SNMP and Network Management

Simple Network Management Protocol

A Standard Protocol for Systems and Network Management

Network Management — the problem: a scenario

- BAD:
  - User: the server has been down for an hour, and printing has stopped working, and the connection to the Internet is down.
  - System manager: Oh, really? Well, let's have a look and see what we can do.

Network Management — the problem: a better scenario

- BETTER:
  - User: the server has just gone down, and printing has stopped working, and the connection to the Internet is down.
  - System manager: Yes, we have been working on it; we know that this is a problem with our main switch, and the guys from Cisco are working with us to solve the problem.

Network Management — the aim

- BEST:
  - The user does not see any problem
  - The system managers could see from trends in the network traffic that there was a problem, e.g., number of bad packets
  - The problem was fixed before the users were aware of it.

Network Management — its aims

- Networks contain equipment and software from many vendors
- Many protocols
- One company's solution can manage their equipment, but not all the rest
- Need a standard way to communicate information about performance, configuration, accounting, faults and security.

Network Management tools that do not (only) use SNMP

- There are programs that check the availability of network services, e.g.:
  - nagios: http://www.nagios.org/
  - mon: http://www.kernel.org/software/mon/
  - sysmon: http://www.sysmon.org/
- Log monitoring software such as logwatch and oak: http://web.mit.edu/ktools/
- Software to analyse network traffic by examining packets: http://www.ntop.org/
- There are other home-made programs and scripts possible, e.g., using cron or scheduler
- A good approach is to use many monitoring methods together

Configuration management: cfengine

- cfengine is a sophisticated system for setting up and maintaining computer systems
- You set up a single central system configuration
  - this determines how every computer on your network is configured
  - interpreter runs on each host copies and parses this file
    - any deviation from the required configuration is automatically fixed (if you choose)
    - Does not depend on network being always available
- can manage large or huge networks, scales well, since each machine looks after itself
- Runs on Linux, Unix and Windows
- http://www.cfengine.org/

Automated installation

- SystemImager: automates Linux installs: http://www.systemimager.org
  - particularly good for clusters
  - built-in support for customising configuration
  - documentation written at HP
- kickstart: automate Red Hat installation
- Symantec Ghost (proprietary): use multicast to distribute system images

SNMP — how it was born

- In 1980's, networks grew, hard to manage
- Many vendors, many protocols
- Many saw a need for standard
- SNMP Proposed to IETF (Internet Engineering Task Force) as a Request for Comments (RFC)
- RFCs are the standards documents for the Internet

SNMP: An IETF standard

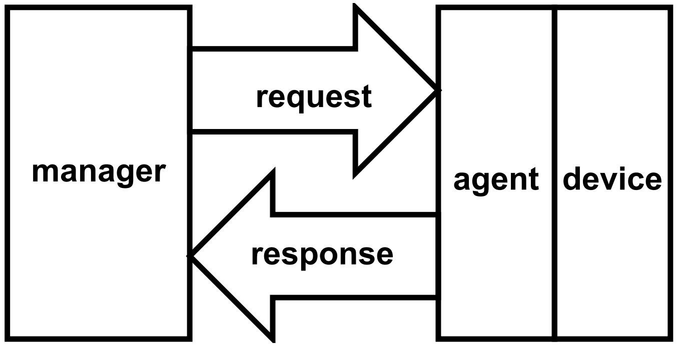
- There are three versions of SNMP
- SNMPv1: RFC 1157
  - Basic functionality, supported by all vendors
- SNMPv2: RFC 1905, 1906, 1907
  - Some useful additional features; supported by many vendors
- SNMPv3: RFC 1905, 1906, 1907, 2571, 2572, 2573, 2574, 2575.
  - Still a proposed standard
  - Adds strong authentication
  - Supported by Net SNMP and some Cisco products

Managers and Agents

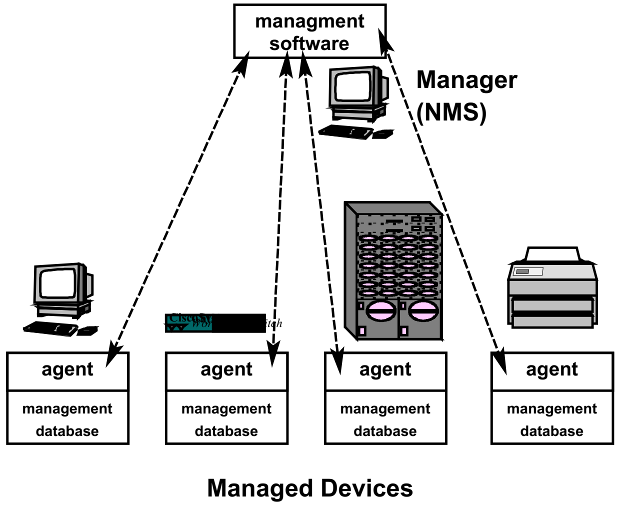
- A network management system consists of two software components:
- Network manager
  - often called a NMS (Network Management Station)
- Agent
  - Software that runs on the device being monitored/managed

Managers and Agents 2

- simple request -> response protocol



Managers and Agents 3



SNMP runs on UDP

- UDP = User Datagram Protocol
- Unreliable (no acknowlegment in UDP protocol)
- Low overhead
- Won't flood a failing network with retransmissions
- UDP port 161 for sending, receiving requests
- UDP port 162 for receiving traps

SNMP Communities

- SNMPv1, v2 use a "community" as a way of establishing trust between manager and agent
- This is simply a plain text password
- There are three:
  - Read-only (often defaults to "public")
  - Read-write (often defaults to "private")
  - Trap
- Change from default for production!!!!!!!!!!!

Authentication in SNMPv3

- Sophisticated authentication system
- User based
- Supports encryption
- Overcomes the biggest weakness of SNMPv1, v2 community strings

What is a managed object?

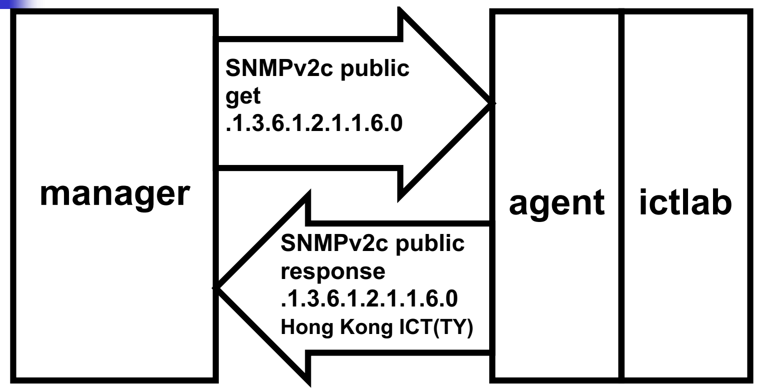
- A better name is variable, but called managed object more often
- You have looked at the managed object system.sysUpTime.0 in the lab
  - Gives time since agent was started
- Is (generally) located on the agent
- A managed object has one object identifier (OID)
- Carries one scalar value, or a table of related information
- Management involves monitoring and setting values in these managed objects
- Agent software changes SNMP requests to action to read or set the requested value(s)

Example: getting location

- The Net-SNMP tools provide a tool **`snmpget`** that directly implements the get request from a manager
- Here we request location of **`ictlab`** from its agent:

```
$ snmpget -v 2c -c public ictlab
  SNMPv2-MIB::sysLocation.0
SNMPv2-MIB::sysLocation.0 = STRING:
  "Hong Kong, IVE(TY)/ICT"
```


Example: getting location 2



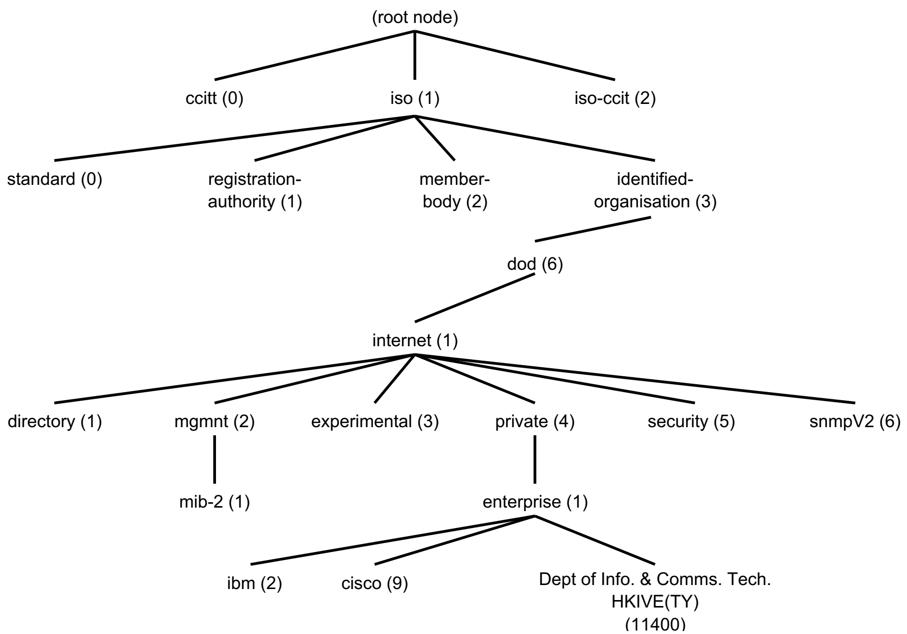
.1.3.6.1.2.1.1.6.0 is SNMPv2-MIB::sysLocation.0

Structure of Management Information (SMI)

- Defines how managed objects are named, and specifies their datatypes (called syntax).
- Definition has three attributes:
  - Name (also called object identifier). Two forms (both very long):
    - Numeric
    - "Human readable"
  - Type and syntax: defined using a subset of ASN.1 (Abstract Syntax Notation One)
    - ASN.1 is machine independent
  - Encoding:
    - how an instance of a managed object is encoded as a string of bytes using the Basic Encoding Rules (BER)

Naming managed objects

- Objects are organised into a tree
- Object ID is series of numbers separated by dots
- "human readable" name substitutes a name for each number
  - But the names are very long and hard for a human to remember
- NMS makes it easier to find variables (objects) in a more human friendly way



ASN.1

- MIBs defined with a **`SYNTAX`** attribute
- The **`SYNTAX`** specifies a datatype, as in a programming language
- Exact specification, so works on any platform
- Will see examples of MIB definitions later

ASN.1 Basic data types

- **`INTEGER`**: length can be specified
- **`OCTET STRING`**: byte string
- **`OBJECT IDENTIFIER`**: 1.3.6.1.4.1.11400 is ICT private enterprise OID.

SNMPv1 data types

- **`Counter`**: 32-bit unsigned value that wraps
- **`IpAddress`**: 32-bit IPv4 address
- **`NetworkAddress`**: can hold other types of addresses
- **`Gauge`**: 32-bit unsigned value that can increase or decrease but not wrap
- **`TimeTicks`**: 32-bit count in hundredths of a second
- **`Opaque`**: allow any kind of data

SNMPv2 data types

- **`Integer32`**: a 32-bit signed integer
- **`Counter32`**: same as **`Counter`**
- **`Gauge32`**: Same as **`Gauge`**
- **`Unsigned32`**: 32-bit unsigned value
- **`Counter64`**: Same as **`Counter32`**, except uses 64 bits, a useful extension to cope with high-speed networks which can wrap a 32-bit counter in a short time
- **`BITS`**: a set of named bits

Protocol Data Unit (PDU)

- The PDU is the message format that carries SNMP operations.
- There is a standard PDU for each of the SNMP operations.

Message Format: message header

message header	PDU

- SNMPv1, v2c message has a header and PDU
- header contains:
  - version number (version of SNMP)
  - Community name (i.e., the shared password)

Message Format: the PDU

PDU type	Request ID	Error Status	Error Index	Object 1 Value 1	Object 2 Value 2	. . .	Object n Value n
				variable bindings			

- **`get`**, **`get-next`**, **`response`**, **`set`** PDUs all contain same fields
- PDU type indicated operation (i.e., **`get`**, or **`set`**)
- request ID associates request with response
- Error status, index: show an error condition
  - used in response only, zero otherwise
- Variable Bindings: object ID and value.
  - SNMP allows more than one OID/value pair to be sent together for efficiency

How Does SNMP Measure...

- Units of network traffic = bits per second
- Counter32 **`IF-MIB::ifOutOctets`** holds bytes
- How does SNMP convert bytes->bps?
- Use simple numerical differentiation:
- Measure **`IF-MIB::ifOutOctets`** now, Nn
- Measure **`IF-MIB::ifOutOctets`** after 5 minutes, Nn+1
- Traffic = (Nn+1-Nn)/time_difference bytes/sec
- Traffic = (Nn+1-Nn)*8/time_difference bits/sec

Example network traffic

- N_1=ifOutOctets at t_1 = 200000 bytes
- N_2=ifOutOctets at t_2 = 230000 bytes
- t_2 – t_1 = 5 minutes = 300 seconds
- Number of bytes transferred = 230000 – 200000 = 30000 bytes
- bytes per second = 30000/300 = 100 bytes per second
- bits per second = bytes/second * 8= 800 bits per second

(ifOutOctets at time t_1)

What is a `gauge` used for?

- Many measurements are absolute, e.g.,
  - temperature
  - CPU load
  - disk usage
- For such measurements, use **`gauge`**
- **`counter`** is used for measuring rates of change, such as errors/sec, network traffic

SNMP Operations

SNMPv1

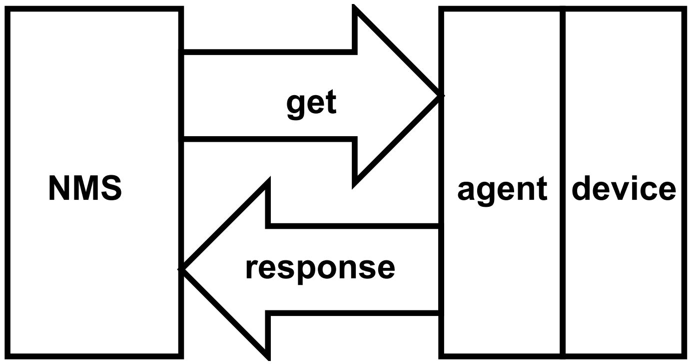
- **`get-request`**
- **`get-next-request`**
- **`set-request`**
- **`get-response`**
- **`trap`**

SNMPv2, v3

- **`get-bulk-request`**
- **`Notification`** (actually just a macro for **`trap`** or **`inform-request`**)
- **`inform-request`**
- **`report`**

`get-request` operation

- Net SNMP tool: **`snmpget`**



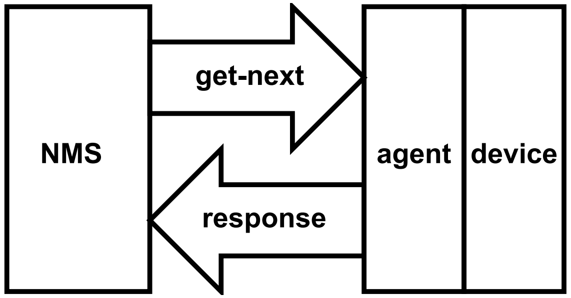
`get-request`

- NMS sends a **`get-request`** for, say, the system load of **`ictlab`**
- The agent on **`ictlab`** sends a **`response`** PDU containing the system load.

```
snmpget -v 2c -c public ictlab UCD-
  SNMP-MIB::laLoad.1
UCD-SNMP-MIB::laLoad.1 = STRING:
  0.39
```

`get-next-request` operation

- Net-SNMP tools:
- `snmpgetnext`
- `snmpwalk`



`get-next-request`

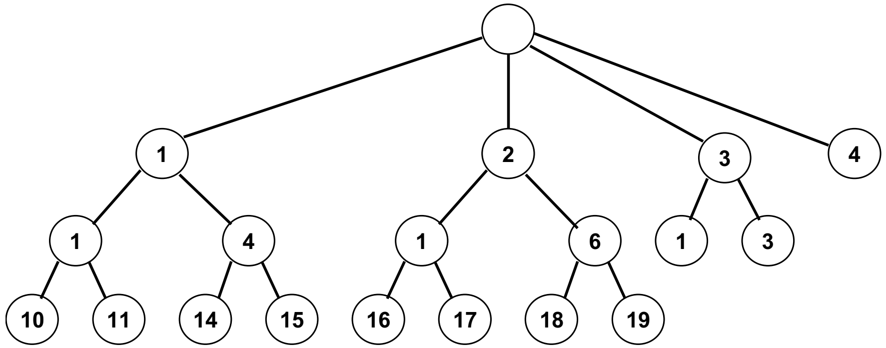
- NMS sends a **`get-next-request`**
- Agent sends a **`response`** PDU containing the value for the next variable:

```
$ snmpgetnext -v 2c -c public ictlab laLoad
UCD-SNMP-MIB::laLoad.1 = STRING: 0.74
```


