Web-Based Management of
IP Networks and Systems

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Outline

- Problems with SNMP-based mgmt
- Web-based mgmt
- Push model
- New communication model
- XML
- JAMAP: research prototype
- Conclusion
IP Management Platforms: Mandatory Tasks

• Monitoring:
  ■ detect faults in network devices, network links, and systems:
    ➤ reactive w.r.t. faults
    ➤ proactive w.r.t. short-term complaints from users

• Data collection:
  ■ gather data to build daily, weekly, and monthly reports:
    ➤ proactive w.r.t. long-term complaints from users

• Notification handling:
  ■ pseudo real-time
  ■ react to events generated by agents (SNMP notifications)
  ■ react to events generated by the manager (rule-based data interpreter)

• Configuration mgmt: (simple and ignored)
Regular Management

• Ongoing monitoring and data collection
• Automated
• 2 modes:
  ■ attended mode: operators gazing at GUIs (red-icon angst)
  ■ unattended mode:
    • automated correlation
    • alarms trigger pager, email, telephone, siren, etc.
• Midsize and large networks
Ad Hoc Management

- Troubleshooting, configuration mgmt, and temporary monitoring
- Not automated
- Single mode: attended (administrators or operators)
- All networks
- Replaces regular mgmt in small networks
Problems with SNMP-Based Mgmt Platforms (1/2)

- For customers:
  - too expensive (hardware and software):
    - dedicated hardware for network mgmt
  - limited support for third-party RDBMSs
  - insufficient integration

- For equipment vendors:
  - the support for device-specific mgmt GUIs is too expensive:
    - many mgmt platforms
    - many operating systems
    - many GUIs
Problems with SNMP-Based Mgmt Platforms (2/2)

- For customers and equipment vendors:
  - poor time-to-market for mgmt GUIs:
    ➤ large vendors: several months after hardware release
    ➤ startups: never --> need separate mgmt platform --> no integration
  - MIB versioning:
    ➤ MIB upgrade in the network causes version mismatch between manager and agents:
      - manually configure the manager for each agent
        (no MIB-discovery protocol)
      - do not use new features of a MIB until all agents are upgraded
  - investment bound to a specific operating system
Problems with SNMP (1/2)

- SNMP expertise is domain specific --> rare and expensive
- Scalability, network overhead, and latency are adversely affected by old protocol design decisions:
  - BER encoding [Mitra 1994]
  - SNMP table retrieval mechanism (“holes”, many messages)
  - OIDs take much more space than values
  - no compression
- Low-level semantics:
  - only instrumentation MIBs
  - no standard high-level APIs
  - site-specific network applications developed from scratch:
    - bound to the API of a specific mgmt platform, not to a standard technology
Problems with SNMP (2/2)

• Security:
  ■ SNMPv1 and SNMPv2c: community string (simplistic)
  ■ SNMPv3: better, still simple, but not used
  ■ Next step: expensive encryption hardware (e.g., VPNs)
  ■ firewalls: complex and costly UDP relays [Chapman & Zwicky 1995]

• Unreliable transport protocol:
  ■ important SNMP notifications (unacknowledged) are lost for silly reasons (e.g., buffer overflow)
  ■ SNMPv3 informs (acknowledged) are not used yet
  ■ important mgmt data requires retransmissions at the application level

• Evolution of SNMP hampered by legacy systems:
  ■ “better replace than repair”
Part 1: Web-Based Management

• Definition: integrated mgmt (= network, systems, application, service, and policy mgmt) based on Web technologies

• Large choice:
  - HTML forms
  - CGI (Perl scripts, Tcl/Tk scripts, shell scripts, binaries)
  - Java applets, servlets, and applications
  - Java Object Serialization
  - Java RMI (distributed objects)
  - Java IDL (CORBA)
  - JDBC (databases)
  - XML
  - ...

Why Use Web Technologies?

