Network Management

Raj Jain
Washington University in Saint Louis
Saint Louis, MO 63130
Jain@wustl.edu

Audio/Video recordings of this lecture are available on-line at:

http://www.cse.wustl.edu/~jain/cse473-09/

Overview

- What is Network Management and How?
- OSI Net Management Standards
- ASN.1
- Management Information Base (MIB)
- SNMP: Protocol, Message formats
- SNMP V2 and SNMP V3

Note: This class lecture is based on Chapter 9 of the textbook (Kurose and Ross) and the figures provided by the authors.

What is Network Management?

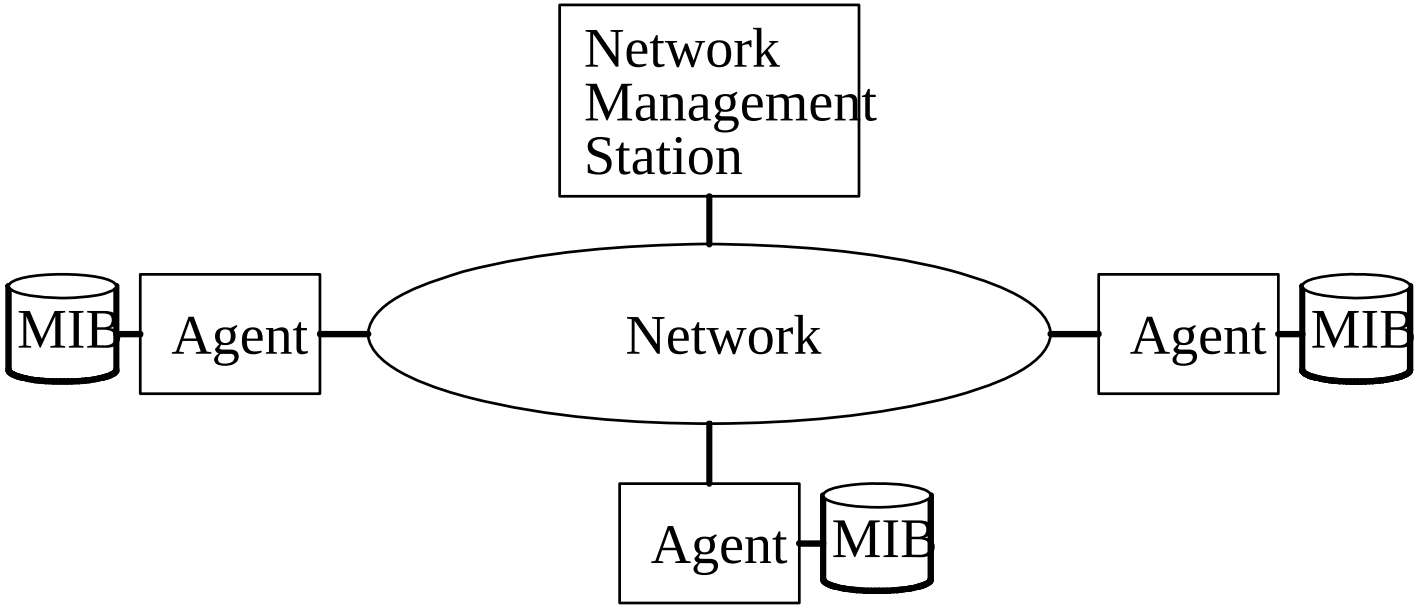
- Traffic on Network = Data + Control + Management
- **Data** = Bytes/Messages sent by users
- **Control** = Bytes/messages added by the system to properly transfer the data (e.g., routing messages)
- **Management** = Optional messages to ensure that the network functions properly and to handle the issues arising from malfunction of any component
- If all components function properly,
  control is still required but management is optional.
- Examples:
  - Detecting failures of an interface card at a host or a router
  - Monitoring traffic to aid in resource deployment
  - Intrusion Detection

