INTERNET MANAGEMENT PROTOCOLS

STATE OF THE ART / RECENT DEVELOPMENTS

TUTORIAL T6 - PRESENTED AT IM'2003
COLORADO SPRINGS, USA
24 MARCH 2003

AIKO PRAS
UNIVERSITY OF TWENTE
THE NETHERLANDS

pras@cs.utwente.nl
http://wwwhome.cs.utwente.nl/~pras

http://www.simpleweb.org/tutorials

OVERVIEW

BACKGROUND
- HISTORY, GOALS & STANDARDS

- STRUCTURE OF MANAGEMENT INFORMATION
  - SCALARS
  - TABLES

- MANAGEMENT INFORMATION BASES
  - OVERVIEW
  - MIB-II
  - SNMPv2, IF & IP MIB

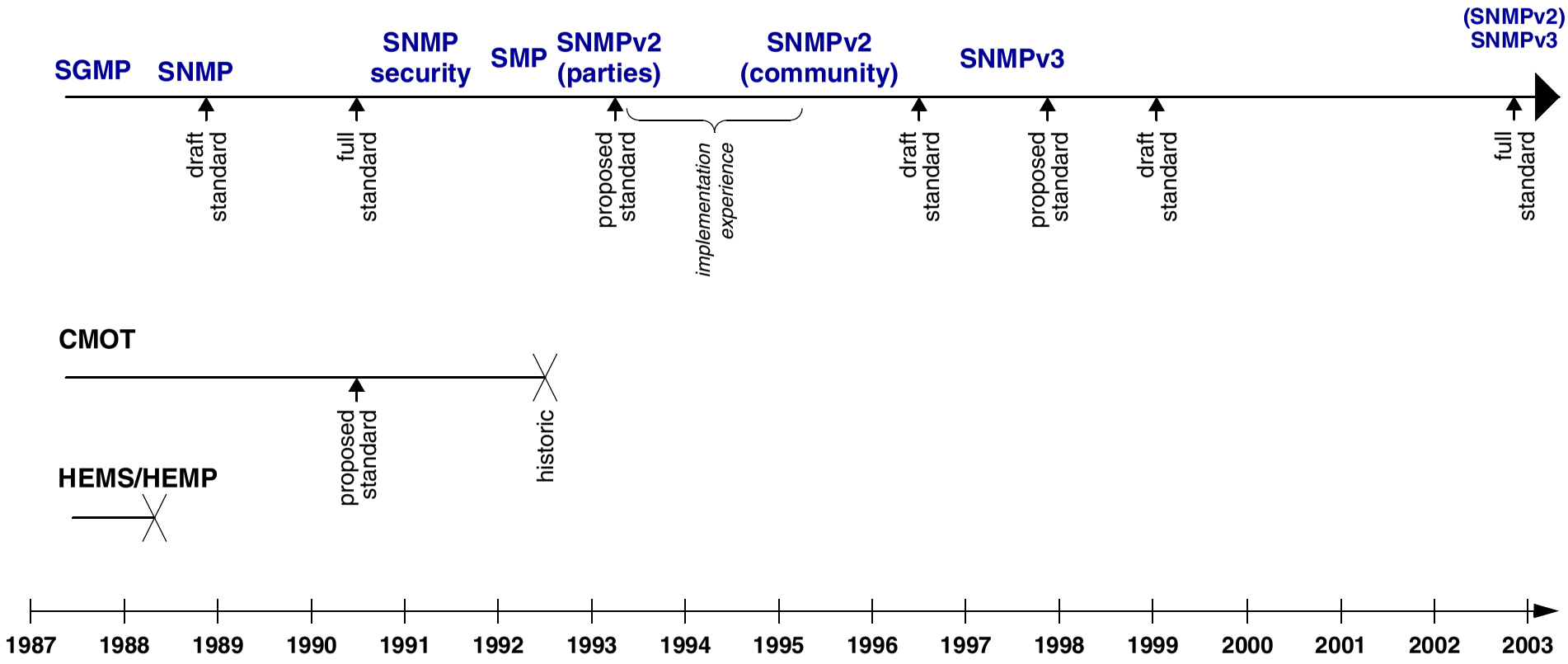
- SIMPLE NETWORK MANAGEMENT PROTOCOL
  - VERSION 1
  - VERSION 2
  - VERSION 3

AGENTX
DISMAN

RECENT DEVELOPMENTS

FURTHER INFORMATION

SNMP HISTORY



SNMP GOALS

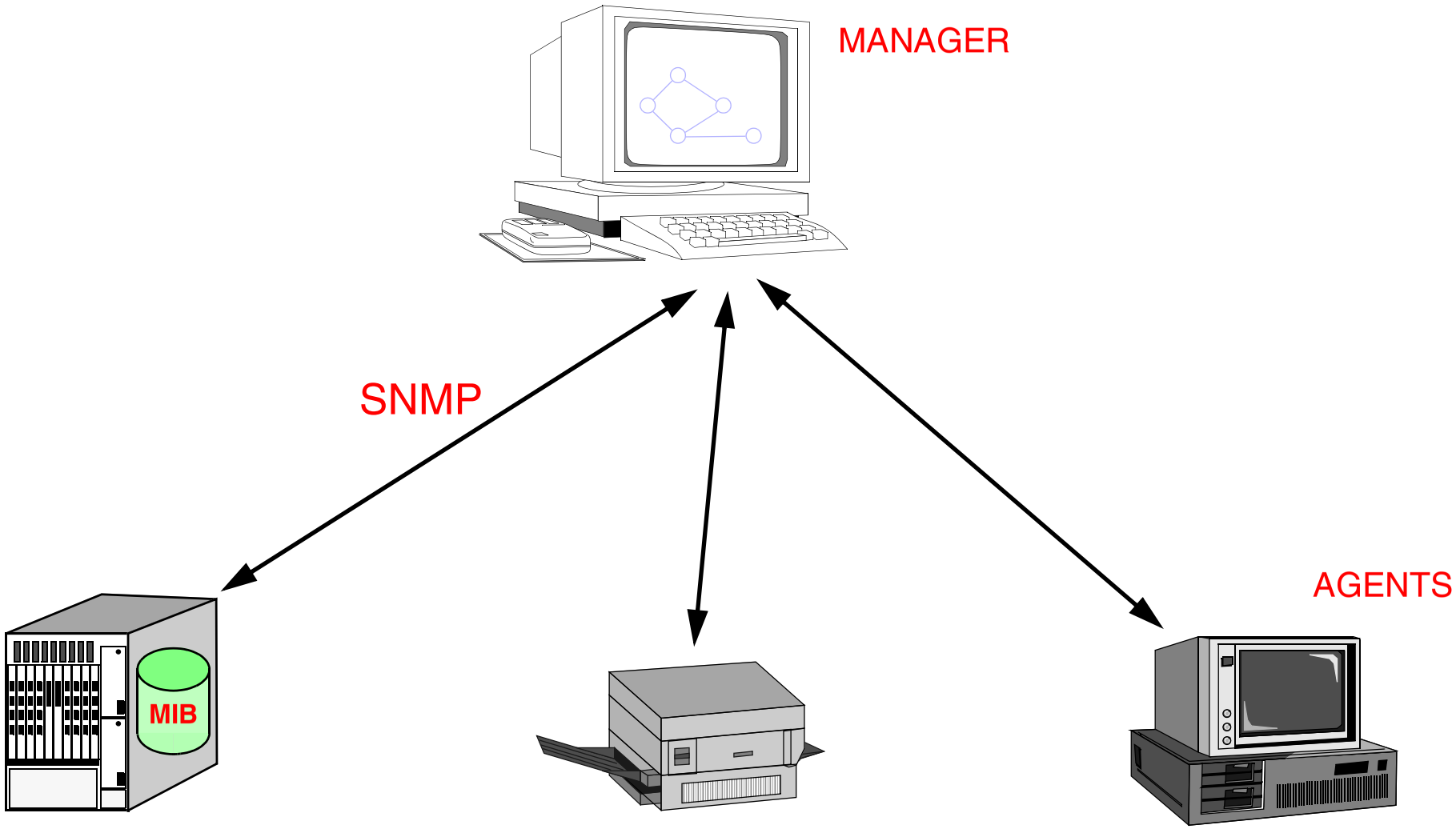
UBIQUITY
- PCs AND CRAYs

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

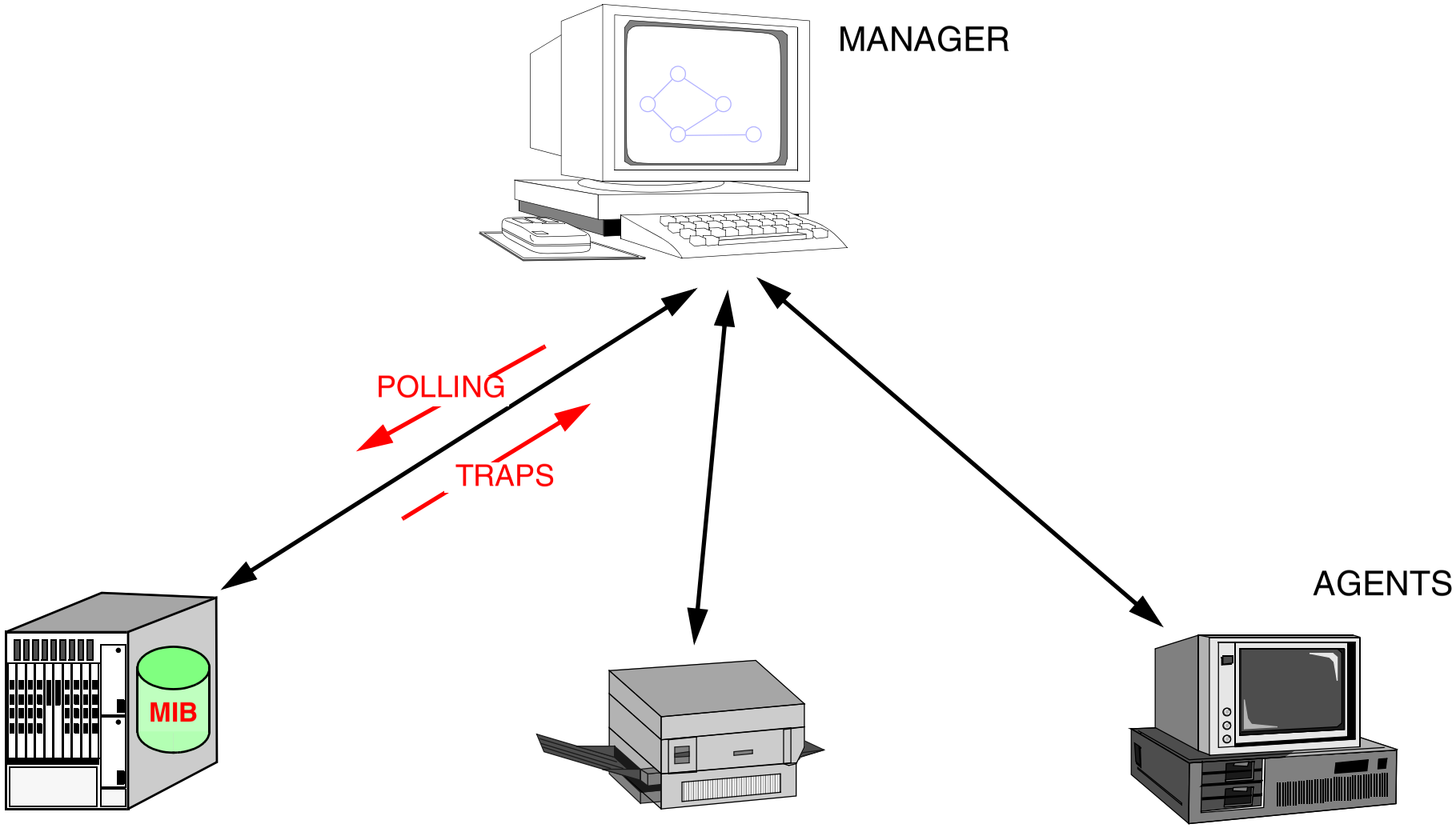
MANAGEMENT EXTENSIONS SHOULD BE POSSIBLE
- NEW MIBs

MANAGEMENT SHOULD BE ROBUST
- CONNECTIONLESS TRANSPORT

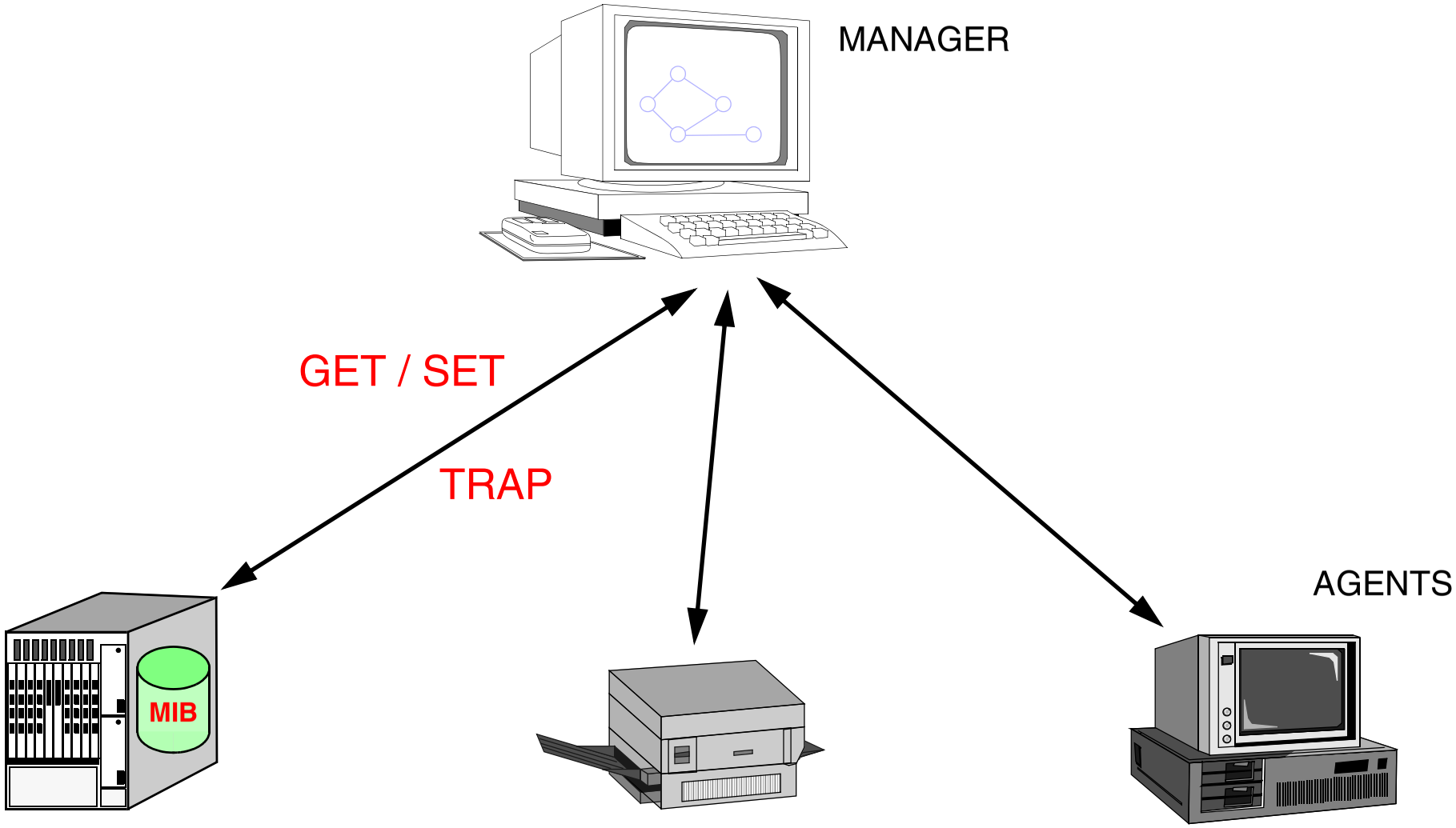
PRINCIPLE OPERATION



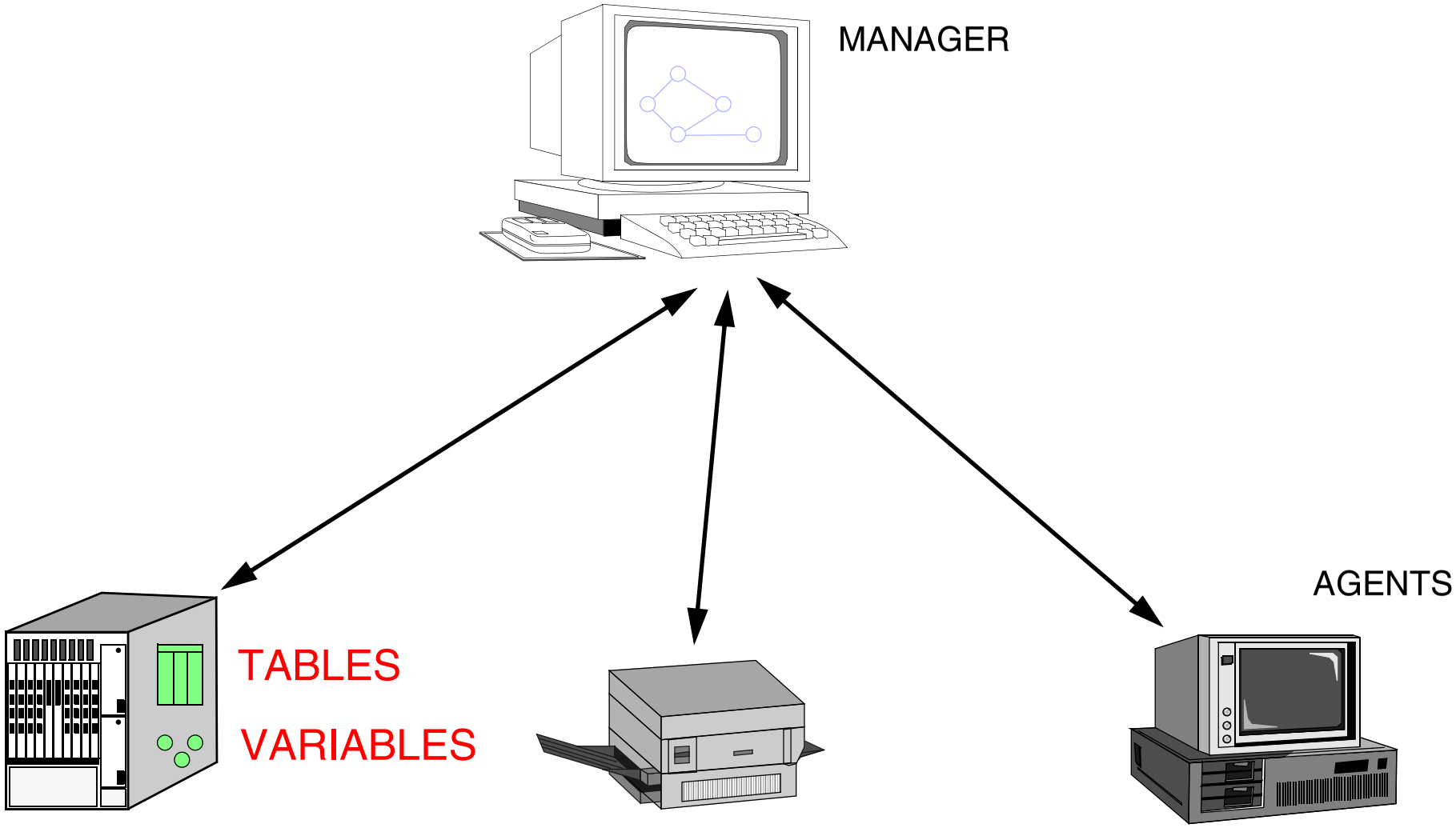
PRINCIPLE OPERATION



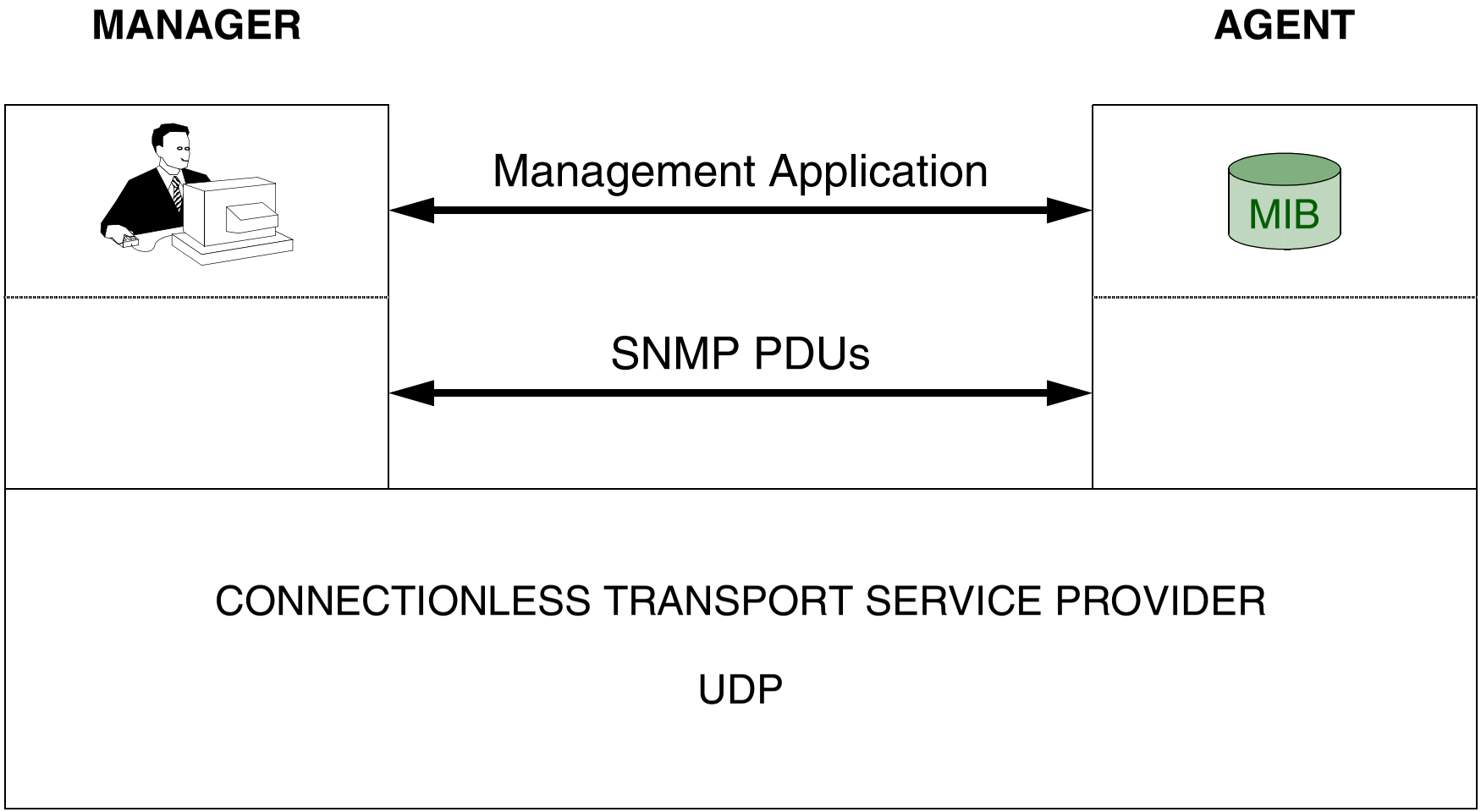
PRINCIPLE OPERATION



PRINCIPLE OPERATION



SNMP STRUCTURE



STANDARDS

SMI

• STRUCTURE OF MANAGEMENT INFORMATION
• TWO VERSIONS
• RFC 1155, RFC 2578, ...

MIBs

• MANAGEMENT INFORMATION BASEs
• A LARGE NUMBER OF MIBs EXIST
• RFC 1213, ...

SNMP

• SIMPLE NETWORK MANAGEMENT PROTOCOL
• NAME IS USED IN A MORE GENERAL SENSE
• VERSION 1: HISTORIC (RFC 1157)
• VERSION 3: STANDARD (RFC 3411-3416)

SMI

STRUCTURE OF MANAGEMENT INFORMATION

RFC 1155: SMIv1

RFC 1212: CONCISE MIB DEFINITIONS

RFC 2578: SMIv2

RFC 2579: TEXTUAL CONVENTIONS

MAKES THE DEFINITION OF (NEW) MIBs EASIER

SMI

MANAGEMENT INFORMATION WITHIN MANAGED SYSTEMS
MUST BE REPRESENTED AS:

- SCALARS
- TABLES

(= TWO DIMENSIONAL ARRAYS OF SCALARS)

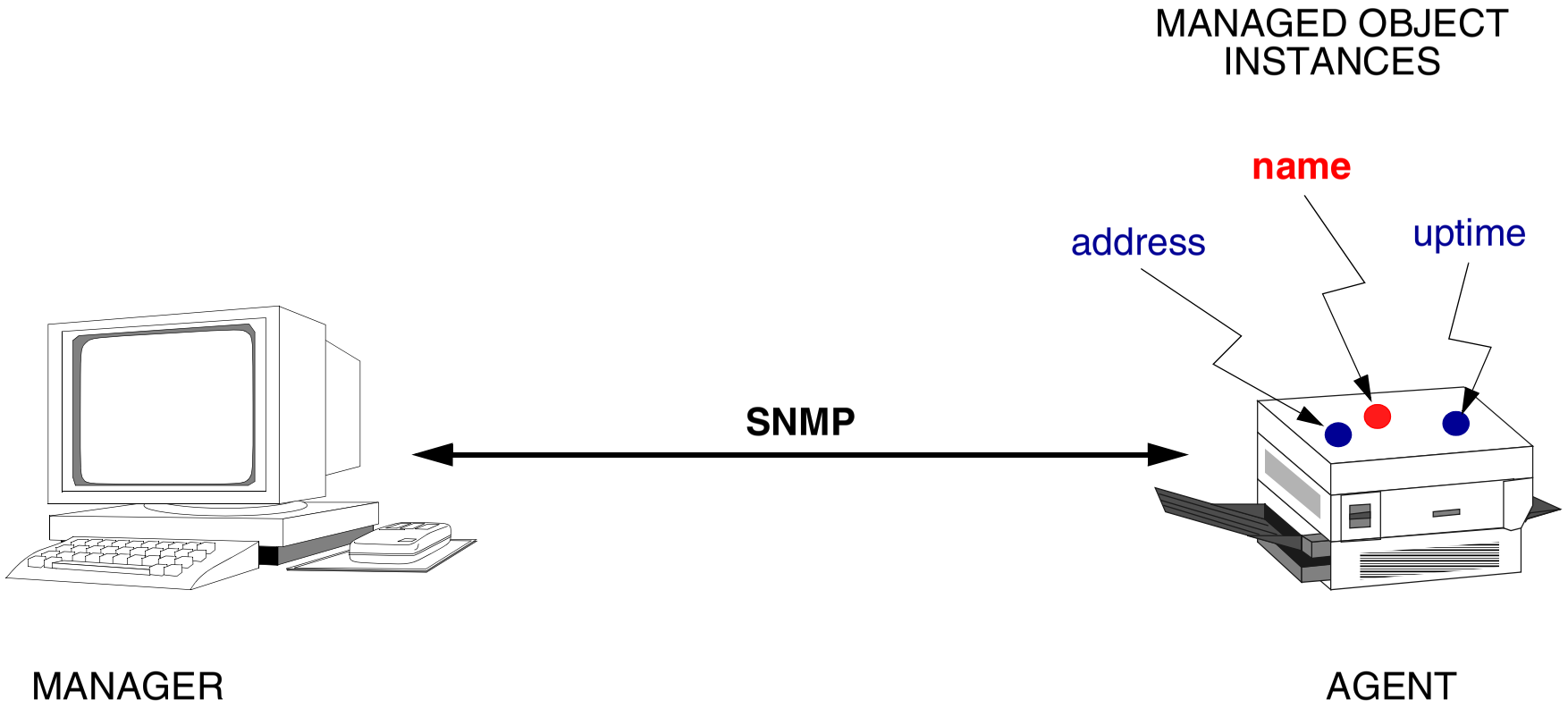
THE SNMP PROTOCOL CAN ONLY EXCHANGE
(A LIST OF) SCALARS

DEFINED IN TERMS OF ASN.1 CONSTRUCTS

SMI: DATA TYPES FOR SCALARS

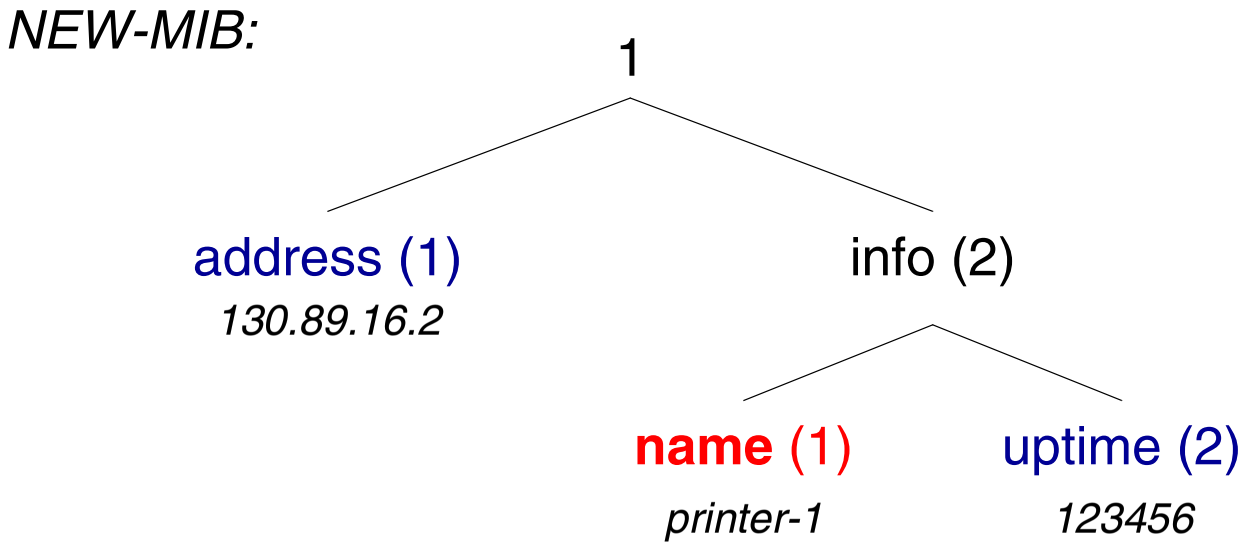
	SMIv1	SMIv2
SIMPLE TYPES:	INTEGER	INTEGER
	OCTET STRING	OCTET STRING
	OBJECT IDENTIFIER	OBJECT IDENTIFIER
	-	Integer32
APPLICATION-WIDE TYPES:	-	Unsigned32
	Gauge	Gauge32
	Counter	Counter32
	-	Counter64
	TimeTicks	TimeTicks
	IpAddress	IpAddress
	Opaque	Opaque
	NetworkAddress	-
PSEUDO TYPES:	-	BITS

EXAMPLE OF SCALAR OBJECTS



OBJECT NAMING

INTRODUCE NAMING TREE



THE LEAVES OF THE TREE REPRESENT THE MANAGED OBJECTS

NODES ARE INTRODUCED FOR NAMING PURPOSES

OBJECT NAMING

• address
Object ID = 1.1
Object Instance = 1.1.0
Value of Instance = *130.89.16.2*