- Reduce development costs of mgmt GUIs (applets):
  - less expensive for customers
- Zero the time-to-market of mgmt GUIs (embedded)
- Suppress the need for separate mgmt platforms:
  - integrated mgmt
  - put small and large equipment vendors in fair competition
- Simplify mgmt of remote subsidiaries across firewalls
- Reduce network overhead (compressed mgmt data)
- Make mgmt platforms more open, more modular, and less costly
- Improve the support for 3rd-party databases
Better Design of Mgmt Platform (1/2)

• Split manager:

  - Mgmt server
  - Agent
  - Data server
  - Mgmt station

• Split mgmt server:
  - was: big, monolithic, opaque, and proprietary code
  - now:
    - integration of COTS components and OO frameworks
    - fine-grained competition between vendors (e.g., buy an event correlator):
      - less expensive
      - manager to manager: more interoperable
      - no longer enchained by big investment
Better Design of Mgmt Platform (2/2)

- Generic hooks for accessing the data server:
  - virtually all databases support JDBC or XML
  - customers are no longer dependent on peer-to-peer agreements between mgmt-platform and database vendors
  - customers need not buy a new database for integrated mgmt
Part 2: The Push Model

- Why use the push model?
  - reduce network overhead of mgmt data --> save network bandwidth
  - move some workload from the manager to the agents
  - e.g., error rate for inbound traffic through interface #3:

  \[
  \begin{align*}
  \text{get:} & \quad (2\times\text{OID}) + \text{value} \\
  \text{get\text{-}next:} & \quad (3\times\text{OID}) + \text{value}
  \end{align*}
  \]
Characterization of the Push Model

• Variant of the Publish-Subscribe design pattern (Observer in [Gamma et al. 1995]):
  ■ one subscriber (manager), many publishers (agents)
  ■ 3 phases: publication, subscription, and distribution
• Pseudo client-server communication model:
  ■ client sends data to server
  ■ server may acknowledge (e.g., SNMPv3 informs) or not acknowledge (e.g., SNMPv1 traps and SNMPv2 notifications) receipt of this data
• Client = agent
• Server = manager
• Parallel and independent data transfers initiated by the clients
Publication and Subscription Phases

[Diagram showing the interactions between Web browser, Mgmt station, Data server, Agent, Mgmt server, and various components like HTTP client, HTTP server, JDBC client, JDBC server, Push scheduler servlet, Push definition servlet, etc.]
Publication and Subscription Phases (Firewall)
Distribution Phase for Monitoring and Data Collection
Distribution Phase for Notifications

Diagram showing the distribution phase for notifications in a network management system.

- **Server**: Web browser, Notification collector, Notification generator, HTTP server, JDBC client, JDBC server, Event handler, Event correlator, Network map registry, HTTP client, Mgmt station, Mgmt server, Administrator or Operator.
- **Client**: Email, Pager, Telephone, Siren.
- **Firewall** includes sensors, Health monitor, Notification dispatcher, Notification generator.
- **Agent** includes Notification filter, Notification collector, HTTP server.
- **Data server** includes General purpose data repository.
Part 3: New Communication Model

• HTTP
• UDP --> TCP
• Persistent TCP connections
• Two connections per agent
• Firewalls
• Persistent HTTP connections with MIME multipart
• Timeouts and reconnections
Communication based on HTTP (1/2)

- Four techniques to communicate between agents and managers:
  - HTTP
  - sockets
  - Java RMI
  - Java IDL (CORBA)
- Distributed objects (Java RMI or CORBA):
  - telecoms world = yes
  - IP world = no
  - the *my-middleware-is-better-than-yours* syndrome
Communication based on HTTP (2/2)

- HTTP > sockets:
  - avoid a domain-specific transfer protocol
  - firewall setup easier for nonexperts:
    - important for small and midsize companies
  - manager: natural communication between servlets
  - same technology:
    - between agents and manager
    - within the manager
Persistent TCP Connections

- TCP vs. UDP:
  - decrease losses of mgmt data:
    - ⇓ still no guarantee of delivery
  - retransmissions and ack’s need not be performed at the app. level:
    - ⇓ better interoperability
    - ⇓ simpler application

- Persistent TCP connections:
  - avoid overhead of frequently setting up and tearing down connections
  - necessary for security reasons: the agent pushes mgmt data in a pre-existing connection
Two Persistent Connections Per Agent

- High priority: e.g., urgent SNMP notifications
- Memory overhead for the manager:
  - several MBytes to manage 100s of agents
  - requires special tuning of the kernel:
    - drawback: we still need a dedicated mgmt platform
• Robustness principle: TCP connections should be created by internal trusted manager, not external untrusted agent:
  ■ avoid TCP ports probing by external intruders
  ■ avoid certain DoS attacks (e.g., TCP SYN flooding)
Reversed Client and Server

