Embedded Web Server Architecture for Web-based Element Management and Network Management

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1. Introduction

1. Network Management
2. Web-based Management
3. Web-based Element Management
4. Web-based Network Management
Network Management

• Definition
  – The sum of all activities related to configure, monitor and control network and systems.

• Goal
  – To ensure reliable and efficient operation of systems and networks.

• Management Layers

• Management Functions
  – Fault, Configuration, Accounting, Performance, Security

• Standard specifications: ITU-T TMN, IETF SNMP
Web-based Management

- Definition
  - The use of Web technology to manage network and systems.

- Benefits
  - Reduced development costs by using open technology and high portability
  - Effective management by using advanced features of Web
  - User-friendliness, ubiquity by using Web browser

- Solutions
  - Industry Standards
    - Web-Based Enterprise Management (WBEM from DMTF)
    - Java Management eXtension (JMX from Sun)
  - Many practical solutions
    - HTTP/HTML, Web push, XML, Dynamic Web

- Status
  - Standards: not quite ready to deploy and less general
  - Practical solutions: Fragmented, concentrated on user interface
1. Introduction

Web-based Element Management

Network Device

Web document/HTTP

Internet

Network Device

Embedded Web Server

Web Browser

Web Browser

Web Browser
Web-based Network Management

1. Introduction
2. Problem Statements

1. Embedded Web Server
2. Web-based Element Management
3. Web-based Network Management
4. Research Approach
Embedded Web Server (EWS)

- **EWS Run-time Requirements**
  - Execute on **limited memory** and **processing power**.
  - **Should not interfere with the main task** of system.

- **Resource scarcity**
  - How to **minimize the computing resource** usage by EWS?
  - What **restrictions on EWS functionality** can be placed for saving computing resource?

- **Reliability and Portability**
  - How does EWS **support the high degree of** network device **reliability**?
  - How to **maximize the portability** of EWS on broader range of embedded system?

- **Security**
  - What **security mechanism** must be supported by EWS to provide secure access to devices?

2. Problem Statements
Web-based Element Management

- Web-based Element Management User Interface
  = Embedded Web Server (Communication)
  + Embedded Web Document (Display)
  + Embedded Management Application (Processing)

- Interface mechanism
  - Between embedded Web document and management application.
  - What’s the appropriate interface mechanism for each Web interface of diverse characteristics?

- Integration mechanism
  - What integration mechanism between embedded Web document and management application must be provided for rapid and low cost development?
Web-based Network Management

• Dual management stack
  – Both SNMP agent and EWS are equipped in most network devices, which require more computing resources.
  – It is hard to guarantee for consistency of control due to multiple access paths to managed resources.

• No centralized management
  – Rich management information through Web-based element management.
  – Such management information is not understandable by program because it is in the form of HTML/Java.
  – It is impossible for a centralized manager to collect or process such management information.
  – Management functions are limited: logging, analysis, report generation

• Use of SNMP
  – SNMP has many problems (scalability, efficiency, security).
  – But it is still in use due to absence of alternatives.
Research Approach

- A lightweight and effective embedded Web server development
  - HTTP engine as a finite state machine.
  - Optimization techniques: compression and preprocessing.
  - Incorporating necessary functions into EWS.
- Web-based element management architecture design
  - Four effective interface mechanisms are defined and analyzed.
  - Effective integration mechanisms for each interface mechanism.
  - Validated by developing commercial system.
- Web-based network management architecture design
  - Extended Web-based element architecture for network management
  - XML is adopted as an enabling technology.
  - Validated on commercial ultradense server systems
Related Work