Components of Network Management

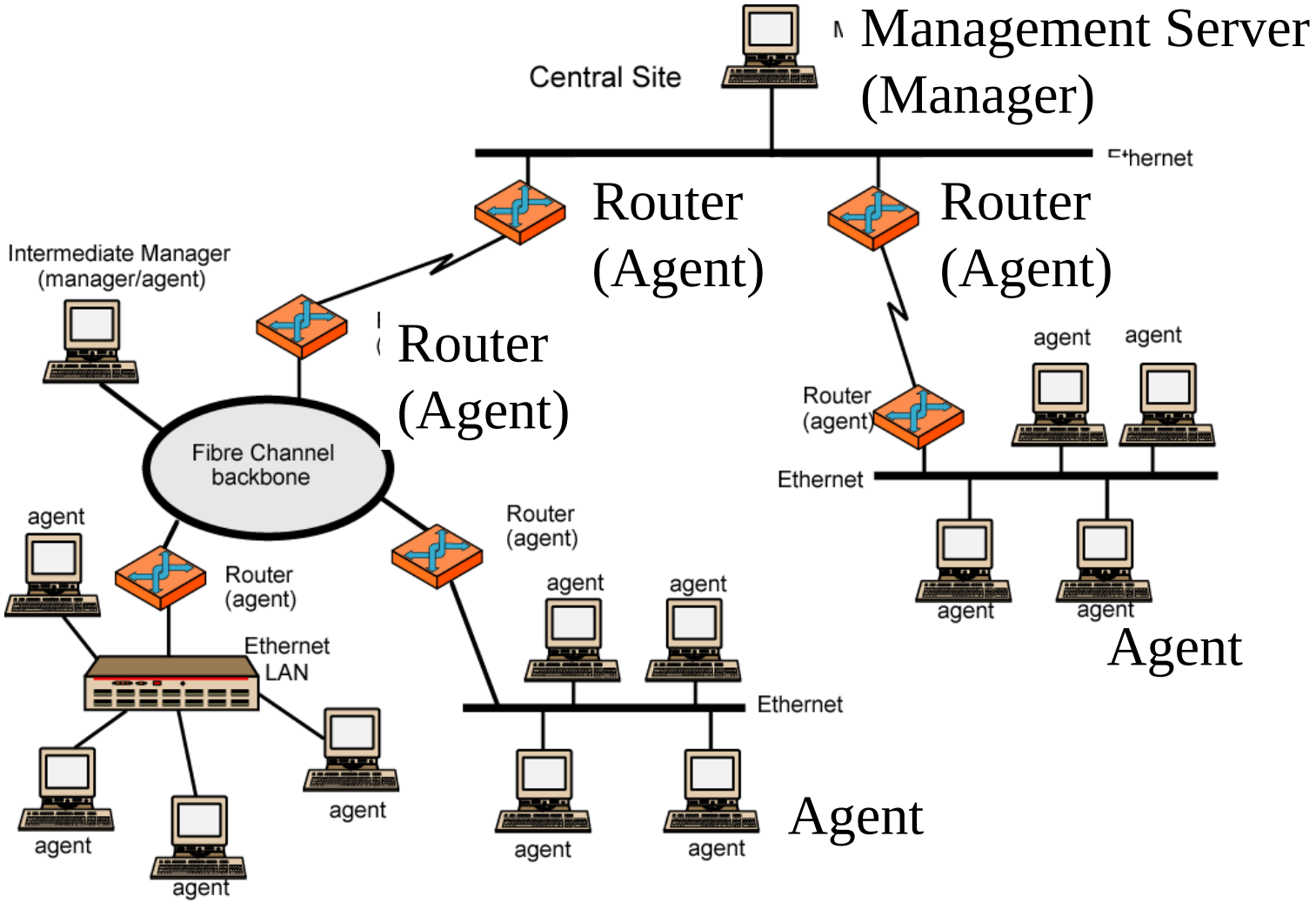
1. **Performance Management**:
   Measure, report, analyze, and control traffic, messages
2. **Fault Management**:
   Detect, log, and respond to fault conditions
3. **Configuration Management**:
   Track and control which devices are on or off
4. **Accounting Management**:
   Monitor resource usage for records and billing
5. **Security Management**:
   Enforce policy for access control, authentication, and authorization

How is Network Managed?

- Management = Initialization, Monitoring, Control
- Manager, Agents, and Management Information Base (MIB)



Example of Network Management



OSI Net Management Standards

- Common Management Information Protocol (CMIP)
- Common Management Information Service (CMIS)
- CMIP is the management (application layer) protocol
- CMIS is the service interface to CMIP
- It was expected that OSI management standards will eventually be used in the Internet. So a tentative simple solution was developed for the time being: Simple Network Management Protocol (SNMP)
- SNMP is now used throughout.
  CMIP/CMIS is being replaced by SNMP.

Internet Management Framework

1. Structure of Management Information (SMI):
   Data definition language for objects
   ASN.1 was defined by ISO and is used in SNMP.
2. Management Information Base (MIB):
   Distributed network management data
3. SNMP protocol:
   Manager ↔ Managed object communication
4. Security, administration capabilities:
   Major addition in SNMPv3

ASN.1

- Abstract Syntax Notation One
- Joint ISO and ITU-T standard, Original 1984, latest 2002.
- Used to specify protocol data structures
- X.400 electronic mail, X.500 and LDAP directory services, H.323 VOIP, SNMP, etc use ASN.1
- Pre-Defined: 1=Boolean, 2=Integer, 3=Bit String, 4=Octet String, 5=Null, 6=Object Identifier, 9=Real
- Constructed: SEQUENCE (structure), SEQUENCE OF (lists), CHOICE, ...

SMI Base Data Types

Data Type	Description
INTEGER	ASN.1 32-bit integer between -2^{31} and $2^{31}-1$
Integer32	32-bit integer between -2^{31} and $2^{31}-1$
Unsigned32	Unsigned 32-bit integer between 0 and $2^{32}-1$
OCTET STRING	ASN.1 byte string for binary or text up to 65,535 bytes long
OBJECT IDENTIFER	ASN.1 format administratively assigned object identifier
IPaddress	32-bit Internet address in network-byte order
Counter32	32-bit counter that increases from 0 to $2^{32}-1$ and wraps to 0
Counter64	64-bit counter
Gauge32	32-bit integer that does not count above $2^{32}-1$ or below 0
TimeTicks	Time interval measured in $1/100^{th}$ of a second
Opaque	Uninterpreted ASN.1 string (needed for backward compantibility)

ASN.1 Example

```
AddressType ::= SEQUENCE {
name        OCTET STRING,
number      INTEGER,
street      OCTET STRING,
city        OCTET STRING,
state       OCTET STRING,
zipCode     INTEGER
}
```

Encoding Rules

- ASN.1 only specifies the structure.
- Encoding rules indicate how to encode the structure in to bits on the wire.
- Examples: Basic Encoding Rules (BER), Packed Encoding Rules (PER), XML Encoding rules (XER), Distinguished Encoding Rules (DER), ...
- In BER, everything is encoded as Tag-Length-Value.

BER Example

- John Miller, 126 Main Street, Big City, MO 63130

30	80	04	0B	4A	6F	68	6E	20	4D	69	6C	6C	65	72
Seq.	Len	Oct Str	Len	J	o	h	n		M	i	l	l	e	r

