Chapter 3

Basic Foundations of NM: Standards, Models, and Language

Objectives

- Standards, Models, and Language needed for network management Network Models
  - OSI
  - Internet
  - TMN
  - IEEE 802
  - Web-based
- Management communication protocols
  - SNMP
  - CMIP
  - XML
  - CORBA
- ASN.1 language
  - Syntax
  - Macro
- Basic encoding rule
- Management application functions

3.1 Network management standards

Introduction

A standard = a widely used model

- Standards
  - Standards organizations
  - Protocol standards of transport layers
  - Protocol standards of management (application) layer
- Management Models
- Language

Notes

We have standards in, almost, everything

Standard	Salient Points
OSI/CMIP	1. International standard (ISO/OSI) 2. Management of data communications network - LAN and WAN 3. Deals with all 7 layers 4. Most complete 5. Object oriented 6. Well structured and layered 7. Consumes large resource in implementation
Internet/ SNMP	1. Industry standard (IETF) 2. Originally intended for management of Internet components, currently adopted for WAN and telecommunication systems 3. Easy to implement 4. Most widely implemented
TMN	1. International standard (ITU-T) 2. Management of telecommunications network 3. Based on OSI network management framework 4. Addresses both network and administrative aspects of management 5. eTOM industry standard for business processes for implementing TMN using NGOSS framework
IEEE	1. IEEE standards adopted internationally 2. Addresses LAN and MAN management 3. Adopts OSI standards significantly 4. Deals with first two layers of OSI model
Web-based Management	1. Web-Based Enterprise Management (WBEM) 2. Java Management Extension (JMX) 3. XML-Based Network Management 4.CORBA-based Network Management

Table 3.1 Network Management Standards

OSI Architecture and Models

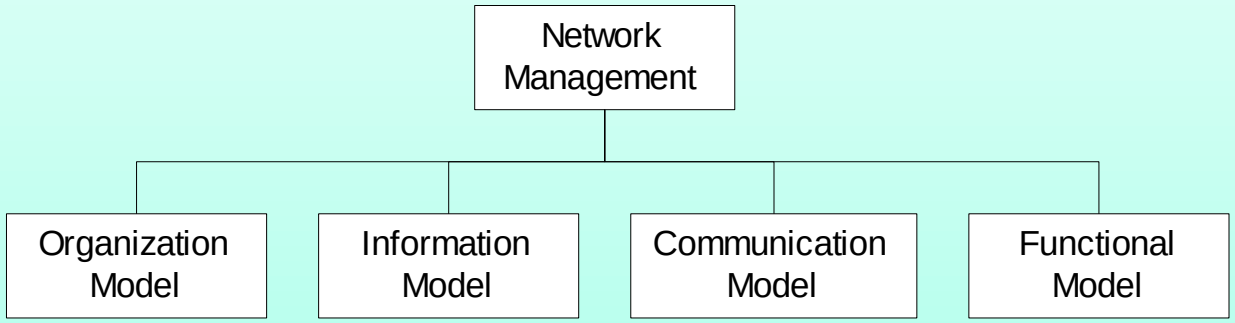


Figure 3.1 OSI Network Management Model

Notes

- Organization
  - Network management components
  - Functions of components
  - Relationships
- Information
  - Structure of management information (SMI)
    - Syntax and semantics
  - Management information (data) base (MIB)
    - Organization of management information
  - Object-oriented

OSI Architecture and Models (cont.)

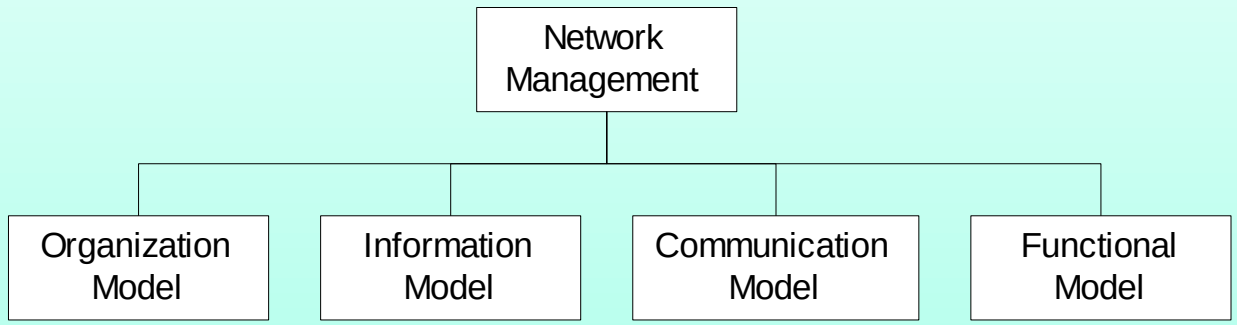


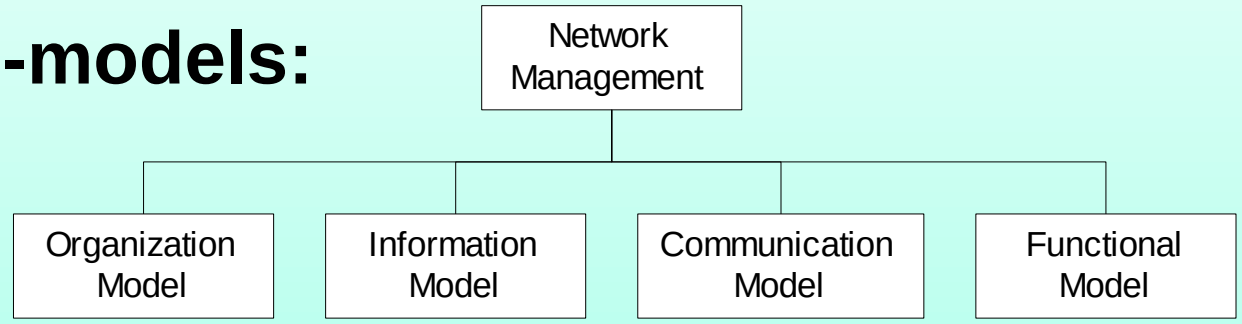
Figure 3.1 OSI Network Management Model

Notes

- Communication
  - Transfer syntax with bidirectional messages
  - Transfer structure (PDU)
- Functions
  - Application functions
    - Configure components
    - Monitor components
    - Measure performance
    - Secure information
    - Usage accounting

SNMP Architecture and Model

SNMP Model consists in 4 sub-models:



Notes

- Organization
  - Same as OSI model
- Information
  - Same as OSI, but scalar
- Communication
  - Messages less complex than OSI and unidirectional
  - Transfer structure (PDU)
- Functions
  - Application functions
    - Fault management
    - Configuration management
    - Account management
    - Performance management
    - Security management

TMN Architecture

- Addresses management of telecommunication networks
- Based on OSI model
- Superstructure on OSI network
- Addresses network, service, and business management