1. Standard Activities
2. XML-based Network Management
## Standard Activities

<table>
<thead>
<tr>
<th>Features</th>
<th>SNMP</th>
<th>WBEM</th>
<th>JMX</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Architecture</strong></td>
<td>Manager-Agent</td>
<td>Clams to support all</td>
<td>Manager-Agent</td>
</tr>
<tr>
<td><strong>Information Model</strong></td>
<td>Object-based</td>
<td>Object-oriented</td>
<td>Object-oriented</td>
</tr>
<tr>
<td><strong>Specification Language</strong></td>
<td>SMI</td>
<td>CIM (MOF, UML, XML)</td>
<td>Java</td>
</tr>
<tr>
<td><strong>Operations</strong></td>
<td>Get, Set, Trap</td>
<td>23 operations</td>
<td>Not specified</td>
</tr>
<tr>
<td><strong>Communication Mode</strong></td>
<td>Sync/Async</td>
<td>Sync</td>
<td>Not specified</td>
</tr>
<tr>
<td><strong>Addressing</strong></td>
<td>MIT with OID</td>
<td>Name and Associations</td>
<td>Java object name</td>
</tr>
<tr>
<td><strong>Standardization Body</strong></td>
<td>IETF</td>
<td>DMTF</td>
<td>Java Community</td>
</tr>
<tr>
<td><strong>Mgmt. Domain</strong></td>
<td>Network Mgmt.</td>
<td>Systems Mgmt.</td>
<td>Unidentified</td>
</tr>
<tr>
<td><strong>Protocol Suit</strong></td>
<td>UDP</td>
<td>HTTP/TCP</td>
<td>Not specified</td>
</tr>
</tbody>
</table>

3. Related Work
XML-based Network Management

• eXtensible Markup Language (XML)
  – XML makes it possible to define its own markup language for specific application (DTD or XML Schema).
  – XML/HTTP is becoming a standard way to exchange data on the Web.

• Document Object Model (DOM)
  – A standard way for accessing and manipulating XML documents.
  – XML begins to approach its promise as a universal, cross-platform, application-independent technology.

• XPath
  – An expression language for addressing parts of an XML document.
  – The syntax of XPath is designed to use URI.
  – XPath operates under assumption that a document has been parsed into a tree of node.

3. Related Work
XML-based Network Management

• XML for management communication
  – WBEM from DMTF
    • CIM-to-XML mapping
  – Web-based Integrated Management Architecture (WIMA)
    • SNMP-to-XML mapping without concrete algorithm
  – eXtensible Network and Application Management Instrumentation (XNAMI)
    • A. John, et al. Bell Lab. 1995
    • XML/HTTP is used for configuring SNMP agent.

• XML for management information
  – C. Ensel, A. Keller, IBM, 2001
  – Applying XML, XPath and RDF to describe, query and compute dependencies among services in distributed environment.

3. Related Work
Web-based Element Management Architecture

1. EWS-based Element Management Architecture
2. EWS Process Structure
3. Extended Architecture
4. Interface Mechanisms
5. Integration Mechanisms
EWS-based Element Management Architecture

- Web documents (html, Java applets)
- Embedded OS
- Virtual File System
  - Configuration
  - Security
  - Application Interface
- EWS
  - HTTP Engine
  - Management Application (Configure, Monitor & Control)
  - Embedded System Application

4. Web-based Element …
EWS Process Structure

- Support multiple connections in a single thread environment.
- An EWS as a finite state machine which is proceeded by a simple scheduling system.

4. Web-based Element …
Extended Architecture – SNMP Integration

- **Web Documents (html, Java applets)**
- **RTOS**
- **VFS**
- **Configuration**
- **Security**
- **Application Interface**
- **EWS**
- **HTTP Engine**
- **Management Application (Configure, Monitor and Control)**
- **SNMP Agent**
- **Embedded Application**

4. Web-based Element …
Interface Mechanisms: CGI-Type

Embedded System

Web Browser

RTOS

Management Application (Configure, Monitor and Control)

Embedded Application

VFS

Configuration

Security

Application Interface

EWS

HTTP Engine

SNMP Agent

Java SNMP Manager

Web Documents (html, Java applets)
Interface Mechanisms : SSI- Type

Embedded System

Web Browser

RTOS

Management Application
(Configuration, Monitor and Control)

Embedded Application

VFS

Configuration

Security

Application Interface

EWS

HTTP Engine

Web Documents (html, Java applets)

RTOS

Management Application
(Configuration, Monitor and Control)

Embedded Application

VFSEWS

HTTP Engine

SNMP Agent

Java SNMP Manager
Interface Mechanisms: SSI SNMP-Type

Embedded System

- Web Browser
- Web Documents (html, Java applets)
- RTOS
- Management Application (Configure, Monitor, and Control)
- Embedded Application
- VFS
- Configuration
- Security
- Application Interface
- EWS
- HTTP Engine
- SNMP Agent
- Java SNMP Manager
Interface Mechanisms: Java SNMP Type

Web Documents (html, Java applets)

VFS
Configuration
Security
Application Interface

EWS
HTTP Engine

RTOS

Management Application
(Configure, Monitor and Control)

