

NET311

Computer Network Management

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Chapter 4

SNMPv1 Network Management: Organization and Information Models

Objectives

- IETF SNMP standard
- Organization Model
 - 2- and 3-tier models
 - Manager and agent
- Management messages
- Structure of management information, SMI
- Object type and instance
- Scalar and aggregate managed objects
- Management information base, MIB
- NMS physical and virtual databases
- IETF MIB-2 standard

Managed LAN

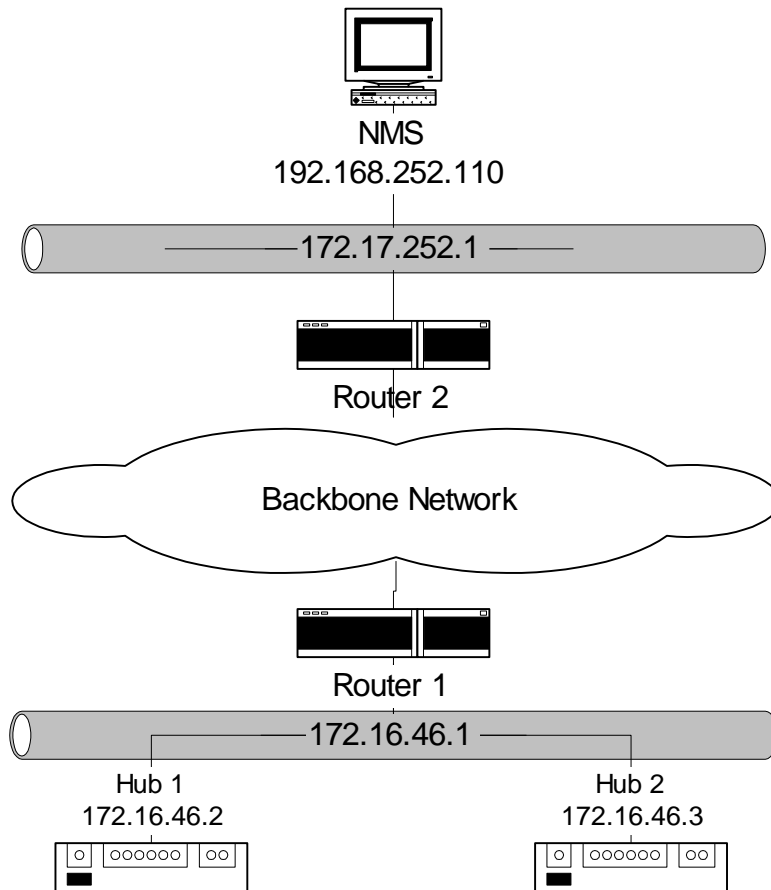


Figure 4.1 Managed LAN Network

Notes

- NMS on subnet 192.168.252.1 manages the router and the hubs on subnet 172.16.46.1 across the backbone network

Managed Hub: System Information

Title: System Information: 172.16.46.2

Name or IP Address: 172.16.46.2

System Name:

System Description: 3Com LinkBuilder FMS, SW version:3.02

System Contact:

System Location:

System Object ID: iso.org.dod.internet.private.enterprises.43.1.8.5

System Up Time: (2475380437) 286 days, 12:03:24.37

Figure 4.2(a) System Information on 172.16.46.2 Hub

Notes

- Information obtained querying the hub
- Data truly reflects what is stored in the hub

Managed Router: System Information

Title: System Information: router1.gatech.edu

Name or IP Address: 172.16.252.1

System Name : router1.gatech.edu

System Description : Cisco Internetwork Operating System Software
: IOS (tm) 7000 Software (C7000-JS-M), Version
: 11.2(6),RELEASE SOFTWARE (ge1)
: Copyright (c) 1986-1997 by Cisco Systems, Inc.
: Compiled Tue 06-May-97 19:11 by kuong

System Contact

System Location :

System Object ID : iso.org.dod.internet.private.enterprises.cisco.ciscoProducts.
cisco 7000

System Up Time : (315131795) 36 days, 11:21:57.95

Figure 4.2(c) System Information on Router

Notes

Managed Hub: Port Addresses

Index	Interface	IP address	Network Mask	Network Address	Link Address
1	3Com	172.16.46.2	255.255.255.0	172.16.46.0	0x08004E07C25C
2	3Com	192.168.101.1	255.255.255.0	192.168.101.0	<none>

Notes

- Information acquired by the NMS on hub interfaces
- Index refers to the interface on the hub
- Link address is the MAC address
- The second row data is a serial link

Managed Router: Port Addresses

Index	Interface	IP address	Network Mask	Network Address	Link Address
23	LEC.1.0	192.168.3.1	255.255.255.0	192.168.3.0	0x00000C3920B4
25	LEC.3.9	192.168.252.15	255.255.255.0	192.168.252.0	0x00000C3920B4
13	Ethernet2/0	172.16..46.1	255.255.255.0	172.16..46.0	0x00000C3920AC
16	Ethernet2/3	172.16.49.1	255.255.255.0	172.16.49.0	0x00000C3920AF
17	Ethernet2/4	172.16.52.1	255.255.255.0	172.16.52.0	0x00000C3920B0
9	Ethernet1/2	172.16.55.1	255.255.255.0	172.16.55.0	0x00000C3920A6
2	Ethernet 0/1	172.16.56.1	255.255.255.0	172.16.56.0	0x00000C39209D
15	Ethernet2/2	172.16.57.1	255.255.255.0	172.16.57.0	0x00000C3920AE
8	Ethernet1/1	172.16.58.1	255.255.255.0	172.16.58.0	0x00000C3920A5
14	Ethernet2/1	172.16.60.1	255.255.255.0	172.16.60.0	0x00000C3920AD

Notes

- Information acquired by NMS on the router interfaces
- Index refers to the interface on the router
- LEC is the LAN emulation card
- Ethernet 2/0 interface refers to the interface card 2 and port 0 in that card

Internet SNMP Management

- Internet Engineering Task Force (IETF)
 - 1990 SNMPv1
 - 1995 SNMPv2
 - 1998 SNMPv3
- Internet documents:
 - Request for Comments (RFC)
 - IETF STD Internet Standard