Ordering of OIDs: the next value

- The ordering of the variables is "lexographical"
  - visit the node, then visit each of its children in order
  - this applies recursively
- The example MIB tree on the next slide…

An example MIB tree



This example MIB tree is listed in this order:

- 1
- 1.1
- 1.1.10
- 1.1.11
- 1.4
- 1.4.14
- 1.4.15
- 2
- 2.1
- 2.1.16
- 2.1.17
- 2.6
- 2.6.18
- 2.6.19
- 3
- 3.1
- 3.3
- 4

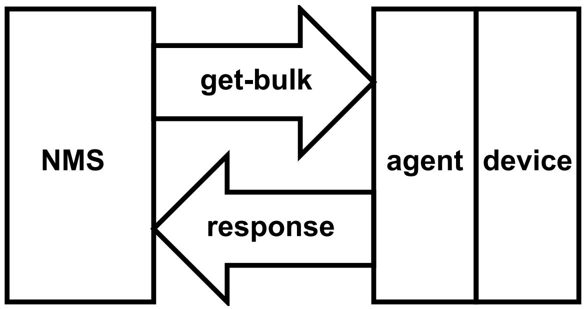
get-next-request: snmpwalk

- **snmpwalk** provides a convenient way to request a number of entries at once:

```
$ snmpwalk -v 2c -c public ictlab laLoad
UCD-SNMP-MIB::laLoad.1 = STRING: 0.74
UCD-SNMP-MIB::laLoad.2 = STRING: 0.53
UCD-SNMP-MIB::laLoad.3 = STRING: 0.48
```


get-bulk-request (v2, v3)

- Net-SNMP tools: **snmpbulkget**, **snmpbulkwalk**



get-bulk-request

- NMS sends a **get-bulk-request** for a number of variables
- Agent replies with a **response** PDU with as many answers as are requested, or will fit in the PDU
- Much more efficient
  - fewer requests and responses required to fetch data

`get-bulk-request` and `snmpbulkget`: example

```
$ snmpbulkget -v 2c -c public ictlab laLoad
UCD-SNMP-MIB::laLoad.1 = STRING: 0.62
UCD-SNMP-MIB::laLoad.2 = STRING: 0.66
UCD-SNMP-MIB::laLoad.3 = STRING: 0.59
UCD-SNMP-MIB::laConfig.1 = STRING: 2.00
UCD-SNMP-MIB::laConfig.2 = STRING: 4.00
UCD-SNMP-MIB::laConfig.3 = STRING: 4.00
UCD-SNMP-MIB::laLoadInt.1 = INTEGER: 61
UCD-SNMP-MIB::laLoadInt.2 = INTEGER: 66
UCD-SNMP-MIB::laLoadInt.3 = INTEGER: 58
UCD-SNMP-MIB::laLoadFloat.1 = Opaque: Float: 0.620000
```


`get-bulk-request` PDU

PDU type	Request ID	Non-repeaters	Max-repetitions	Object 1 Value 1	Object 2 Value 2	. . .	Object n Value n

variable bindings

- All fields same as other SNMP PDUs in v1, v2c, except Nonrepeaters and Max-repetitions
- Nonrepeaters: Specifies the number of object instances in the variable bindings field that should be retrieved no more than once from the beginning of the request.
  - used when some of the instances are scalar objects with only one variable.
- Max-repetitions: Defines the maximum number of times that other variables beyond those specified by the non-repeaters field should be retrieved.

