An Architectural Framework For XML-based Network Management

PhD Thesis Defence

December 18, 2003

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Introduction (1)

- Current situation of network management
  - A variety of network devices are emerging
  - The scale of network is large
  - SNMP reveals weaknesses to manage large-scale and complex network
- SNMP problems
  - Management information model: weak
  - Management protocol: weak
  - Analysis: no standard method or support for DB
  - Presentation: no standard method

  ➔ Inappropriate to manage huge and complex networks

Introduction (2)

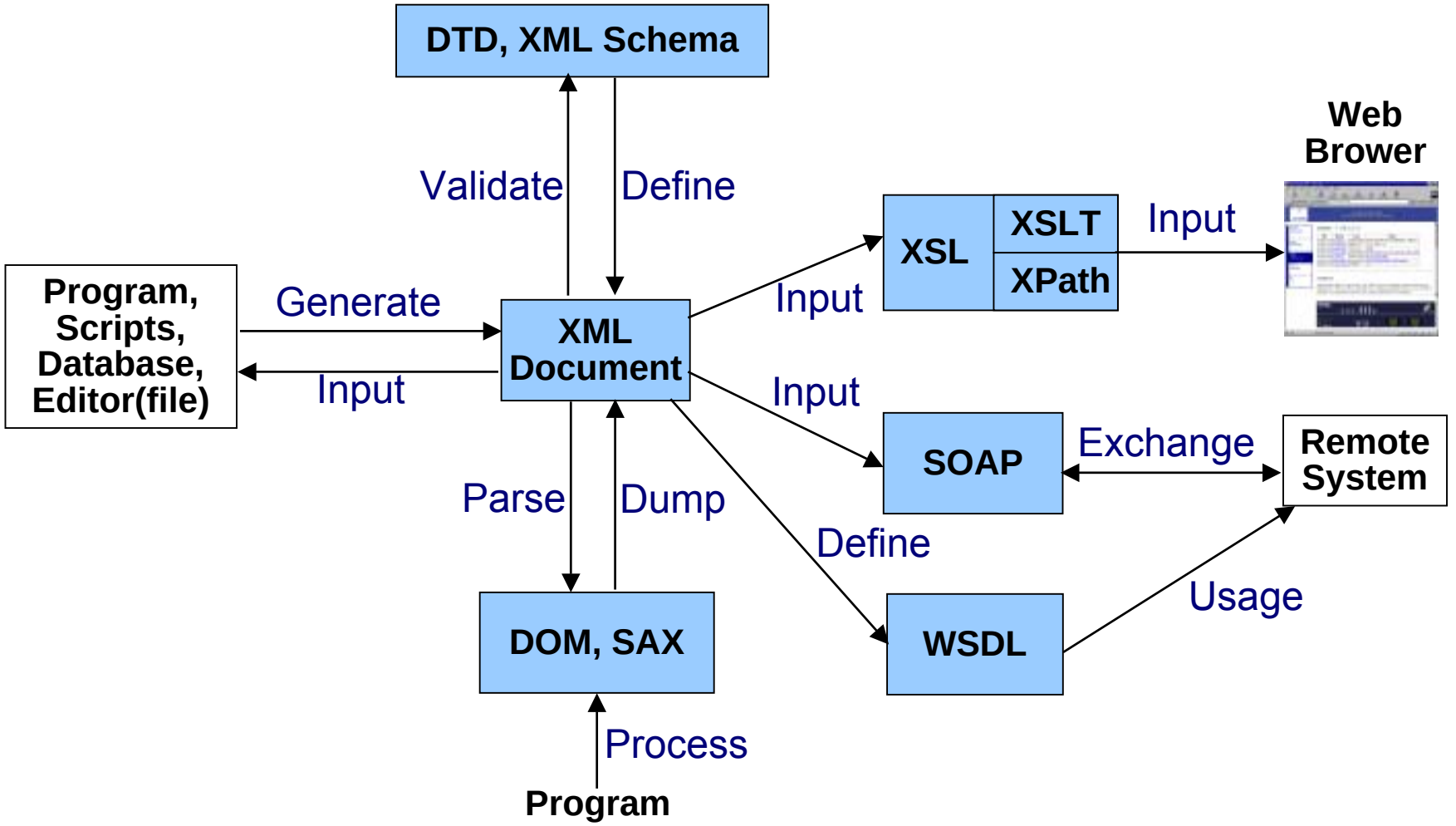
❖ XML-based network management (XNM)

- Much effort to improve the deficiencies of SNMP has failed
- XNM is proposed as an alternative to SNMP-based NM
- Advantages of applying XML to network management
  - XML Schema: used to define rich structure of management information in a flexible manner
  - HTTP: used to reliably transfer bulk management data.
  - DOM APIs: used to easily access and manipulate management data from applications
  - XPath: used to efficiently address the objects within management data documents
  - XSL: used to process management data easily and generate HTML documents for a variety of user interface views

Introduction (3)

- Problems of current XML-based NM
  - General architecture for XML-based NM is not provided
  - Performance of XML-based NM is not validated
  - Concrete method for integrating existing SNMP agents is not supported
- Our Approaches for solving the problems
  - Provide the applicability of XML technologies to network management to solve SNMP problems
  - Propose an architecture of XML-based NMS from the aspect of manager and agent
  - Implement XML-based NMS for network management
  - Evaluate the performance of XNMS
  - Propose a method of XML/SNMP gateway

Related Work: XML Technology Map



Related Work: XNM (1)

- Configuration Management
  - Cisco's CNS Configuration Registrar
  - Juniper Network's JUNOScript
  - IETF Working Group on Network Configuration (NetConf)
  - ➔Few reports for implementation results yet
  - ➔Insufficient information to implement and apply
- Architecture
  - J.P Martin's Web-based Integrated Management Architecture: propose only information model and communication model
  - Our previous XNM: provide an architecture of agent, but insufficient in manager architecture
  - ➔Lack of overall architecture of XML-based NM

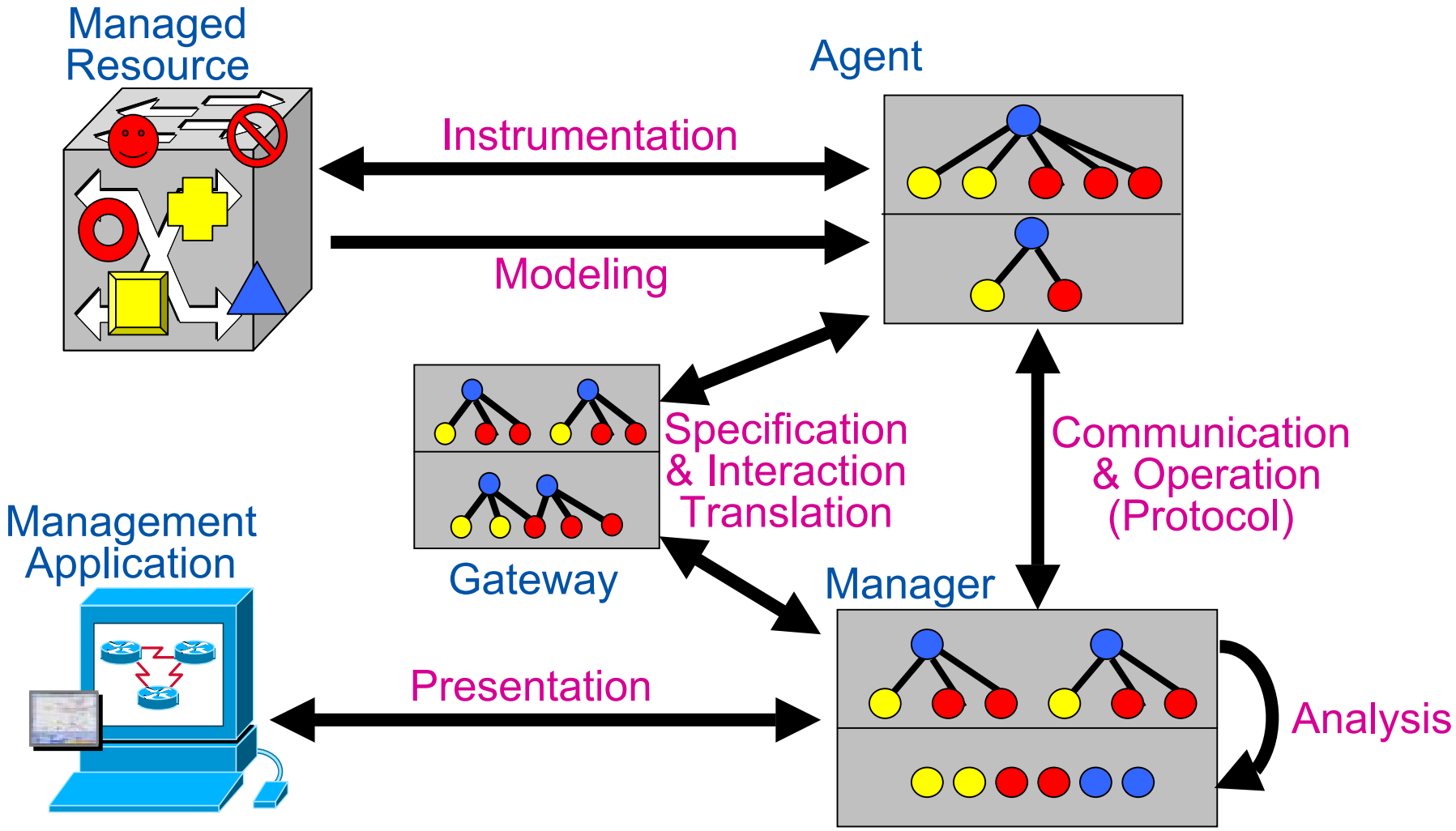
Related Work: XNM (2)

- Performance
  - Network bandwidth of transferring XML data is large because XML is text-based
  - Not been proved that XML is applicable to embedded systems

  ➔Lack of performance evaluation results available
- SNMP Integration
  - Avaya Labs: early stage of research, merely propose a method of the XML/SNMP gateway
  - J. Muller: provide the simple functionality of gateway
  - XNAMI: propose a method for complementing the weakness of SNMP

  ➔Lack of a gateway architecture and a method to develop the gateway

Network Management Tasks



Problem Definition: SNMP

- Management information model
  - Defines management information using Structure of Management Information (SMI)
  - Insufficient to present management information because it does not support concepts such as structured data types, objects, methods, or relationships
- Management protocol
  - Only 3 simple management operations: Get, Set, Trap
  - UDP only → not support bulk data retrievals in a reliable manner
- Analysis
  - No standard APIs of analysis
  - No support for database
- Presentation
  - No standard methods of presentation

Problem Definition: Current XNM

- No general architecture for XML-based NM
  - A general architecture of XNMS consisting of manager and agent is not provided yet
- Insufficient implementation and performance validation of XML-based NMS
  - Implementation experience of XNMS including configuration management is not properly provided
  - Performance evaluation of XNMS is main concern, but no report on performance of XML-based NM
- No concrete method for integrating existing SNMP agents
  - Need to support the management of existing SNMP agents for integrated network management
  - No specific method and system for managing existing SNMP agents using XNMS

Our Approaches (1)

- To solve SNMP problems → Applicability analysis of XML technologies to network management
  - **Management information model**
    - Use powerful management information modeling of XML Schema
  - **Instrumentation**
    - Use DOM and SAX for interpretation of XML document
  - **Management protocol**
    - Transfer XML data using protocols such as HTTP or SOAP
    - Possible to bulk data transfer in a reliable manner
    - Possible to reduce transferred data through compression
  - **Analysis**
    - Manipulate XML document using DOM parser
    - Use DOM API for management information analysis
  - **Presentation**
    - Transform XML format to HTML format using XSLT

Our Approaches (2)

- To solve current XNM problems → Propose an architecture & validate it through implementation and performance evaluation
  - Propose an architecture of XNMS from the aspect of manager and agent
  - Implement XNMS for network management based on the proposed architecture
  - Evaluate the performance of XNMS in resource utility, network traffic, and response time
  - Propose a method of XML/SNMP gateway, implement the gateway, and apply the gateway to the management of POSTECH campus network

Applicability Analysis (1)

- Management information model
  - Use XML Schema for management information model
    - Define the data structure of XML document
    - Flexible and extensible: add new tags
    - Support 44 kinds of basic data types and add new data types
    - Easy to learn
    - Powerful and convenient XML tools are freely-available
- Instrumentation
  - Must guarantee consistency between managed objects and managed resources in agent system
  - Use DOM or SAX for the manipulation of XML document
    - Interpretation, creation, and modification of XML document using DOM or SAX parses

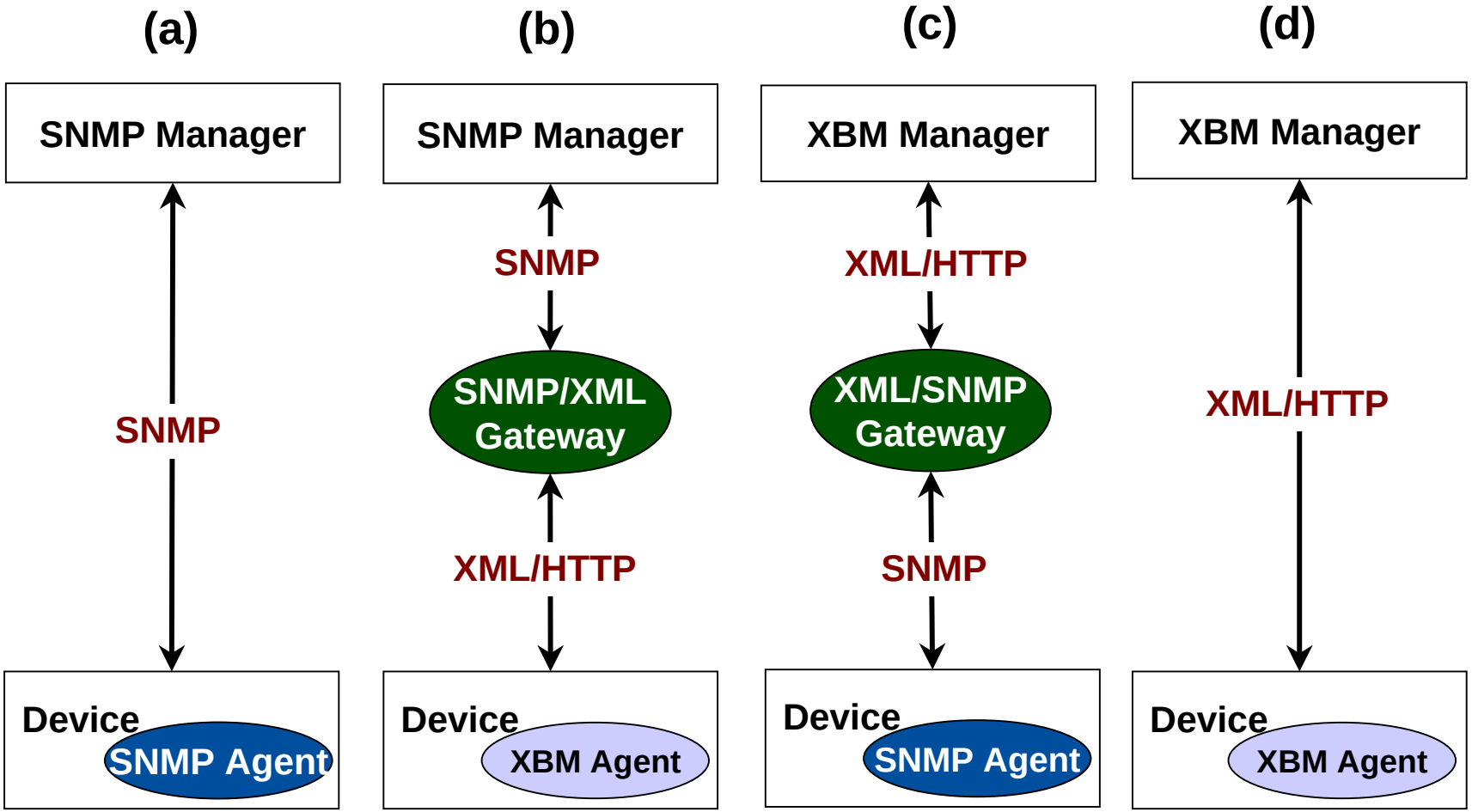
Applicability Analysis (2)

- Management Protocol
  - Use HTTP or SOAP
    - Transfer bulk data without the limitation of data size in a reliable manner
    - Compress messages with the HTTP header option and reduces network traffic volumes
    - Define management operations using WSDL and call management operation using SOAP
  - Use XPath for the addressing of management information
- Analysis
  - Use DOM and SAX API to access management data for application
  - Manipulate XML document and analyze management information using DOM API
  - Use XMLDB for DB processing
  - Plenty of tools available for XML technologies

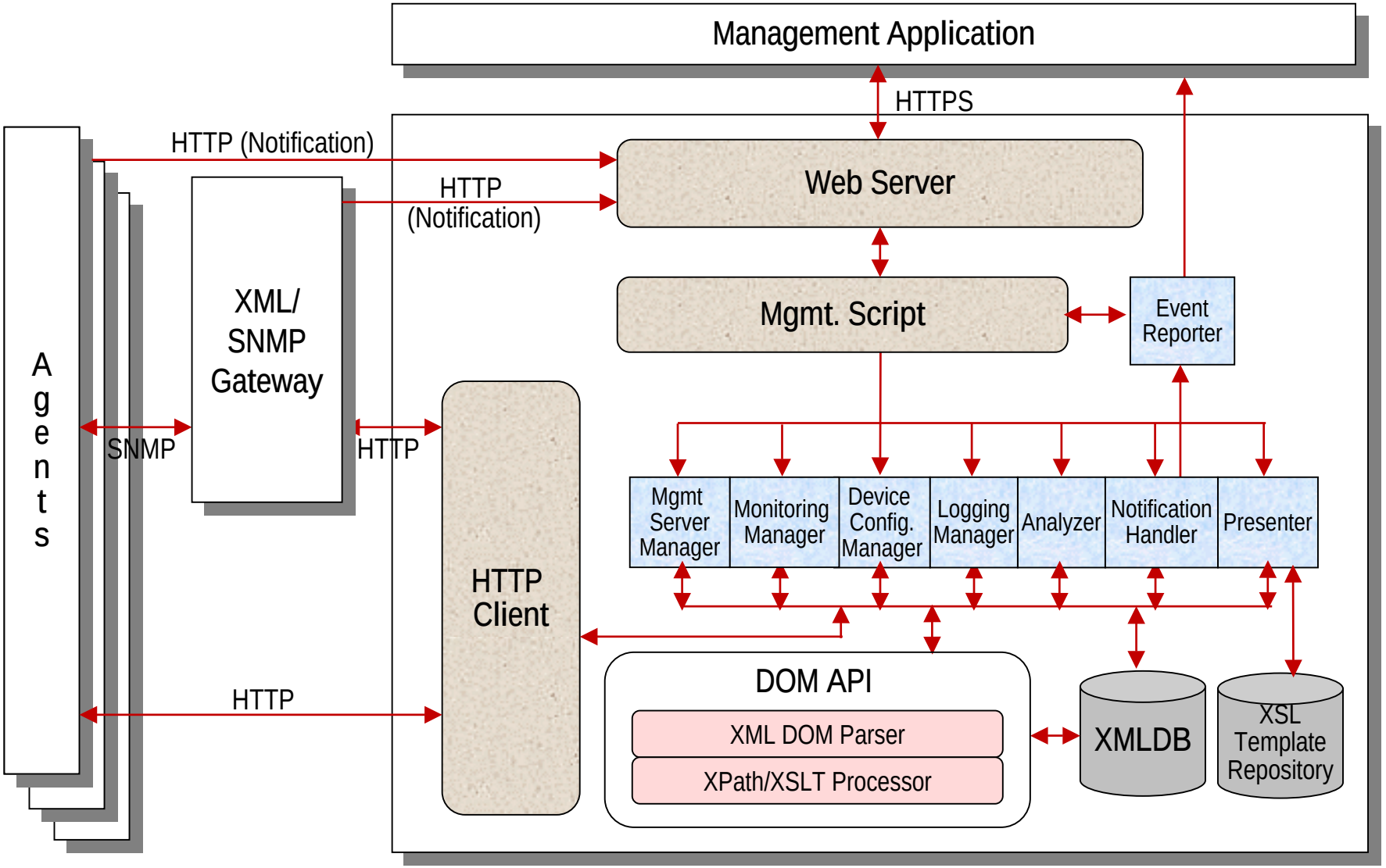
Applicability Analysis (3)

- Presentation
  - XML separates the contents of the document from the display
  - Use XSL and XSLT to transform XML data to HTML or another XML document
  - Transformation from XML to HTML or other display format makes it possible to provide a Web-based management user interface (Web-MUI)