02	01	FE
Int	Len	123

04	0B	4D	61	69	6E	20	53	74	72	65	65	74
Oct str	11	M	a	i	n		S	t	r	e	e	t

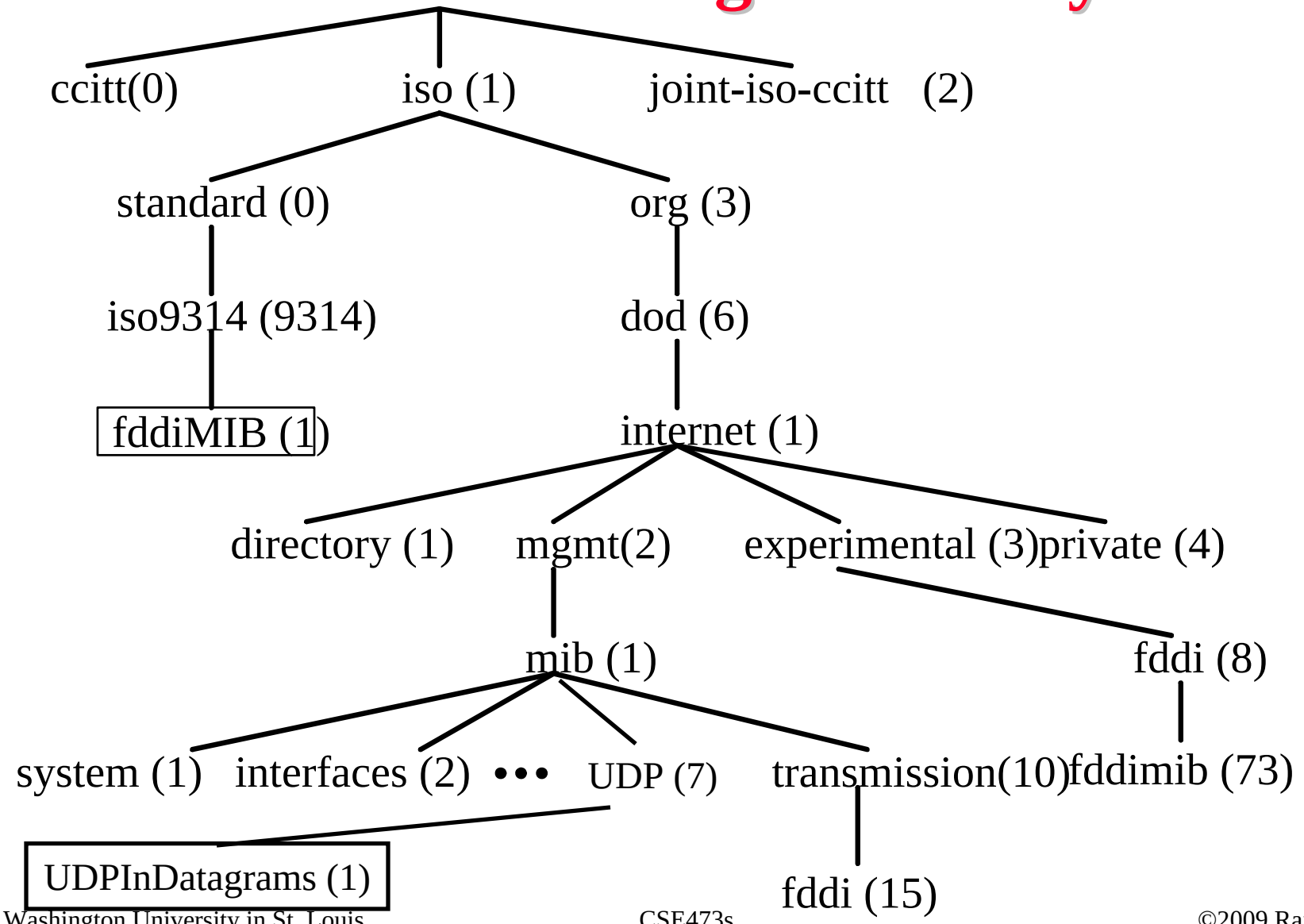
04	08	42	69	67	20	43	69	74	79
Oct Str	Len	B	i	g		C	i	t	y

04	02	4D	4F	02	02	F6	96	0
Oct Str	Len	M	O	Int	len	63130		Null

Management Information Base

- MIBs follow a fixed naming and structuring convention
  $\Rightarrow$ Structure of Management Information (**SMI**)
- These conventions were adopted from Common management Information Protocol (**CMIP**) designed by ISO
- All names are globally unique
- All nodes of the name tree are assigned numeric values by standards authorities
  iso.org.dod.internet.mgmt.mib.ip.ipInReceives
  1.3.6.1.2.1.4.3
- Tables rows are referenced by appending the index
- All names are specified using a subset of Abstract Syntax Notation (ASN.1)
- ASN.1 specifies notation (that humans can read) and encoding (representation and ranges)

Global Naming Hierarchy



MIB Naming Example: UDP Module

Object ID	Name	Type	Comments
1.3.6.1.2.1.7.1	UDPInDatagrams	Counter32	total # datagrams delivered at this node
1.3.6.1.2.1.7.2	UDPNoPorts	Counter32	# underliverable datagrams no app at portl
1.3.6.1.2.1.7.3	UDInErrors	Counter32	# undeliverable datagrams all other reasons
1.3.6.1.2.1.7.4	UDPOutDatagrams	Counter32	# datagrams sent
1.3.6.1.2.1.7.5	udpTable	SEQUENCE	one entry for each port in use by app, gives port # and IP address

MIB Definition: Example

```
ipAddrTable ::= SEQUENCE of ipAddrEntry
ipAddrEntry ::= SEQUENCE {
ipAdEntAddr ipAddress,
ipAdEntIfIndex INTEGER,
ipAdEntNetMask ipAddress,
ipAdEntBcastAddr ipAddress,
ipAdEntReasmMaxSize INTEGER (0..65535)
}
ipAddrEntry {ipAddrTable 1}
ipAdEntNetMask {ipAddrTable 3}
```

