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

<table>
<thead>
<tr>
<th>Date</th>
<th>Milestone</th>
<th>Status</th>
<th>RFC</th>
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<tbody>
<tr>
<td>October 1987</td>
<td>High-Level Entity Management System</td>
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<td>November 1987</td>
<td>Simple Gateway Monitoring Protocol</td>
<td></td>
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<tr>
<td>February 1988</td>
<td>IAB SNMP Working Group</td>
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<td>August 1988</td>
<td>First SNMP Specification</td>
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<td>1065-1067</td>
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<td>May 1990</td>
<td>SNMP Version 1 (Community)</td>
<td>STD 15, 16</td>
<td>1155-1157</td>
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<td>March 1991</td>
<td>Management Information Base II</td>
<td>STD 17</td>
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<td>April 1993</td>
<td>SNMP Version 2 (Parties)</td>
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<tr>
<td>January 1996</td>
<td>SNMP Version 2 (Community)</td>
<td>DRAFT*</td>
<td>1901-1908</td>
</tr>
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</table>

* 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
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

MANAGER

SNMP

POLLING
TRAPS

SNMP AGENTS
SNMP STRUCTURE

MANAGER

Management Application

SNMP PDUs

AGENT

MIB

CONNECTIONLESS TRANSPORT SERVICE PROVIDER

UDP
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
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

MANAGER

SNMP

AGENT

MANAGED OBJECT INSTANCES

name

address

uptime
OBJECT NAMING

INTRODUCE NAMING TREE

new-MIB:

1

address (1) info (2)
130.89.16.2

name (1) uptime (2)
printer-1 123456

THE LEAVES OF THE TREE REPRESENT THE MANAGED OBJECTS

NODES ARE INTRODUCED FOR NAMING PURPOSES
TABLES

1

address (1)
130.89.16.2

info (2)

name (1)
printer-1

uptime (2)
123456

route-table (3)

route-entry (1)

<table>
<thead>
<tr>
<th>index (1)</th>
<th>dest (2)</th>
<th>next (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
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<tr>
<td>6</td>
<td>9</td>
<td>3</td>
</tr>
</tbody>
</table>
NAMING OF TABLE ENTRIES

X.C.I

OID of Entry  Column number  Index value

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

route-table (3)

route-entry (1)

index

dest (1) next (2)

<table>
<thead>
<tr>
<th>dest</th>
<th>next</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
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<tr>
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<td>8</td>
<td>3</td>
</tr>
<tr>
<td>9</td>
<td>3</td>
</tr>
</tbody>
</table>

EXAMPLES:

1.3.1.1.9 $\Rightarrow$ 9
1.3.1.2.9 $\Rightarrow$ 3
1.3.1.2.7 $\Rightarrow$ 2
1.3.1.1.1 $\Rightarrow$ entry does not exist
1.3.1.2.1 $\Rightarrow$ entry does not exist
TABLE INDEX - 2

route-table (3)

route-entry (1)

dest (1) next (2)

<table>
<thead>
<tr>
<th>dest</th>
<th>next</th>
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</thead>
<tbody>
<tr>
<td>130.89.16.1</td>
<td>130.89.16.1</td>
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<tr>
<td>130.89.16.4</td>
<td>130.89.16.4</td>
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<tr>
<td>130.89.16.23</td>
<td>130.89.16.23</td>
</tr>
<tr>
<td>130.89.19.121</td>
<td>130.89.16.1</td>
</tr>
<tr>
<td>192.1.23.24</td>
<td>130.89.16.4</td>
</tr>
<tr>
<td>193.22.11.97</td>
<td>130.89.16.1</td>
</tr>
</tbody>
</table>

EXAMPLES:

1.3.1.1.130.89.16.1 \(\rightarrow\) 130.89.16.1

1.3.1.2.130.89.16.1 \(\rightarrow\) 130.89.16.1

1.3.1.2.192.1.23.24 \(\rightarrow\) 130.89.16.4

1.3.1.2.193.22.11.97 \(\rightarrow\) 130.89.16.1

1.3.1.2.1 \(\rightarrow\) 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)

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
SYSTEM GROUP

system (1)

sysDescr (1)  sysUpTime (3)  sysName (5)  sysServices (7)

sysObjectID (2)  sysContact (4)  sysLocation (6)
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

interface (2)

ifNumber (1)  ifTable (2)
**ifTable**

- **ifAdminStatus / ifOperStatus**
  
  1 = up
  
  2 = down
  
  3 = testing

- **ifType**

  EXAMPLES:

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
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<td>16</td>
<td>LAPB</td>
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<tr>
<td>6</td>
<td>Ethernet</td>
<td>20</td>
<td>ISDN Basic</td>
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<tr>
<td>7</td>
<td>IEEE 802.3</td>
<td>21</td>
<td>ISDN Primary</td>
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<tr>
<td>8</td>
<td>IEEE 802.4</td>
<td>23</td>
<td>PPP</td>
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<td>9</td>
<td>IEEE 802.5</td>
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<td>IEEE 802.6</td>
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<td>SLIP</td>
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<tr>
<td>15</td>
<td>FDDI</td>
<td>32</td>
<td>Frame Relay</td>
</tr>
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</table>
IF PACKET COUNT

ifInUcastPkts + ifInNUcastPkts
ifInDiscards
ifInUnknownProtos
ifInErrors

ifOutUcastPkts + ifOutNUcastPkts
ifOutErrors
ifOutDiscards
# TRANSMISSION MIBs

<table>
<thead>
<tr>
<th>Title</th>
<th>RFC</th>
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<tbody>
<tr>
<td>IEEE 802.3 Repeater Devices</td>
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<tr>
<td>Data Link Switching</td>
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<tr>
<td>IEEE 802.5</td>
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<td>ATM</td>
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<tr>
<td>Frame Relay</td>
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<td>SONET / SDH</td>
<td>1595</td>
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<tr>
<td>FDDI</td>
<td>1512</td>
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<tr>
<td>Link Control Protocol of PPP</td>
<td>1471</td>
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<tr>
<td>Multiprotocol Interconnect over X.25</td>
<td>1461</td>
</tr>
<tr>
<td>DS3 / E3</td>
<td>1407</td>
</tr>
<tr>
<td>DS1 / E1</td>
<td>1406</td>
</tr>
<tr>
<td>Frame Relay DTEs</td>
<td>1315</td>
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## NETWORK LAYER MIBs

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<td>IP Forwarding Table</td>
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<td>RMON Version 2</td>
<td>2021</td>
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<tr>
<td>IP Mobility Support</td>
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<td>OSPF Version 2</td>
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<td>RMON</td>
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<td>RIP</td>
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<td>BGP Version 4</td>
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<td>Token Ring extensions to RMON</td>
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<td>Identification MIB</td>
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## APPLICATION LAYER MIBs

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<tr>
<td>WWW servers</td>
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<td>RDBMS</td>
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<td>DNS Resolver</td>
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<td>DNS Server</td>
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<td>X.500 Directory</td>
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<td>Mail</td>
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<td>Network Services</td>
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<td>Host Resources</td>
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# HARDWARE SPECIFIC MIBs

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<td>Entity</td>
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<td>Printer</td>
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<td>RS-232-like Hardware</td>
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<td>UPS</td>
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# VENDOR SPECIFIC MIBs

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<td>TCP/IPX Connection</td>
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<td>Appletalk</td>
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<tr>
<td>SNA NAUs</td>
<td>1666</td>
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<td>DECNET Phase IV</td>
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<td>SNMP over IPX</td>
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<td>SNMP over Appletalk</td>
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## Relation Between MIBs - 1

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<th>HOST</th>
<th>REPEATER</th>
<th>BRIDGE</th>
<th>RMON</th>
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<tr>
<td>Host Job Counts</td>
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<td>Host File System Information</td>
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<td>Link Testing</td>
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<td>HOST</td>
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<td>RMON</td>
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<td>SPANNING TREE PERFORMANCE</td>
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<td>WIDE AREA LINK PERFORMANCE</td>
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<td>TRESHOLDS FOR ANY VARIABLE</td>
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<td>TRAFFIC MATRIX WITH ALL NODES</td>
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<tr>
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<td>PACKET / PROTOCOL ANALYSIS</td>
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<td>DISTRIBUTED LOGGING</td>
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</tbody>
</table>
SNMP PROTOCOL

MANAGER

UDP

IP

LINK

SNMP PDUs

AGENT

UDP

IP

LINK
**MESSAGE & PDU STRUCTURE**

**variable bindings:**

<table>
<thead>
<tr>
<th>NAME 1</th>
<th>VALUE 1</th>
<th>NAME 2</th>
<th>VALUE 2</th>
<th>...</th>
<th>...</th>
<th>NAME n</th>
<th>VALUE n</th>
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</table>