Notes

SNMPv1 & SNMPv2 Documents

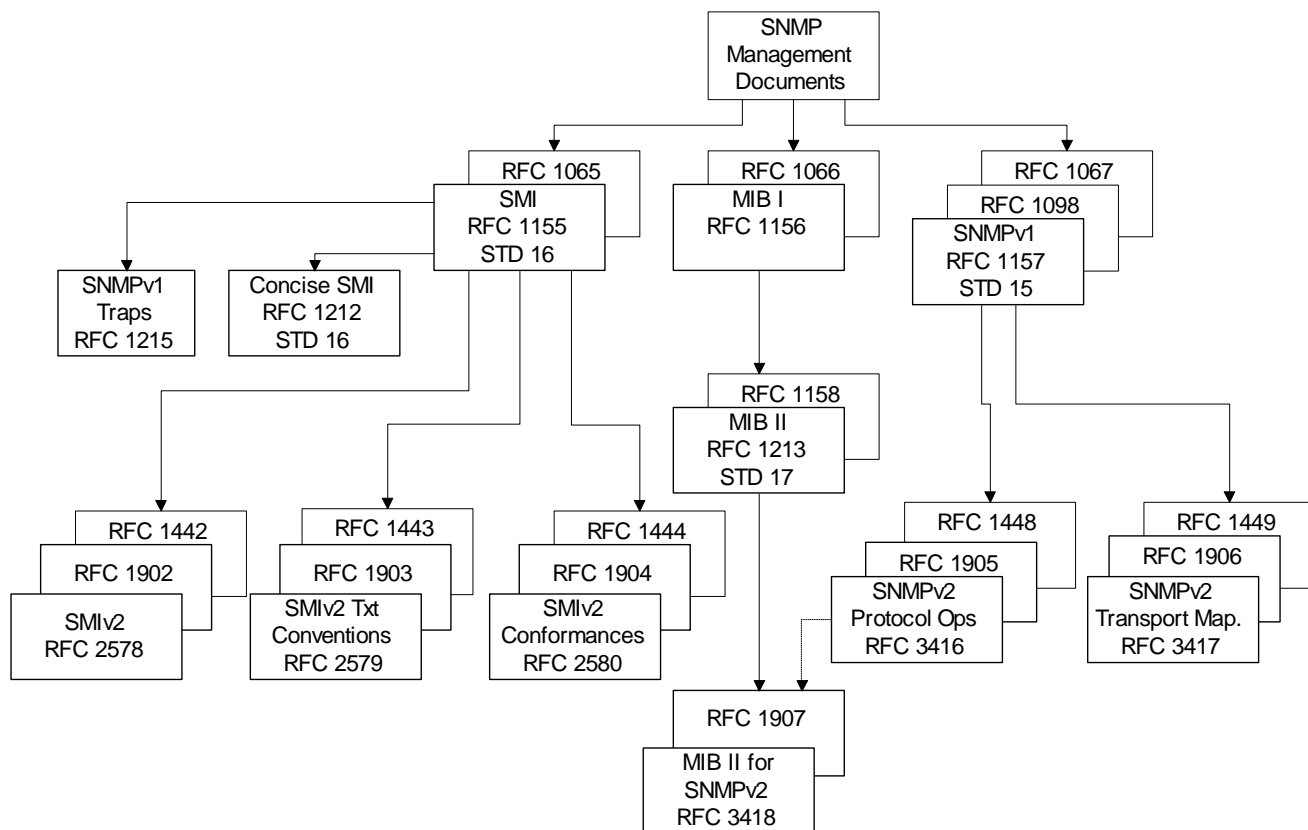


Figure 4.4 SNMP Document Evolution

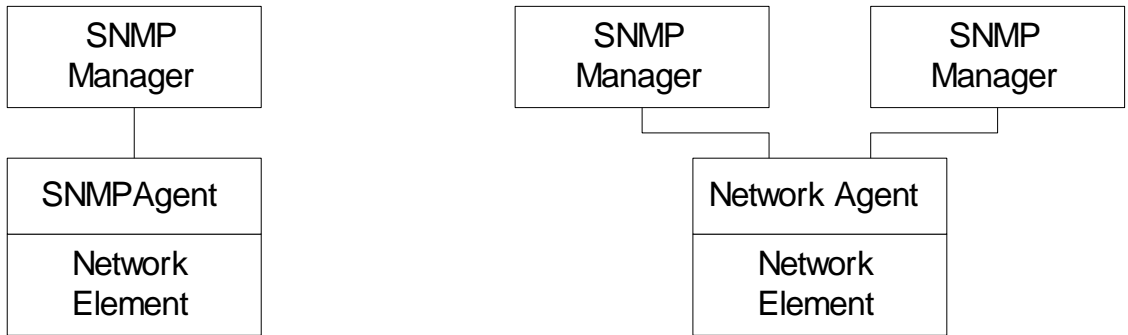
Notes

SNMP Model

- Organization Model
 - Relationship between network element, agent, and manager
 - Hierarchical architecture
- Information Model
 - Uses ASN.1 syntax
 - SMI (Structure of Management Information)
 - MIB (Management Information Base)
- Communication Model
 - Transfer syntax
 - SNMP over TCP/IP
 - Communication services addressed by messages
 - Security framework community-based model

Notes

Two-Tier Organization Model



(a) One Manager-One Agent Model

(b) Multiple Managers-One Agent Model

Figure 4.5 Two-Tier Organization Model

Notes

- Any host that could query an agent is a manager.

Three-Tier Organization Model: RMON

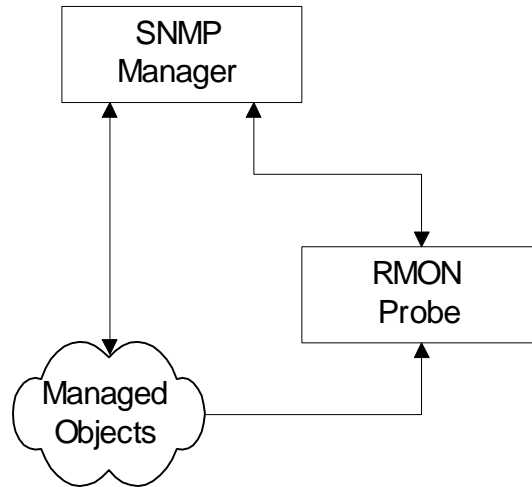


Figure 4.6 Three-Tier Organization Model

Notes

- Managed object comprises network element and management agent
- RMON acts as an agent and a manager
- RMON (Remote Monitoring) gathers data from MO, analyses the data, and stores the data
- Communicates the statistics to the manager

Three-Tier Organization Model: Proxy Server

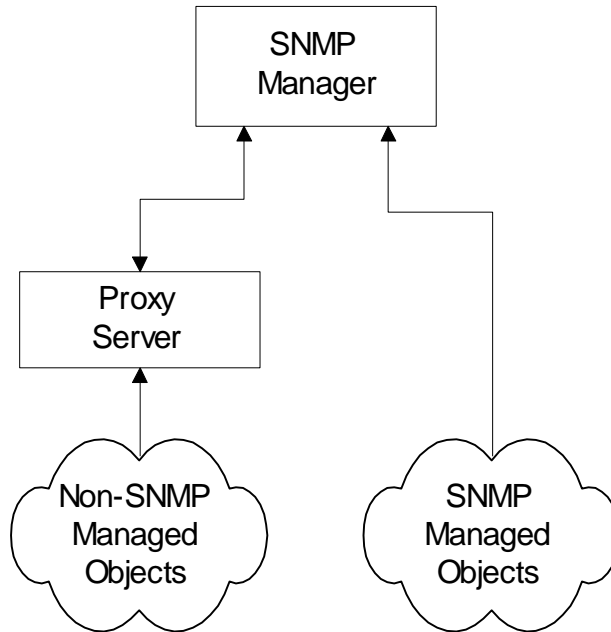


Figure 4.7 Proxy Server Organization Model

Notes

- Proxy server converts non-SNMP data from non-SNMP objects to SNMP compatible objects and messages

Managed Object

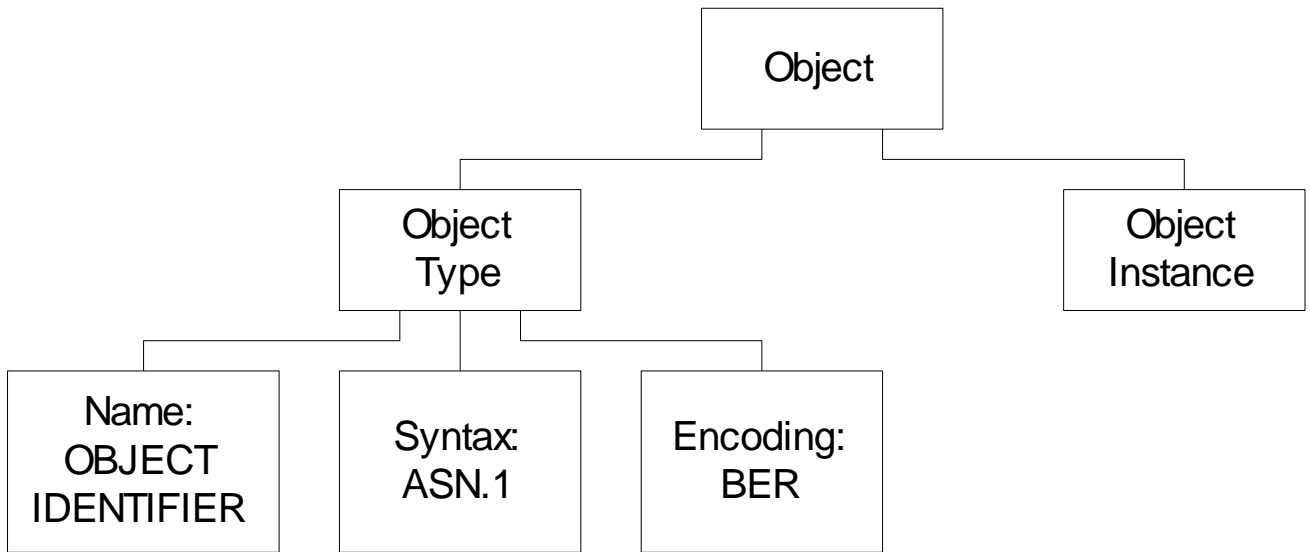


Figure 4.10 Managed Object : Type and Instance

Notes

- Object type and data type are synonymous
- Object identifier is data type, not instance
- Object instance IP address (See Figure 4.2)

Name

Uniquely defined by

- DESCRIPTOR AND
- OBJECT IDENTIFIER

internet OBJECT IDENTIFIER ::=
 {iso org(3) dod(6) 1 }.

internet OBJECT IDENTIFIER ::= {iso(1) standard(3) dod(6) internet(1)}
internet OBJECT IDENTIFIER ::= {1 3 6 1}
internet OBJECT IDENTIFIER ::= {iso standard dod internet }
internet OBJECT IDENTIFIER ::= { iso standard dod(6) internet(1) }
internet OBJECT IDENTIFIER ::= { iso(1) standard(3) 6 1 }

