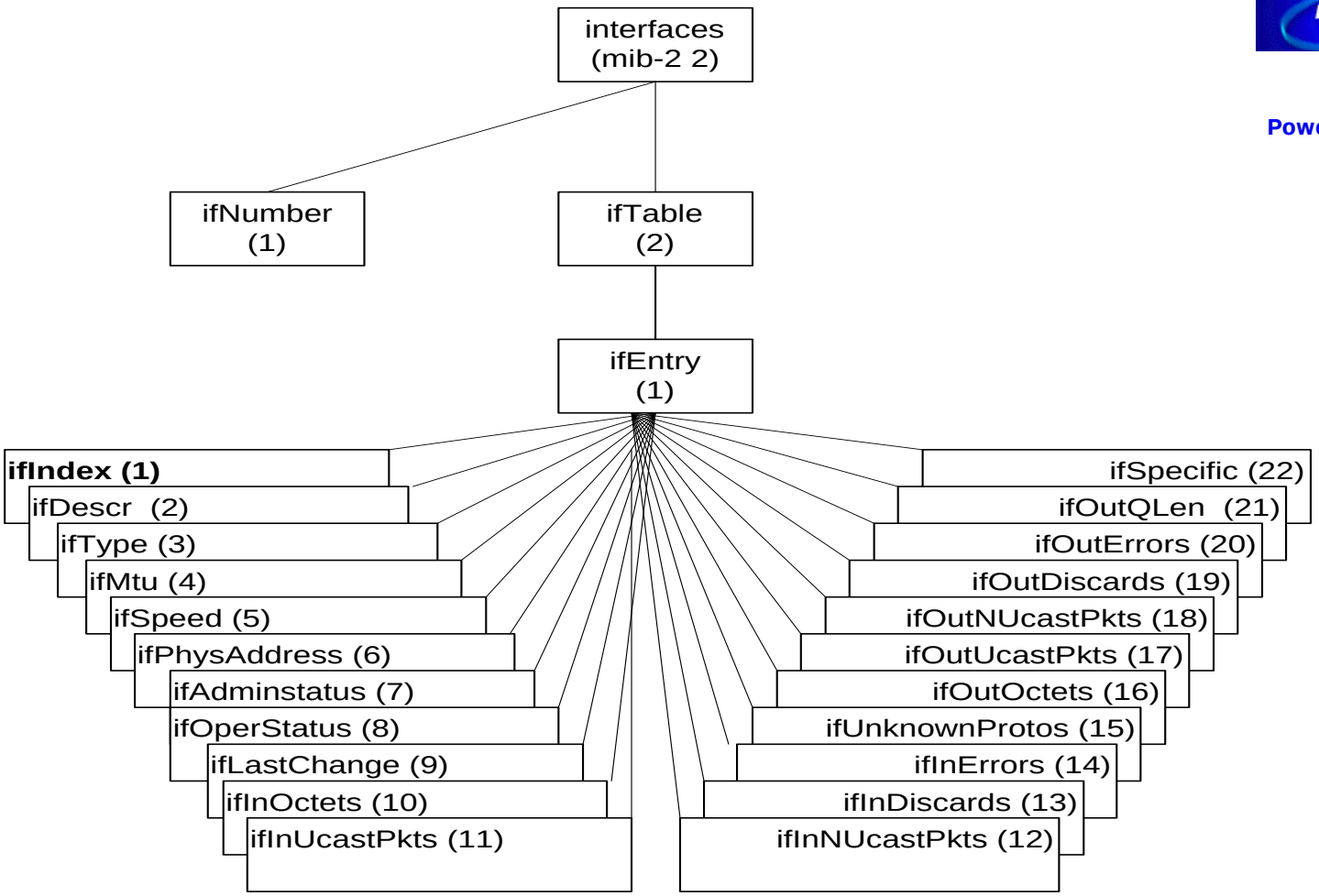
- sysDescr (1) -- descriptive text
- sysObjectID (2) -- vendor's id for this mgmt subsystem
- sysUpTime (3) -- in 10 ms ticks
- sysContact (4) -- administrative contact person
- sysName (5) -- name of the managed node
- sysLocation (6) -- physical location of this node
- sysServices (7) -- 7-bit integer indicating the OSI layers of this node's primary services