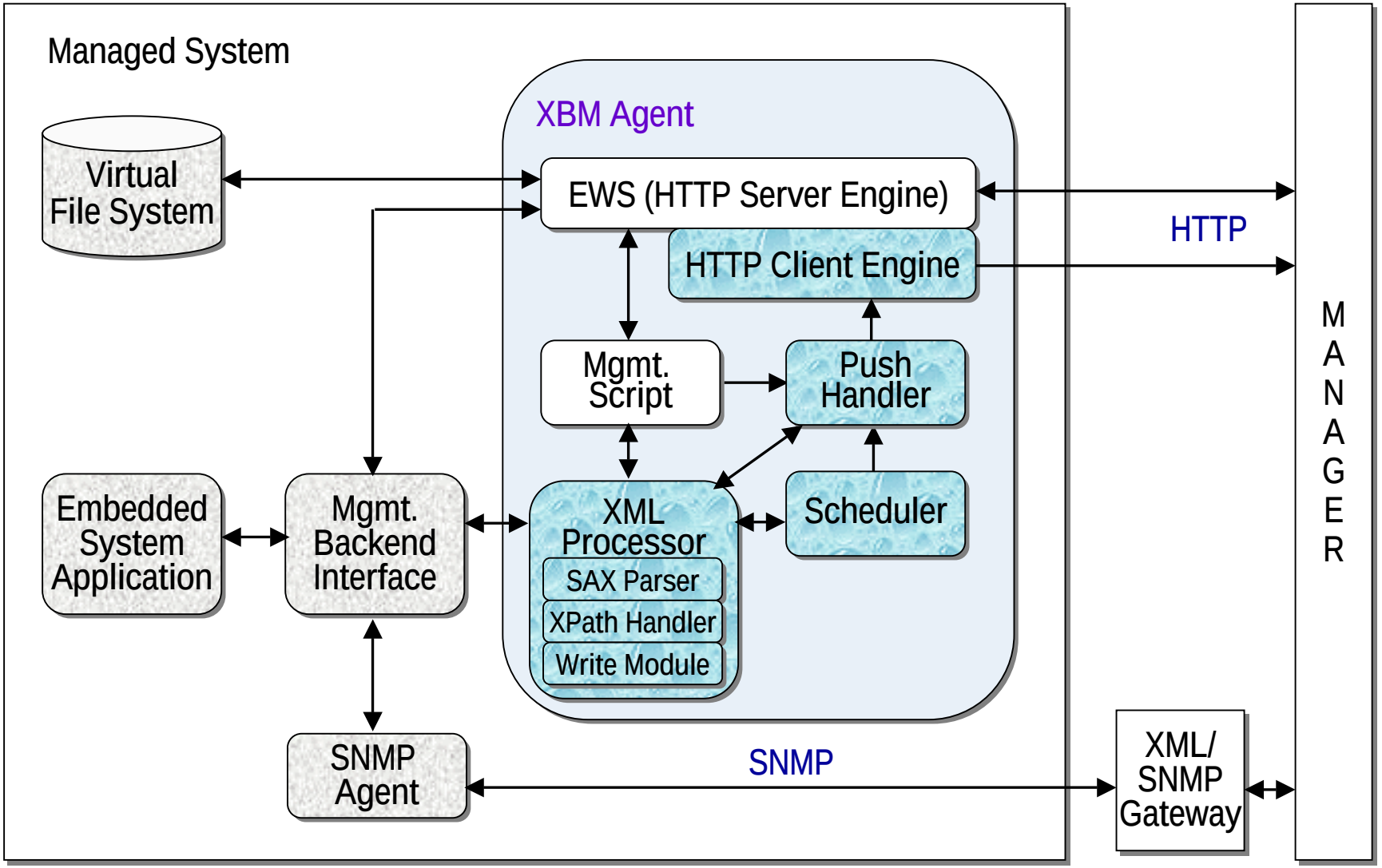
Combinations of Managers and Agents



Architecture – XBM Manager

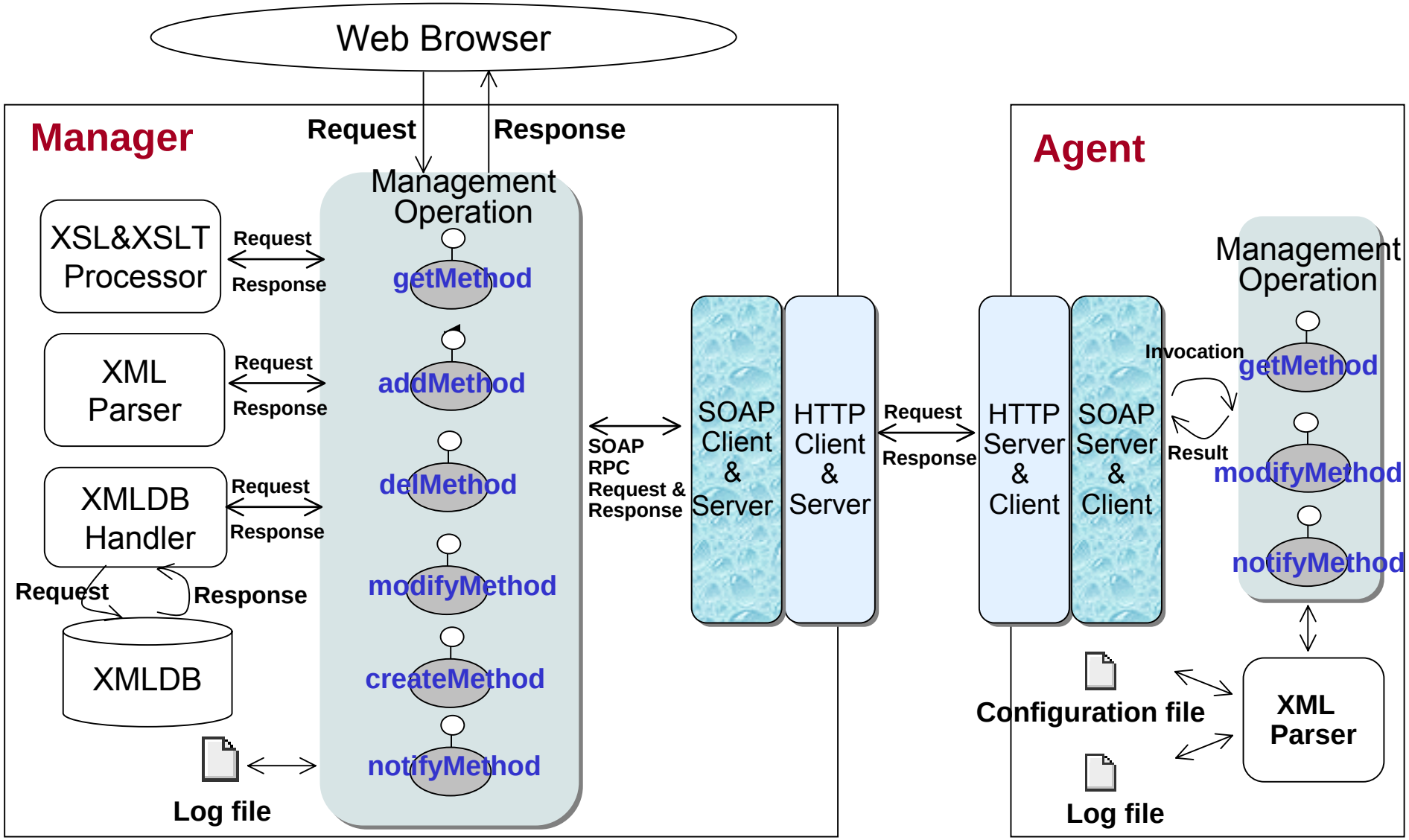


Architecture – XBM Agent

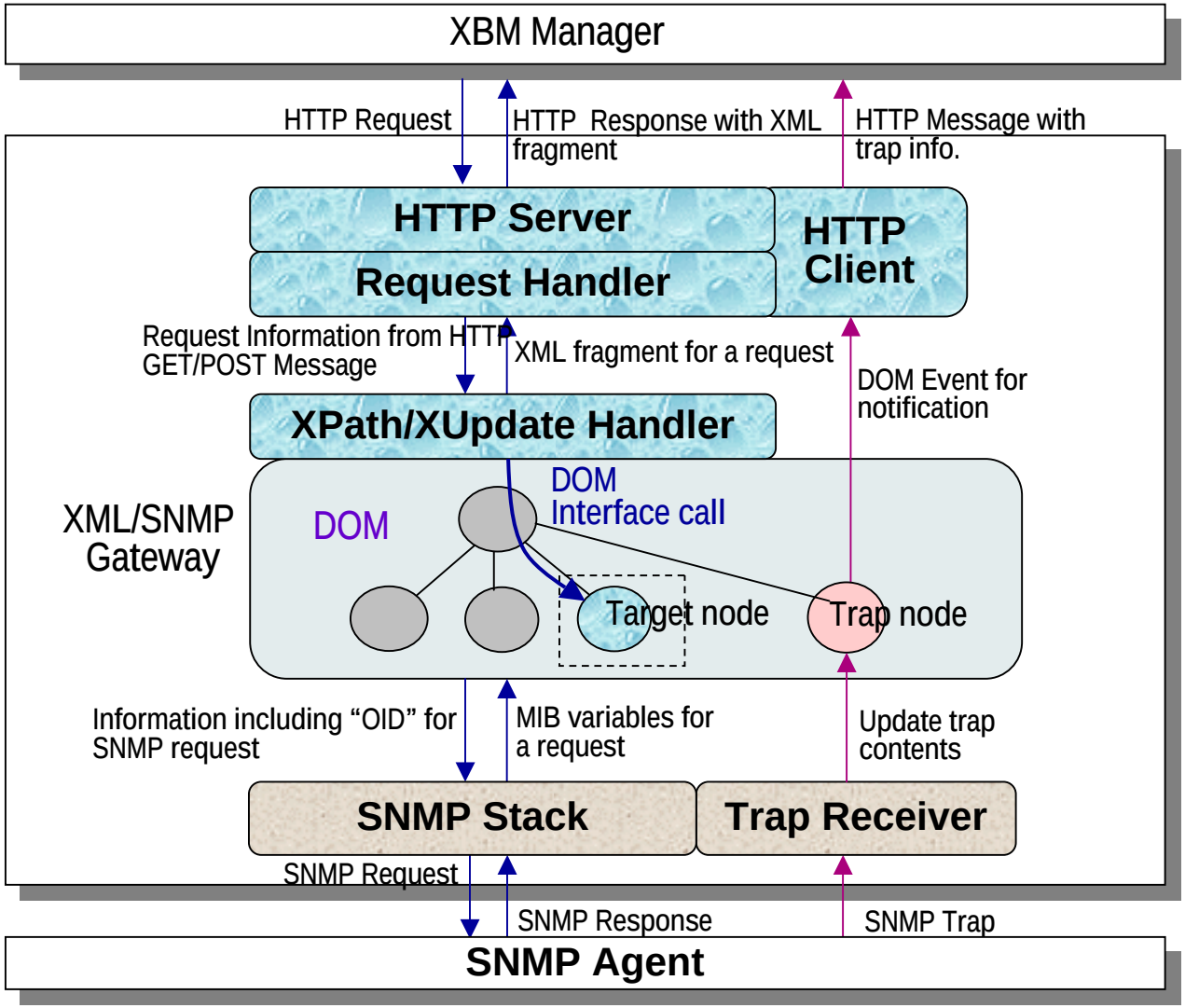


Architecture of X-CONF

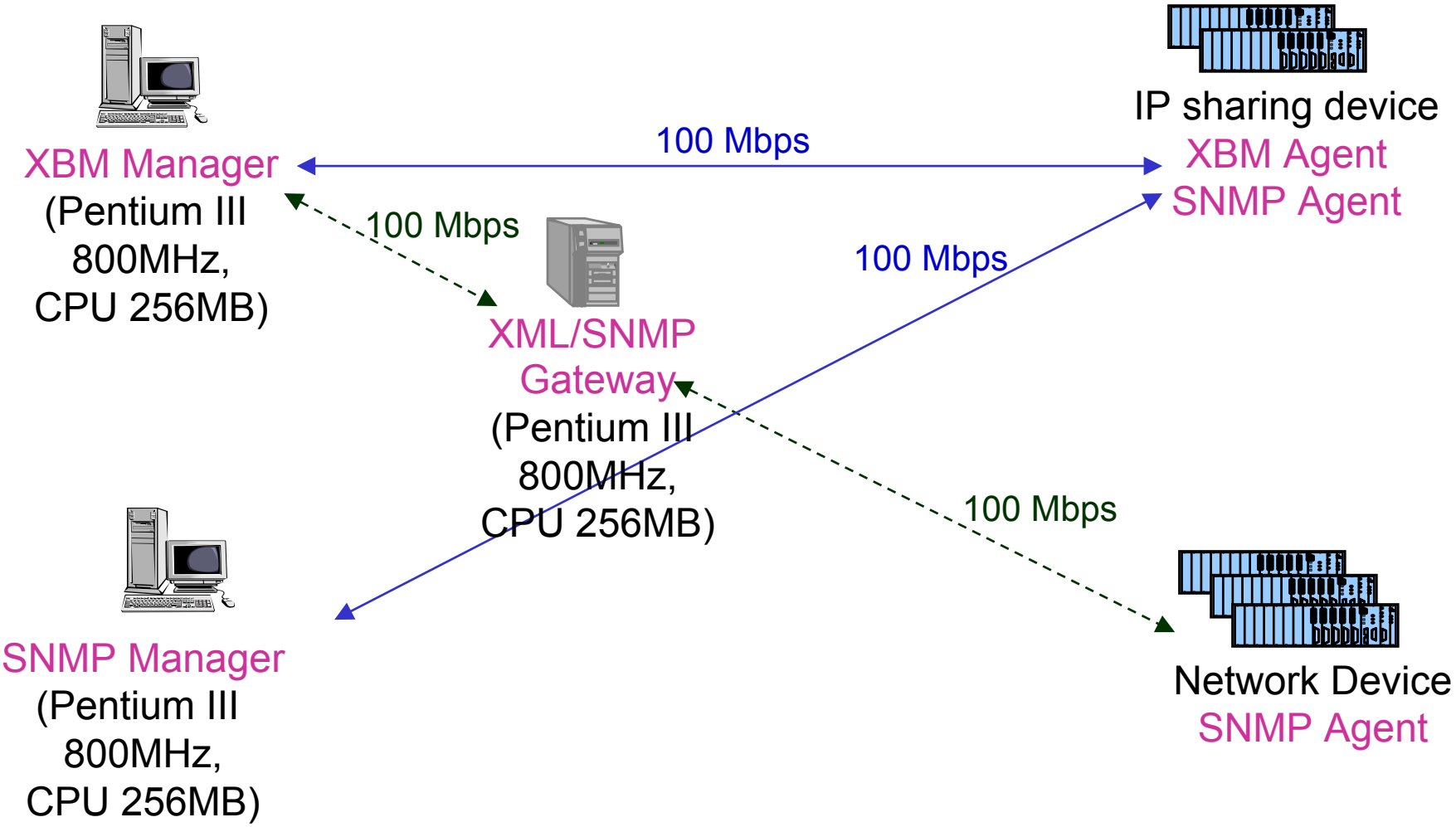
(Xml-based CONFiguration management system)