Notes

Organizational Model

- Manager
  - Sends requests to agents
  - Monitors alarms
  - Houses applications
  - Provides user interface
- Agent
  - Gathers information from objects
  - Configures parameters of objects
  - Responds to managers' requests
  - Generates alarms and sends them to managers
- Managed object
  - Essentially, network element (Hubs, bridges, routers, transmission facilities) that is managed
  - Houses management agent

Notes

Two-Tier Model

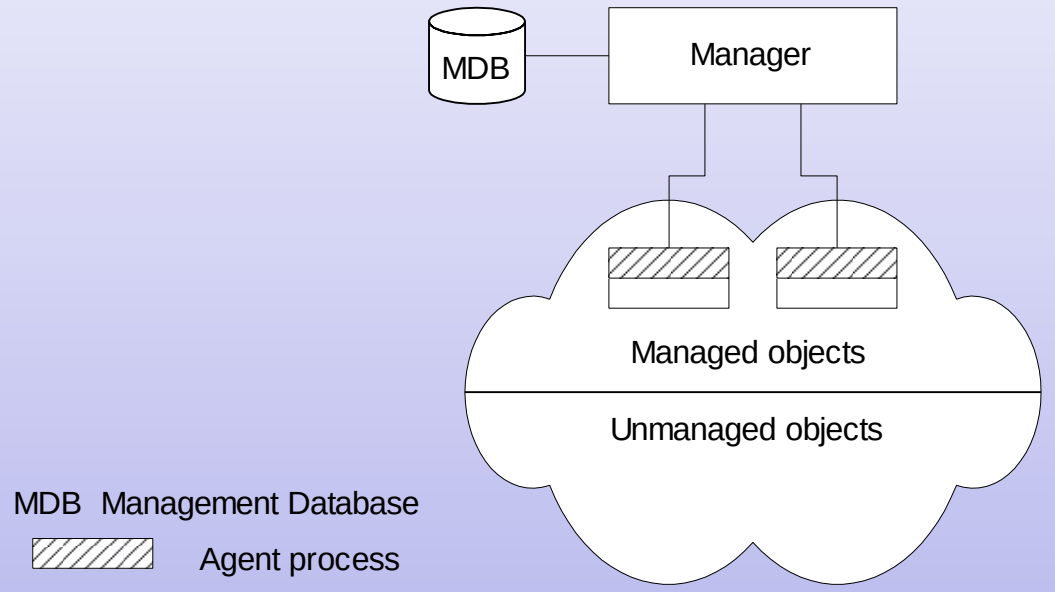


Figure 3.2 Two-Tier Network Management Organization Model

Notes

- Agent built into network element
  Example: Managed hub, managed router
- An agent can manage multiple elements
  Example: Switched hub, ATM switch
- MDB is a physical database
- Unmanaged objects are network elements that are not managed - both physical (unmanaged hub) and logical (passive elements)

Three-Tier Model

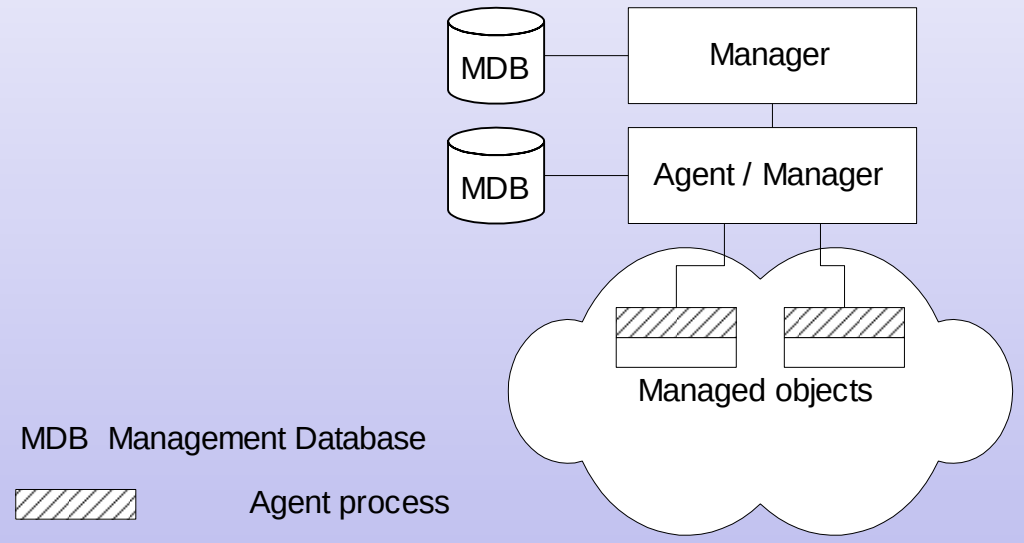


Figure 3.3 Three-Tier Network Management Organization Model

Notes

- Middle layer plays the dual role
  - Agent to the top-level manager
  - Manager to the managed objects
- Example of middle level: Remote monitoring agent (RMON)

Manager of Managers

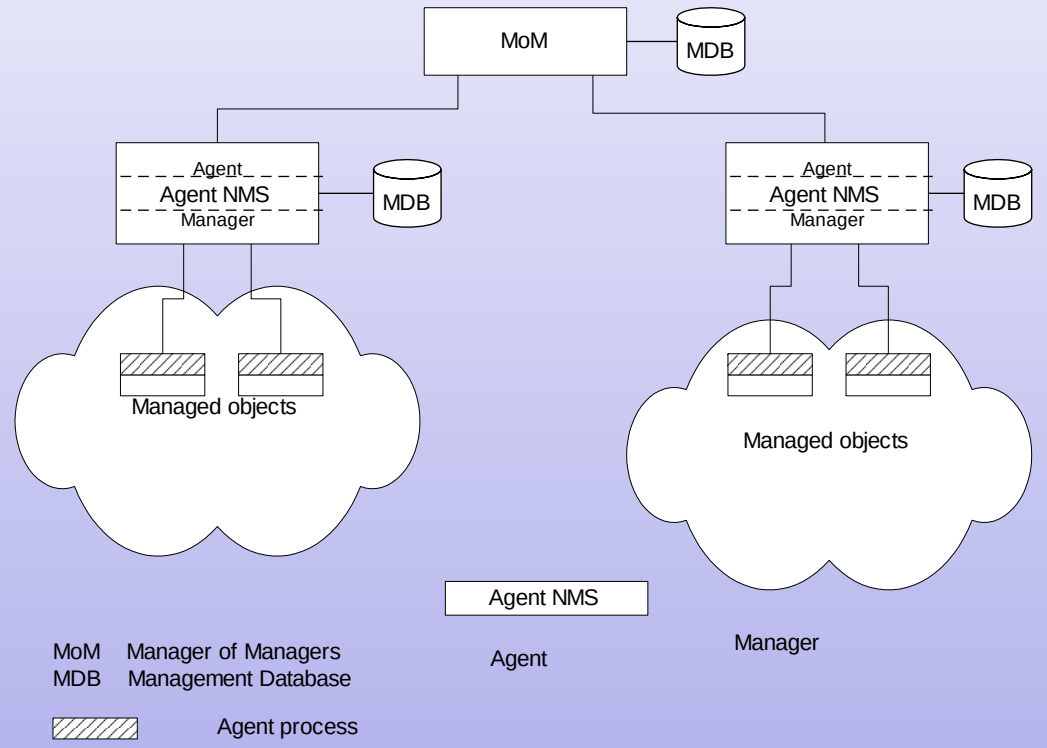


Figure 3.4 Network Management Organization Model with MoM

Notes: Network domains can be managed locally

- Agent NMS manages the domain
- MoM presents integrated view of domains
- Domain may be geographical, administrative, vendor-specific products, etc.

