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Integrated Network Management Systems Using Mobile Agents: A Prototype

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ABSTRACT

Today's network management is still dominated by the platform-centered paradigm based on Client/Server technologies. This centralized approach has drawbacks in scalability, reliability, efficiency and flexibility, and is unsuitable for large and hetero-generous networks. Mobile Agent-based technologies represent an opportunity to solve some of those problems. In this paper a new Web- and Mobile Agents-based network management framework is proposed and the results of a prototype implementation are discussed.

BACKGROUND

Despite the fact that networks are becoming larger and more complex, today's network management is still dominated by the platform-centered paradigm based on Client/Server (C/S) technologies (e.g. SNMP). This centralized approach has drawbacks in scalability, reliability, efficiency and flexibility, and is unsuitable for large and heterogeneous networks (Goldszmidt et al., 1998; Lazar et al., 1997; Yemini, 1993).

Numerous studies have shown that new technologies such as Mobile Agents (MA), CORBA and Web technologies have individually solved some of the problems associated with network management (Baek et al., 1998; Baldi et al., 1997; Bieszczad et al., 1998; Deri et al., 1997; Goldszmidt et al., 1998; Haggerty et al., 1998; Hegering et al., 1999; Luo et al., 1999; Terplan, 1999; Wren & Gutiérrez, 1999). However, few studies have looked into the impact of combining the strengths of these new technologies on an integrated network management system (INMS).

The paper is organised as follows: section 2 briefly describes the key components of the proposed model. Section 3 presents the proposed INMS framework. Section 4 describes how the framework facilitates the integration of network management information; and finally section 5 includes the conclusions and summarizes the paper.

THE CONCEPTUAL MODEL

This conceptual framework was derived from a rigorous compilation of the agent-, CORBA- and web-based network management literature. The goals in designing a scalable INMS with the help of these new technologies include:

- To improve accessibility and ease-of-use
- To solve the problems of scalability, extensibility, and interoperability
- To solve current efficiency and flexibility problems
- To solve the legacy interoperability problem

The proposed framework (Figure 1) was designed with those goals in mind.

The conceptual model follows a completely distributed architecture with the following components:

- Web browsers act as accessible, easy-to-use, portable user interfaces
- A CORBA ORB acts as the scalable, extensible, interoperable middleware with support for legacy Network Management (NM) applications, MA-based NM applications as well as CORBA-based NM applications.
- Mobile agents supports efficient, reliable and interoperable executions; extend the functionalities of CORBA, and support legacy integrations such as with SNMP services
- Optionally, network management gateways support legacy systems interoperability.

Each component and various factors that affect each component will be described in more detail in the following section.

Figure 1: The conceptual model of the proposed scalable INMS Framework

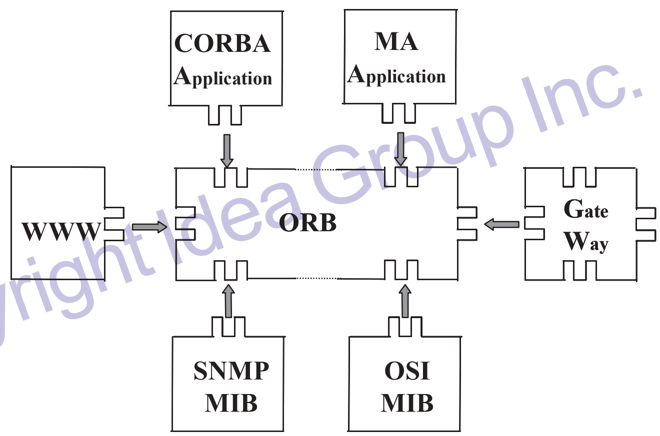
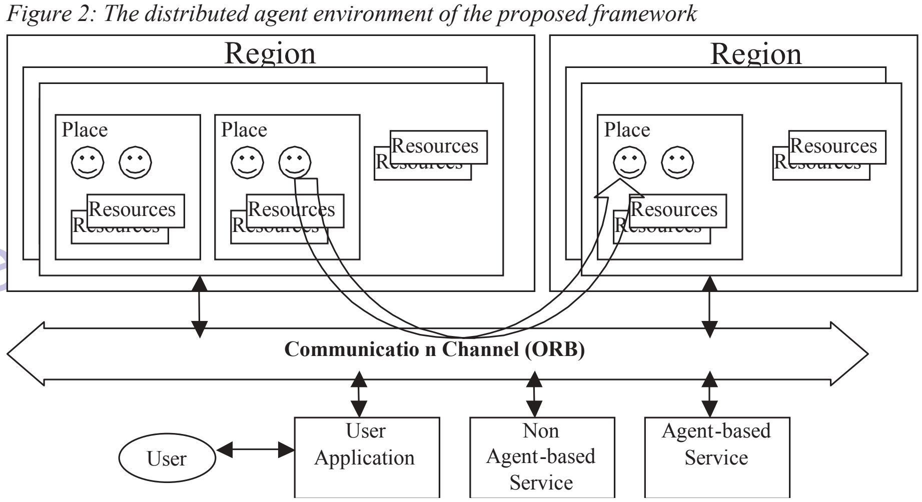