Legend: INDEX in bold

Figure 4.28 Interfaces Group

Example: Interface table (RFC 1213)

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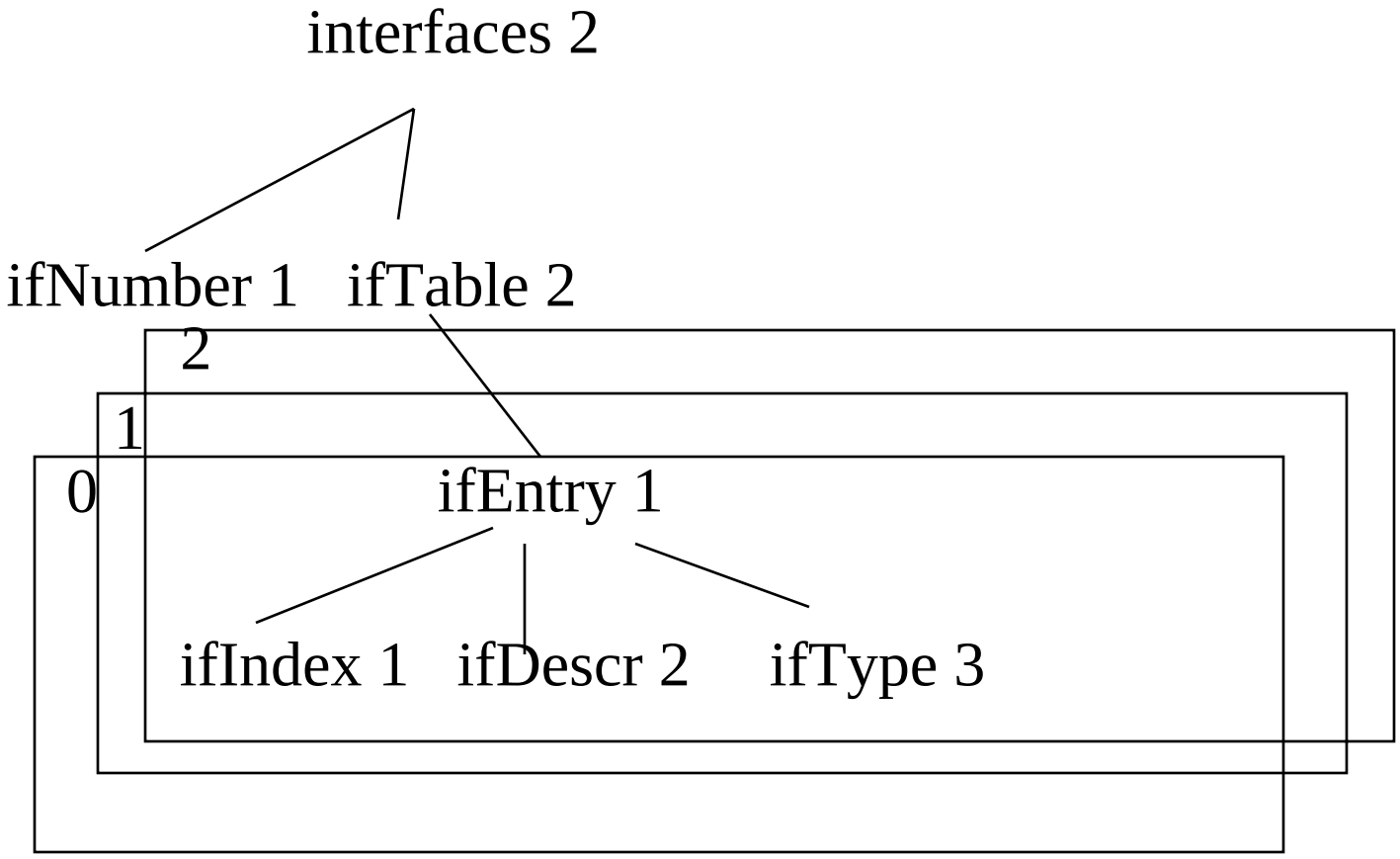
```
ifTable  OBJECT-TYPE
                SYNTAX    SEQUENCE OF ifEntry
                ACCESS     not-accessible
                STATUS     mandatory
                DESCRIPTION  “A list of interfaces….”
        ::=  { interfaces 2}

ifEntry OBJECT-TYPE
                SYNTAX              IfEntry
                ACCESS               not-accessible
                STATUS               mandatory
                DESCRIPTION     “Details of one
interface...”
                INDEX               { ifIndex }
        ::=    {ifTable  1 }
```

```
IfEntry ::=         ----   a   type
        SEQUENCE  {
                ifIndex    INTEGER,
                ifDescr    DisplayString,
                ifType     INTEGER,
                :
                :
                        }
```

```
ifIndex OBJECT-TYPE
        SYNTAX   INTEGER
        ACCESS   read-only
        STATUS   mandatory
        DESCRIPTION     "……"
        ::=   {ifEntry   1}

ifDescr   OBJECT-TYPE
        SYNTAX   DisplayString  (SIZE  (-0…..255))
        ACCESS    read-only
        STATUS    mandatory
        DESCRIPTION   "….."
        ::=   {ifEntry   2}
```