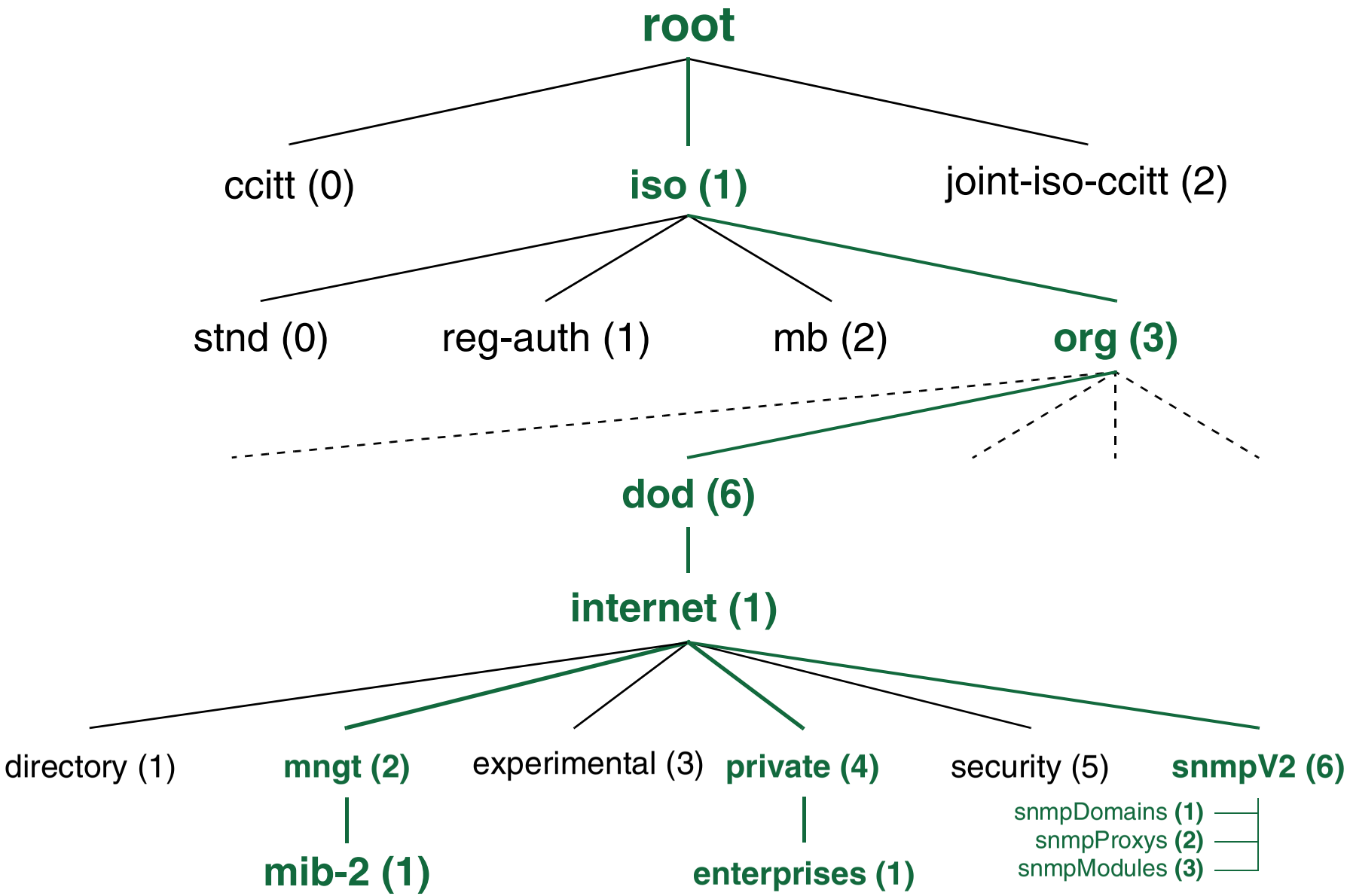
• info
Object ID = 1.2

• name
Object ID = 1.2.1
Object Instance = 1.2.1.0
Value of Instance = *printer-1*

• uptime
Object ID = 1.2.2
Object Instance = 1.2.2.0
Value of Instance = *123456*

ALTERNATIVE:
Object ID = NEW-MIB info uptime

OBJECT NAMING: MIBs



OBJECT TYPE DEFINITION

OBJECT-TYPE:

SYNTAX
- INTEGER
- OCTET STRING
- OBJECT IDENTIFIER
- BITS
- IpAddress
- Integer32
- Counter32
- Counter64
- Gauge32
- TimeTicks
- Opaque
- New Type

MAX-ACCESS
- read-only
- read-write
- read-create
- accessible-for-notify
- not-accessible

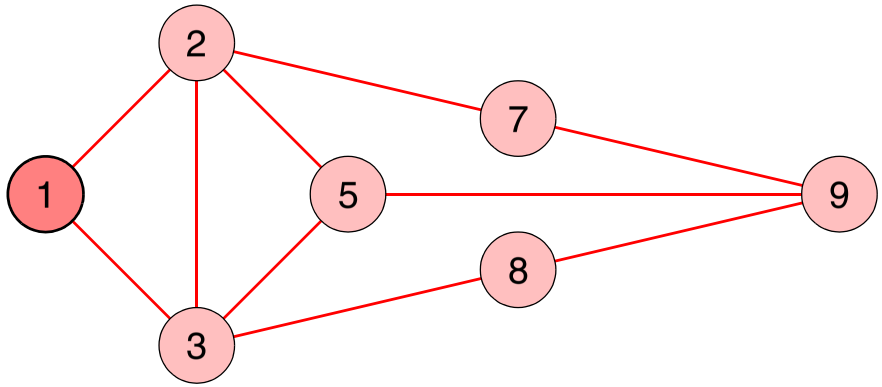
STATUS
- current
- deprecated
- obsolete

DESCRIPTION ""

TABLES

EXAMPLE: ROUTING TABLE

destination	next
2	2
3	3
5	2
7	2
8	3
9	3



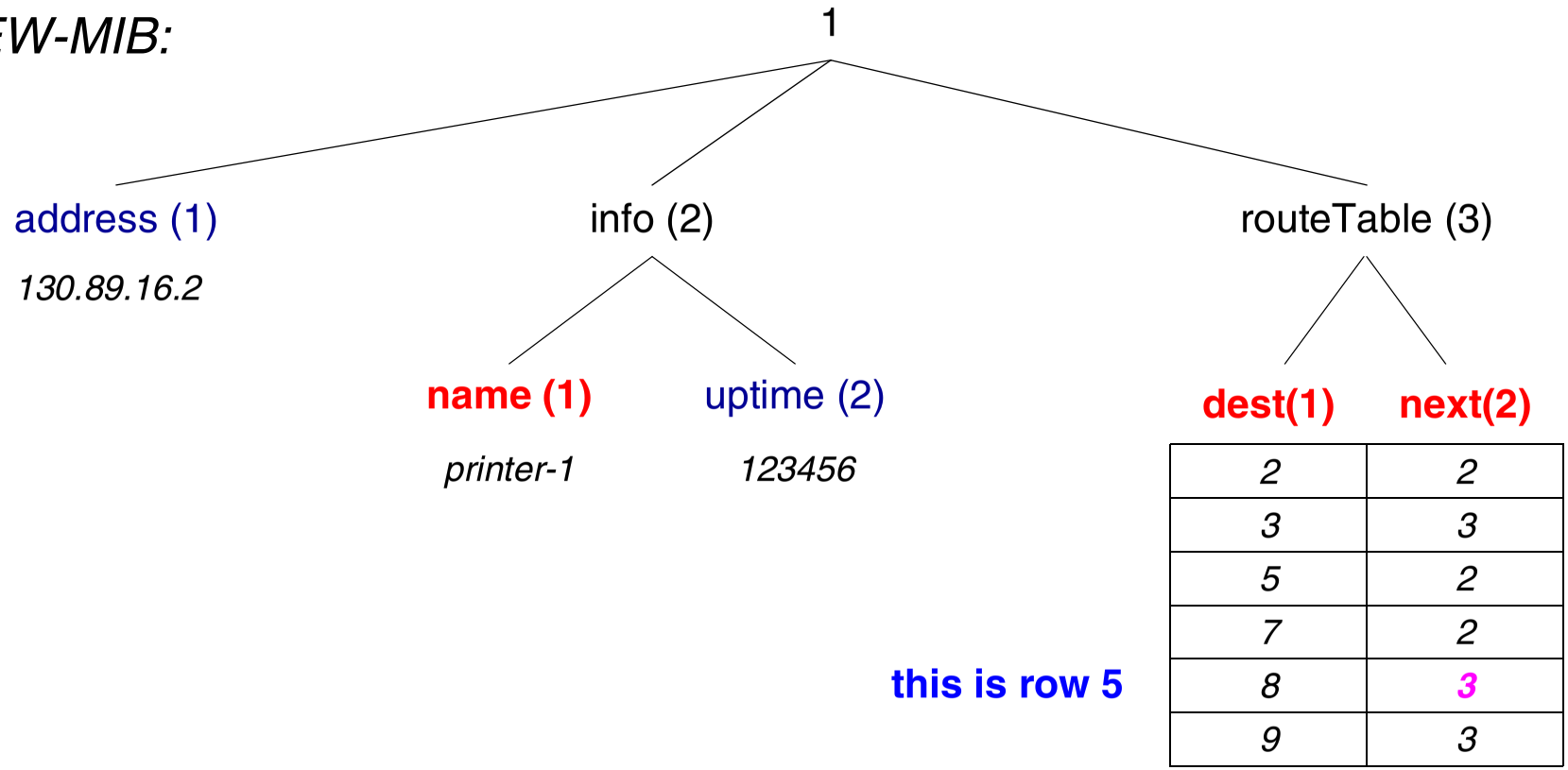
TO RETRIEVE INDIVIDUAL TABLE ENTRIES

EACH ENTRY SHOULD GET AN IDENTIFIER

NAMING OF TABLE ENTRIES - I

POSSIBILITY 1 (NOT BEING USED BY SNMP): USE ROW NUMBERS

NEW-MIB:

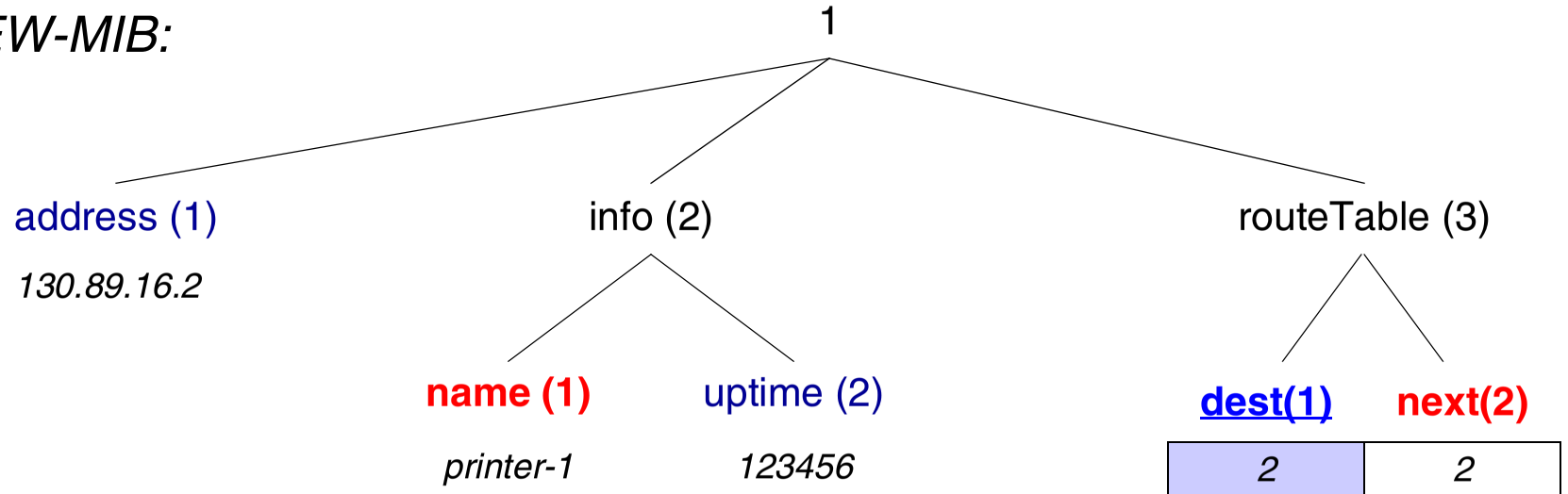


EXAMPLE: THE VALUE OF *NEW-MIB routeTable next 5* IS *3*

NAMING OF TABLE ENTRIES - II

POSSIBILITY 2 (USED BY SNMP): INTRODUCE AN INDEX COLUMN

NEW-MIB:



EXAMPLE: THE VALUE OF *NEW-MIB routeTable next 5* IS *2*

TABLE INDEXING

GENERAL SCHEME

X.C.I

OID of Table Column number Index value

EXAMPLES:

OID of Table = 1.3

1.3.1.5 => *5*
1.3.2.5 => *2*
1.3.1.9 => *9*
1.3.2.9 => *3*
1.3.2.7 => *2*
1.3.1.1 => *entry does not exist*
1.3.2.1 => *entry does not exist*

TABLE INDEXING - NON-INTEGER INDEX

AN INDEX NEED NOT BE AN INTEGER

routeTable (3)

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

EXAMPLES:

OID of Table = 1.3

1.3.1.130.89.16.23 => *130.89.16.23*

1.3.2.130.89.16.23 => *130.89.16.1*

1.3.1.193.22.11.97 => *193.22.11.97*

1.3.2.193.22.11.97 => *130.89.16.4*

1.3.2.130.89.19.121 => *130.89.16.1*

TABLE INDEXING - MULTIPLE INDEX FIELDS

USE OF MULTIPLE INDEX FIELDS

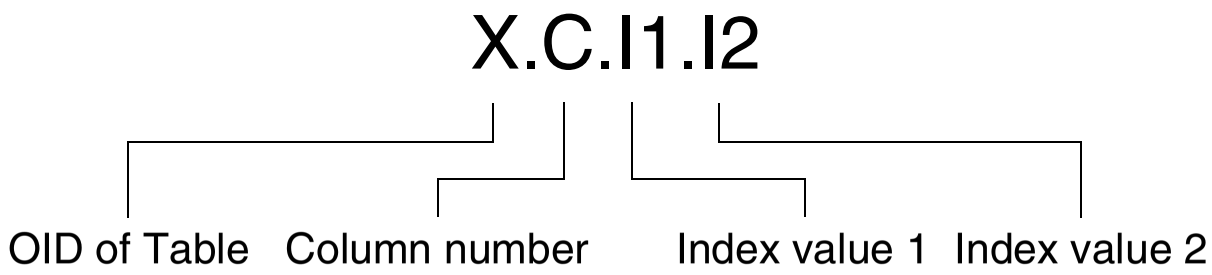
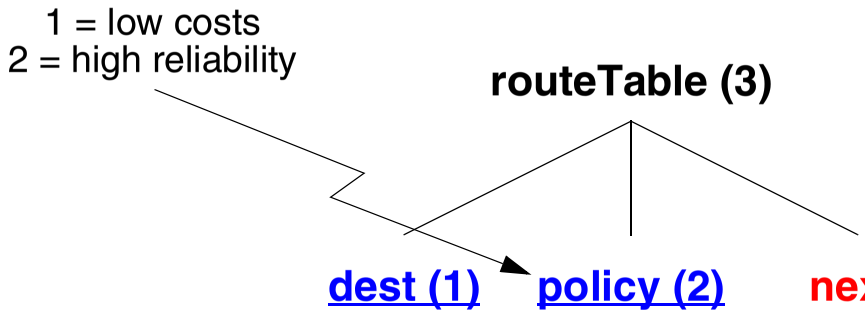


TABLE INDEXING - MULTIPLE INDEX FIELDS: EXAMPLE

EXAMPLE:



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*

1.3.3.192.1.23.24.1 => *130.89.16.1*

1.3.3.192.1.23.24.2 => *130.89.16.4*

DEFINITION OF NEW TYPES

TEXTUAL CONVENTIONS

TO REFINE SEMANTICS OF EXISTING TYPES

EXAMPLE:

```
RunState ::= TEXTUAL CONVENTION
   STATUS current
   DESCRIPTION "..."
   SYNTAX INTEGER{
      running(1)
      runable(2)
      waiting(3)
      exiting(4)}
```

TEXTUAL CONVENTIONS

- PhysAddress
- MacAddress
- TruthValue
- AutonomousType
- InstancePointer
- VariablePointer
- RowPointer
- RowStatus
- TimeStamp
- TimeInterval
- DateAndTime
- StorageType
- TDomain
- TAddress

- Inet-Address...

NOTIFICATION TYPES

SMIv2:

- MIBs MAY NOW INCLUDE NOTIFICATION TYPE MACROS

EXAMPLE:

```
linkUp NOTIFICATION-TYPE
   OBJECTS   {ifIndex}
   STATUS    current
   DESCRIPTION
      "A linkUp trap signifies that the
      entity has detected that the
      ifOperStatus object has changed to Up"
::= {snmpTraps 4}
```

SMIng

PROBLEMS WITH SMIv1 / v2

- SMIv2 RELIED ON 1988 VERSION OF ASN.1
- TOOLS FOR SMIv2 RELATIVELY COMPLEX
- CERTAIN DATA TYPES WERE MISSING IN SMIv2
  64 bit integers, …
- LIMITED FACILITIES TO REUSE DEFINITIONS
- SMIv2 DID NOT ALLOW FOR EXTENSIONS
- NEW, POSSIBLY INCOMPATIBLE VARIANTS APPEARED
  SPPI, ...

SMIng

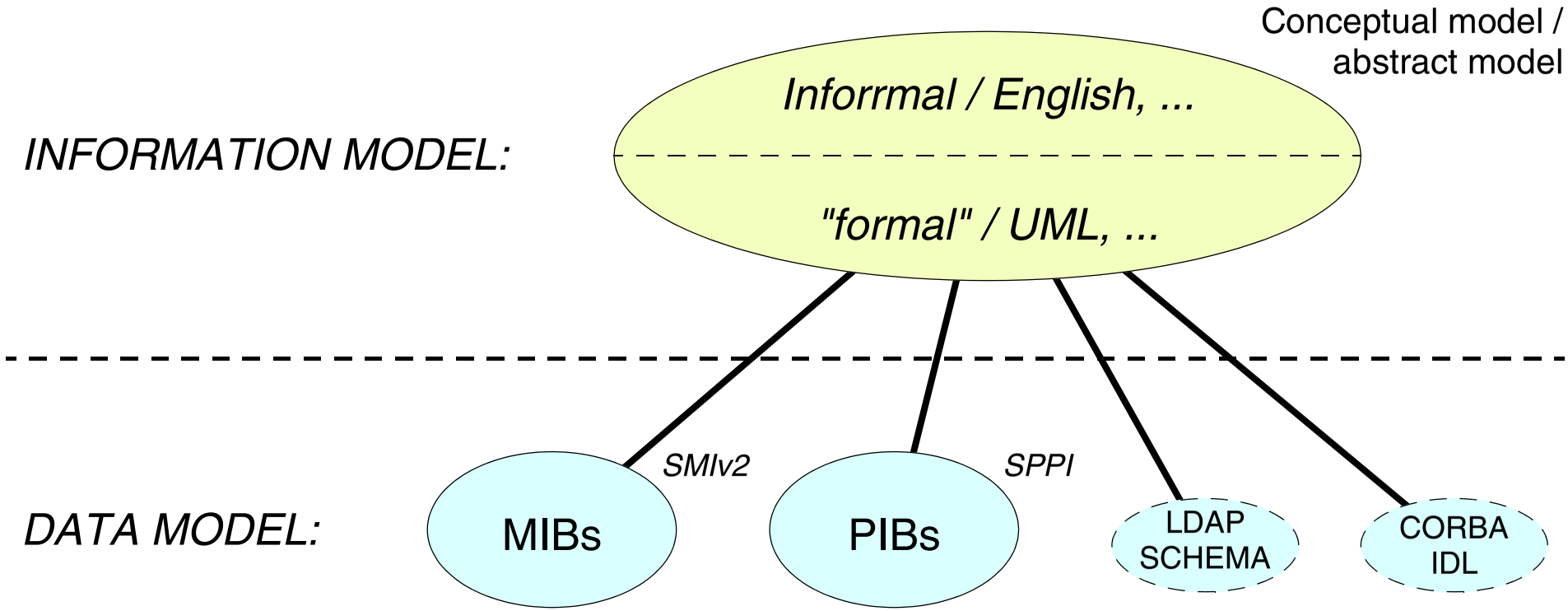
TO RESOLVE THESE PROBLEMS

THE IRTF NMRG DEFINED:

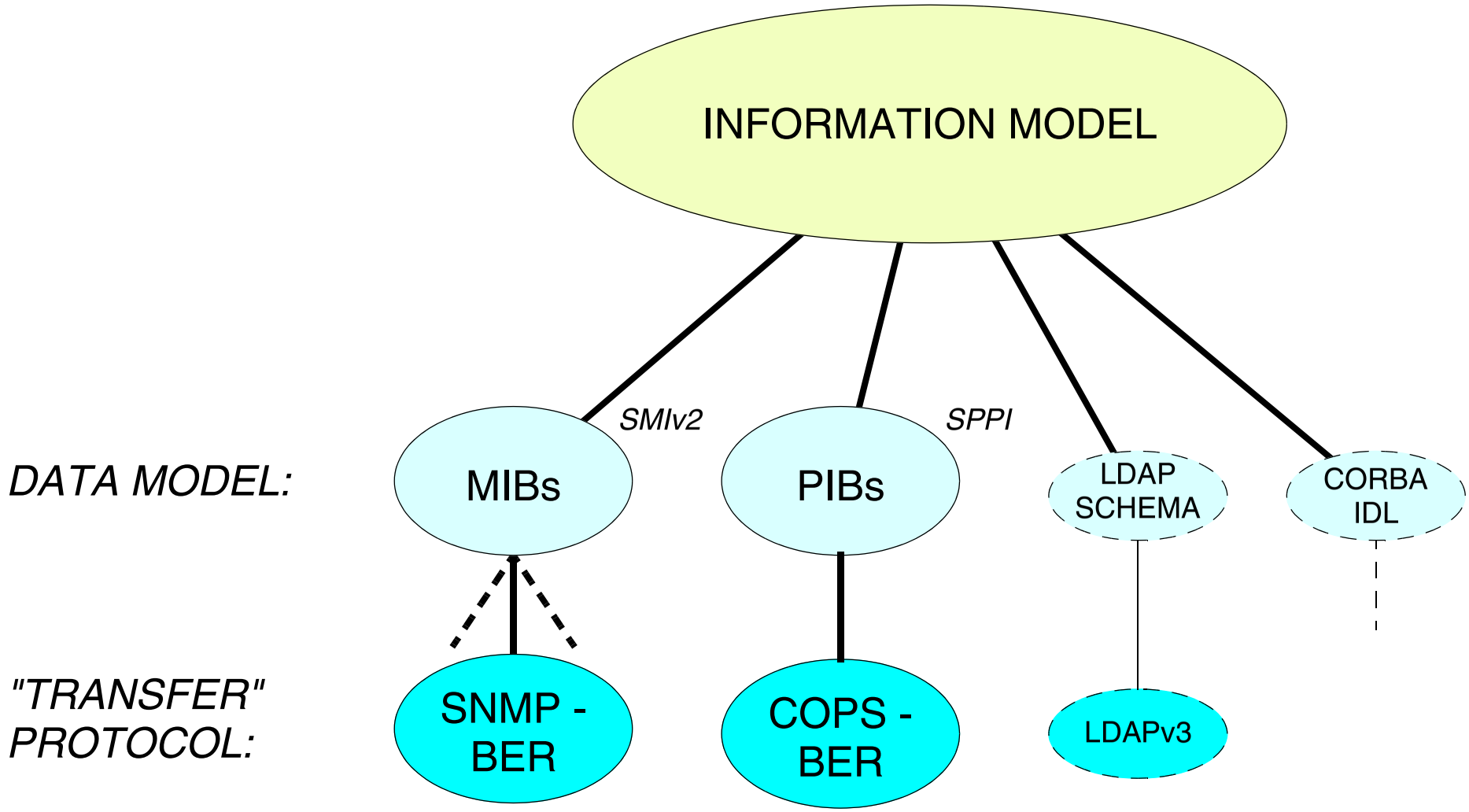
SMI Next Generation (ng)

THE CHALLANGE:
CREATE A COMMON DATA DEFINITION LANGUAGE,
INDEPENDENT OF SPECIFIC PROTOCOLS

DATA VERSUS INFORMATION MODEL

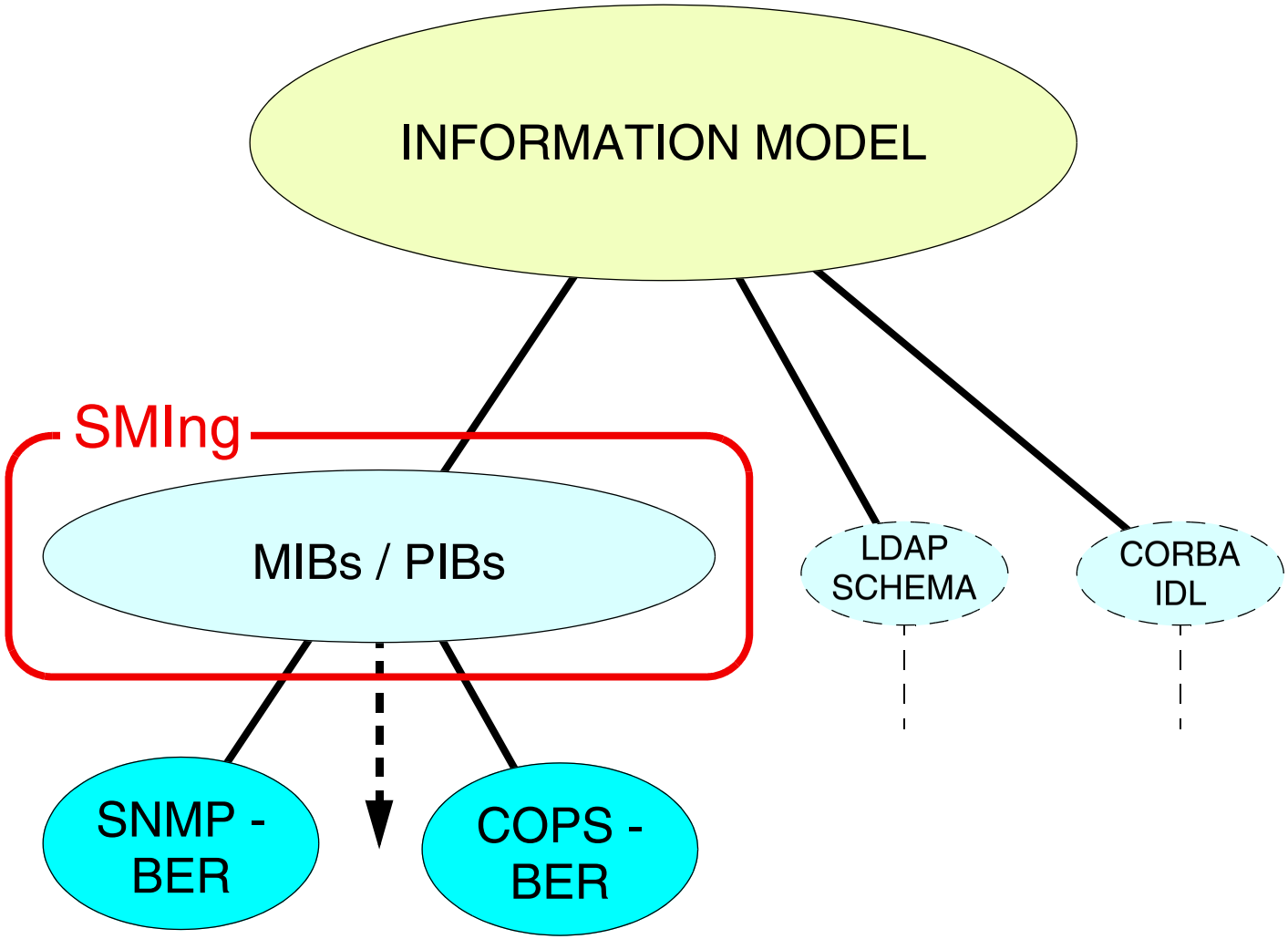


DATA MODEL & "TRANSFER" PROTOCOL"



ROLE OF SMIng

DATA MODEL:



SMIv3

IRTF-NMRG PROPOSAL FORWARDED TO IETF

SMIng WORKING GROUP FORMED

SMIv3

2000

SMIv3 OBJECTIVES

ALLOW ARBITRARILY NESTED DATA STRUCTURES

EASE REUSABILITY OF COMPLEX STRUCTURED TYPES

DETAILED LIST OF OBJECTIVES: RFC 3216

HOWEVER:

PROTOCOL INDEPENDENCE NO LONGER DESIRABLE

LANGUAGE EXTENSIBILITY NO LONGER DESIRABLE

FINALLY SMIv3 IS A RELATIVE SMALL UPDATE OF SMIv2

MIBs

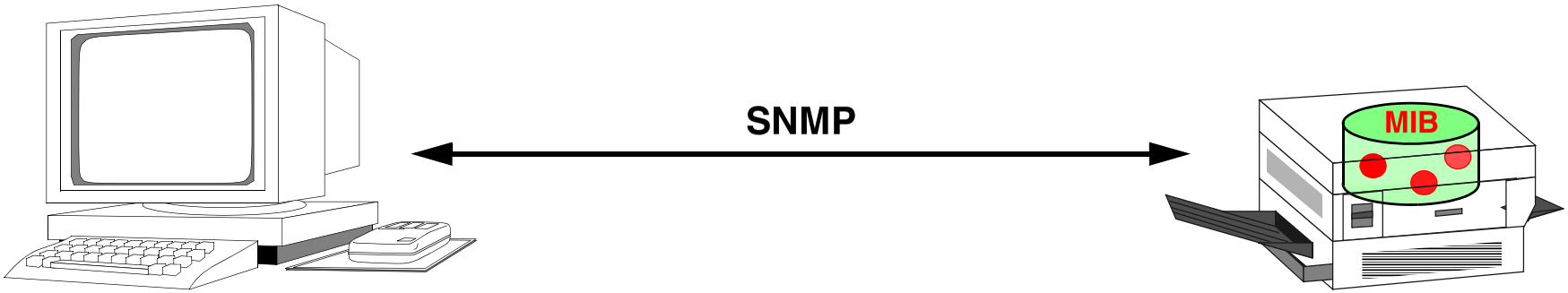
MANAGEMENT INFORMATION BASES

CONTAIN THE MANAGED OBJECTS (VARIABLES)

THAT REPRESENT THE RESOURCES OF A SYSTEM

AND WHICH MAY BE MONITORED AND MODIFIED BY A (REMOTE) MANAGER

TO CONTROL THE BEHAVIOUR OF THAT SYSTEM



MIB DEFINITION AND MIB INSTANCE

MIB DEFINITIONS SHOULD BE KNOWN BY:

- THE IMPLEMENTORS OF THE MANAGED SYSTEM
- THE MANAGER

THE MIB IS INSTANTIATED WITHIN THE MANAGED SYSTEM

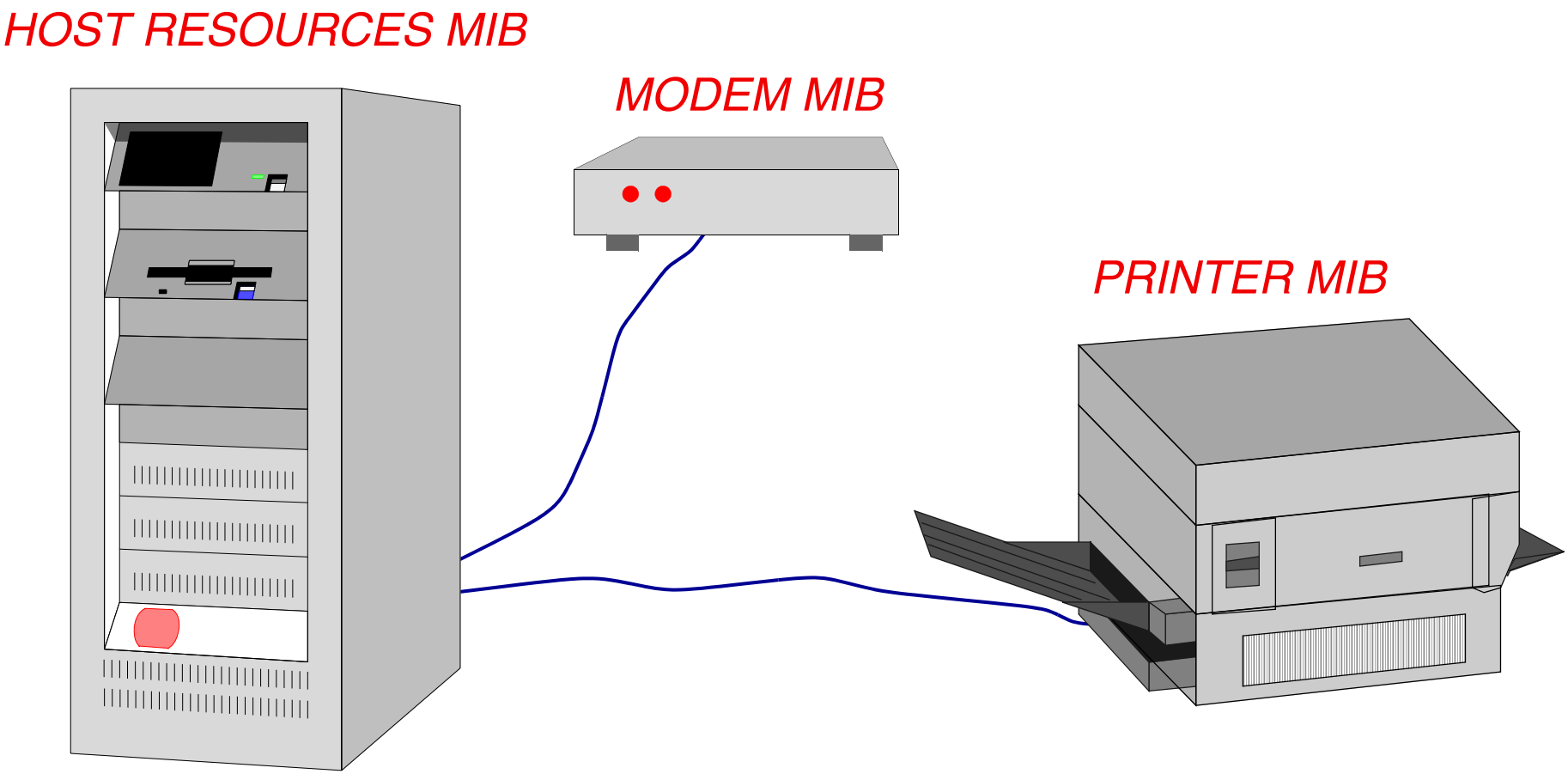
MODULARITY

THE MANAGED OBJECTS OF A SYSTEM
ARE USUALLY DEFINED IN MULTIPLE MIB DEFINITIONS

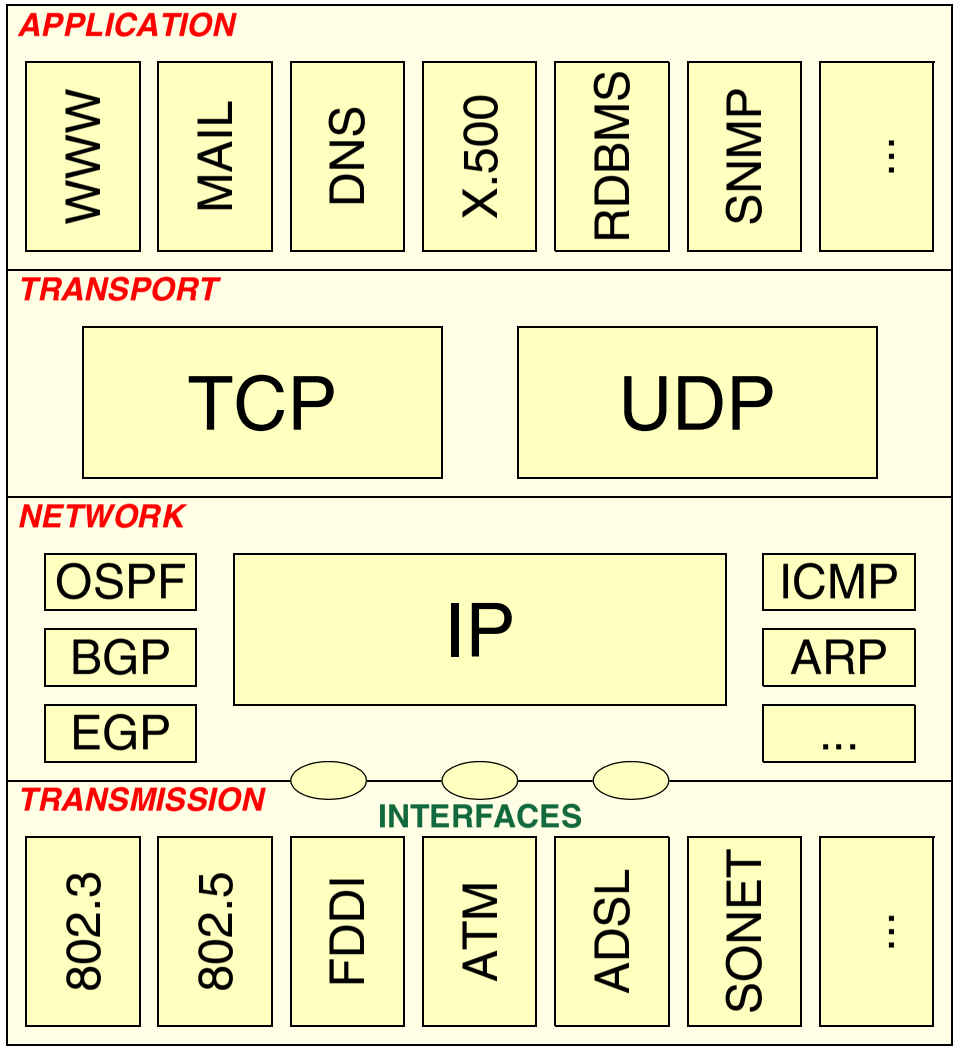
MODULES

- DIFFERENT MODULES CAN BE DEFINED BY DIFFERENT TEAMS
- MANAGEMENT FUNCTIONALITY CAN GRADUALLY BE EXTENDED
- DIFFERENT TYPES OF SYSTEMS
  CAN SUPPORT DIFFERENT MIB MODULES
- VENDORS CAN EXTEND THE MANAGEMENT FUNCTIONALITY
  VIA PROPRIETARY MIBS

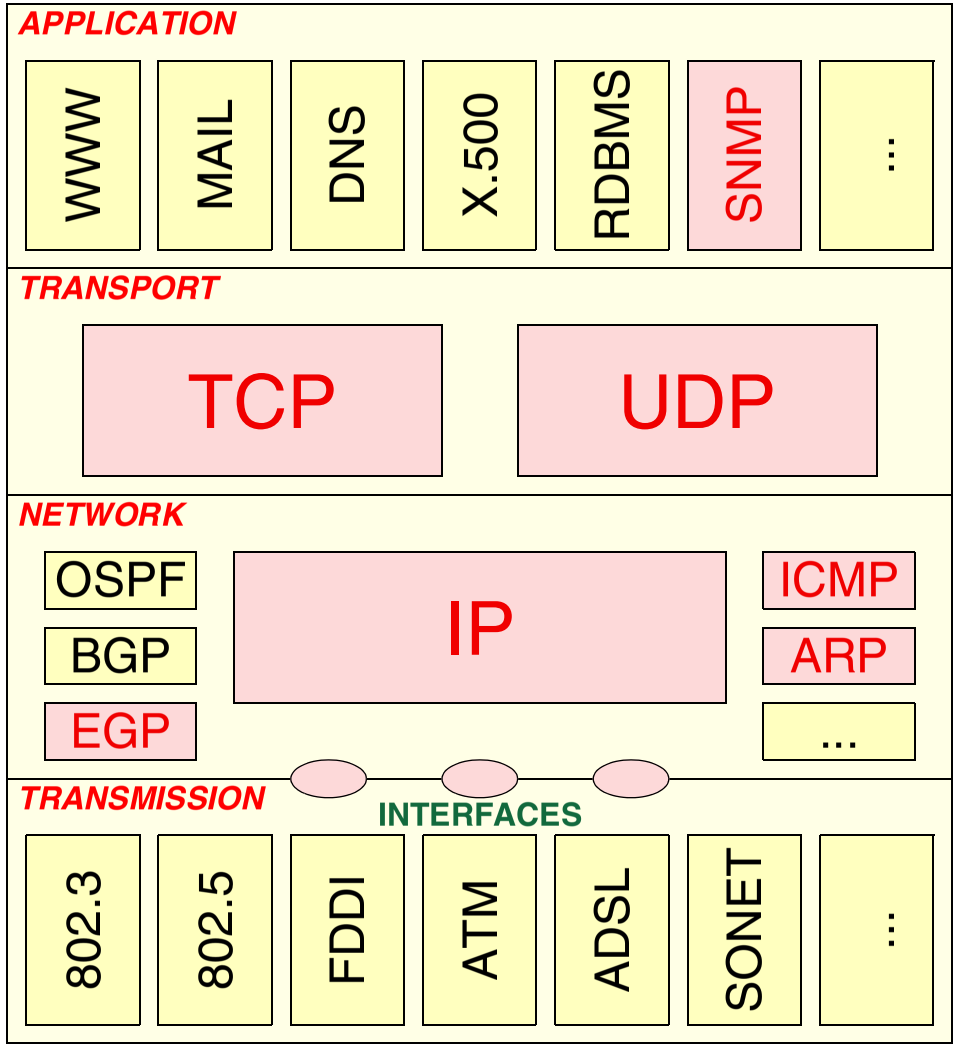
HARDWARE MIBS



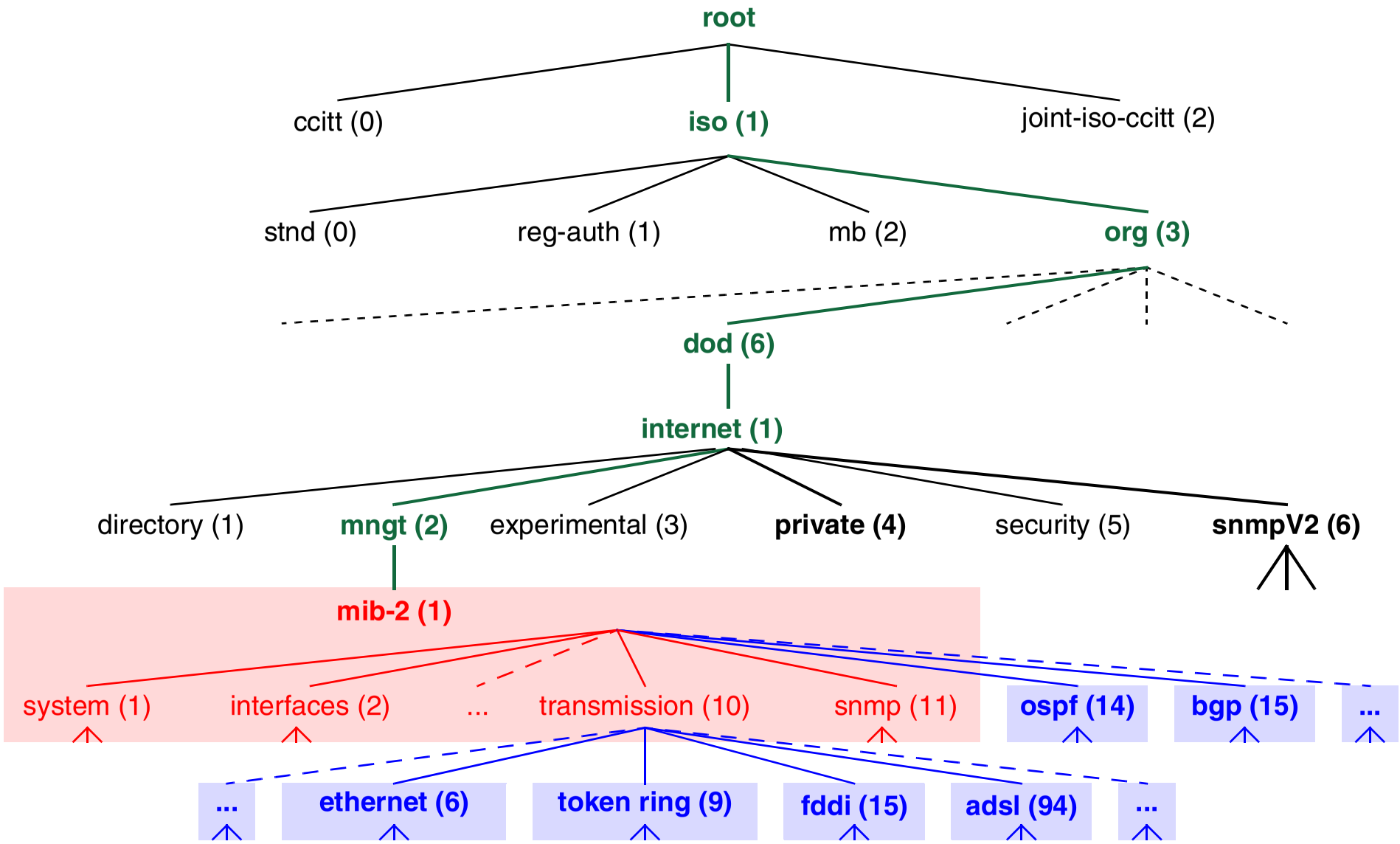
PROTOCOL MIBS



PROTOCOL MIBS - EXAMPLE: MIB-II



NAMING OF MIBs



MIB-II

DEFINES THE VARIABLES TO MANAGE THE TCP/IP PROTOCOL STACK

170 VARIABLES

RFC 1213
SMIv1

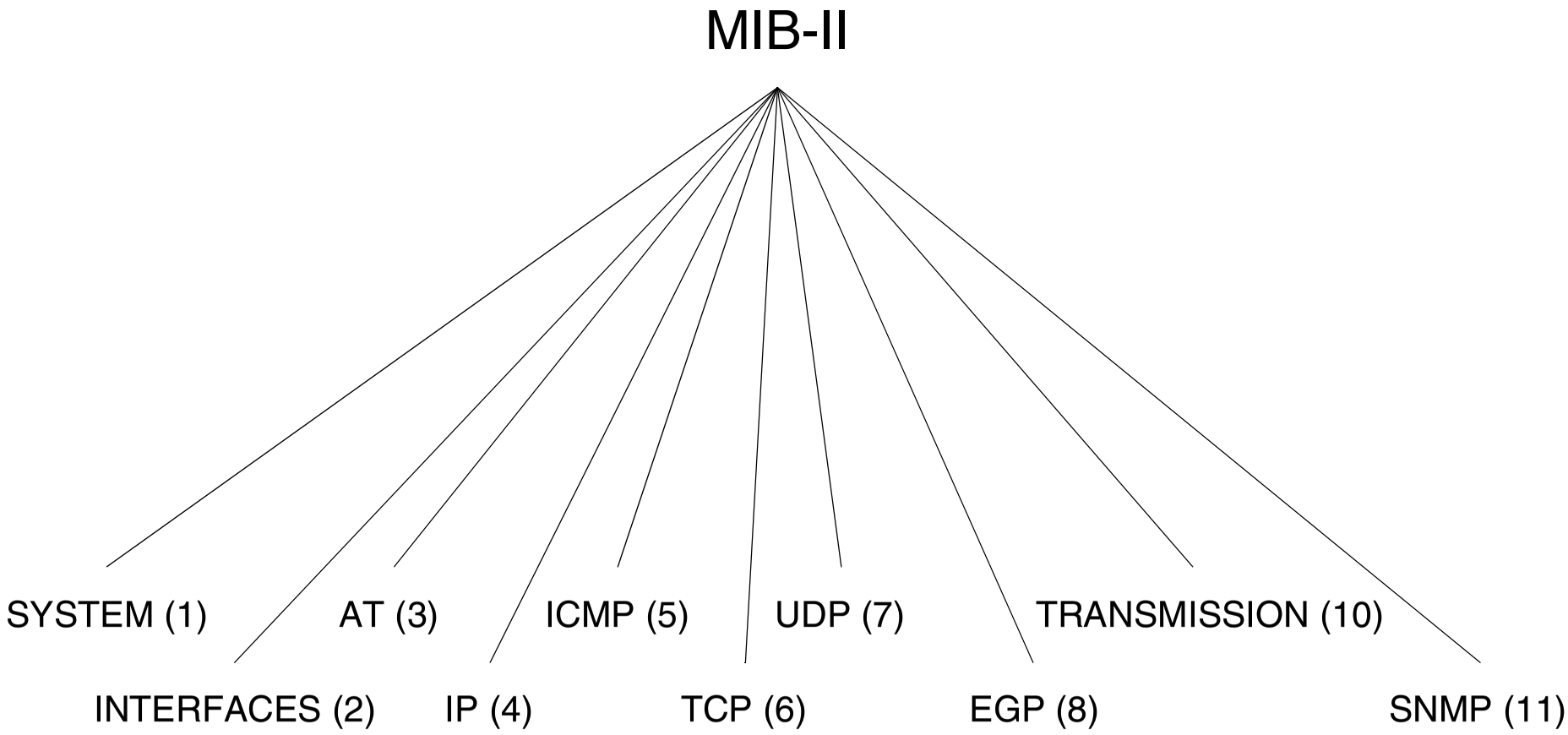
ENHANCEMENT OF MIB-I

RFC 1156

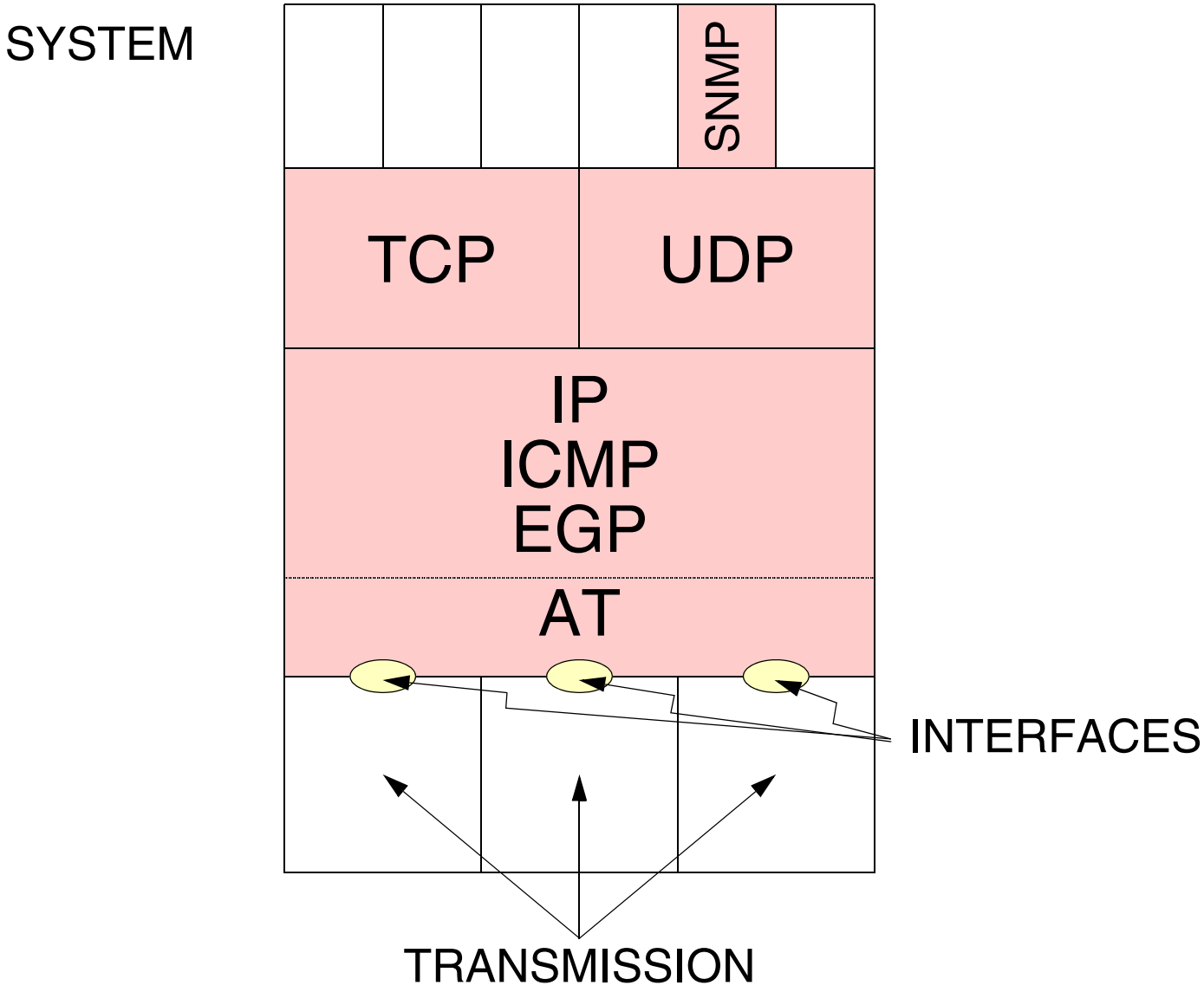
DESIGN CRITERIA

- 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

STRUCTURE


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 IN A PROTOCOL STACK



NEW VERSIONS

SYSTEM GROUP ⇨ SNMPv2 MIB (RFC 3418)

INTERFACES (IF) GROUP ⇨ IF-MIB (RFC 2863)

ADDRESS TRANSLATION (AT) GROUP ⇨ DEPRECATED

IP & ICMP GROUPS ⇨ IP-MIB (RFC 2011)

TCP GROUP ⇨ TCP-MIB (RFC 2012)

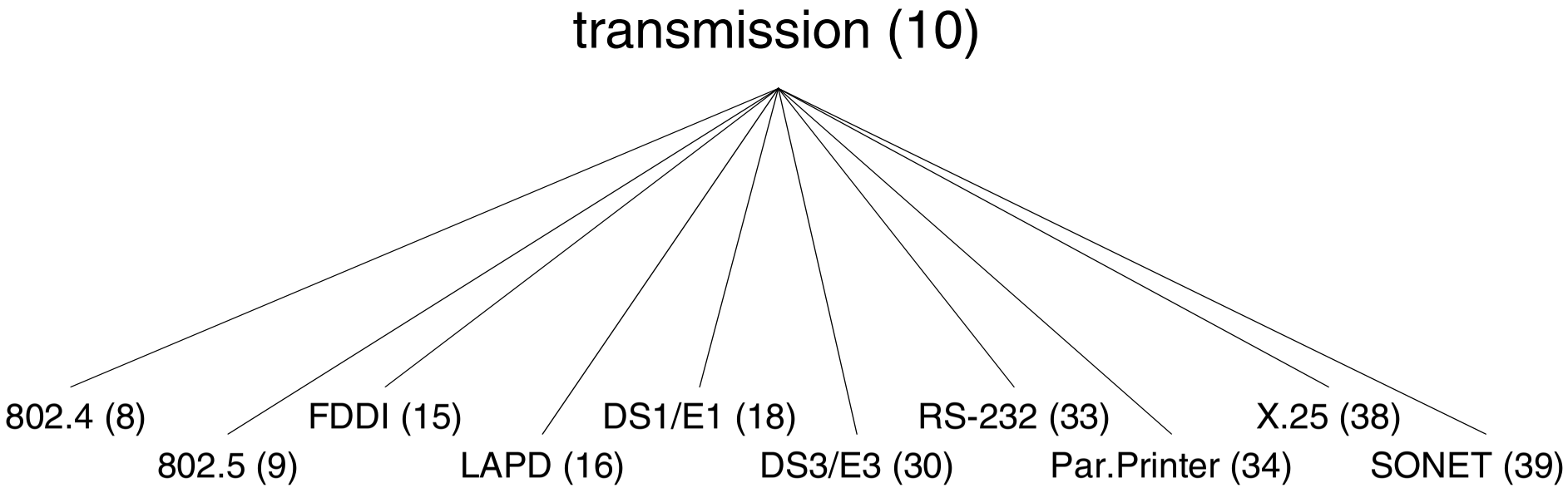
UDP GROUP ⇨ UDP-MIB (RFC 2013)

EGP GROUP ⇨ OUTDATED (BGP)

TRANSMISSION GROUP ⇨ IS PLACEHOLDER

SNMP GROUP ⇨ SNMPv2 MIB (RFC 3418)

TRANSMISSION GROUP

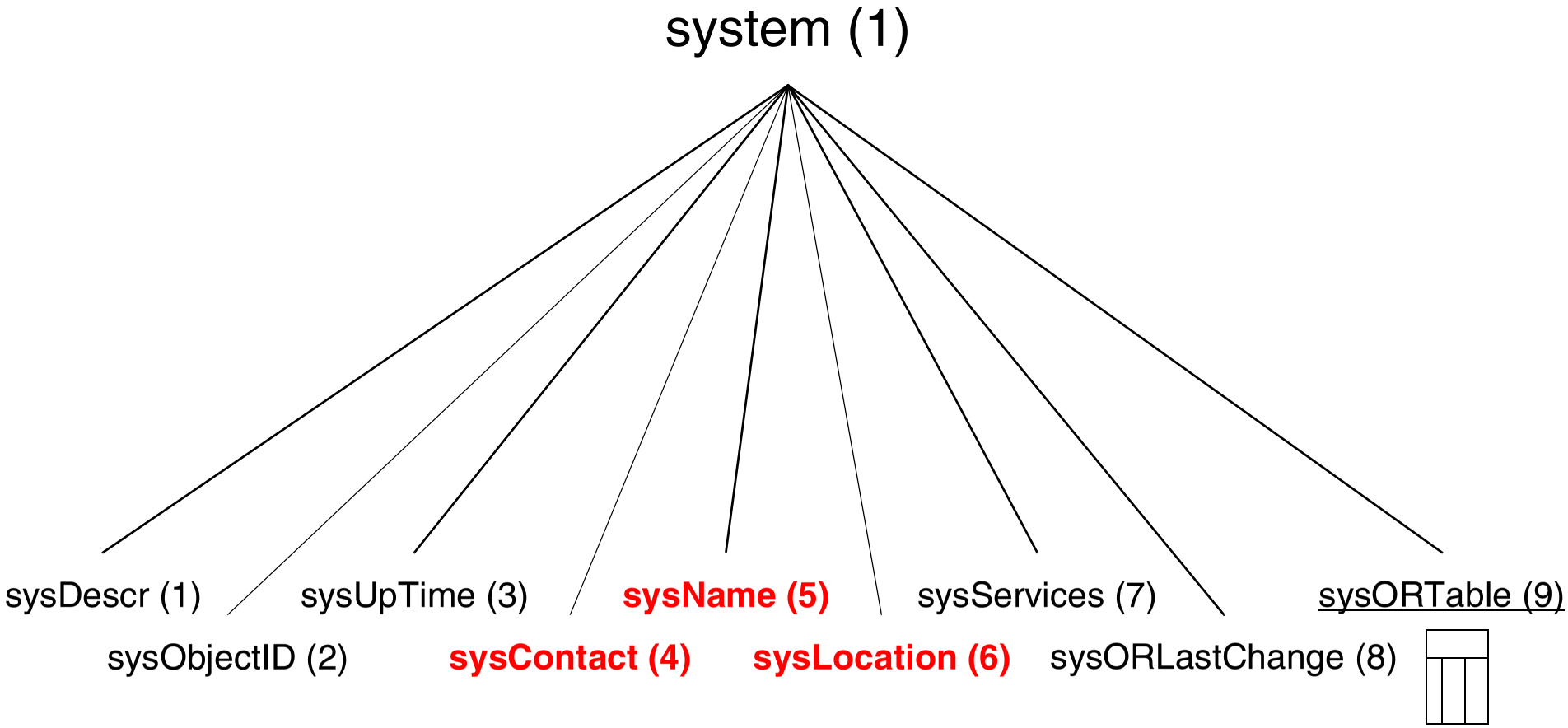


SNMPv2 MIB

RFC 3418
STANDARD

- SYSTEM GROUP
- SNMP GROUP
- SNMP MIBObjects GROUP
  snmpTrap
  snmpTraps
  snmpSet (snmpSetSerialNo)

SYSTEM GROUP

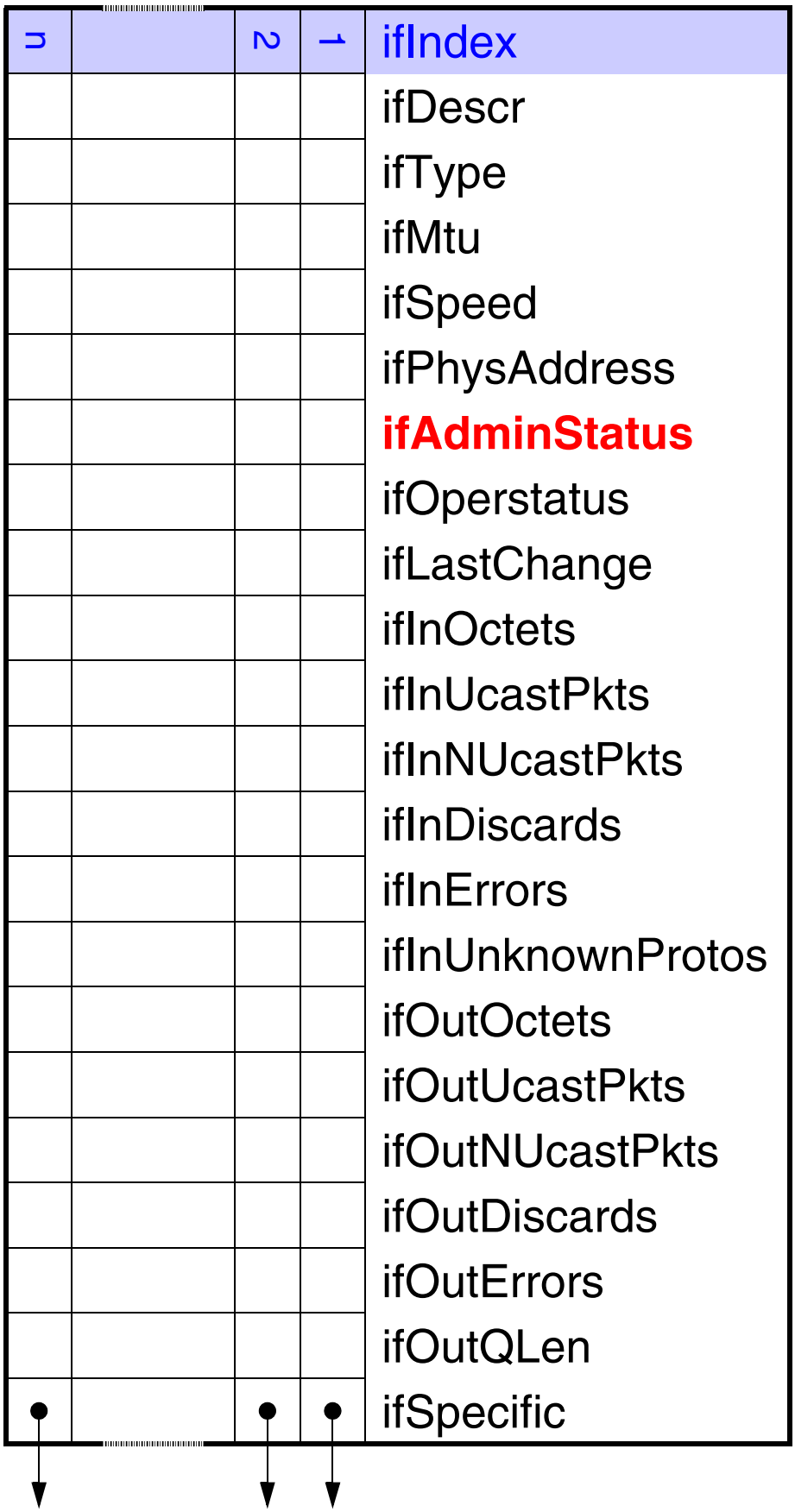


IF MIB

RFC 2863
DRAFT STANDARD

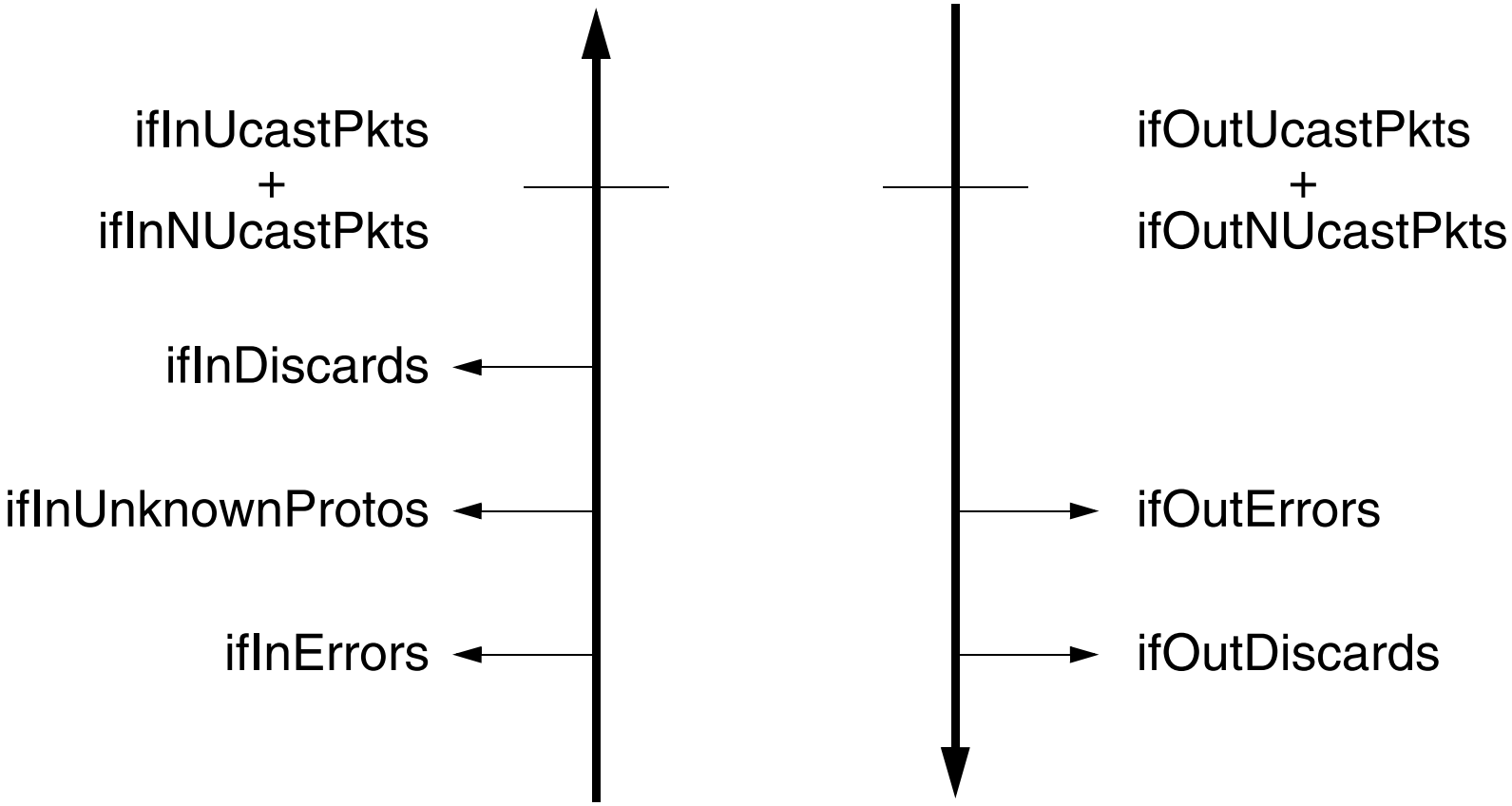
REPLACES IF GROUP OF MIB-II
- RFC 1213
- RFC1229 (EXTENSIONS TO THE IF GROUP)