Notes

Example

ipAddrTable ip 20

Internet Subnodes

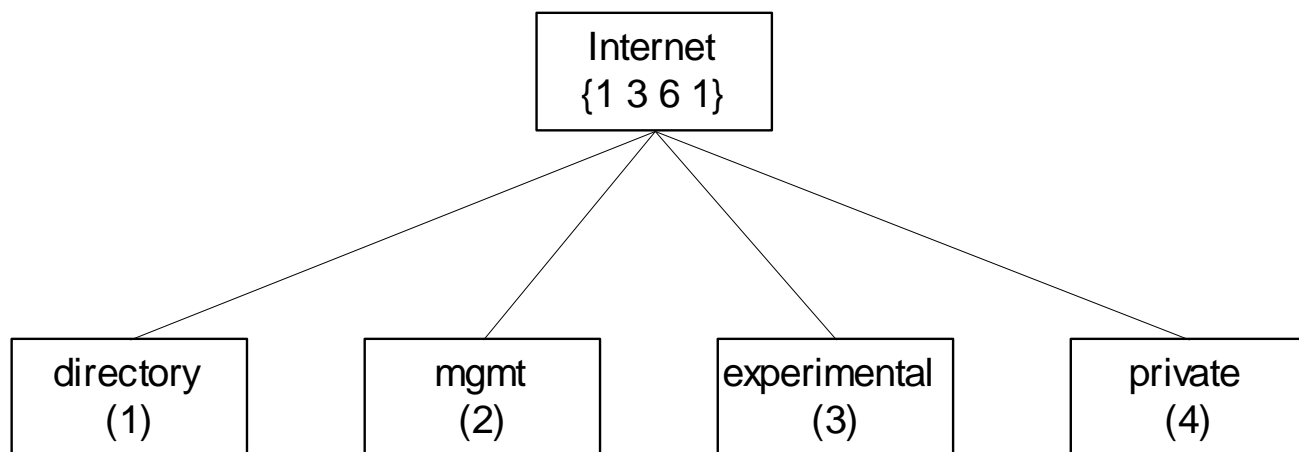


Figure 4.13 Subnodes under Internet Node in SNMPv1

Notes

- | | |
|--------------|------------------------------------|
| • directory | OBJECT IDENTIFIER ::= {internet 1} |
| mgmt | OBJECT IDENTIFIER ::= {internet 2} |
| experimental | OBJECT IDENTIFIER ::= {internet 3} |
| private | OBJECT IDENTIFIER ::= {internet 4} |

Private MIB Example

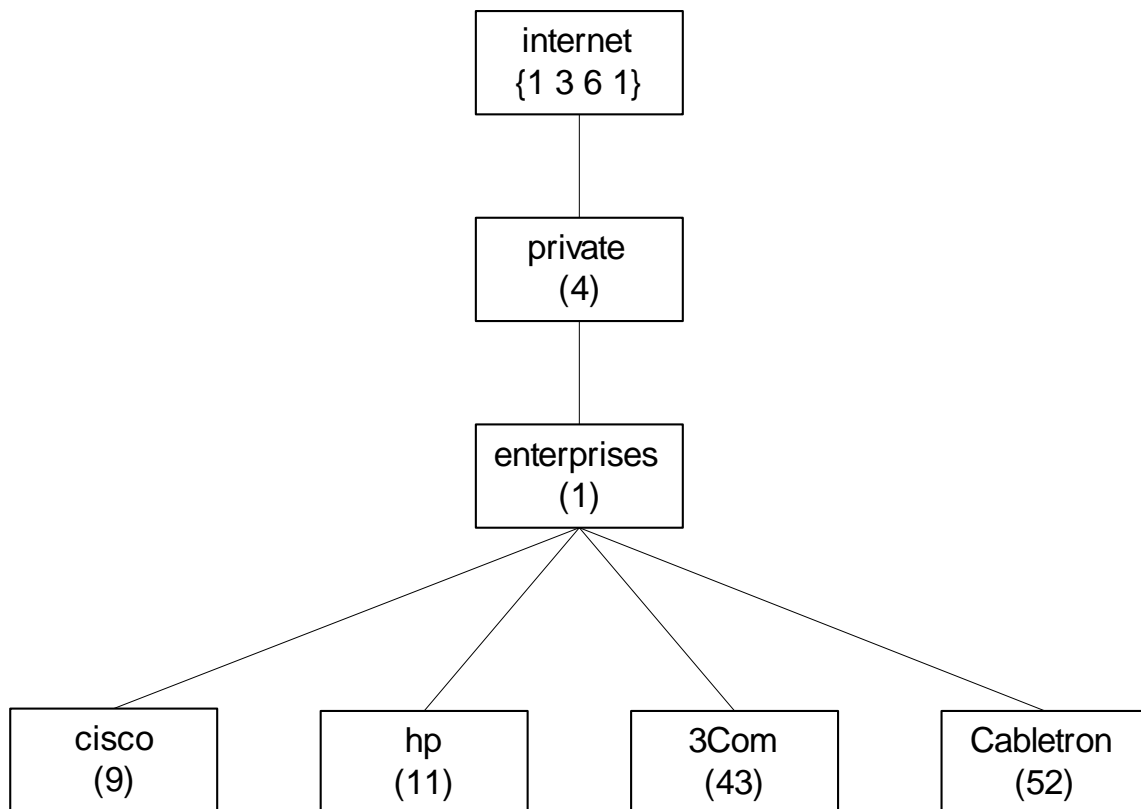


Figure 4.14 Private Subtree for Commercial Vendors

Notes

- *private* MIB intended for vendor equipment
- IANA (Internet Assigned Numbers Authority) assigns identifiers

SNMP ASN.1 Data Type

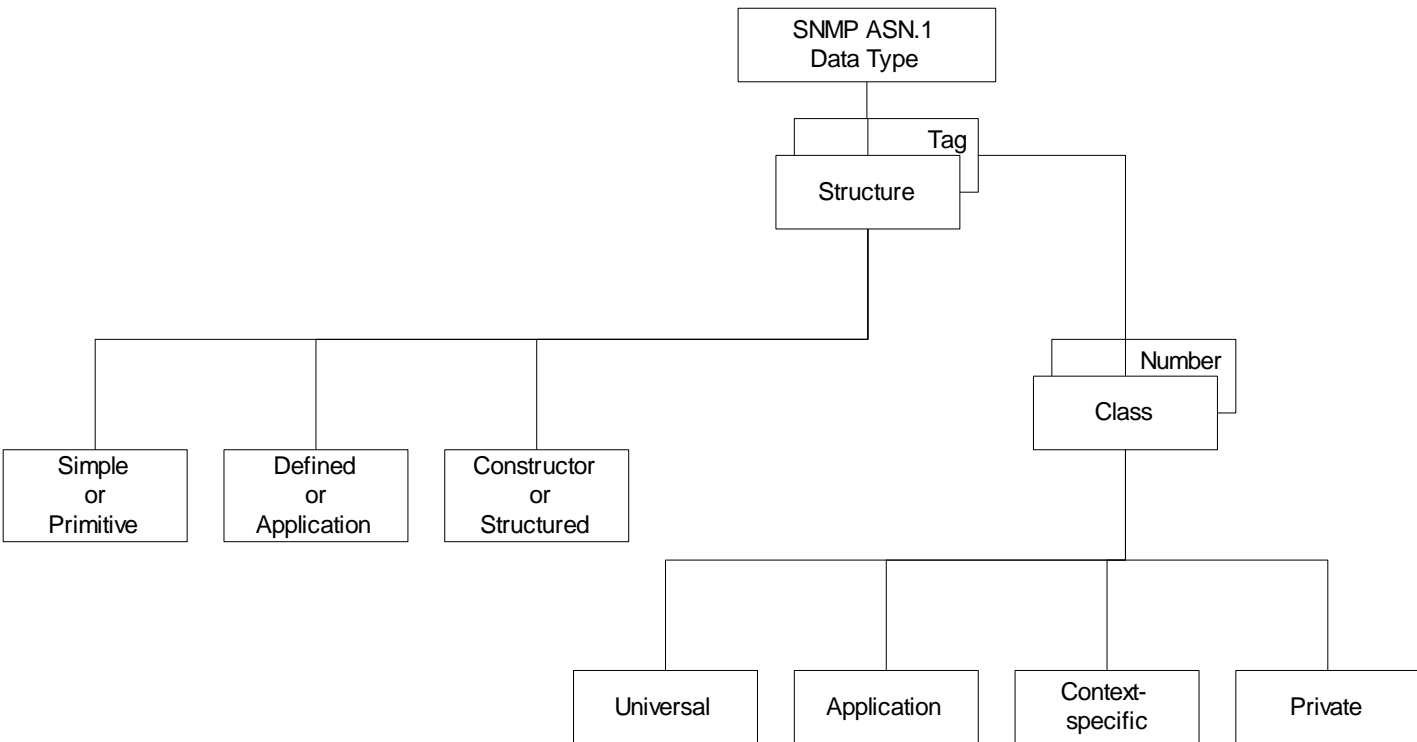


Figure 4.15 SNMP ASN.1 Data Type

Primitive Data Types

Structure	Data Type	Comments
Primitive types	INTEGER	Subtype INTEGER (n1..nN) Special case: Enumerated INTEGER type
	OCTET STRING	8-bit bytes binary and textual data Subtypes can be specified by either range or fixed
	OBJECT IDENTIFIER	Object position in MIB
	NULL	Placeholder

Notes

- *get-request* message has NULL for value fields and *get-response* from agent has the values filled in subtype:
 - INTEGER (0..255)
 - OCTET STRING (SIZE 0..255)
 - OCTET STRING (SIZE 8)

Enumerated

- Special case of INTEGER data type

```
error-status INTEGER {  
    noError(0)  
    tooBig(1)  
    genErr(5)  
    authorizationError(16)  
}
```

