Chapter 9
Network Management

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Chapter 9: Network Management

Chapter goals:

- introduction to network management
  - motivation
  - major components
- Internet network management framework
  - MIB: management information base
  - SMI: data definition language
  - SNMP: protocol for network management
  - security and administration
- presentation services: ASN.1
Chapter 9 outline

- What is network management?
- Internet-standard management framework
  - Structure of Management Information: SMI
  - Management Information Base: MIB
  - SNMP Protocol Operations and Transport Mappings
  - Security and Administration
- ASN.1
What is network management?

- autonomous systems (aka “network”): 1000s of interacting hardware/software components
- other complex systems requiring monitoring, control:
  - jet airplane
  - nuclear power plant
  - others?

"Network management includes the deployment, integration and coordination of the hardware, software, and human elements to monitor, test, poll, configure, analyze, evaluate, and control the network and element resources to meet the real-time, operational performance, and Quality of Service requirements at a reasonable cost."
definitions:

Network management infrastructure includes managing entities that manage managed devices. Managed devices contain managed objects whose data is gathered into a Management Information Base (MIB).
Network management standards

**OSI CMIP**
- Common Management Information Protocol
- Designed 1980’s: the unifying net management standard
- Too slowly standardized

**SNMP: Simple Network Management Protocol**
- Internet roots (SGMP)
- Started simple
- Deployed, adopted rapidly
- Growth: size, complexity
- Currently: SNMP V3
- De facto network management standard
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SNMP overview: 4 key parts

- Management information base (MIB):
  - distributed information store of network management data

- Structure of Management Information (SMI):
  - data definition language for MIB objects

- SNMP protocol
  - convey manager<->managed object info, commands

- security, administration capabilities
  - major addition in SNMPv3
SMI: data definition language

**Purpose:** syntax, semantics of management data well-defined, unambiguous

- base data types:
  - straightforward, boring
- **OBJECT-TYPE**
  - data type, status, semantics of managed object
- **MODULE-IDENTITY**
  - groups related objects into MIB module

**Basic Data Types**

- INTEGER
  - Integer32
  - Unsigned32
- OCTET STRING
- OBJECT IDENTIFIED
  - IPaddress
  - Counter32
  - Counter64
  - Guage32
  - Time Ticks
  - Opaque
SNMP MIB

MIB module specified via SMI

MODULE-IDENTITY

(100 standardized MIBs, more vendor-specific)

MODULE

OBJECT TYPE: 

OBJECT TYPE: 

OBJECT TYPE: 

OBJECT TYPE: 

objects specified via SMI

OBJECT-TYPE construct
SMI: object, module examples

OBJECT-TYPE: ipInDelivers

ipInDelivers OBJECT TYPE
SYNTAX Counter32
MAX-ACCESS read-only
STATUS current
DESCRIPTION
“The total number of input datagrams successfully delivered to IP user-protocols (including ICMP)”
 ::= { ip 9}

MODULE-IDENTITY: ipMIB

ipMIB MODULE-IDENTITY
LAST-UPDATED “941101000Z”
ORGANIZATION “IETF SNPv2 Working Group”
CONTACT-INFO
“Keith McCloghrie
……”
DESCRIPTION
“The MIB module for managing IP and ICMP implementations, but excluding their management of IP routes.”
REVISION “019331000Z”
……
 ::= {mib-2 48}
## MIB example: UDP module

<table>
<thead>
<tr>
<th>Object ID</th>
<th>Name</th>
<th>Type</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.3.6.1.2.1.7.1</td>
<td>UDPInDatagrams</td>
<td>Counter32</td>
<td>total # datagrams delivered at this node</td>
</tr>
<tr>
<td>1.3.6.1.2.1.7.2</td>
<td>UDPNoPorts</td>
<td>Counter32</td>
<td># undeliverable datagrams: no application at port</td>
</tr>
<tr>
<td>1.3.6.1.2.1.7.3</td>
<td>UDInErrors</td>
<td>Counter32</td>
<td># undeliverable datagrams: all other reasons</td>
</tr>
<tr>
<td>1.3.6.1.2.1.7.4</td>
<td>UDPOutDatagrams</td>
<td>Counter32</td>
<td># datagrams sent</td>
</tr>
<tr>
<td>1.3.6.1.2.1.7.5</td>
<td>udpTable</td>
<td>SEQUENCE</td>
<td>one entry for each port in use by app, gives port # and IP address</td>
</tr>
</tbody>
</table>

Object ID 1.3.6.1.2.1.7.5 is a SEQUENCE type and represents the udpTable, which contains one entry for each port in use by an application, providing the port number and IP address.
**SNMP naming**

**question:** how to name every possible standard object (protocol, data, more..) in every possible network standard??

**answer:** *ISO Object Identifier tree:*

- hierarchical naming of all objects
- each branchpoint has name, number

```
1.3.6.1.2.1.7.1
```

- ISO
- US DoD
- Internet
- *udpInDatagrams*
- *UDP*
- *MIB2*
- *management*
OSI Object Identifier Tree
SNMP protocol

Two ways to convey MIB info, commands:

request/response mode

trap mode
## SNMP protocol: message types

<table>
<thead>
<tr>
<th>Message type</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>GetRequest</td>
<td>Mgr-to-agent: “get me data”</td>
</tr>
<tr>
<td>GetNextRequest</td>
<td>(instance,next in list, block)</td>
</tr>
<tr>
<td>GetBulkRequest</td>
<td></td>
</tr>
<tr>
<td>InformRequest</td>
<td>Mgr-to-Mgr: here’s MIB value</td>
</tr>
<tr>
<td>SetRequest</td>
<td>Mgr-to-agent: set MIB value</td>
</tr>
<tr>
<td>Response</td>
<td>Agent-to-mgr: value, response to Request</td>
</tr>
<tr>
<td>Trap</td>
<td>Agent-to-mgr: inform manager of exceptional event</td>
</tr>
</tbody>
</table>
SNMP protocol: message formats

SNMP PDU

Get/set header

Variables to get/set

PDU type (0-3) | Request ID | Error Status (0-5) | Error Index | Name | Value | Name | Value |...
---|---|---|---|---|---|---|---|---

PDU type 4 | Enterprise | Agent Addr | Trap Type (0-7) | Specific code | Time stamp | Name | Value |...
---|---|---|---|---|---|---|---|---

Trap header

Trap info

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SNMP security and administration

- **encryption**: DES-encrypt SNMP message
- **authentication**: compute, send $\text{MIC}(m,k)$: compute hash (MIC) over message (m), secret shared key (k)
- **protection against playback**: use nonce
- **view-based access control**:
  - SNMP entity maintains database of access rights, policies for various users
  - database itself accessible as managed object!
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- The presentation problem: ASN.1
The presentation problem

**Q:** does perfect memory-to-memory copy solve “the communication problem”?

**A:** not always!

```c
struct {
    char code;
    int x;
} test;

test.x = 256;
test.code = ‘a’
```

<table>
<thead>
<tr>
<th></th>
<th>test.code</th>
<th>test.x</th>
</tr>
</thead>
<tbody>
<tr>
<td>host 1</td>
<td></td>
<td>a</td>
</tr>
<tr>
<td></td>
<td>00000001</td>
<td></td>
</tr>
<tr>
<td></td>
<td>00000011</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>test.code</th>
<th>test.x</th>
</tr>
</thead>
<tbody>
<tr>
<td>host 2</td>
<td></td>
<td>a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>00000011</td>
</tr>
<tr>
<td></td>
<td></td>
<td>00000001</td>
</tr>
</tbody>
</table>

**Problem:** different data format, storage conventions
A real-life presentation problem:

- Grandma
- Aging 60's hippie
- 2012 teenager

Groovy!
Presentation problem: potential solutions

1. Sender learns receiver’s format. Sender translates into receiver’s format. Sender sends.
   - real-world analogy?
   - pros and cons?

2. Sender sends. Receiver learns sender’s format. Receiver translates into receiver-local format.
   - real-world-analogy
   - pros and cons?

   - real-world analogy?
   - pros and cons?
Solving the presentation problem

1. Translate local-host format to host-independent format
2. Transmit data in host-independent format
3. Translate host-independent format to remote-host format
ASN.1: Abstract Syntax Notation 1

- **ISO standard X.680**
  - used extensively in Internet
  - like eating vegetables, knowing this “good for you”!
- **defined data types, object constructors**
  - like SMI
- **BER: Basic Encoding Rules**
  - specify how ASN.1-defined data objects to be transmitted
  - each transmitted object has Type, Length, Value (TLV) encoding
TLV Encoding

Idea: transmitted data is self-identifying

- **T**: data type, one of ASN.1-defined types
- **L**: length of data in bytes
- **V**: value of data, encoded according to ASN.1 standard

<table>
<thead>
<tr>
<th>Tag Value</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Boolean</td>
</tr>
<tr>
<td>2</td>
<td>Integer</td>
</tr>
<tr>
<td>3</td>
<td>Bitstring</td>
</tr>
<tr>
<td>4</td>
<td>Octet string</td>
</tr>
<tr>
<td>5</td>
<td>Null</td>
</tr>
<tr>
<td>6</td>
<td>Object Identifier</td>
</tr>
<tr>
<td>9</td>
<td>Real</td>
</tr>
</tbody>
</table>
TLV encoding: example

lastname ::= OCTET STRING
weight ::= INTEGER

{weight, 259}
{lastname, “smith”}

module of data type declarations written in ASN.1

instances of data type specified in module

Basic Encoding Rules (BER)

transmitted byte stream

Value, 259
Length, 2 bytes
Type=2, integer

Value, 5 octets (chars)

Length, 5 bytes
Type=4, octet string
Network management: summary

- network management
  - extremely important: 80% of network “cost”
  - ASN.1 for data description
  - SNMP protocol as a tool for conveying information
- network management: more art than science
  - what to measure/monitor
  - how to respond to failures?
  - alarm correlation/filtering?