`get-bulk-request`

- Get can request more than one MIB object
  - But if agent cannot send it all back, sends error message and no data
- **`get-bulk-request`** tells agent to send as much of the response back as it can
- Possible to send incomplete data
- Requires two parameters:
  - Nonrepeaters
  - Max-repetitions

`get-bulk-request`: nonrepeaters, max-repetitions: 1

- Nonrepeaters:
  - A number, N
  - Indicates first N objects can be retrieved with simple get-next operation
- Max-repetitions:
  - A number, R
  - Can attempt up to R get-next operations to retrieve remaining objects

get-bulk-request: nonrepeaters, max-repetitions: 2

```
$ snmpbulkget -v 2c -C n2r3 -c public ictlab laLoad ifInOctets
   ifOutOctets
UCD-SNMP-MIB::laLoad.1 = STRING: 0.63
IF-MIB::ifInOctets.1 = Counter32: 35352440
IF-MIB::ifOutOctets.1 = Counter32: 35352440
IF-MIB::ifOutOctets.2 = Counter32: 297960502
IF-MIB::ifOutOctets.3 = Counter32: 0
```

- Notice that we have one entry only for `laLoad`, and for **ifInOctets**
  - the first two variables are "non-repeaters", i.e., we just fetch one value for each
- We get three values for `ifOutOctets`
  - we ask for three values for all remaining variables after the first two

get-bulk-request: nonrepeaters, max-repetitions: 3

```
$ snmpbulkget -v 2c -C n1r3 -c public ictlab laLoad
   ifInOctets ifOutOctets
UCD-SNMP-MIB::laLoad.1 = STRING: 0.77
IF-MIB::ifInOctets.1 = Counter32: 5356045
IF-MIB::ifOutOctets.1 = Counter32: 5356045
IF-MIB::ifInOctets.2 = Counter32: 1881446668
IF-MIB::ifOutOctets.2 = Counter32: 3664336845
IF-MIB::ifInOctets.3 = Counter32: 0
IF-MIB::ifOutOctets.3 = Counter32: 0
```

- We have one value for the first variable `laLoad` (non-repeaters = 1)
- We have 3 values for all the remaining variables we ask for

get-bulk-request: nonrepeaters, max-repetitions: 4

```
$ snmpbulkget -v 2c -C n3r3 -c public ictlab laLoad
   ifInOctets ifOutOctets
UCD-SNMP-MIB::laLoad.1 = STRING: 0.71
IF-MIB::ifInOctets.1 = Counter32: 35370916
IF-MIB::ifOutOctets.1 = Counter32: 35370916
```

- Notice we only have one entry for all three OIDs we specified on the command line.
- Same result, regardless of value of R, I.e., `snmpbulkget -v 2c -C n3r0 ...` gives the same result.

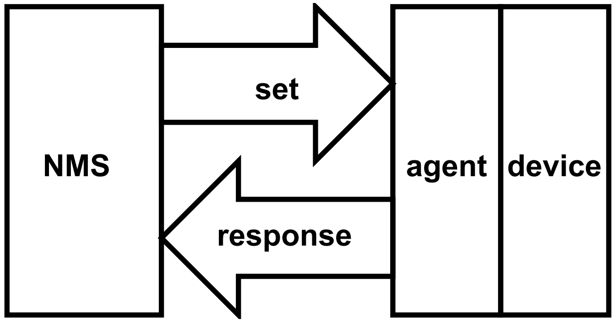
get-bulk-request: snmpbulkwalk

- `snmpbulkwalk` is convenient for efficiently browsing large tables in the MIB tree

```
$ snmpbulkwalk -v 2c -c public ictlab laLoad
UCD-SNMP-MIB::laLoad.1 = STRING: 0.52
UCD-SNMP-MIB::laLoad.2 = STRING: 0.58
UCD-SNMP-MIB::laLoad.3 = STRING: 0.56
```

