Toward Proactive Application-centric Management

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Abstract : Management of large-scale networks and their applications is an extremely complex task due to factors such as centralized built-in management architectures, lack of coordination and compatibility among heterogeneous network management systems, and dynamic characteristics of networks and applications. We do need to develop an integrated application and network management paradigm that is proactive, scalable, and robust. In this paper, we present a framework for Proactive Application-centric Management System (PAMS) and its implementation approach using management delegation with intelligence. We discuss preliminary results of PAMS prototype to proactively manage the network and the performance of real-time distributed applications.

Keywords: Distributed Network Management, Application Management, Delegation, Intelligent Agent

1. Introduction

The emerging high speed networks and the advances in computing technology are important driving forces to merge the communications and computing technologies that will result in an explosive growth in network complexity, size and networked applications. Furthermore, we are observing an explosive growth in network applications that use computing, networking and storage resources that can be accessed from global national and/or international networks. The management of such networks and their distributed applications has become increasingly complex, and unmanageable. