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Network Management

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Outline

Introduction

SNMP architecture

Management Information Base

SNMP protocol

Network management in practice

Niksula

Network Management

> *“When you have 100s of computers in a network or you are running a backbone, you are almost always interested about the state of the network nodes and want to know about the traffic flows.”*
>
> – Timo Kiravuo

Using the network to manage the network

- Network management requires a protocol which should:
  - Not generate too much load on the network and nodes
  - Be affected as little as possible by congestion, packet loss, outages etc.
  - Report meaningful information about the network and its nodes
  - Not block the management or managed nodes

Network management tasks

- ITU-T Telecommunications Management Network recommends FCAPS network management model
- A useful check list:
  - Fault Management
  - Configuration Management
  - Accounting
  - Performance Management
  - Security Management
- OSI CMIP (Common Management Information Protocol) implements this as a single protocol

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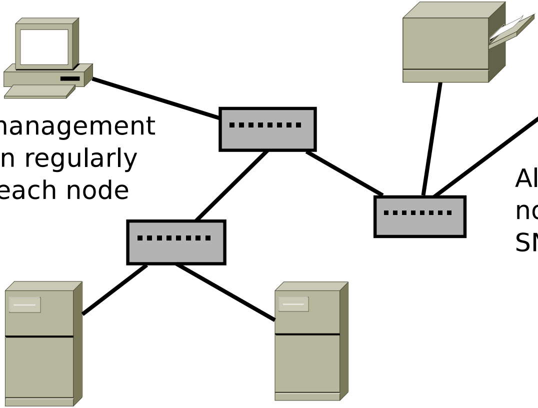
Network Management with SNMP

- Simple Network Management Protocol (SNMP)
- IETF's network management protocol and architecture
- Four defined components:
  - Network elements have a small server program called **agent**
  - **Management station** queries network elements for information
  - Simple Network Management **Protocol** for exchanging information between agents and management station
  - Management Information Base (**MIB**) defines the information given by SNMP agents

SNMP architecture



The management station regularly polls each node

All managed nodes have SNMP agents

SNMP Agent

- The agent is a server on the managed device that collects information of the system
- Sources of information:
  - Operating system tables
  - Network interfaces
  - Software (servers)
- The agent replies to SNMP queries from the management station
- Commercial and freeware implementations
- Typically an agent comes with the operating system

Management station

- Typically commercial or free software running on a workstation
- The network management station software queries various agents in network elements for information
- The management station software reads the MIB descriptions
- The management software has addresses of the managed network elements
- The management software knows what particular information to fetch from the element

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MIB descriptions

- The administrators read the MIB descriptions to understand the data
- The management software keeps the MIB descriptions in files for reference
- MIB description specifies the data on the managed equipment as variables
- Variables can be queried and set by the manager
- Variables are named using Object IDentifiers (OIDs), a hierarchical scheme, e.g. iso.org.dod.internet.mgmt.mib-2
- MIB descriptions are written using ASN.1 (Abstract Syntax Notation One)

- The OID of the element is 1.3.6.1.2.1.1.3 – or iso.org.dod.internet.mgmt.mib-2.system.sysUpTime

```
sysUpTime OBJECT-TYPE
SYNTAX      TimeTicks
MAX-ACCESS  read-only
STATUS      current
DESCRIPTION
   "The time (in hundredths of a second)
    since the network management portion
    of the system was last re-initialized."
::= { system 3 }
```

MIB datatypes

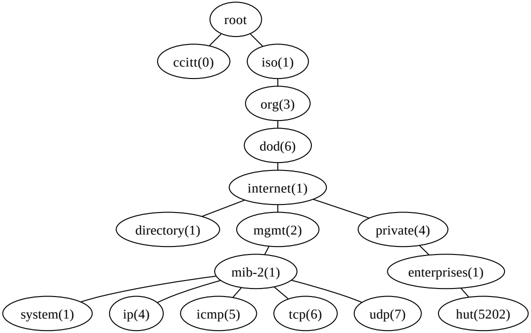
- Most common types
  - Integer, usually signed 32 bit
  - Octet String, a sequence of bytes
  - Gauge, can go up and down within a range
  - Counter, grows until it rolls to zero at max value (2ˆ32)
  - TimeTicks, time measure in hundredths of seconds
- Data can also be stored in tables
- More complex data types can be constructed using sequence and union

Using MIB datatypes

- Integers and octet strings are useful for relatively static data
- Gauge can be for example the CPU load as percents
- Counter is especially useful for collecting traffic statistics
  - It grows only up and at the max value it rolls around
  - The counter should be read several times before it rolls around to obtain a correct reading
  - The management station is in charge of interpreting the counter and collecting statistics
  - The agent just keeps the current state of variables

MIB naming tree

- Every SNMP variable has a place in the global MIB tree



Example: MIB-II

- The Internet MIB-II database (RFC-1213) defines commonly used MIB variables for Internet network elements
- Standard protocol MIBs start with 1.3.6.1.2.1 (iso.org.dod.internet.mgmt.mib-2)
  - The same management software can be used for monitoring network devices by different vendors
  - E.g. the IP address for the host is held in the mib-2.ip.ipAddrTable table (one host may have many addresses)
- Enterprise MIBs start with 1.3.6.1.4.1 (iso.org.dod.internet.private.enterprises)
  - Manufacturers (or anyone) can define their own MIB descriptions

