INTERNET NETWORK MANAGEMENT STANDARDS

COURSE PRESENTED AT THE SBRC '97
SÃO CARLOS, BRASIL
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OVERVIEW

BACKGROUND

- HISTORY
- GOALS
- RELATION WITH OSI AND TMN
- STRUCTURE OF INTERNET MANAGEMENT
- STANDARDS

• STRUCTURE OF MANAGEMENT INFORMATION

- SCALARS
- TABLES

• MANAGEMENT INFORMATION BASES

- MIB-II
- OTHER MIBs

• SIMPLE NETWORK MANAGEMENT PROTOCOL

- VERSION 1
- VERSION 2
- VERSION 3

NEW DEVELOPMENTS

- EXTENSIBLE AGENT TECHNOLOGY
- DISTRIBUTED MANAGEMENT

FURTHER INFORMATION

SNMP HISTORY AND SPECIFICATIONS

DATE	MILESTONE	STATUS	RFC
OCTOBER 1987	HIGH-LEVEL ENTITY MANAGEMENT SYSTEM		1023
NOVEMBER 1987	SIMPLE GATEWAY MONITORING PROTOCOL		1028
FEBRUARY 1988	IAB SNMP WORKING GROUP		1052
AUGUST 1988	FIRST SNMP SPECIFICATION		1065-1067
MAY 1990	SNMP VERSION 1 (COMMUNITY)	STD 15, 16	1155-1157
MARCH 1991	MANAGEMENT INFORMATION BASE II	STD 17	1213
APRIL 1993	SNMP VERSION 2 (PARTIES)	HISTORIC	1441-1452
JANUARY 1996	SNMP VERSION 2 (COMMUNITY)	DRAFT*	1901-1908

* EXCEPT RFC 1901 (EXPERIMENTAL)

INTERNET MANAGEMENT GOALS

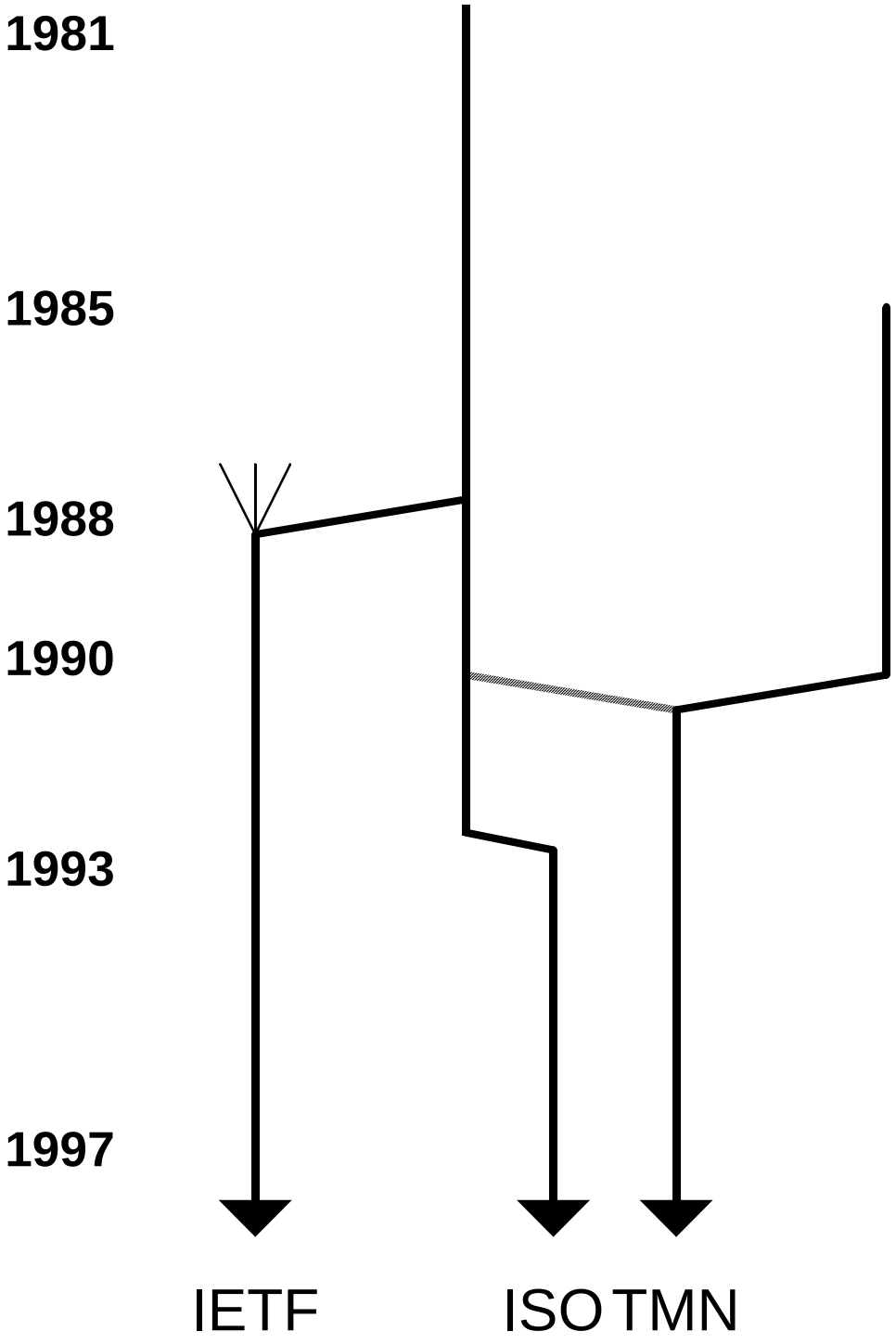
UBIQUITY
- PCs AND CRAYs

INCLUSION OF MANAGEMENT SHOULD BE INEXPENSIVE
- SMALL CODE
- LIMITED FUNCTIONALITY

MANAGEMENT EXTENSIONS SHOULD BE POSSIBLE
- NEW MIBs

MANAGEMENT SHOULD BE ROBUST
- CONNECTIONLESS TRANSPORT

HISTORY



COMPARISON

IETF

• MANAGEMENT SHOULD BE SIMPLE
• VARIABLE ORIENTED APPROACH
• MANAGEMENT INFORMATION EXCHANGES MAY BE UNRELIABLE

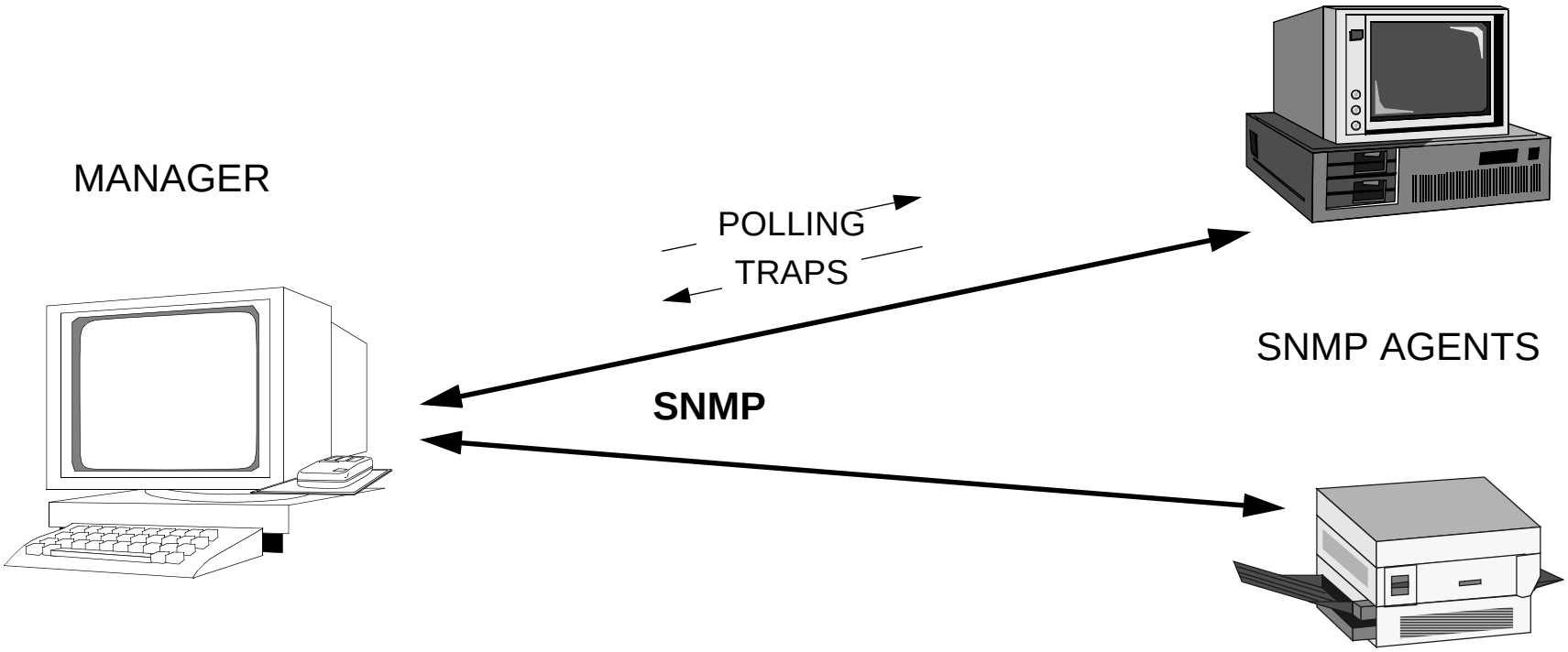
ISO

• MANAGEMENT SHOULD BE POWERFUL
• OBJECT ORIENTED APPROACH
• MANAGEMENT INFORMATION MUST BE EXCHANGED IN A RELIABLE FASHION

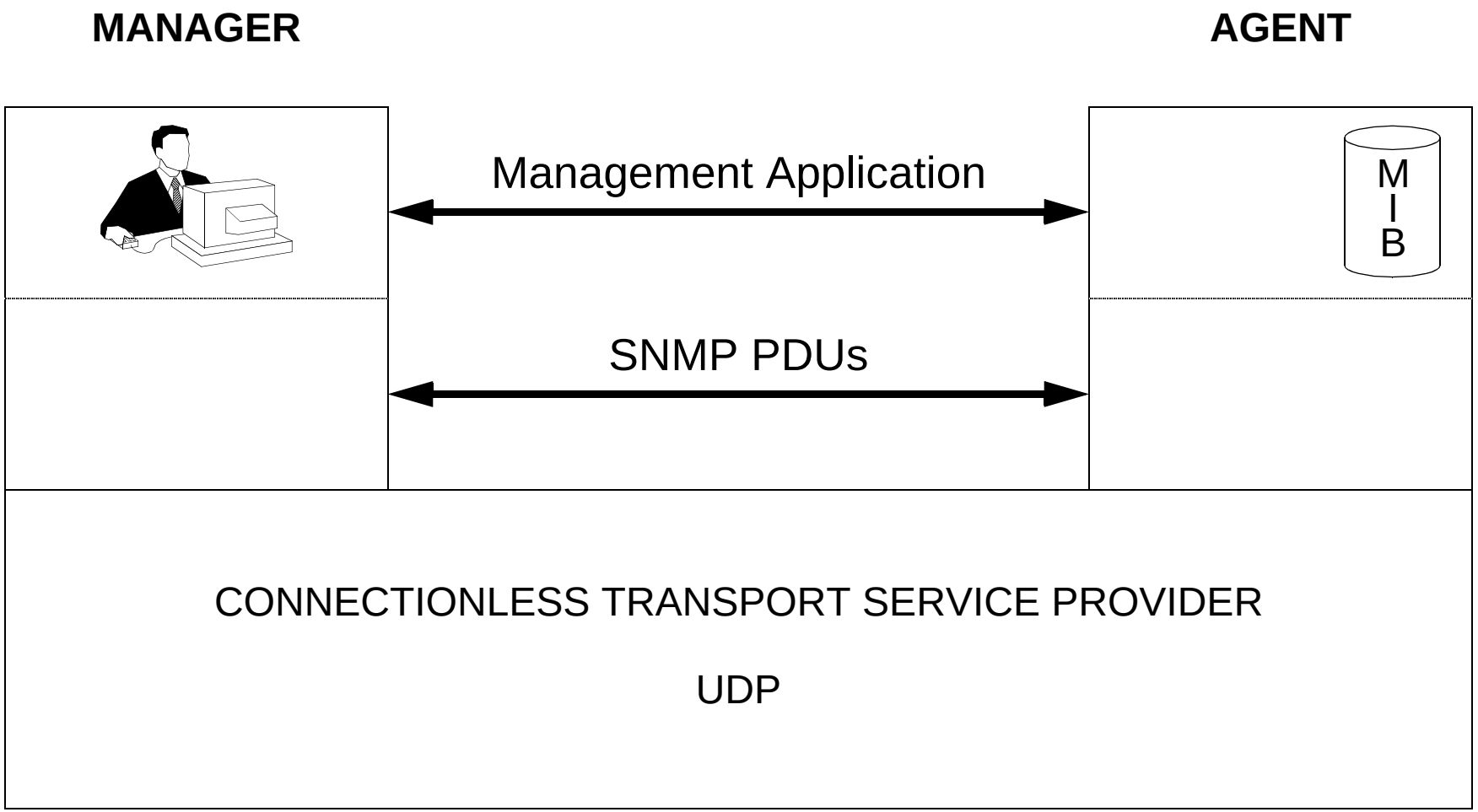
TMN

• DEFINES ONLY A MANAGEMENT *ARCHITECTURE*
• THE ACTUAL PROTOCOLS ARE THOSE OF OSI
• OUT-OF-BAND MANAGEMENT

SNMP STRUCTURE



SNMP STRUCTURE



STANDARDS

SMI

- STRUCTURE OF MANAGEMENT INFORMATION
- RFC 1155

MIB-II

- MANAGEMENT INFORMATION BASE
- RFC 1212
- A LARGE NUMBER OF ADDITIONAL MIBs EXIST

SNMP

- SIMPLE NETWORK MANAGEMENT PROTOCOL
- RFC 1157
- NAME IS USED IN A MORE GENERAL SENSE

SNMP VERSION 2

- RFC 1901-1908

SMI

STRUCTURE OF
MANAGEMENT INFORMATION
=
RFC 1155

CONCISE MIB DEFINITIONS
=
RFC 1212

MAKES THE DEFINITION
OF (NEW) MIBs EASIER

SMI

MANAGEMENT INFORMATION
WITHIN MANAGED SYSTEMS
MUST BE REPRESENTED AS:

- SCALARS
- TABLES

(= TWO DIMENSIONAL ARRAYS OF SCALARS)

THE SNMP PROTOCOL
CAN ONLY EXCHANGE
(A LIST OF) SCALARS

DEFINED IN TERMS OF
ASN.1
CONSTRUCTS

SMI: DATA TYPES FOR SCALARS

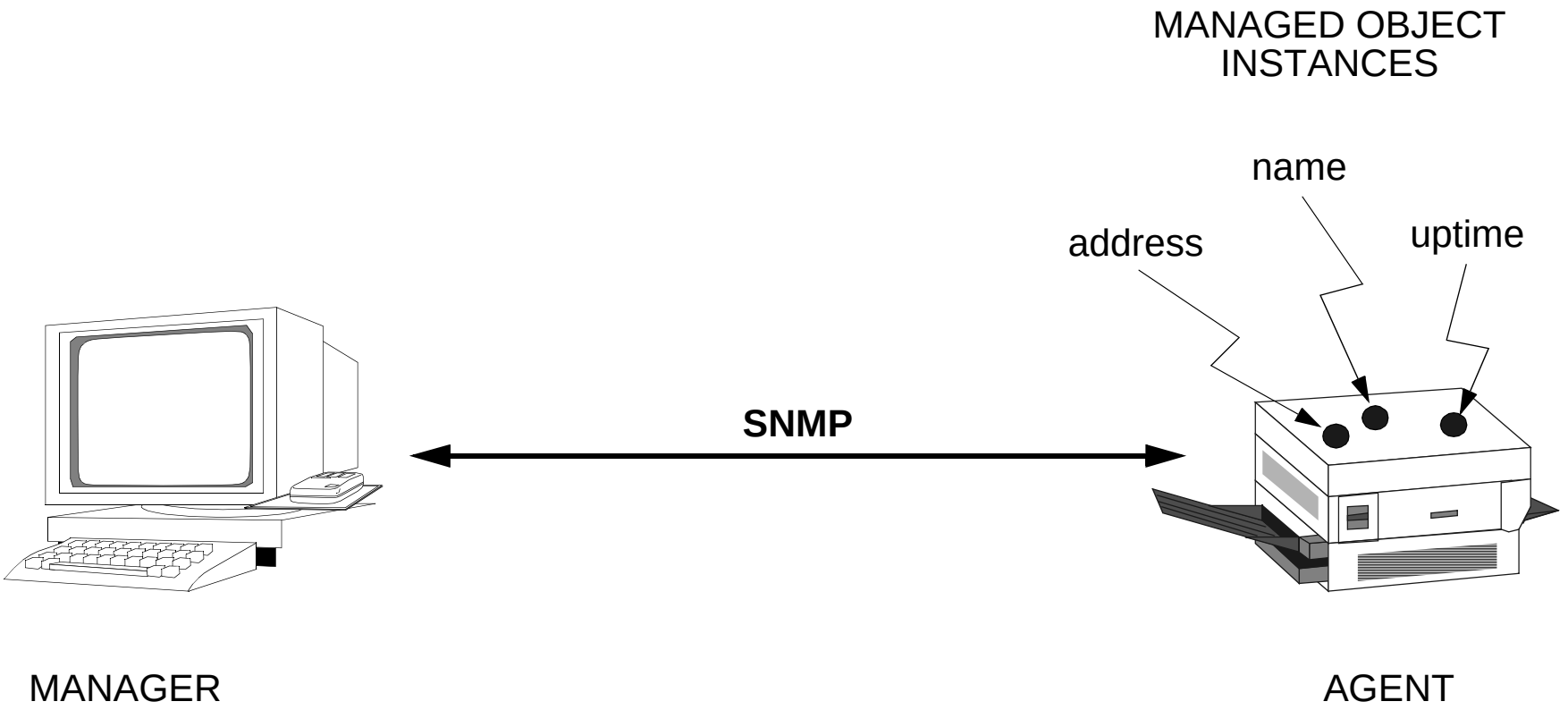
SIMPLE TYPES

- INTEGER
- OCTET STRING
- OBJECT IDENTIFIER
- NULL

APPLICATION-WIDE TYPES

- IpAddress
- NetworkAddress
- Counter
- Gauge
- TimeTicks
- Opaque

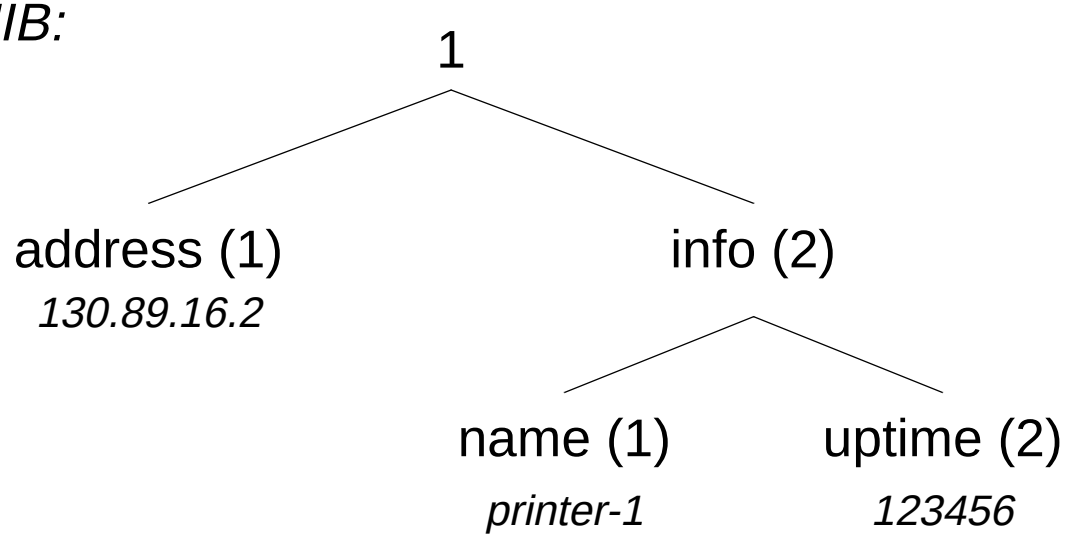
EXAMPLE OF SCALAR OBJECTS



OBJECT NAMING

INTRODUCE NAMING TREE

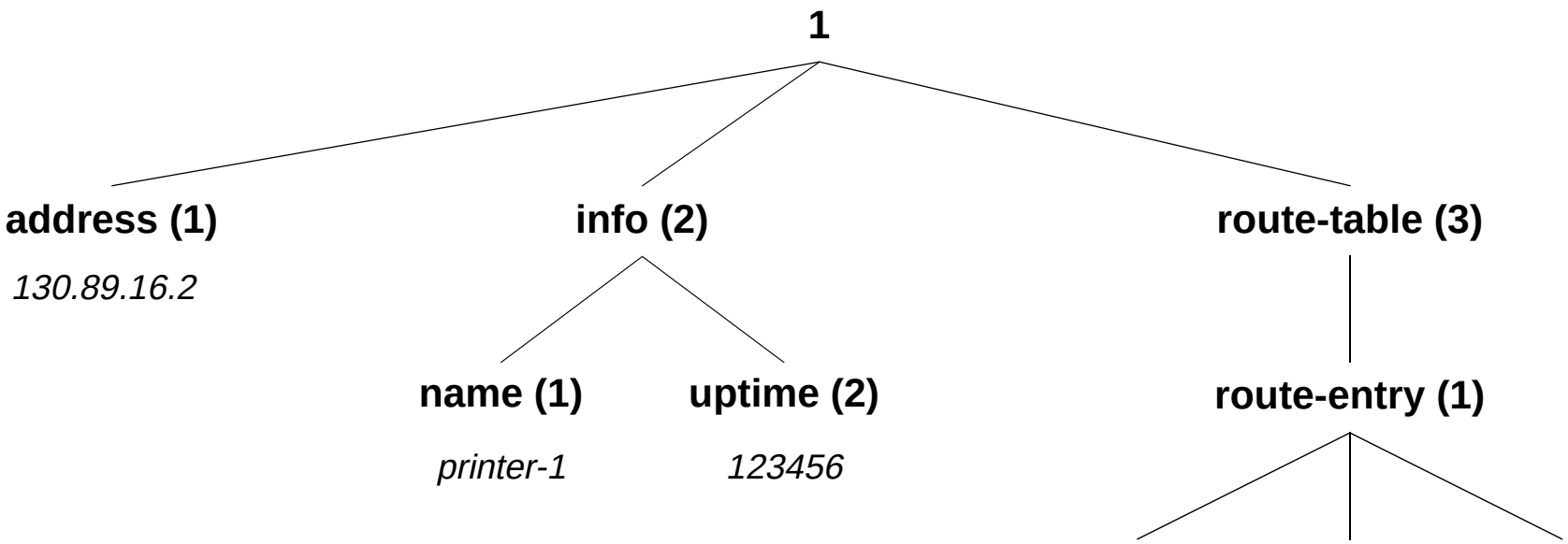
new-MIB:

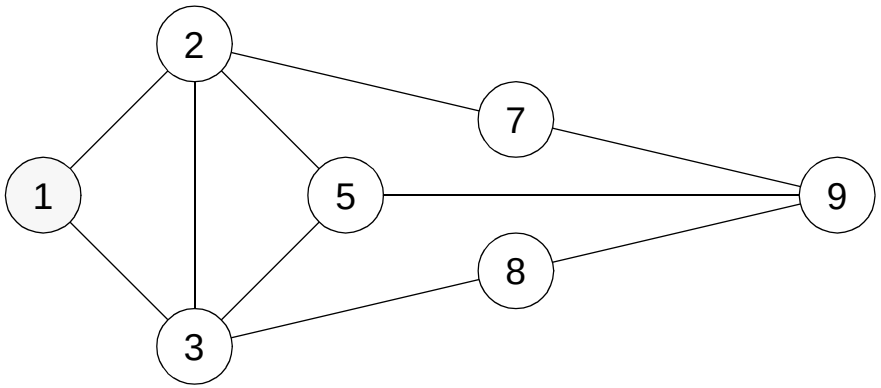


THE LEAVES OF THE TREE
REPRESENT THE MANAGED OBJECTS

NODES ARE INTRODUCED
FOR NAMING PURPOSES

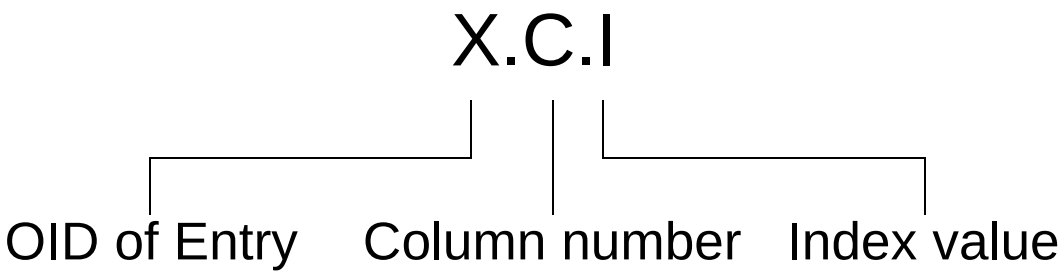
TABLES





index (1)	dest (2)	next (3)
1	*2*	*2*
2	*3*	*3*
3	*5*	*2*
4	*7*	*2*
5	*8*	*3*
6	*9*	*3*

NAMING OF TABLE ENTRIES



EXAMPLES:

OID of Entry = 1.3.1

1.3.1.1.1 ⇨ *1*

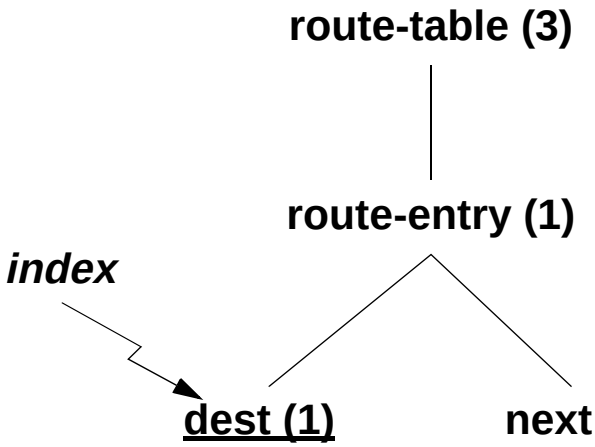
1.3.1.2.1 ⇨ *2*

1.3.1.3.1 ⇨ *2*

1.3.1.1.4 ⇨ *4*

1.3.1.2.4 ⇨ *7*

TABLE INDEX - 1



2	*2*
3	*3*
5	*2*
7	*2*
8	*3*
9	*3*

EXAMPLES:

1.3.1.1.9 ⇨ *9*

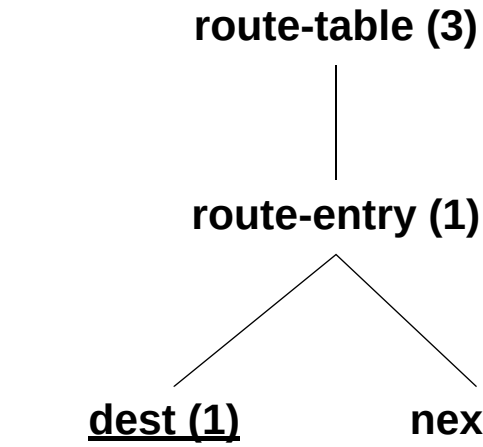
1.3.1.2.9 ⇨ *3*

1.3.1.2.7 ⇨ *2*

1.3.1.1.1 ⇨ *entry does not exist*

1.3.1.2.1 ⇨ *entry does not exist*

TABLE INDEX - 2



130.89.16.1	*130.89.16.1*
130.89.16.4	*130.89.16.4*
130.89.16.23	*130.89.16.23*
130.89.19.121	*130.89.16.1*
192.1.23.24	*130.89.16.4*
193.22.11.97	*130.89.16.1*

EXAMPLES:

1.3.1.1.130.89.16.1 ⇨ *130.89.16.1*

1.3.1.2.130.89.16.1 ⇨ *130.89.16.1*

1.3.1.2.192.1.23.24 ⇨ *130.89.16.4*

1.3.1.2.193.22.11.97 ⇨ *130.89.16.1*

1.3.1.2.1 ⇨ *entry does not exist*

TABLE INDEX - 3

USE OF MULTIPLE INDEX FIELDS

X.C.I1.I2

OID of Entry | Column number | Index value 1 | Index value 2

EXAMPLE:

route-table (3)

1 = low costs
2 = high reliability

route-entry (1)

dest (1)	**policy (2)**	**next (3)**
130.89.16.23	*1*	*130.89.16.23*
130.89.16.23	*2*	*130.89.16.23*
130.89.19.121	*1*	*130.89.16.1*
192.1.23.24	*1*	*130.89.16.1*
192.1.23.24	*2*	*130.89.16.4*
193.22.11.97	*1*	*130.89.16.1*

1.3.1.2.192.1.23.24.1 ⇨ *130.89.16.1*

1.3.1.2.192.1.23.24.2 ⇨ *130.89.16.4*

MIB-II

DEFINES THE VARIABLES
TO MANAGE THE
TCP/IP PROTOCOL STACK

170 VARIABLES

RFC 1213

ENHANCEMENT OF MIB-I

RFC 1156

MIB-II

• ESSENTIAL FOR
FAULT OR CONFIGURATION MANAGEMENT

• ONLY WEAK CONTROL OBJECTS

• SMALL NUMBER OF OBJECTS

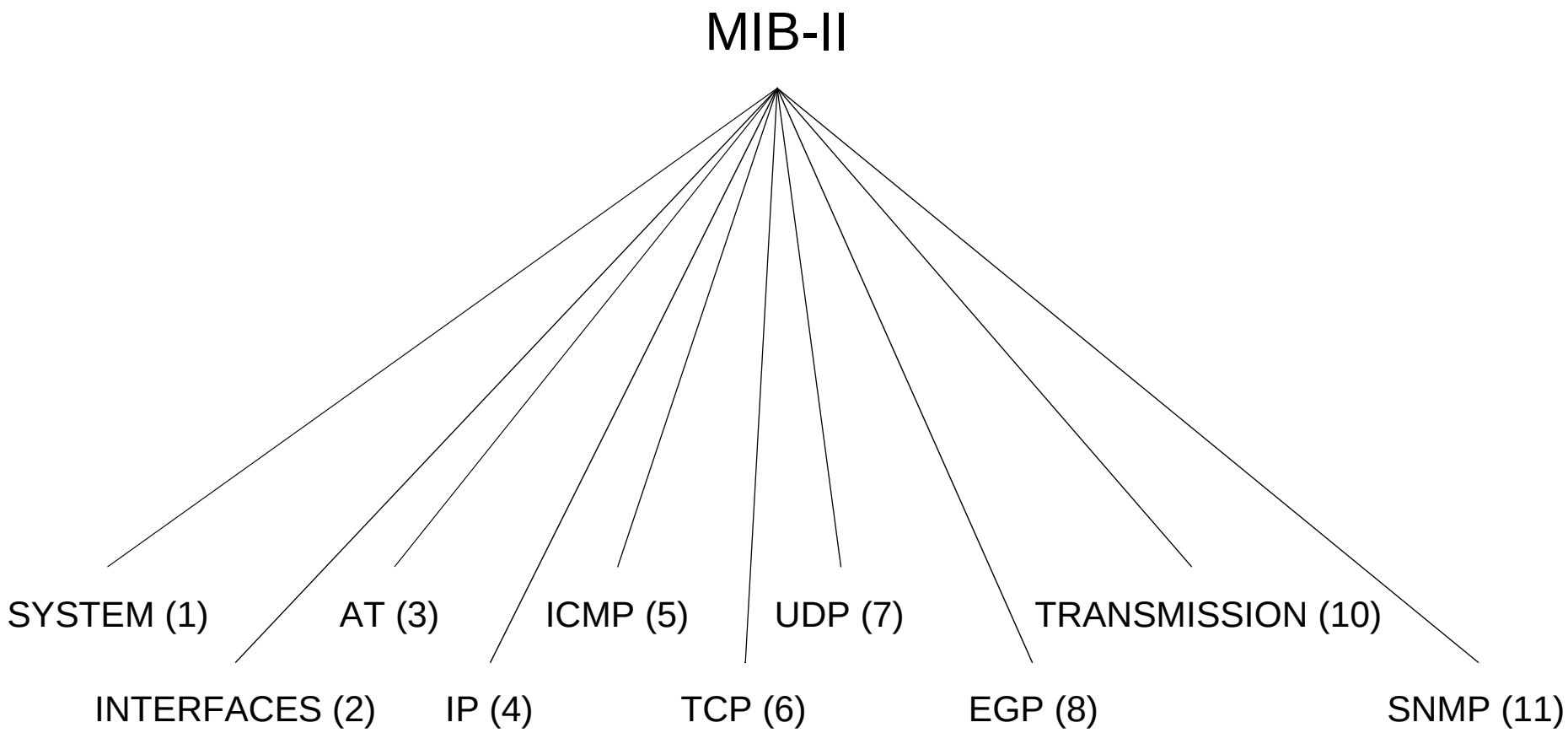
• AVOID REDUNDANCY

• EVIDENCE OF UTILITY

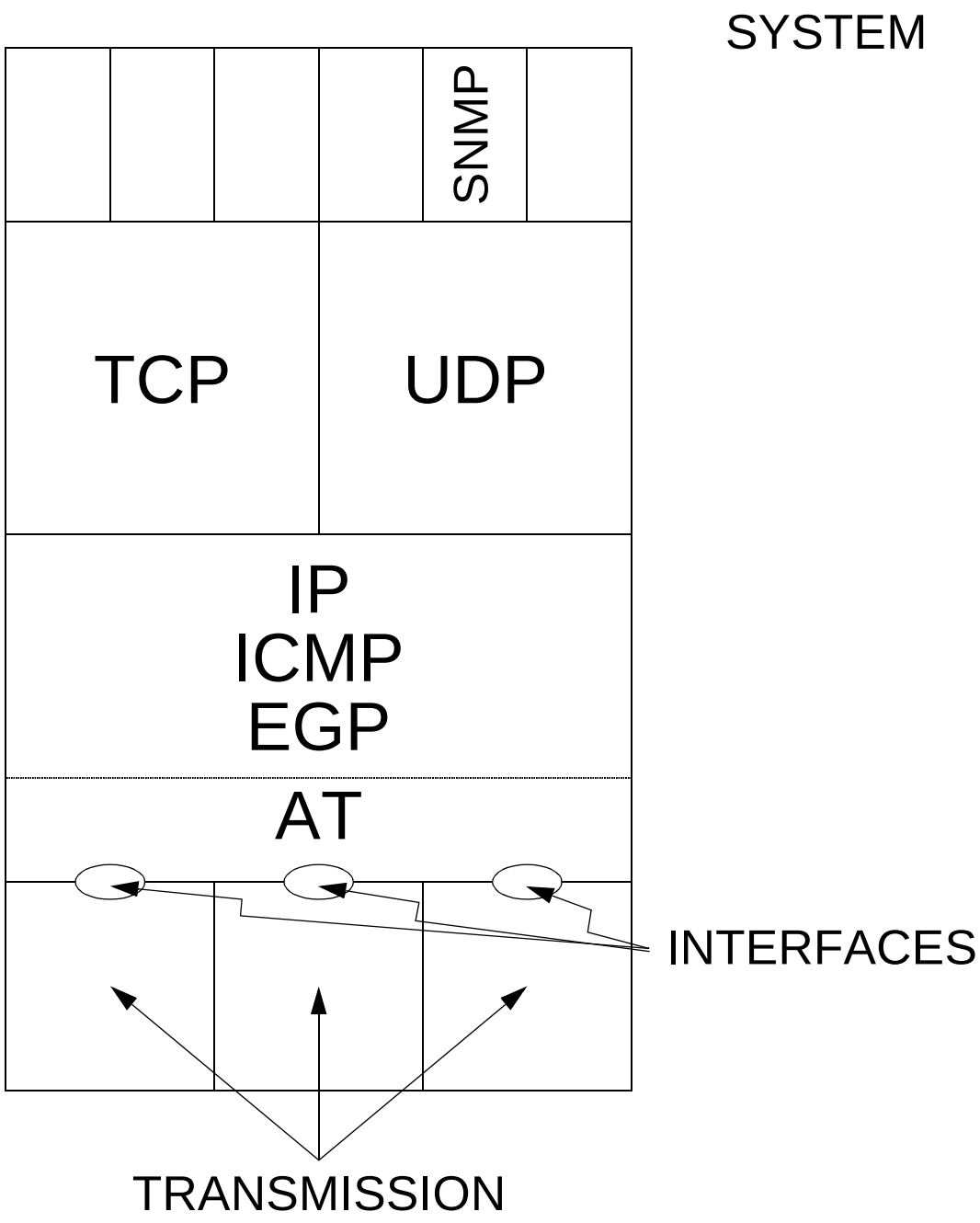
• DO NOT DISTURB NORMAL OPERATION

• NO IMPLEMENTATION SPECIFIC ISSUES

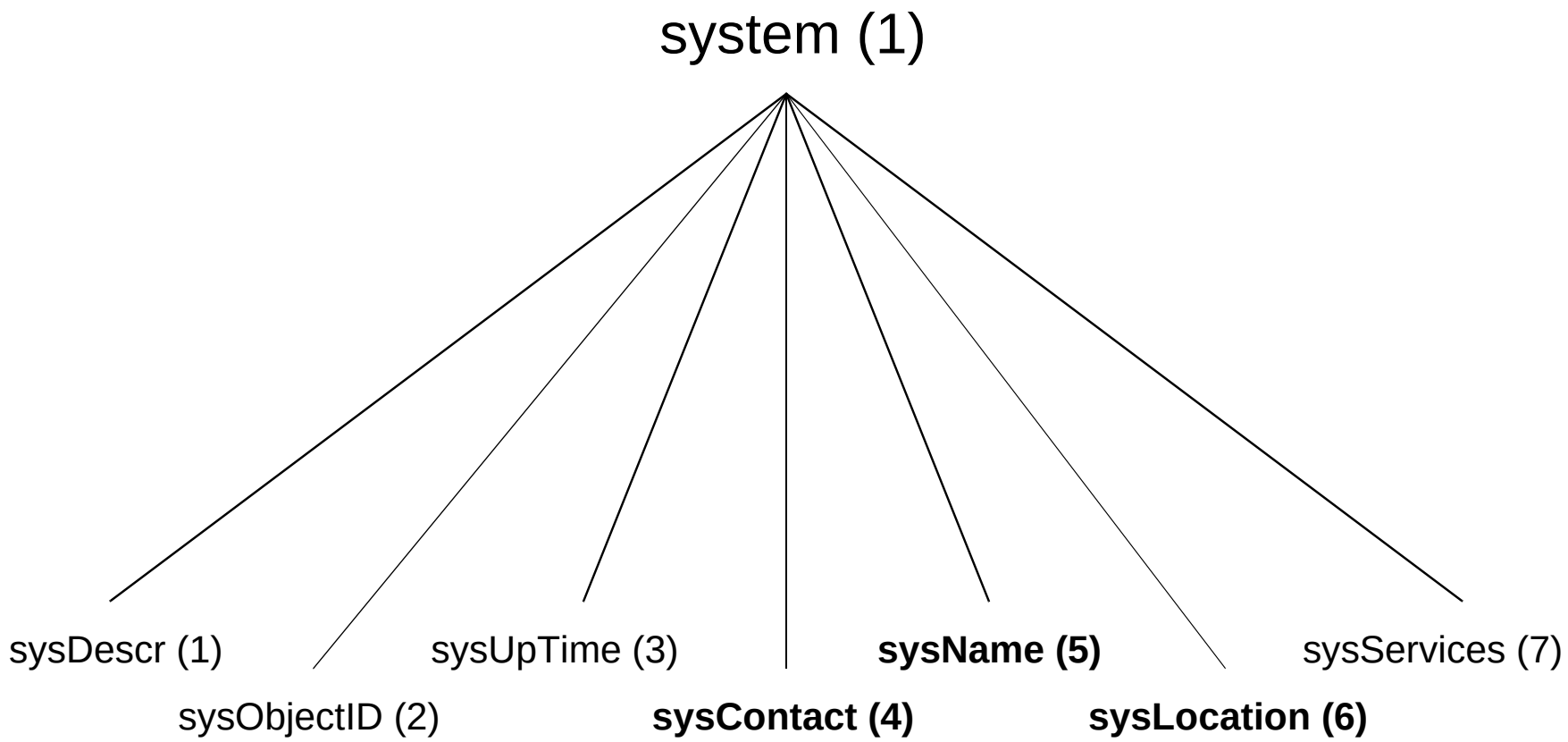
MIB-II


MIB-II
SYSTEM (1)
INTERFACES (2)
AT (3)
IP (4)
ICMP (5)
TCP (6)
UDP (7)
EGP (8)
TRANSMISSION (10)
SNMP (11)