Architecture of XML/SNMP Gateway



Performance Evaluation Environments



Performance Evaluation (1)

- Verify the performance of XBM agent by comparing it with the SNMP agent on the same IP sharing device
- SNMP agent extends the Net-SNMP and supports only SNMPv1
- CPU load, run-time memory usage, and executable code size

Agent	CPU load	Run-time memory usage	Executable code size
SNMPv1	17 %	600 KB	400 KB
XBM	20 %	700 KB	550 KB

< Resource Usage of SNMP and XBM Agents >

Performance Evaluation (2)

❖ Network traffic (MIB II – system, interfaces group)

Management Property	Get request message (bytes)			Get response message (bytes)		
	SNMP	XBM	XML/SNMP Gateway	SNMP	XBM	XML/SNMP Gateway
sysDescr	82	508	666 (584 + 82)	145	510	671 (526 + 145)
sysContact	82	510	678 (586 +82)	103	460	579 (476 + 103)
system Group	572	511	1159 (587 + 572)	722	710	1448 (726 + 722)
inOctets (2 interfaces)	169	511	755 (586 + 169)	175	522	713 (538 + 175)
outOctets (2 interfaces)	169	511	756 (587 + 169)	176	526	718 (572 + 176)
interfaces Group	3720	511	4307 (587 + 3720)	3818	1924	5758 (1940 + 3818)

< Message Size of Get Request/Response Operation >

Performance Evaluation (3)

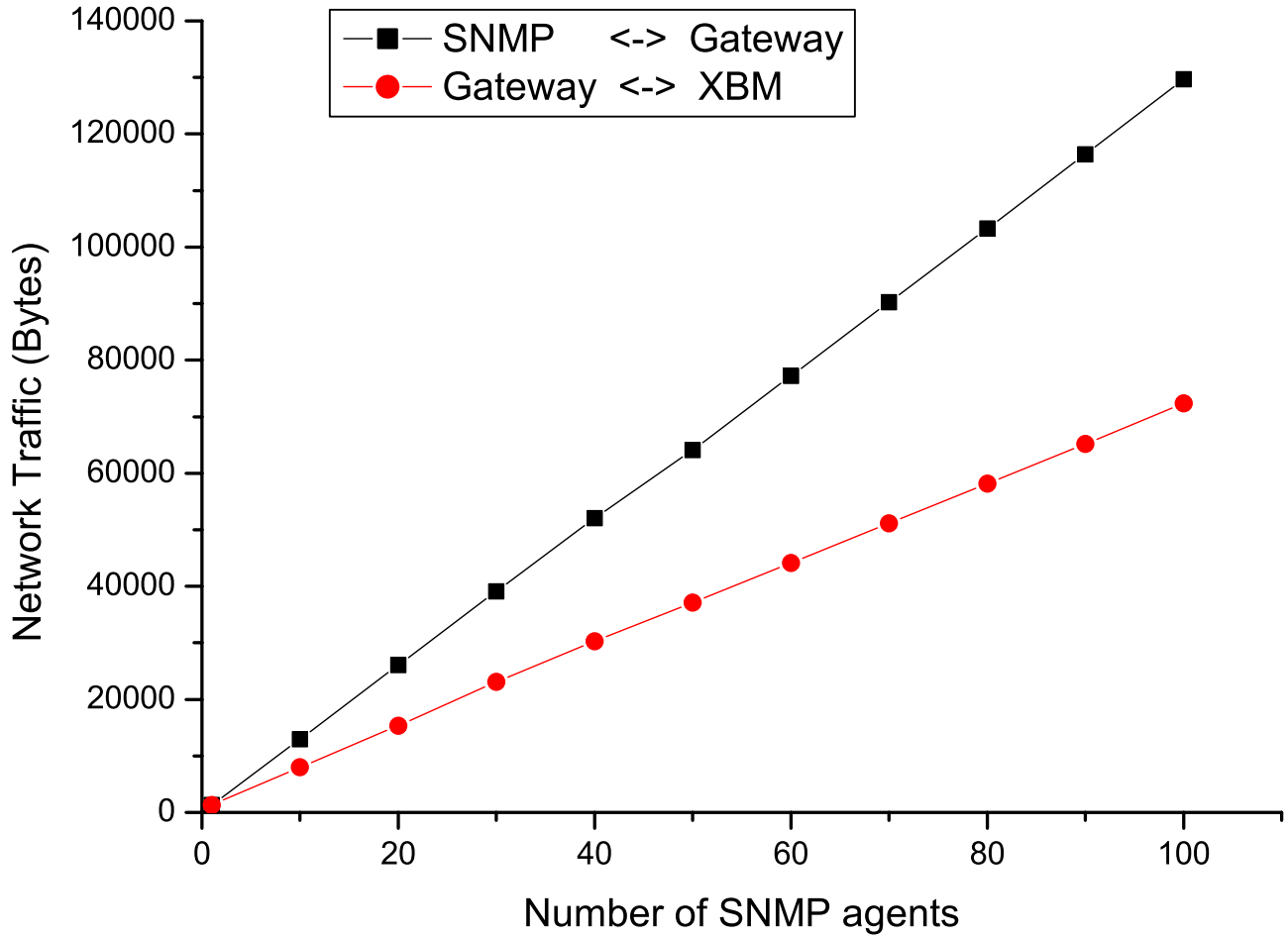
❖ Response time (MIB II – system, interfaces group)

Management Property	Response Time (ms)		
	SNMP	XBM	XML/SNMP Gateway
sysDescr	40	50	80
system Group	160	140	250
interfaces Group	980	800	1250

< Response Time of Get Operation >

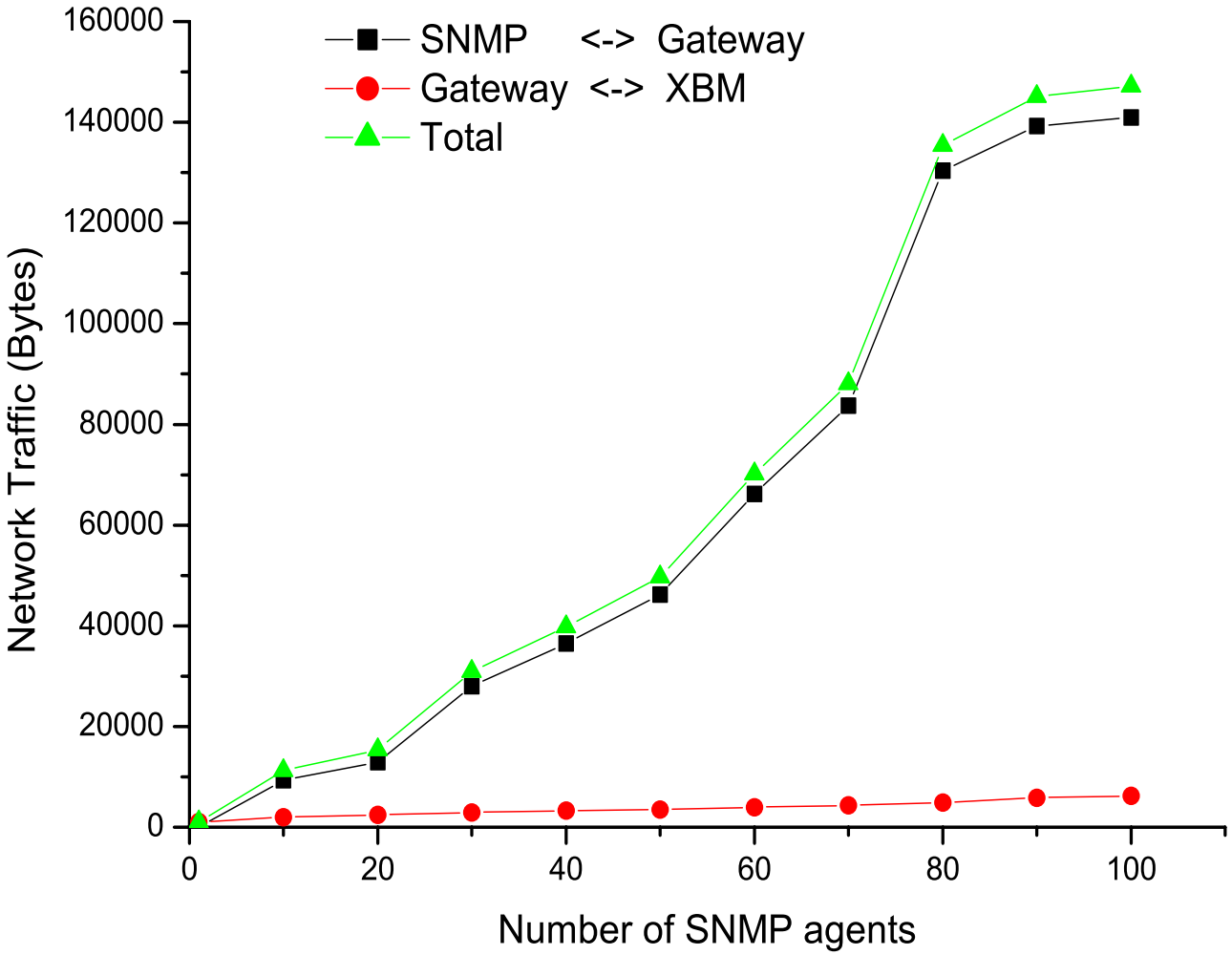
Performance Evaluation (4)

❖ Network Traffic (MIB II – system group)



Performance Evaluation (5)

❖ Response Time (MIB II – system group)



Concluding Remarks

- Identified the problems of SNMP and current XML-based NM
- Proposed the solutions to SNMP problems using XML technologies
- Provided an architecture of XML-based network management system (XNMS)
  - XBM manager, XBM agent, XML/SNMP Gateway, X-CONF
- Implemented an XNMS and evaluate the performance of our XNMS

Contributions

- Proposed the solutions of the SNMP problems from the aspect of management tasks using XML technologies
- Proposed solutions to the problems of current XML-based NM
- Provided an architecture for XNMS
- Provided a guideline for developing XNMS by implementation experience
- Validated the performance of our XNMS

Future Work

- Optimize the performance of our XNMS
  - XBM manager, XBM agent, XML/SNMP Gateway
- Evaluate the performance of pure XML-based network management
- XNMS using Web Services
  - Use SOAP, WSDL, UDDI

Published Papers (1)

- International Journals: 5편
  - **Mi-Jung Choi**, James W. Hong and Hong-Taek Ju, "XML-based Network Management for IP Networks", ETRI Journal, Vol. 25, No. 6, Dec. 2003, pp. 445-463. (SCI)
  - Myung-Sup Kim, **Mi-Jung Choi** and James W. Hong, "A Load Cluster Management System using SNMP and Web, International Journal of Network Management (IJNM)", Vol. 12, No. 6, November 2002, pp. 367-378.
  - **Mi-Jung Choi** and James Won-Ki Hong, "A Secure Web-based Global Management System For Firewall/VPN Devices", Journal of Communications and Networks (JCN), Vol. 4, No. 1, March 2002, pp. 71-78. (SCIE)
  - Hong-Taek Ju, **Mi-Jung Choi** and James W. Hong, "EWS-based Management Application Interface and Integration Mechanisms for Web-based Element Management", Journal of Network and Systems Management (JNSM), Vol. 9, No. 1, March 2001, pp. 31-50.
  - Hong-Taek Ju, **Mi-Jung Choi** and James W. Hong, "An efficient and lightweight embedded Web server for Web-based network element management", International Journal of Network Management (IJNM), Vol. 10, Issue 5, September/October 2000, pp. 261-275.