SNMP

Versions

V1: simple, most widely-used
drawbacks esp. security

V2: improved security, other features
more complex, not yet widely-used

"v2c":V2 with community-based security

"v3": full V2

SNMP objects

attributes

operations: get, set

notifications "traps"

behaviours

Uses UDP/IP

- Maximum PDU size = 468 bytes
- Get, set — port161
- Traps — port162

Messages

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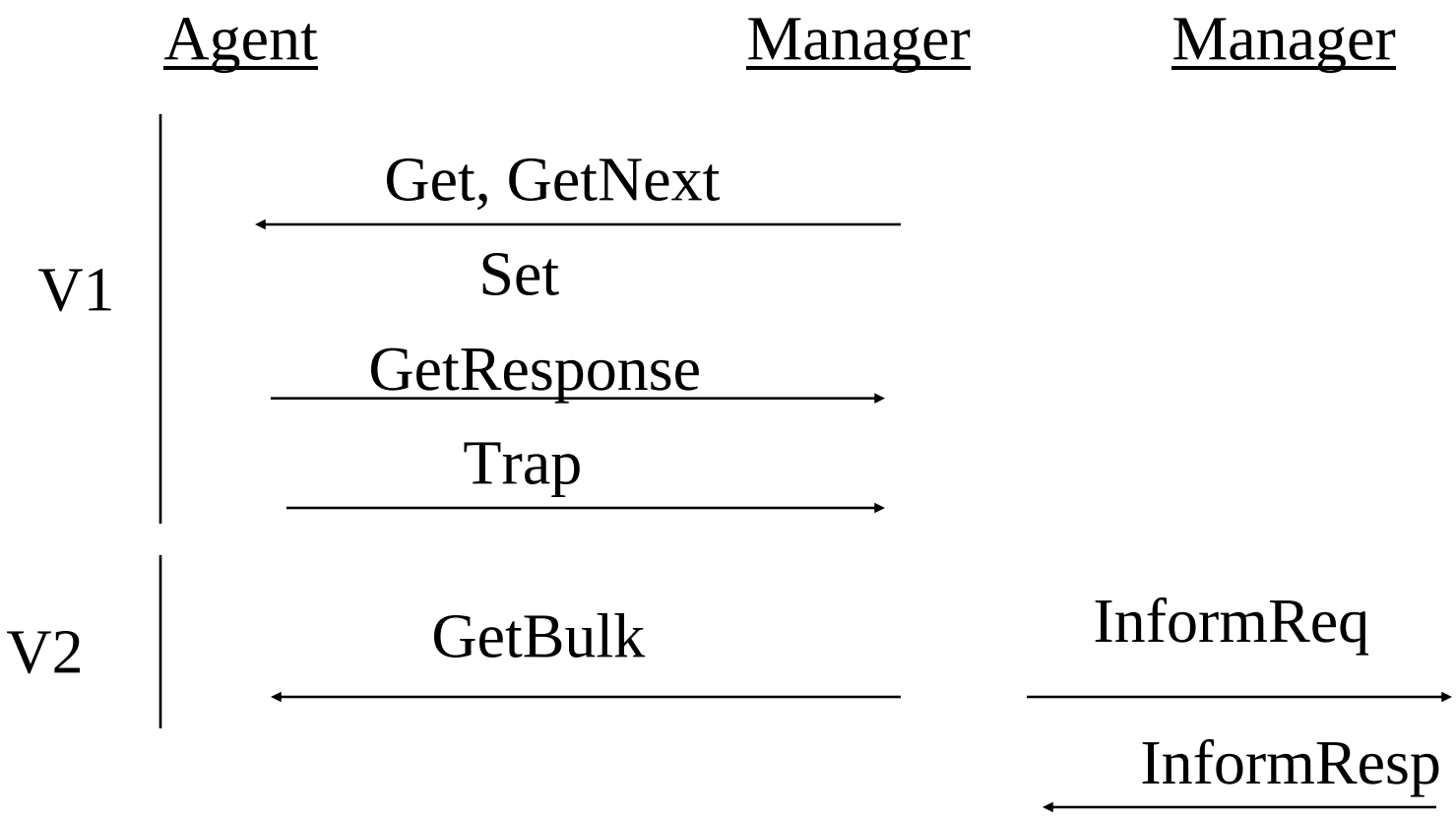