`set-request` operation

- Net-SNMP tool: **`snmpset`**

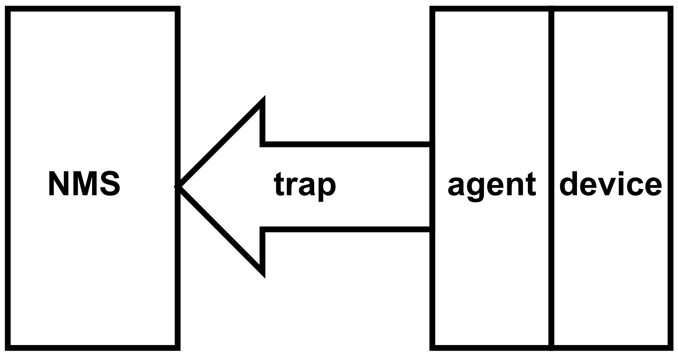


`set`

- NMS sends a **`set-request`** to set **`sysLocation`** to ICT Laboratory, Hong Kong
- Agent replies with either an error response, or a noError response in a **`request`** PDU

Trap

- A trap has no response:



SNMP traps

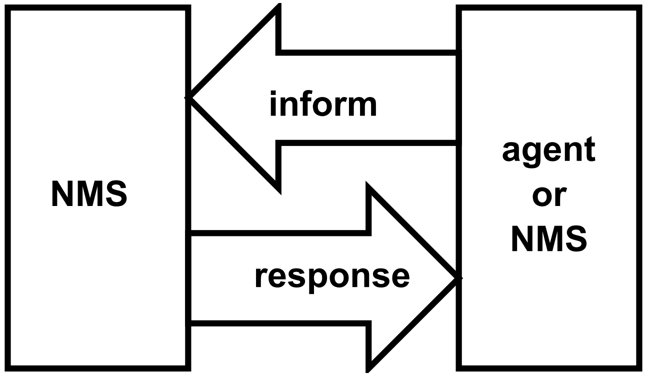
- Lets the agent tell the manager something happened, e.g.,
  - A network interface is down on the device where the agent is installed
  - The network interface came back up
  - A call came in to the modem rack, but could not connect to any modem
  - A fan has failed

SNMP **`inform-request`** (v2, v3)

- A kind of trap with an acknowledgment
- Can be sent by a manager or by an agent
- There is an acknowledgement: a **`response`** PDU
- The agent can resend the **`inform-request`** if no response is received in a reasonable time.

`inform-request`

- An **`inform-request`** has a confirmation response:



SNMP **`notification`** (v2, v3)

- This is a macro that sends either a trap or an inform-request

Traps and Inform: port 162

- Other SNMP operations are on UDP port 161
- trap and inform-request operations are on UDP port 162.

SNMP v3

Authentication and Encryption

Some security at last!

SNMPv1 now officially "historic"

- Recently, SNMPv3 has moved futher to becoming an official standard
- SNMPv1 RFCs are being changed from the status of standard to being historic
- for details:
  - see news link from Net-SNMP web site
  - or go directly to http://sourceforge.net/forum/forum.php?forum_id=203052

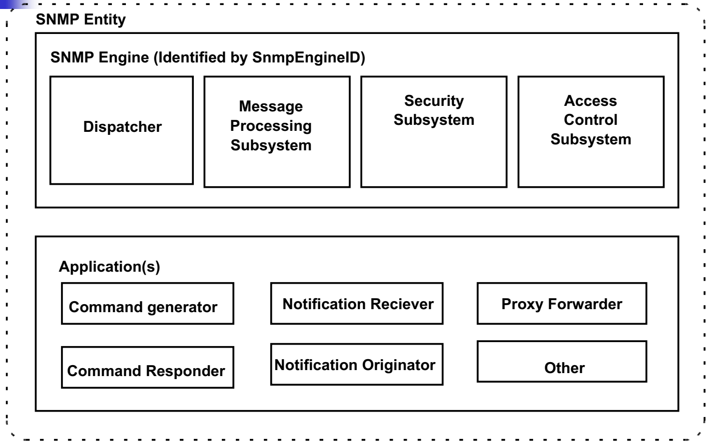
Main RFCs for SNMP v3

- RFC 3411: an architecture for describing SNMP Management Frameworks
- RFC 3412: Message Processing and Dispatch for SNMP
- RFC 3413: SNMPv3 Applications MIBs
- RFC 3414: User-based Security Model (USM) for SNMPv3
- RFC 3415: View-based Access Control Model (VACM) for SNMP