DEFINES THE FOLLOWING MAIN TABLES:
- ifStackTable
- ifTable
- ifXTable


3
2
1
ifIndex
ifDescr
ifType
ifMtu
ifSpeed
ifPhysAddress
ifAdminStatus
ifOperstatus
ifLastChange
ifInOctets
ifInUcastPkts
ifInNUcastPkts
ifInDiscards
ifInErrors
ifInUnknownProtos
ifOutOctets
ifOutUcastPkts
ifOutNUcastPkts
ifOutDiscards
ifOutErrors
ifOutQLen
ifSpecific

ifTable

IF PACKET COUNT



IP MIB

RFC 2011

PROPOSED STANDARD

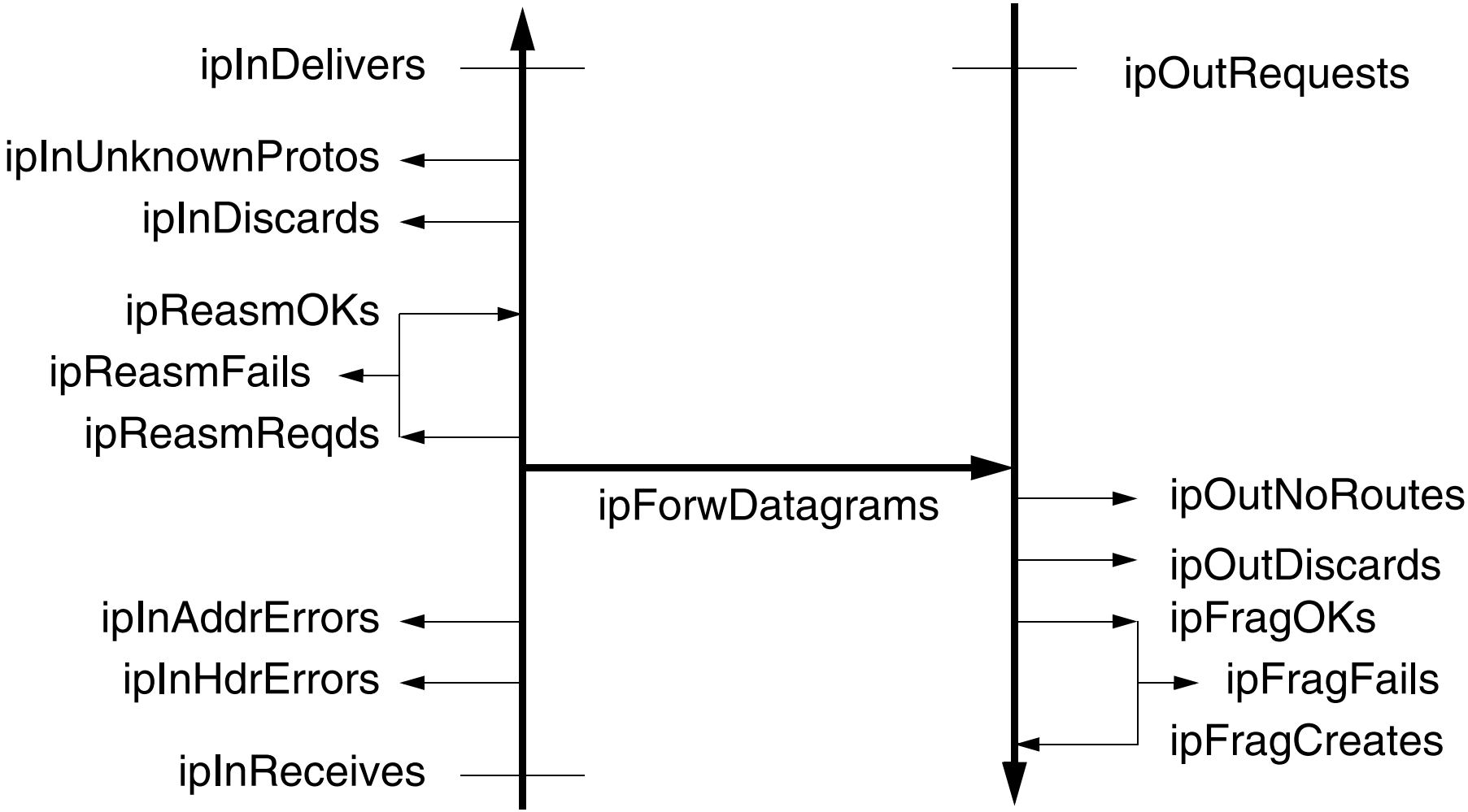
- IP GROUP
- ICMP GROUP
- IP MIB Conformance

IP GROUP

IP (4)

- ipForwarding (1)
- ipDefaultTTL (2)
- ipInReceives (3)
- ipInHdrErrors (4)
- ipInAddrErrors(5)
- ipInForwDatagrams (7)
- ipInUnknownProtos (7)
- ipInDiscards (8)
- ipInDelivers (9)
- ipOutRequest (10)
- ipOutDiscards (11)
- ipOutNoRoutes (12)
- ipReasmTimeout (13)
- ipReasmReqds (14)
- ipReasmOKs (15)
- ipReasmFails (16)
- ipFragOKs (17)
- ipFragFails (18)
- ipFragCreates (19)
- ipAddrTable (20)
- ipRouteTable (21)
- ipNetToMediaTable (22)
- ipRoutingDiscards (23)

IP PACKET COUNT



SNMP PROTOCOL

VERSION 1

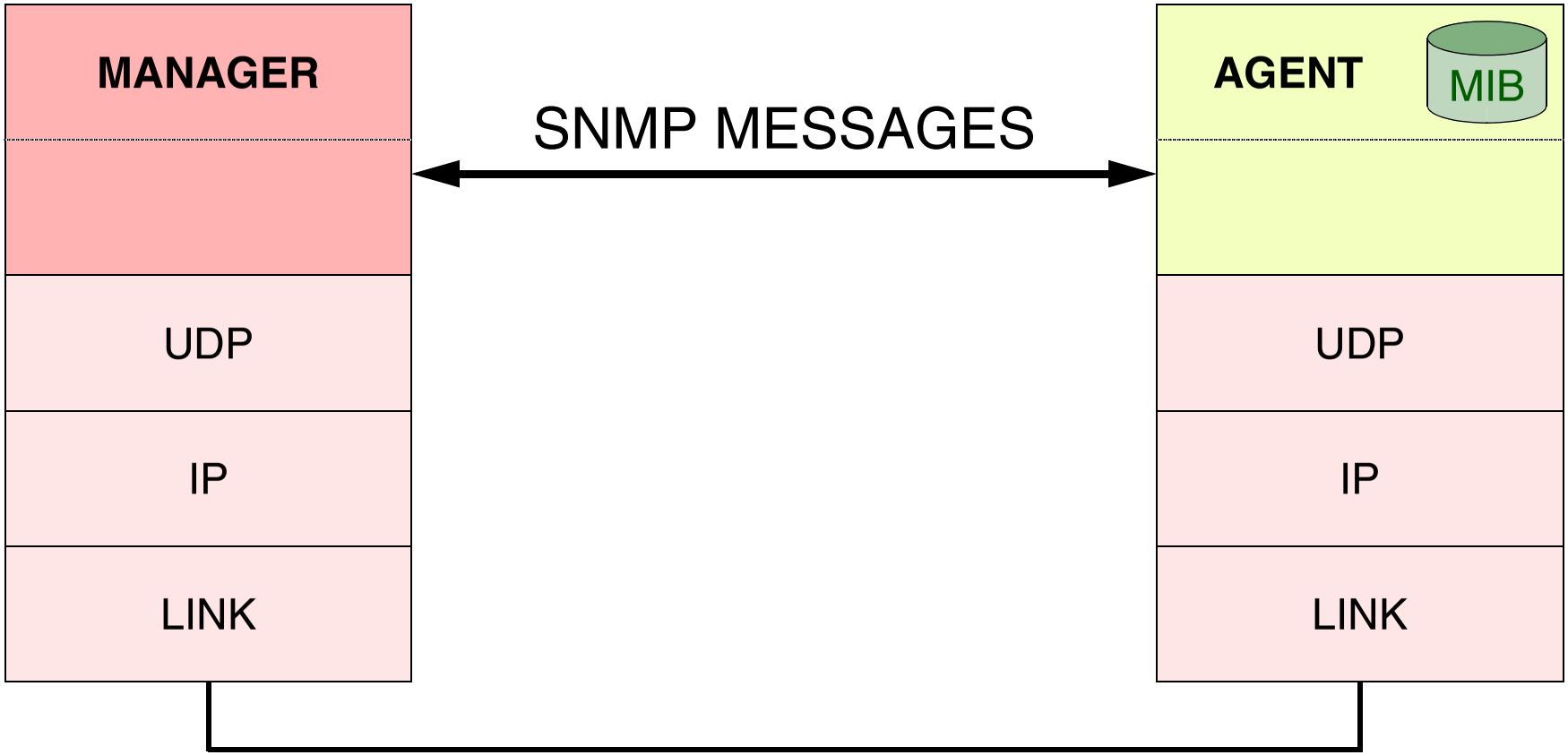
VERSION 2

- HISTORY
- PROTOCOL OPERATIONS

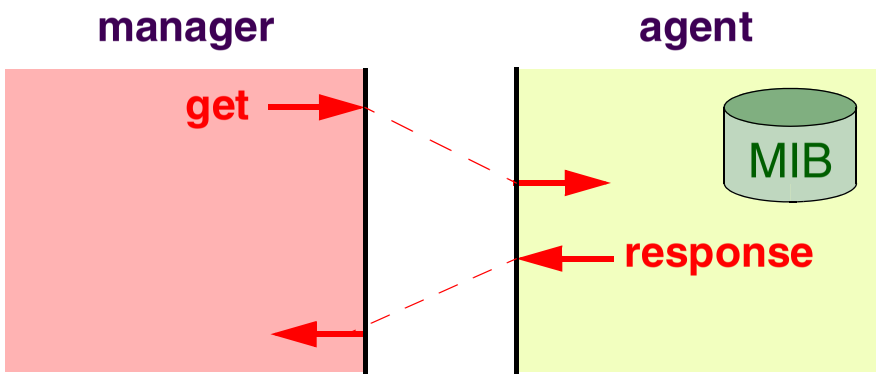
VERSION 3

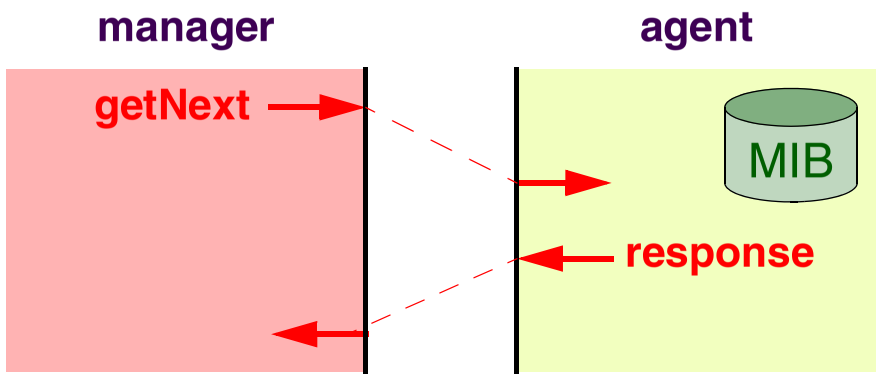
- ARCHITECTURE
- MESSAGE STRUCTURE
- SECURITY

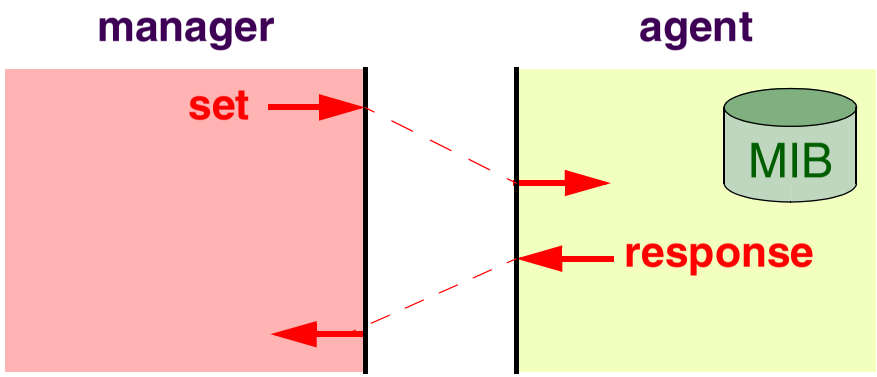
SNMPV1

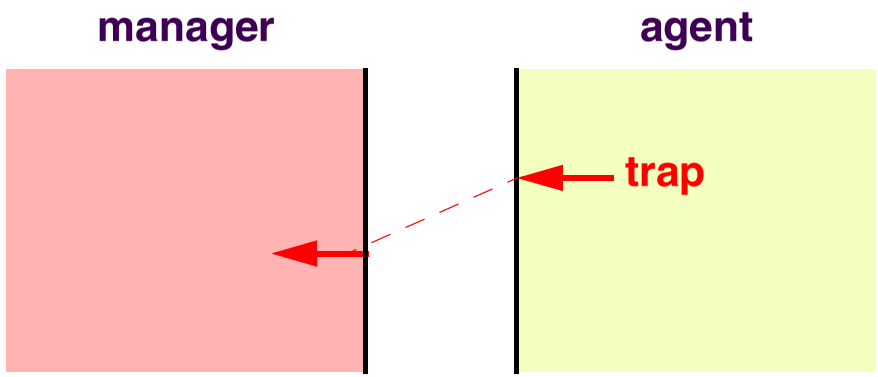


OVERVIEW OF PDUs









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

SNMPv2

OVERVIEW:

RFCs

LIMITATIONS OF SNMPv1

HISTORY OF SNMPv2
- HIERARCHIES
- SECURITY

SNMPv2 PROTOCOL OPERATIONS

SNMPv2 RFCs

COMMUNICATION MODEL

- DRAFT STANDARD
- RFC 3416, RFC3417

SECURITY MODEL - SNMPv2C:

- COMMUNITY BASED SNMP
- SAME 'SECURITY MECHANISMS' AS SNMPv1
- HISTORIC
- RFC 1901

SECURITY MODEL - SNMPv2U:

- USER BASED SECURITY (AUTHENTICATION / ENCRYPTION / ACCESS CONTROL)
- HISTORIC
- RFC 1909, RFC1910

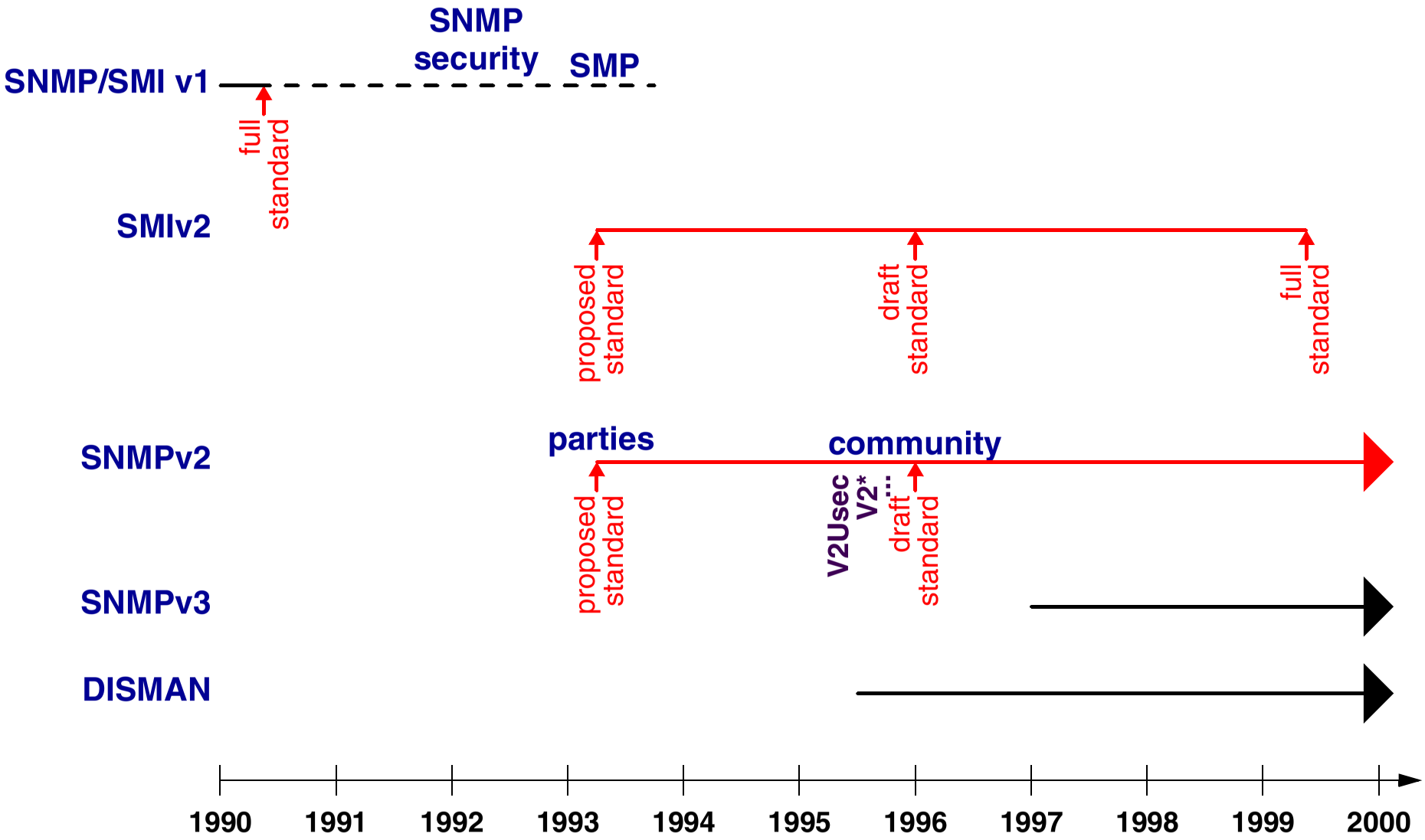
INFORMATION MODEL:

- STANDARD
- RFC2578, RFC2579, RFC2580

LIMITATIONS OF SNMPv1

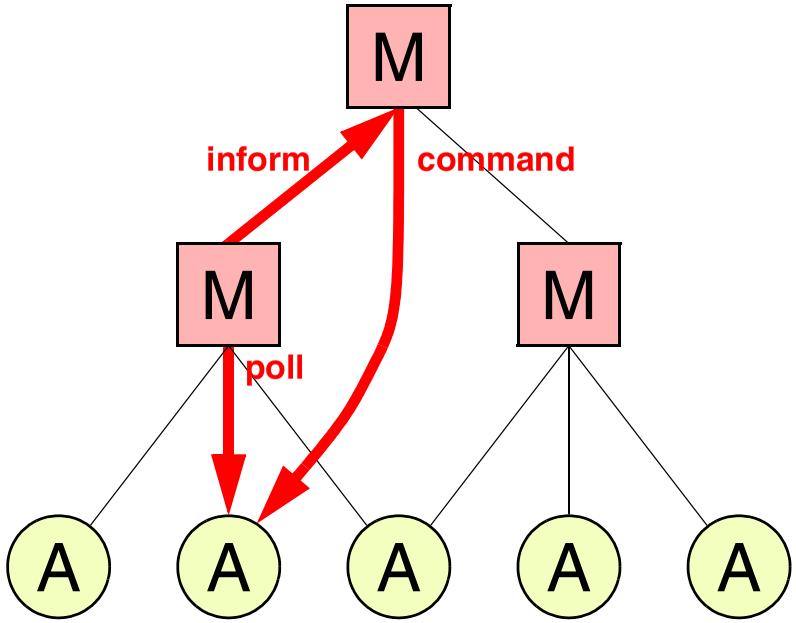
- LIMITED ERROR CODES
- LIMITED NOTIFICATIONS
- LIMITED PERFORMANCE
- TRANSPORT DEPENDENCE
- LACK OF HIERARCHIES
- LACK OF SECURITY
- UNDOCUMENTED RULES (SMIv1)
- LIMITED DATA TYPES (SMIv1)

HISTORY OF SNMPv2



HIERARCHIES: ORIGINAL IDEA

MANAGER TO MANAGER (M2M) MIB



- STANDARD MIB APPROACH
- LIMITED FUNCTIONALITY
- RUN-TIME BEHAVIOUR MUST BE DEFINED AT IMPLEMENTATION TIME

HIERARCHIES: STATUS

WORK HAS MOVED TO A SEPARATE
DISTRIBUTED MANAGEMENT GROUP
(DISMAN)

THREE APPROACHES ARE STANDARDIZED:

- MIB BASED (EXPRESSION, EVENT AND NOTIFICATION LOG MIB)
- SCRIPT BASED (SCRIPT AND SCHEDULE MIB)
- REMOTE OPERATIONS BASED (REMOPS MIB)

SNMPv2 SECURITY: WHAT HAPPENED?

APRIL 1993:

PROPOSED STANDARD
FOUR EDITORS
SECURITY BASED ON *PARTIES*
FIRST PROTOTYPES APPEARED SOON

JUNE 1995:

PROPOSED STANDARD REJECTED BY TWO OF THE ORIGINAL EDITORS!

AUGUST 1995:

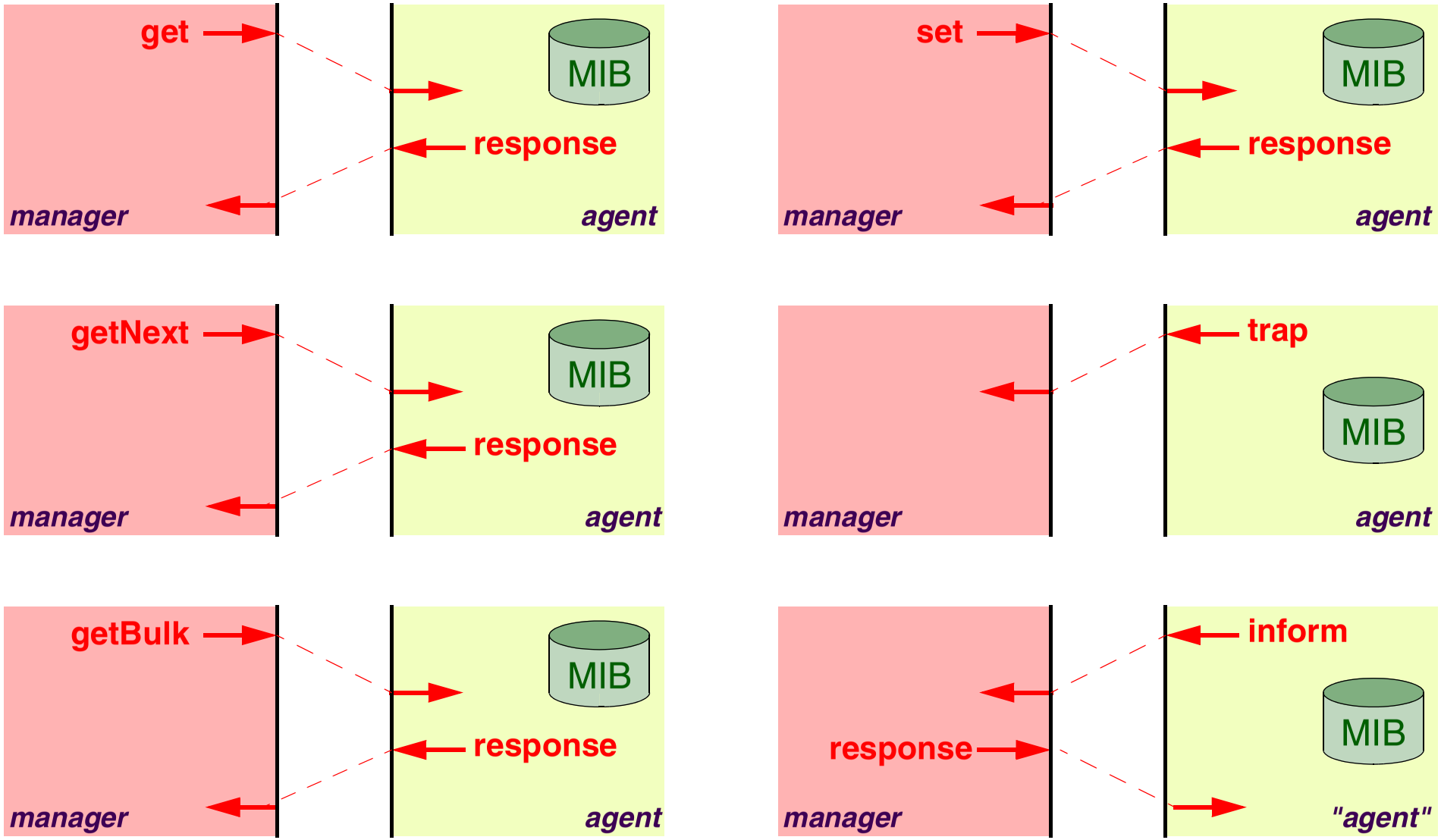
GENERAL AGREEMENT THAT PARTY BASED MODEL WAS TOO COMPLEX!
MANY NEW PROPOSALS APPEARED:

- SNMPv2C: COMMUNITY BASED
- SNMPv2U: USER BASED
- ...

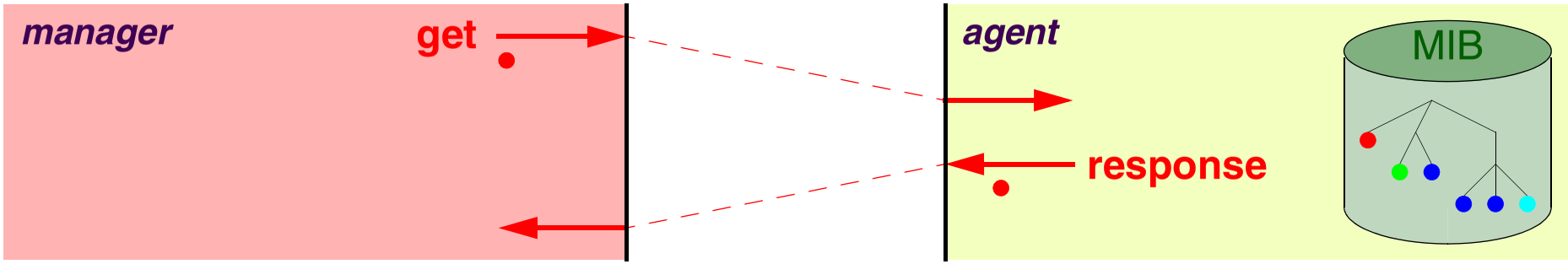
1997:

NEW SNMPv3 WORKING GROUP WAS FORMED
WITH NEW EDITORS

SNMPv2 PROTOCOL OPERATIONS



GET



SIMILAR TO SNMPv1, EXCEPT FOR "EXCEPTIONS"

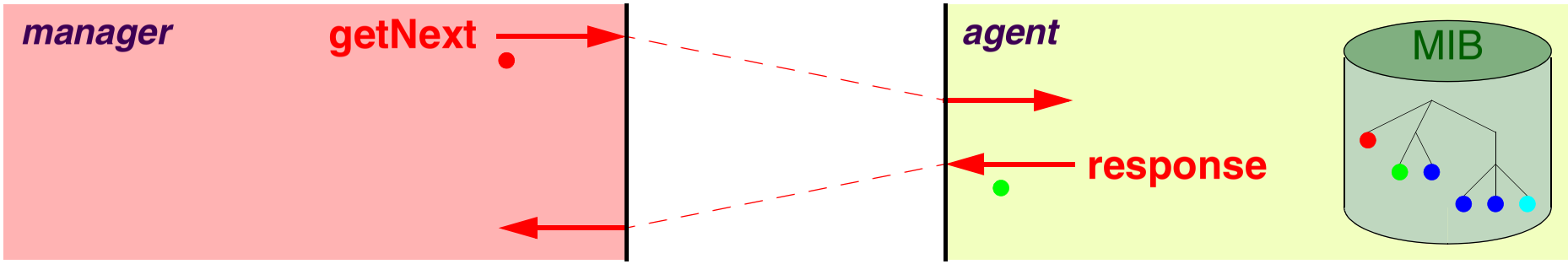
POSSIBLE EXCEPTIONS:

- noSuchObject
- noSuchInstance

EXCEPTIONS ARE CODED WITHIN THE VARBINDS

EXCEPTIONS DO NOT RAISE ERROR STATUS AND INDEX

GET-NEXT



SIMILAR TO SNMPv1, EXCEPT FOR "EXCEPTIONS"

POSSIBLE EXCEPTIONS:

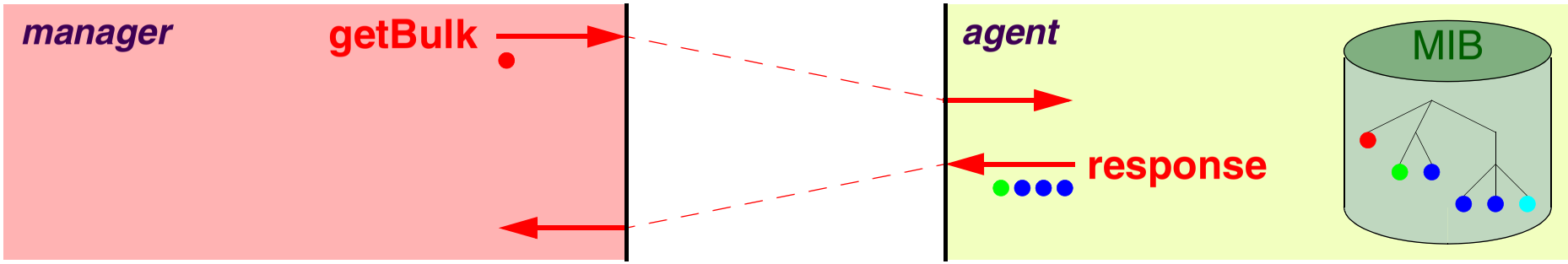
- endOfMibView

EXAMPLE

getNext(7.4.0)

response(error-status => noError, 7.4.0 => endOfMibView)

GET-BULK



NEW IN SNMPv2

TO RETRIEVE A LARGE NUMBER OF VARBINDS

IMPROVES PERFORMANCE!