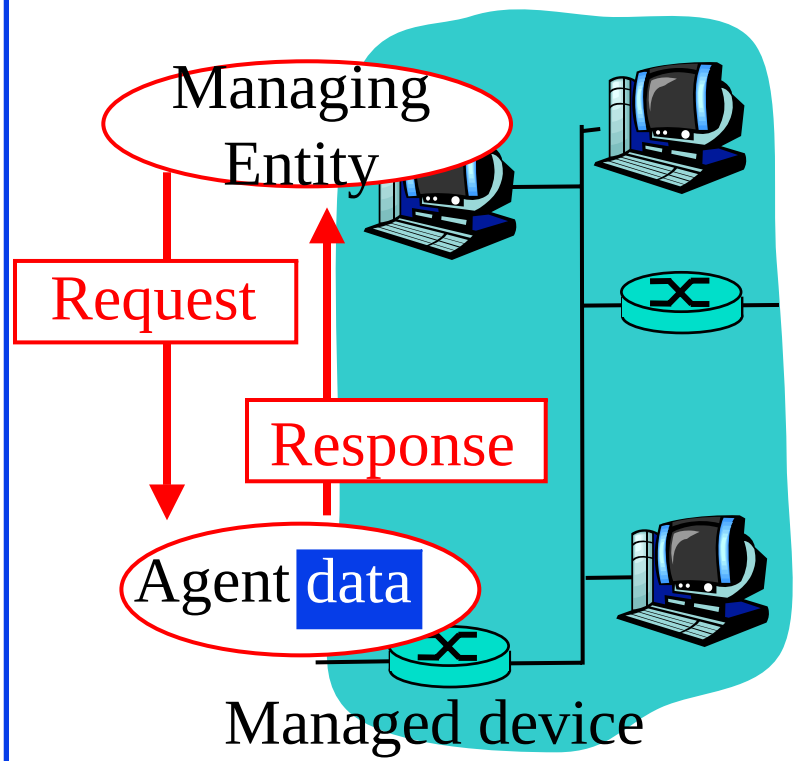
SNMP

- Based on Simple Gateway Management Protocol (SGMP) – RFC 1028 – Nov 1987
- SNMP = **S**imply ***N***ot ***M***y ***P***roblem [Marshall Rose]
  Simple Network Management Protocol
- RFC 1058, April 1988
- Only Five commands

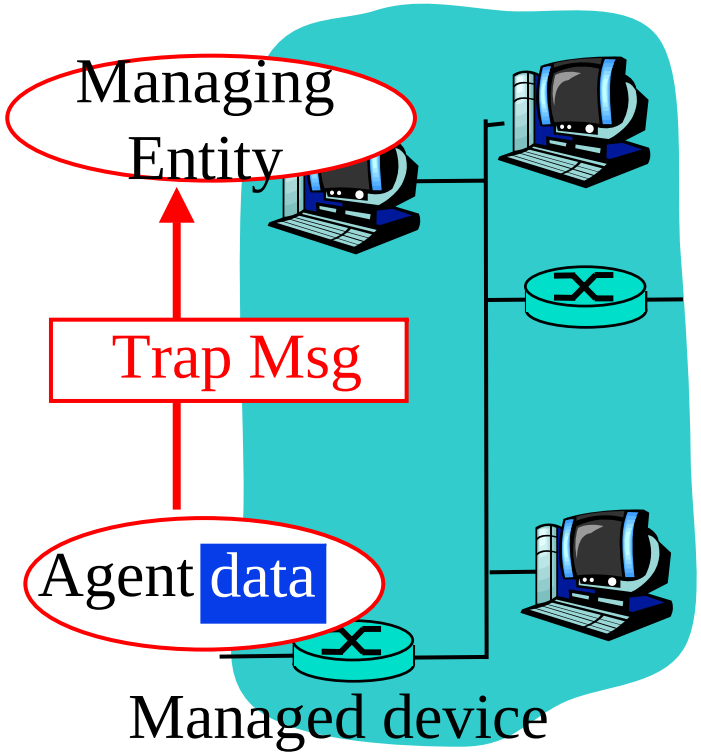
Command	Meaning
get-request	Fetch a value
get-next-request	Fetch the next value (in a tree)
get-response	Reply to a fetch operation
set-request	Store a value
trap	An event

SNMP protocol

Two ways to convey MIB info, commands:



Request/response mode

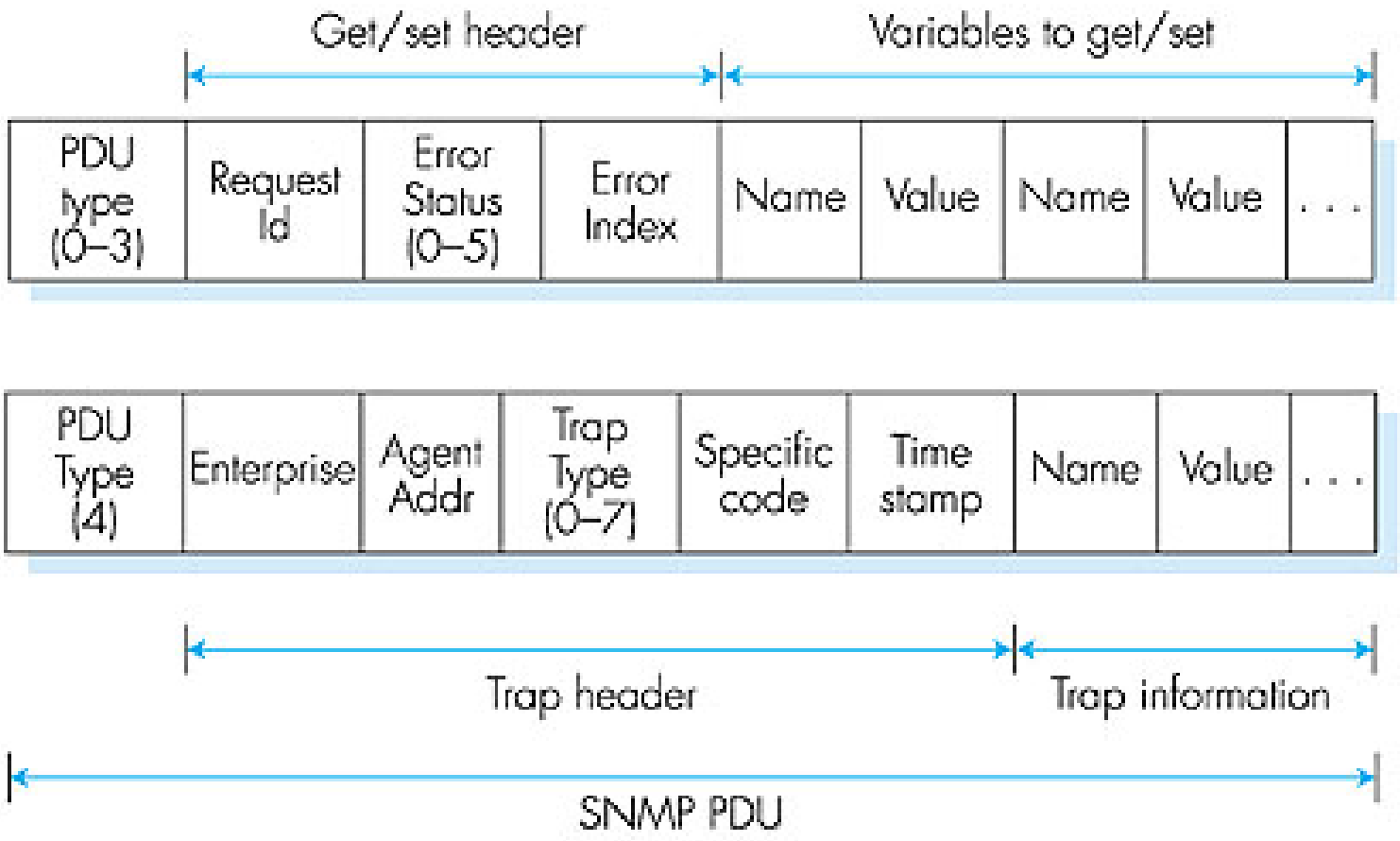


Trap mode

SNMPv2 PDU Types

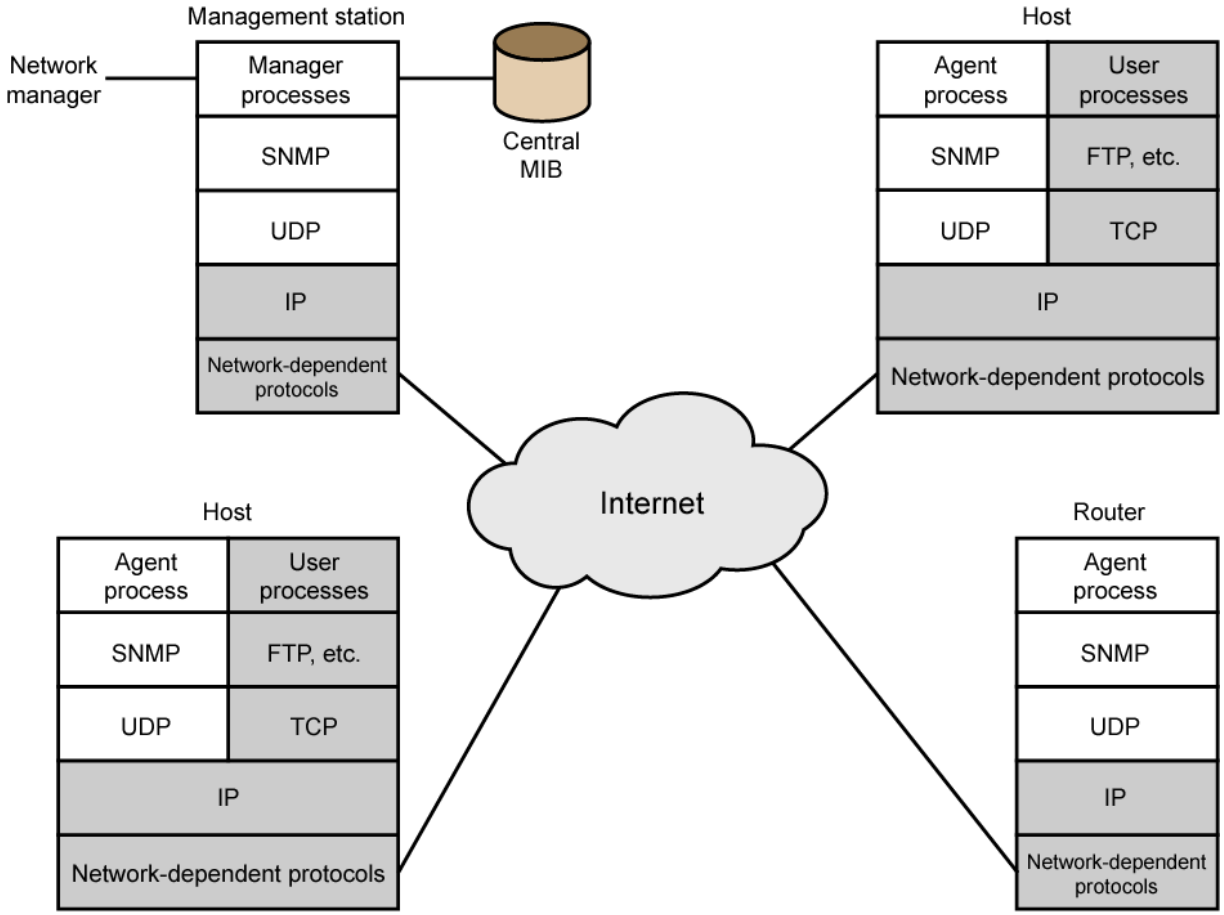
SNMPv2 PDU Type	Sender-Receiver	Description
GetRequest	Manager-to-agent	Get value of one or more MIB object instances
GetNextRequest	Manager-to-agent	Get value of next MIB object instance in list or table
GetBulkRequest	Manager-to-agent	Get values in large block of data, e.g., whole table
InformRequest	Manager-to-manager	Inform remote managing entity of MIB values
SetRequest	Manager-to-agent	Set value of one or more MIB object
Response	Agent-to-Manager	GetRequest, GetNextRequest, GetBulkRequest,SetRequest or InformRequest
SNMPv2 Trap	Angent-to-	Inform manager of exceptional