Peer NMSs

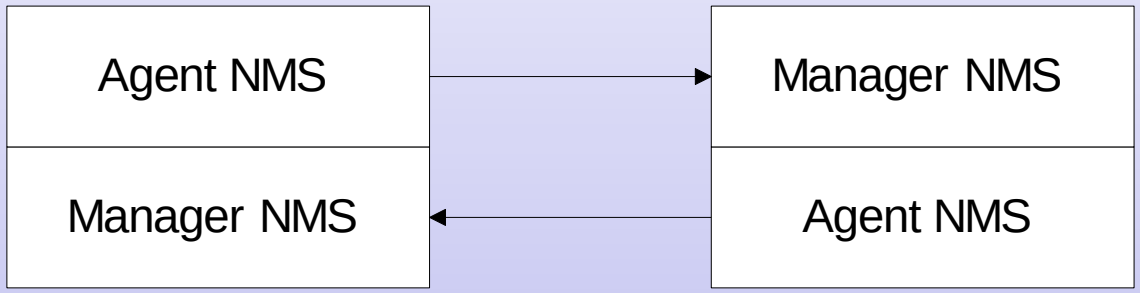


Figure 3.5 Dual Role of Management Process

Notes: NMS organized in a peer to peer system

- Dual role of both NMSs
- Network management system acts as peers
- Dumbbell architecture discussed in Chapter 1
- Notice that the manager and agent functions are processes and not systems

Information Model: Analogy

- concerned with structure and storage of information
- Consider the information model within a library
  - a figure in a book uniquely identified by
    - ISBN, Chapter, and Figure number in that hierarchical order
  - ID: {ISBN, chapter, figure}
- The three elements above define the syntax
- Semantics is the meaning of the three entities according to Webster's dictionary

→ The information comprises syntax and semantics about an object

Notes

Structure of Management Information (SMI)

- SMI defines for a managed object
  - Syntax
  - Semantics
  - Plus additional information such as status
- Example

Notes

-

sysDescr: { system 1 }
Syntax: OCTET STRING
Definition: "A textual description of the entity. "
Access: read-only
Status: mandatory

Management Information Base (MIB)

- Information base contains information about objects
- Organized by grouping of related objects
- Defines relationship between objects
- It is NOT a physical database. It is a *virtual* database that is compiled into management module

Notes

Information Base View: An Analogy

- Fulton County library system has many branches
- Each branch has a set of books
- The books in each branch is a different set
- The information base of the county has the view (catalog) of all books
- The information base of each branch has the catalog of books that belong to that branch. That is, each branch has its view (catalog) of the information base
- Let us apply this to MIB view

Notes

MIB View and Access of an Object

- A managed object has many attributes - its information base
- There are several operations that can be performed on the objects
- A user (manager) can view and perform only certain operations on the object by invoking the management agent
- The view of the object attributes that the agent perceives is the MIB view
- The operation that a user can perform is the MIB access

Notes

Management Data Base / Information Base

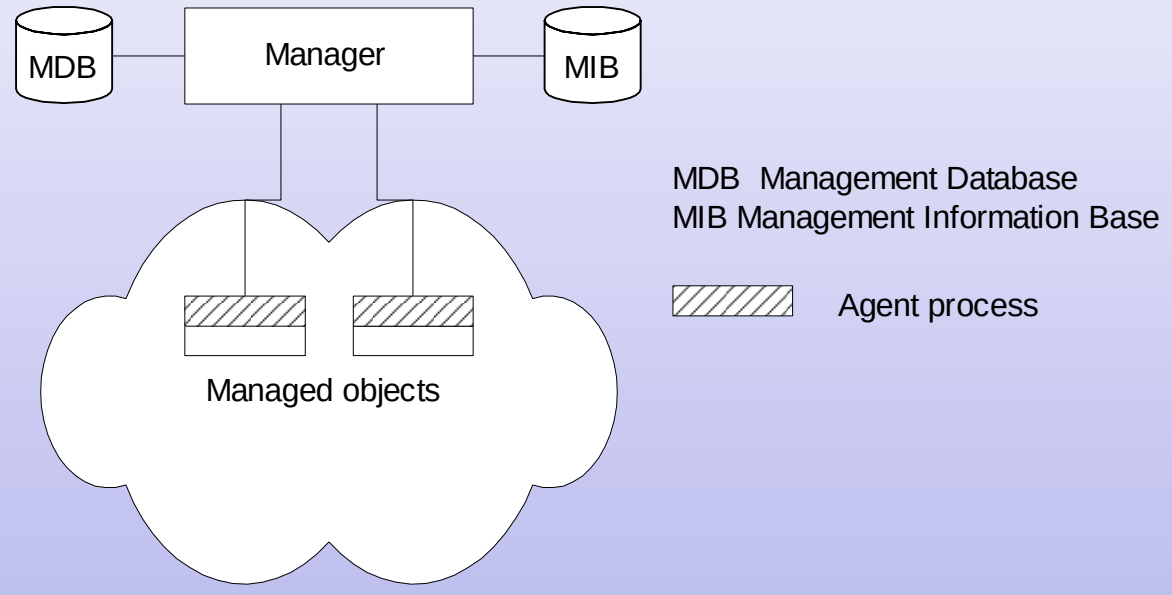


Figure 3.6 Network Configuration with Data and Information Base

Notes

- Distinction between MDB and MIB
  - MDB physical database; e.g., Oracle, Sybase
  - MIB virtual database; schema compiled into management software.
- An NMS can automatically discover a managed object, such as a hub, when added to the network
- The NMS can identify the new object as hub only after the MIB schema of the hub is compiled into NMS software.