Published Papers (2)

- International Conferences: 12편
  - Hyoun-Mi Choi, **Mi-Jung Choi**, and James W. Hong, "Design and Implementation of XML-based Configuration Management System for Distributed Systems", Accepted to appear in the Proc. of the IEEE/IFIP Network Operations and Management Symposium (NOMS 2004), Seoul, Korea, Apr. 2004.
  - **Mi-Jung Choi**, Jung-Min Oh and James W. Hong, "Design and Implementation of an XML-Based Management Agent", Proc. of 2003 Asia-Pacific Network Operations and Management Symposium (APNOMS 2003), Fukuoka, Japan, October 1-3, 2003, pp. 331-342.
  - Hyoun-Mi Choi, **Mi-Jung Choi**, James W. Hong, "XML-Based Configuration Management for Distributed System", Proc. of 2003 Asia-Pacific Network Operations and Management Symposium (APNOMS 2003), Fukuoka, Japan, October 1-3, 2003, pp. 599-600.
  - **Mi-Jung Choi**, Hong-Taek Ju and James W. Hong, "Towards XML and SNMP Integrated Network Management", Proc. of 2002 Asia-Pacific Network Operations and Management Symposium (APNOMS 2002), Jeju, Korea, September 25-27, 2002, pp. 507-508.
- Domestic Journal:4편 , Domestic Conference: 4편

SNMP-based NM vs. XML-based NM (1)

❖ Comparison of Managers

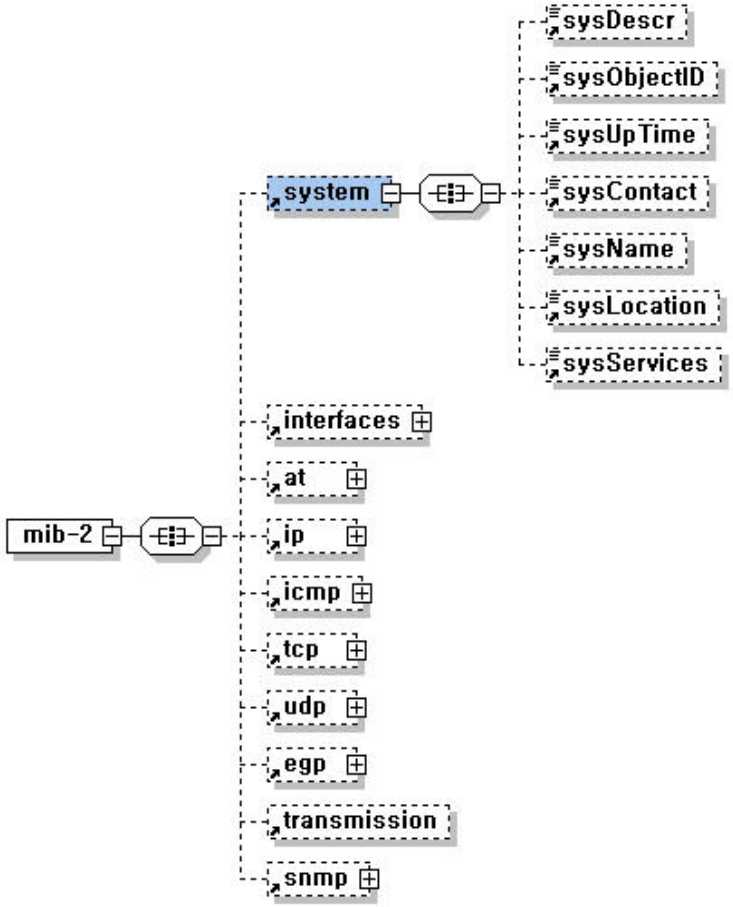
Features	SNMP Manager (SNMPv1/v2)	XBM Manager
Mgmt. User Interface (MUI)	Desktop-MUI or Web-MUI	Web-MUI or Desktop-MUI
Mgmt. Protocol	SNMP (UDP)	XML/HTTP (TCP)
Mgmt. Information Model	SNMP SMI, MIB	XML DTD, XML Schema
Development Cost of Mgmt. Functionality	More difficult No standard API Limited support of RDBMS	Easier Standard API to access XML documents Support of the third party RDBMS
Security	Community string	HTTP authentication, HTTPS (HTTP over SSL)
Resource	Many resources	Many resources

SNMP-based NM vs. XML-based NM (2)

❖ Comparison of Agents

Features	SNMPv1/v2 Agent	EWS	XBM Agent
Protocol	SNMP (UDP)	HTML/HTTP (TCP)	XML/HTTP (TCP)
Mgmt. Info. Model	SNMP SMI (MIBII + Private MIB)	No specific model	XML DTD, XML Schema
Mgmt. Domain	Element + Network mgmt.	System (Element) mgmt.	Element + Network mgmt.
Operation	SNMP Get, Set, Trap	HTTP operation (Get, Post)	HTTP operation (Get, Post)
Security	Community string	HTTP authentication, HTTPS	HTTP authentication, HTTPS
Development Expertise	Yes	Yes	Yes
Resource	Small	Small	Medium

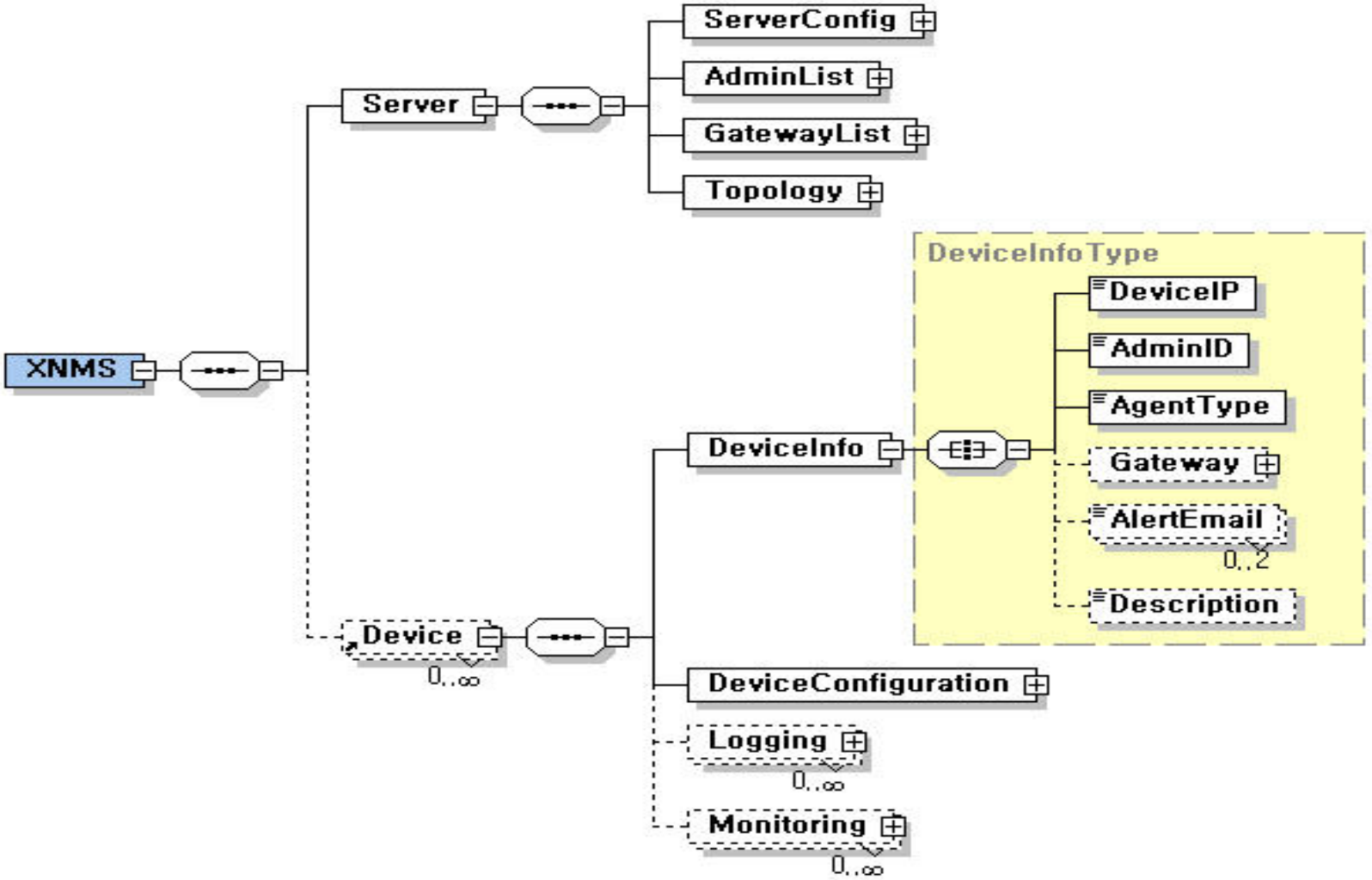
Management Information Model (1)




```
<xsd:element name="system">
<xsd:complexType>
  <xsd:all>
    <xsd:element ref="sysDescr" minOccurs="0"/>
    <xsd:element ref="sysObjectID" minOccurs="0"/>
    <xsd:element ref="sysUpTime" minOccurs="0"/>
    <xsd:element ref="sysContact" minOccurs="0"/>
    <xsd:element ref="sysName" minOccurs="0"/>
    <xsd:element ref="sysLocation" minOccurs="0"/>
    <xsd:element ref="sysServices" minOccurs="0"/>
  </xsd:all>
 </xsd:complexType>
</xsd:element>
<xsd:element name="sysDescr">
 <xsd:complexType>
  <xsd:simpleContent>
    <xsd:restriction base="DisplayString_0_255">
      <xsd:attribute name="access" type="xsd:string"
            use="fixed"  value="read-only"/>
    </xsd:restriction>
  </xsd:simpleContent>
 </xsd:complexType>
</xsd:element>
...
```

<Management Information for Agent>

Management Information Model (2)

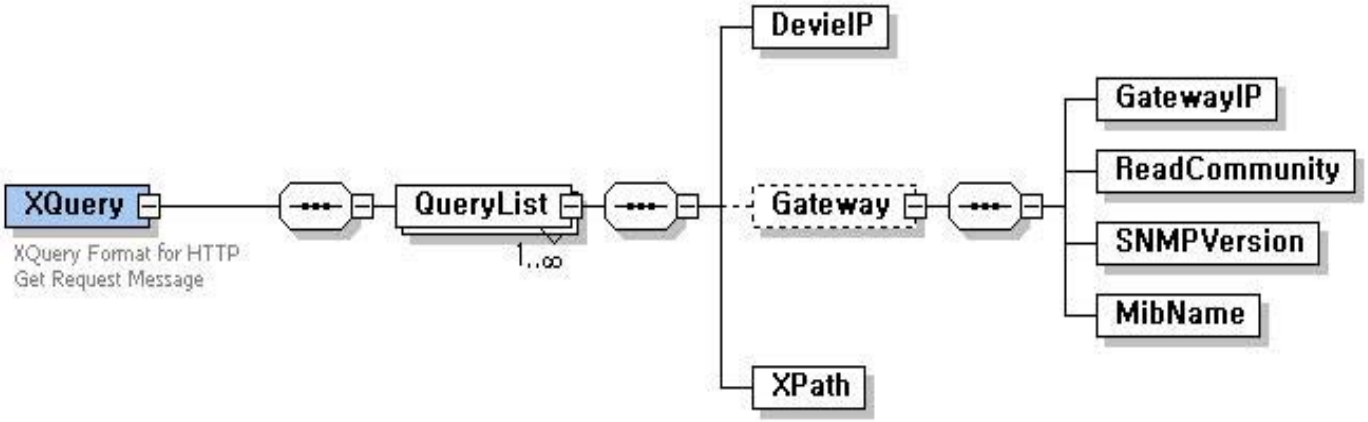


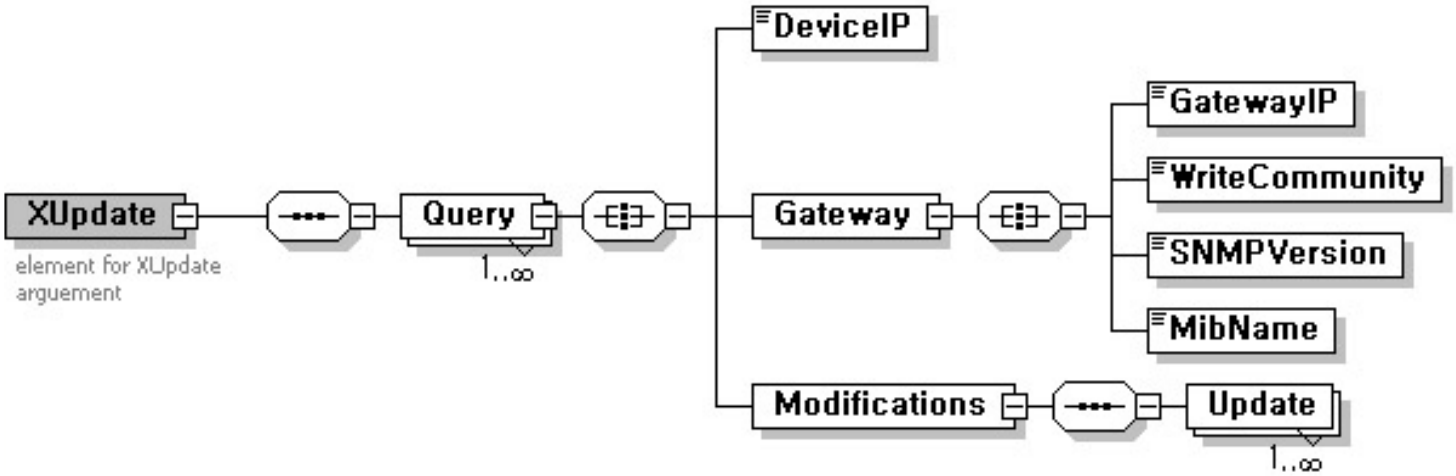
<Management Information for Manager>

Management Information Model (3)