Figure 2: The distributed agent environment of the proposed framework



THE PROPOSED FRAMEWORK

The proposed framework follows a three-tier architecture: web browser, CORBA and MA-based management platform with built-in web server, and managed network resources such as agents and agencies. The environment in which the agents are executed is called a Distributed Agent Environment (DAE) or Agent Execution Environment (AEE) (See Figure 2). It consists of a set of agent systems called agencies, representing the runtime environments for mobile agents. Each agency comprises one or more places, each providing a set of resources, like a certain amount of memory, access to a file system and SNMP services. Agencies can be grouped into regions or domains in order to facilitate management operations. For instance, a region can be associated with a single authority, providing certain security policies for each member agency.

The proposed mobile agent-based platform was built on top of an object request broker (ORB), and Java (JDK1.2) was used as the development language. The CORBA components of the AdventNet SNMP API (http://www.adventnet.com/) package were used to integrate the CORBA middleware with SNMP. Java enables distributed web-enabled applications to transparently invoke operations on remote network services using the industry-standard OMG (Object Management Group, http://www.omg.org) Interface Definition Language and the Internet Inter-ORB protocol defined also by the OMG. The agent transport and further interactions between DAEs and non-DAE components are performed via CORBA mechanisms. In this way, standard services such as CORBA trading, naming, or event services can be used to enhance the platform functionality in a very comfortable manner.

INTEGRATED NETWORK MANAGEMENT

The framework proposed is an object-oriented information model where the value of an object's attribute can be defined as an arbitrary computation (i.e., by a mobile agent) over other attribute values (i.e., SNMP MIB parameters). The latter can be information residing inside element management agents (i.e., SNMP agents) or other computed attributes (i.e., results produced by mobile agents). Figure 3 shows the data structures and different levels of access.

Figure 3: Data structure and levels of access

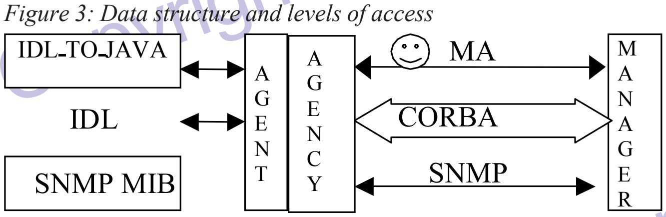
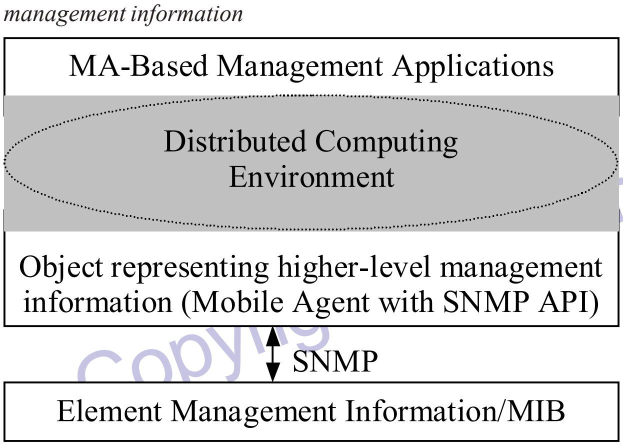
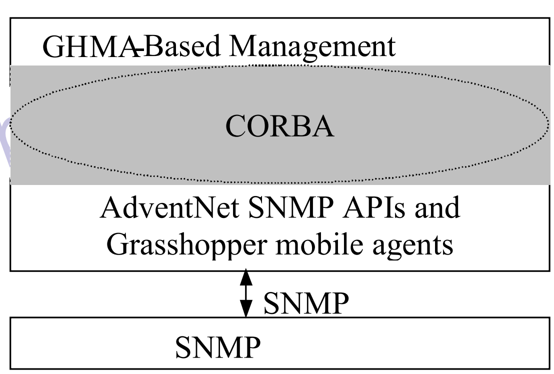


Figure 4: Three-level architecture for generating computed views of management information





With this OO information model, network managers can define and interact with managed objects that represent a "computed view " (Anerousis, 1999) of management information. Computed views can represent a summary of lower level configuration and performance information. The objects representing computed views of management information could be regarded as implementing a mobile agent with "middleware management services". These middleware management services are carried by mobile agents that move around the network, extracting information from local managed elements using a standards-based management protocol such as SNMP, processing this information according to the specification of the computed view, and making it available to management applications through a distributed computing environment (i.e., CORBA or Java) (See Figure 4). This higher-level management information improves the efficiency of the INMS. Network managers hence don't need to interact with and interpret raw management data. In our prototype we used a Grasshopper (IKV, 1999) mobile agent with an AdventNet SNMP API.

The SNMP data handling services included a set of Java classes for high-level representation of SNMP data types and Protocol Data Units. A set of Java-based ASN.1/BER encoding methods is also available to be used by other SNMP Services.

The SNMP manager service selected by the proposed framework allows mobile agents to interact with SNMP agents using a third-party SNMP stack integrated in the agents code; to query SNMP agents, and includes a Trap Listener that receives SNMP traps and redirects them to the interested mobile agents.

The prototyping for the proposed INMS framework included a scenario of Web-SNMP integration, a scenario of CORBA-SNMP integration, and a scenario of MA-SNMP integration. This paper discusses the MA-SNMP scenario. Full details of the complete prototype system and proof-of-concept experiments can be found in Cui (2000).

The INMS consists of a HTTP Web server, Java applets and the management platform, which performs network management operations. The web server that allows for remote access and control from standard web browsers brings ease-of-use, and accessibility to network management development. Additionally, the lower cost of web and Java technologies improves the cost/benefit ratio of these enhanced systems. A dynamic binding mechanism, which is realized by implementing interfaces using CORBA IDL, is used for linking a manager (either legacy or MA-based applications) to the platform. The resources of a managed network are thus modelled with abstractions (i.e. service names). This makes the management operation efficient and consistent and also improves the extensibility and interoperability of the INMS.

In summary, the presence of web technology decouples user interfaces from traditional NM consoles, supports web-based management and therefore improves the user friendliness and the user accessibility of the INMS. The use of CORBA technology as the INMS infrastructure increases the system's capability for handling new features without requiring significant redesign and coding; adds the capability of handling large numbers of objects without inflicting performance or resource constrains; and adds the capability of interacting with other external components to request or offer services and facilities. This improves the extensibility, scalability and interoperability of the INMS. Finally the implementation of Mobile agents-based technologies introduces a higher-level abstraction of management information, reduces data collected, allows faster, and often preventative maintenance as opposed to slow, and often reactive maintenance and hence improves the efficiency of the INMS.

PROOF-OF-CONCEPT IMPLEMENTATION

The implementation was carried out in a networking laboratory using three Cisco routers (2500 series), two Cisco Catalyst 1900 switches, an Allied Telesyn 3600 series hub and 10 Windows 95 workstations. The following applications and systems were used to develop the prototype:

- Operating systems: Windows NT Server 4.0 and Windows 95
- Browser: Internet Explorer (IE) 5.0
- MIB: WINNT SNMP services
- Web server: Jetty Web server
- ORB: JDK1.2/1.2.2 ORB and IONA's OrbixWeb3.0
- MA: Grasshopper toolkit
- SUN's JDF1.2/1.2.2 Java – used to design and map SNMP/Java/CORBA
- AdventNet API – used to design SNMP network management applications and to provide SNMP access to Web, CORBA, and MA-based applications.

We used the independent variable, "use of MA technology" to test the theory that an improvement of NM efficiency is caused by the application of MA-based technologies. We measured the response time of completing certain pre-defined SNMP operations. The measured time was an average measurement over a high number of executions.