Writing your own MIB

- Get your enterprise MIB address from IANA
- Understand the properties of the phenomenon to be monitored or controlled
  - webcam, vending machine, toaster...
- Describe the data to be transferred in terms of single variables and tables
- Write the MIB definition in ASN.1 language
- Select a module from an existing SNMP agent and rewrite it to implement the MIB
- Feed your MIB file to a management software and test it

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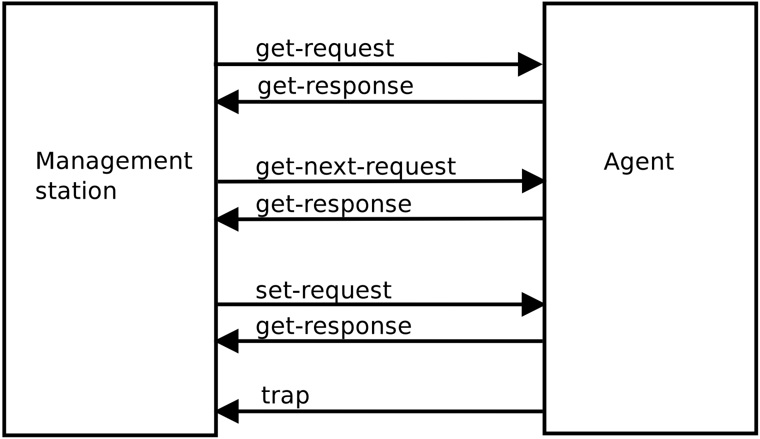
SNMP protocol

- Works on top of UDP
- Agent listens port 161
- Management station listens port 162 for trap messages
- Simple get/set protocol: device is managed by setting variables
- Messages are coded with ASN.1
- Three major versions

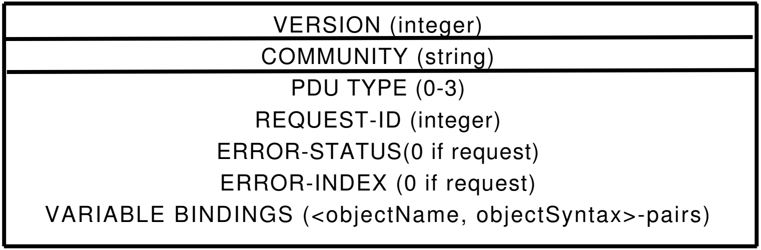
SNMPv1

- Defined in RFC-1157 (1990)
- Five message types:
  - get-request – fetching the value of some variables
  - get-next-request – fetch the value of next OID (useful)
  - set-request – set the value of some variables
  - get-response – return message from queries above
  - trap – notify the manager

SNMPv1 messages



SNMP message format



VERSION (integer)

COMMUNITY (string)

PDU TYPE (0-3)

REQUEST-ID (integer)

ERROR-STATUS(0 if request)

ERROR-INDEX (0 if request)

VARIABLE BINDINGS (<objectName, objectSyntax>-pairs)

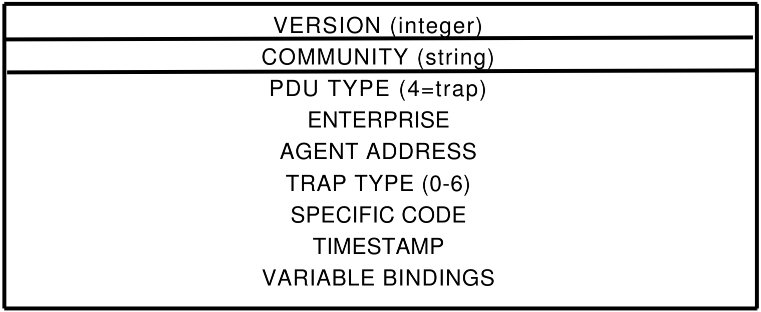
SNMP message format

- Version is the version number of the protocol
- Community is the common name for managed area and it can be used as a clear-text password between the manager and agent
- PDU Type tells the message type
- Request ID is an identifier for separating the requests
- Error Status and Error Index are used in get-response to indicate problems e.g. noSuchName or readOnly.
- Variable Bindings is a list of object name-value pairs

SNMPv1 Traps

- A SNMP agent can send a trap to the SNMP manager when something happened in the agent that the manager wants to know about
- There is no reply, which means that traps are not reliable
- Traps should be considered an informational addition to the normal get -sequences of collecting the management information

SNMPv1 Traps



VERSION (integer)

COMMUNITY (string)

PDU TYPE (4=trap)

ENTERPRISE

AGENT ADDRESS

TRAP TYPE (0-6)

SPECIFIC CODE

TIMESTAMP

VARIABLE BINDINGS

SNMPv1 Traps

- PDU Type = 4 = trap
- Enterprise is the OID of the enterprise
- Agent Address is the address of the device
- Trap Type, six pre-defined traps, plus one vendor specific
    - ColdStart
    - WarmStart
    - linkDown
    - linkUp
    - authenticationFailure
    - egpNeighborLoss
    - enterpriseSpecific
- Specific Code some enterprise specific trap code
- Timestamp is the time since last initialization of the network