SNMP Agent
Java SNMP Manager

Embedded Application

Embedded System

Web Browser
## Comparison of Interface Mechanisms

<table>
<thead>
<tr>
<th></th>
<th>CGI-Type</th>
<th>SSI-Type</th>
<th>SSI SNMP-Type</th>
<th>Java SNMP-Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Web documents development method</td>
<td>Management Application Program</td>
<td>Web Authoring Tool + Marked-up tags insertion</td>
<td>MIB2HTML Compiler</td>
<td>Java applet program</td>
</tr>
<tr>
<td>Web documents development cost</td>
<td>High</td>
<td>Low</td>
<td>Very Low</td>
<td>High</td>
</tr>
<tr>
<td>Management application programming</td>
<td>Necessary</td>
<td>Necessary</td>
<td>Unnecessary (Library code)</td>
<td>Unnecessary (SNMP Agent)</td>
</tr>
<tr>
<td>Management information source</td>
<td>Web interface</td>
<td>Web interface</td>
<td>SNMP Agent</td>
<td>SNMP Agent</td>
</tr>
<tr>
<td>Network load / Web page</td>
<td>1 HTTP requests</td>
<td>1 HTTP requests</td>
<td>n-SNMP &amp; 1-HTTP</td>
<td>1-HTTP &amp; Continuous SNMP</td>
</tr>
<tr>
<td>CPU Load</td>
<td>Small</td>
<td>Medium</td>
<td>Large</td>
<td>Medium</td>
</tr>
<tr>
<td>Code size</td>
<td>Management Application Program</td>
<td>HTML + Management Application Program</td>
<td>HTML + Management Application Program</td>
<td>Java class</td>
</tr>
<tr>
<td>Portability</td>
<td>Low</td>
<td>Middle</td>
<td>Middle</td>
<td>High</td>
</tr>
<tr>
<td>Event Support</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

4. Web-based Element ...
Integration Mechanism

SNMP MIB

MIB2HTML Compiler

MIB Browser HTML (Marked-up)

Web Compiler

Preprocessed HTML

Java SNMP Manager

ROM file Maker

ROM file

Management Application Libraries (CGI and SSI SNMP Interface)

C Compiler

Executable Code

4. Web-based Element …
Web-based Network Management Architecture

- Web-based Network Management Model
  - Information Model
  - Communication Model
  - Organization Model
  - Functional Model (TMN FCAPS)

- Web-based Network Management Platform
  - WBM Agent
  - WBM Manager
Information Model

• Modeling approach for managed objects
• A unique notation for describing management information.
• XML schema is adopted for management information model.
  – Information modeling using XML schema is a wide-spread approach in other application area.
  – Compared with SNMP SMI and WBEM CIM, XML schema has many advantages
    • easy to learn
    • powerful and convenient XML editor
    • no need for translation
    • concise and easy to read
Communication Model

• The concepts for the exchange of management information.
• The structured data over HTTP without any extension.
• For notification delivery, HTTP client and server swapping
  – WBM Manager: HTTP Server + HTTP Client
  – WBM Agent: HTTP Server + HTTP Client
• XML is used for management information encoding.
• XPath is adopted for addressing of managed objects.
  – Standard for addressing parts of an XML document.
  – Effective query mechanism.
Organization Model

- Defines the actors, their role and the fundamental principles of their corporation.
  - Well-known organization models.
    - Manager-agent paradigm
    - Push-based network management
    - Management by delegation
    - Policy-based management
- Based on manager-agent paradigm.
- Integrate push-based network management.
  - Automated information delivery
  - Procedure: publish/subscription/distribution.
Organization model - Continue

- Publish
  - By self-description capability of XML

- Subscription
  - By sending subscription information
  - Based on new information model

- Distribution
  - By HTTP swapping and WBM agent scheduler.
WBM Agent

5. Web-based Network …
5. Web-based Network …
SNMP Integration

5. Web-based Network …
5. Validation

1. POStech Embedded Web Server (POS-EWS)
2. Validation of Web-based Element Management Architecture.
3. Validation of Web-based Network Management Architecture
POS-EWS

- OS: Xinu, pSOS, Linux
- CPU: Any CPU with a C compiler
- HTTP/1.1 compliant
  - Cache control
  - Persistent TCP connection
- Single thread based on extended architecture
  - Simple scheduler
  - Multiple finite state machines
- Virtual File System
  - Limited set of read-only file interface
  - Compression at compile time & Decompression at run time
- Web compiler
  - To build up virtual file system
  - Efficient server side include

6. Validation
Validation of Web-based Element Management Architecture

6. Validation
Validation of Web-based Element Management Architecture

6. Validation

system - 1.3.6.1.2.1.1
Validation of Web-based Network Management Architecture

6. Validation
Validation of Web-based Network Management Architecture

6. Validation
Validation of Web-based
Network Management Architecture

6. Validation
Conclusion

1. Summary
2. Contribution
3. Future Work
Summary

- Formulated the concept of Web-based management and introduced related work for them.