GET-BULK

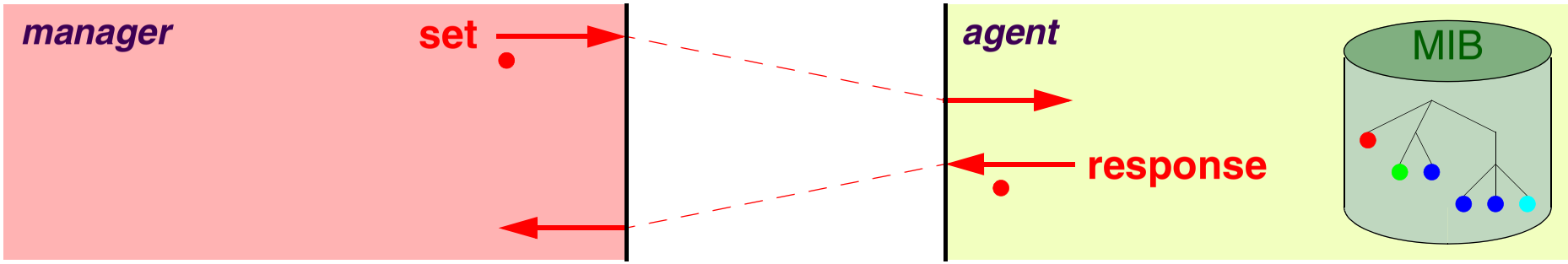
getBulk REQUEST HAS TWO ADDITIONAL PARAMETERS:

- non-repeators
- max-repetitions

- THE FIRST N ELEMENTS (non-repeators) OF THE VARBIND LIST ARE TREATED AS IF THE OPERATION WAS A NORMAL getnext OPERATION

- THE NEXT ELEMENTS OF THE VARBIND LIST ARE TREATED AS IF THE OPERATION CONSISTED OF A NUMBER (max-repetitions) OF REPEATED getnext OPERATIONS

SET



SIMILAR TO SNMPv1

CONCEPTUAL TWO PHASE COMMIT:

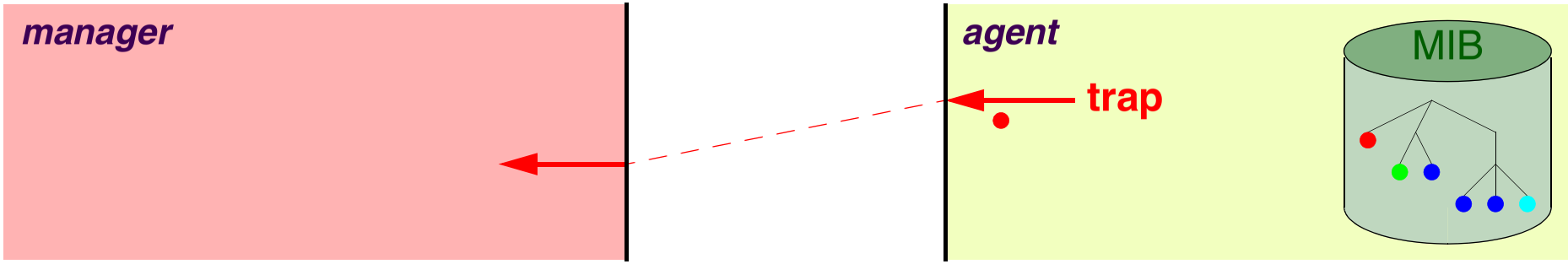
- PHASE 1: PERFORM VARIOUS CHECKS
- PHASE 2: PERFORM THE ACTUAL SET

MANY NEW ERROR CODES ARE DEFINED

SET: NEW ERROR CODES

	SNMPv1	SNMPv2
PHASE 1:	badValue	wrongValue
	badValue	wrongEncoding
	badValue	wrongType
	badValue	wrongLength
	badValue	inconsistentValue
	noSuchName	noAccess
	noSuchName	notWritable
	noSuchName	noCreation
	noSuchName	inconsistentName
	genErr	resourceUnavailable
	genErr	genErr
PHASE 2:	genErr	CommitFailed
	genErr	undoFailed

TRAP



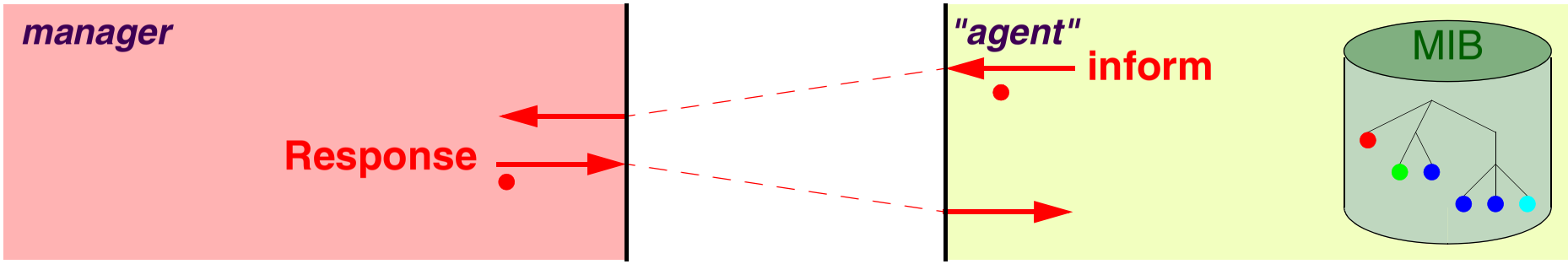
SNMPv1:

- COLD START
- WARM START
- LINK DOWN
- LINK UP
- AUTHETICATION FAILURE
- EGP NEIGHBOR LOSS

SNMPv2:

- MIBs MAY NOW INCLUDE NOTIFICATION TYPE MACROS
- FIRST TWO VARBINDS: sysUptime AND snmpTrapOID
- USES SAME FORMAT AS OTHER PDUs

INFORM



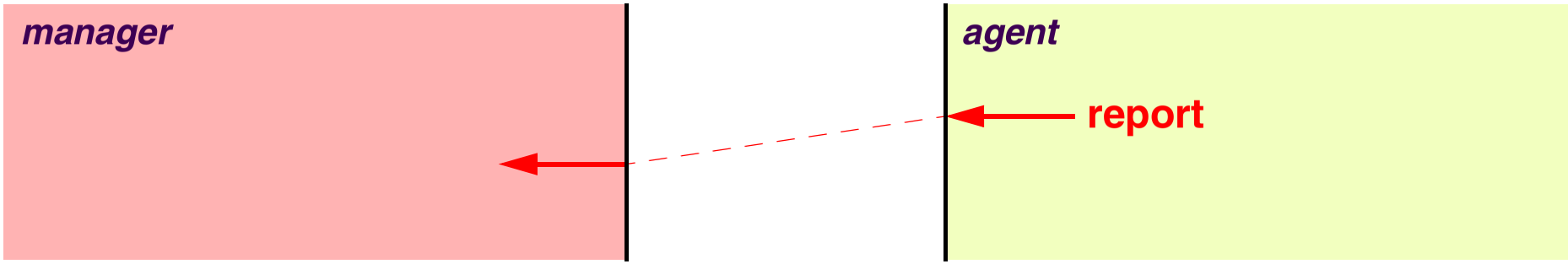
CONFIRMED TRAP

ORIGINALLY TO INFORM A HIGHER LEVEL MANAGER

SAME FORMAT AS TRAP PDU

POSSIBLE ERROR: tooBig

REPORT



NEW PDU TO SIGNAL PROTOCOL EXCEPTIONS / ERRORS

NO SEMANTICS DEFINED IN SNMPv2

SNMPv3

OVERVIEW:

DESIGN DECISIONS

ARCHITECTURE

SNMP MESSAGE STRUCTURE

SECURE COMMUNICATION
- USER SECURITY MODEL (USM)

ACCESS CONTROL
- VIEW BASED ACCESS CONTROL MODEL (VACM)

RFCs

DESIGN DECISIONS

ADDRESS THE NEED FOR SECURY SET SUPPORT

DEFINE AN ARCHITECTURE THAT ALLOWS FOR LONGEVITY OF SNMP

ALLOW THAT DIFFERENT PORTIONS OF THE ARCHITECTURE
MOVE AT DIFFERENT SPEEDS TOWARDS STANDARD STATUS

ALLOW FOR FUTURE EXTENSIONS

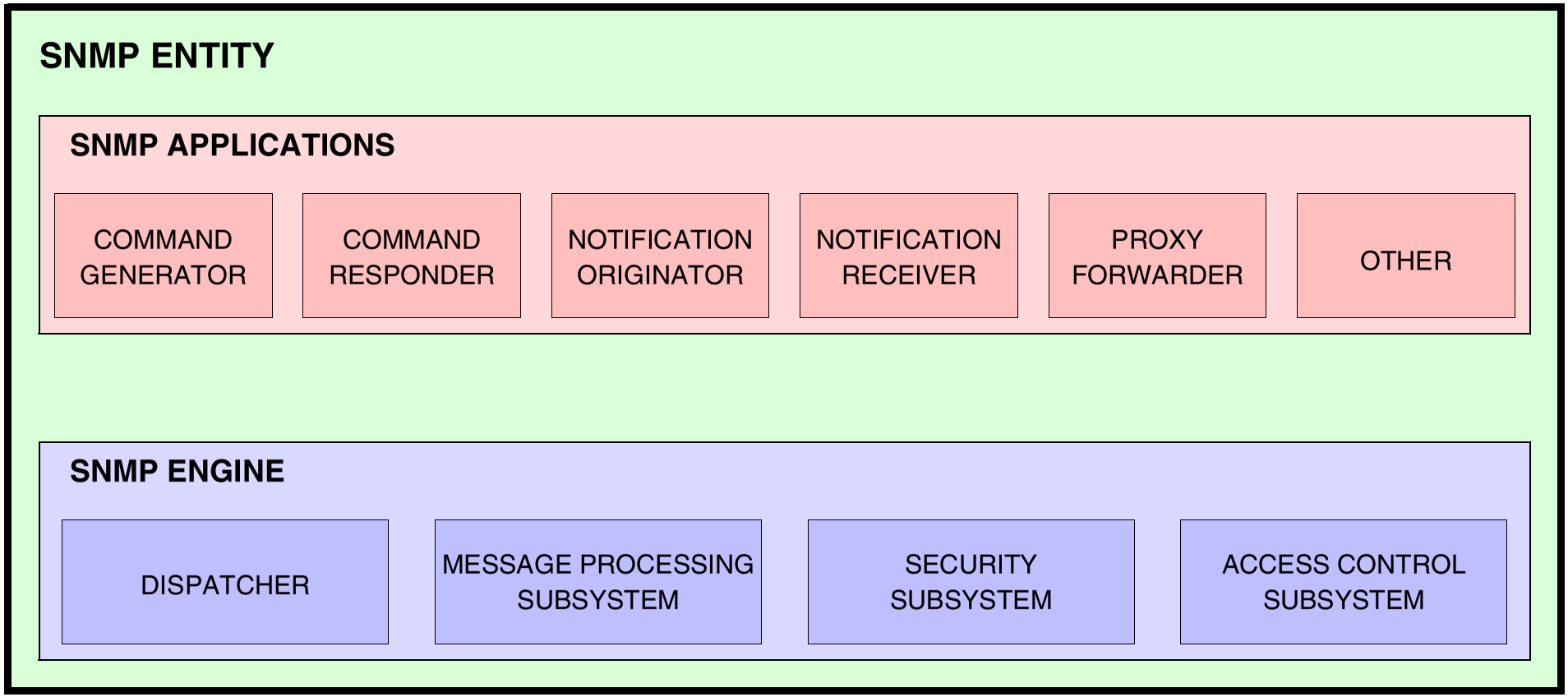
KEEP SNMP AS SIMPLE AS POSSIBLE

ALLOW FOR MINIMAL IMPLEMENTATIONS

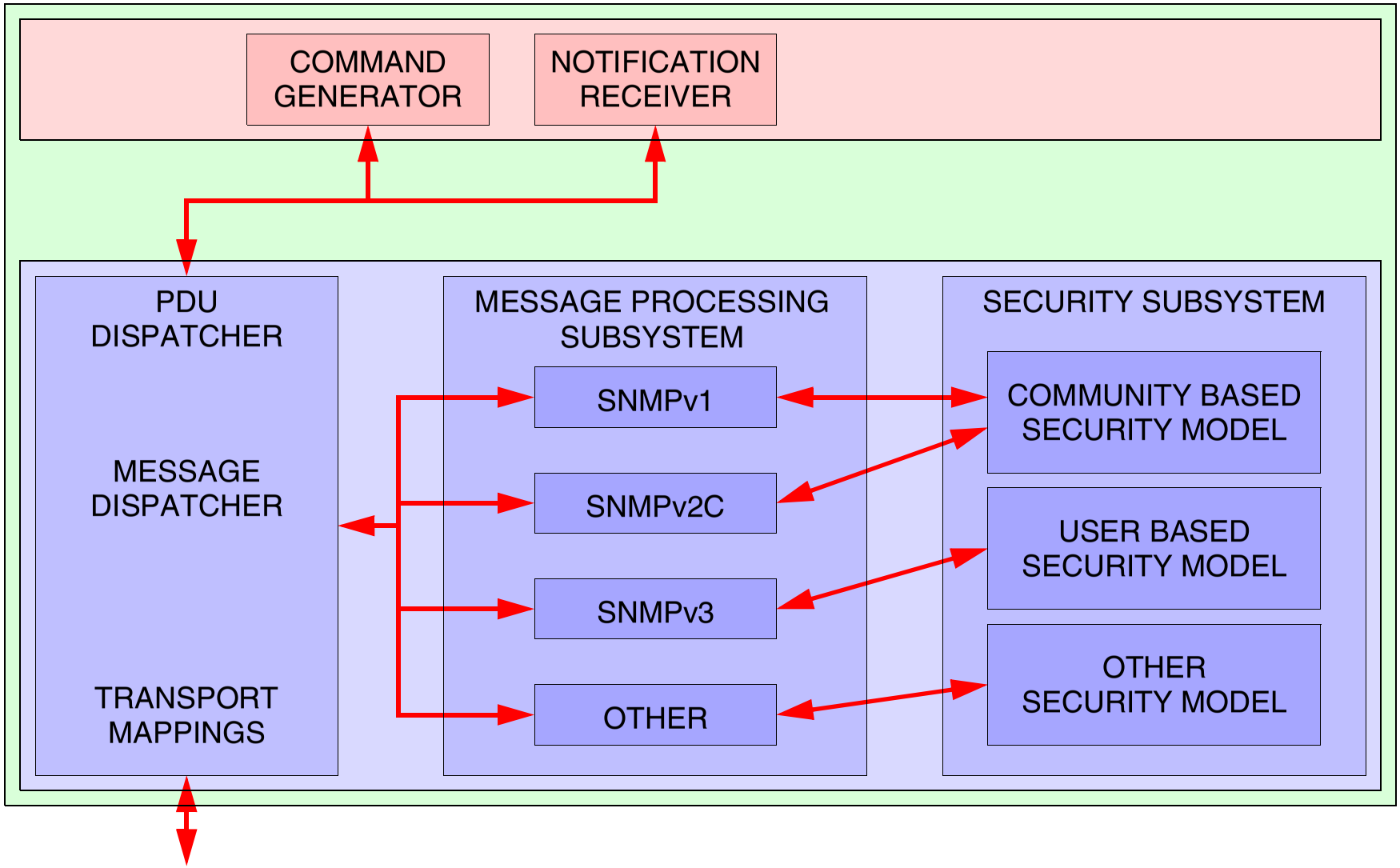
SUPPORT ALSO THE MORE COMPLEX FEATURES,
WHICH ARE REQUIRED IN LARGE NETWORKS

RE-USE EXISTING SPECIFICATIONS, WHENEVER POSSIBLE

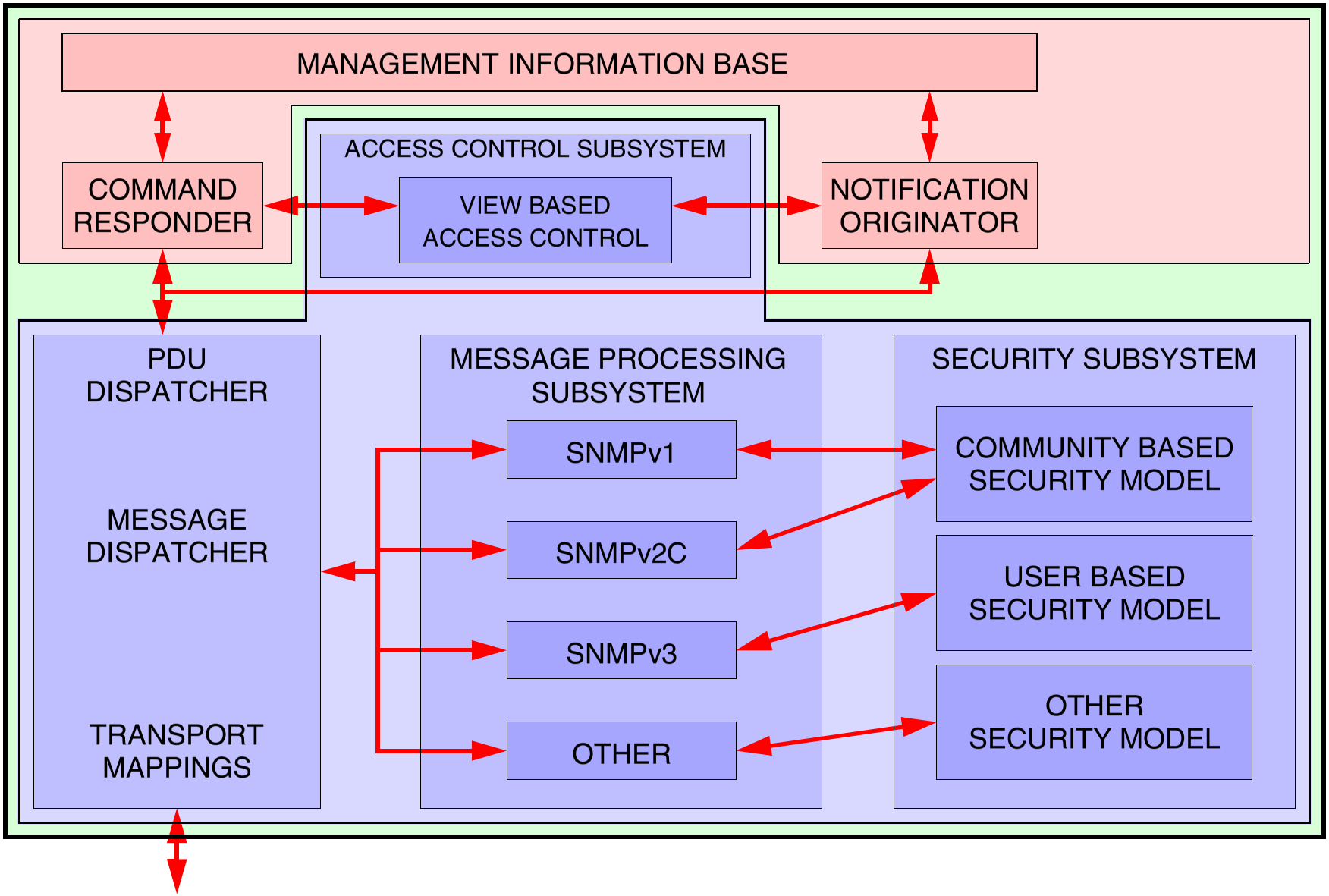
SNMPv3 ARCHITECTURE



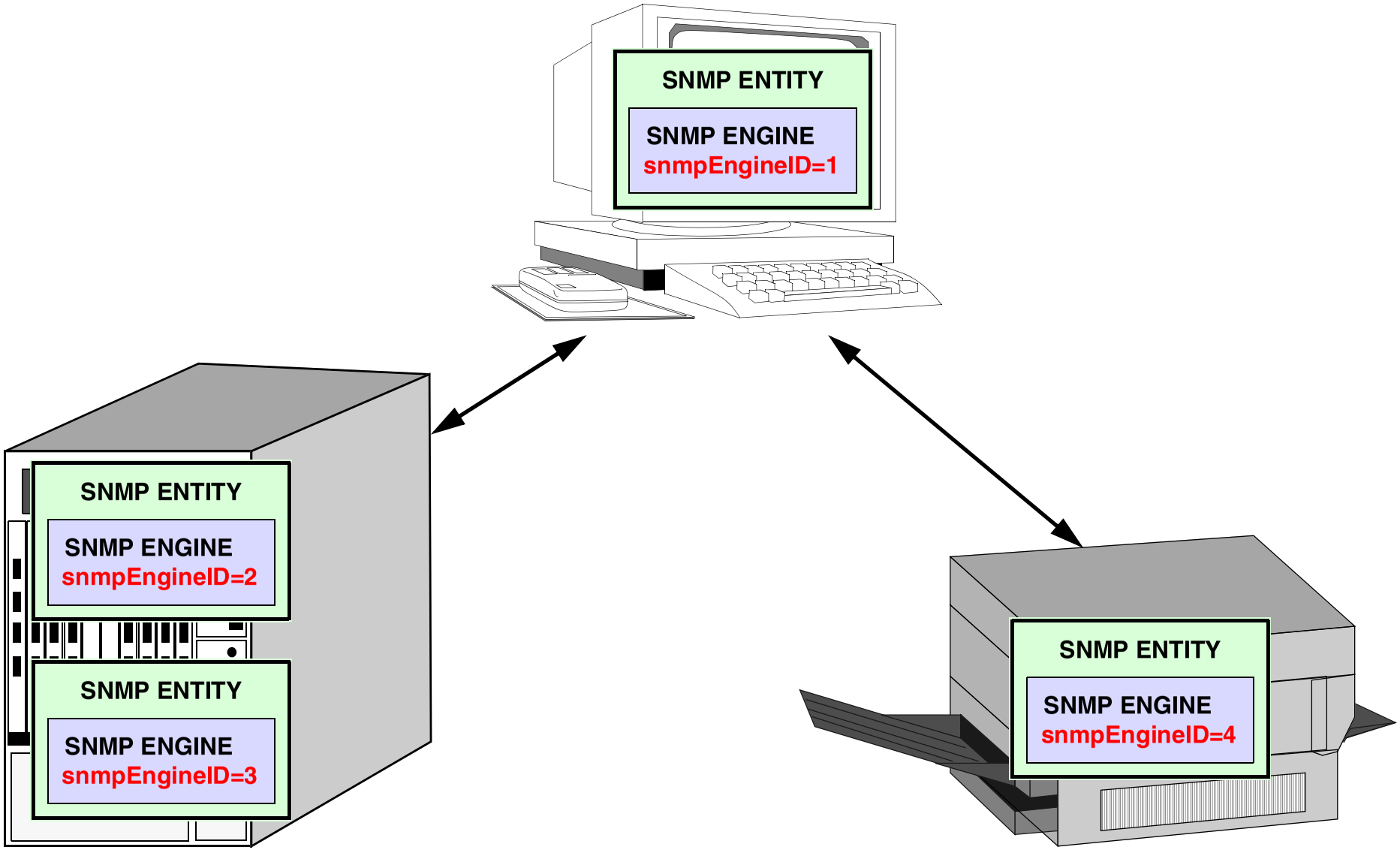
SNMPv3 ARCHITECTURE: MANAGER



SNMPv3 ARCHITECTURE: AGENT



CONCEPTS: snmpEngineID



CONCEPTS: snmpEngineID

SYNTAX DEFINED VIA TEXTUAL CONVENTION

OCTET STRING (5..32)

THE VALUE OF snmpEngineID MAY BE DETERMINED BY:

- HUMAN OPERATOR
- AUTOMATIC ALGORITHM

AUTOMATIC ALGORITHM USES:

- PRIVATE ENTERPRISE NUMBER
- IPv4 ADDRESS / IPv6 ADDRESS / MAC ADDRESS

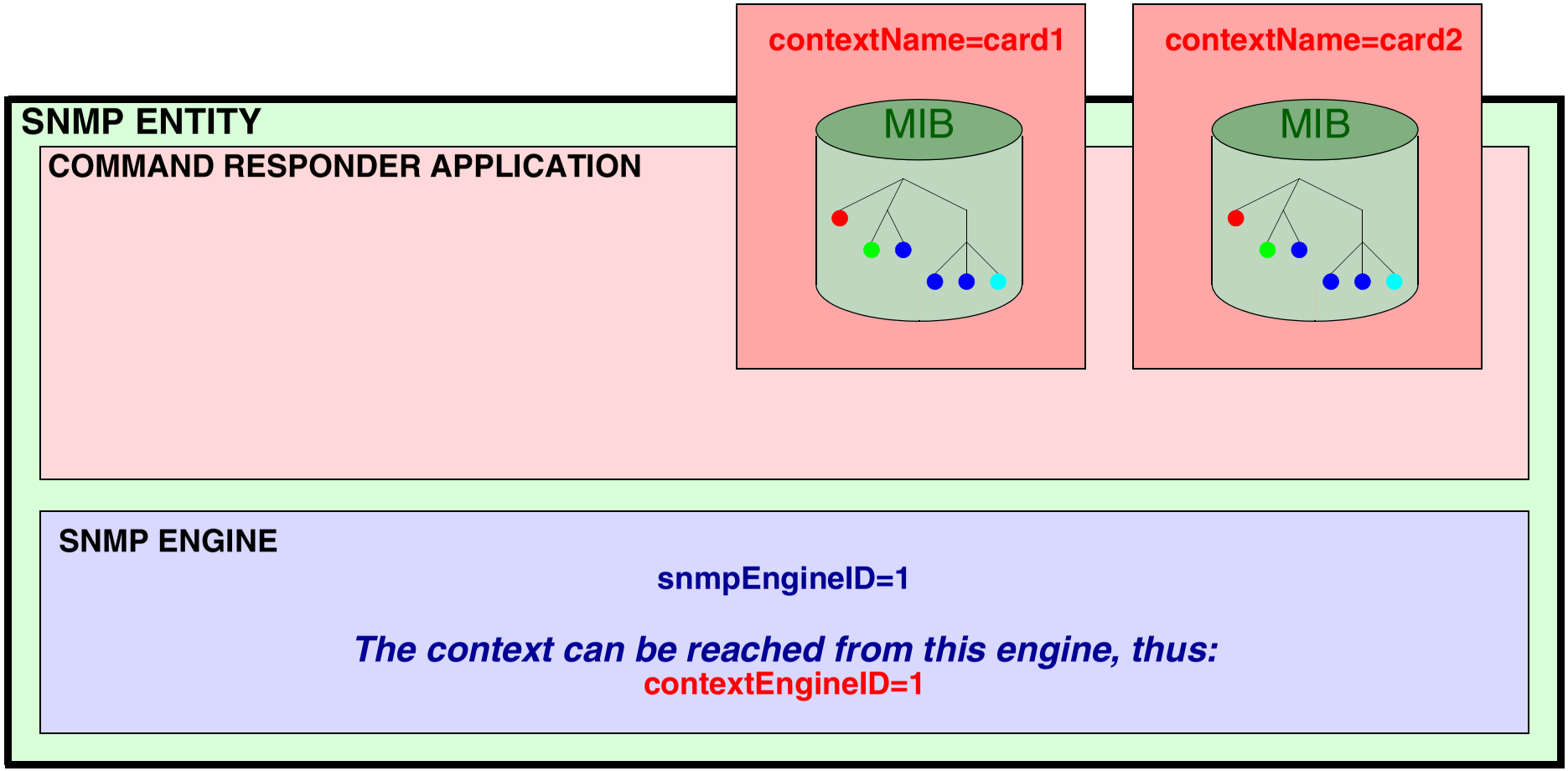
TEXTUAL CONVENTION DEFINED IN SNMP FRAMEWORK MIB

CONCEPTS: snmpEngineID

THE TERM EngineID IS FREQUENTLY USED

SnmpEngineID	The textual convention.
snmpEngineID	The identifier of an SNMP engine.
securityEngineID	Parameter of primitives in the architecture. The *authoritative* SNMP entity (which is the receiver of a confirmed PDU, the sender of a trap).
contextEngineID	Parameter in messages. Identifies the engine associated with the data.
msgAuthoritativeEngineID	Parameter in messages. USM security parameter.
usmUserEngineID	An object in the snmpUsmMIB. In a simple agent, this is the agent's own snmpEngineID. It may also be the snmpEngineID of a remote SNMP engine with which this user can communicate.
usmStatsUnknownEngineID	An object in the snmpUsmMIB.
snmpCommunityContextEngineID	An object in the communityMIB.
entLogicalContextEngineID	An object in the entityMIB.
snmpProxyContextEngineID	An object in the proxyMIB.

