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

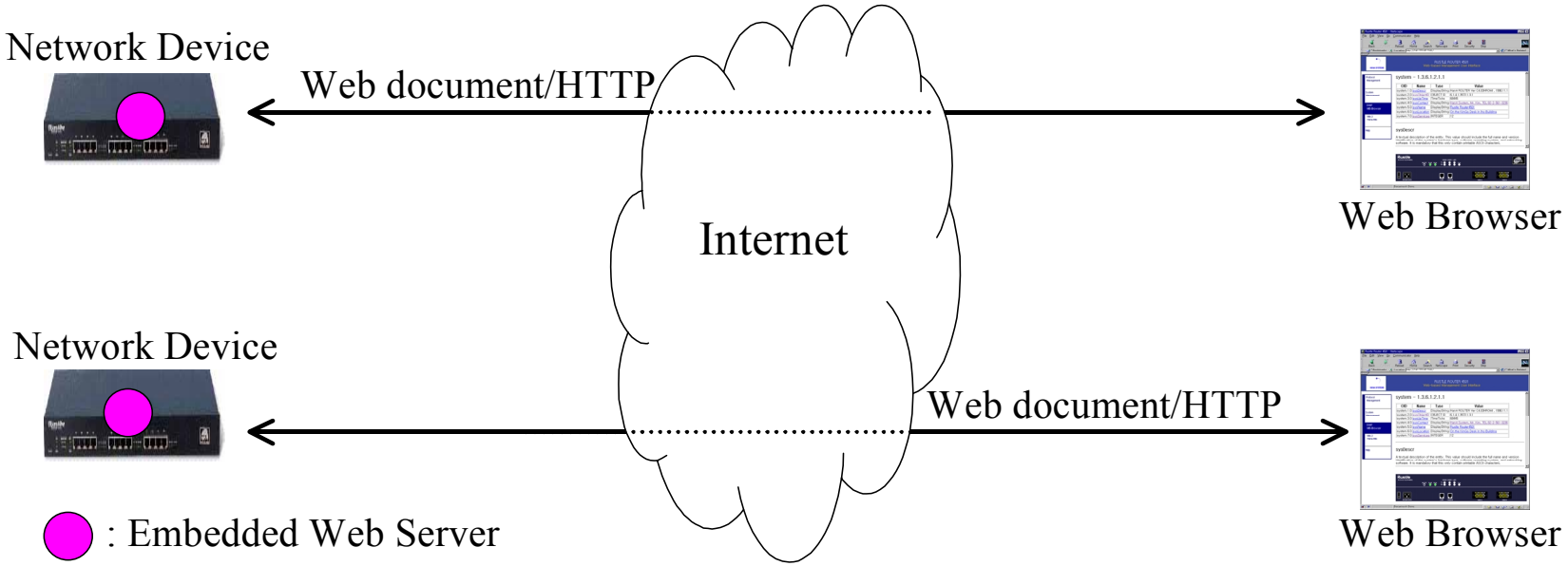
Network Management

- 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
  - **Element Management, Network Management**, Service Management, Business Management.
- Management Functions
  - Fault, Configuration, Accounting, Performance, Security
- Standard specifications: ITU-T TMN, IETF SNMP

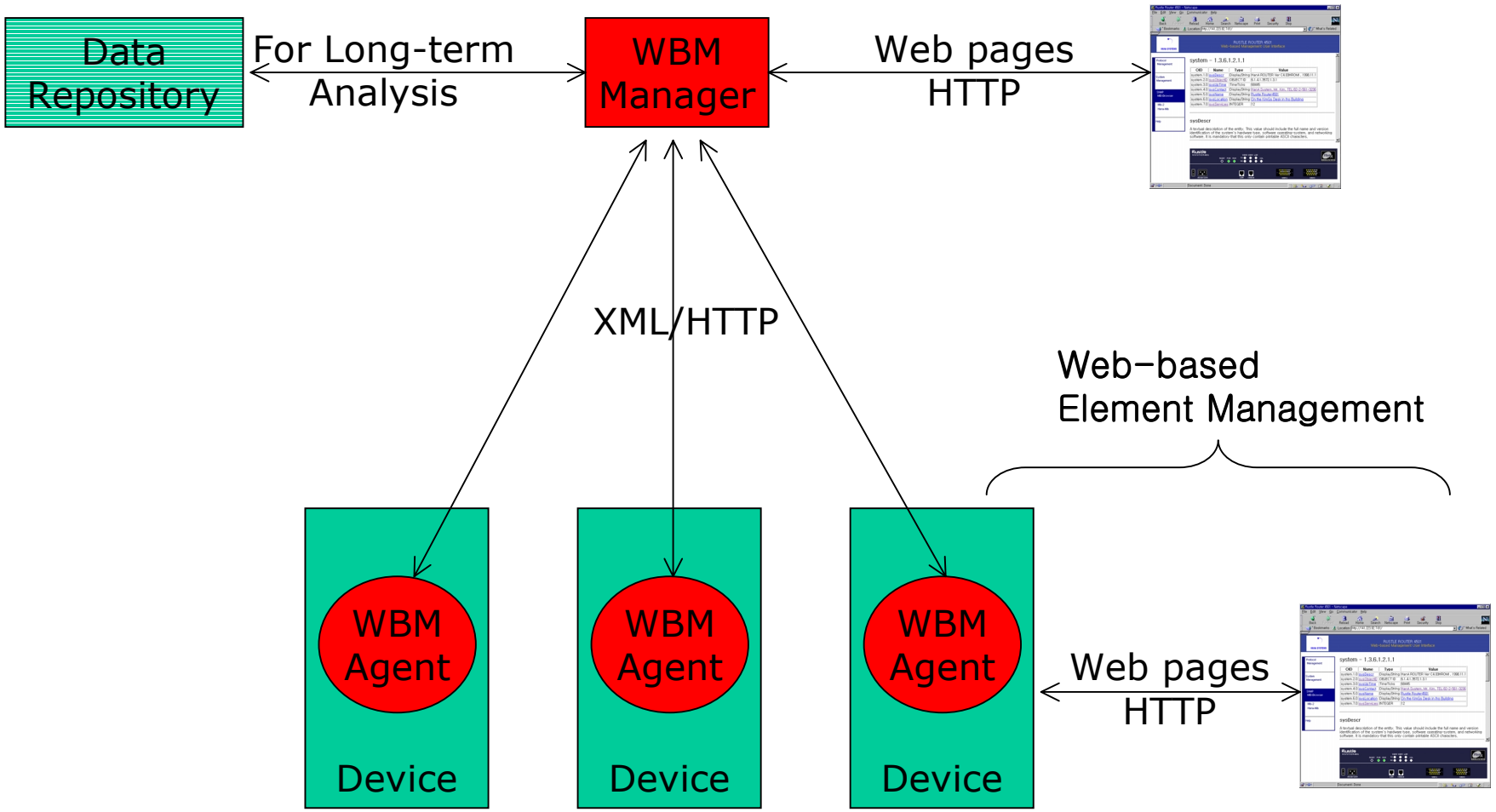
Web-based Management

- 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

Web-based Element Management



Web-based Network Management



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?

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

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

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.

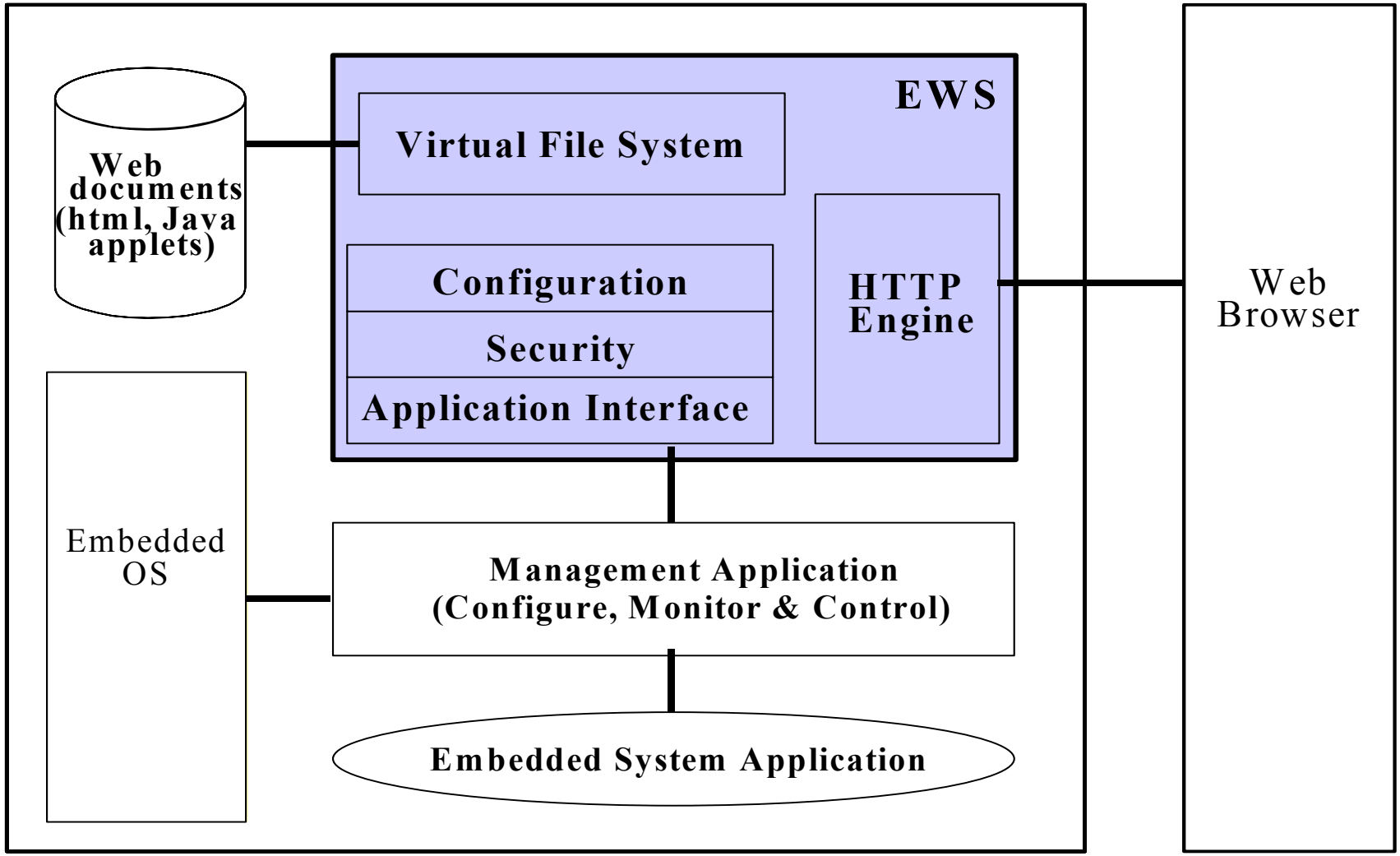
XML-based Network Management

- XML for management communication
  - WBEM from DMTF
    - CIM-to-XML mapping
  - Web-based Integrated Management Architecture (WIMA)
    - J.P. Martin's Ph.D thesis, EPFL, Aug. 2000
    - 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.