Device equipped with an SNMP Agent	Device equipped with an XBM Agent
XNMS/Device/DeviceInfo <? xml version= “1.0” ?> <DeviceInfoList DeviceID= “device1” > <DeviceIP>141.223.82.121</DeviceIP> <AdminID>mjchoi</AdminID> <AlertEmail>mjchoi@postech.ac.kr</AlertEmail> <AlertEmail>siwa@postech.ac.kr</AlertEmail> <AgentType>1 (SNMP agent)</AgentType> <Gateway > <GatewayIP>141.223.82.77</GatewayIP> <ReadCommunity>public</ReadCommunity> <WriteCommunity>private</WriteCommunity> <MIBName>RFC1213-MIB</MIBName> </Gateway> <Description>Linux Machine</Description> </DeviceInfoList>	XNMS/Device/DeviceInfo <? xml version= “1.0” ?> <DeviceInfoList DeviceID= “device2” > <DeviceIP>141.223.82.122</DeviceIP> <AdminID>mjchoi</AdminID> <AlertEmail>meanie@postech.ac.kr </AlertEmail> <AgentType>2 (XBM agent) </AgentType> <Description>IP Sharing Device </Description> </DeviceInfoList>

Management Protocol (1)





Management Protocol (2)

❖ XQuery (Get)

Between XNMS and the XML/SNMP Gateway	Between XNMS and the XBM Agent
http://XNMS/monitoring.jsp?XQuery=<XQuery> <QueryList><DeviceIP >141.223.82.121</DeviceIP> <Gateway><GatewayIP>141.223.82.56</GatewayIP> <ReadCommunity>pubic</ReadCommunity> <SNMPVersion>0</SNMPVersion> <MibName>RFC1213-MIB</MibName></Gateway> <XPath>//interfaces</XPath></QueryList></XQuery>	http://XNMS/monitoring.jsp?XQuery= <XQuery><QueryList> <DeviceIP >141.223.82.122</DeviceIP> <XPath>//interfaces</XPath> </QueryList></XQuery>

❖ XUpdate (Set)

Between XNMS and the XML/SNMP Gateway	Between XNMS and the XBM Agent
http://XNMS/monitoring.jsp?XUpdate=<XUpdate> <Query><DeviceIP>141.223.82.72</DeviceIP> <Gateway><GatewayIP>141.223.82.121</GatewayIP> <WriteCommunity>media</ WriteCommunity> <SNMPVersion>1</SNMPVersion> <MibName>RFC1213-MIB</MibName></Gateway> <Modifications><Update select=”//sysConact”>admin</Update><Update>… </Update></Modifications></Query></XUpdate>	http:// XNMS/monitoring.jsp? XUpdate=<XUpdate><Query> <DeviceIP>141.223.82.122</DeviceIP> <Modifications><Update select=”//sysConact”>admin</Update> <Update>…</Update></Modifications> </Query></XUpdate>

Analysis (1)

Operation	DOM Interfaces
Creation	**interface Document : Node** • Element createElement(in DOMString tagName) **interface Node** • Node appendChild(in Node newChild) raises(DOMException) • Node insertBefore(in Node newChild, in Node refChild) raises(DOMException)
Deletion	**interface Node** • Node removeChild(Node oldChild) raises(DOMException)
Navigation/ Retrieval	**interface Node** • readonly attribute Node parentNode • readonly attribute Node firstChild • readonly attribute Node lastChild • readonly attribute Node previousSibling • readonly attribute Node nextSibling • readonly attribute NodeList childNodes **interface NamedNodeMap** • Node getNamedItem(in DOMString name) **interface Document** • NodeList getElementsByTagName(in DOMString tagname)
Setting values/ Modification	**interface Node** • attribute DOMString nodeValue **interface Element : Node** • void setAttribute(in DOMString name, in DOMString value) raises(DOMException)

Analysis (2)

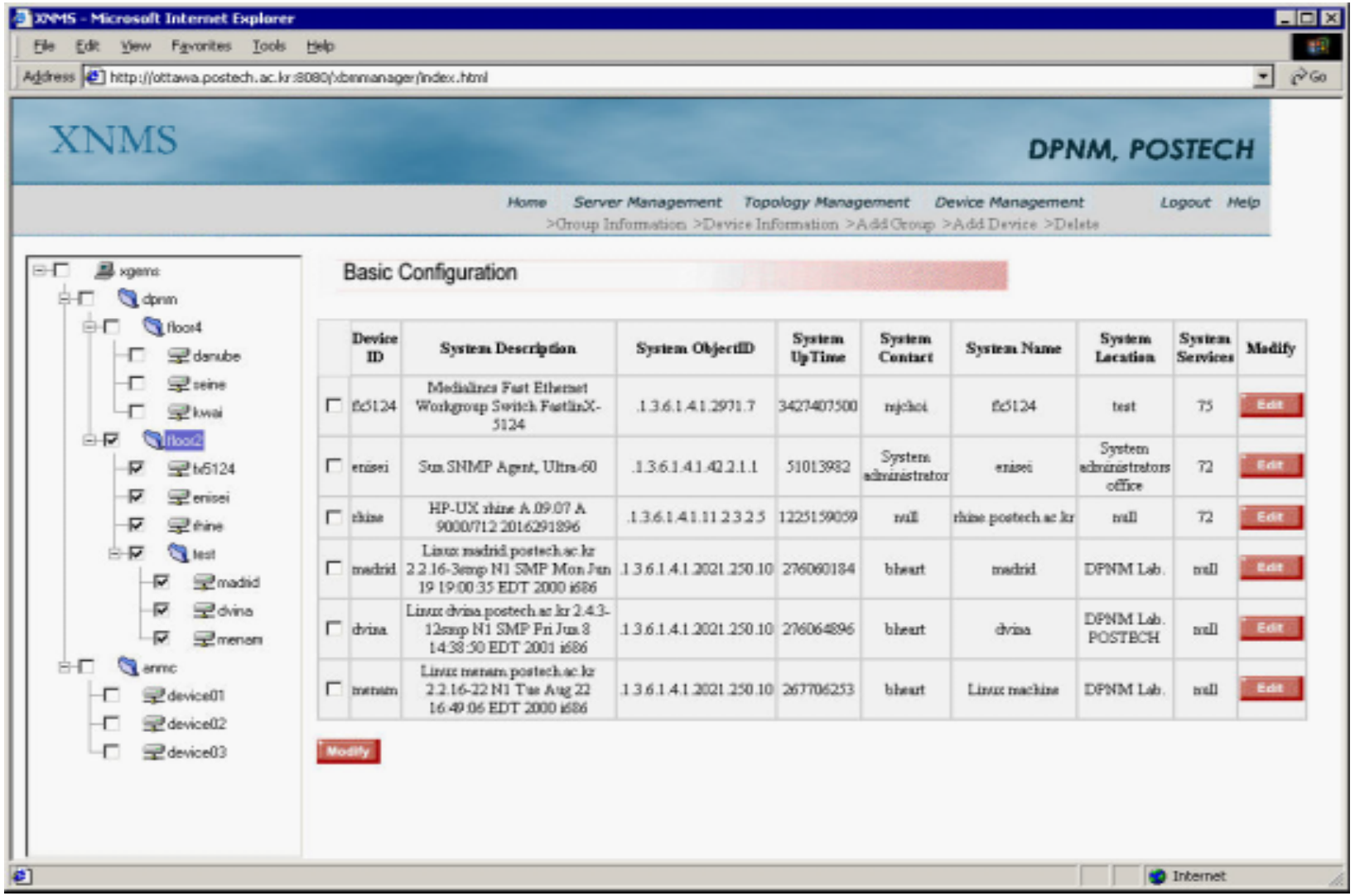
Operation	DOM Interfaces
Filtering & Scoping	**interface XPathEvaluator** • XPathExpression createExpression • DOMString lookupNamespaceURI(in DOMSring prefix) • Node iterateNext() raises(XPathException, dom::DOMException) • Node snapshotItem(in unsigned long index) raises(XPathException) **interface NodeFilter** • short acceptNode(in Node n) **interface TreeWalker :TreeWalker** **interface NodeIterator** • Node nextNode() raises(dom::DOMException) • Node previousNode() raises(dom::DOMException) • void detach()

Presentation (1)