Notes

- noError NULL by convention

Defined or Application Data Type

Defined Types	NetworkAddress	Not used
	IpAddress	Dotted decimal IP address
	Counter	Wrap-around, non-negative integer, monotonically increasing, max $2^{32} - 1$
	Gauge	Capped, non-negative integer, increase or decrease
	TimeTicks	Non-negative integer in hundredths of second units
	Opaque	Application-wide arbitrary ASN.1 syntax, double wrapped OCTET STRING

Notes

- Defined data types are simple or base types
- Opaque is used to create data types based on previously defined data types

Constructor or Structured Data Type: SEQUENCE

- List maker

SEQUENCE { <type1>, <type2>, ..., <typeN> }

	Object	OBJECT IDENTIFIER	ObjectSyntax
1	ipAdEntAddr	{ipAddrEntry 1}	IpAddress
2	ipAdEntIfIndex	{ipAddrEntry 2}	INTEGER
3	ipAdEntNetMask	{ipAddrEntry 3}	IpAddress
4	ipAdEntBcastAddr	{ipAddrEntry 4}	INTEGER
5	ipAdEntReasmMaxSize	{ipAddrEntry 5}	INTEGER
6	ipAddrEntry	{ipAddrTable 1}	SEQUENCE

```
List: IpAddrEntry ::=
      SEQUENCE {
          ipAdEntAddr          IpAddress
          ipAdEntIfIndex       INTEGER
          ipAdEntNetMask       IpAddress
          ipAdEntBcastAddr     INTEGER
          ipAdEntReasmMaxSize  INTEGER (0..65535)
      }
```

Managed Object IpAddrEntry as a list

Notes

Constructor or Structured Data Type: SEQUENCE OF

SEQUENCE OF <entry>

where <entry> is a list constructor

	Object Name	OBJECT IDENTIFIER	Syntax
7	ipAddrTable	{ip 20}	SEQUENCE OF

Table: IpAddrTable ::=
SEQUENCE OF IpAddrEntry

Managed Object ipAddrTable as a table

Notes

SEQUENCE OF Example

Title: System Information : router1.gatech.edu

Name or IP Address: 172.162.52.1

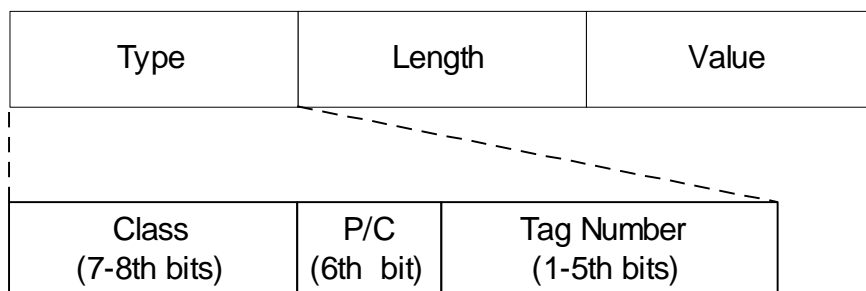
Index	Interface	IP address	Network Mask	Network Address	Link Address
23	LEC.1.0	192.168.3.1	255.255.255.0	192.168.3.0	0x00000C3920B4
25	LEC.3.9	192.168.252.15	255.255.255.0	192.168.252.0	0x00000C3920B4
13	Ethernet2/0	172.16..46.1	255.255.255.0	172.16..46.0	0x00000C3920AC
16	Ethernet2/3	172.16.49.1	255.255.255.0	172.16.49.0	0x00000C3920AF
17	Ethernet2/4	172.16.52.1	255.255.255.0	172.16.52.0	0x00000C3920B0
9	Ethernet1/2	172.16.55.1	255.255.255.0	172.16.55.0	0x00000C3920A6
2	Ethernet 0/1	172.16.56.1	255.255.255.0	172.16.56.0	0x00000C39209D
15	Ethernet2/2	172.16.57.1	255.255.255.0	172.16.57.0	0x00000C3920AE
8	Ethernet1/1	172.16.58.1	255.255.255.0	172.16.58.0	0x00000C3920A5
14	Ethernet2/1	172.16.60.1	255.255.255.0	172.16.60.0	0x00000C3920AD

Notes

- The above example (Figure 4.3) uses part of the IP MIB discussed for SEQUENCE OF construct.

Encoding

- Basic Encoding Rules (BER)
 - Tag, Length, and Value (TLV)



- SNMP Data Types and Tags

Type	Tag
OBJECT IDENTIFIER	UNIVERSAL 6
SEQUENCE	UNIVERSAL 16
IpAddress	APPLICATION 0
Counter	APPLICATION 1
Gauge	APPLICATION 2
TimeTicks	APPLICATION 3
Opaque	APPLICATION 4

Notes

Managed Object: Macro

```
OBJECT-TYPE MACRO ::=
BEGIN
    TYPE NOTATION ::= "SYNTAX" type(TYPE ObjectSyntax)
        "ACCESS" Access
        "STATUS" Status
    VALUE NOTATION ::= value(VALUE ObjectName)

    Access ::= "read-only" | "read-write" | "write-only" | "not-accessible"
    Status ::= "mandatory" | "optional" | "obsolete"

END
```

Figure 4.18(a) OBJECT-TYPE Macro [RFC 1155]

```
sysDescr OBJECT-TYPE
    SYNTAX DisplayString (SIZE (0..255))
    ACCESS read-only
    STATUS mandatory
    DESCRIPTION
        "A textual description of the entity. This value should
        include the full name and version identification of the
        system's hardware type, software operating-system, and
        networking software. It is mandatory that this only
        contain printable ASCII characters."
    ::= {system 1 }
```

**Figure 4.18(b) Scalar or Single Instance Macro: sysDescr
[RFC 1213]**

Aggregate Object

- A group of objects
- Also called tabular objects
- Can be represented by a table with
 - Columns of objects
 - Rows of instances

Table of Objects



List of Objects



Objects

Notes

- Example: IP address table
- Consists of objects:
 - IP address
 - Interface
 - Subnet mask (which subnet this address belongs to)
 - Broadcast address (value of l.s.b. in IP broadcast address)
 - Largest IP datagram that can be assembled
- Multiple instances of these objects associated with the node

Tabular Representation of Aggregate Object

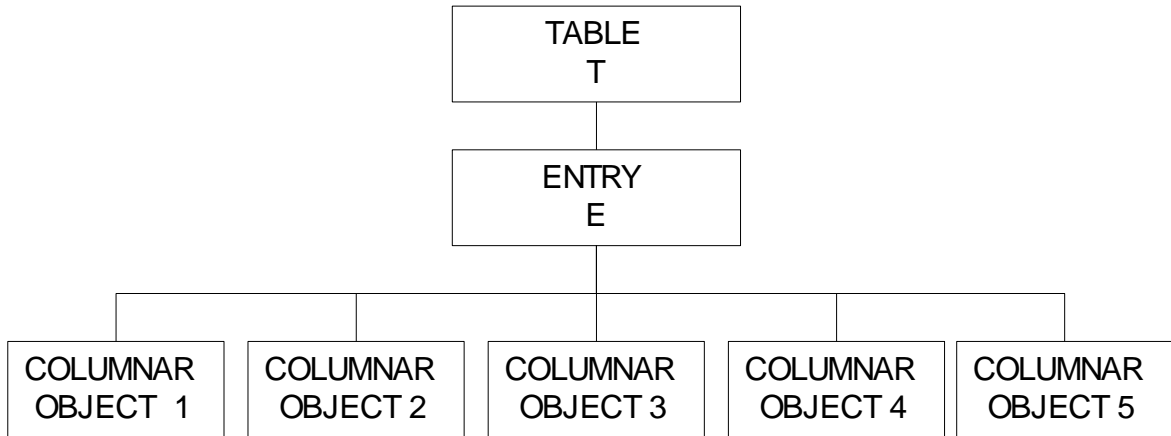


Figure 4.22(a) Multiple Instance Managed Object

Notes

- The objects *TABLE T* and *ENTRY E* are objects that are logical objects. They define the grouping and are not accessible.
- Columnar objects are objects that represent the attributes and hence are accessible.
- Each instance of *E* is a row of columnar objects 1 through 5.
- Multiple instances of *E* are represented by multiple rows.

Tabular Representation of Aggregate Object (cont.)