Managed Object

- Managed objects can be
  - Network elements (hardware, system)
    - Hubs, bridges, routers, transmission facilities
  - Software (non-physical)
    - Programs, algorithms
  - Administrative information
    - Contact person, name of group of objects (IP group)

Notes

Management Information Tree

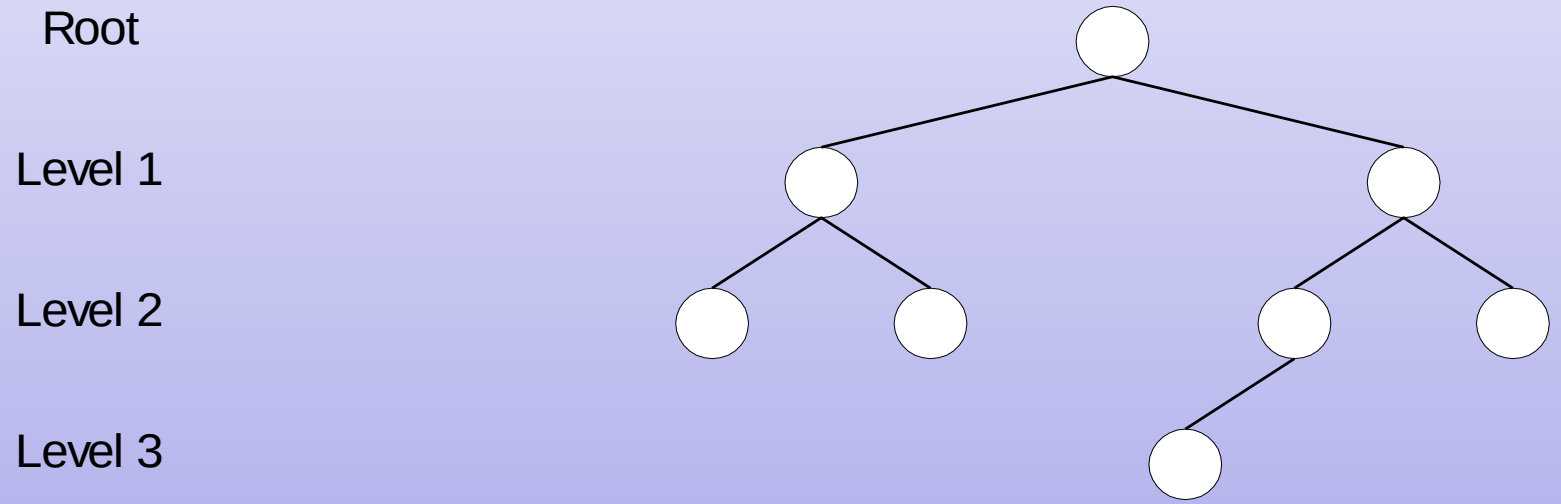
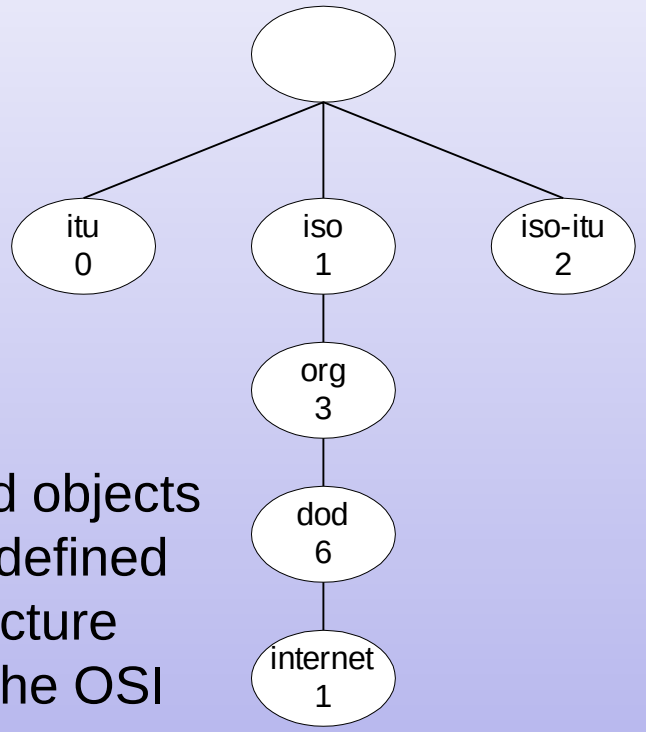


Figure 3.7 Generic Representation of Management Information Tree

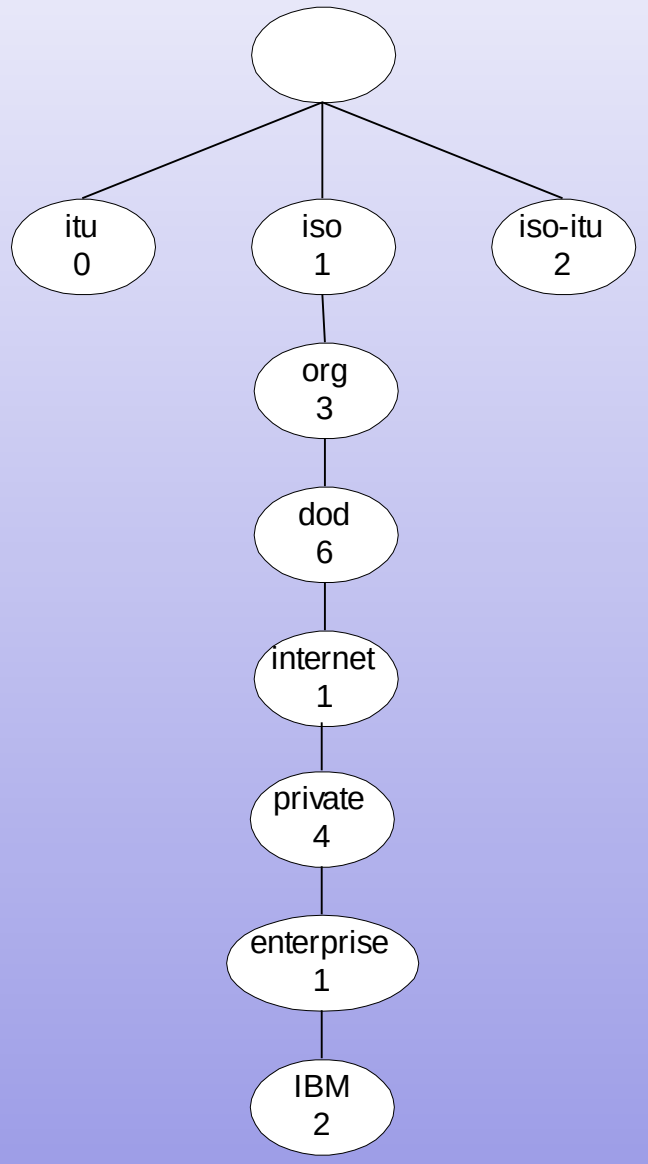
Notes

OSI Management Information Tree



The managed objects are uniquely defined by a tree structure specified by the OSI model

Figure 3.8 **OSI Management Information Tree**



Notes

- iso International Standards Organization
  itu International Telecommunications Union
  dod Department of Defense
- Designation:
  - iso 1
  - org 1.3
  - dod 1.3.6
  - internet 1.3.6.1