SNMP Message Formats



SNMPv1 Configuration

- Manager sends request to UDP port 161.
  Agents send traps to UDP port 162



SNMPv2

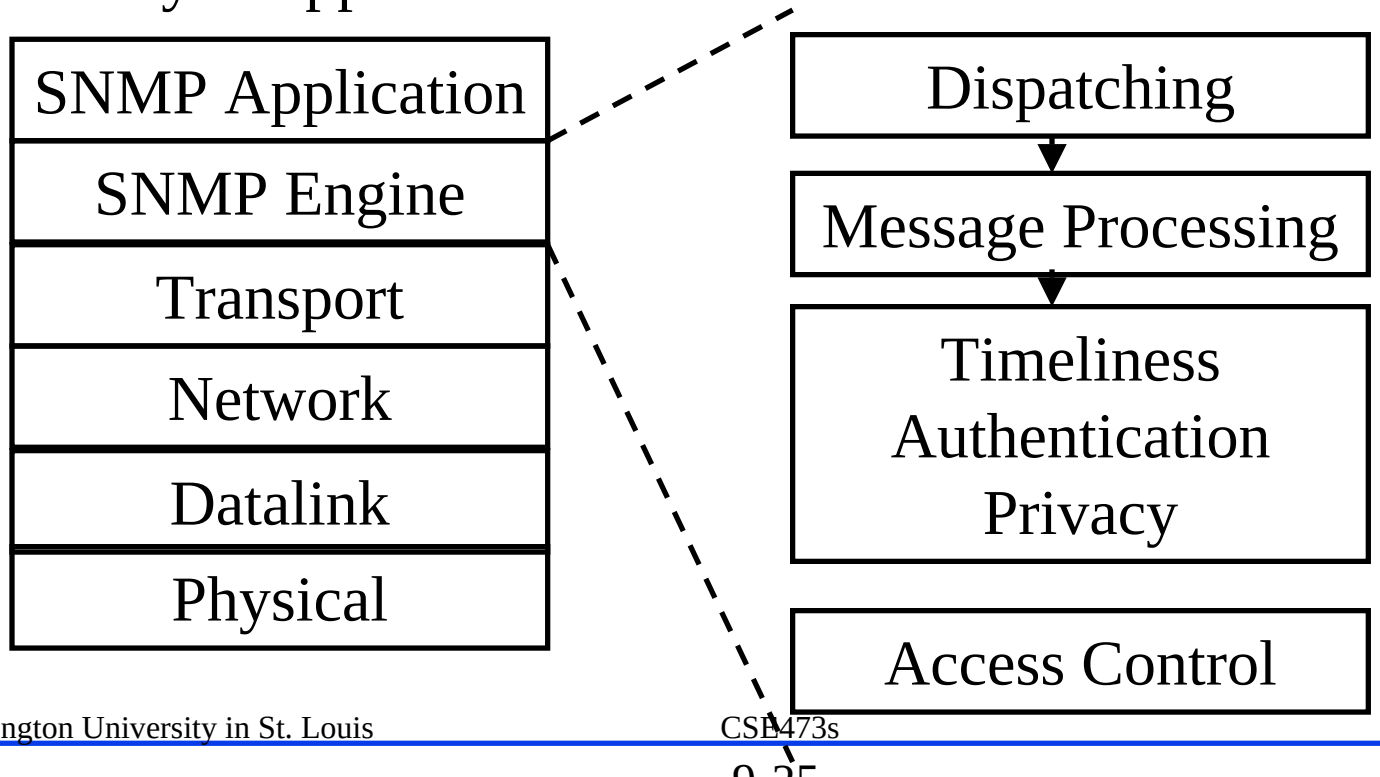
- Improved security: authentication and integrity using Data Encryption Standard (DES)
- *inform request* ⇒ Multiple manager coordination
  Locking mechanisms prevent multiple managers from writing at the same time
- *get bulk* ⇒ Better table handling
- Confirmation option for Traps
  ⇒ Agents can ensure that trap was received correctly.
- New Error codes: noSuchName, badValue, readOnly
- Reference: RFC 1441, April 1993 and more

SNMPv3

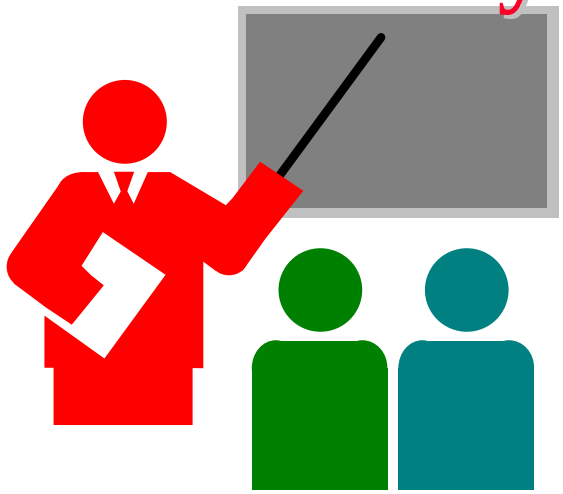
- Security update of SNMPv2
- Authentication: Message authentication code with a shared secret key
- Privacy: Encryption using a shared secret key
- Access Control: Each manager can have a different set of read/write permission for various component of MIB
- Ref: RFC 2570, April 1999 and more

SNMPv3 Engine

- SNMP Applications generate GetRequest, SetRequest, …, commands
- SNMP Engine where SNMP version is determined, wrapped in a header containing version, message ID, size and then in a security wrapper.



Summary



- Management = Initialization, Monitoring, and Control
- SNMP = Only 5 to 7 commands
- Standard MIBs defined for each object
- Uses ASN.1 encoding
- SNMPv2 fixed issues with bulk requests and simple security
- SNMPv3 added security

Review Exercises

- **Try but do not submit**
- Review Questions: R1 through R12
- Problems P1 through P8