Web-based Element Management Architecture

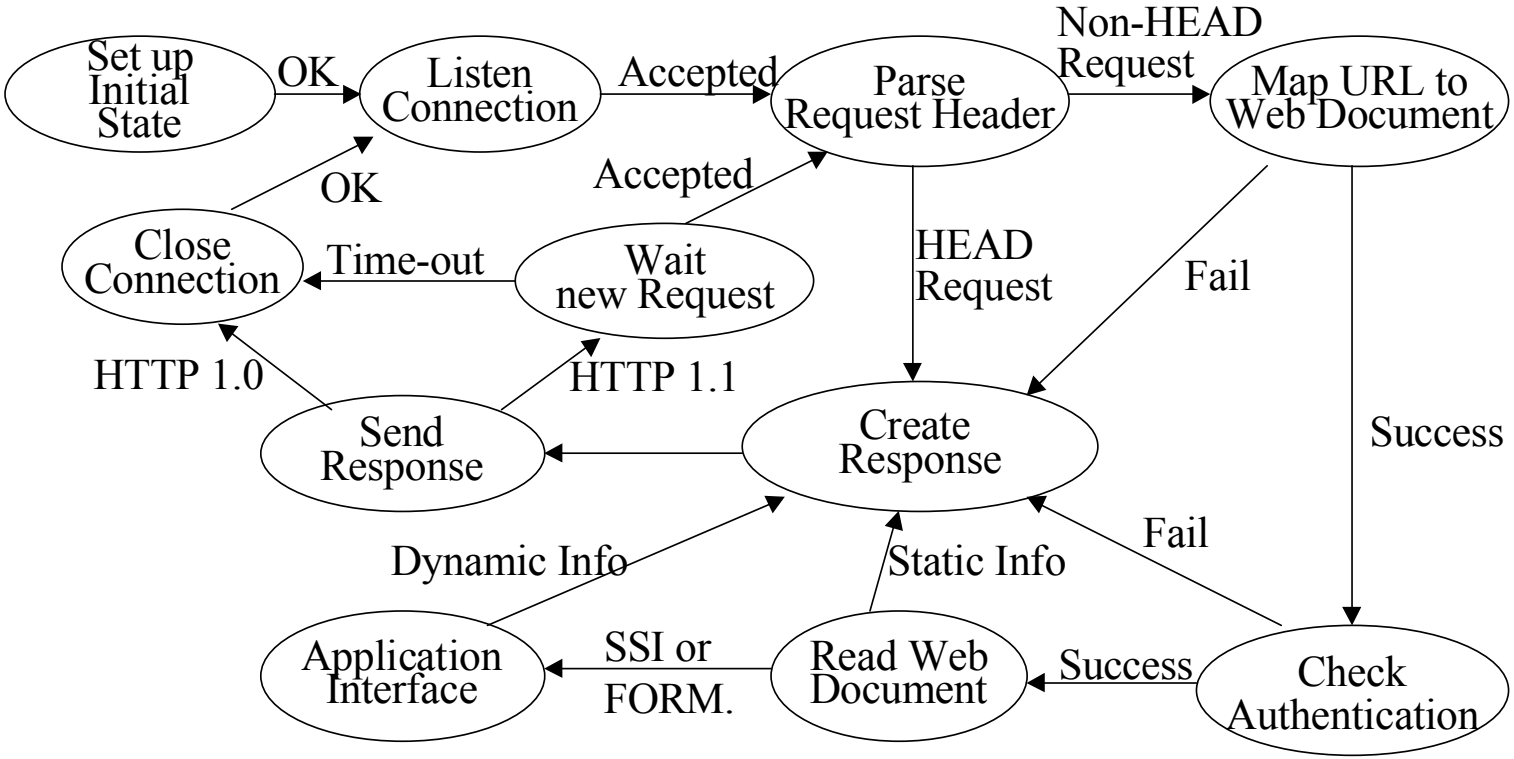
1. EWS-based Element Management Architecture
2. EWS Process Structure
3. Extended Architecture
4. Interface Mechanisms
5. Integration Mechanisms

EWS-based Element Management Architecture

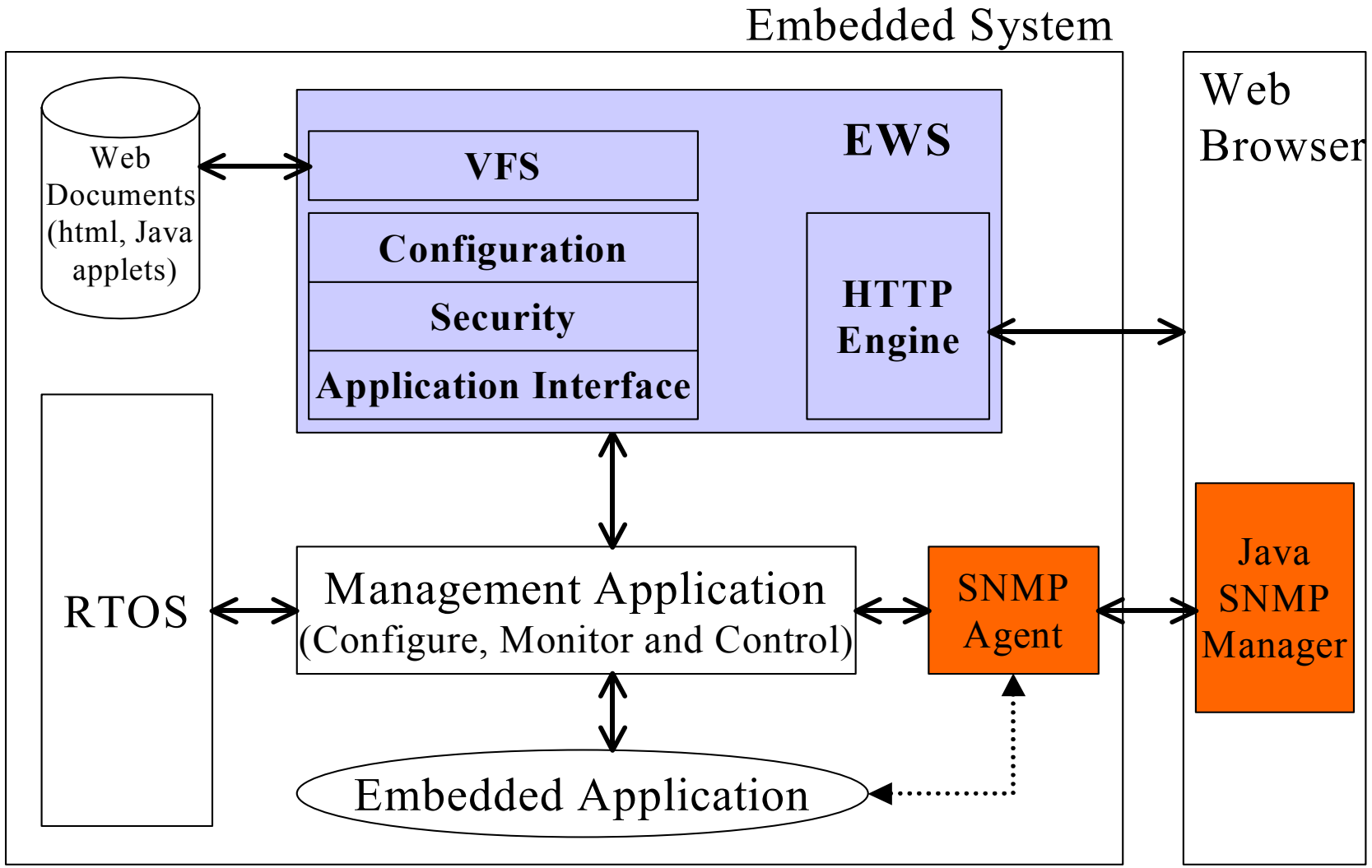


EWS Process Structure

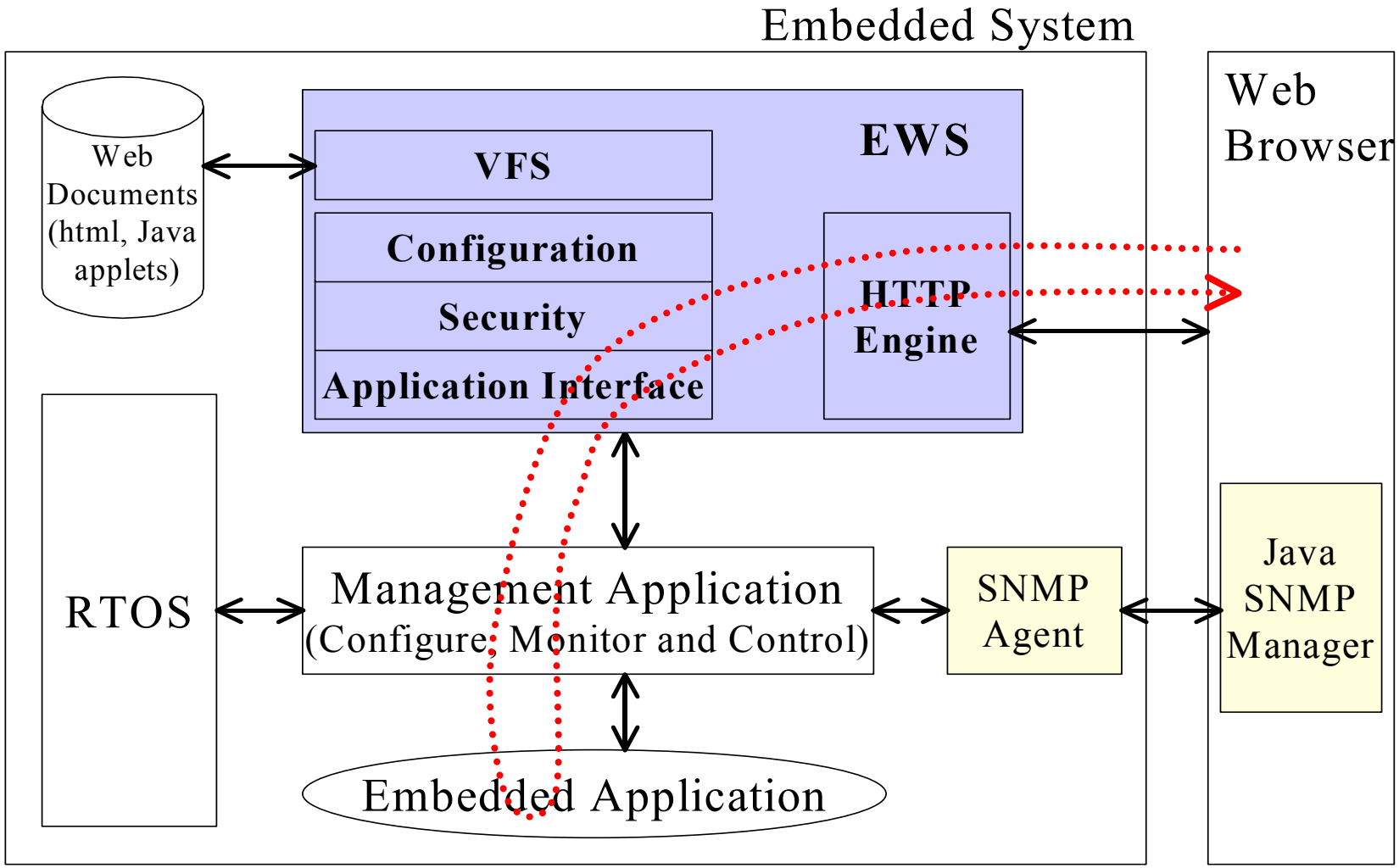
- Support multiple connections in a single thread environment.
- An EWS as a finite state machine which is proceeded by a simple scheduling system.