- internet OBJECT IDENTIFIER ::=
  {ISO(1) ORG(3) DOD(6) INTERNET(1)}

Object Type and Instance

- Type
  - Name
  - Syntax
  - Definition
  - Status
  - Access
- Instance

Notes

- Example of a circle
  - “circle” is syntax
  - Semantics is definition from dictionary
    “A plane figure bounded by a single curved line, every point of which is of equal distance from the center of the figure.”
- Analogy of nursery school

Managed Object: Internet Perspective

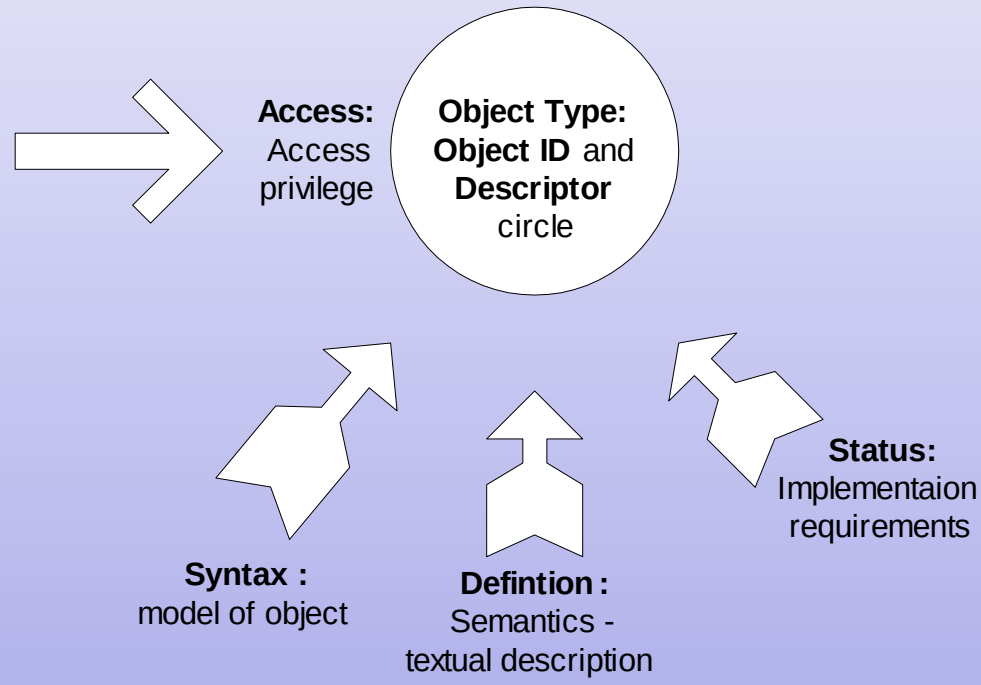


Figure 3.9(a) Internet Perspective

Notes

- *object ID* and *descriptor* — unique ID and name for the object
- *syntax* — used to model the object
- *access* — access privilege to a managed object
- *status* — implementation requirements
- *definition* — textual description of the semantics of object type

Managed Object: OSI Perspective

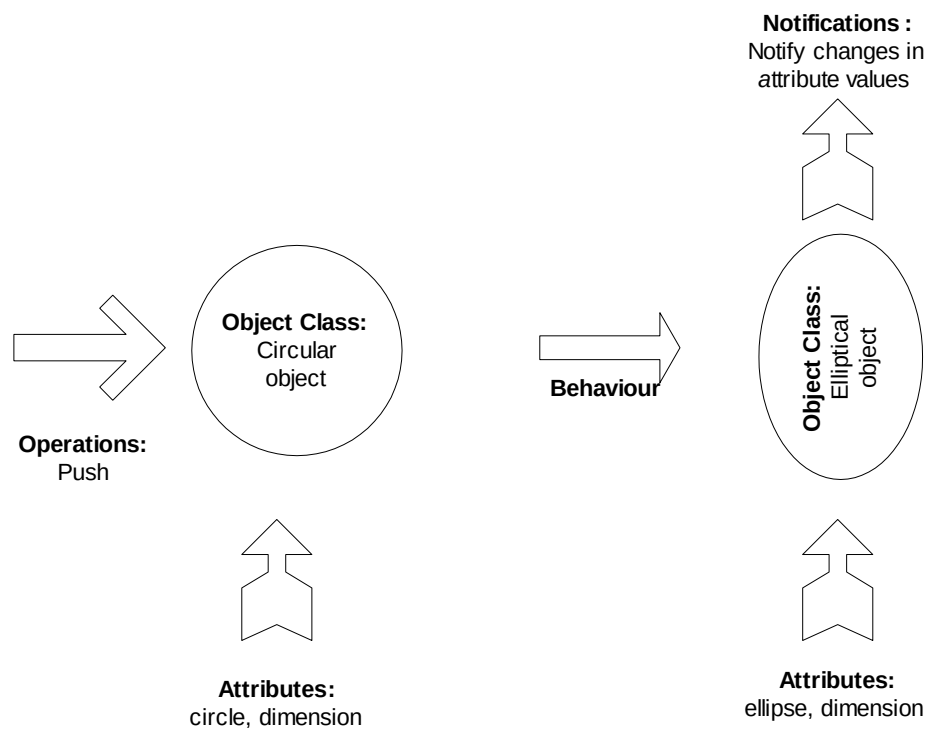


Figure 3.9(b) OSI Perspective

Notes

- *object class* managed object
- *attributes* attributes visible at its boundary
- *operations* operations which may be applied to it
- *behaviour* behavior exhibited by it in response to operation
- *notifications* notifications emitted by the object

Packet Counter Example

Characteristics	Example
Object type	PktCounter
Syntax	Counter
Access	Read-only
Status	Mandatory
Description	Counts number of packets

Figure 3.10(a) Internet Perspective

Characteristics	Example
Object class	Packet Counter
Attributes	Single-valued
Operations	get, set
Behavior	Retrieves or resets values
Notifications	Generates notifications on new value

Figure 3.10 (b) OSI Perspective

Figure 3.10 Packet Counter As Example of Managed Object

Notes

Internet vs. OSI Managed Object

- Scalar object in Internet vs. Object-oriented approach in OSI
- OSI characteristics of operations, behavior, and notification are part of communication model in Internet: get/set and response/alarm
- Internet syntax is absorbed as part of OSI attributes
- Internet access is part of OSI security model
- Internet status is part of OSI conformance application
- OSI permits creation and deletion of objects; Internet does not: Enhancement in SNMPv2

Notes

Mgmt. Communication Model

- how the information/management data is exchanged between agent and manager processes, as well as between manager processes.

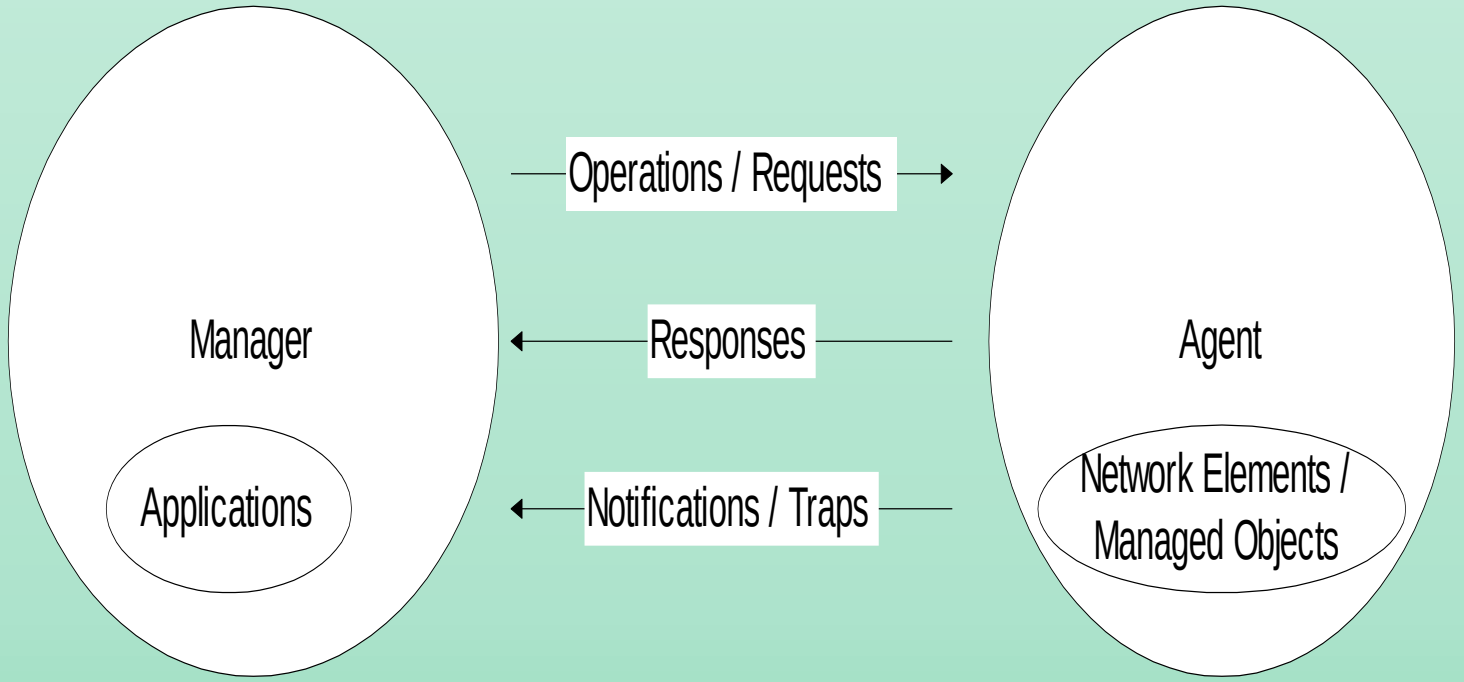


Figure 3.11 Management Message Communication Model

Figure 3.11 presents the communication model.

The applications in the manager module initiate requests to the agent in the Internet model. It is part of the operations in the OSI model. The agent executes the request on the network element; i.e., managed object, and returns responses to the manager.

The traps/notifications are the unsolicited messages, such as alarms, generated by the agent.

Transfer Protocols

Three aspects need to be addressed in the communication of information between two entities:

- transport medium of message exchange (transport protocol),
- message format of communication (application protocol),
- and the actual message (commands and responses).

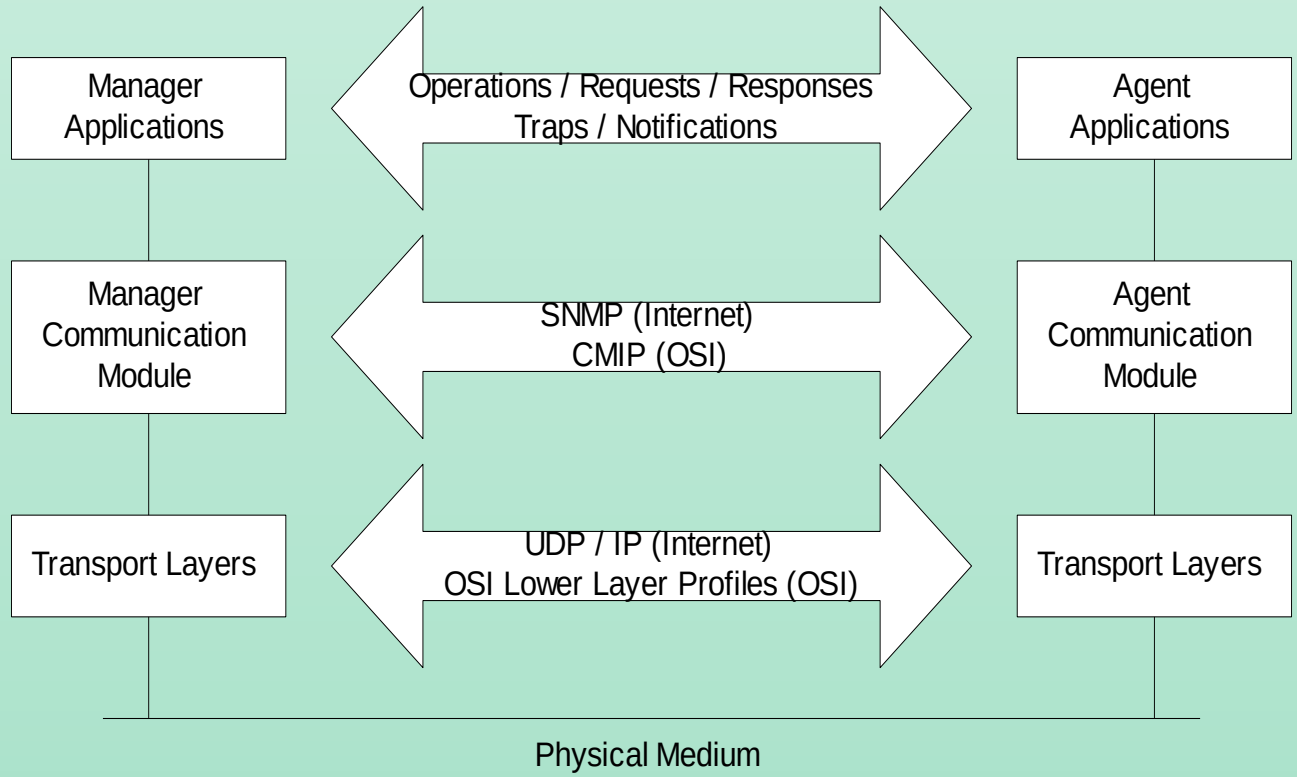


Figure 3.12 Management Communication Transfer Protocols

Notes

- Internet is based on SNMP; OSI is based on CMIP
- OSI uses CMISE (Common Management Information Service Element) application with CMIP
- OSI specifies both c-o (connection-oriented) and connectionless transport protocol; SNMPv2 extended to c-o, but rarely used