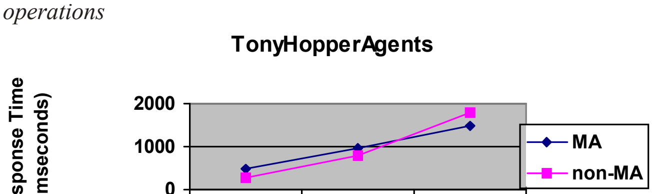
The experimental results shown in Figure 5 indicate that the performance management MA has a shorter response time than equivalent SNMP operations as the number of NEs increases. In other words, once the MA service has been established, the speed of response from SNMP operations is faster than from non-MA SNMP operations when handling a large number of objects.

Figure 6 shows the experimental results of the comparison of response times in the non-JVM NE performance management MA and the related controlled non-MA scenarios. These figures show the total time (in msec) to complete the task in a network composed of several domains each with several Ethernet-connected workstations.

The results indicate that the speed of completing the performance management tasks with agents is slightly slower than with equivalent SNMP operations. Although the prototype has proved the feasibility of managing non-JVM NE by using mobile agents, it is clear that proxy-based operations introduce significant overheads.

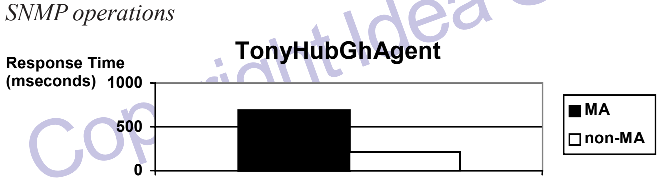
Figure 7 shows the experimental results of the comparison of response times using a policy-driven configuration management MA and the controlled non-MA scenarios. The results indicate that the speed of completing the policy-driven configuration tasks with agents is faster than with equivalent SNMP operations.

Figure 5: Comparison of TonyHopperAgents and non-MA SNMP operations



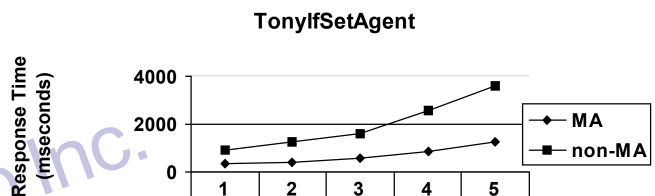
	1	2	3
MA	473	956	1490
non-MA	288	785	1792

Figure 6: The comparison of TonyHubGhAgent and the non-MA SNMP operations



MA	697
non-MA	211

Figure 7: Results of the comparison between TonyIfSetAgent and non-MA SNMP operations



	1	2	3	4	5
MA	355	415	585	850	1234
non-MA	914	1250	1615	2586	3600

Our preliminary results show that mobile agents can offer a solution more suitable than traditional solutions for dealing with computed views of management information or dealing with "what if" applications.

CONCLUSIONS

The proposed MA-based INMS framework has been compared with non-MA-based SNMP management operations. SNMP management applications have been implemented as control models. The experimental results showed that the MA-based prototype improved the efficiency of network management operators.

During the lab experiments, other characteristics of the proposed INMS have also been observed. For instance, the fact that the MA approach for network management is able to avoid any centralization point and provides better scalability and flexibility than centralized Client/Server schemes. Several administrators can be concurrently active and even cooperate to obtain a single administrative goal. It is easy to generate or destroy agents and to replicate them in case of a large number of nodes in the subnetwork. In the prototyped applications, agents act on behalf of administrators and fulfill administration needs by moving and executing on different nodes. Furthermore, it is easy to tailor new agents to meet new administration needs and/or to delegate the automation of new management tasks.

In summary, the proposed framework can be used to delegate management activities to agents as well as to add web and CORBA advantages to the INMS. The implementation of the Grasshopper management environment has shown that MA solutions can also be convenient from a performance point of view.

Currently the INMS is implemented at a homogeneous configuration. It is desirable that the concepts of the proposed framework are tested in a heterogeneous environment, which is more common in a real network. The ideas described in this paper have broad applications for distributed computing services. The current WBEM, JMX, and even Microsoft's COM/DCOM platforms may provide other ways for integrating CORBA, the web, and Mobile agents-based technologies into an INMS.

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