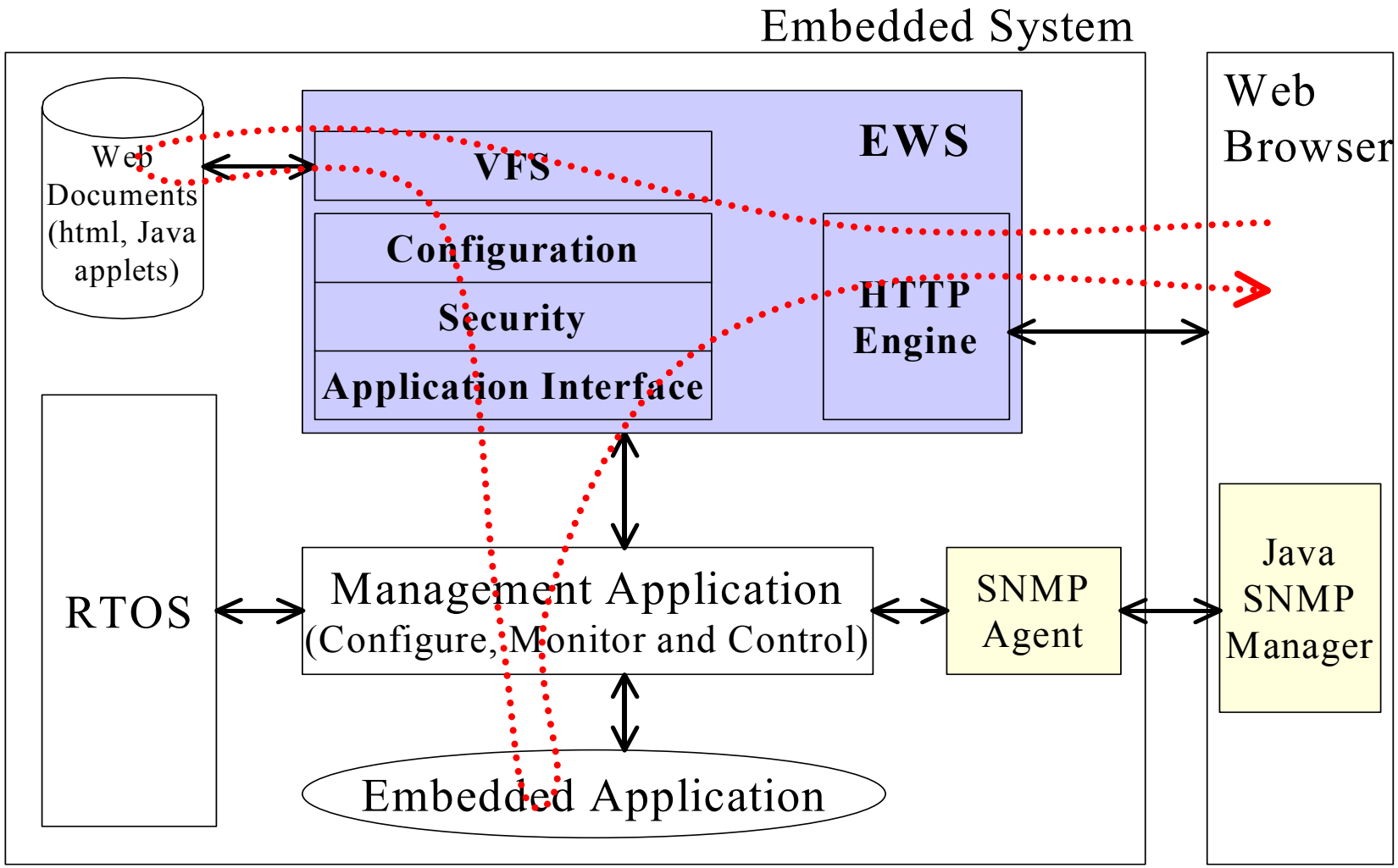
Extended Architecture – SNMP Integration