CONCEPTS: Context



MODULES OF THE SNMPv3 ARCHITECTURE

DISPATCHER AND MESSAGE PROCESSING MODULE

- SNMPv3 MESSAGE STRUCTURE
- snmpMPDMIB
- RFC 3412

APPLICATIONS

- snmpTargetMIB
- snmpNotificationMIB
- snmpProxyMIB
- RFC 3413

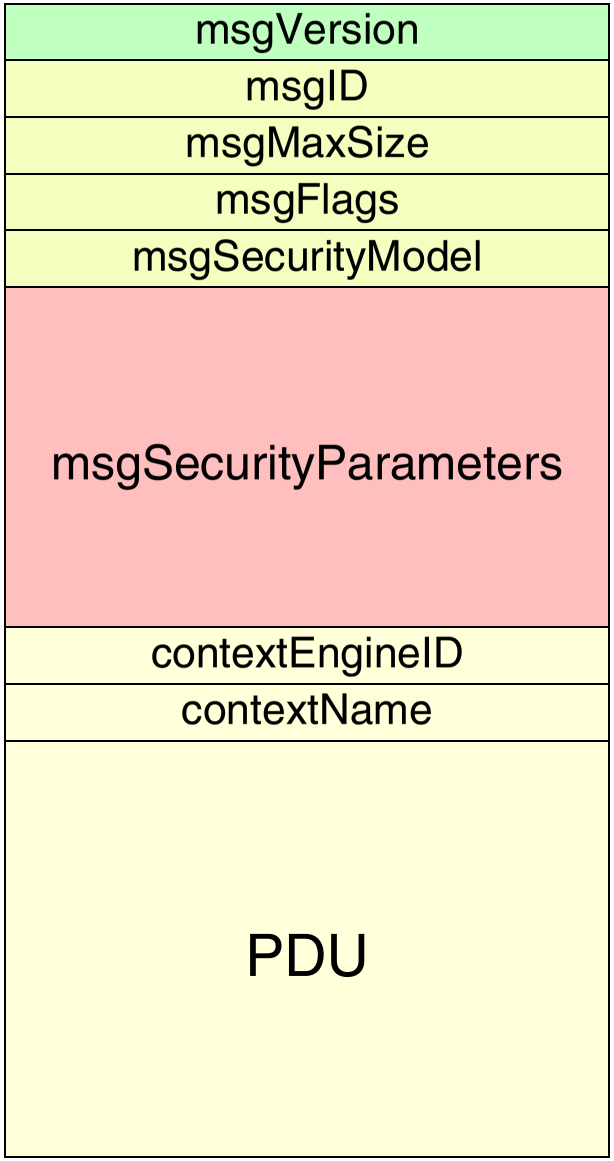
SECURITY SUBSYSTEM

- USER BASED SECURITY MODEL
- snmpUsmMIB
- RFC 3414

ACCESS CONTROL SUBSYSTEM

- VIEW BASED ACCESS CONTROL MODEL
- snmpVacmMIB
- RFC 3415

SNMPv3 MESSAGE STRUCTURE



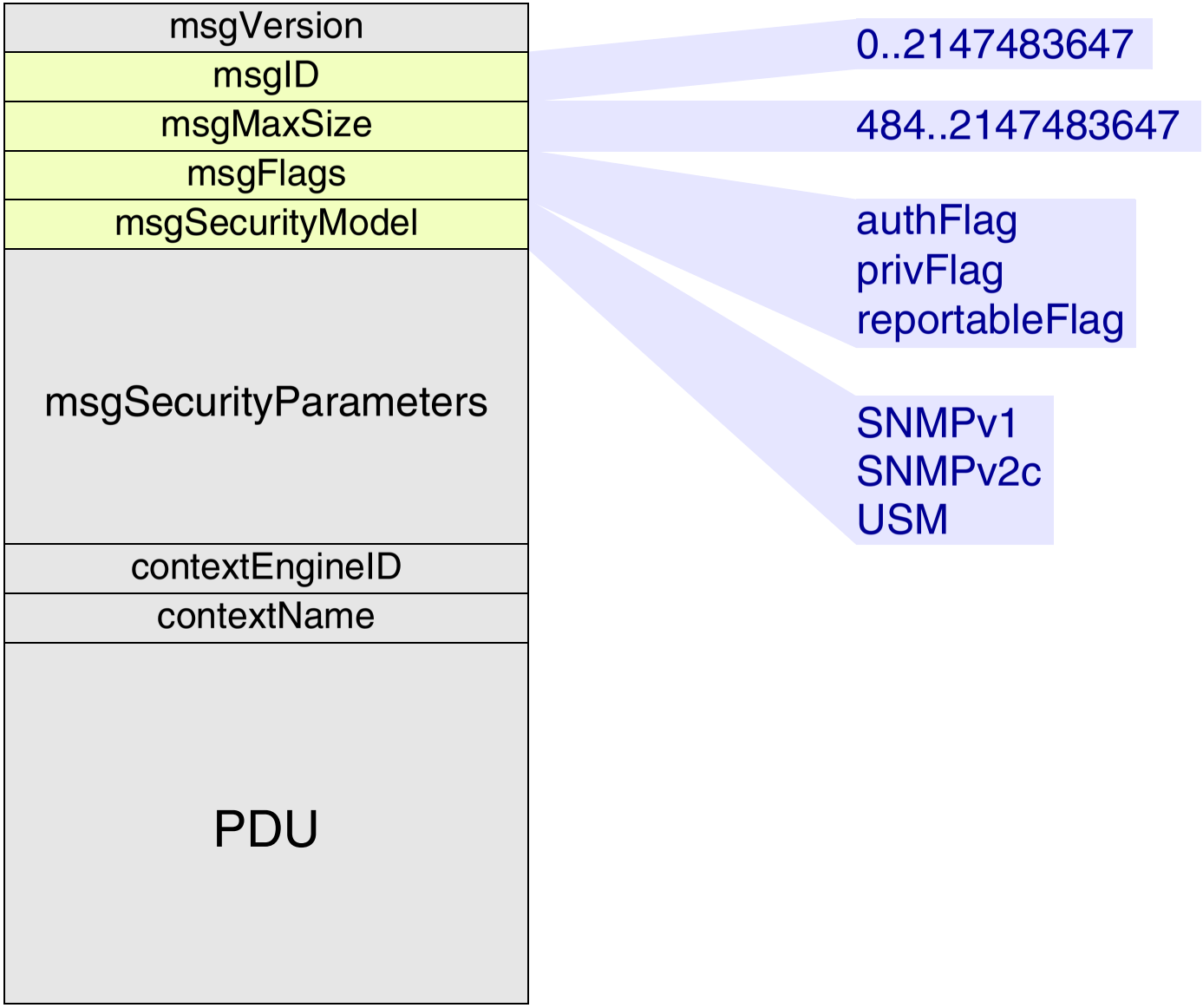
USED BY MESSAGE PROCESSING SUBSYSTEM

USED BY SNMPv3 PROCESSING MODULE

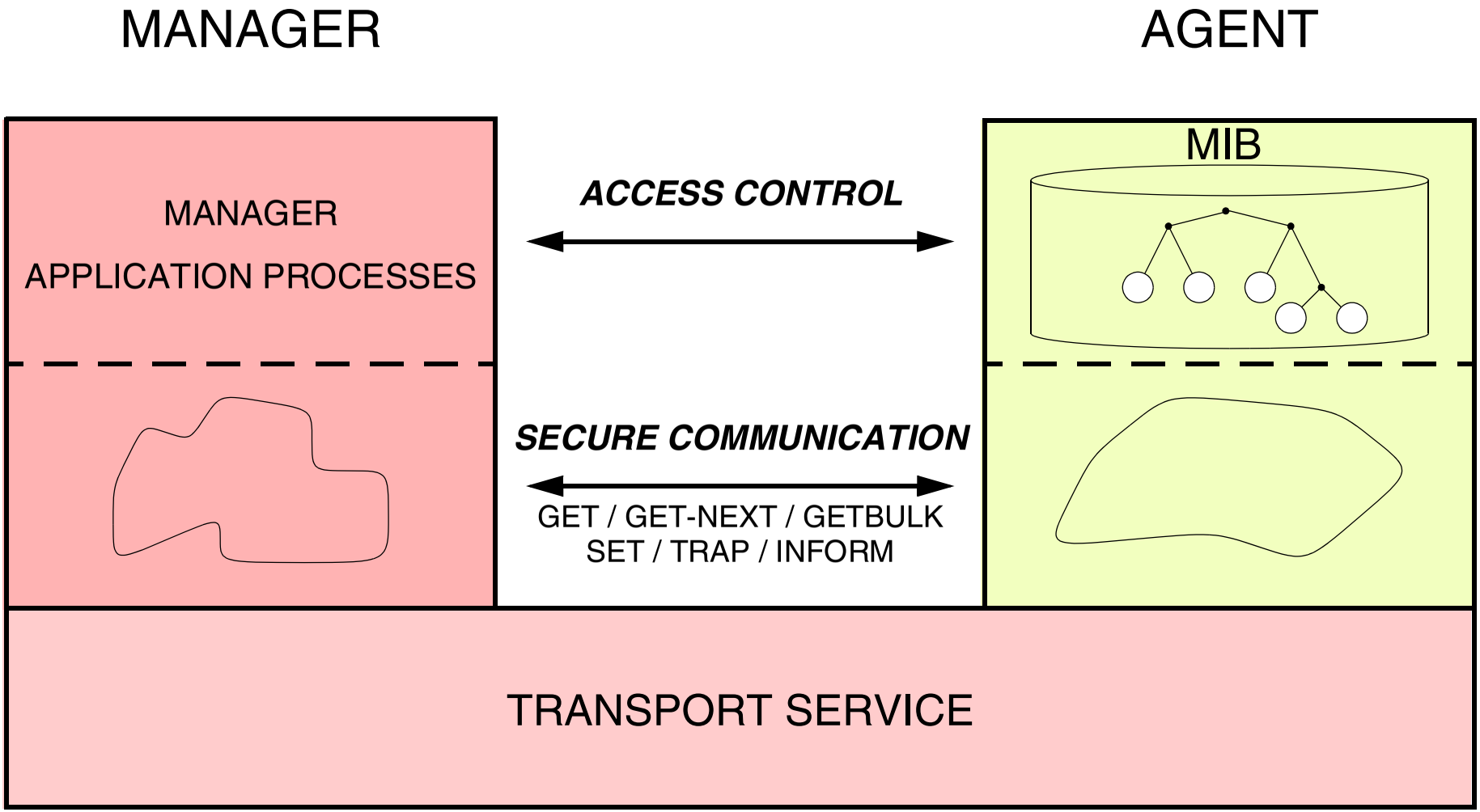
USED BY SECURITY SUBSYSTEM

USED BY ACCESS CONTROL SUBSYSTEM AND APPLICATIONS

SNMPv3 PROCESSING MODULE PARAMETERS



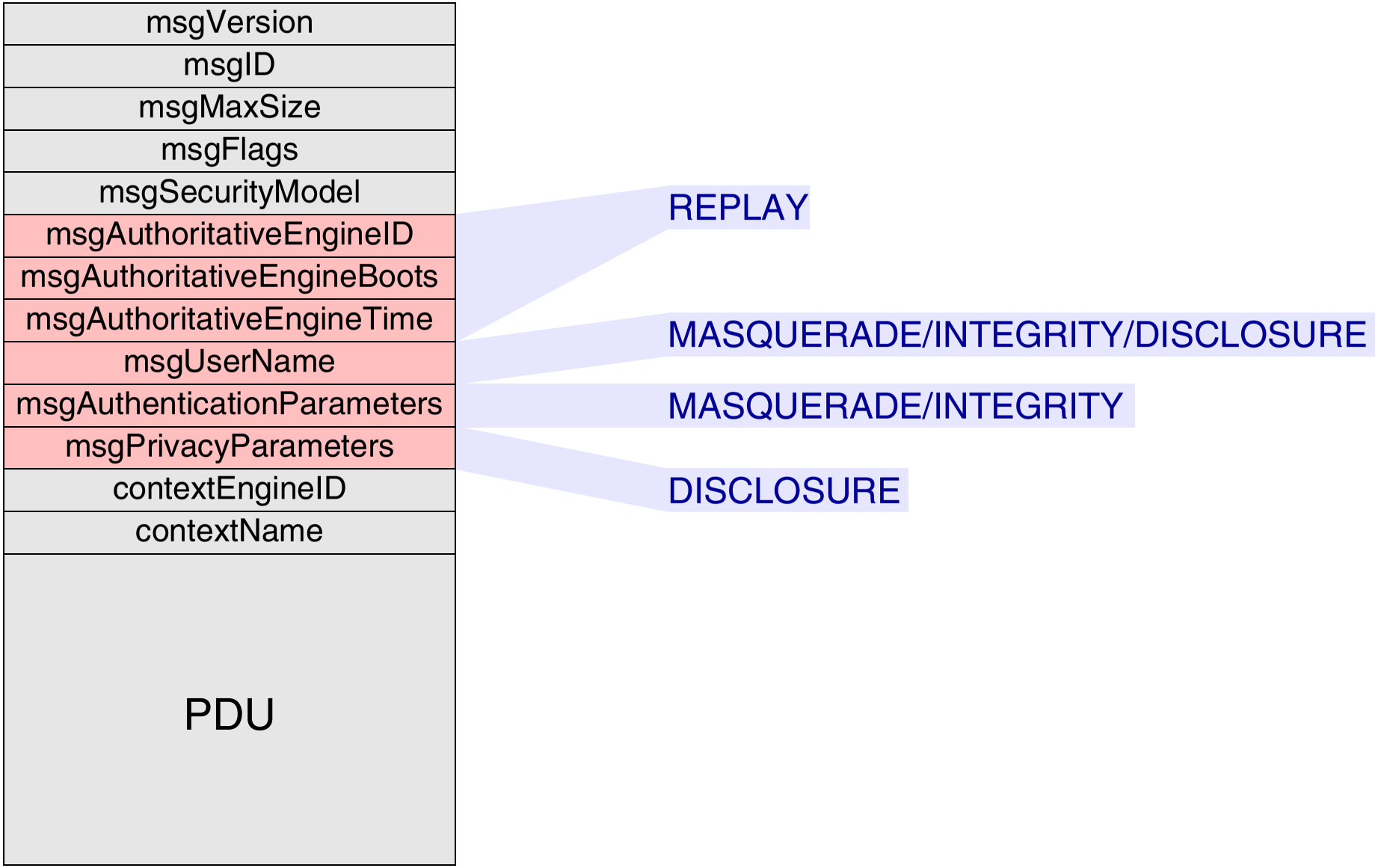
SECURE COMMUNICATION VERSUS ACCESS CONTROL



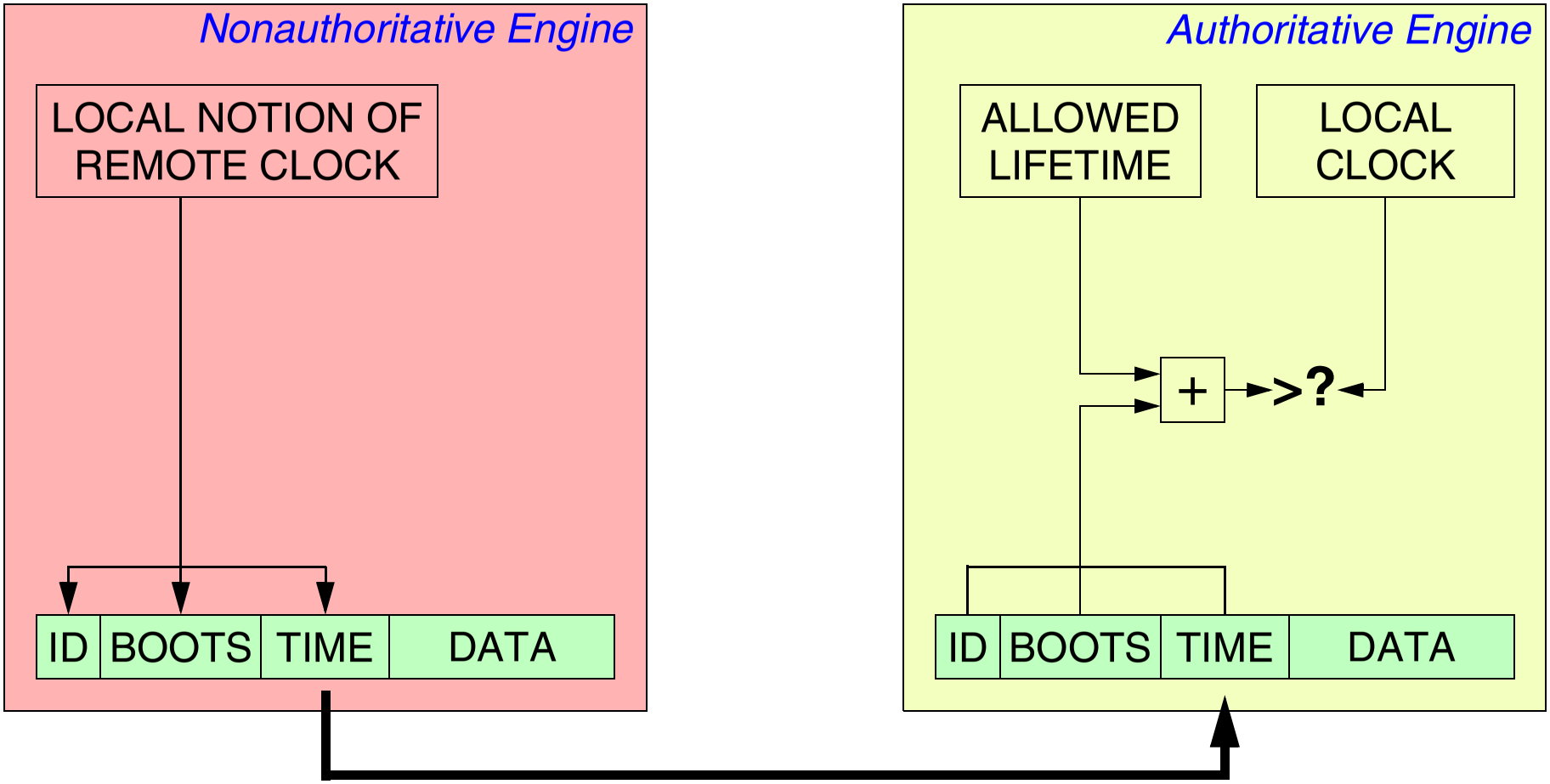
USM: SECURITY THREATS

THREAT	ADDRESSED?	MECHANISM
REPLAY	YES	TIME STAMP
MASQUERADE	YES	MD5 / SHA-1
INTEGRITY	YES	(MD5 / SHA-1)
DISCLOSURE	YES	DES
DENIAL OF SERVICE	NO	
TRAFFIC ANALYSIS	NO	

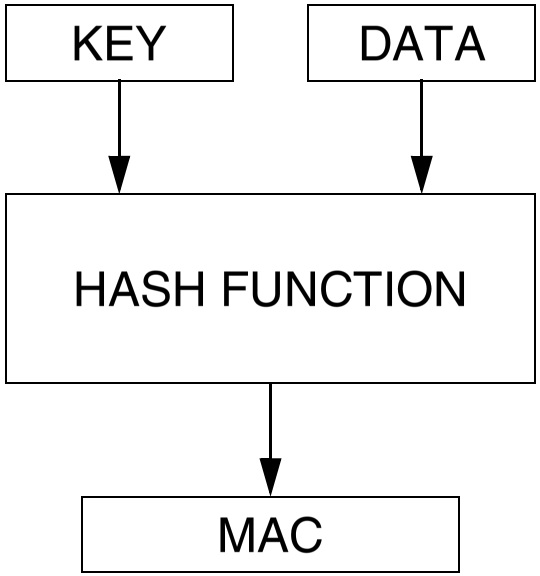
USM MESSAGE STRUCTURE



IDEA BEHIND REPLAY PROTECTION

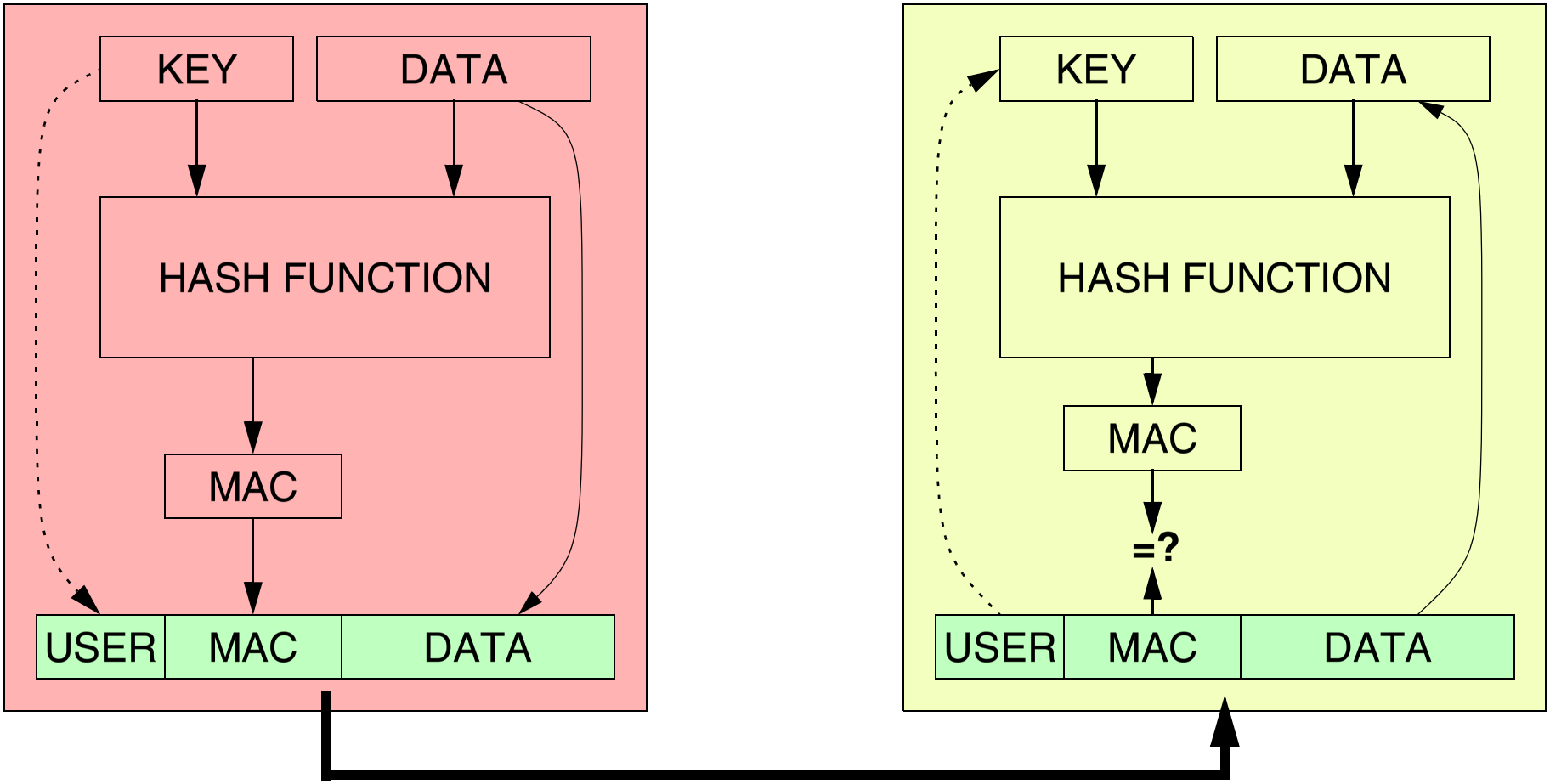


IDEA BEHIND DATA INTEGRITY AND AUTHENTICATION

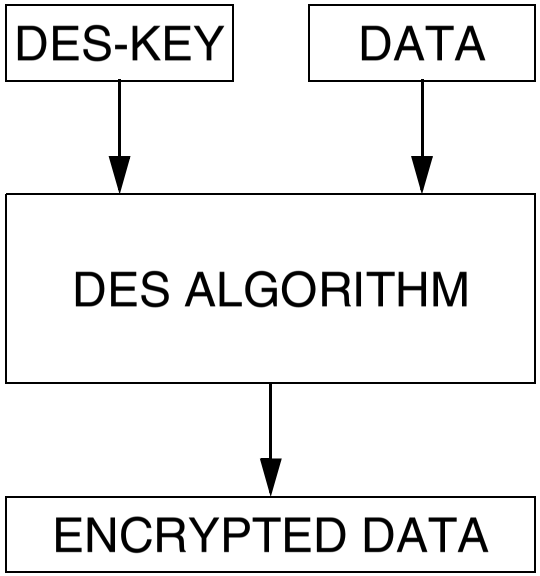


ADD THE MESSAGE AUTHENTICATION CODE (MAC) TO THE DATA
AND SEND THE RESULT

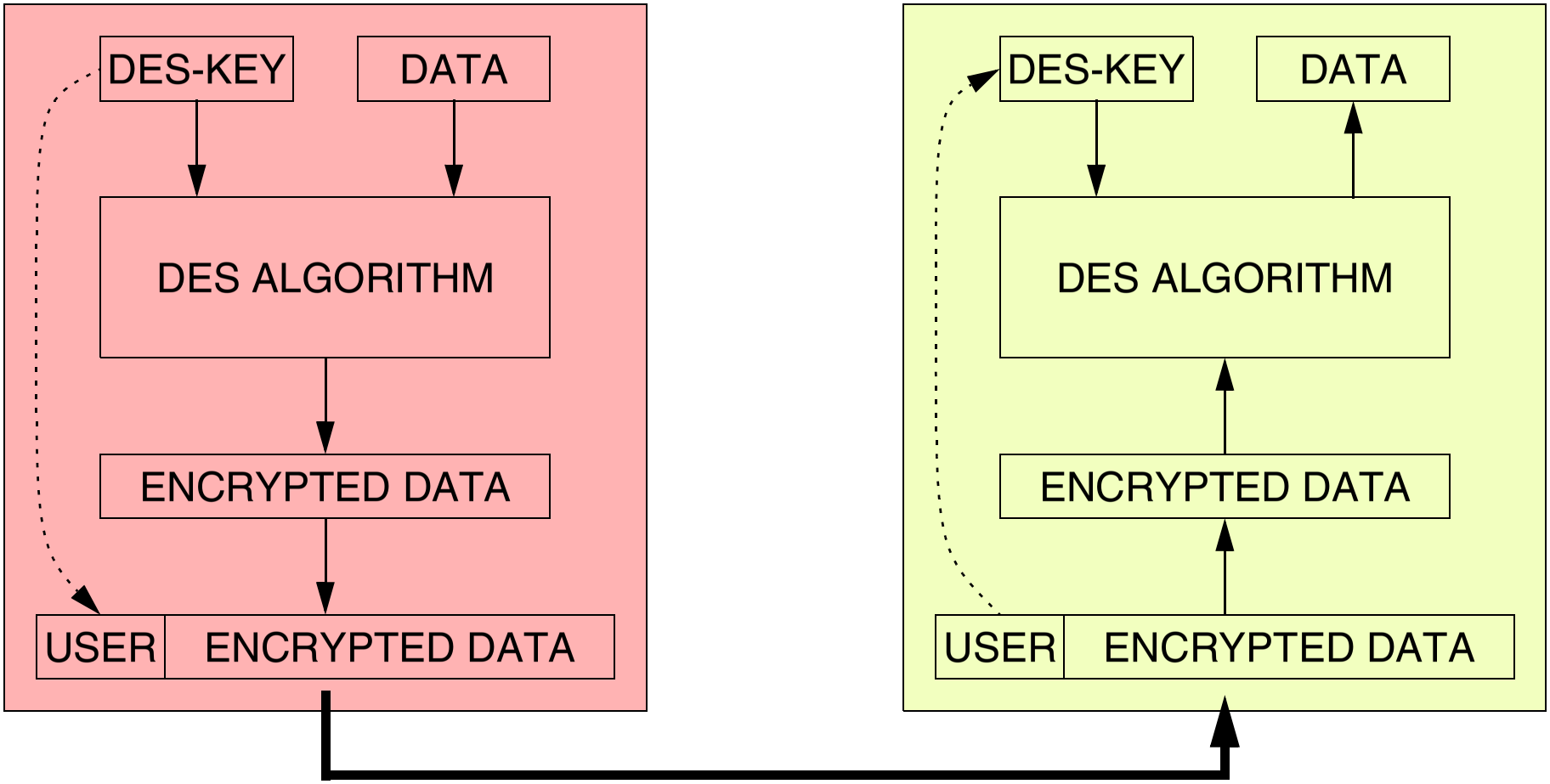
IDEA BEHIND AUTHENTICATION



IDEA BEHIND THE DATA CONFIDENTIALITY (DES)



IDEA BEHIND ENCRYPTION



VIEW BASED ACCESS CONTROL MODEL

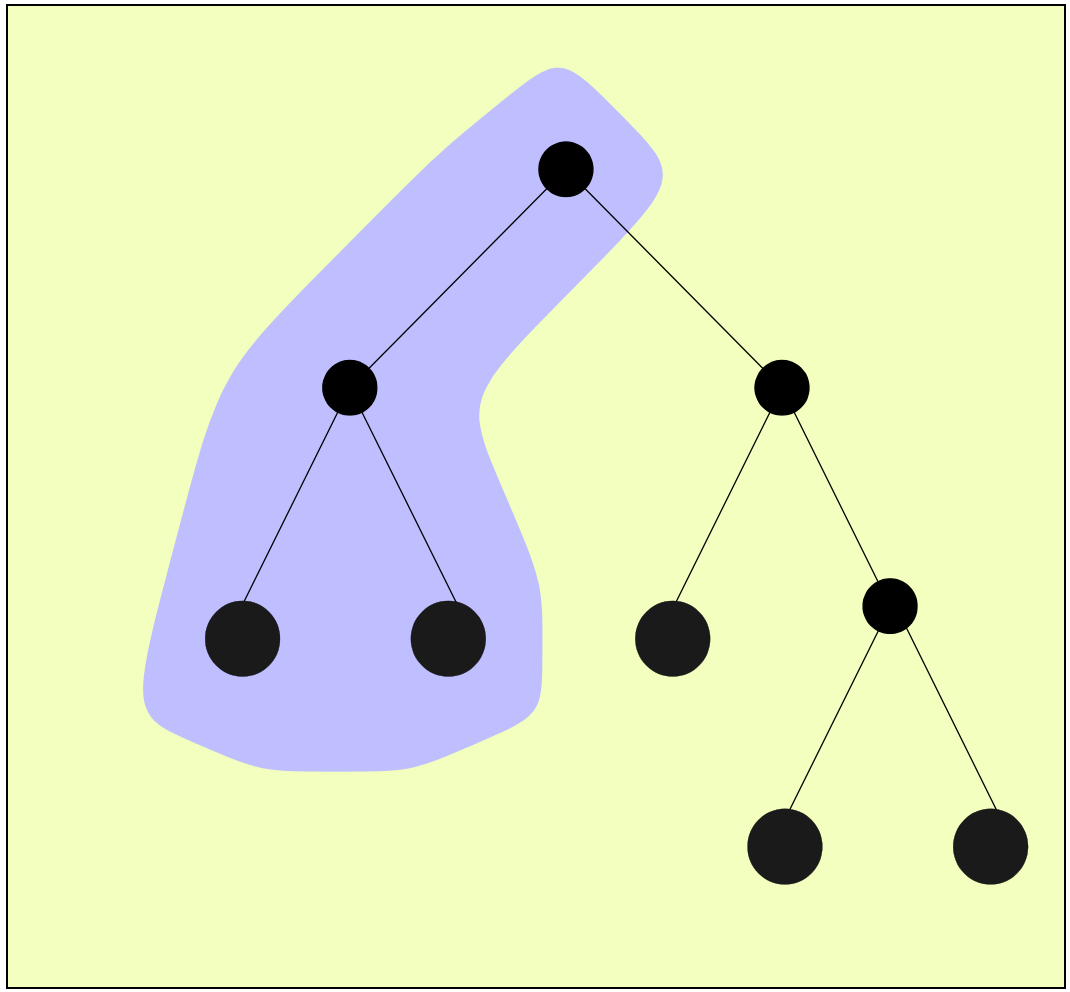
ACCESS CONTROL TABLE

MIB VIEWS

ACCESS CONTROL TABLES

MIB VIEW	ALLOWED OPERATIONS	ALLOWED MANAGERS	REQUIRED LEVEL OF SECURITY
Interface Table	SET	John	Authentication Encryption
Interface Table	GET / GETNEXT	John, Paul	Authentication
Systems Group	GET / GETNEXT	George	None
•••	•••	•••	•••
•••	•••	•••	•••
•••	•••	•••	•••
•••	•••	•••	•••

MIB VIEWS



SNMPv3 RFCs

SNMP ENTITY — **RFC 3411**

SNMP APPLICATIONS — **RFC 3413**

SNMP ENGINE

RFC 3412	RFC 3412	USM: RFC 3414	VACM: RFC 3415
DISPATCHER	MESSAGE PROCESSING SUBSYSTEM	SECURITY SUBSYSTEM	ACCESS CONTROL SUBSYSTEM

EXTENSIBLE AGENTS

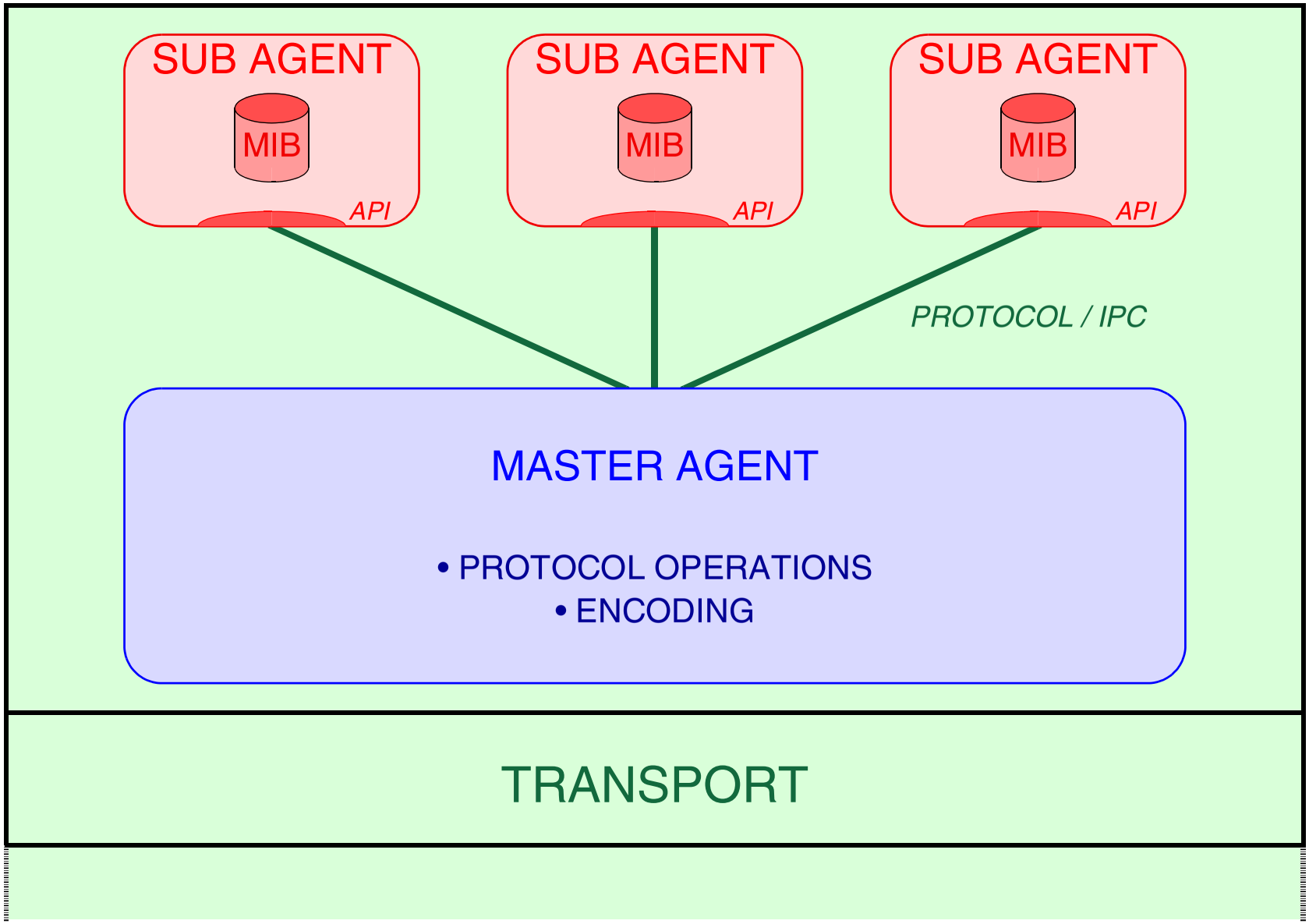
FACILITATE THE EXTENSION OF SNMP AGENTS
WITH NEW MIB MODULES

- SEPARATE SNMP PROTOCOL ENGINE
FROM MIB INSTRUMENTATION

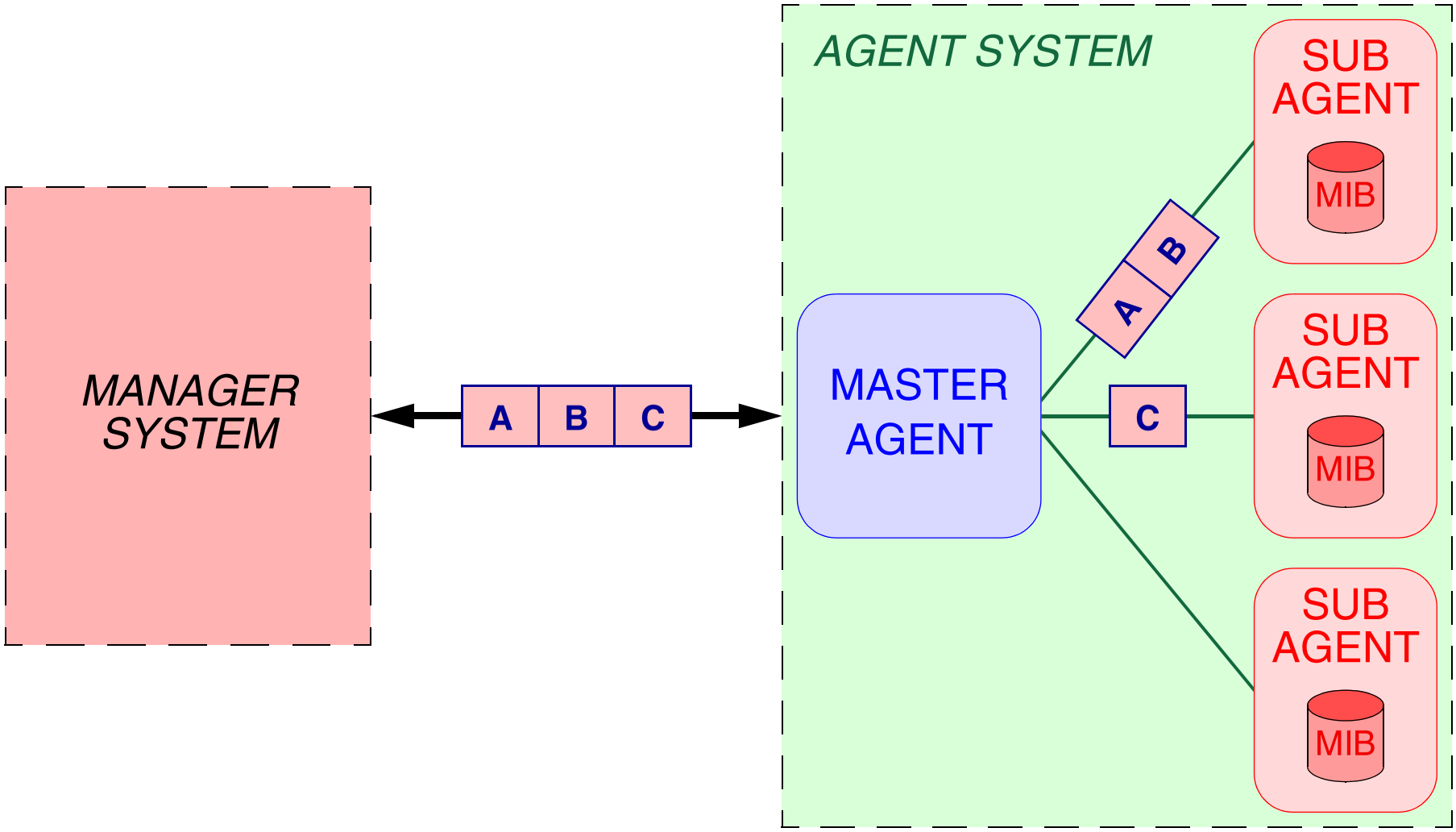
- ALLOW DYNAMIC ADDITION
OF NEW MIB MODULE IMPLEMENTATIONS

- EXTENSIBLE AGENTS SHOULD BE TRANSPARENT

BASIC STRUCTURE



SPLITTING OF VARBIND LIST



CHARACTERISTICS

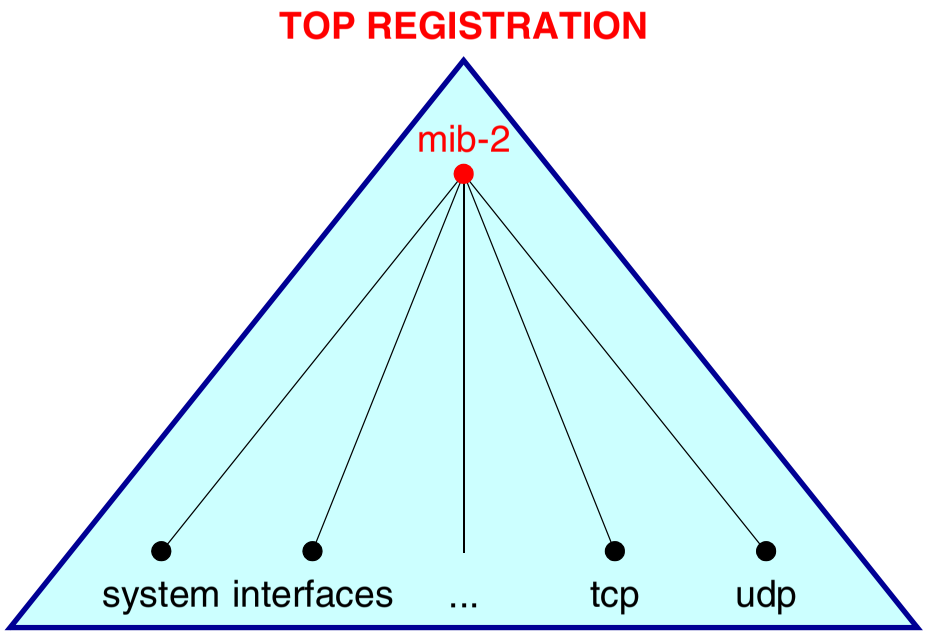
REQUIRES OID REGISTRATION:

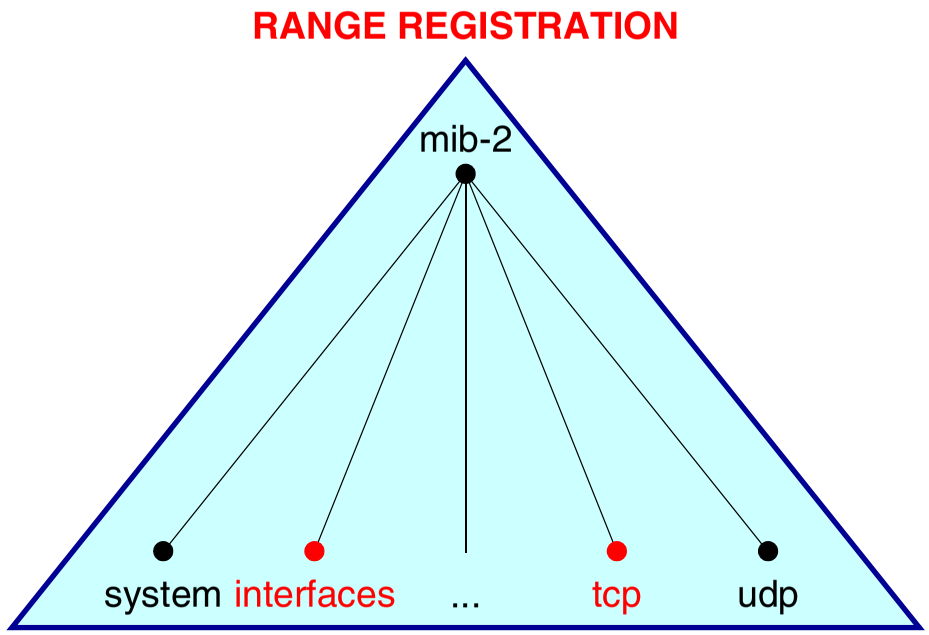
- TOP REGISTRATION

EXAMPLE: REGISTER(mib-2)

- RANGE REGISTRATION

EXAMPLE REGISTER(interfaces -> tcp)





POTENTIAL PROBLEMS

- TABLE ENTRIES MAY BE CREATED AND DELETED AT RUN-TIME

- ENTRIES OF A SINGLE TABLE MAY BE LOCATED IN DIFFERENT SUBAGENTS

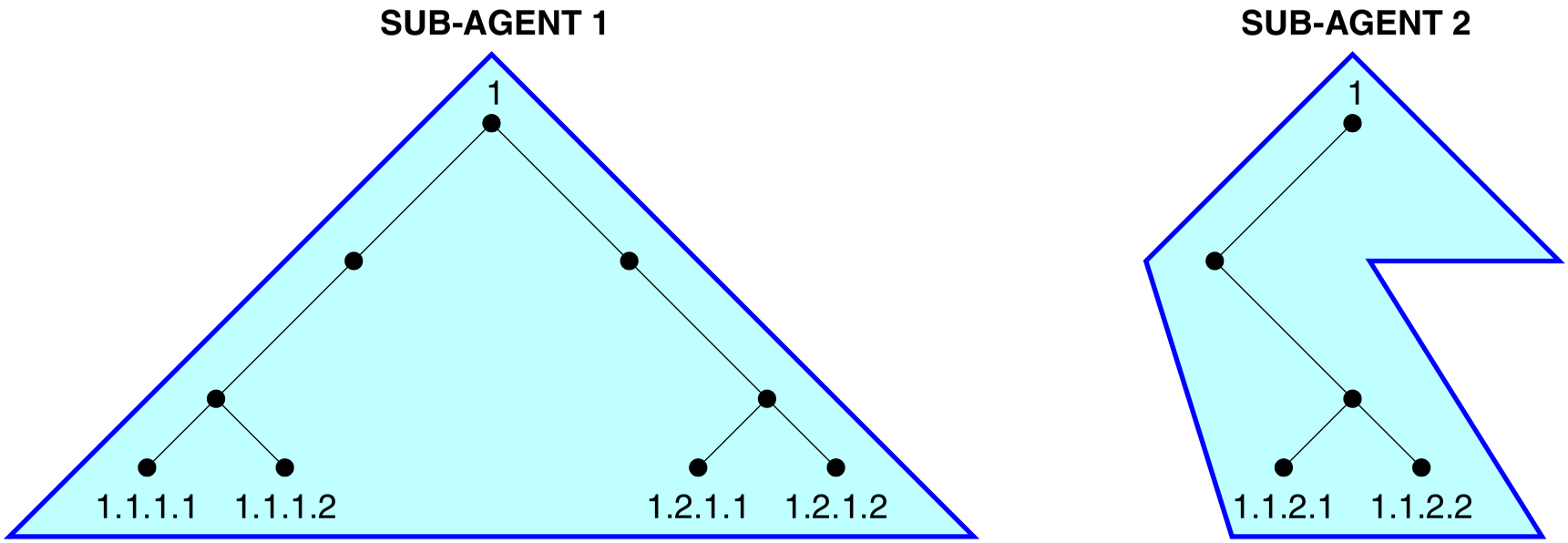
- DUPLICATED OIDs

- GAPS

- SETS

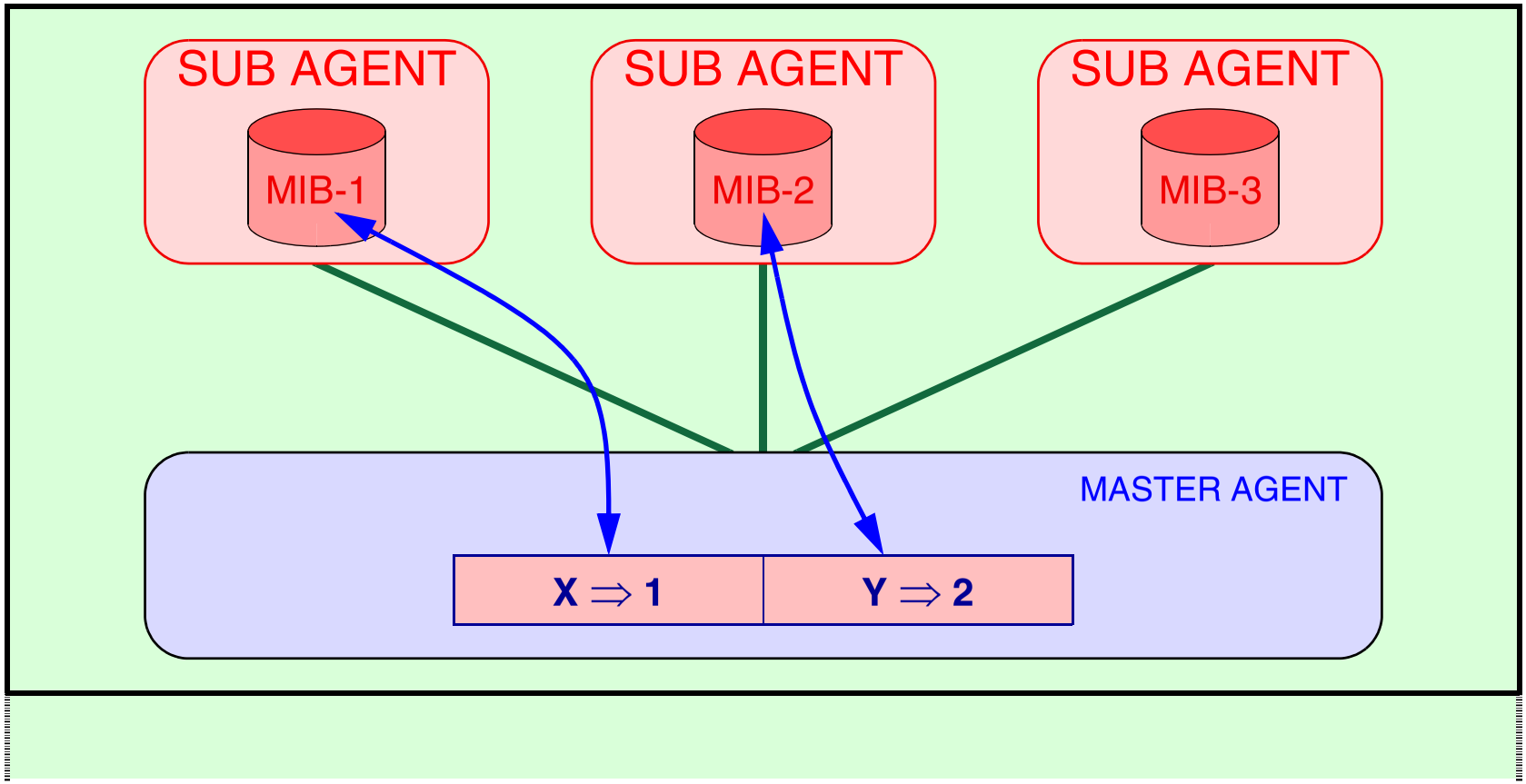
- sysUpTime

EXAMPLE: GAPS



GET-NEXT ...

SETS AND ATOMICITY



TRANSACTION-LIKE APPROACH

- TEST
- COMMIT
- UNDO / CLEAN

HISTORY

SMUX (1991: RFC 1227)
SNMP MULTIPLEXING PROTOCOL

DPI (1991-1994: RFC 1228 & RFC 1592)
DISTRIBUTED PROTOCOL INTERFACE

RESEARCH PROTOTYPES
FOR EXAMPLE: UNIVERSITY OF TWENTE - UT-SNMPv2

COMMERCIAL PRODUCTS
FOR EXAMPLE: SNMP RESEARCH - EMANATE
(ENHANCED MANAGEMENT AGENT THROUGH EXTENSIONS)

AGENTX (1998-2000: RFC2741 & RFC2742)

AGENTX

PROPOSED IETF STANDARD

- RFC 2741 & RFC 2742
- http:www.scguild.com/agentx/

HAS EFFICIENT MESSAGE FORMAT AND CODING

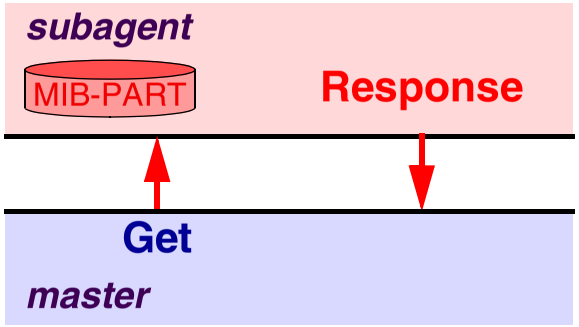
SUPPORTS

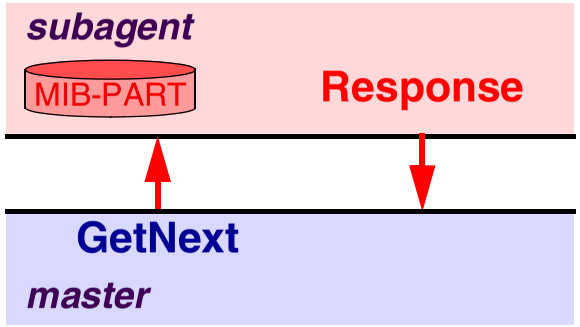
- SUBAGENTS IMPLEMENTING SEPARATE MIB MODULES
- SUBAGENTS IMPLEMENTING ROWS IN "SIMPLE TABLES"
- SUBAGENTS SHARING TABLES ALONG NON-ROW BORDERS

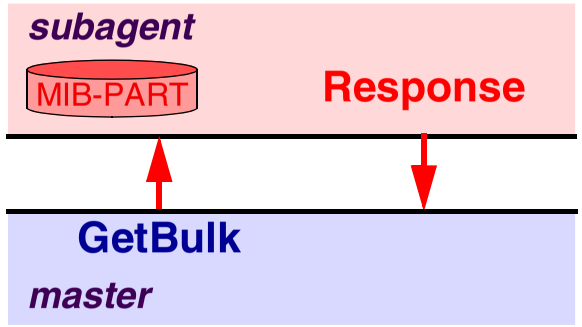
NON-GOALS

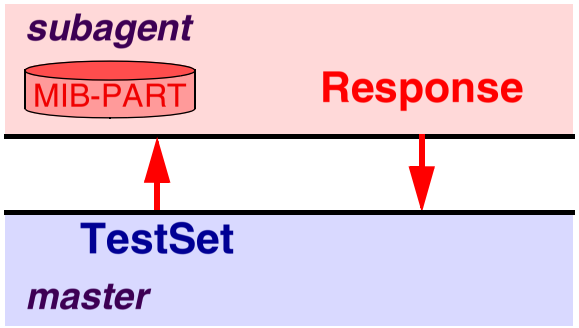
- SUBAGENTS SHARING "COMPLEX TABLES"
- SUBAGENT TO SUBAGENT COMMUNICATION

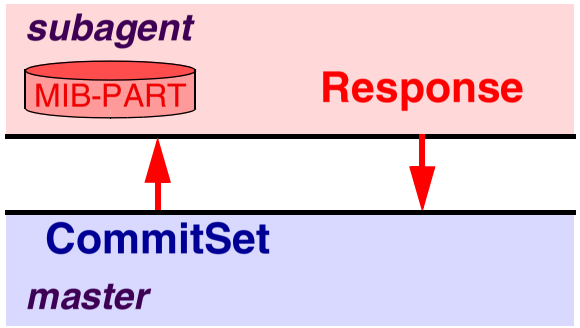
AGENTX - NORMAL PDUS

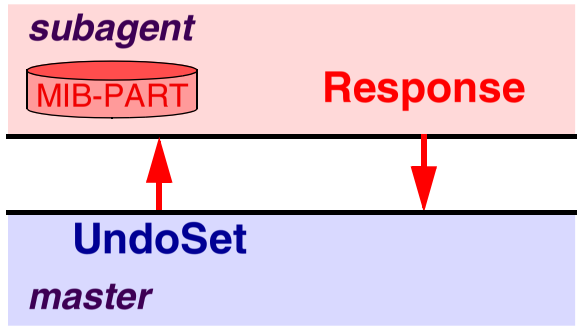


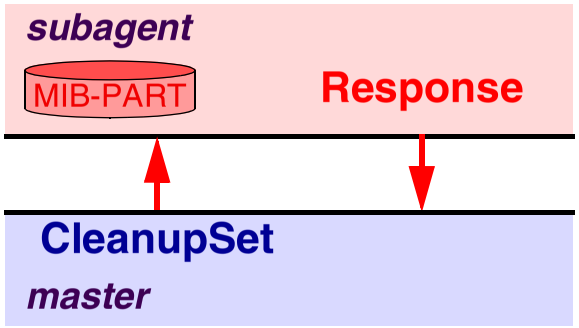


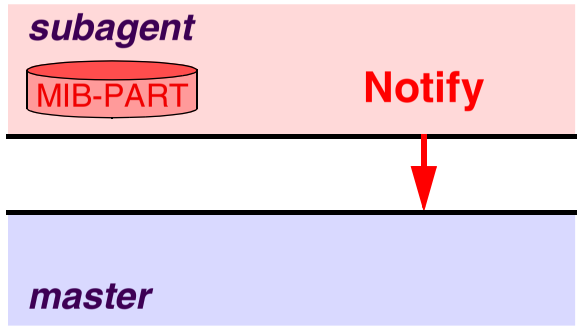




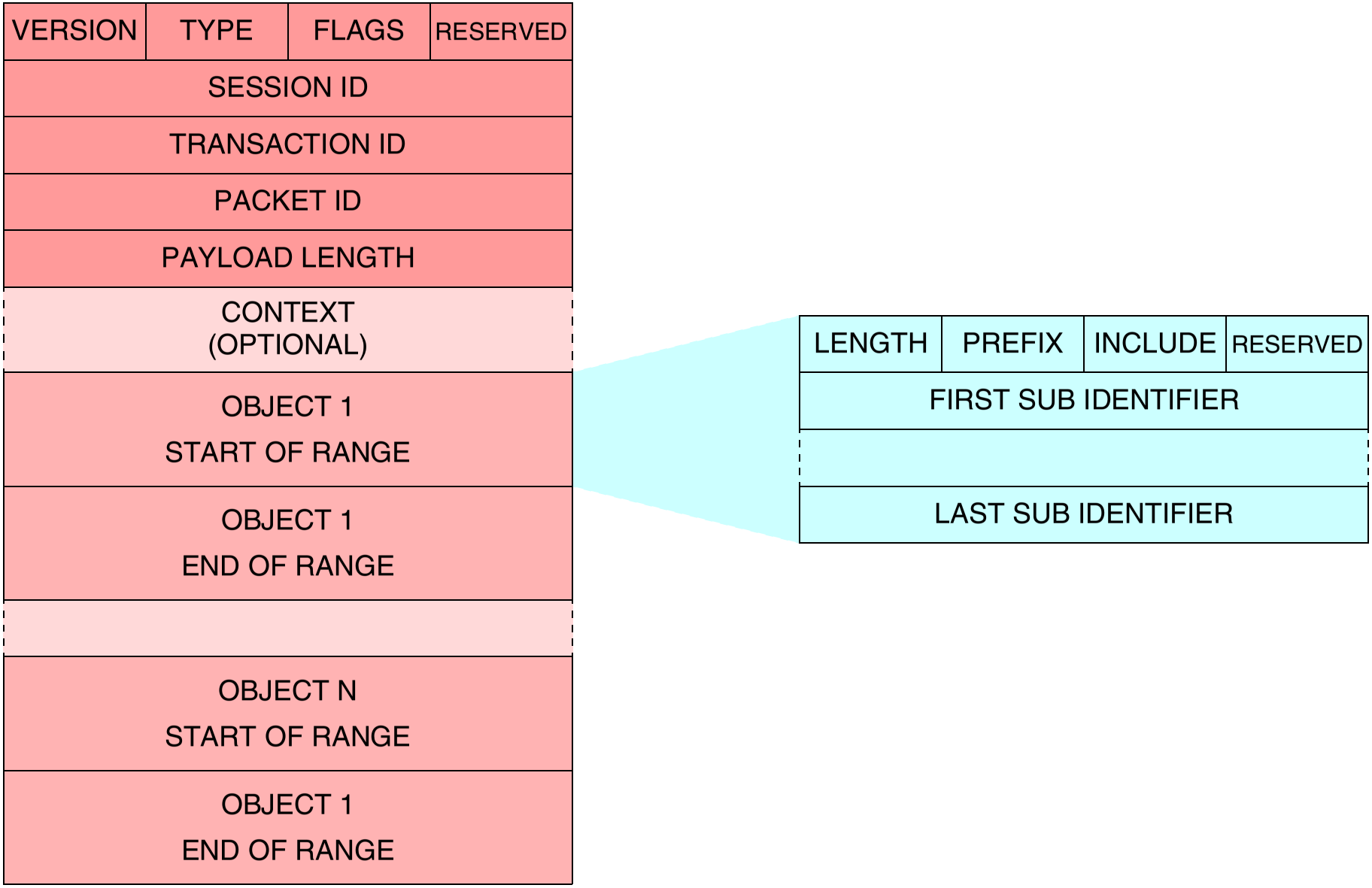








EXAMPLE: PDU FORMAT OF GetNext



AGENTX - ADMINISTRATIVE PDUS

Open
Close

AddAgentCaps
RemoveAgentCaps

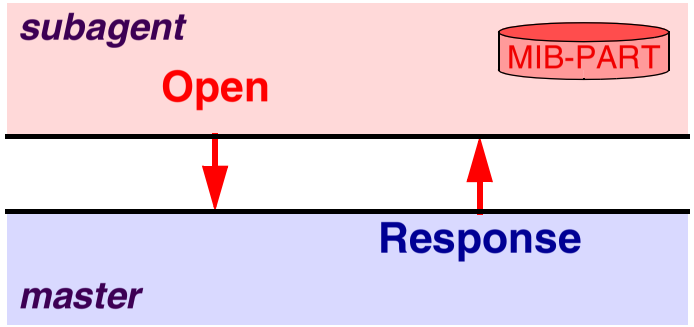
Register
Unregister

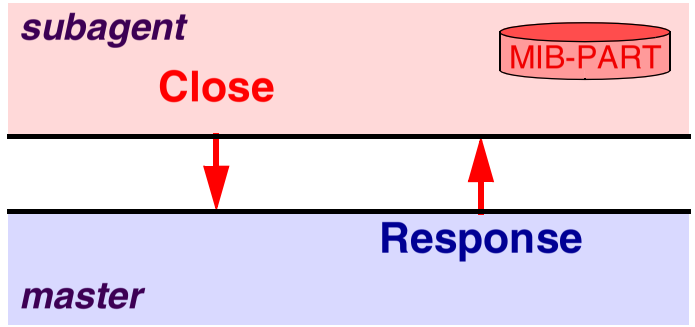
IndexAllocate
IndexDeallocate

Ping

Response

OPEN & CLOSE





TO ESTABLISH A SESSION

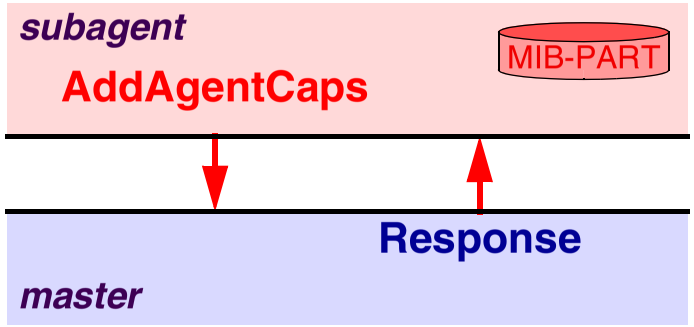
A UNIQUE sessionID IS ASSIGNED

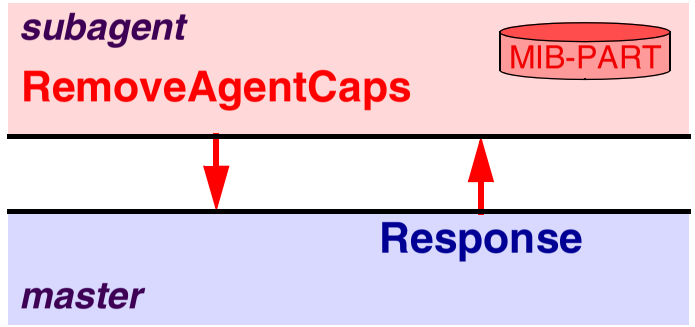
SUBAGENT SPECIFIES DEFAULT TIME-OUT

RESPONSES FROM MASTER ALWAYS INCLUDE sysUpTime

SESSION CAN BE CLOSED BY MASTER OR SUBAGENT

AGENT CAPABILITIES



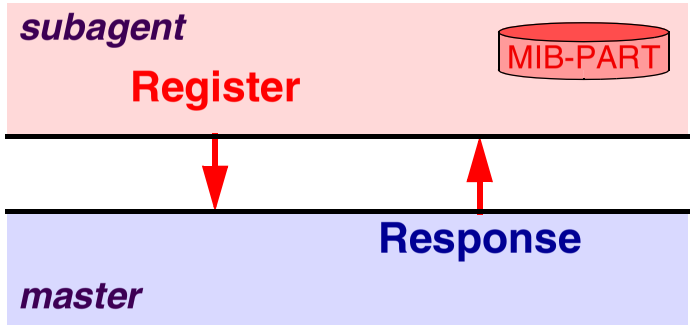


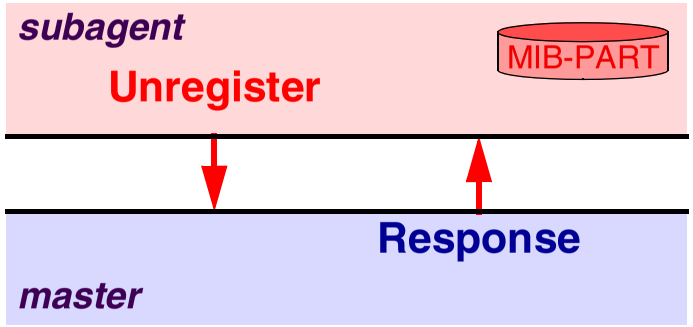
TO INFORM THE MASTER OF THE AGENT'S CAPABILITIES

CAPABILITIES ARE DEFINED AS:
- AN OBJECT ID
- A HUMAN READABLE STRING

THE CAPABILITIES ARE STORED IN THE sysORTable

REGISTRATION



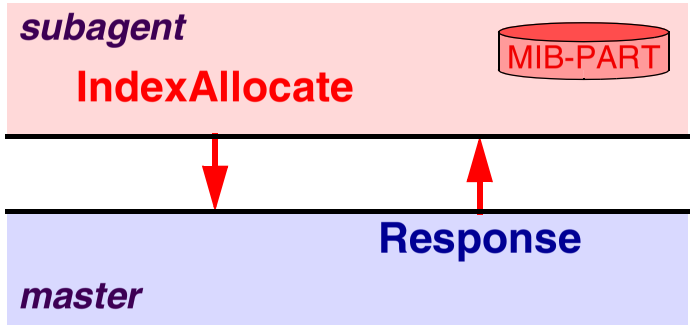


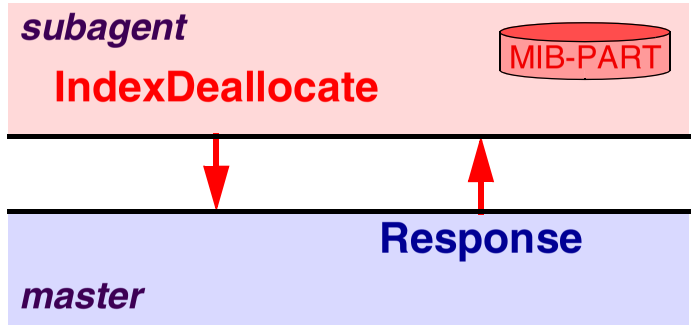
CHOICE BETWEEN:
- TOP REGISTRATION
- RANGE REGISTRATION

PRIORITY CAN BE SPECIFIED
- TO DETERMINE THE AUTHORITATIVE SUBAGENT

TIME-OUT CAN BE SPECIFIED

INDEXALLOCATION





TO ALLOCATE ONE OR MORE TABLE ROWS

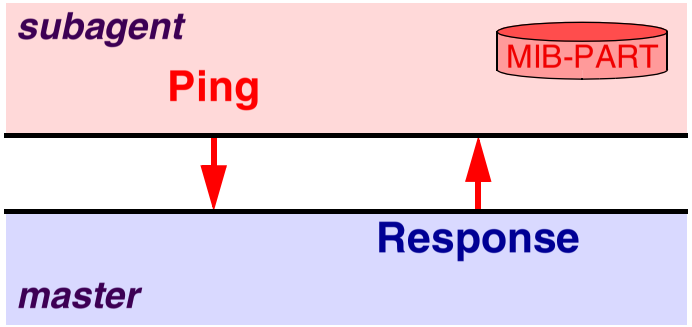
SUBAGENT REQUESTS ALLOCATION OF:

- A SPECIFIC INDEX VALUE
- AN INDEX VALUE THAT IS NOT CURRENTLY ALLOCATED
- AN INDEX VALUE THAT HAS NEVER BEEN ALLOCATED

MASTER AGENT MAINTAINS DATABASE

AFTER ALLOCATION REGISTRATION IS STILL NEEDED

PING



TO MONITOR IF THE MASTER AGENT IS STILL ABLE
TO RECEIVE AND SEND AGENTX PDUs

DISTRIBUTED MANAGEMENT

THREE APPROACHES ARE BEING DEFINED

MIB BASED
- EXPRESSION MIB
- EVENT MIB
- NOTIFICATION LOG MIB

SCRIPT BASED
- SCRIPT MIB
- SCHEDULE MIB

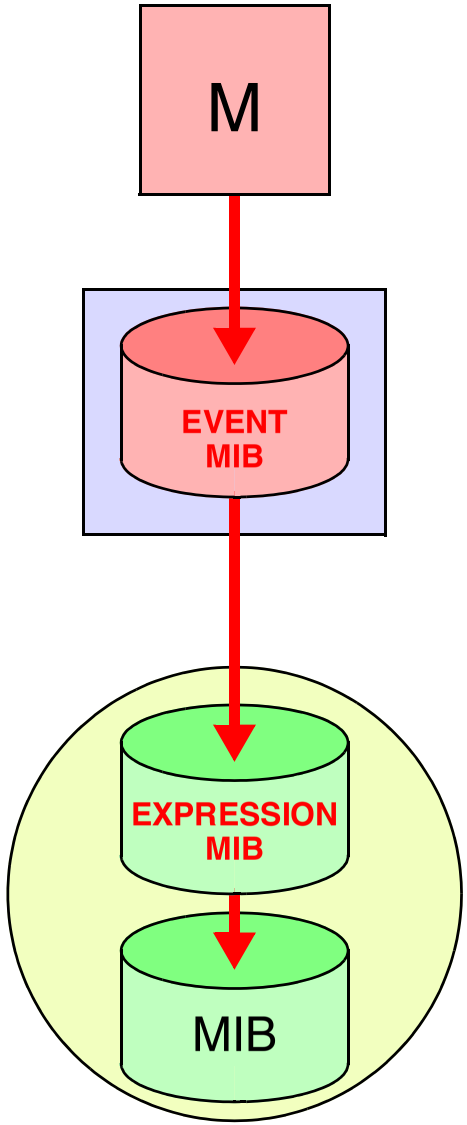
REMOTE OPERATIONS BASED
- REMOTE OPERATIONS MIB

EXPRESSION AND EVENT MIB

TOP LEVEL MANAGER

INTERMEDIATE LEVEL MANAGER

AGENT



EXPRESSION AND EVENT MIB: CHARACTERISTICS

• STANDARD MIB APPROACH

• RESEMBLES THE OLD SNMPv2 M2M MIB

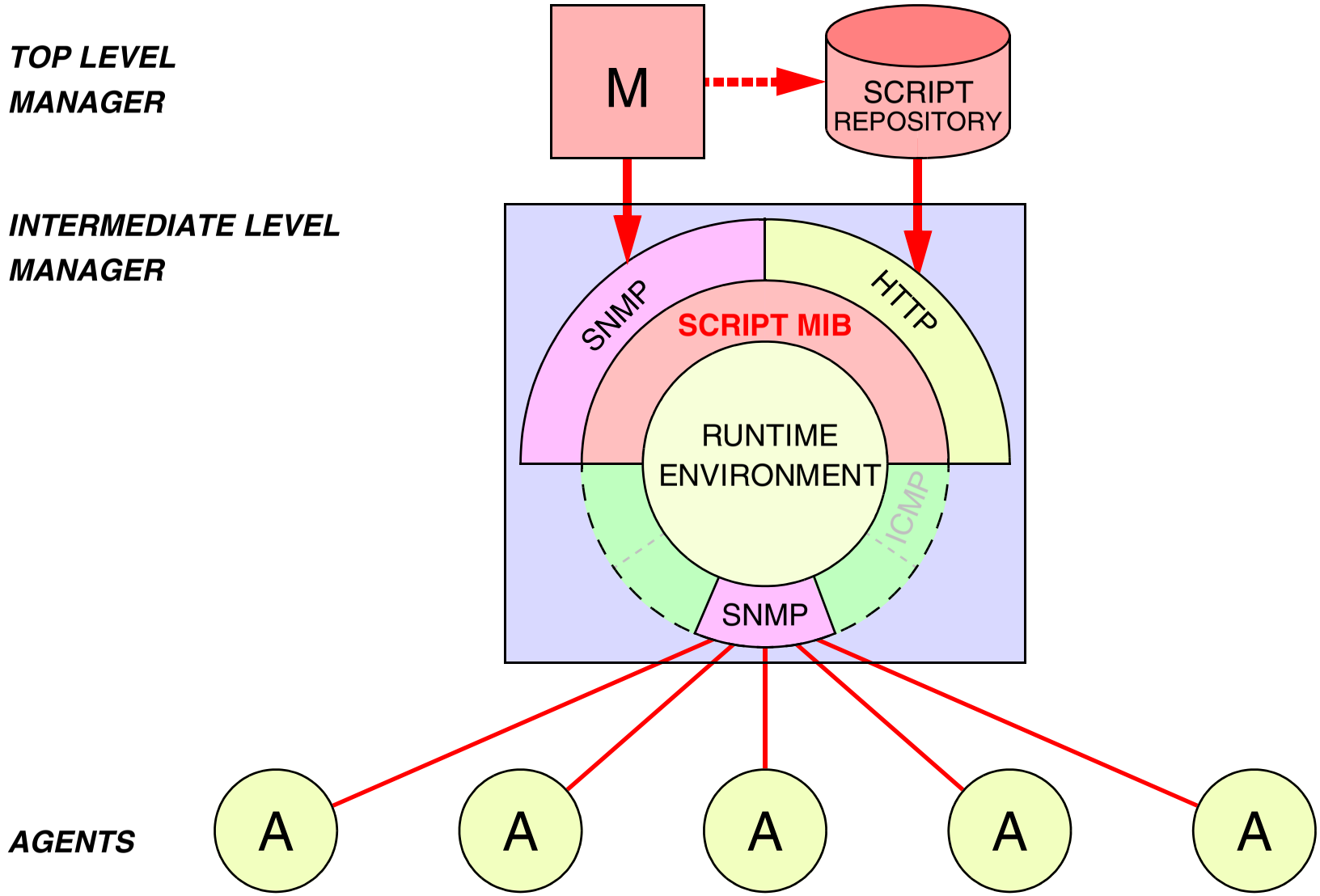
EXPRESSION MIB:

• INPUT ARE (WILDCARDED) VARIABLES OF A (LOCAL) MIB
• OPERATES ON ABSOLUTE AS WELL AS DELTA VALUES
• RICH SET OF EXPRESSIONS
• THE OUTPUT IS STORED IN THE *VALUE TABLE*
• THIS TABLE MAY SERVE AS INPUT FOR OTHER EXPRESSIONS

EVENT MIB:

• INPUT ARE VARIABLES OF A (REMOTE) MIB
• TRIGGERS ON CHANGES, OR TRESHOLD CROSSING
• GENERATES A NOTIFICATION OR SET OPERATION

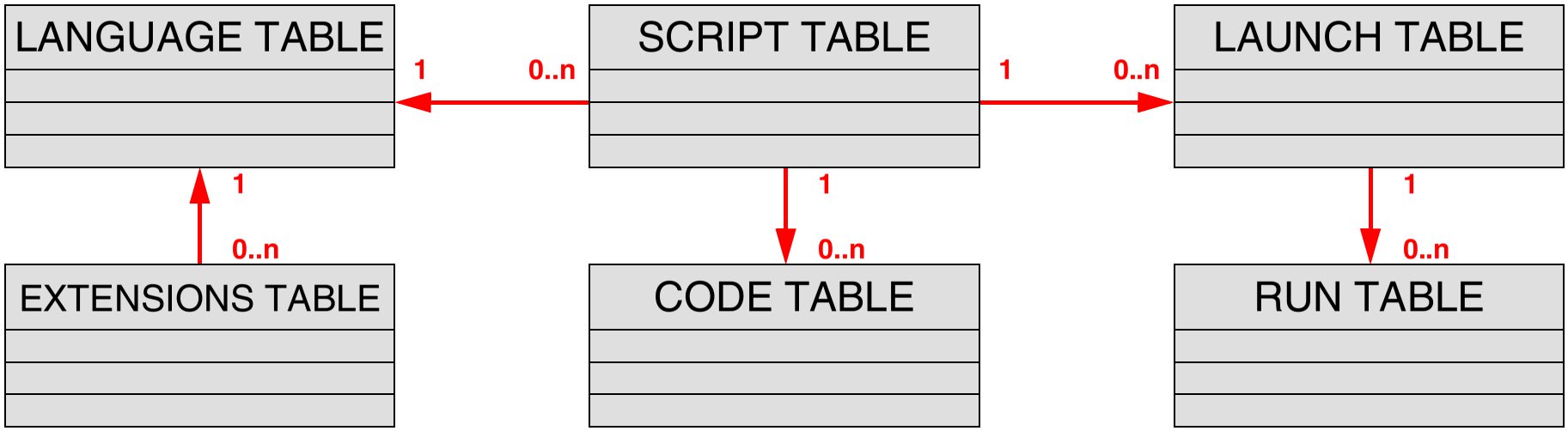
SCRIPT MIB


TOP LEVEL
MANAGER
INTERMEDIATE LEVEL
MANAGER
AGENTS
M
SCRIPT
REPOSITORY
SNMP
SCRIPT MIB
HTTP
RUNTIME
ENVIRONMENT
ICMP
SNMP
A
A
A
A
A

SCRIPT MIB: CHARACTERISTICS

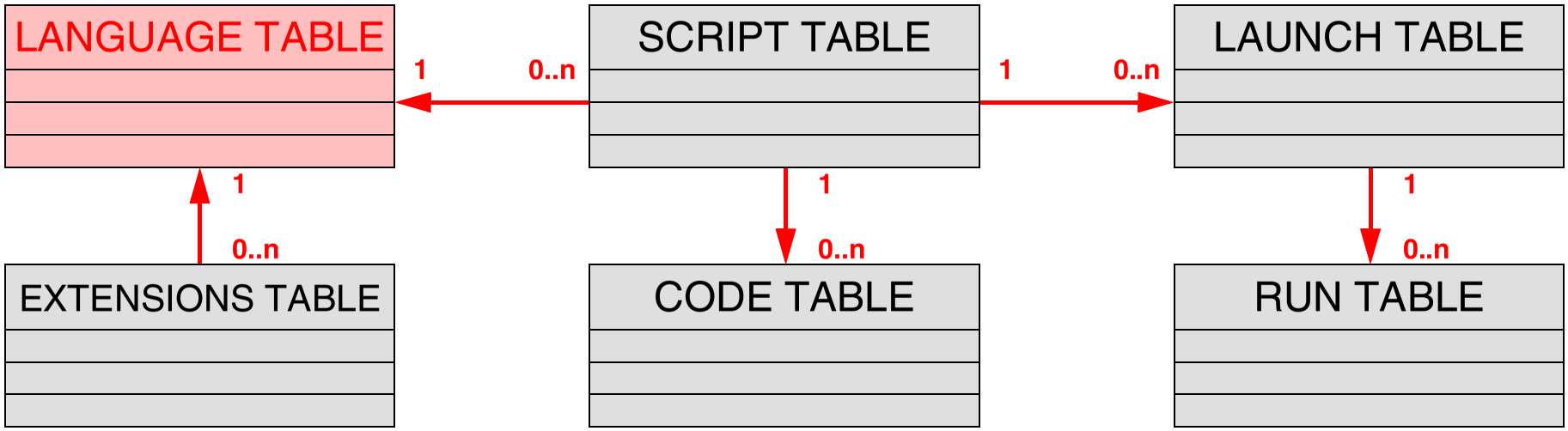
- FUNCTIONALITY CAN BE DEFINED AT RUN-TIME
- POWERFUL AUTONOMOUS ACTIONS
- MAY BE EASIER TO OPERATE FOR THE TOP-LEVEL MANAGER
- PROTECTION MECHANISMS NECESSARRY
- DIFFERENT SCRIPT LANGUAGES

SCRIPT MIB: STRUCTURE



CONSISTS OF 6 TABLES

SCRIPT MIB: LANGUAGE TABLE

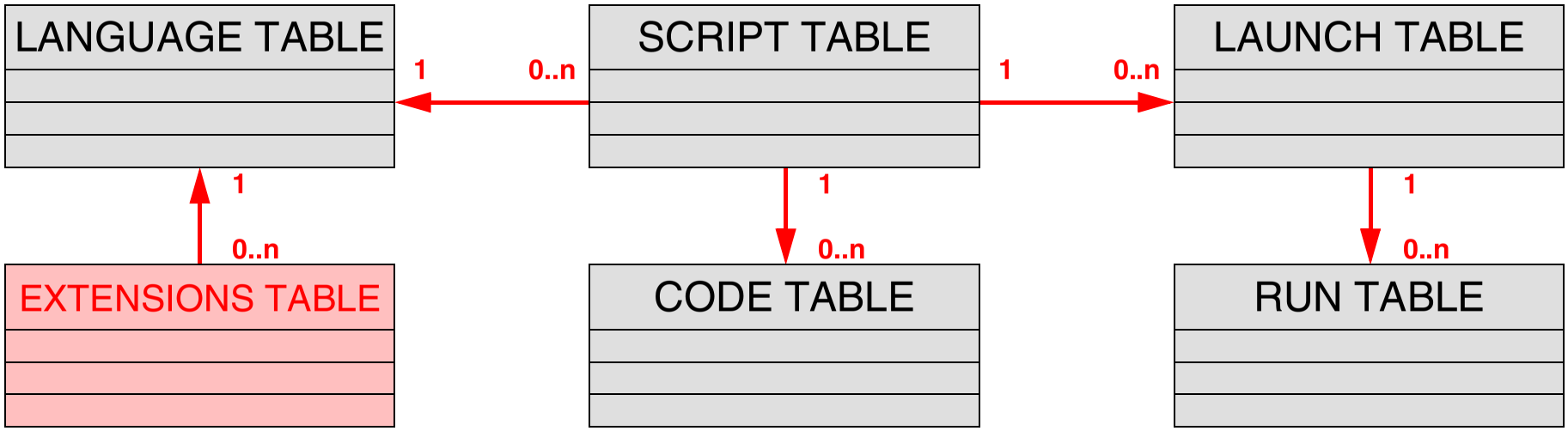


DEFINES THE LANGUAGES THIS SYSTEM SUPPORTS

- AN OID TO INDICATE THE LANGUAGE
- THE VERSION
- AN OID TO INDICATE THE VENDOR
- THE REVISION
- A DESCRIPTION

TABLE IS READ ONLY

SCRIPT MIB: EXTENSIONS TABLE

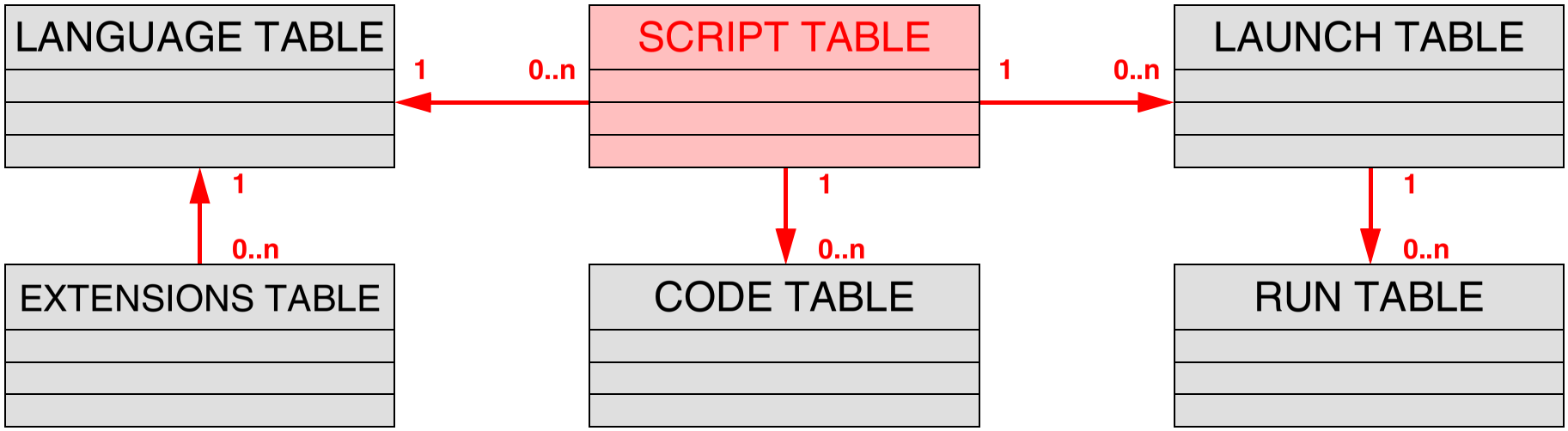


DEFINES THE EXTENSIONS FOR EACH LANGUAGE

- AN OID TO INDICATE THE EXTENSION
- THE VERSION
- AN OID TO INDICATE THE VENDOR
- THE REVISION
- A DESCRIPTION

TABLE IS READ ONLY

SCRIPT MIB: SCRIPT TABLE

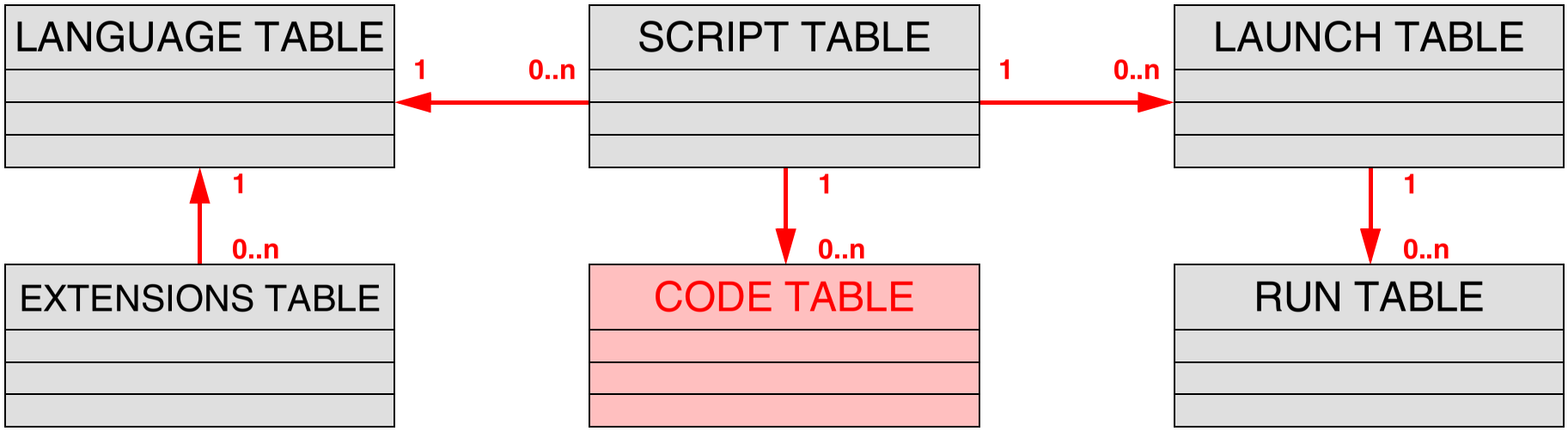


LISTS ALL SCRIPTS KNOWN TO THE SYSTEM

ALLOWS TO:

- DOWNLOAD SCRIPTS FROM A URL (PULL MODEL)
- READ SCRIPTS FROM LOCAL NON-VOLATILE STORAGE
- STORE SCRIPTS IN LOCAL NON-VOLATILE STORAGE
- DELETE SCRIPTS FROM LOCAL NON-VOLATILE STORAGE
- LIST PERMANENT SCRIPTS (THAT CAN NOT BE CHANGED OR REMOVED)
- READ AND MODIFY THE SCRIPT STATUS (ENABLED, DISABLED, EDITING)

SCRIPT MIB: CODE TABLE



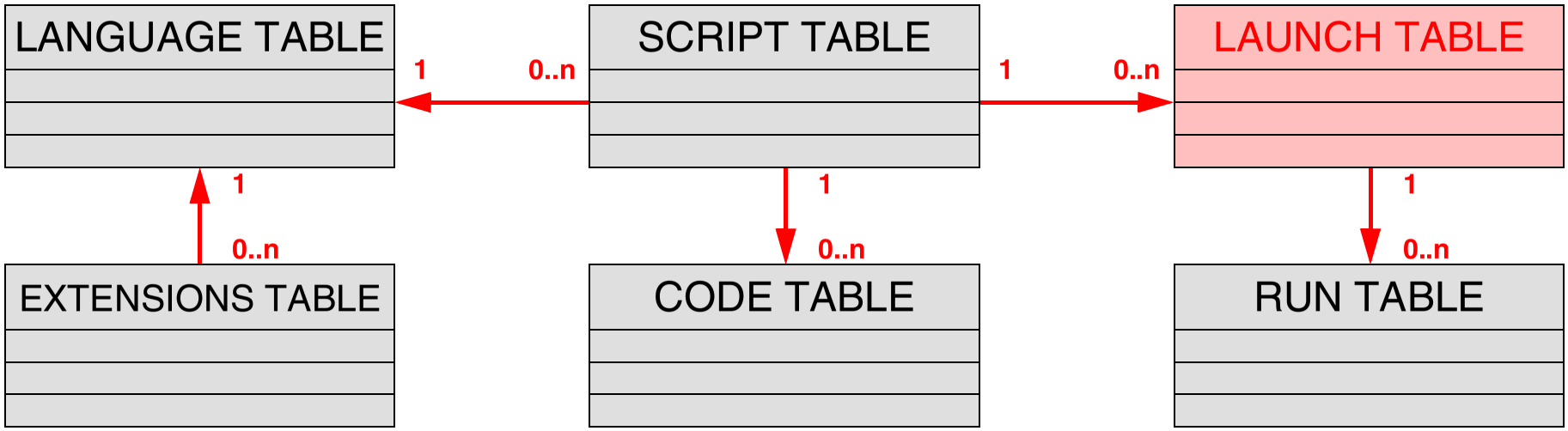
LISTS THE CODE OF A SCRIPT

ALLOWS TO:

- DOWNLOAD SCRIPTS VIA SNMP (PUSH MODEL)
- MODIFY SCRIPTS VIA SNMP (EDITING)

IMPLEMENTATION IS OPTIONAL

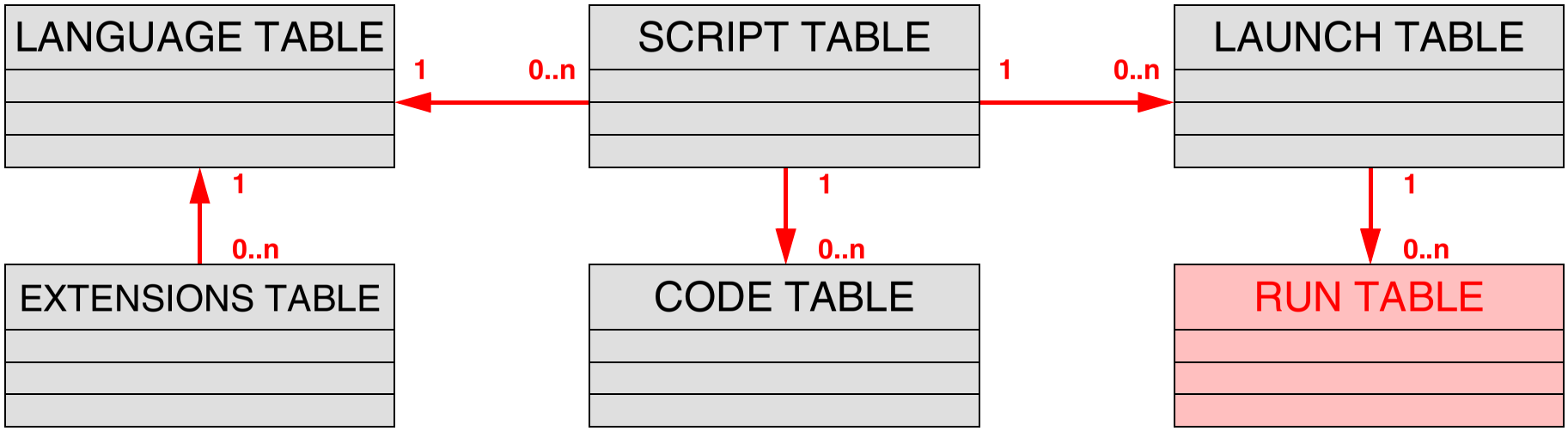
SCRIPT MIB: LAUNCH TABLE



ALLOWS TO:

- ASSOCIATE A SCRIPT WITH A ‘PERSON’ WHO INVOKES EXECUTION
- PROVIDE ARGUMENTS AND PARAMETERS FOR SCRIPT INVOCATION
- INVOKE SCRIPTS WITH A SINGLE SET OPERATION
- CONTROL THE NUMBER OF ACTIVE INVOCATIONS
- CONTROL THE TOTAL NUMBER OF INVOCATIONS

SCRIPT MIB: RUN TABLE



ALLOWS TO:

- RETRIEVE STATUS INFORMATION FROM RUNNING SCRIPTS
- CONTROL RUNNING SCRIPTS (SUSPEND, RESUME, ABORT)
- RETRIEVE RESULTS FROM RECENTLY TERMINATED SCRIPTS
- CONTROL THE REMAINING MAXIMUM LIFETIME OF A RUNNING SCRIPT
- CONTROL HOW LONG SCRIPT RESULTS ARE ACCESSIBLE

SCHEDULE MIB

PERFORMS SET OPERATIONS

FOR EXAMPLE ON THE SCRIPT MIB

- TARGET MUST BE Integer32

ON A PERIODIC OR CALENDER DRIVEN BASE

REMOTE OPERATIONS MIB

PING MIB

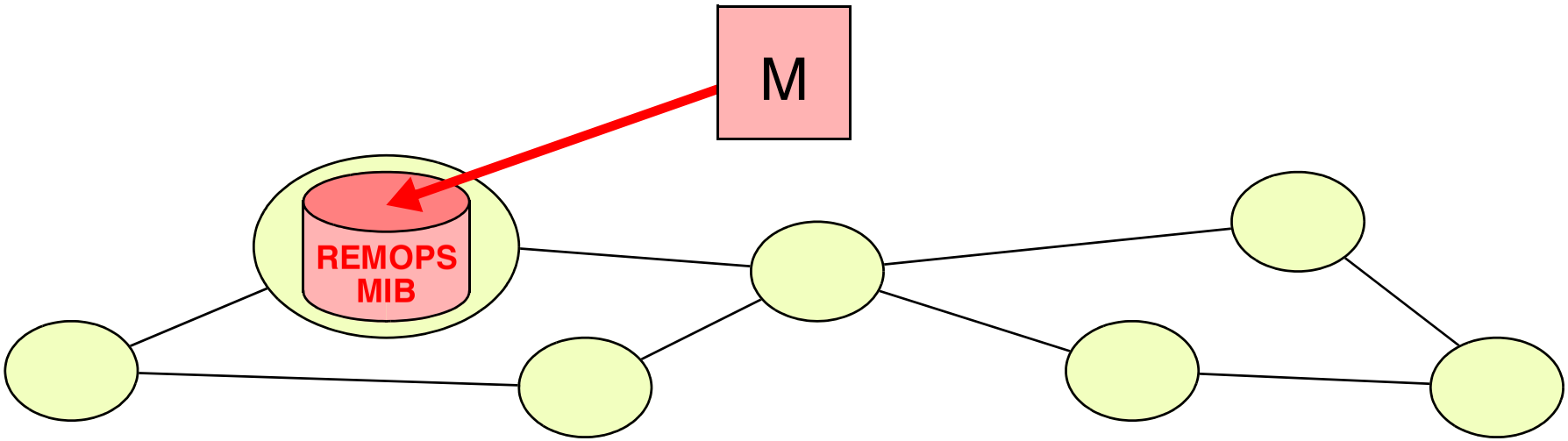
• TO PERFORM PING FROM A REMOTE HOST

TRACEROUTE MIB

• TO PERFORM TRACEROUTE FROM A REMOTE HOST

NAME LOOKUP MIB

• TO PERFORM NAME LOOKUP FROM A REMOTE HOST



IETF WGs - I

PROTOCOL AND DATA DEFINITION:

- SNMPv3
- SMIng
- EOS
- DISMAN

MIBs

- ADSL
- BRIDGE
- ENTITY
- ETHERNET INTERFACES & HUB

MEASURING

- BENCHMARK
- RMON
- IPFIX
- PSAMP
- PTOMAINE

IETF WGs - II

OPERATIONS AND DEPLOYMENT

- DNS
- IPv6
- MBONED

AAA

- AAA
- NASREQ

POLICY & CONFIGURATION

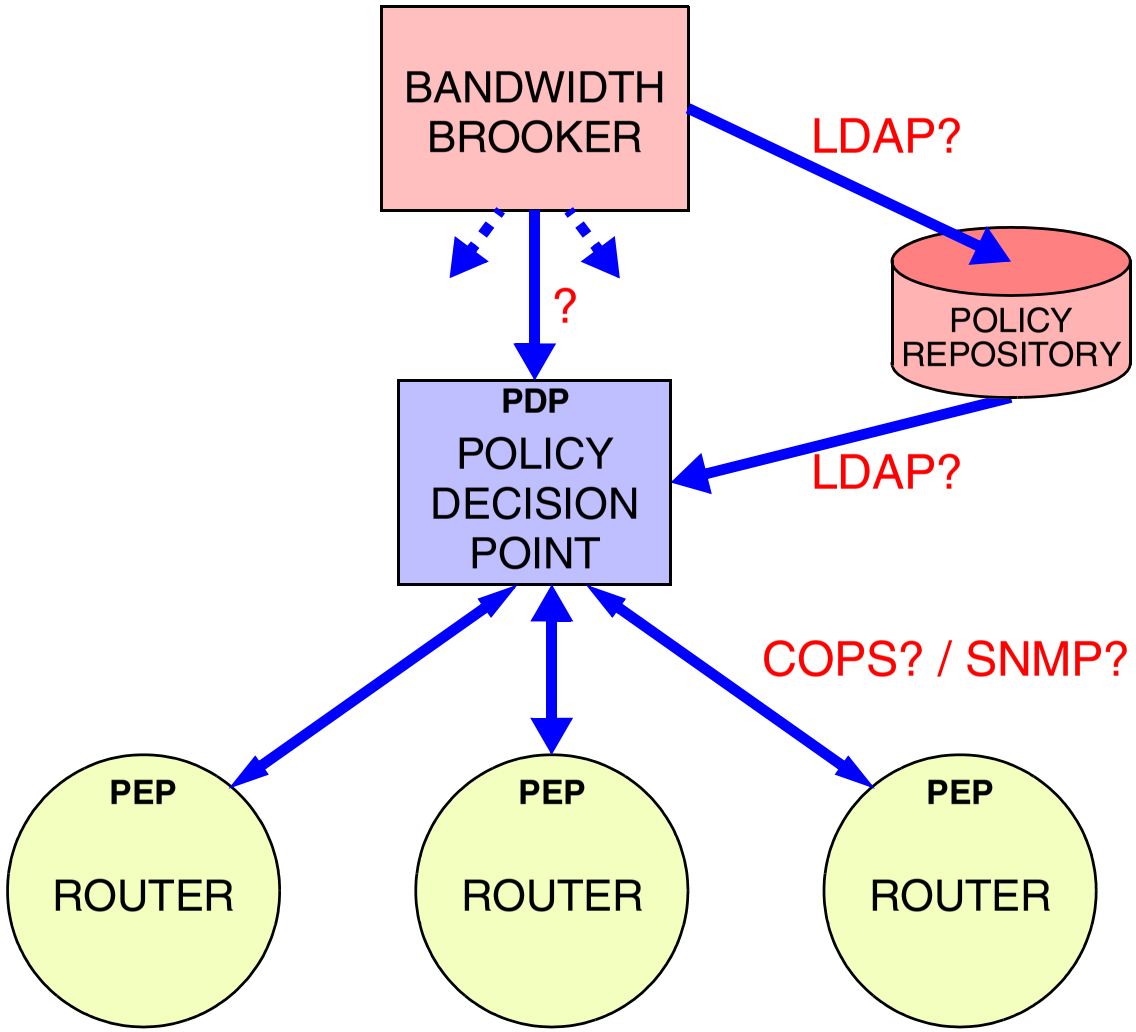
- POLICY
- RAP
- CONFIGURATION MANAGEMENT

OTHER

- MULTI6

NEW DEVELOPMENTS

POLICY BASED MANAGEMENT



COPS VERSUS SNMP

COPS:

- SPECIAL CASE OF CONFIGURATION MANAGEMENT
- HIGHER LEVEL OBJECTS THAN USUAL WITH SNMP
- POLICY INFORMATION BASE (PIB)
- SINGLE OPERATION TO ADD OR DELETE TABLE ROWS
- RELIABLE COMMUNICATION BETWEEN PDP AND PEP (BECAUSE OF TCP)
- EACH PEP IS CONNECTED TO SINGLE PDP

SNMP:

- INTEGRATED APPROACH TO MANAGEMENT
- POLICIES CAN BE DEFINED WITHIN MIBs
- EACH PEP MAY BE CONNECTED TO MULTIPLE PDPs

EVOLUTION OF SNMP

EOS
2001

BASIC GOAL:
IMPROVE PERFORMANCE OF SNMP BULK DATA RETRIEVALS

DIFFERENT ALTERNATIVES:
- OID DELTA COMPRESSION
- NEW PDUs (LIKE GET-TABLE)
- NEW BULK DATA TRANSFER MIBS

MANY IDEAS COME FROM IRTF-NMRG

SNMP OVER TCP MAPPING
RFC3430

XML BASED MANAGEMENT

DMTF HAS ALWAYS BEEN ACTIVE IN THIS FIELD

INTERNET STANDARDIZATION ORGANIZATIONS:

- IRTF-NMRG
- XMLCONF MAILING LIST
- IETF BOFs
- IAB WORKSHOP

VENDORS:

- JUNIPER

GOOD FOR:

- SOLVING SNMP's DEFICIENCIES
- CONFIGURATION MANAGEMENT
- CLI INTEGRATION / CODE REUSE

EXAMPLE

```
<rpc>
   <get-interface-information>
      <statistics/>
   </get-interface-information>
</rpc>

<rpc-reply>
  <interface-information>
     <InOctets>123456</InOctets>
     <InErrors>789</InErrors>
     <OutOctets>654321</OutOctets>
     <OutErrors>0</OutErrors>
  </interface-information>
</rpc-reply>
```

WEB SERVICES FOR MANAGEMENT

RECENT RESEARCH

OASIS

ADVANTAGES:

- COMMON MIDDLEWARE TECHNOLOGY
- MANY SOFTWARE COMPONENTS
- FAST (MANAGEMENT APPLICATION) DEVELOPMENT

EXAMPLE

```
<definitions name="InterfaceInformation"
   ...

  <message name="Statistics">
  </message>

  <message name="StatisticsResult">
    <part name="InOctets"
        element="xsd:unsignedInt"/>
    <part name="InErrors" ...
    <part name="OutOctets" ...
    <part name="OutErrors" ...
  </message>

  <service name="InterfaceInfoService">
    <port ...
      {mapping on underlying protocol}
      {URI of web service}
    </port>
  </service>

</definitions>
```

MORE INFO ON WEB SERVICES FOR MANAGEMENT

SEE PANEL 1 TOMORROW

(10:30-12:00)

WWW SERVERS

- IETF
  http://www.ietf.org/

- The SimpleWeb
  http://www.simpleweb.org/

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

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

BOOKS

- W. Stallings

SNMP, SNMPv2, SNMPv3 and RMON1 and 2
Third edition, Addison-Wesley, 1999
ISBN: 0-201-48534-6

- D. Zeltserman

A Practical Guide to SNMPv3 and Network Management
Prentice Hall, 1999
ISBN: 0-13-021453-1

- D. Perkins, E. McGinnis

Understanding SNMP MIBs
Prentice Hall, 1996
ISBN: 0-13-437708-7

ARTICLES

The Simple Times: *Special issue on Agent Extensibility*
Issue 4-2, April 1996

The Simple Times: *Special issue on SNMPv3*
Issue 5-1, December 1997

The Simple Times: *An overview of the AgentX Protocol*
Issue 6-1, March 1998

The Simple Times: *Special issue on SNMPv3*
Issue 7-2, November 1999

William Stallings,
Security Comes to SNMP: The New SNMPv3 Proposed Internet Standards
The Protocol Journal, December 1998

William Stallings,
SNMPv3: A Security Enhancement for SNMP,
IEEE Communications Survey, Q4, 1998