MIB-II GROUPS



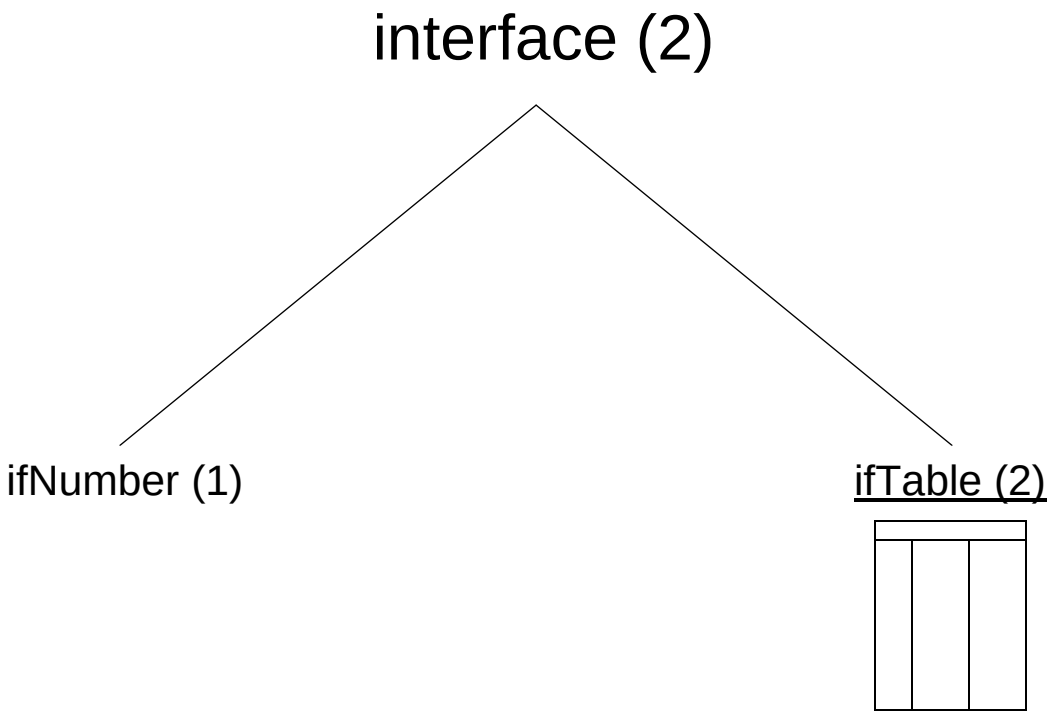
SYSTEM GROUP



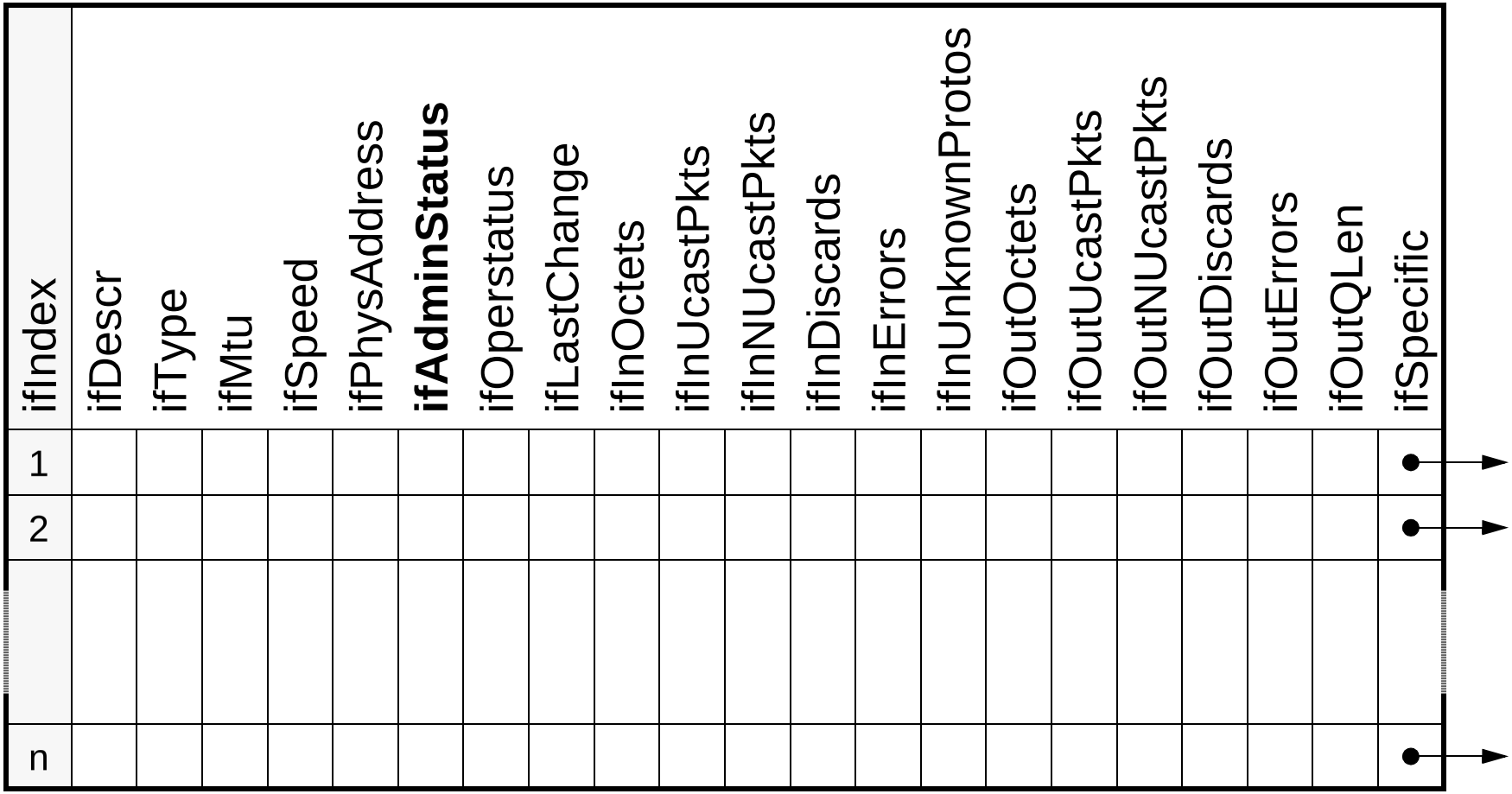
EXAMPLE

sysDescr:	"**Cisco Gateway**"
sysObjectID:	**1.3.6.1.4.1.9.1.1**
sysUpTime:	**37153422** *(4 days, 7 h, 12 min, 14.22 s)*
sysContact:	"**helpdesk@cs.utwente.nl**"
sysName:	"**utic01.cs.utwente.nl**"
sysLocation:	"**near logica meeting room**"
sysServices:	**6** *(bridge and router functions)*

INTERFACES GROUP



ifTable


ifIndex
ifDescr
ifType
ifMtu
ifSpeed
ifPhysAddress
ifAdminStatus
ifOperstatus
ifLastChange
ifInOctets
ifInUcastPkts
ifInNUcastPkts
ifInDiscards
ifInErrors
ifInUnknownProtos
ifOutOctets
ifOutUcastPkts
ifOutNUcastPkts
ifOutDiscards
ifOutErrors
ifOutQLen
ifSpecific
1
2
n

ifTable

- ifAdminStatus / ifOperStatus

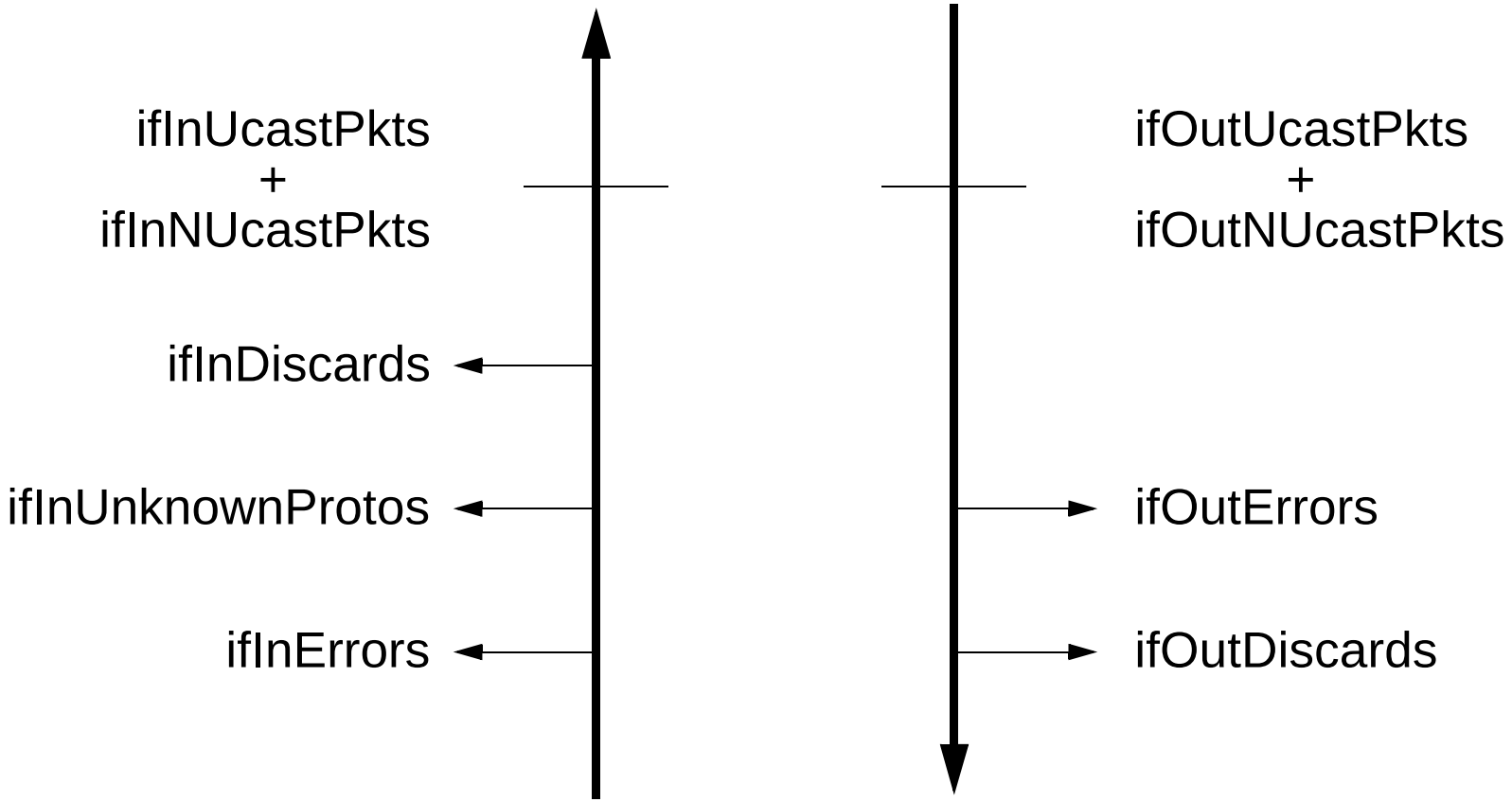
1 = up
2 = down
3 = testing

- ifType

EXAMPLES:

1	Undefined	16	LAPB
6	Ethernet	20	ISDN Basic
7	IEEE 802.3	21	ISDN Primary
8	IEEE 802.4	23	PPP
9	IEEE 802.5	24	Loopback
10	IEEE 802.6	28	SLIP
15	FDDI	32	Frame Relay

IF PACKET COUNT



TRANSMISSION MIBs

Title	RFC
IEEE 802.3 Repeater Devices	2108
Data Link Switching	2024
IEEE 802.5	1748
ATM	1695
SMDS	1694
Ethernet	1650
Frame Relay	1604
SONET / SDH	1595
FDDI	1512
Link Control Protocol of PPP	1471
Multiprotocol Interconnect over X.25	1461
DS3 / E3	1407
DS1 / E1	1406
Frame Relay DTEs	1315

NETWORK LAYER MIBs

Title	RFC
IP Forwarding Table	2096
RMON Version 2	2021
IP Mobility Support	2006
OSPF Version 2	1850
RMON	1757
RIP	1724
BGP Version 4	1657
Token Ring extensions to RMON	1513
Identification MIB	1414
BGP Version 3	1269
MIB-II	1213

APPLICATION LAYER MIBs

Title	RFC
WWW servers	2039
RDBMS	1697
DNS Resolver	1612
DNS Server	1611
X.500 Directory	1657
Mail	1566
Network Services	1565
Host Resources	1514

HARDWARE SPECIFIC MIBs

Title	RFC
Entity	2037
Printer	1759
Modem	1696
Parallel printer-like Hardware	1660
RS-232-like Hardware	1659
Character Stream Devices	1658
UPS	1628

VENDOR SPECIFIC MIBs

Title	RFC
APPC	2051
TCP/IPX Connection	1792
SNA Data Link Control (SDLC)	1747
Appletalk	1742
SNA NAUs	1666
DECNET Phase IV	1559
SNMP over IPX	1420
SNMP over Appletalk	1419