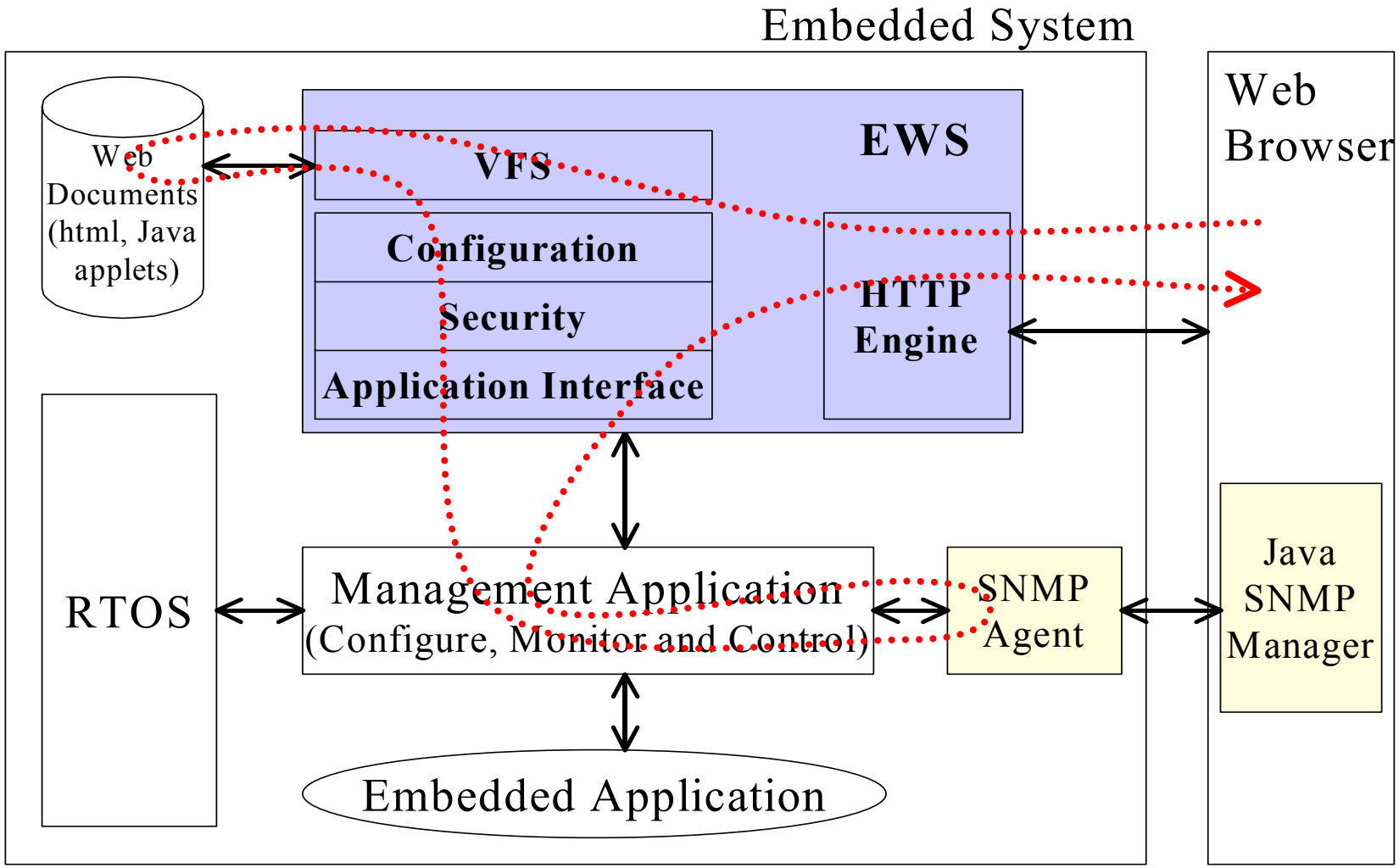
Interface Mechanisms : CGI-Type



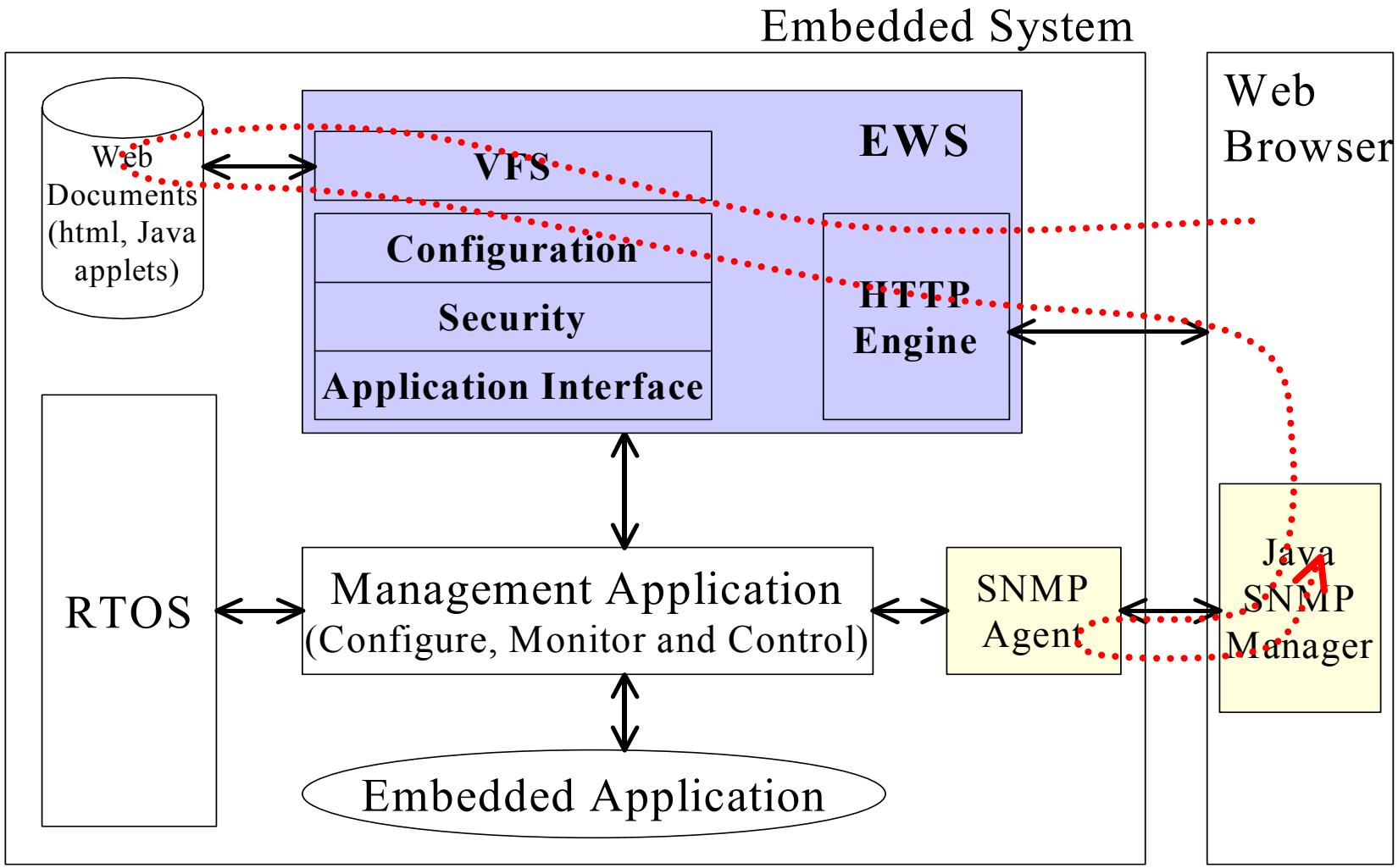
Interface Mechanisms : SSI- Type



Interface Mechanisms : SSI SNMP-Type



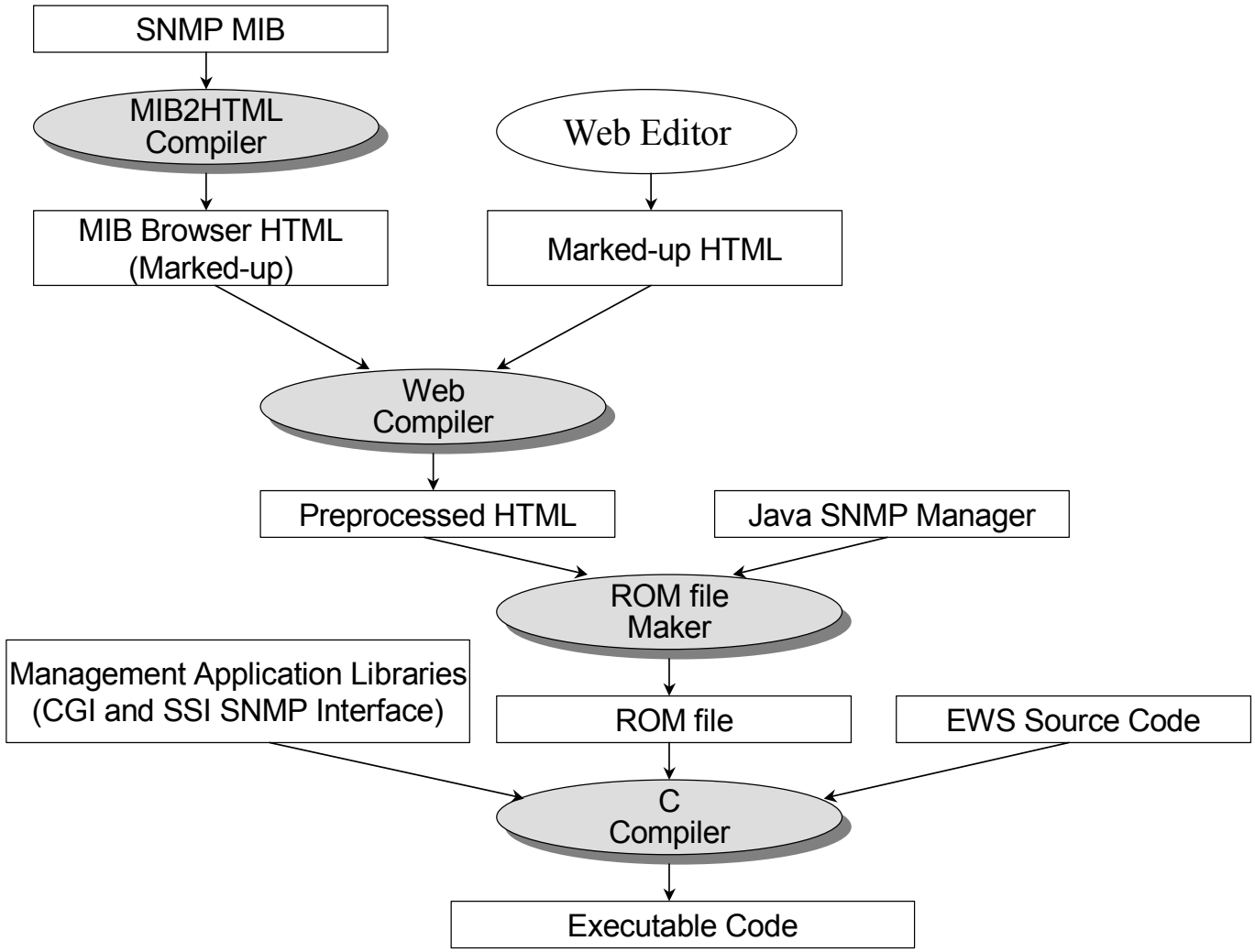
Interface Mechanisms : Java SNMP Type



Comparison of Interface Mechanisms

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

Integration Mechanism



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.

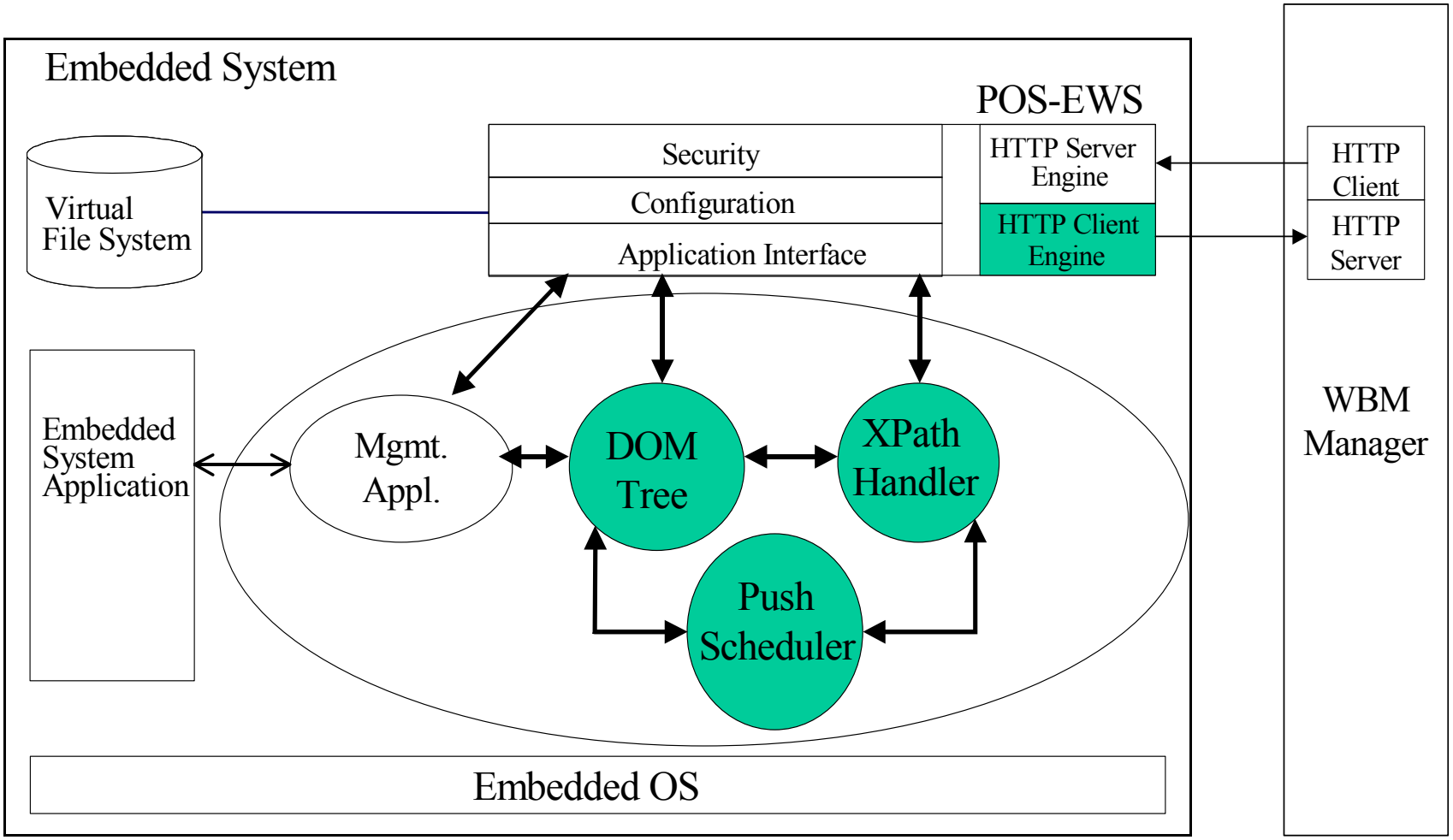
Organization Model

- 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.