• Firewalls --> positions of client and server now reversed:
  ■ transfer of mgmt data initiated by the agent
  ■ client side of the persistent connection still on the manager side
  ■ we want the server to initiate a transfer in a client-server architecture!
Persistent HTTP Connections with MIME Multipart

<table>
<thead>
<tr>
<th>HTTP header</th>
<th>MIME message header</th>
<th>MIME part header</th>
<th>gzip’ed data</th>
<th>MIME boundary</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIME part header</td>
<td>gzip’ed data</td>
<td>MIME boundary</td>
<td>...</td>
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MIME = Multipurpose Internet Mail Extensions

- **Advantages:**
  - simple to implement
  - firewalls: minor change (assuming Web access already)

- **Drawback:**
  - how does the manager detect that a connection was broken?
Timeouts and Reconnections

- Persistent connections:
  - timeouts by operating system and HTTP server?
  - how does the manager reconnect in case of teardown?

- The agent detects a transmission problem after 9 minutes (or TCP_MAXRT in Posix.1g), but the manager does not

- The agent knows when it reboots, but the manager does not

- Three solutions:
  - per kernel: keepalives (SO_KEEPALIVE):
    - Linux kernel 2.3.28: tcp_keepalive_time (7200 s), tcp_keepalive_intvl (75 s), tcp_keepalive_probes (9)
  - per socket: read timeout (SO_RCVTIMEO or select(....,timer))
  - per socket: keepalives (TCP_KEEPALIVE in Posix.1g)
Part 4: XML

• Why use XML?

  • A truce in the middleware war
  • More generic than IIOP and JRMP
  • Low footprint on agents and managers
  • Cost =~ zero:
    ➤ a lot of freeware available
  • Demanded by customers:
    ➤ becoming ubiquitous in software eng.
  • Feature rich:
    ➤ state: transfer data
    ➤ behavior: invoke remote methods
XML for Distribution

Top-level manager

Sub-level 1 manager

Sub-level 2 manager

Agent

Agent

Agent

Agent

policies

NM + SM

NM + SM

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XML for High-Level Semantics

• Clean invocation of remote methods:
  ■ no need to resort to SNMP’s programming by side effect
• The DMTF learned from the IETF’s mistakes:
  ■ working on instrumentation MIBs and high-level MIBs
• XML renders easy many tasks that are not with SNMP:
  ■ transfer SNMP MIB table in one bulk (no more “holes”)
  ■ transfer entire time series for 24h in one bulk
  ■ ...
• XML interfaces nicely with OO info. models (e.g., CIM), which offer high-level semantics to mgmt applications designers
XML: Dealing with Multiple Information Models

XXX is site specific
New MIME Types for Part Headers

- Three levels of granularity:
  - information model:
    - e.g., CIM-to-XML, SNMPv1-to-BER, SNMPv2c-to-string
  - RFC:
    - e.g., RFC2261-to-Java, RFC2271-to-string, RFC2571-to-XML
  - XML mapping:
    - e.g., CIM2.2-to-XML-v2.0, CIM3.0-to-XML-v0.1

- Two naming schemes for the new MIME types:
  - Content-Type=“CIM2.2-to-XML-v2.0”
    - poor scalability and scalability (constant flow of updates by IANA/ICANN)
  - Content-Type=“application/mgmt”; mapping=“CIM2.2-to-XML” version=“2.0”
    - our solution
Part 5: JAMAP

Mgmt station

- Event notification applet
- Rule edition applet
- MIB data subscription applet

Pushed data collector servlet

Mgmt server

Event manager servlet

Agent

MIB data dispatcher servlet

SNMP

MIB

Notification subscription applet

Event manager servlet

Notification collector servlet

Notification dispatcher servlet

Agent

Mgmt server

Event notification applet

Rule edition applet

Notification subscription applet

Pushed data collector servlet

Event manager servlet

Notification collector servlet

Notification dispatcher servlet
JAMAP: A Research Prototype

• Purpose:
  ■ demonstrate push and MIME multipart
  ■ demonstrate simplicity of implementation:
    ➪ the core was coded in 2 weeks

• Many simplifications:
  ■ NFS instead of JDBC
  ■ only SNMP MIBs, no CIM MIBs
  ■ only serialized Java objects, no XML
  ■ simplistic event correlator
  ■ partial support for notifications
  ■ one OID per MIME part