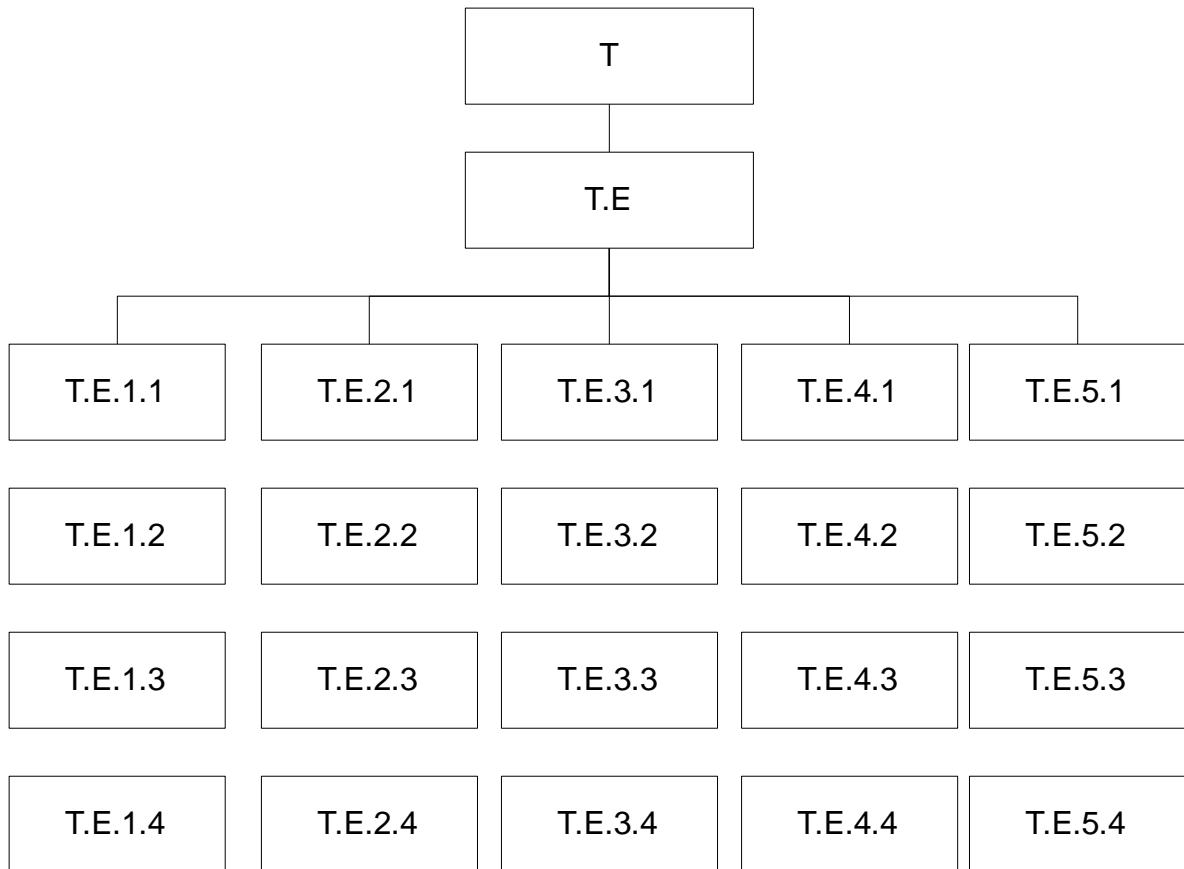


Figure 4.22(b) Example of 5 Columnar Object with 4 Instances (rows)

Notes

- Notice that the column-row numeric designation is reverse of what we are used to as row-column

Multiple Instances of Aggregate Managed Object

```
ipAddrTable {1.3.6.1.2.1.4.20}
```

```
  ipAddrEntry (1)
```

```
    ipAdEntAddr (1)
```

```
    ipAdEntIfIndex (2)
```

```
    ipAdEntNetMask (3)
```

```
    ipAdEntBcastAddr (4)
```

```
    ipAdEntReasmMaxSize (5)
```

Columnar object ID of ipAdEntBcastAddr is (1.3.6.1.2.1.4.20.1.4):

```
iso org dod internet mgmt mib ip ipAddrTable ipAddrEntry ipAdEntBcastAddr
 1  3  6      1      2  1  4      20      1      4
```

Figure 4.23(a) Columnar objects under ipAddrEntry

Row	ipAdEntAddr	ipAdEntIfIndex	IpAdEntNetMask	IpAdEntBcastAddr	IpAdEntReasmMaxSize
1	123.45.2.1	1	255.255.255.0	0	12000
2	123.45.3.4	3	255.255.0.0	1	12000
3	165.8.9.25	2	255.255.255.0	0	10000
4	9.96.8.138	4	255.255.255.0	0	15000

Figure 4.23(b) Object instances of ipAddrTable (1.3.6.1.2.1.4.20)

Columnar Object	Row # in (b)	Object Identifier
ipAdEntAddr 1.3.6.1.2.1.4.20.1.1	2	{1.3.6.1.2.1.4.20.1.1.123.45.3.4}
ipAdEntIfIndex 1.3.6.1.2.1.4.20.1.2	3	{1.3.6.1.2.1.4.20.1.2.165.8.9.25}
ipAdEntBcastAddr 1.3.6.1.2.1.4.20.1.4	1	{1.3.6.1.2.1.4.20.1.4.123.45.2.1}
IpAdEntReasmMaxSize 1.3.6.1.2.1.4.20.1.5	4	{1.3.6.1.2.1.4.20.1.5.9.96.8.138}

Figure 4.23(c) Object Id for specific instance

SMI Definition STD 16 / 1155 RFC

RFC1155-SMI DEFINITIONS ::= BEGIN

EXPORTS -- EVERYTHING

internet, directory, mgmt, experimental, private, enterprises,
OBJECT-TYPE, ObjectName, ObjectSyntax, SimpleSyntax,
ApplicationSyntax, NetworkAddress, IpAddress, Counter, Gauge,
TimeTicks, Opaque;

-- the path to the root

internet OBJECT IDENTIFIER ::= { iso org(3) dod(6) 1 }

directory OBJECT IDENTIFIER ::= { internet 1 }

mgmt OBJECT IDENTIFIER ::= { internet 2 }

experimental OBJECT IDENTIFIER ::= { internet 3 }

private OBJECT IDENTIFIER ::= { internet 4 }

enterprises OBJECT IDENTIFIER ::= { private 1 }

Notes

- EXPORTS identifies the objects that any other module could import.

MIB

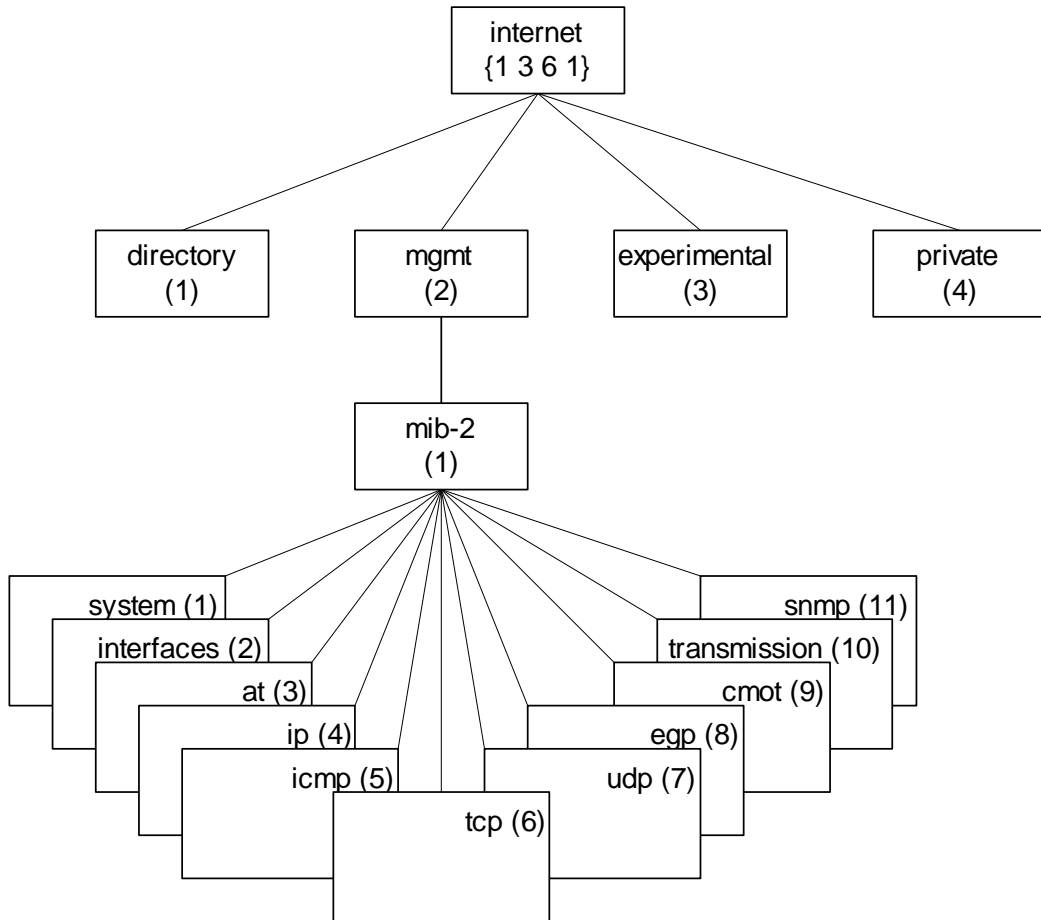


Figure 4.26 Internet MIB-II Group

Notes

- MIB-II (RFC 1213) is superset of MIB-I.
- Objects that are related grouped into object groups.
- MIB module comprises module name, imports from other modules, and definitions of current module.
- RFC 1213 defines eleven groups; expanded later.