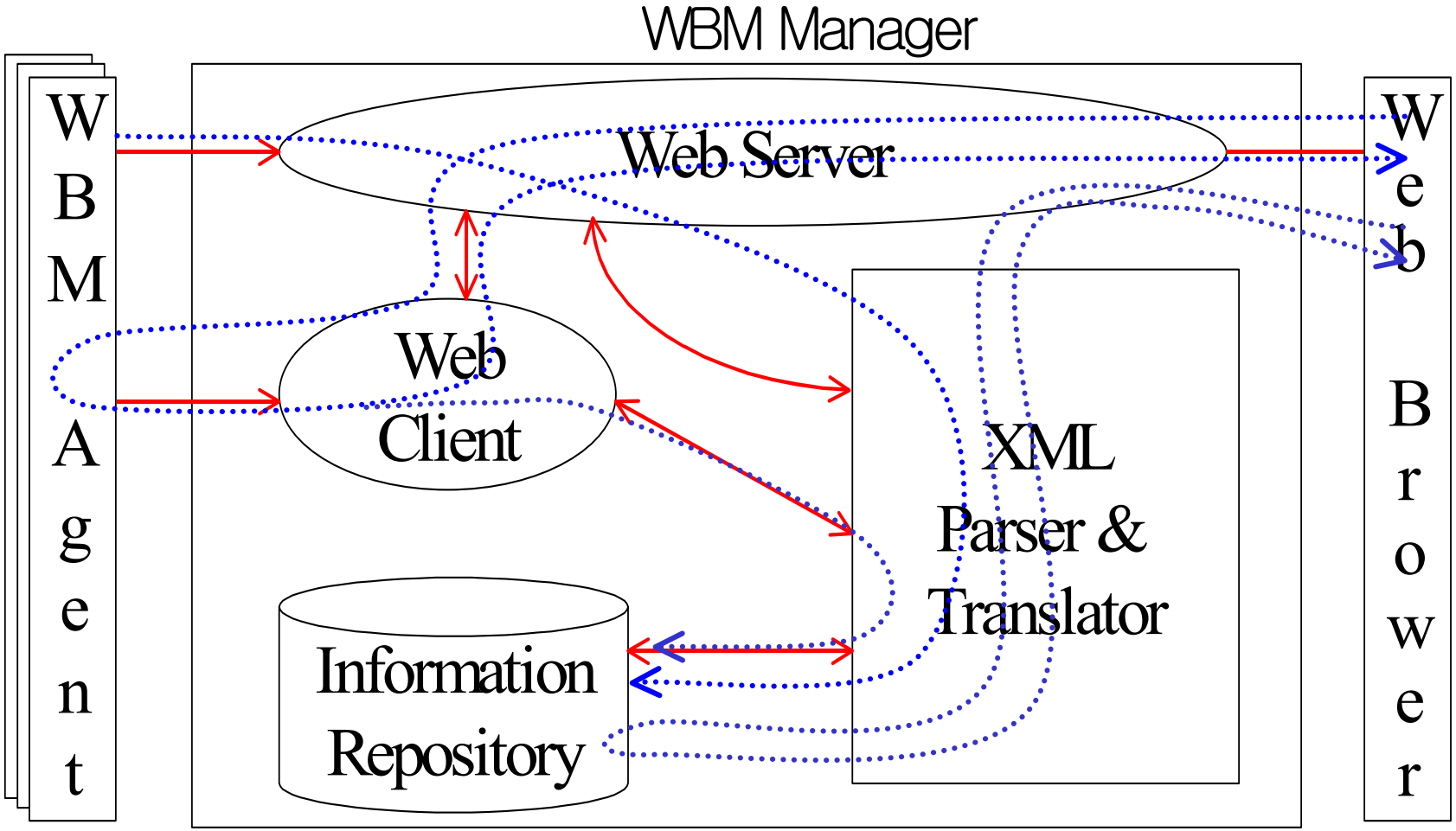
Organization model - Continue

- 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.

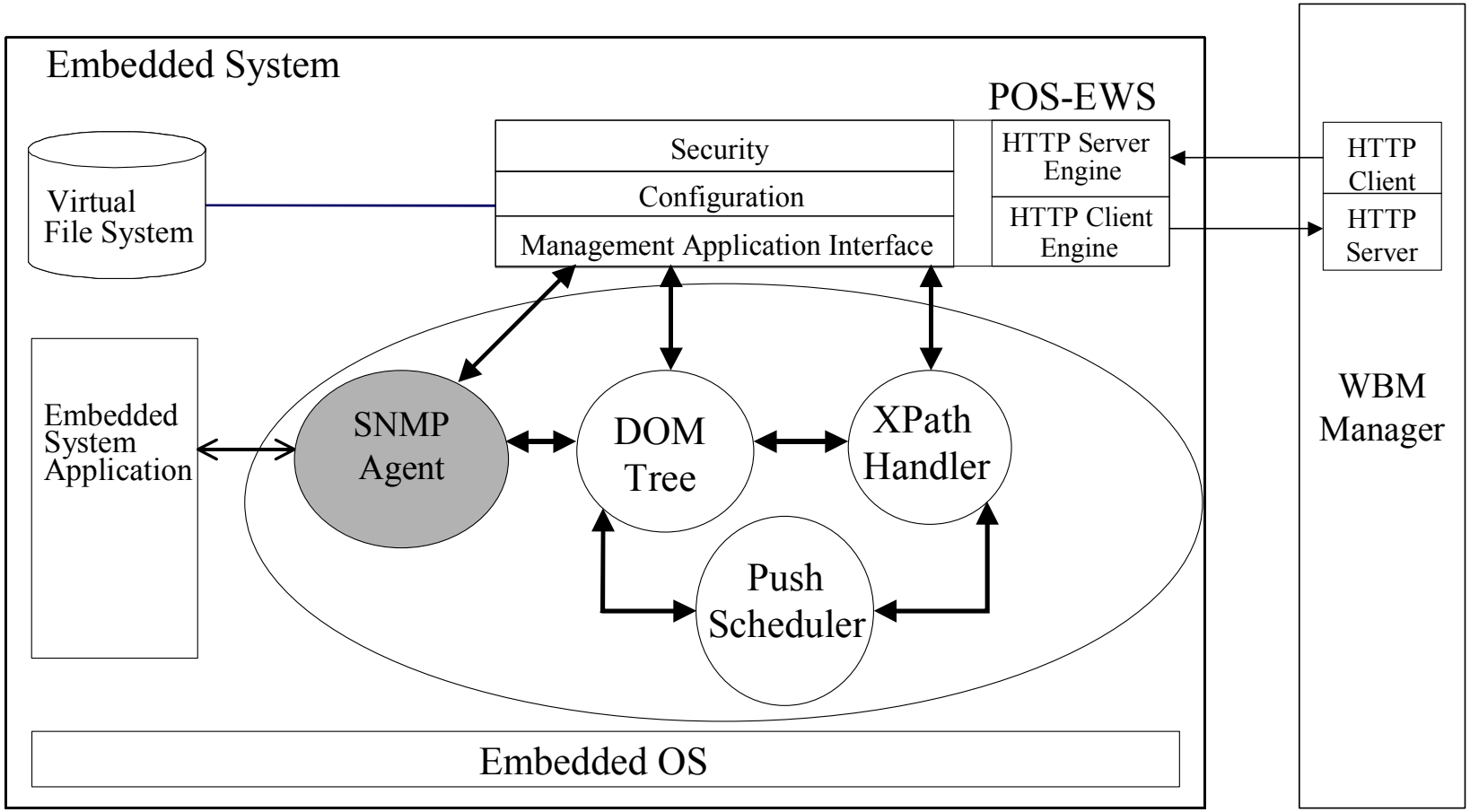
WBM Agent


Embedded System
POS-EWS
Security
Configuration
Application Interface
HTTP Server Engine
HTTP Client Engine
Virtual File System
HTTP Client
HTTP Server
WBM Manager
Embedded System Application
Mgmt. Appl.
DOM Tree
XPath Handler
Push Scheduler
Embedded OS

WBM Manager


WBM Manager
WBM Agent
Web Server
Web Client
XML Parser & Translator
Information Repository
Web Brower