PDU Formats

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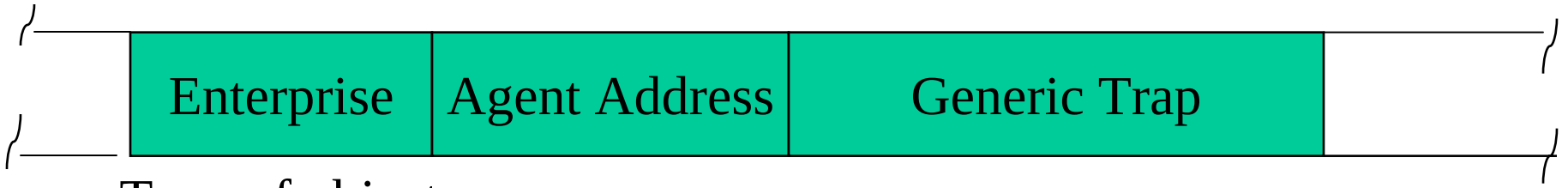
Version 0, 1	Community *"public"*	PDU Type	Request Id	Error Status

0 = Get
1 = GetNext
2 = GetResp
3 = Set
4 = Trap

0 = noError
1 = tooBig
2 = noSuchName

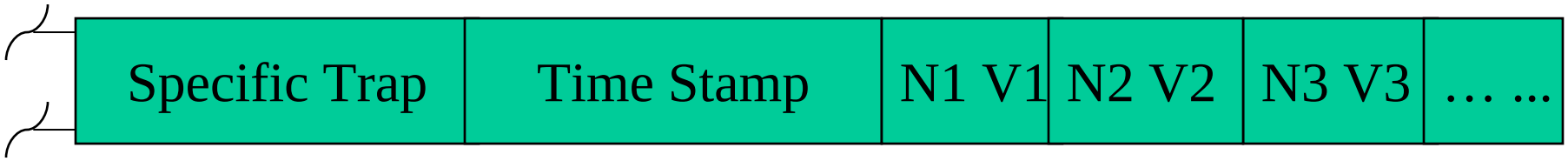
Error Index	Name 1 Value 1	N2 V2	N3 V3	… …

Trap PDU (V1)



Type of object

0 = coldStart
1 = warmStart
2 = linkDown
3 = linkUp
4 = auth. failure
5 = enterpriseSpecific



Uptime in
10 ms ticks

Related variables

V2 Trap PDU same format as other messages

SNMP GetRequest

Atomic: all values returned, or none
In case of error, errorIndex indicates which variable binding has errorStatus

SNMP GetNextRequest

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Given varible name N, returns the value of the lexicographically next variable in MIB view
GetNext(system) ⇒system.sysDescr.0 = "Linux ..."
GetNext(system.sysDescr) ⇒
system.sysDescr.0 = "Linux ..."
GetNext(system.sysDescr.0) ⇒
system.sysObjectID.0 =OID: ...ucdSnmpAgent.linux
Traverse a sub-tree without knowing names
GetNext(icmp.27.0) ⇒ tcp.tcpRtoAlgorithm.0 = other(1)
Get(icmp.27.0) ⇒ Error: (noSuchName) icmp.27