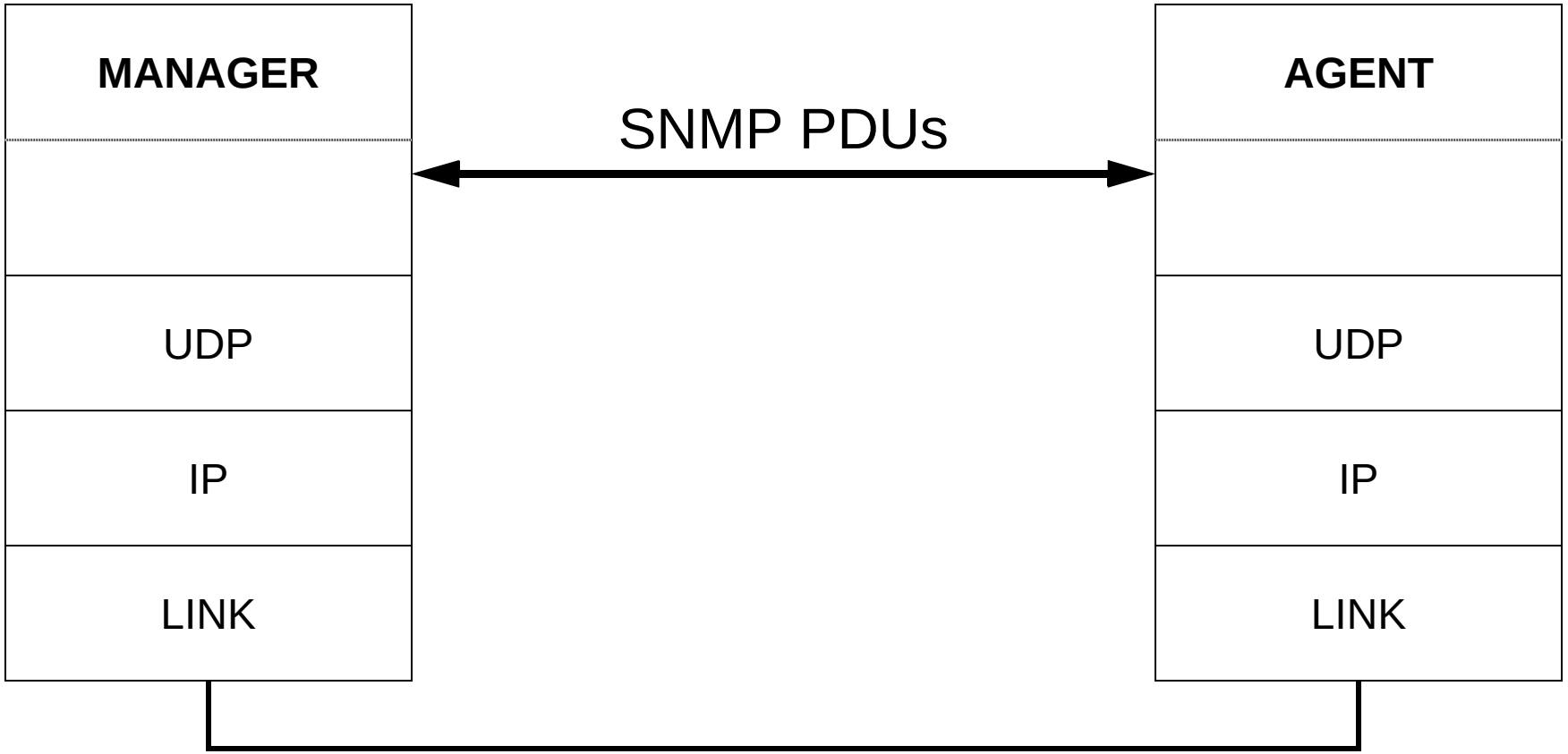
RELATION BETWEEN MIBs - 1

	MIB-II	HOST	REPEATER	BRIDGE	RMON
INTERFACE STATISTICS	✓				
IP, TCP & UDP STATISTICS	✓				
SNMP STATISTICS	✓				
HOST JOB COUNTS		✓			
HOST FILE SYSTEM INFORMATION		✓			
LINK TESTING			✓	✓	
NETWORK TRAFFIC STATISTICS			✓	✓	✓
TABLE WITH ALL ADDRESSES			✓		✓
HOST STATISTICS			✓		✓

RELATION BETWEEN MIBs - 2

	MIB-II	HOST	REPEATER	BRIDGE	RMON
HISTORICAL STATISTICS					✓
SPANNING TREE PERFORMANCE				✓	
WIDE AREA LINK PERFORMANCE				✓	
TRESHOLDS FOR ANY VARIABLE					✓
CONFIGURABLE STATISTICS					✓
TRAFFIC MATRIX WITH ALL NODES					✓
‘HOST TOP N’ INFORMATION					✓
PACKET / PROTOCOL ANALYSIS					✓
DISTRIBUTED LOGGING					✓

SNMP PROTOCOL



MESSAGE & PDU STRUCTURE

variable bindings:

NAME *1*	VALUE *1*	NAME *2*	VALUE *2*	•••	•••	NAME *n*	VALUE *n*

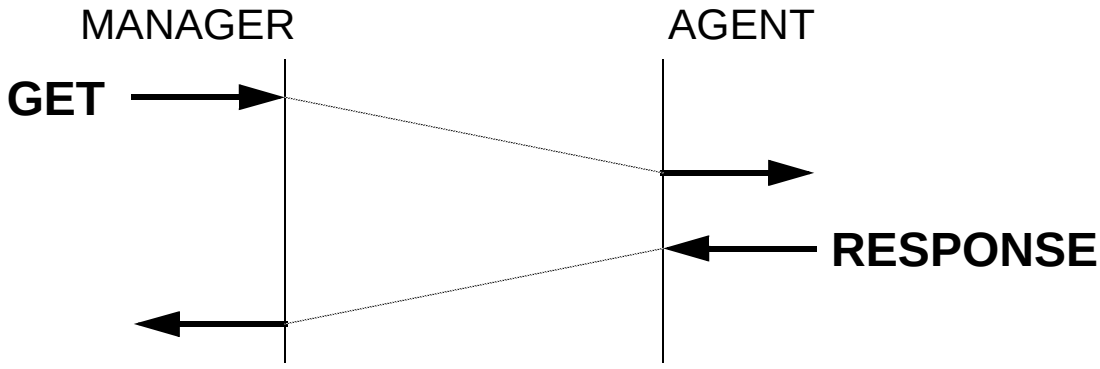
SNMP PDU:

PDU TYPE *	REQUEST ID	ERROR STATUS	ERROR INDEX	VARIABLE BINDINGS

SNMP message:

VERSION	COMMUNITY	SNMP PDU

GET



TO REQUEST THE VALUE OF
1 OR MORE
VARIABLES

POSSIBLE ERRORS:

• NoSuchName

⇩

Object does not exist
Object is not a leaf

• tooBig

⇩

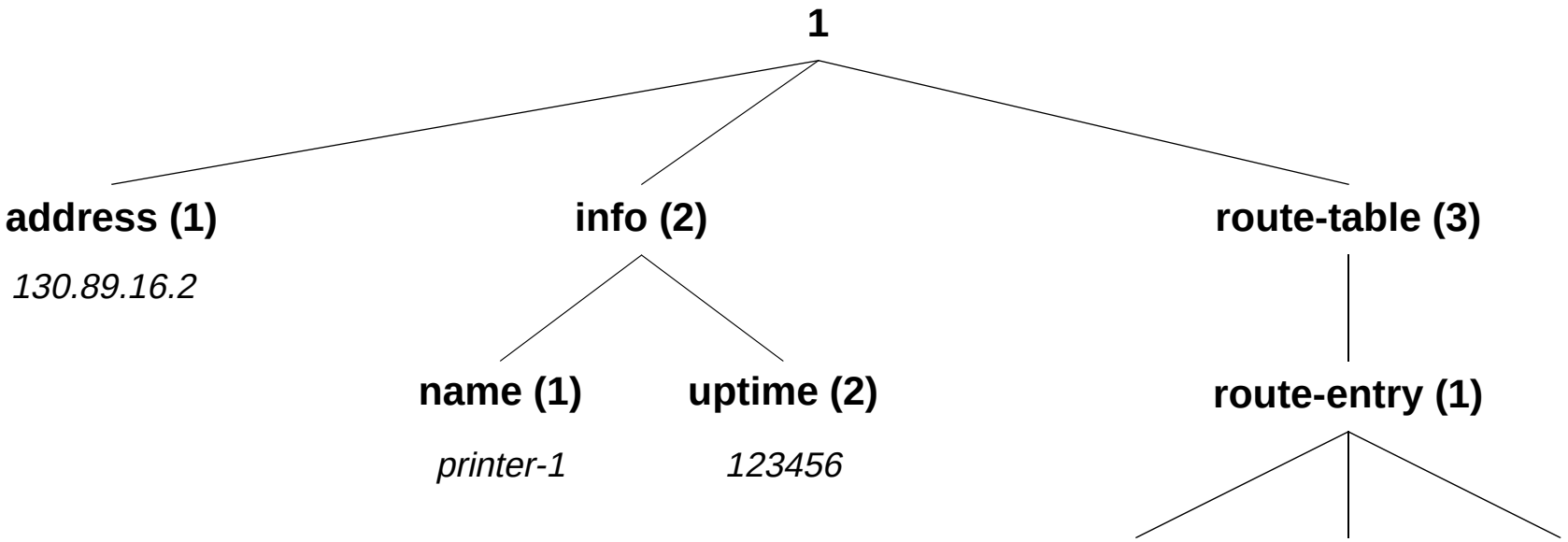
Result does not fit in Response PDU

• genErr

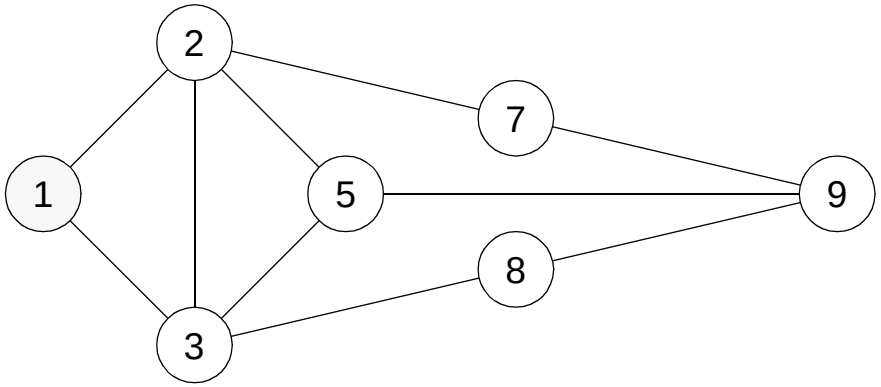
⇩

All other causes

EXAMPLE MIB



index (1)	dest (2)	next (3)
1	*2*	*2*
2	*3*	*3*
3	*5*	*2*
4	*7*	*2*
5	*8*	*3*
6	*9*	*3*



GET EXAMPLES

GET(1.1.0)
RESPONSE(1.1.0 ⇨ *130.89.16.2*)

GET(1.2.0)
RESPONSE(ErrorStatus = NoSuchName)

GET(1.1)
RESPONSE(ErrorStatus = NoSuchName)

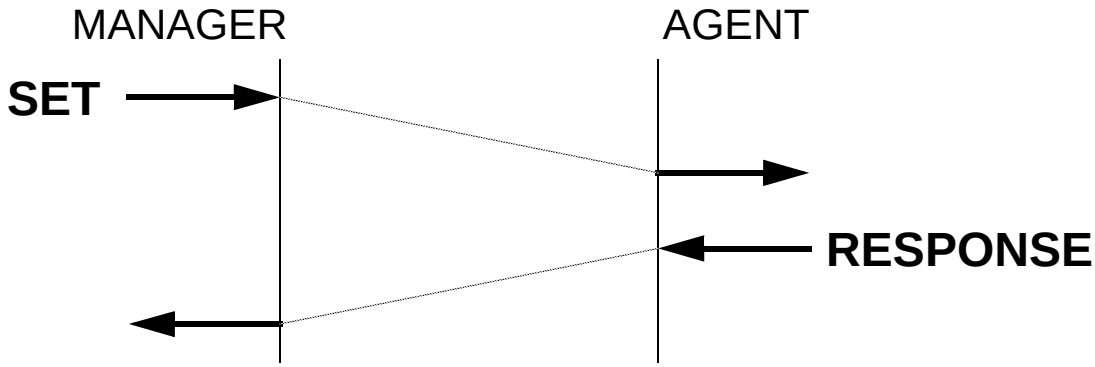
GET(1.1.0; 1.2.2.0)
RESPONSE(1.1.0 ⇨ *130.89.16.2*; 1.2.2.0 ⇨ *123456*)

GET(1.3.1.1.4)
RESPONSE(1.3.1.1.4 ⇨ *4*)

GET(1.3.1.3.4)
RESPONSE(1.3.1.3.4 ⇨ *2*)

GET(1.3.1.2.4, 1.3.1.3.4)
RESPONSE(1.3.1.2.4 ⇨ *7*, 1.3.1.3.4 ⇨ *2*)

SET



SET(1.2.1.0 ⇨ *my-printer*)
RESPONSE(noError; 1.2.1.0 ⇨ *my-printer*)

POSSIBLE ERRORS:

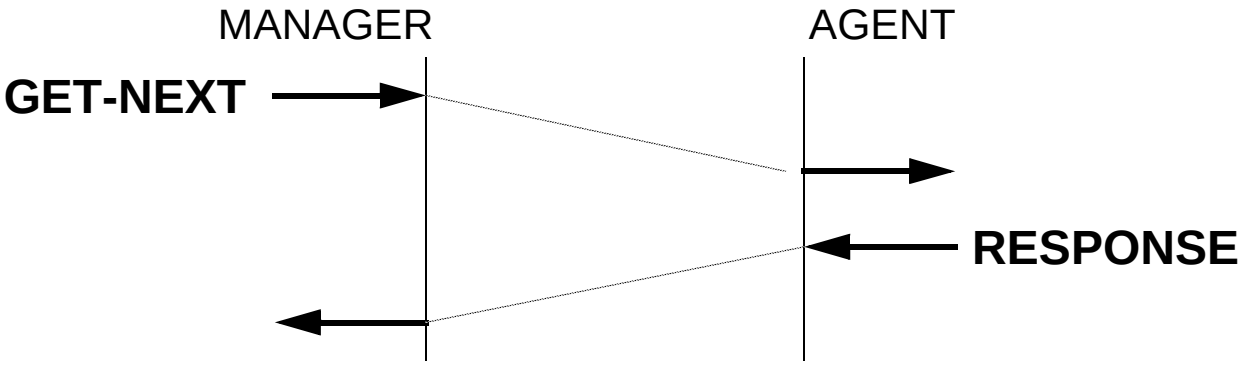
- noSuchName
- badValue
- genErr
- tooBig

SET

THE SET REQUEST IS
ATOMIC

SET(1.2.1.0 ⇨ *my-printer*, 1.2.2.0 ⇨ *0*)
RESPONSE(ErrorStatus = noSuchName; ErrorIndex = 2)

GET-NEXT



RETRIEVES THE
INSTANCE NAME AND VALUE
OF THE **NEXT** MIB ELEMENT

TO DISCOVER MIB STRUCTURES

TO RETRIEVE TABLE ROWS

POSSIBLE ERRORS:

- noSuchName (= END OF MIB)
- genErr
- tooBig

GET-NEXT EXAMPLES

GET-NEXT(1.1.0)
RESPONSE(1.2.1.0 ⇨ *printer-1*)

GET-NEXT(1.2.1.0)
RESPONSE(1.2.2.0 ⇨ *123456*)

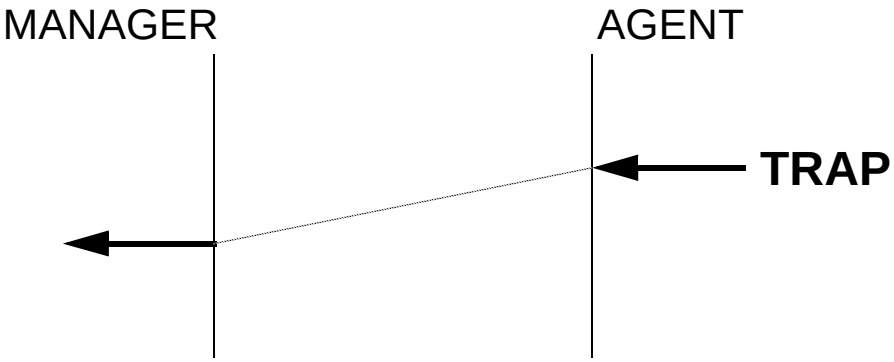
GET-NEXT(1.1)
RESPONSE(1.1.0 ⇨ *130.89.16.2*)

GET-NEXT(1.3.1.1.1)
RESPONSE(1.3.1.1.2 ⇨ *2*)

GET-NEXT(1.3.1.1.6)
RESPONSE(1.3.1.2.1 ⇨ *2*)

GET-NEXT(1.3.1.1.1; 1.3.1.2.1; 1.3.1.3.1)
RESPONSE(1.3.1.1.2 ⇨ *2*; 1.3.1.2.2 ⇨ *3*; 1.3.1.3.2 ⇨ *3*)

TRAP



TRAP RECEPTION
IS NOT CONFIRMED
(THUS UNRELIABLE)

POLLING REMAINS NECESSARY

AGENTS MAY BE CONFIGURED
TO DISCARD TRAPS

DEFINED TRAPS

- COLDSTART
- WARMSTART
- LINKDOWN
- LINKUP
- AUTHENTICATION FAILURE
- EGPNEIGHBOURLOSS
- ENTERPRISESPECIFICTRAP

SNMPv2 versus SNMPv1

IMPROVED PERFORMANCE

- GET-BULK PDU

SECURITY

- AUTHENTICATION
- ENCRYPTION
- ACCESS CONTROL

MANAGEMENT HIERARCHY

- MANAGER TO MANAGER COMMUNICATION

OTHER IMPROVEMENTS

OTHER IMPROVEMENTS

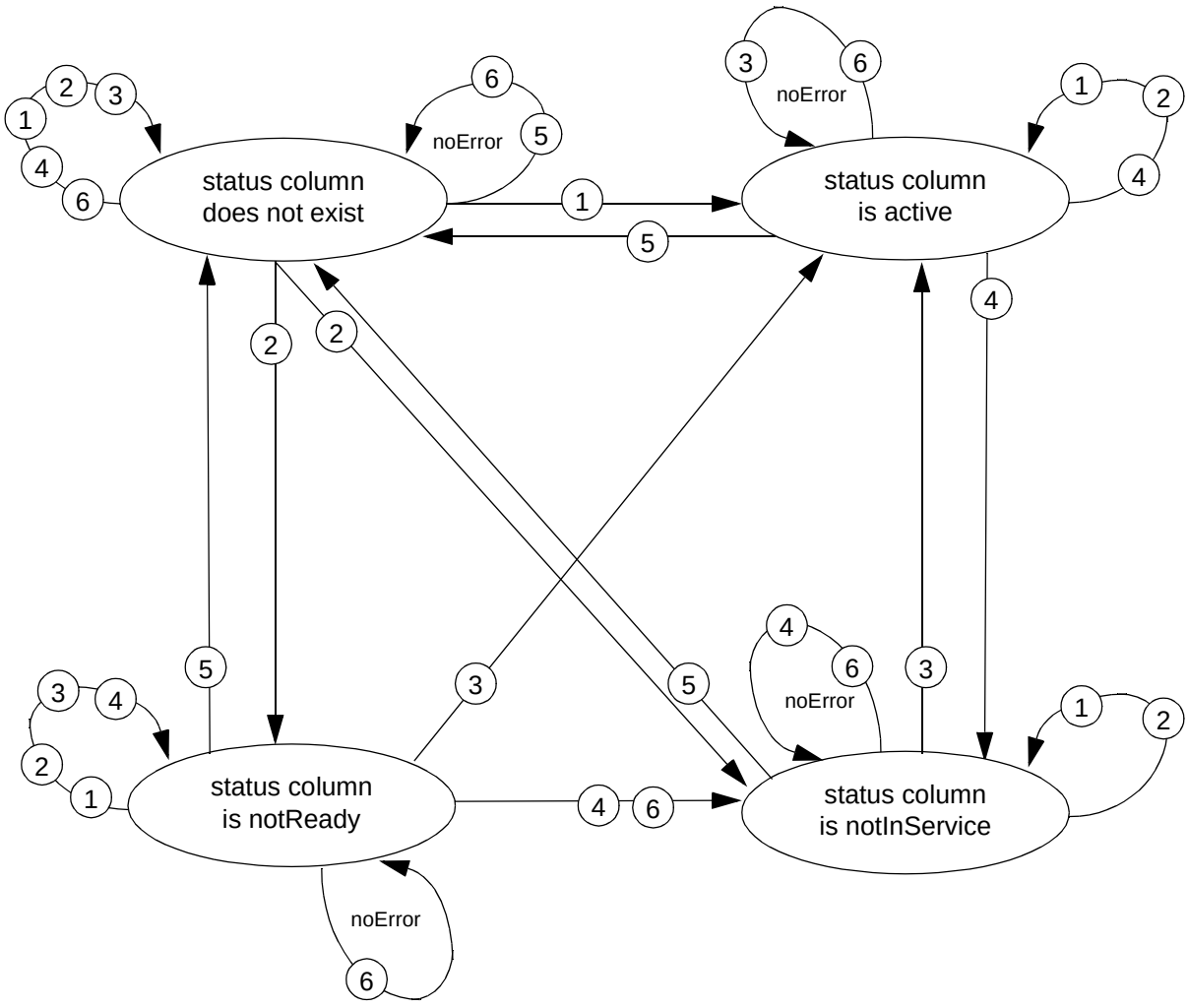
• DEFINITION OF ADDITIONAL DATA TYPES
AND FORMALISMS
BASED ON IMPLEMENTATION EXPERIENCE

• TRANSPORT SERVICE INDEPENDENCE:
MAPPINGS FOR SNMPV2
OVER SEVERAL TRANSPORTS ARE DEFINED

• RECORDING THE UNWRITTEN RULES OF SNMP
- ROW STATUS PLUS OTHER TEXTUAL CONVENTIONS

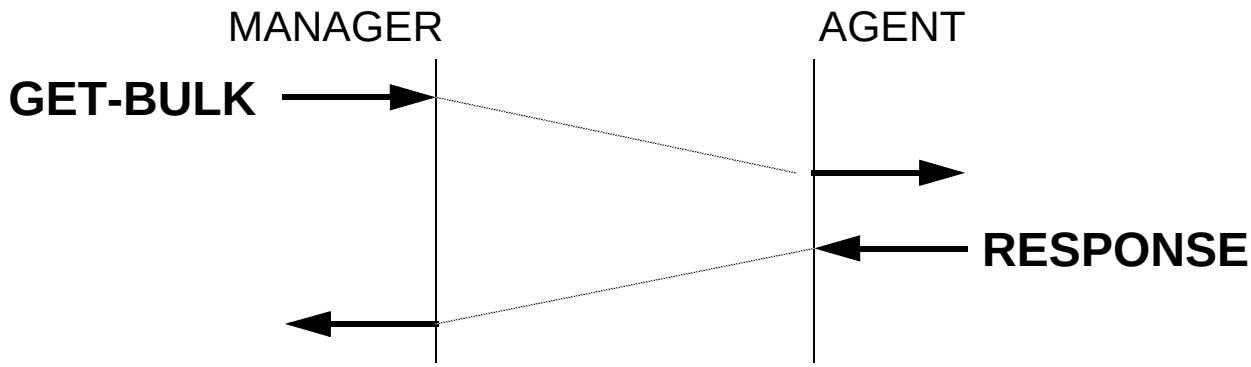
• REDEFINED TRAP PDU
- HAS SAME PDU FORMAT AS OTHER PDUs
- MAY BE SEND TO ZERO, ONE OR MORE MANAGERS

ROW STATUS



1	set status column to createAndGo	4 6	4 or 6
2	set status column to createAndWait		
3	set status column to active		
4	set status column to notInService		
5	set status column to destroy		
6	set any other column to some value		

GET-BULK



GET-BULK(max-repetitions = 4; 1.1)

RESPONSE(
1.1.0 ⇨ *130.89.16.2*
1.2.1.0 ⇨ *printer-1*
1.2.2.0 ⇨ *123456*
1.3.1.1.1 ⇨ *1*
)

GET-BULK(max-repetitions = 3;
1.3.1.1; 1.3.1.2; 1.3.1.3)

RESPONSE(

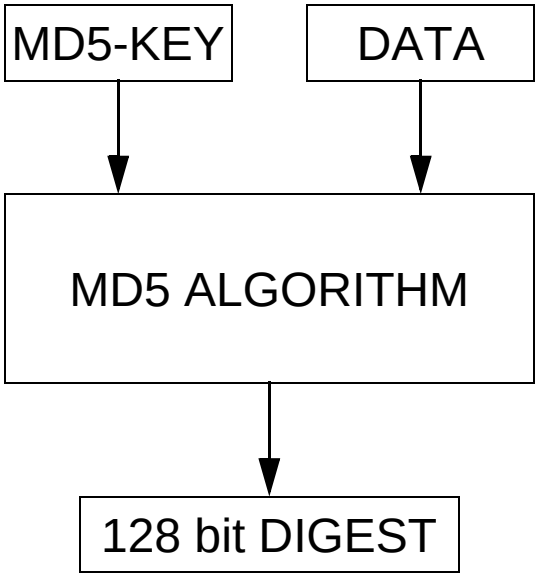
1.3.1.1.1 ⇨ *1*;	1.3.1.2.1 ⇨ *2*;	1.3.1.3.1 ⇨ *2*
1.3.1.1.2 ⇨ *2*;	1.3.1.2.2 ⇨ *3*;	1.3.1.3.2 ⇨ *3*
1.3.1.1.3 ⇨ *3*;	1.3.1.2.3 ⇨ *5*;	1.3.1.3.3 ⇨ *2*

)