So far, we discussed the information model and the communication model, a communication language is needed to specify syntax and semantics of the communication: formats and semantics for data transfer

3.6 Abstract Syntax Notation One: ASN.1

- ASN.1 is more than a syntax; it's a language
- Addresses both syntax and semantics
- Two types of syntax
  - Abstract syntax: set of rules that specify data type and structure for information storage
  - Transfer syntax: set of rules for communicating information between systems
- Makes application layer protocols independent of lower layer protocols

- Can generate machine-readable code: Basic Encoding Rules (BER) is used in management modules

Notes

ASN.1 Symbols

Symbol	Meaning
::=	Defined as
|	or, alternative, options of a list
-	Signed number
--	Following the symbol are comments
{}	Start and end of a list
[]	Start and end of a tag
()	Start and end of subtype
..	Range

Notes

Backus-Nauer Form (BNF)

Definition:

<name> ::= <definition> *[To be read: Name of the entity ::=(defined as) definition]*

Rules:

<digit> ::= 0|1|2|3|4|5|6|7|8|9

<number> ::= <number> | <digit> <number>

<op> ::= +|-|x|/

<SAE> ::= <number>|<SAE>|<SAE><op><SAE>

Example:

- 9 is *primitive* 9
- 19 is *construct* of 1 and 9
- 619 is *construct* of 6 and 19

Notes

- BNF is used for ASN.1 constructs
- Constructs developed from primitives
- The above example illustrates how numbers are constructed from the primitive <digit>
- Simple Arithmetic Expression entity (<SAE>) is constructed from the primitives <digit> and <op>

Simple Arithmetic Expression

<SAE> ::= <number> | <SAE><op><number>

Example: 26 = 13 x 2

Constructs and primitives

Notes

Type and Value

- Assignments
  - <BooleanType> ::= BOOLEAN
  - <BooleanValue> ::= TRUE | FALSE

- ASN.1 module is a group of assignments

```
person-name     Person-Name::=
                {
                first          "John",
                middle    “T",
                last          "Smith"
                }
```

person-name is an ASN module which allows here to fix values of the data type Person-Name through 3 assignments

Notes

Keyword Examples

- CHOICE
- SET
- SEQUENCE
- OF
- NULL

Notes

- Keywords are in all UPPERCASE letters
- Alternatives : CHOICE
- List maker: SET, SEQUENCE
- Repetition: SET OF, SEQUENCE OF:

Data Type: Example 1

```
PersonnelRecord ::= SET
            {       Name,
             title      GraphicString,
             division   CHOICE
                marketing       [0]  SEQUENCE
                  {Sector,
                   Country},
                research        [1]  CHOICE
                  {product-based    [0]  NULL,
                   basic            [1]  NULL},
                production      [2]  SEQUENCE
                  {Product-line,
                   Country }                }
etc.
```

Figure 3.13 ASN.1 Data Type Definition: Example 1

Notes

- Module name starts with capital letters
- Data types:
  - Primitives: NULL, GraphicString
  - Constructs
    - Alternatives : CHOICE
    - List maker: SET, SEQUENCE
    - Repetition: SET OF, SEQUENCE OF:
- Difference between SET and SEQUENCE

Data Type: Example 2

```
Trade-message ::= SEQUENCE
      {invoice-no          INTEGER
       name                GraphicString,
       details          SEQUENCE OF
                           SEQUENCE
                  {part-no        INTEGER
                   quantity       INTEGER},
       charge           REAL,
       authenticator       Security-Type}

Security-Type ::= SET
      {     …
            …
            …   }
```

Figure 3.14 ASN.1 Data Type Definition: Example 2

Notes

- SEQUENCE OF SEQUENCE makes table of rows

ASN.1 Data Type Conventions

Data Types	Convention	Example
Object name	Initial lowercase letter	sysDescr, etherStatsPkts
Application data type	Initial uppercase letter	Counter, IpAddress
Module	Initial uppercase letter	PersonnelRecord
Macro, MIB module	All uppercase letters	RMON-MIB
Keywords	All uppercase letters	INTEGER, BEGIN

Notes

Data Type: Structure & Tag

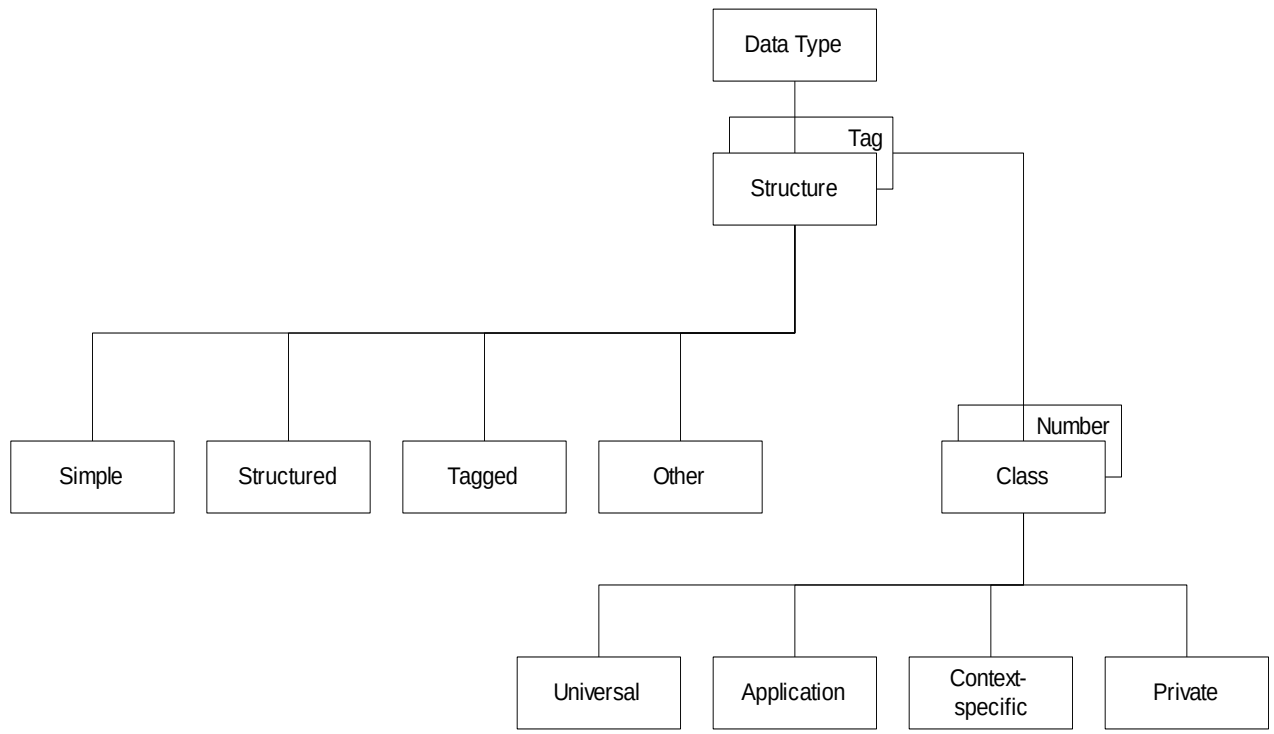


Figure 3.15 ASN.1 Data Type: Structure and Tag

Notes

- Structure defines how data type is built
- Tag uniquely identifies the data type