…SNMP GetNextRequest

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- Read a table without knowing the size of the table

GetNext Parameter	*Returned value*	
interfaces.ifTable	ifTable.1.1.1 = 1	-- index
interfaces.ifTable.1.1.1	ifTable.1.1.2 = 2	
interfaces.ifTable.1.1.2	ifTable.1.2.1 = "lo0"	-- descr
interfaces.ifTable.1.2.1	ifTable.1.2.2 = "eth0"	
interfaces.ifTable.1.2.2	ifTable.1.3.1 = softwareLoopback	
interfaces.ifTable.1.3.1	ifTable.1.3.2 = ethernet-csmacd	
		-- type

- Table is read column-wise

	index(1)	descr(2)	type(3)	...	ifSpecific(22)
1	1	lo0	softwareLoopback		
2	2	eth0	ethernet-csmacd		

SNMP SetRequest

- Atomic: all values set and returned, or none
- In case of error, errorIndex indicates which variable binding has errorStatus

SNMP Trap

- From agent to manager
- Manager registers with agent for traps of interest
- No response — to guarantee receipt, agent must periodically retransmit until manager takes action

SNMP v2

Key Concepts

- revised OBJECT definitions
  - counter64 type
- improved tables
  - unambiguous row selection
  - procedures for creation and deletion of rows
  - augmenting of tables
- Notification definition
- Manager-manager communication

GetBulk

- With Get and GetNext:

one OID per message ⇒ inefficient

- OR

many OIDs per message ⇒ manager must use trial-and-error to fit into a PDU

- GetBulk: Repeated GetNext in one message
- Example:
- GetBulk(1, 6, sysUptime, ifOperStatus, ifInOctets, ifOutOctets)
- Response(sysUptime=345923, ifOperStatus.1=1, ifInOctets.1=54678, ifOutOctets.1=345239, ifOperStatus.2=1, ifInOctets.2=345, ifOutOctets.2=9324, ...)

… GetBulk

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GetBulk(N, M, v1, ..., vN, vN+1, ..., vL)

1 value each

M values each

Order in PDU:

1st successor for all variables,

...,

Mth successor for all variables

⇒ if variables are columns

PDU contains values row-wise

- If response too big, puts as much as possible in PDU

⇒ simplifies managers task

InformRequest

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- Manager-manager
- A→B
  InformRequest(reqID, n1, v1, n2, v2, ...)
- B→A
  Response(reqID, n1, v1, n2, v2, ...)

SNMP Utilities

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snmpbulkwalk, snmpdelta, snmpget, snmpgetnext, snmpnetstat, snmpset, snmpstatus, snmptable, snmptest, snmptranslate, snmptrap, snmpwalk

snmpget localhost public system.sysDescr.0
system.sysDescr.0 = "Linux oriole.ooty.tenet.res.in"

snmpgetnext localhost public system.sysDescr.0
system.sysObjectID.0 = OID: enterprises.ucdavis.ucdSnmpAgent.linux

snmpset localhost public system.sysLocation.0 s "Ooty”
system.sysLocation.0 = "Ooty" Hex: 4F 6F 74 79

snmpget localhost public system.sysLocation.0
system.sysLocation.0 = "Ooty" Hex: 4F 6F 74 79

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SNMP Utilities

snmpwalk localhost public system
system.sysDescr.0 = "Linux oriole.ooty.tenet.res.in”
system.sysObjectID.0 = OID: enterprises.ucdavis.ucdSnmpAgent.linux
system.sysUpTime.0 = Timeticks: (272328) 0:45:23.28
system.sysContact.0 = "Root <root@localhost>”
system.sysName.0 = "oriole.ooty.tenet.res.in”
system.sysLocation.0 = "Unknown”
system.sysServices.0 = 72

- OID: for a simple variable, end with .0
  for a table variable, end with index (>0)
- Full form: initial “.”
  E.g. “.1.3.6.1.2.1.1.3.0” or “system.sysUptime.0”

Summary

- Manager-Agent model for NMS
- Data transfer — ASN.1 basic encoding
- Object definition — ASN.1 macros
- MIB — hierachical collection of objects
- SNMP — get, getnext, set, trap
- SNMPv2
  - GetBulk for efficiency
  - InformRequest for manager-manager