SNMP Integration



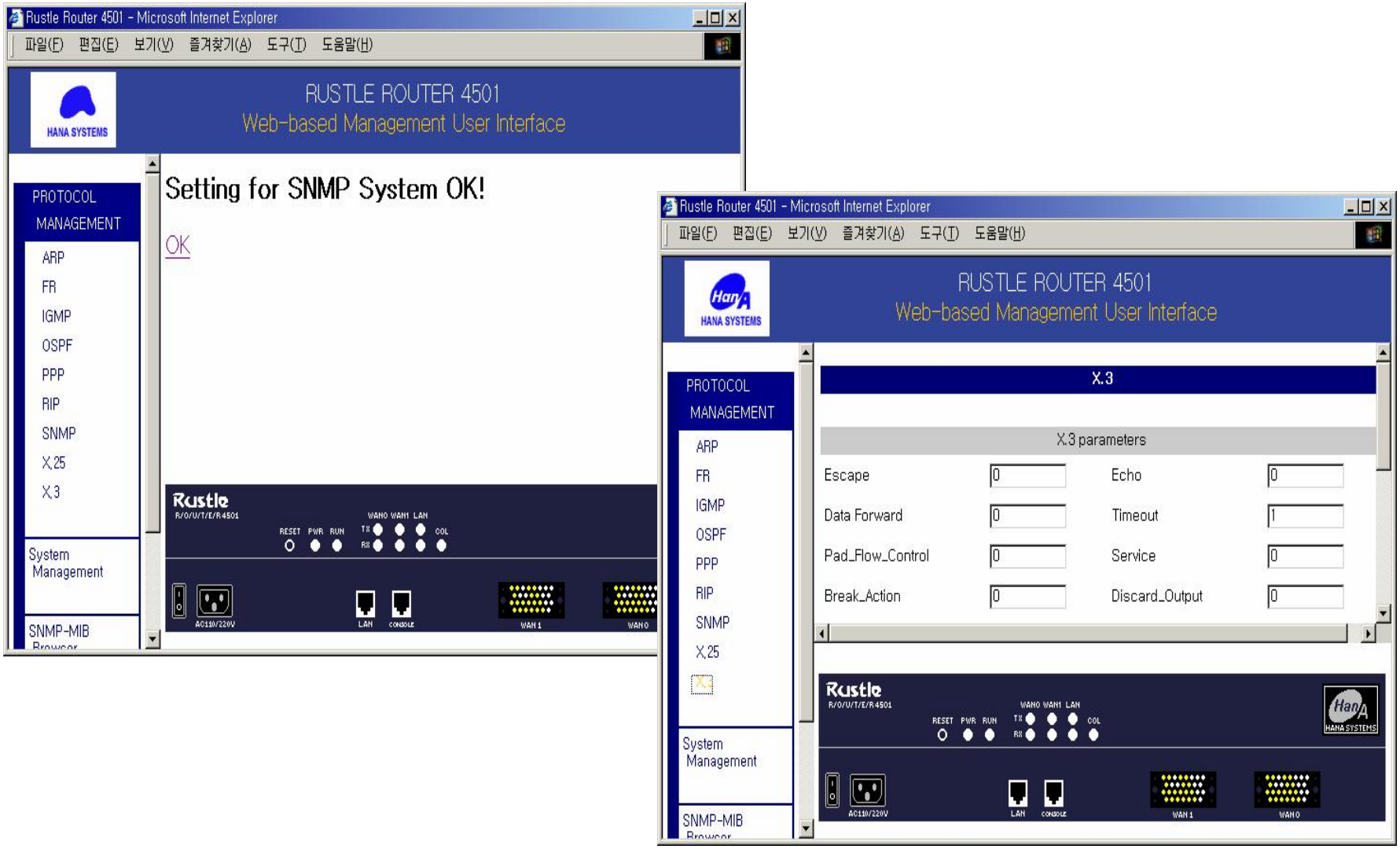
5. Validation

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

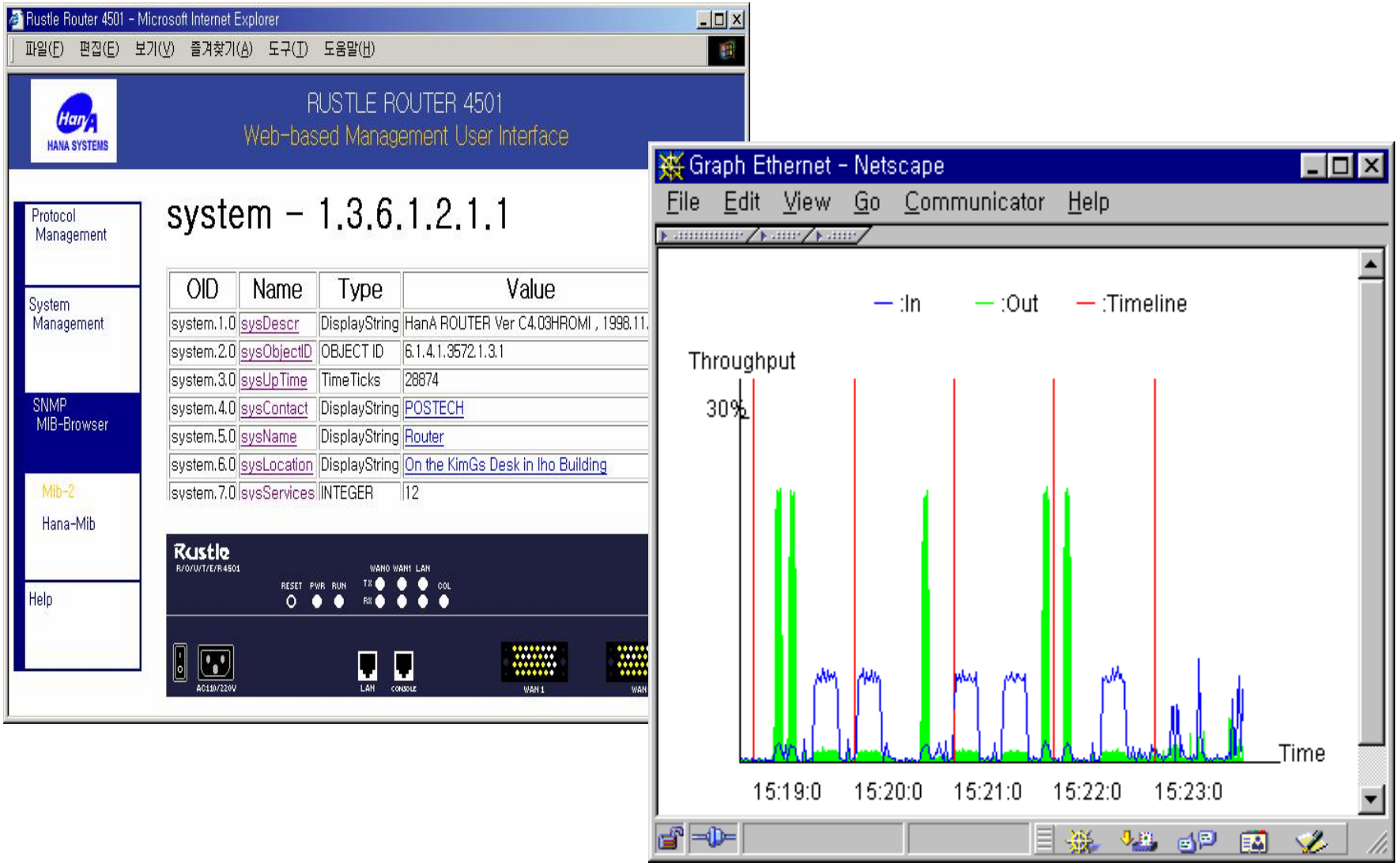
POS-EWS

- 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

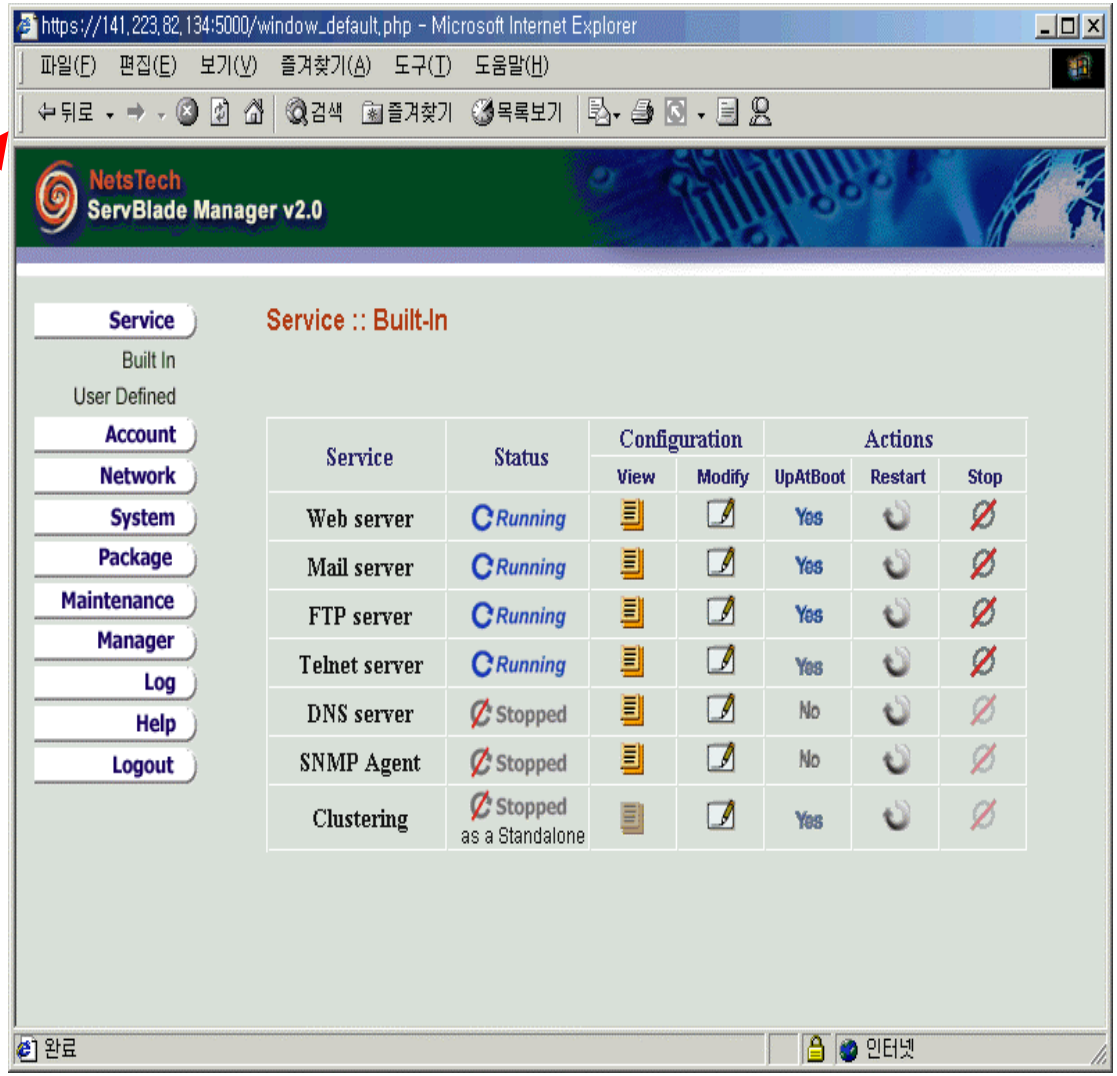
Validation of Web-based Element Management Architecture



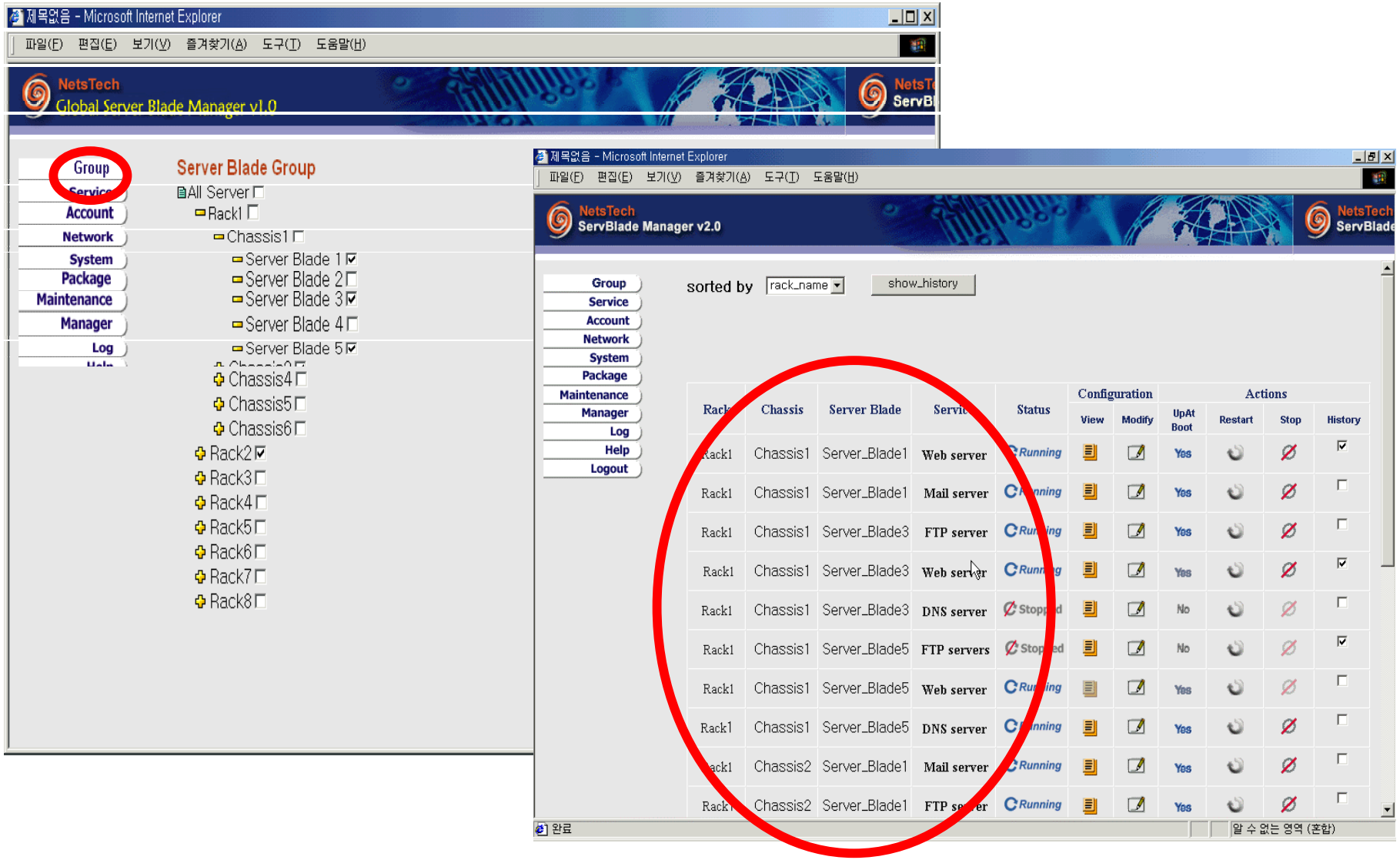
Validation of Web-based Element Management Architecture