Structure

- Simple
  - PageNumber ::= INTEGER
  - ChapterNumber ::= INTEGER
- Structure / Construct
  - BookPageNumber ::=
    SEQUENCE
    {ChapterNumber, Separator, PageNumber
    Example: {1-1, 2-3, 3-39}
- Tagged
  - Derived from another type; given a new ID
  - In Fig. 3-14, INTEGER is either universal or application specific
- Other types:
  - CHOICE, ANY

Notes

- BookPages ::= SEQUENCE OF { BookPageNumber}
  or
  BookPages ::=
  SEQUENCE OF
  {
  SEQUENCE
  {ChapterNumber, Separator, PageNumber}
  }

Tag

- Tag uniquely identifies a data type
- Comprises *class* and *tag number*
- Class:
  - Universal - always true
  - Application - only in the application used
  - Context-specific - specific context in application
  - Private - used extensively by commercial vendors

Notes

Example:

BOOLEAN	Universal 1
INTEGER	Universal 2
research	Application [1] (Figure 3.13)
product-based	Context-specific under *research* [0]

Enumerated Integer

```
RainbowColors ::= ENUMERATED
        {
                violet          (0)
                indigo          (1)
                blue            (2)
                green           (3)
                yellow          (4)
                orange          (5)
                red             (6)
        }
```

Notes

- ENUMERATED is a special case of INTEGER
- Example: RainbowColors(5) is orange

ASN.1 Module Example

Let us conclude this section with a real-life example in network management of a data type, which is the address translation table in SNMP IP MIB. An entry in the table is of data type IpNetMediaEntry, which is a sequence of four managed objects with associated data types as shown below. Each of the four objects starts with a lowercase letter, and the associated data type with either a capital letter or is all capital letters.

```
IpNetMediaEntry ::=SEQUENCE{
        ipNetToMediaIfIndex             INTEGER
        ipNetToMediaPhysAddress         PhysAddress
        ipNetToMediaNetAddress          IpAddress
        ipNetToMediaType                INTEGER}
```

```
Name:                 John T Smith
Title:                Director
Employee Number       51
Date of Hire:         17 September 1971
Name of Spouse;       Mary T Smith
Number of Children    2
Child Information
        Name          Ralph T Smith
        Date of Birth 11 November 1957
Child Information
        Name          Susan B Jones
        Date of Birth 17 July 1959
```

(a) Informal description of personnel record

```
PersonnelRecord ::= [APPLICATION 0] IMPLICIT SET {
        Name,
        title [0] VisibleString,
        number EmployeeNumber,
        dateOfHire [1] Date,
        nameOfSpouse [2] Name,
        children [3] IMPLICIT SEQUENCE OF ChildInformation DEFAULT { } }
ChildInformation ::= SET {
        Name,
        dateOfBirth [0] Date }
Name ::= [APPLICATION 1] IMPLICIT SEQUENCE {
        givenName VisibleString,
        initial VisibleString,
        familyName VisibleString }

EmployeeNumber ::= [APPLICATION 2] IMPLICIT INTEGER

Date ::=  [APPLICATION 3] IMPLICIT VisibleString -- YYYYMMDD
```

(b) ASN.1 description of the record structure

```
{                           {givenName “John”, initial “T”, familyName “Smith”},
        title               “Director”
        number              51
        dateOfHire          “19710917”
        nameOfSpouse        {givenName “Mary”, initial “T”, familyName “Smith”},
        children
        { {                 {givenName “Ralph”, initial “T”, familyName “Smith”},
           dateOfBirth              “19571111”},
          {                 {givenName “Susan”, initial “B”, familyName “Jones”}
           dateOfBirth              “19590717”}}}
```

(c) ASN.1 description of a record value

Macro

```
<macroname> MACRO ::=
BEGIN
    TYPE NOTATION ::=  <syntaxOfNewType>
    VALUE NOTATION ::= <syntaxOfNewValue>
    <auxiliaryAssignments>
END
```

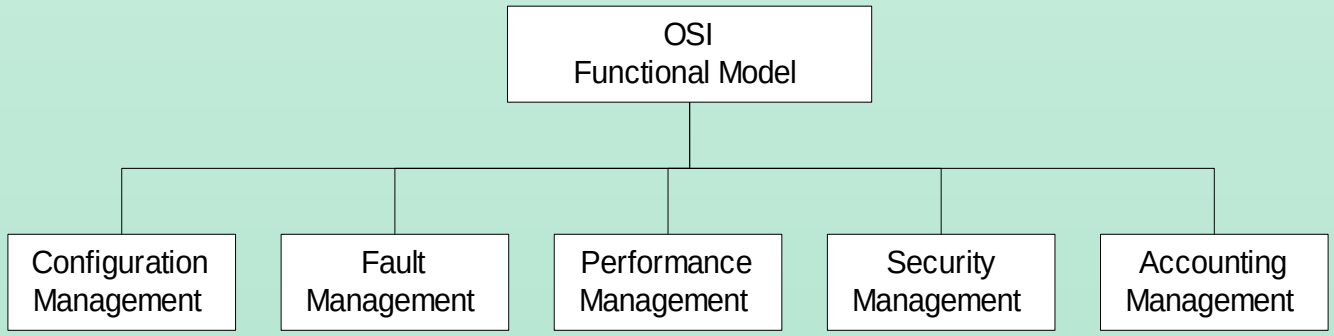
Example:

```
CS8803 OBJECT-IDENTITY
    STATUS       current
    DESCRIPTION    "A graduate-level network
    management course offered every fall by
    College of Computing in Georgia Institute of
    Technology."
        ::= {csclasses 50}
```

Notes

- Macro is used to create new data types

Functional Model



user-oriented applications

Notes

- Configuration management
  - Set and change network configuration and component parameters
  - Set up alarm thresholds
- Fault management
  - Detection and isolation of failures in network
  - Trouble ticket administration
- Performance management
  - Monitor performance of network
- Security management
  - Authentication
  - Authorization
  - Encryption
- Accounting management
  - Functional accounting of network usage