**SNMP PDU:**

<table>
<thead>
<tr>
<th>PDU TYPE</th>
<th>REQUEST ID</th>
<th>ERROR STATUS</th>
<th>ERROR INDEX</th>
<th>VARIABLE BINDINGS</th>
</tr>
</thead>
<tbody>
<tr>
<td>*</td>
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**SNMP message:**

<table>
<thead>
<tr>
<th>VERSION</th>
<th>COMMUNITY</th>
<th>SNMP PDU</th>
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</thead>
<tbody>
<tr>
<td></td>
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</tr>
</tbody>
</table>
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

address (1)
130.89.16.2

info (2)
name (1)
printer-1
upetime (2)
123456

route-table (3)
route-entry (1)

<table>
<thead>
<tr>
<th>index (1)</th>
<th>dest (2)</th>
<th>next (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
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<td>4</td>
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<td>6</td>
<td>9</td>
<td>3</td>
</tr>
</tbody>
</table>
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 \(\Rightarrow\) my-printer)
RESPONSE(noError; 1.2.1.0 \(\Rightarrow\) my-printer)

POSSIBLE ERRORS:
- noSuchName
- badValue
- genErr
- tooBig
THE SET REQUEST IS ATOMIC

\[
\text{SET}(1.2.1.0 \mapsto \text{my-printer}, 1.2.2.0 \mapsto 0) \\
\text{RESPONSE}(\text{ErrorStatus} = \text{noSuchName}; \text{ErrorIndex} = 2)
\]
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
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 \rightarrow 130.89.16.2
  1.2.1.0 \rightarrow \text{printer-1}
  1.2.2.0 \rightarrow 123456
  1.3.1.1.1 \rightarrow 1
)

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

RESPONSE(
  1.3.1.1.1 \rightarrow 1; 1.3.1.2.1 \rightarrow 2; 1.3.1.3.1 \rightarrow 2
  1.3.1.1.2 \rightarrow 2; 1.3.1.2.2 \rightarrow 3; 1.3.1.3.2 \rightarrow 3
  1.3.1.1.3 \rightarrow 3; 1.3.1.2.3 \rightarrow 5; 1.3.1.3.3 \rightarrow 2
)
## SECURITY, AS DEFINED BY SNMPv3

<table>
<thead>
<tr>
<th>THREAT</th>
<th>ADDRESSED?</th>
<th>MECHANISM</th>
</tr>
</thead>
<tbody>
<tr>
<td>MASQUERADE</td>
<td>YES</td>
<td>MD5</td>
</tr>
<tr>
<td>REPLAY</td>
<td>YES</td>
<td>TIME STAMP</td>
</tr>
<tr>
<td>DISCLOSURE</td>
<td>YES</td>
<td>DES</td>
</tr>
<tr>
<td>INTEGRITY</td>
<td>YES</td>
<td>(MD5)</td>
</tr>
<tr>
<td>DENIAL OF SERVICE</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>TRAFFIC ANALYSIS</td>
<td>NO</td>
<td></td>
</tr>
</tbody>
</table>
IDEA BEHIND MESSAGE DIGEST ALGORITHM (MD5)

MD5-KEY  DATA

MD5 ALGORITHM

128 bit DIGEST

ADD THE DIGEST TO THE DATA AND SEND THE RESULT
AUTHENTICATION

MD5 ALGORITHM

MD5-KEY
DATA

DIGEST
ID
DIGEST
DATA

MD5-KEY
DATA

MD5 ALGORITHM

DIGEST
ID
DIGEST
DATA

=?
REPLAY PROTECTION

LOCAL CLOCK

ALLOWED LIFETIME

NOTION OF REMOTE CLOCK

TIMESTAMP	DATA

TIMESTAMP	DATA

+ 

>?
IDEA BEHIND THE DATA ENCRYPTION STANDARD (DES)

DES-KEY -> DES ALGORITHM -> ENCRYPTED DATA

DATA -> DES ALGORITHM -> ENCRYPTED DATA
EXTENSIBLE AGENTS

• PROTOCOL OPERATIONS
• ENCODING

UDP
EXTENSIBLE AGENTS
EXTENSIBLE AGENTS

SETS AND ATOMICITY

TRANSACTION-LIKE APPROACH

• PROBE
• COMMIT
• CLEAR / ROLL-BACK
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 NECESSARY

• 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
  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