Validation of Web-based Network Management Architecture



Validation of Web-based Network Management Architecture



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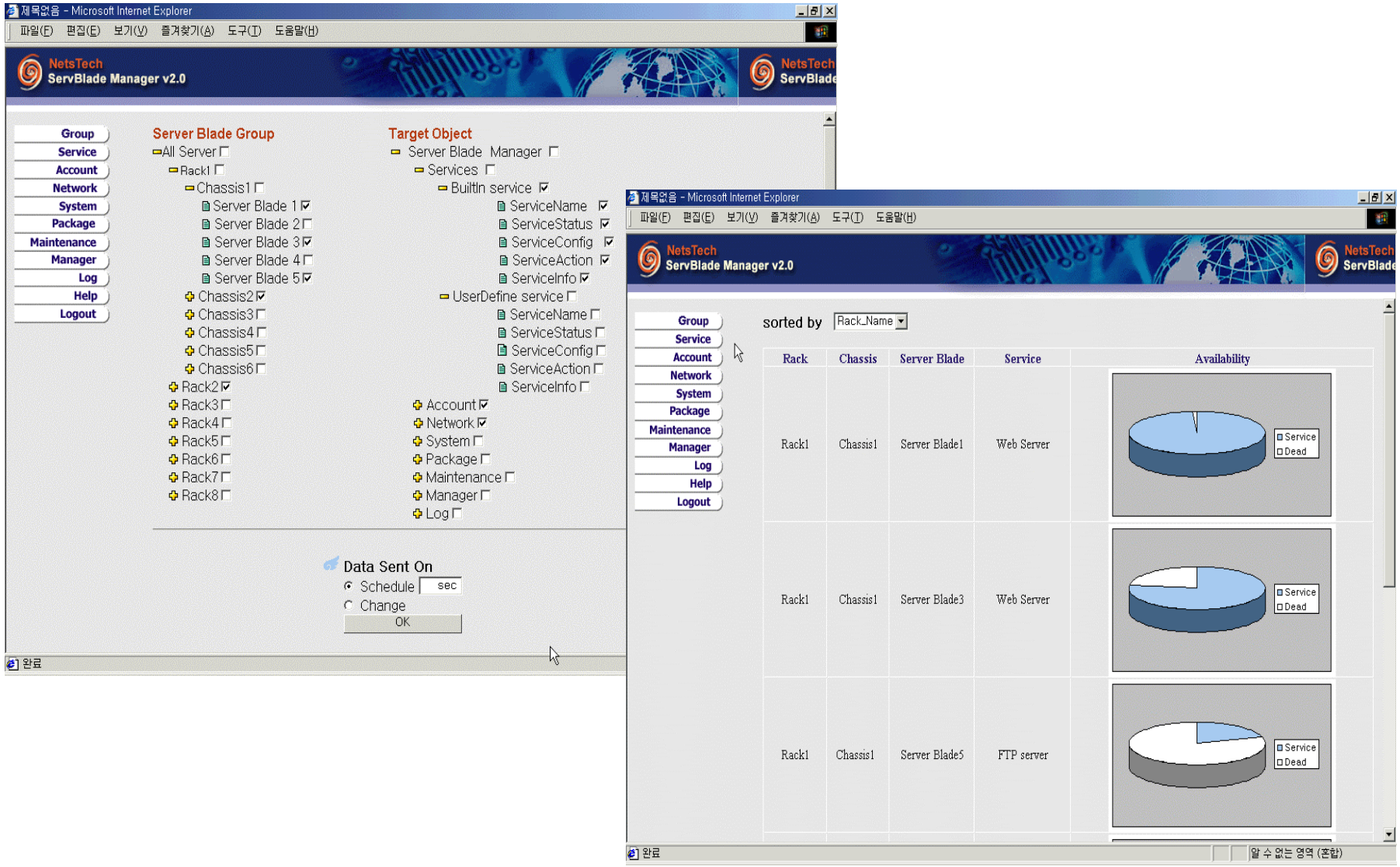


Conclusion

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.

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.