System Group

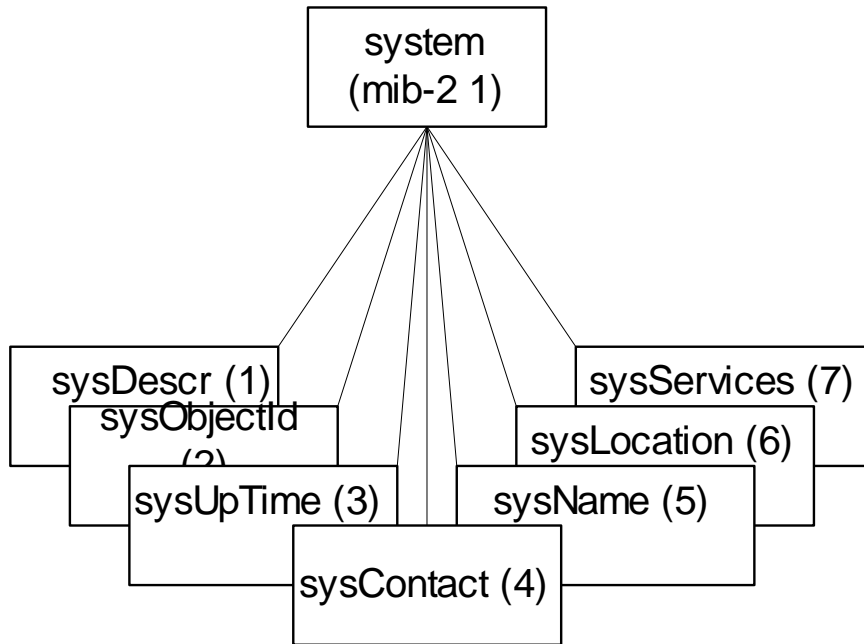
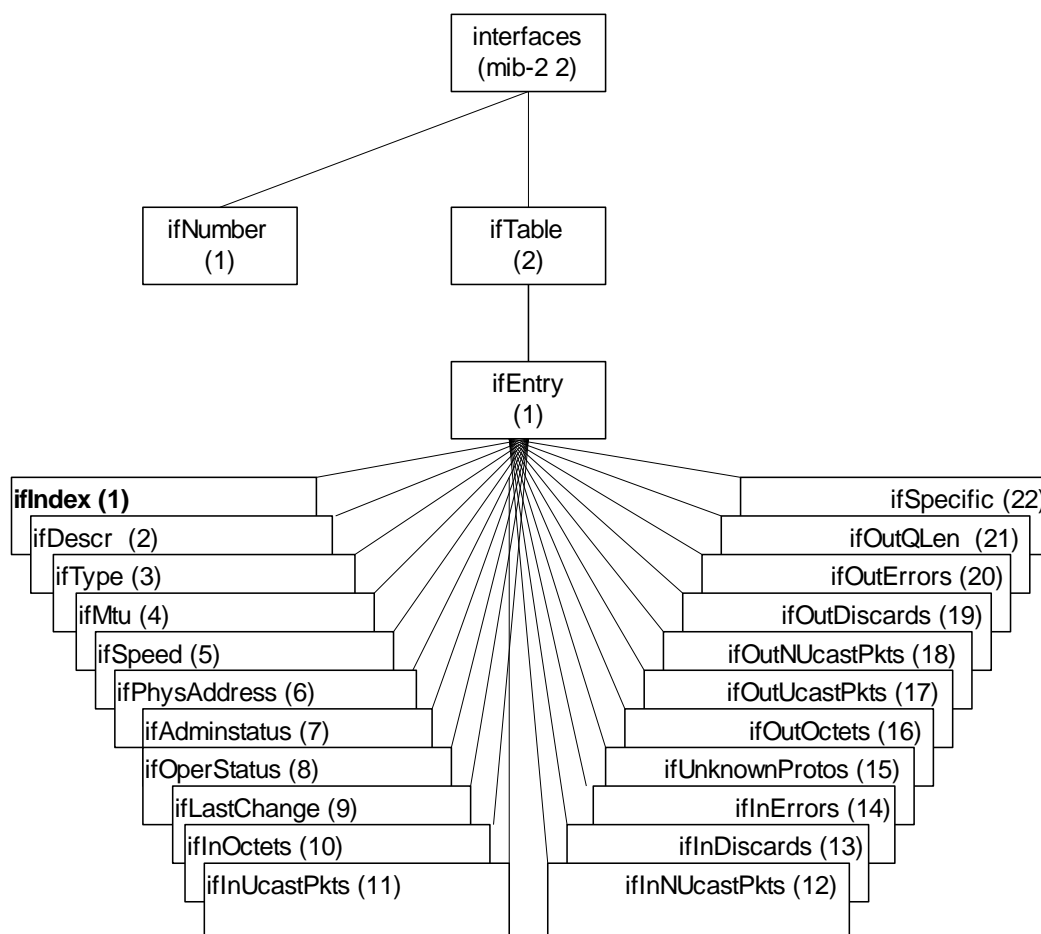


Figure 4.27 System Group

Notes

Entity	OID	Description (brief)
sysDescr	system 1	Textual description
sysObjectID	system 2	OBJECT IDENTIFIER of the entity
sysUpTime	system 3	Time (in hundredths of a second since last reset)
sysContact	system 4	Contact person for the node
sysName	system 5	Administrative name of the system
sysLocation	system 6	Physical location of the node
sysServices	system 7	Value designating the layer services provided by the entity

Interfaces Group



Legend: INDEX in bold

Figure 4.28 Interfaces Group

Notes

ifEntry

IfEntry OBJECT-TYPE

SYNTAX IfEntry

ACCESS not-accessible

STATUS mandatory

DESCRIPTION

"An interface entry containing
objects at the subnetwork layer and
below for a particular interface."

INDEX {ifIndex}

::= {ifTable 1}

Notes

- ifEntry specifies the objects in a row in the ifTable.
- Each interface is defined as a row in the table.

ifType

ifType OBJECT-TYPE

```
SYNTAX INTEGER {  
    other(1),          -- none of the following  
    regular1822(2),  
    hdh1822(3),  
    ddn-x25(4),  
    rfc877-x25(5),  
    ethernet-csmacd(6),  
    iso88023-csmacd(7),  
    iso88024-tokenBus(8),  
    iso88025-tokenRing(9),  
    iso88026-man(10),  
    starLan(11),  
    proteon-10Mbit(12),  
    proteon-80Mbit(13),  
    hyperchannel(14),  
    fddi(15),  
    lapb(16),  
    sdlc(17),  
    ds1(18),           -- T-1  
    e1(19),            -- european equiv. of T-1  
    basicISDN(20),  
    primaryISDN(21),  -- proprietary serial  
    propPointToPointSerial(22),  
    ppp(23),  
    .....
```

Notes

- Type of interface below the network layer defined as enumerated integer.

IP Group

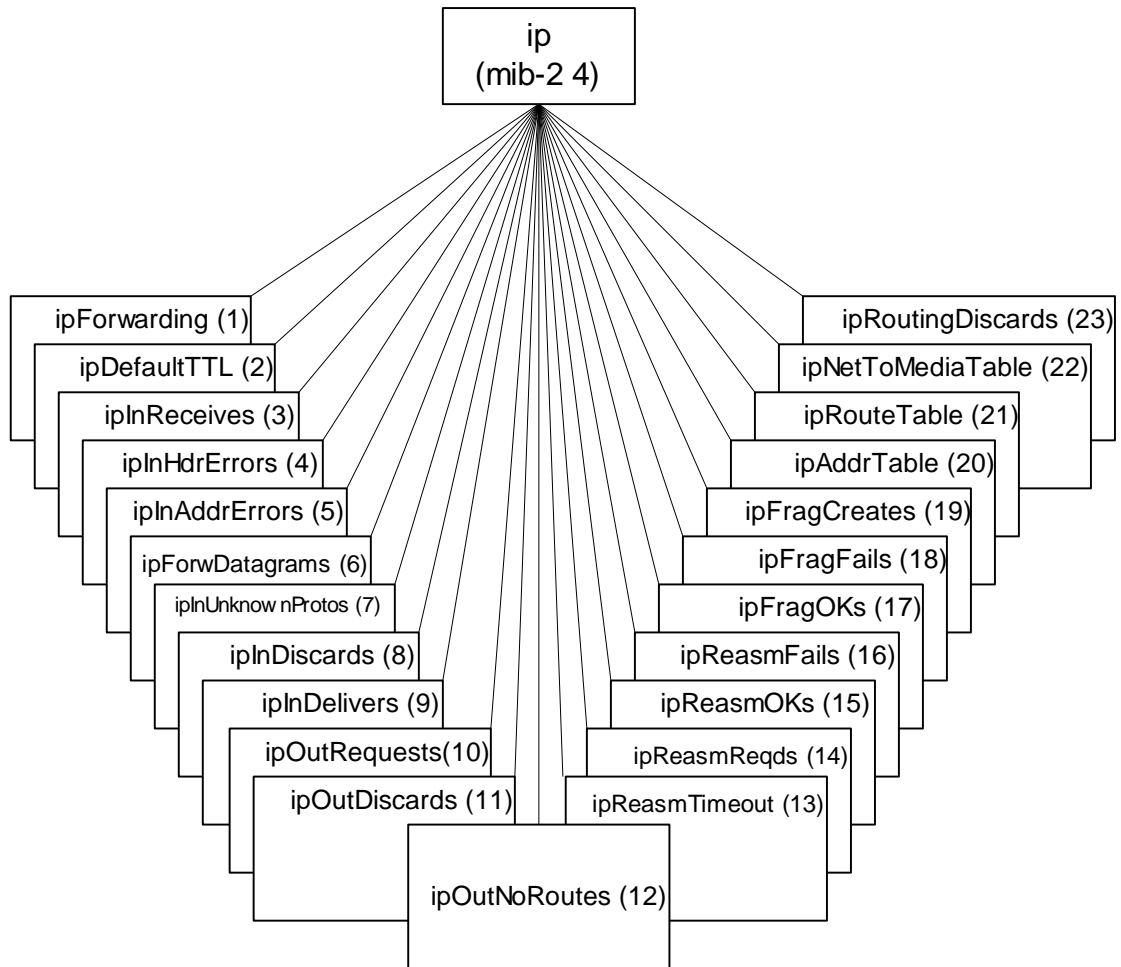
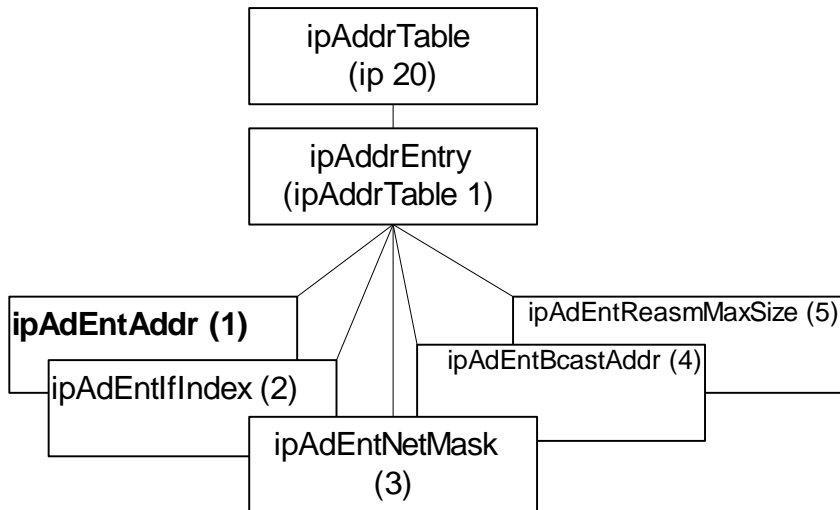