SECURITY, AS DEFINED BY SNMPv3

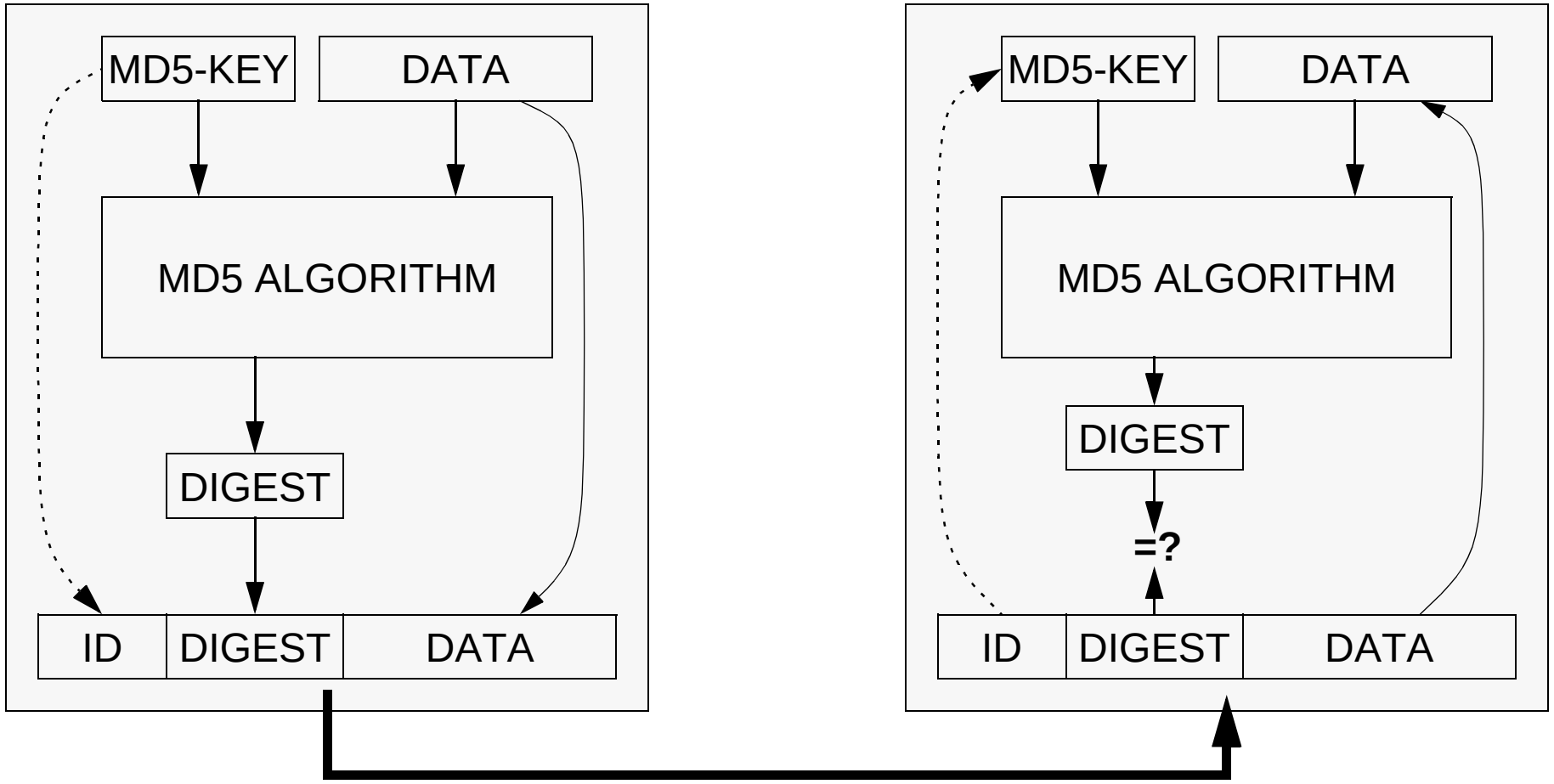
THREAT	ADDRESSED?	MECHANISM
MASQUERADE	YES	MD5
REPLAY	YES	TIME STAMP
DISCLOSURE	YES	DES
INTEGRITY	YES	(MD5)
DENIAL OF SERVICE	NO	
TRAFFIC ANALYSIS	NO	

IDEA BEHIND MESSAGE DIGEST ALGORITHM (MD5)