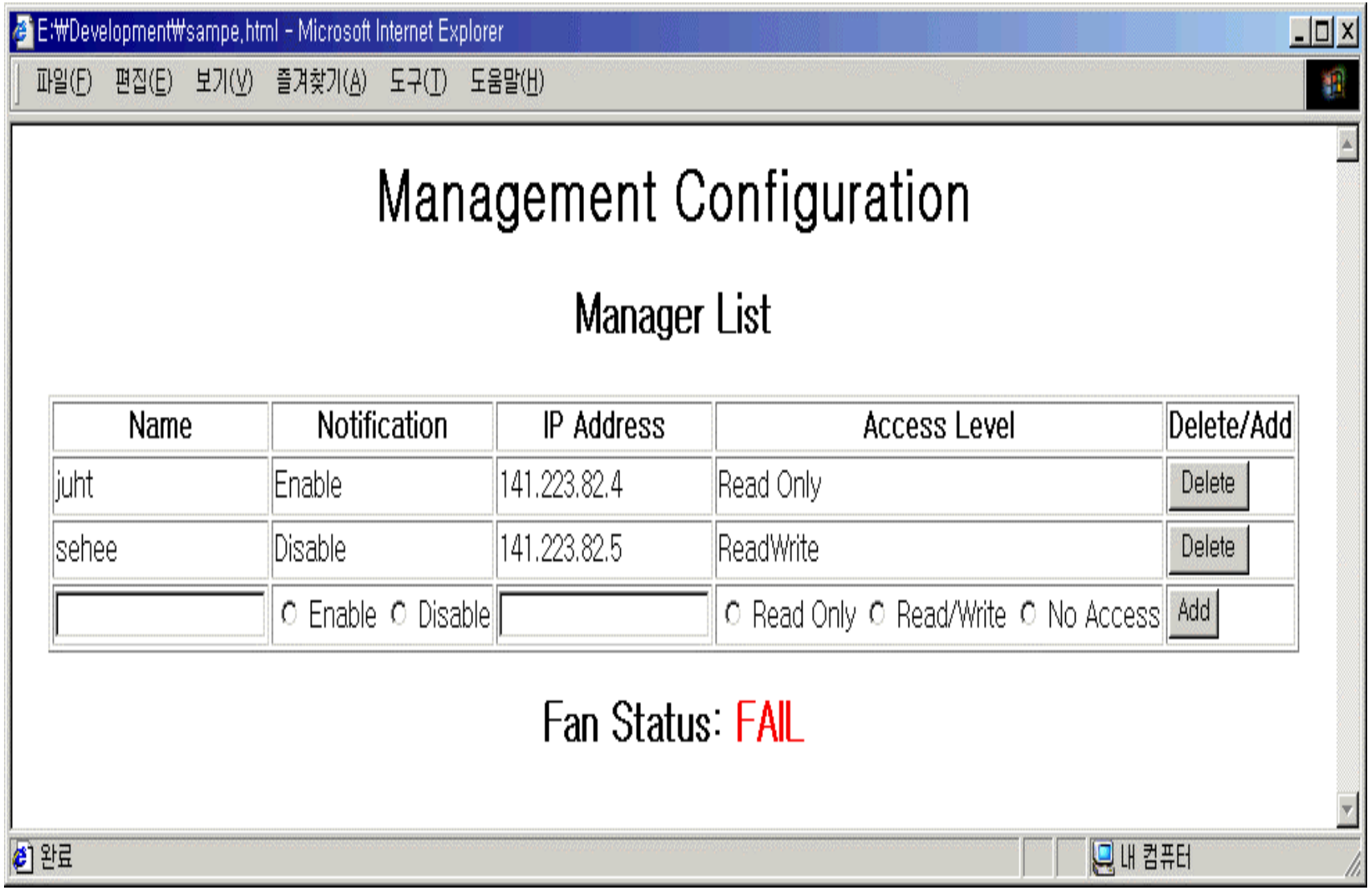
Future Work

- 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

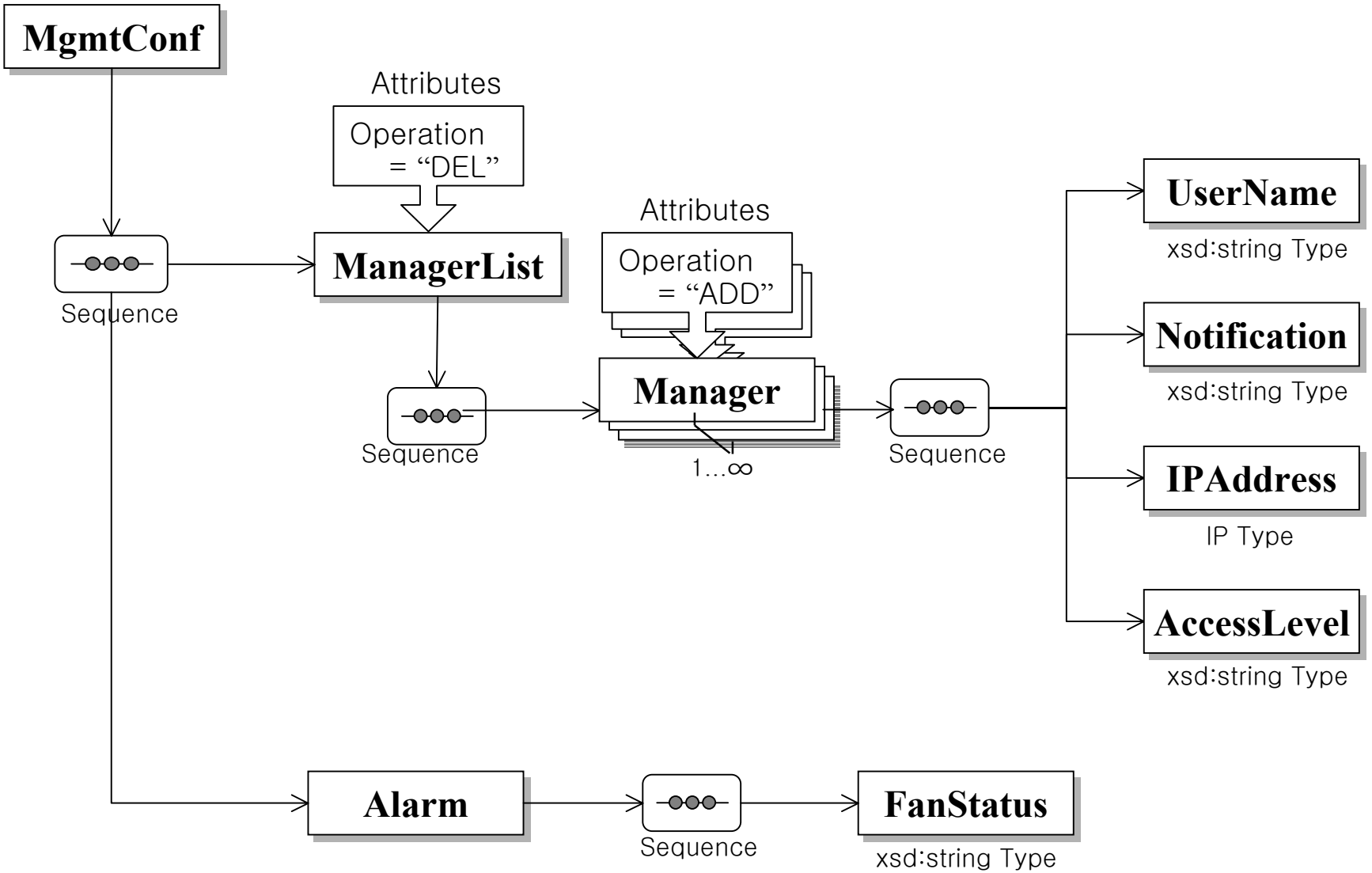
Web Technologies

- 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

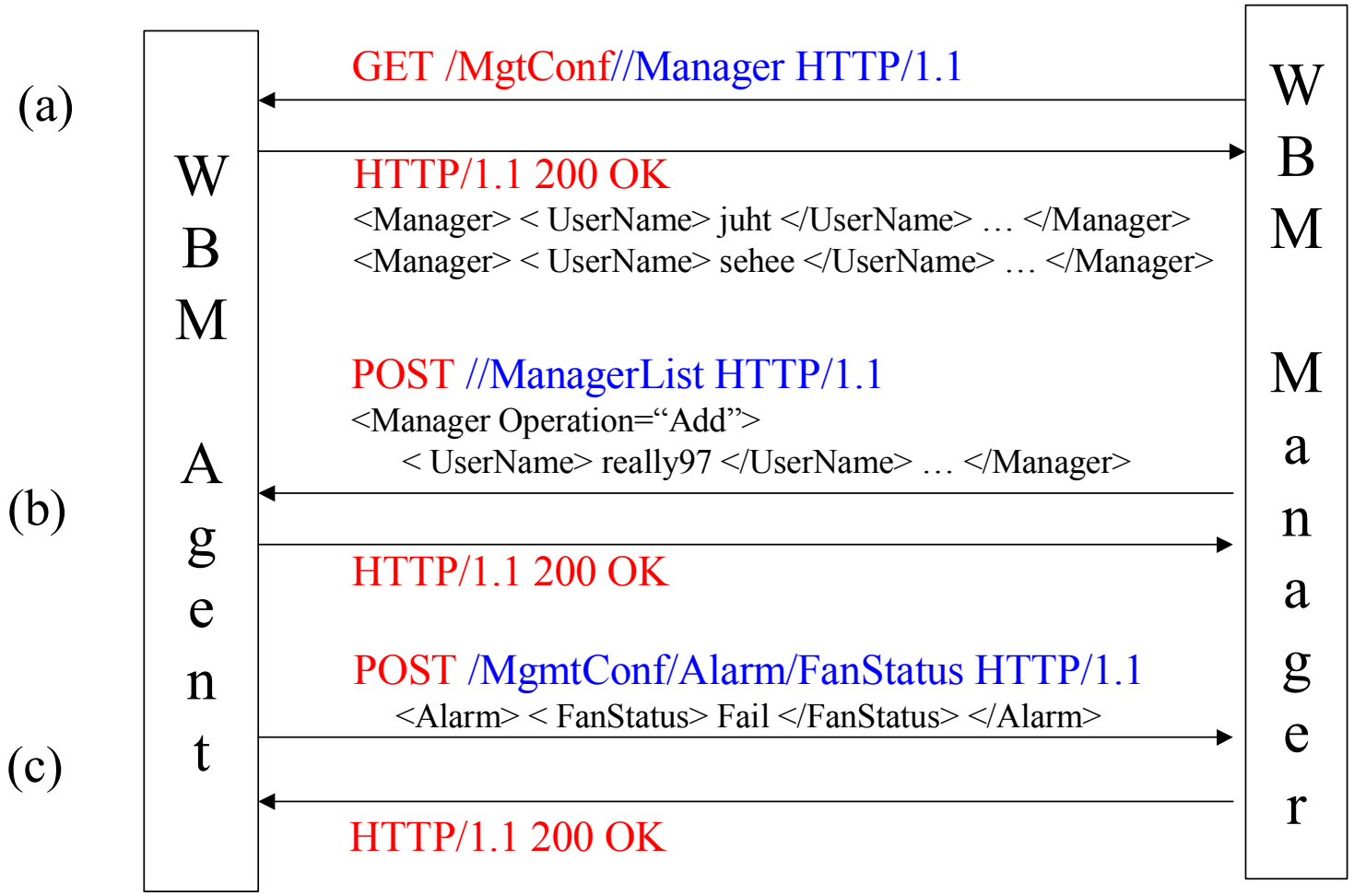
Information Modeling Example



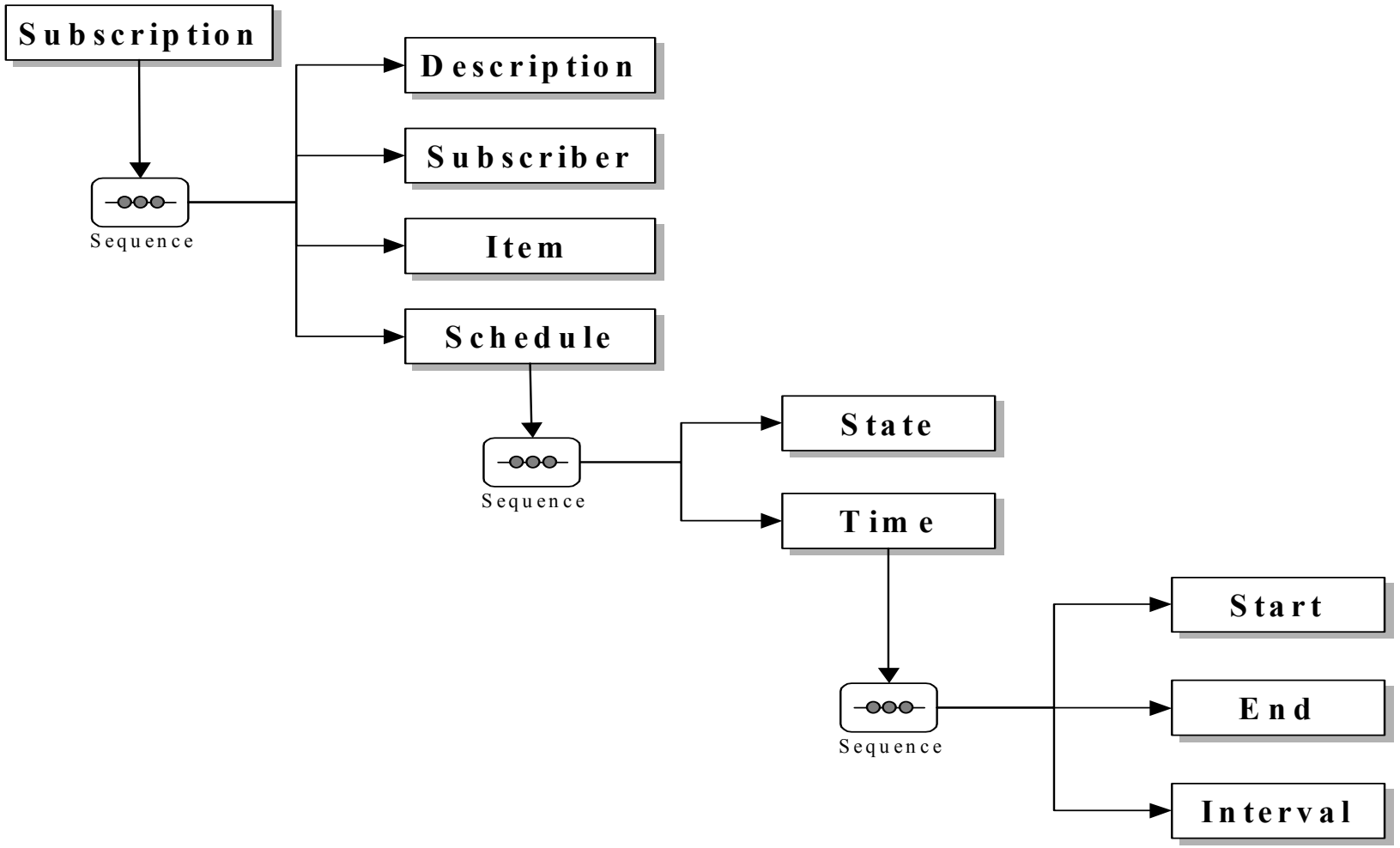
Information Modeling Example –cont.



Communication Example



Subscription information model



Communication Example