Figure 4.29 IP Group

Notes

- ipForwarding: Gateway(1) and Router(2)
- IP Address Table contains table of IP addresses
- IP Route Table contains an entry for each route
- IP Network-to-Media Table is address translation table mapping IP addresses to physical addresses

IP Address Table



Legend: INDEX in bold

Figure 4.30 IP Address Table

Notes

Entity	OID	Description (brief)
ipAddrTable	ip 20	Table of IP addresses
ipAddrEntry	IpAddrTable 1	One of the entries in the IP address table
ipAdEntAddr	IpAddrEntry 1	The IP address to which this entry's addressing information pertains
ipAdEntIfIndex	IpAddrEntry 2	Index value of the entry, same as ifIndex
ipAdEntNetMask	IpAddrEntry 3	Subnet mask for the IP address of the entry
ipAdEntBcastAddr	IpAddrEntry 4	Broadcast address indicator bit
ipAdEntReasmMaxSize	IpAddrEntry 5	Largest IP datagram that can be reassembled on this interface

IP Routing Table

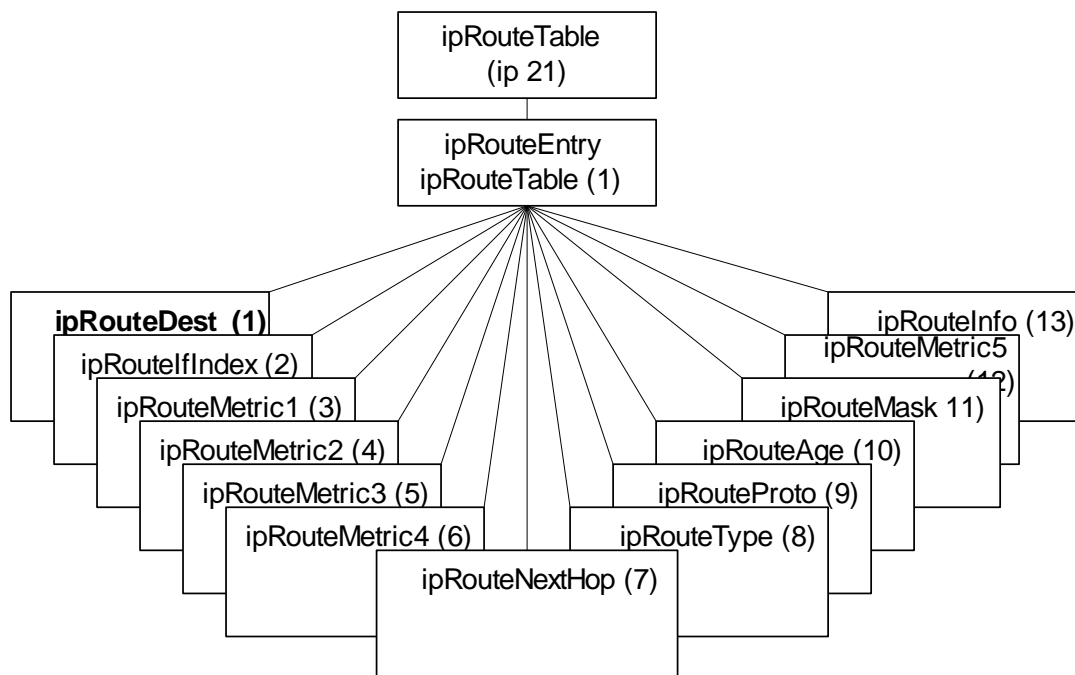


Figure 4.31 IP Routing Table

Entity	OID	Description (brief)
ipRouteTable	ip 21	IP routing table
ipRouteEntry	ipRouteTable 1	Route to a particular destination
ipRouteDest	ipRouteEntry 1	Destination IP address of this route
ipRouteIfIndex	ipRouteEntry 2	Index of interface, same as ifIndex
ipRouteMetric1	ipRouteEntry 3	Primary routing metric for this route
ipRouteMetric2	ipRouteEntry 4	An alternative routing metric for this route
ipRouteMetric3	ipRouteEntry 5	An alternative routing metric for this route
ipRouteMetric4	ipRouteEntry 6	An alternative routing metric for this route
ipRouteNextHop	ipRouteEntry 7	IP address of the next hop
ipRouteType	ipRouteEntry 8	Type of route
ipRouteProto	ipRouteEntry 9	Routing mechanism by which this route was learned
ipRouteAge	ipRouteEntry 10	Number of seconds since routing was last updated
ipRouteMask	ipRouteEntry 11	Mask to be logically ANDed with the destination address before comparing with the ipRouteDest field
ipRouteMetric5	ipRouteEntry 12	An alternative metric for this route
ipRouteInfo	ipRouteEntry 13	Reference to MIB definition specific to the routing protocol

ICMP Group

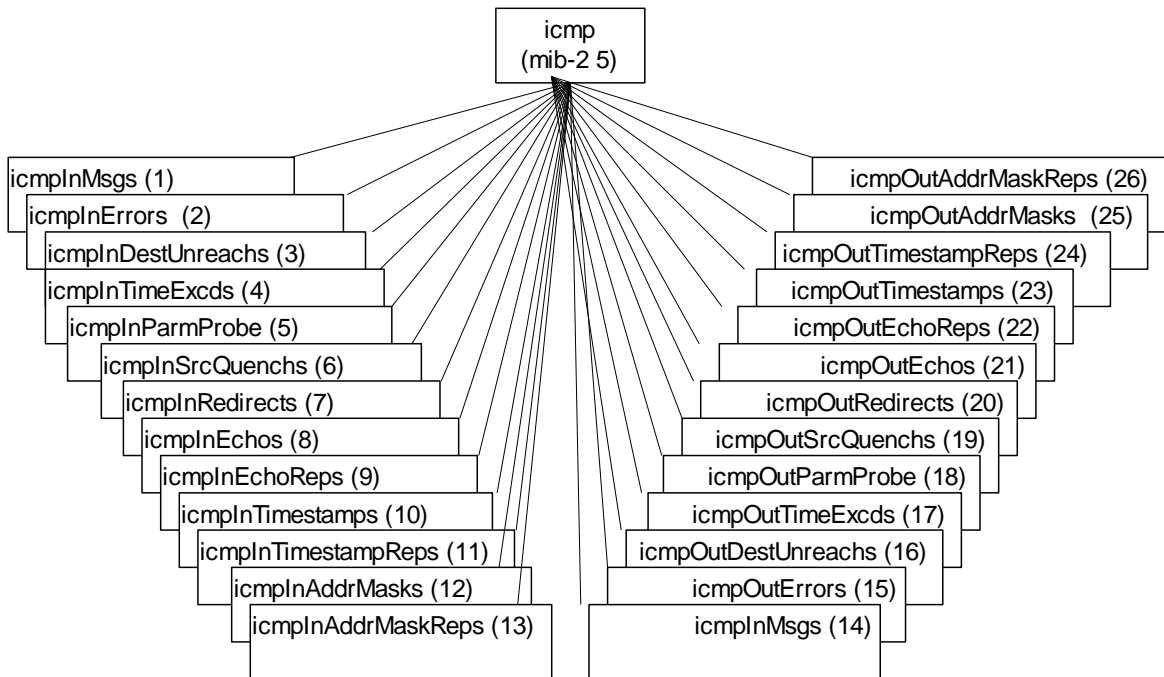


Figure 4.34 ICMP Group

Notes

- Objects associated with *ping*
 - icmpOutEchos # ICMP echo messages sent
 - icmpInEchoReps # ICMP echo reply messages received
- Objects associated with *traceroute/tracert*
 - icmpInTimeExcs # ICMP time exceeded messages received