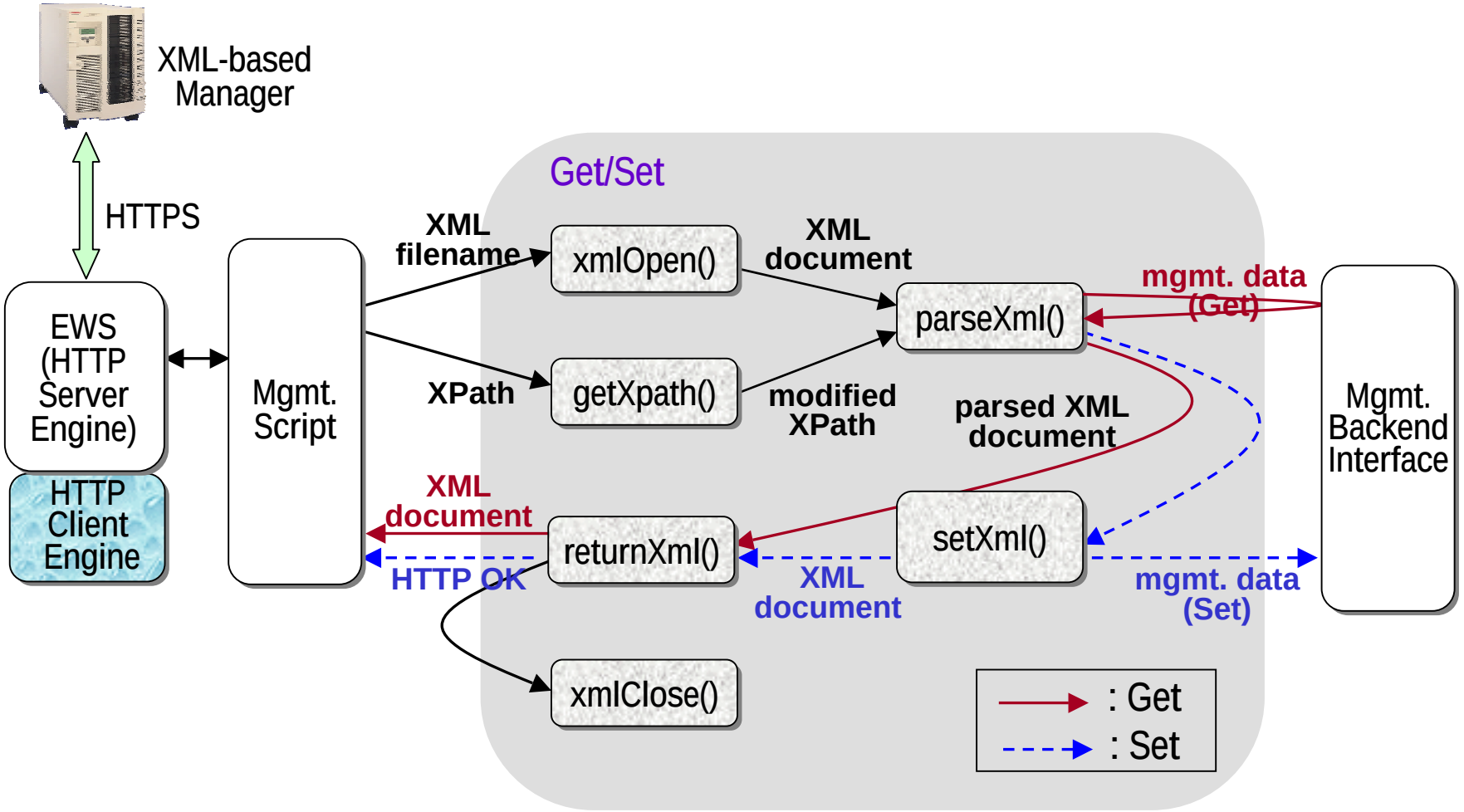
XML	XSL

…
<system>
<sysDescr>IBM IRC System/6000
Machine Type </sysDescr>
<sysObjectID> .1.3.6.1.4.1.2.3.1.2.1.1.2
</sysObjectID>
<sysUpTime>120774384</sysUpTime>
<sysContact>mjchoi@postech.ac.kr
</sysContact>
<sysName>seine</sysName>
<sysLocation>DPNM,
PIRL</sysLocation>
<sysServices>72</sysServices>
</system>
…
	<xsl:template match="sysDescr|
	sysObjectID|sysUpTime|sysContact|sysN
	ame|sysLocation|sysServices">
	<Script Language="JavaScript">
	var val = "<xsl:value-of select="."/>";
	if (val == "" || val == " ")
	val = "null";
	data += "|" + val;
	document.write('<td>\<p
	align="center">' + val + '\</p>\</td>');
	</Script>
	</xsl:template>

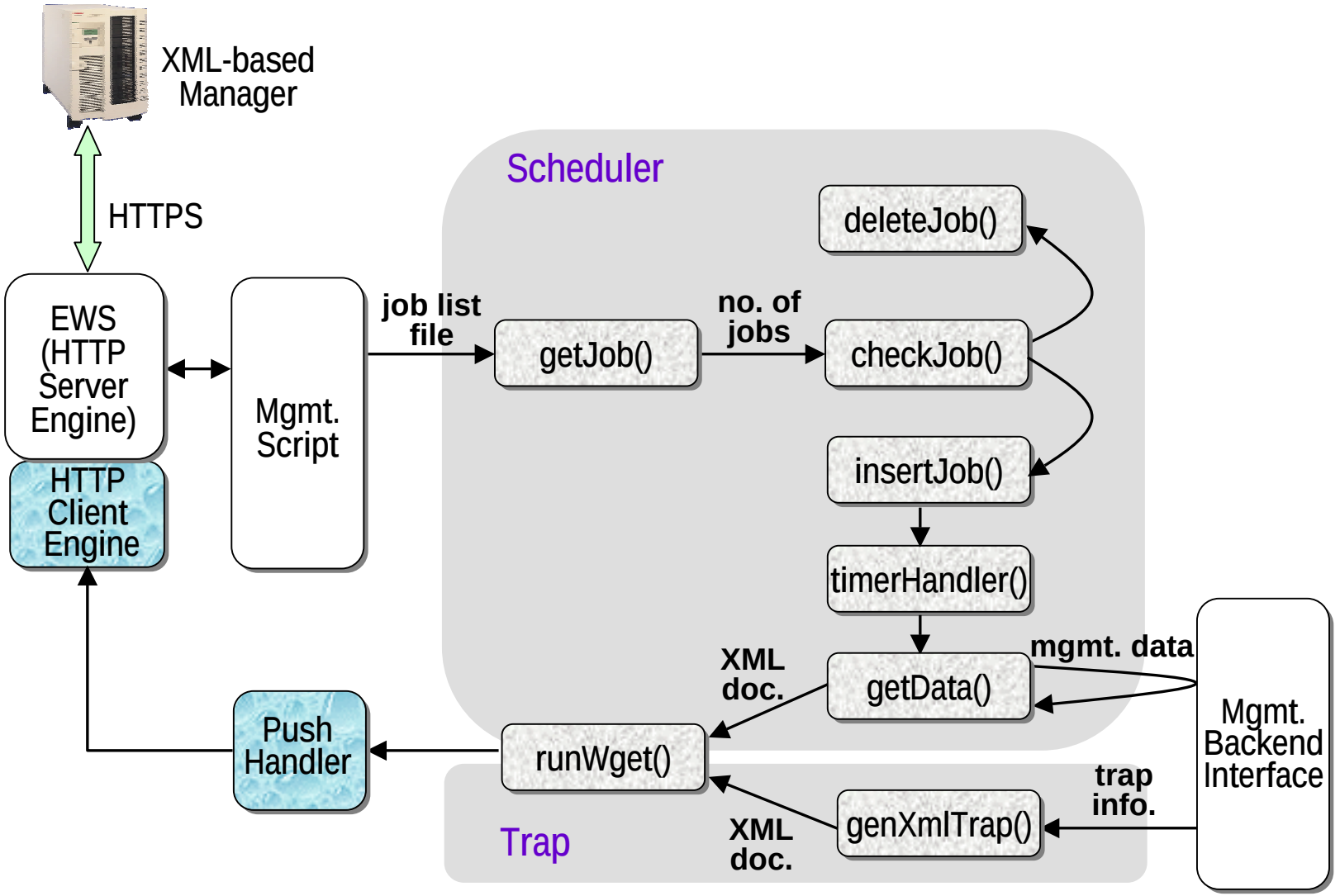
Presentation (2)



XBM Agent – Get/Set



XBM Agent - Trap



XBM Agent - XPath

Grammar	Explanation	Example
/	The basic Xpath syntax similar to filesystem addressing	//AAA/BBB
//	All elements in the document which fulfill following criteria are selected	//BBB
*	All elements located by proceeding path	//*
@	Attributes are specified by @ prefix	//@id
[ ]	Filter	BBB[@id='b1']
=	Comparative operator	BBB[@id='b1']
|	Equals to logical OR	//AAA | //BBB
&	Equals to logical AND	//AAA & //BBB

Implementation (1) – XBM Manager

- Implementation environments
  - Linux Server with Pentium-III 800 MHz CPU and 256 MB RAM
  - Apache Xerces 1.4.4 for XML parser
  - Apache Xalan 2.4.0 for XPath & XSLT processor
  - Apache Xindice 1.0 for XMLDB
  - Apache Tomcat 4.0 for HTTP server
  - Innovation's HTTP Client V0.3

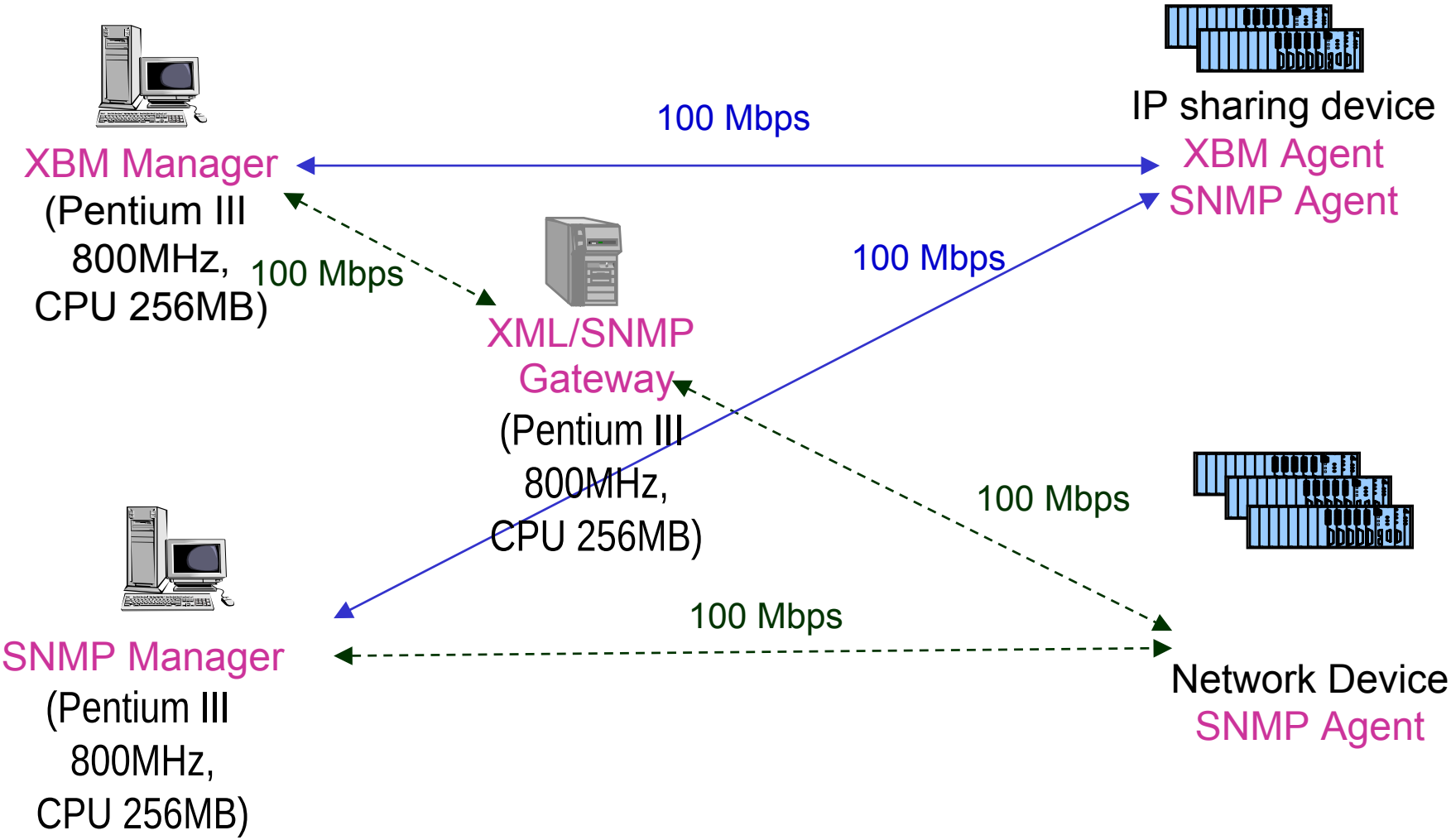
Implementation (2) – XBM Agent

- Implementation considering requirements
  - Low Resource Utility: Implement parts of XML parser and XPath handler for processing management information in XML format
  - Portability: Develop components for each module using C language
  - Security: The access is permitted through authentication with ID and password in the initial contact
- Implementation environment (IP sharing device)
  - Processor: MPC850DE
  - ROM Size: 16MB
  - OS: Embedded Linux based on linux2.2.13-7 Kernel
  - Compiler: powerpc-linux-gcc