SNMPv2

- Extends the original SNMP version
- Multiple subversions: v2, v2c and v2u, several RFCs each
- New features:
  - GetBulkRequest – transfer potentially large amount of data, efficient for especially large tables
  - InformRequest – implements acknowledged trap
  - Trap – format changes
- Security enhancements in v2u, not widely used

SNMPv3

- RFC 3410-3418 (2002), an Internet standard STD0062 (2004)
- A new framework (architecture) for processing the messages
- Provides important security features:
  - Confidentiality, message integrity, authentication
- Not widely deployed yet

SNMP and security

- V1 has no security in the protocol
- V2 has some security features, not widely used
- V3 has cryptographic integrity and confidentiality protection for the protocol
  - User-based Security Model (USM) RFC-3414
- New:
  - RFC-5592 Secure Shell Transport Model for SNMP, 2009
  - RFC-5953 TLS Transport model for SNMP, 2010

SNMP and security in practice

- SNMP should not be used in untrusted networks
  - And blocked in the firewall
  - Better yet, in its own virtual LAN (VLAN) in a private network
- IPSec may be used directly to protect the SNMP traffic that uses UDP

Network Configuration Protocol (NETCONF)

The next generation of network management?

- IETF Internet standard RFC-6241
- On top of a secure transport layer e.g. SSH or TLS
- RPC-based client-server model with XML encoding
- Strong industry support (Cisco, Juniper, etc.)

NETCONF key features

- Separation of Configuration and State Data
- Configuration change transactions
- Configuration datastores
- Configuration testing and validation support

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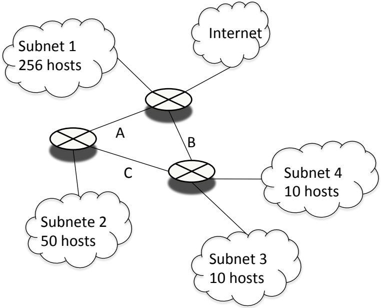
Network subnet planning

- Start from the biggest subnet, the network that needs most addresses
- Continue to smaller subnets
- Make sure to count in the network address and broadcast address. Router needs an address as well!
    - E.g. the network 130.233.192.0/24 has 8 bits for hosts ($32 - 24 = 8$). This means $2^8 = 256$ addresses, but two of them are reserved – one for the network and one for broadcast, so there are 254 addresses for devices.

Network subnet planning



Network subnet planning

Network	# of devices	# of host addresses	CIDR	Network address (last two octets in binary)
The network given to be divided			/22	130.233.192.0/22 1000 0010 1110 1001 1100 0000 0000 0000
Subnet 1	256 hosts 1 router	2^8-2=254, 2^9-2=510	/23	130.233.192.0/23 1100 0000 0000 0000
Subnet 2	50 hosts 1 router	2^6-2=62	/26	130.233.194.0/26 1100 001 0 0000 0000
Subnet 3	10 hosts 1 router	2^4-2=14	/28	130.233.194.64/28 1100 0010 0100 0000
Subnet 4	10 hosts 1 router		/28	130.233.194.80/28 1100 0010 0101 0000
Subnet A	2 routers	2^2-2=2	/30	130.233.194.96/30 1100 0010 0110 0000
Subnet B	2 routers		/30	130.233.194.100/30 1100 0010 0110 0100
Subnet C	2 routers		/30	130.233.194.104/30 1100 0010 0110 1000

SNMP freeware tools

- Several freeware packages are available that have both an agent and the command line tools for management
- The (command line) tools usually correspond to the SNMP protocol actions e.g. `snmpget`
  - Additionally often included the useful `snmpwalk` tool which traverses an OID branch of the MIB tree using the get-next-response
- DEMOS!

Network Management in action using SNMP

- When the management software finds something wrong, e.g. one of the power supplies of the switch fails, the management software sends an email alert
- Network manager may set variables in a network element, e.g. changing the network (VLAN) of a switch port to another
- A network element may send a trap, for example a printer may signal that it is out of paper

Practical network management

- Network management is about monitoring and tuning performance
  - How to locate performance bottlenecks
  - Planning for future needs
- Sometimes it is about disaster recovery
  - Devices break or an ignorant user causes problems for example by accidentally creating a loop to the network
  - Denial of Service attacks
  - Hunting down infected or misbehaving devices e.g. laptops or network flooding computers

Deploying SNMP to a network

- Activate agents at the nodes to be monitored
- Configure the management station
  - Decide which OIDs to monitor
    - For a router a table of interfaces
    - How often to poll
- Enjoy the show
  - Learn to interpret the data and behavior of the devices
  - Produce nice graphs and summaries for the management

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CS-building network and Niksula

- One router and about 50 switches
- Hundreds of hosts
- Multiple subnets from HUT/AALTO domain
- Devices managed via SNMP include printers, servers and network
- Other management tools: puppet, git
- DEMO

Questions?