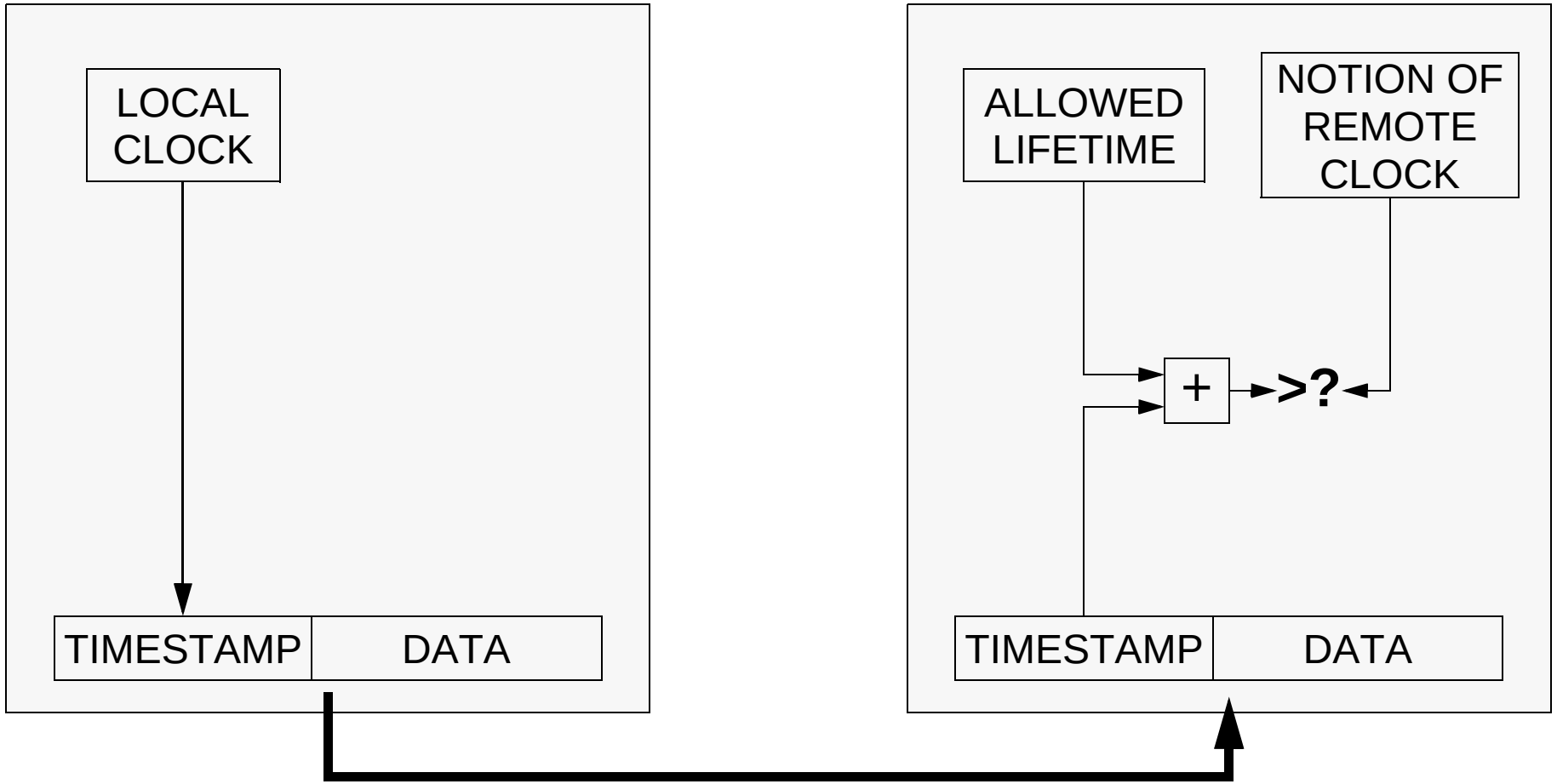


ADD THE DIGEST TO THE DATA
AND SEND THE RESULT

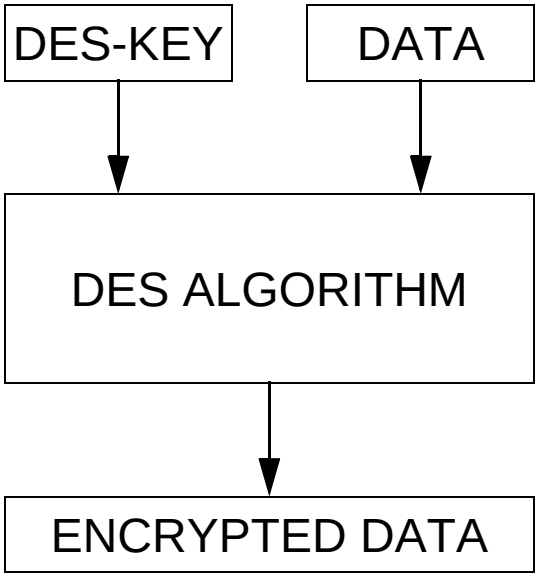
AUTHENTICATION



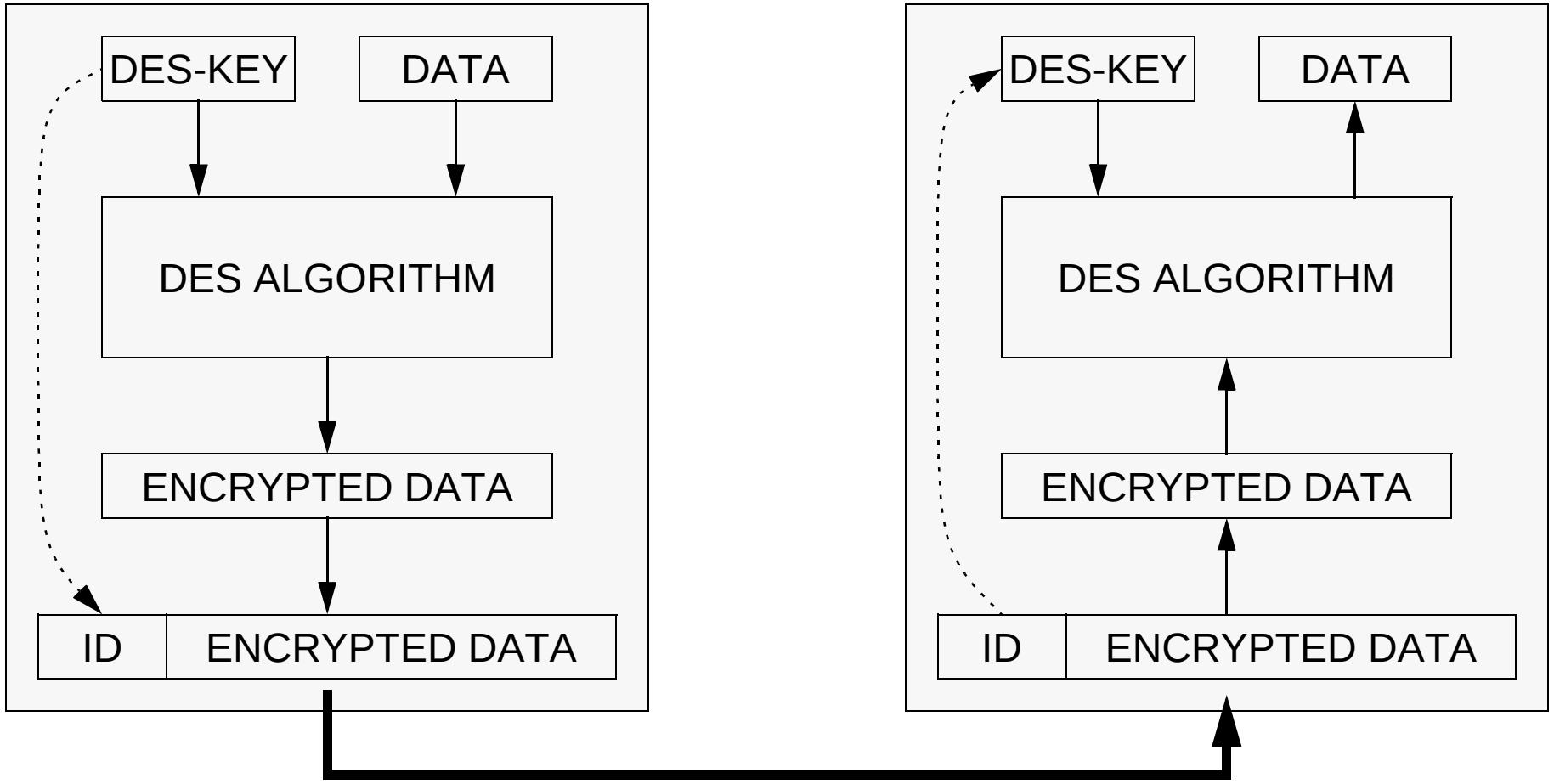
REPLAY PROTECTION



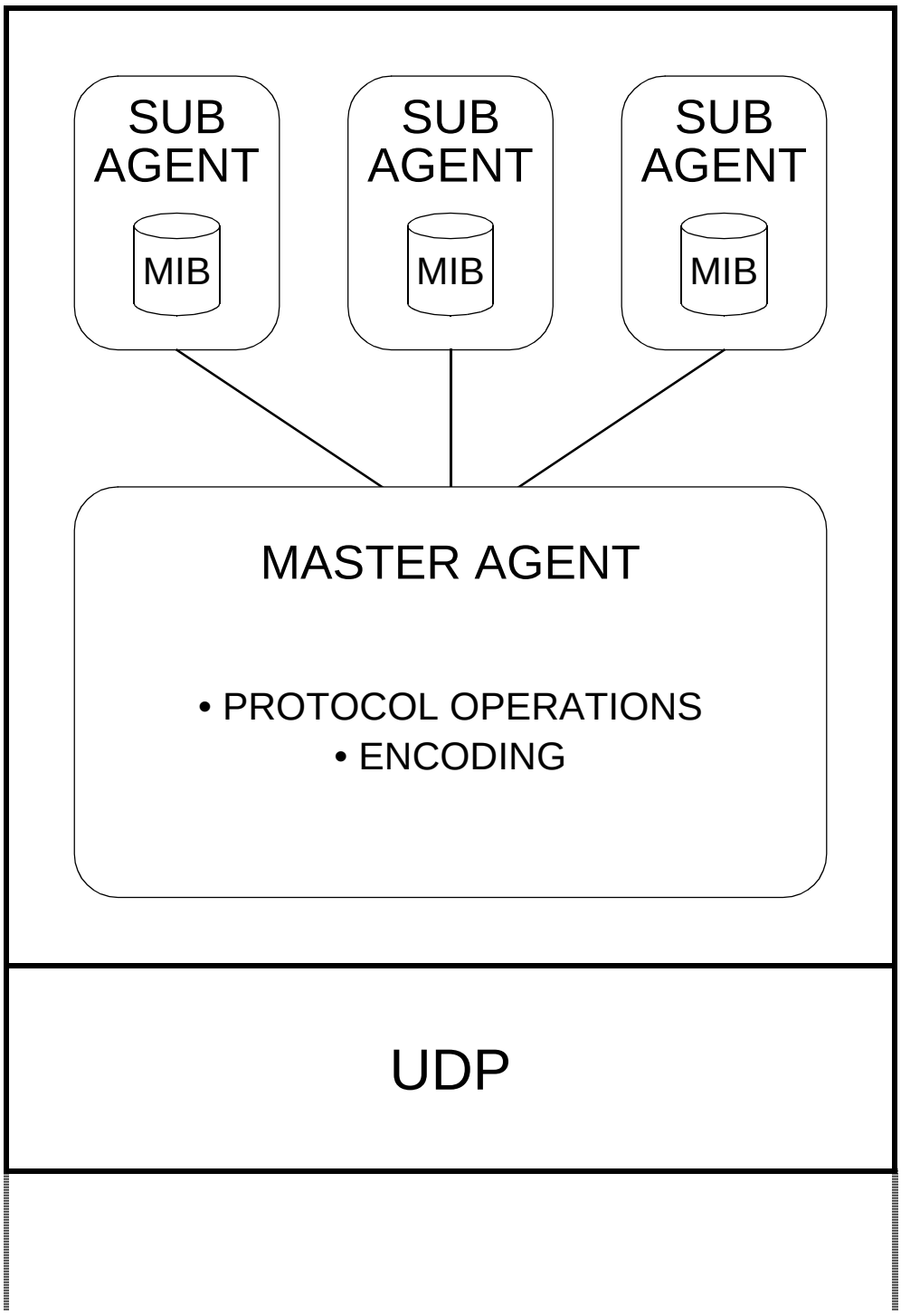
IDEA BEHIND THE DATA ENCRYPTION STANDARD (DES)



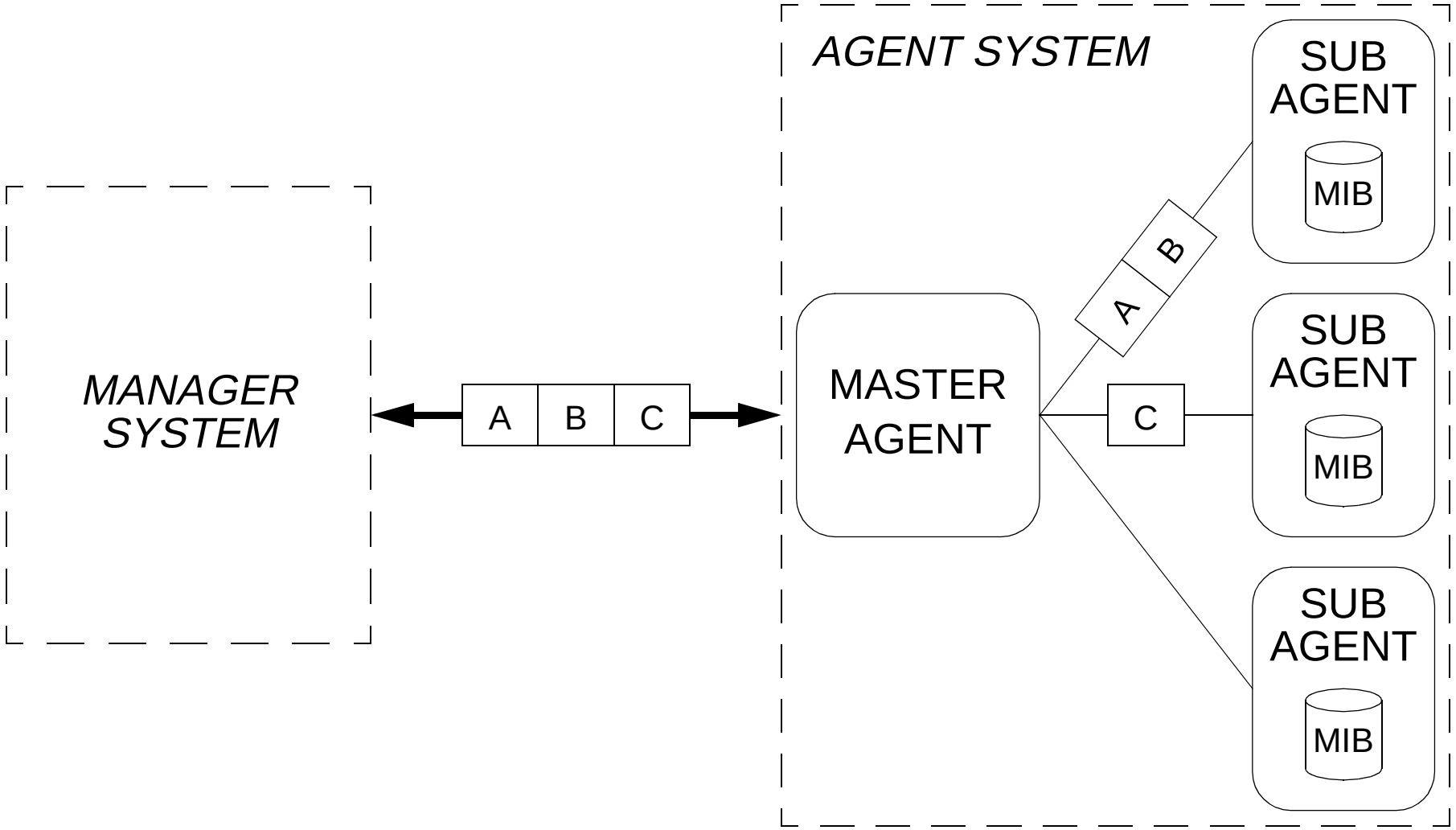
ENCRYPTION


DES-KEY
DATA
DES ALGORITHM
ENCRYPTED DATA
ID
ENCRYPTED DATA
DES-KEY
DATA
DES ALGORITHM
ENCRYPTED DATA
ID
ENCRYPTED DATA

EXTENSIBLE AGENTS

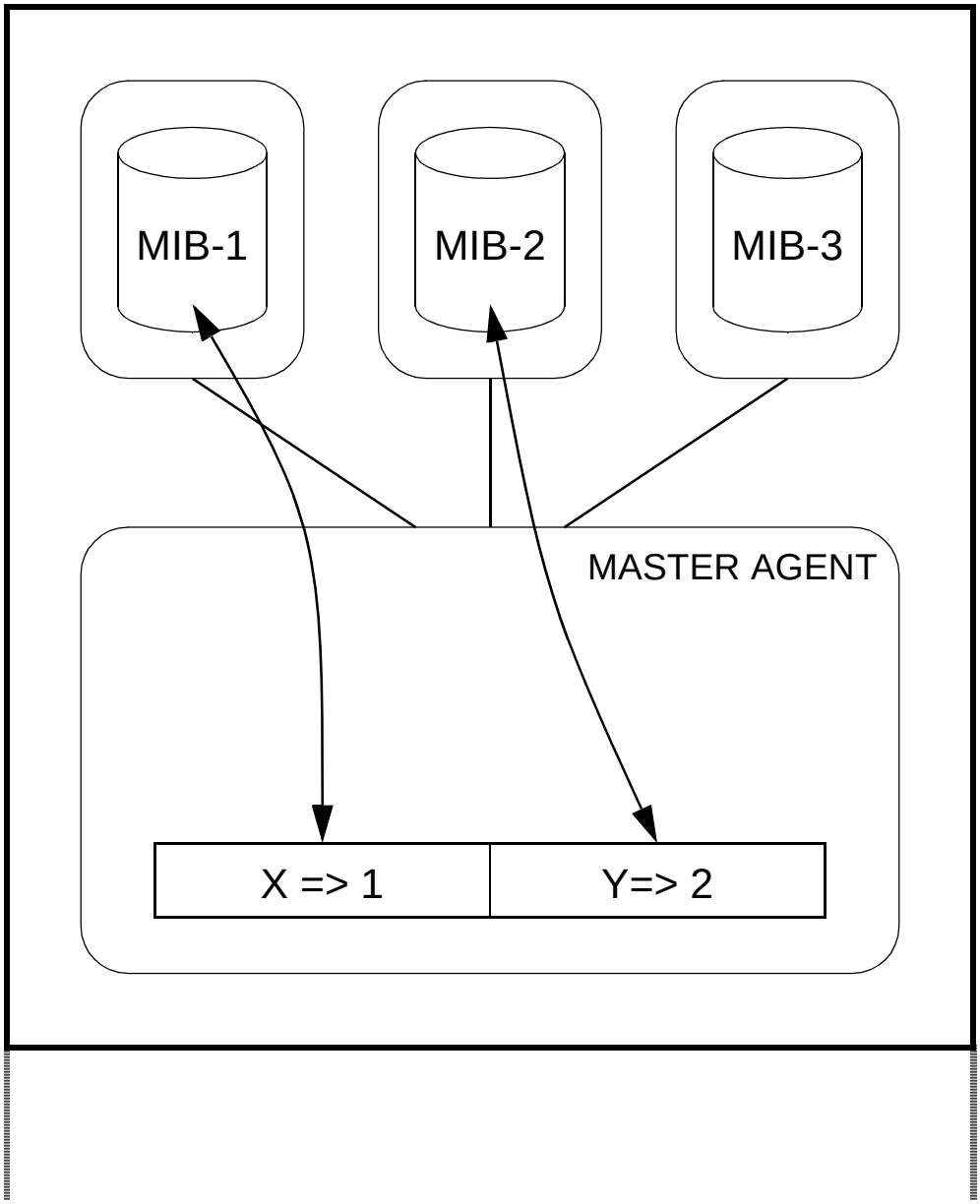


EXTENSIBLE AGENTS



EXTENSIBLE AGENTS

SETS AND ATOMICITY



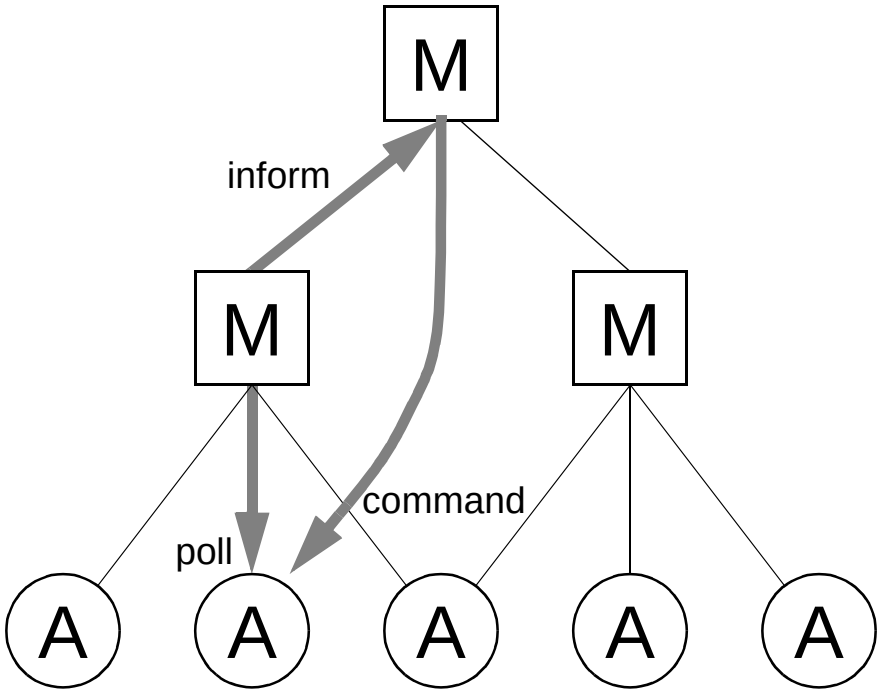
TRANSACTION-LIKE APPROACH

- PROBE
- COMMIT
- CLEAR / ROLL-BACK

DISTRIBUTED MANAGEMENT

TWO APPROACHES ARE BEING DEFINED:
- MIB BASED
- SCRIPT BASED

MIB-BASED:



- STANDARD MIB APPROACH

- LIMITED FUNCTIONALITY

- RUN-TIME BEHAVIOUR MUST BE DEFINED AT IMPLEMENTATION TIME

SCRIPT BASED

• FUNCTIONALITY CAN BE DEFINED
AT RUN-TIME

• POWERFUL
AUTONOMOUS ACTIONS

• MAY BE EASIER TO OPERATE
FOR THE TOP-LEVEL MANAGER

• PROTECTION MECHANISMS NECESSARRY

• DIFFERENT SCRIPT LANGUAGES

FURTHER INFORMATION

WWW SERVERS

- The SimpleWeb
http://wwwsnmp.cs.utwente.nl

- The Smurfland NM Web Server
- http://netman.cit.buffalo.edu

- The Simple Times
http://www.simple-times.org/pub/simple-times

- IETF
http://www.ietf.org

FURTHER INFORMATION

BOOKS

• W. Stallings
SNMP, SNMPv2 and RMON
2nd edition, Addison-Wesley, 1996
ISBN: 0-201-63479-1

• M.T. Rose
The Simple Book
2nd edition, Prentice Hall, 1994
ISBN: 0-131-77254-6

• M.T. Rose, K. McCloghrie
How to manage your network using SNMP
Prentice Hall, 1995
ISBN: 0-13-141517-4

• D. Perkins, E. McGinnis
Understanding SNMP MIBs
Prentice Hall, 1997
ISBN: 0-13-437708-7