- Presented a method for providing various types of management information from static to dynamic and real-time through Web interface.

- Simplified the procedure by use of compilers and libraries for cost effective development.

- Provided a way to collect and process the rich management information provided by Web-based element management interface.

7. Conclusion
Contributions

• POS-EWS Development
  – Good performance in memory and CPU usage, while supporting all essential Web server functions.
  – It can be ported into industrial equipments, home appliances and office automation machines, as well as network devices.
  – The applied optimization techniques have a wide application such as a small Web browser, e-mail server, etc.

• Web-based element management architecture
  – Effective four interface mechanism.
  – Effective integration mechanism for each interface.

• Web-based network management architecture
  – Effective use of XML technology, we have maximized the advantages of using XML in network management.
  – The architecture can be alternative for SNMP.
  – The result of our research can be feed into WBEM.

7. Conclusion
Future Work

- XML DOM as a common interface for implementing various management backend.
  - CLI, SNMP, WBEM, DMI, etc.
- Integration with proven management organization models
  - policy-driven network management, mobile and intelligent agent, etc.
- Web-based service and business management.
- Web-based network management for QoS, application, telecommunication and mobile network.
- Integration with standard framework.
  - SNMP manager, WBEM manager and agent, CMIP agent and manager
Web Technologies

• HTTP/1.1
  – Explicit cache control
    • Performance improvement for static Web pages.
    • Indispensable feature to retrieve up-to-date information.
  – Persistent TCP connection
    • Saves large amount of computing resources.

• Web documents
  – Hyperlink
    • Guide the well-defined management procedure.
  – Dynamic Web contents
    • Generate Web pages with up-to-date information

• Java applet
  – Small application program of Web browser.
    • No java platform requirement for embedded system.
  – Asynchronous communication
    • Automatic update of continuous data and event notification

3. Related Work
Information Modeling Example

Management Configuration

Manager List

<table>
<thead>
<tr>
<th>Name</th>
<th>Notification</th>
<th>IP Address</th>
<th>Access Level</th>
<th>Delete/Add</th>
</tr>
</thead>
<tbody>
<tr>
<td>junt</td>
<td>Enable</td>
<td>141.223.82.4</td>
<td>Read Only</td>
<td>Delete</td>
</tr>
<tr>
<td>sehee</td>
<td>Disable</td>
<td>141.223.82.5</td>
<td>Read/Write</td>
<td>Delete</td>
</tr>
</tbody>
</table>

Fan Status: **FAIL**
Information Modeling Example –cont.

5. Web-based Network …

(userName xsd:stringType)

(notification xsd:stringType)

(ipAddress xsd:stringType)

(accessLevel xsd:stringType)
Communication Example

(a) GET /MgtConf//Manager HTTP/1.1
HTTP/1.1 200 OK
<Manager> < UserName> juht </UserName> … </Manager>
<Manager> < UserName> sehee </UserName> … </Manager>

(b) POST //ManagerList HTTP/1.1
<Manager Operation="Add">
    < UserName> really97 </UserName> … </Manager>
HTTP/1.1 200 OK

(c) POST /MgmtConf/Alarm/FanStatus HTTP/1.1
<Alarm> < FanStatus> Fail </FanStatus> </Alarm>
HTTP/1.1 200 OK

5. Web-based Network …
Subscription information model

5. Web-based Network …
Communication Example

Post /PushMgt/Subscription HTTP/1.1
<Subscription>
  <Description>FanState logging</Description>
  <Subscriber>http://manager/logger/FanState</Subscriber>
  <Item>/MgtConf/Alarm/FanState</Item>
  <Schedule><State>Yes</State></Schedule>
</Subscription>

ok

Post /MgtCont/Alarm/FanState HTTP/1.1
<MgtConf><Alarm><FanStatus>Fail</FanStatus></Alarm></MgtConf>

ok

5. Web-based Network …