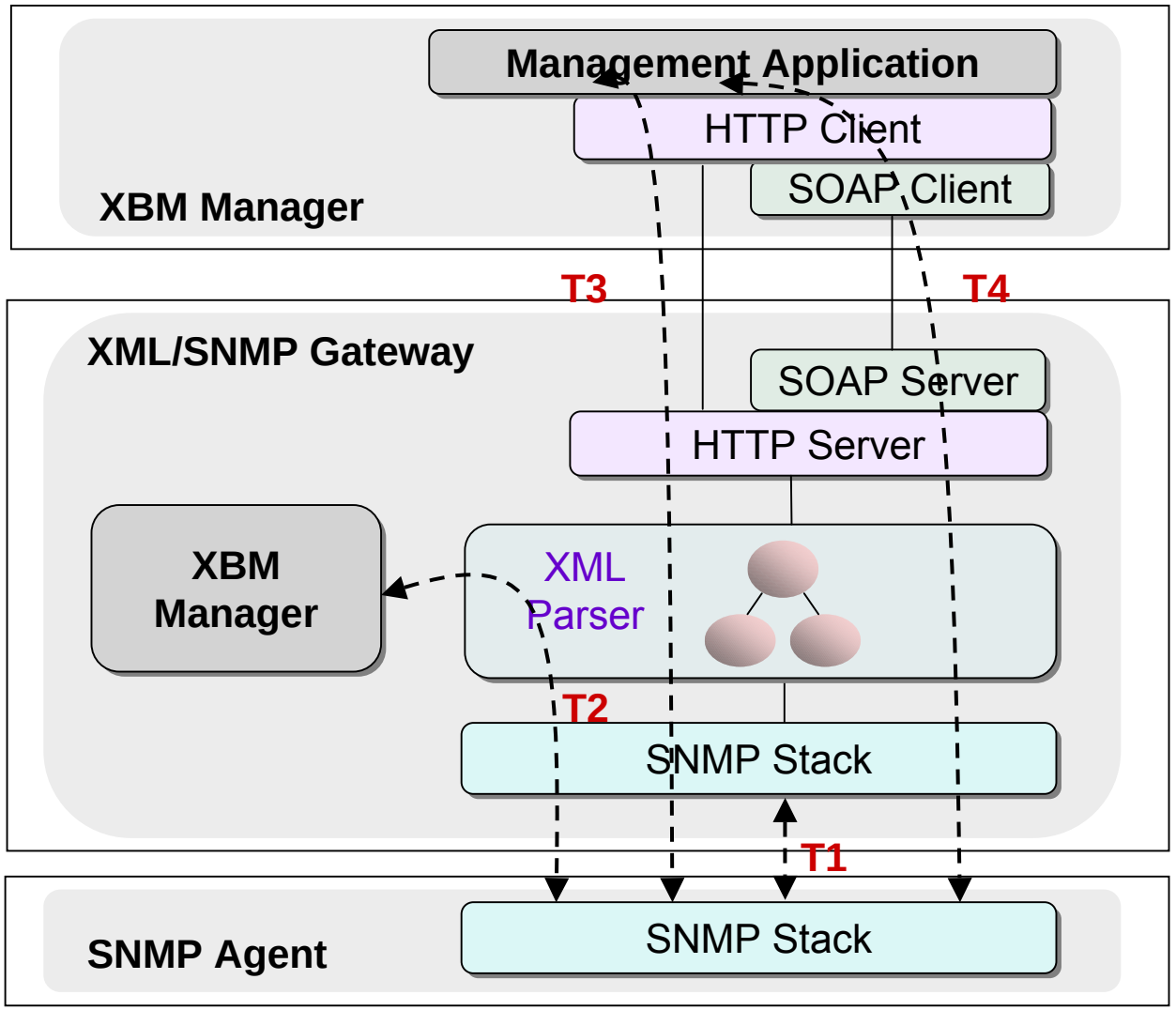
Implementation (3) – Gateway

- Implementation environments
  - Linux Server with Pentium-III 800 MHz CPU and 256 MB RAM
  - Apache Xerces 1.4.4 for XML parser
  - Apache Xalan 2.4.0 for XPath & XSLT processor
  - OpenNMS's joeSNMP 0.2.6 for SNMP Handler and Trap Handler
  - Apache Tomcat 4.0 for HTTP server
  - Innovation's HTTP Client V0.3

Performance Evaluation Environments



Performance Evaluation - Gateway



Performance Evaluation -Gateway

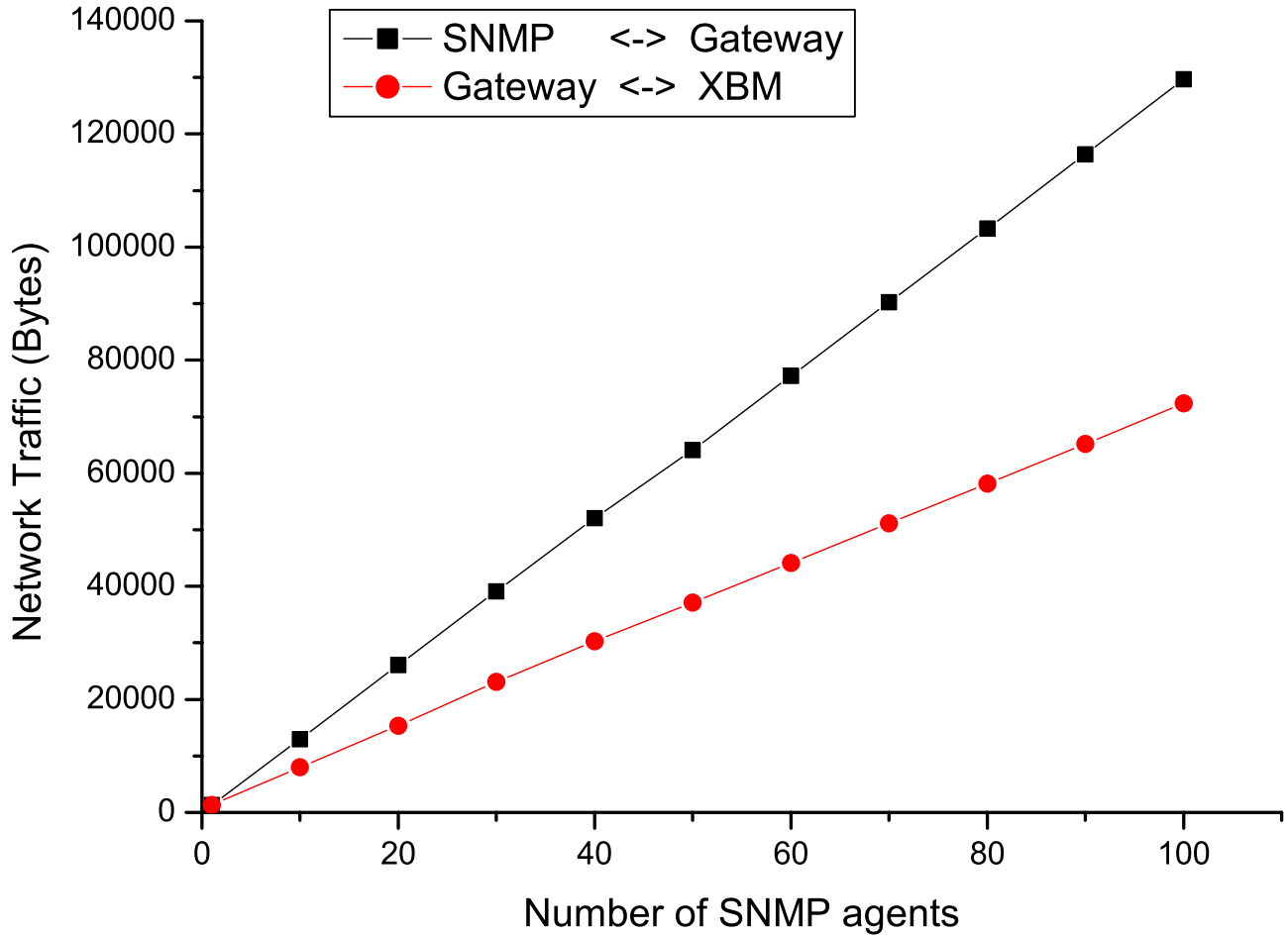
❖ Response time (MIB II)

Device (MIB size) Method	Device 1 (28 KB)	Device 2 (54 KB)
SNMP Stack: T1 (ms)	1307.1	4283.6
XML Parser-based Translation: T2 (ms)	1360.6 (4.1 %)	4317.6 (0.8 %)
HTTP-based Translation: T3 (ms)	1419.1 (8.6 %)	4418.8 (3.2 %)
SOAP-based Translation: T4 (ms)	1613.3 (23.4 %)	4922.2 (14.9 %)

< Response Time of Get >

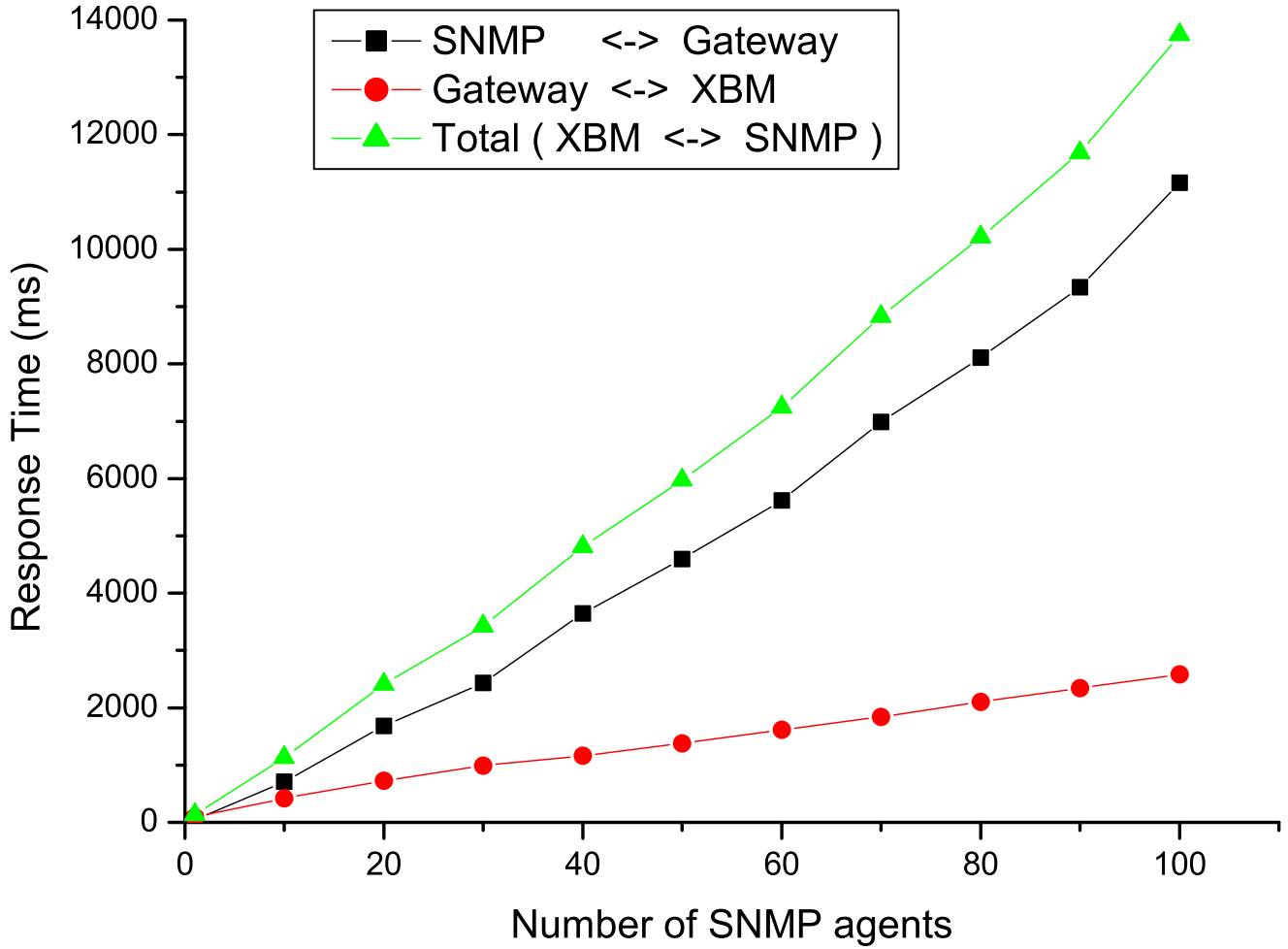
Performance Evaluation -Traffic

- Network Traffic (MIB II – system group)



Performance Evaluation – Response Time

- Response Time (MIB II – system group)



Performance Evaluation – Resource Utility

❖ CPU Usage & Memory Usage