• Wanted: manpower!
Conclusion: The Problem Is Solved (1/4)

• For customers:
  
  ■ platforms are too expensive (hardware and software):
    ➞ mgmt GUIs are less expensive (applets)
    ➞ different vendors write different parts of the mgmt application --> less costly
    ➞ capitalize on previous investment (e.g., use in-house RDBMS)
  
  ■ limited support for third-party RDBMS vendors:
    ➞ no need for peer-to-peer agreement, use JDBC or XML instead
  
  ■ insufficient integration:
    ➞ flexible architecture for integrating network, systems, application, service, and policy mgmt (esp. SNMP and CIM MIBs)
Conclusion: The Problem Is Solved (2/4)

• For equipment vendors:
  ■ the support for device-specific mgmt GUIs is too expensive:
    ➤ single applet

• For customers and equipment vendors:
  ■ poor time-to-market for mgmt GUIs:
    ➤ zero time-to-market, whatever the market share
    ➤ access to integrated mgmt for startup companies --> fair competition
  ■ MIB versioning:
    ➤ the manager retrieves the mgmt GUI from the agent --> no version mismatch
  ■ investment bound to a specific operating system:
    ➤ Java, HTTP, HTML, MIME, and XML are independent of the OS
    ➤ still the problem of the JVM version
Conclusion: The Problem Is Solved (3/4)

• SNMP expertise is domain specific:
  ■ Web expertise is generic

• Scalability, network overhead, and latency problems:
  ■ BER encoding no longer used
  ■ SNMP protocol replaced with HTTP
  ■ compressed mgmt data
  ■ distribution with XML

• Low-level semantics:
  ■ the DMTF is currently working on instrumentation MIBs and high-level MIBs
  ■ site-specific applications now depend on standard technologies: XML, Java, etc.
Conclusion: The Problem Is Solved (4/4)

• Security:
  ■ HTTP security may be used instead of costly encryption hardware:
    ➤ still weak security
    ➤ better than SNMP’s community string
  ■ firewall setup: HTTP simpler than SNMP

• Unreliable transport protocol:
  ■ HTTP makes it possible to use TCP to transfer mgmt data
  ■ reliable transport layer for SNMP notifications:
    ➤ important notifications are no longer lost for silly reasons
    ➤ still no guarantee of delivery

• Evolution of SNMP hampered by legacy systems:
  ■ Web-based mgmt: start with a clean slate but preserve SNMP MIBs
New Problems

• Reliability of new mgmt platforms based on COTS components and OO frameworks:
  ■ new means buggy

• Integration of components sold by multiple vendors:
  ■ it does not work, whose fault is it? who should fix it?
  ■ need integrators

• Synchronization of all clocks (managers, agents)

• Java is slow, even with JIT compiler:
  ■ scalability of the mgmt server?
  ■ may need to resort to C++ --> compiled
Related Work (1/2)

• Architectures:
  - Bruins, Deri, Harrison et al., Maston, Mullaney, Thompson, etc.

• Prototypes:
  - Marvel by Anerousis, CyberAgent by Burns and Quinn, Webbin by Barillaud et al., WbASM by Kasteleijn, NetFinity by Reed et al., etc.

• Commercial offerings:
  - http://joe.lindsay.net/webbased.html
Related Work (2/2)

- **WBEM:**
  - DMTF
  - HMMP --> HTTP + XML
  - new OO info. model: CIM
  - CIM-to-XML mapping (meta level)
  - extensions to HTTP: new headers for firewalls
  - ongoing: working groups are defining CIM MIBs

- **Java-based mgmt:**
  - Sun Microsystems and the Java Community
  - OO mappings of existing info. models
  - communication via Java RMI (distributed OO)
  - ongoing: JMX (agent) and FMA (manager) are merging
Future Work

• Convince the DMTF and Sun Microsystems to adopt our mgmt architecture and communication model
• Convince startups to develop smart software for the mgmt server
• Register new MIME type with IANA/ICANN
• Define SNMP-to-XML mapping:
  ■ MIB level or meta level?
• Coexistence of SNMP and CIM MIBs:
  ■ what are the issues?
• Design patterns:
  ■ how to avoid well-known design mistakes?