TCP Group

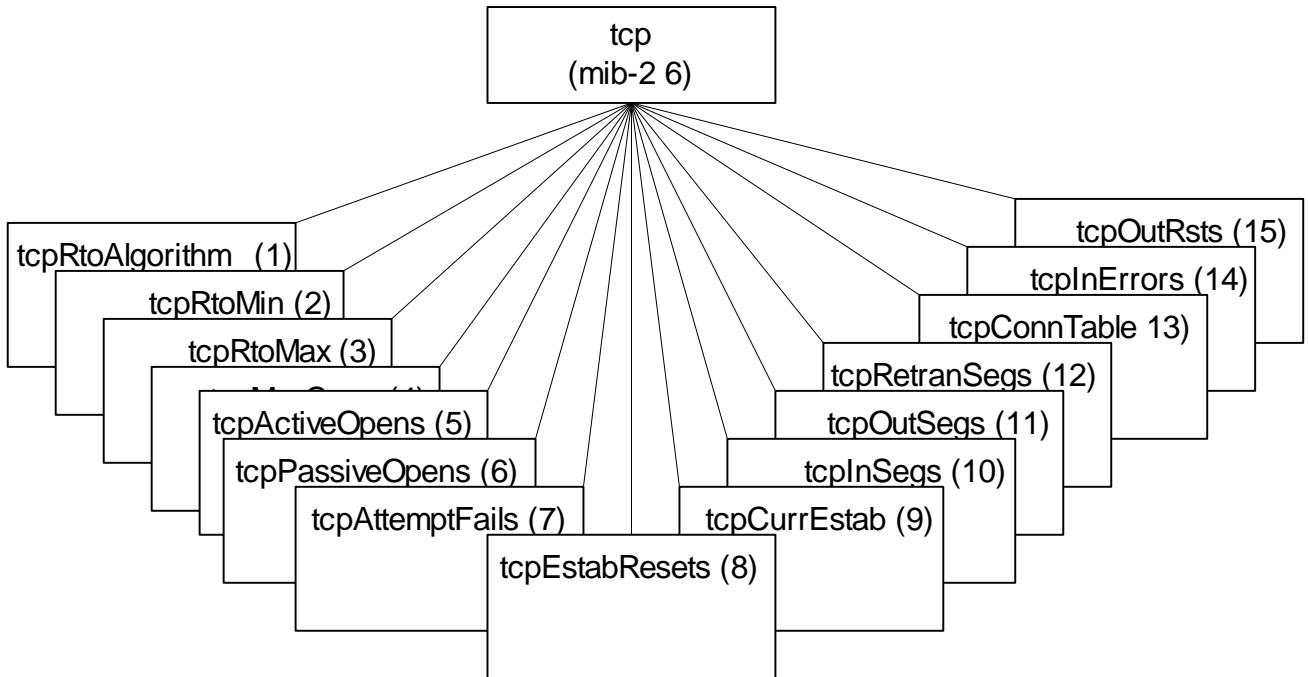


Figure 4.35 TCP Group

Notes

- Connection-oriented transport protocol group
- Has one table

TCP Connection Table

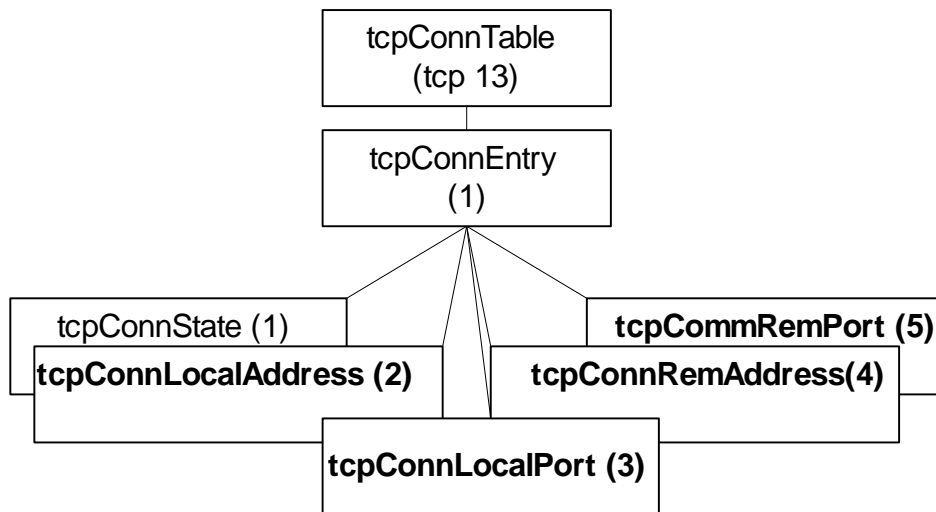


Figure 4.36 TCP Connection Table

Notes

Entity	OID	Description (brief)
tcpConnTable	tcp 13	TCO connection table
tcpconnEntry	TcpConnTable 1	Information about a particular TCP connection
tcpConnState	TcpConnEntry 1	State of the TCP connection
tcpConnLocalAddress	TcpConnEntry 2	Local IP address
tcpConnLocalPort	TcpConnEntry 3	Local port number
tcpConnRemAddress	TcpConnEntry 4	Remote IP address
tcpConnRemPort	TcpConnEntry 5	Remote port number

UDP Group

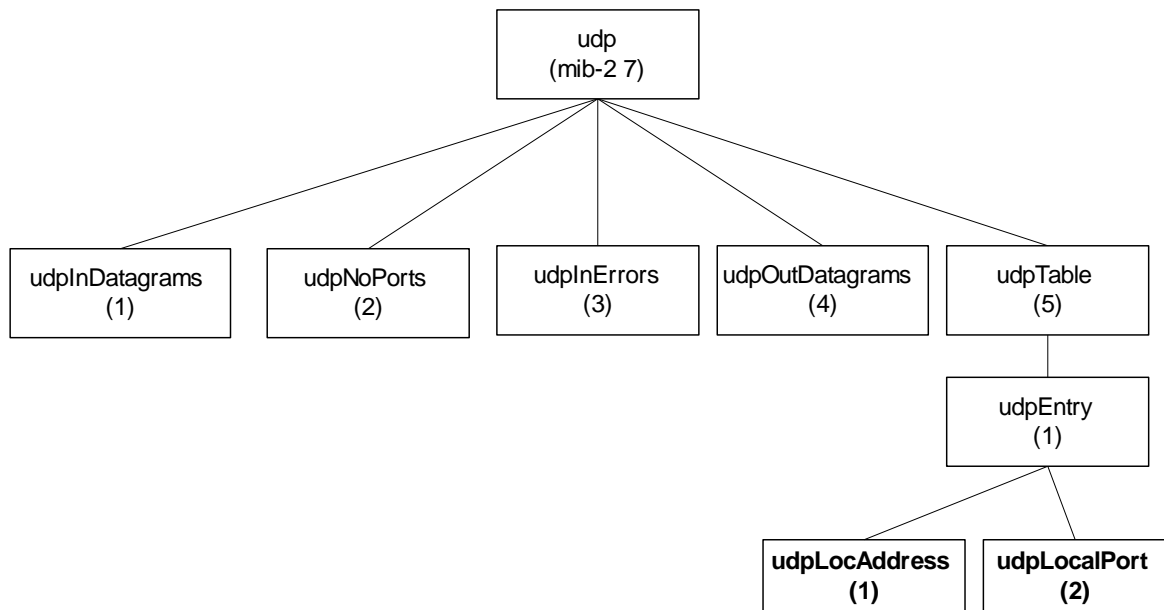


Figure 4.37 UDP Group

Notes

- Connectionless transport protocol group
- Has one table, UDP table

Entity	OID	Description (brief)
udpInDatagrams	udp 1	Total number of datagrams delivered to the users
udpNoPorts	udp 2	Total number of received datagrams for which there is no application
udpInErrors	udp 3	Number of received datagrams with errors
udpOutDatagrams	udp 4	Total number of datagrams sent
udpTable	udp 5	UDP Listener table
udpEntry	udpTable 1	Information about a particular connection or UDP listener
udpLocalAddress	udpEntry 1	Local IP address
udpLocalPort	udpEntry 2	Local UDP port