Changes in SNMPv3

- Aim: provide cryptographic security
- Make backwardly compatible with SNMPv1, SNMPv2c
- Many new terms
- Most importantly:
  - now abandon notion of managers and agents
  - both managers and agents now called SNMP entities
- SNMPv3 defines an architecture
  - not just a set of messages

SNMPv3 architecture (RFC 3411)



SNMP Engine: 5 components

- Dispatcher
  - send and receive messages.
  - determines version of each received message (v1, v2, v3)
  - if can handle received message, hands to Message Processing Subsystem
- Message Processing Subsystem
  - prepares messages to be sent
  - extracts data from received messages
  - can have modules for each of SNMP v1, v2 and v3 (or any other future type of message)
- Security Subsystem
  - provides authentication and encryption ("privacy")
  - Uses MD5 or SHA algorithms to authenticate users
  - passwords not sent in clear text
- Access Control Subsystem
  - controls access to MIB objects
  - which objects, and level of access
- Applications module (discussed next)

SNMPv3 Applications Module

- Each SNMPv3 entity has one or more applications
- Really are elements used to build applications:
- command generator (NMS)
- notification receiver (NMS)
- proxy forwarder (NMS)
- command responder (agent)
- notification originator (agent)

Command Generator: manager role

- This application is found on managers
- used to send
  - **`get-request`**
  - **`get-next-request`**
  - **`set-request`**
  - **`get-bulk-request`**

Command Responder: agent role

- processes commands sent by Command Generator
- performs the action required
- sends a **`response`** message

Notification Originator: agent role

- Generates a **`trap`** or **`inform-request`** message
- generally implemented on agents

Notification Receiver: manager

- receives **`traps`** and **`inform-request`**s, and
- acts on them

Proxy Forwarder: manager role

- A front end to manager for older SNMP agents
- e.g., convert **`get-bulk-request`** to **`get-next-request`**s
- handles requests from:
  - command generator
  - command responder
  - notification generator.

SNMPv3 names: Engine ID

- A manager or agent has an identifier: SNMP engineID, unique in this network
  - the management software expects all SNMP engines it talks to have different SNMP Engine IDs.
  - See RFC 3411 for details of how to assign an SNMP Engine ID
- The SNMP engineID is used when calculating hashes of USM passwords.

SNMPv3 names: context

- An entity can be responsible for more than one managed device.
- Usually means the agent on one network device is a proxy for another separate legacy physical device that does not support SNMP
  - The default context will be for the local physical device, called ""
  - other named contexts may be for other remote physical devices for which this machine is a proxy
- Each managed device has a contextEngineID and a contextName
  - contextName is unique in one SNMP entity
- normally contextEngineID = snmpEngineID

SNMPv3 MIBs

- New MIBs for SNMPv3 support
  - management architecture
  - authentication and encryption
- Location: under snmpv2 (.1.3.6.1.6) in snmpModules (.1.3.6.1.6.3)

SNMPv3 User-based Security Model (USM)

- Supports authentication using
  - MD5 (Message Digest 5) or
  - SHA1 (Secure Hash Algorithm)
- Supports encryption using DES (Data Encryption Standard)
- Supports individual user accounts

SNMPv3 Access Control: VACM

- Uses the View-based Access Control Model (VACM)
- Has 5 elements:
  - groups
  - security level
  - contexts
  - MIB views and view families
  - access policy

VACM: MIB views and view families

- A MIB view is a subset of the MIB tree
- can be a subtree (i.e., SNMPv2-MIB::system and below)
- Can be a set of trees
- Can be a family of view subtrees:
  - e.g., monitor a set of columns from a table, but not all the columns
  - useful for ISPs to allow customers to monitor input, output traffic

VACM: groups

- Basically, a set of one or more users (security names)
- All elements belonging to a group have equal access rights

VACM: security level

- There are three levels:
  - no authentication, no privacy
  - authentication, no privacy
  - authentication, privacy
- privacy means encryption using DES
- authentication requires a password hashed with MD5 or SHA1.

VACM: Access Policy

- Four levels:
  - not accessible
  - read view
  - write view
  - notify view

SNMPv3 Notes Continued:

- My new set of notes on SNMPv3 continue from here
- Provide a practical exploration of SNMPv3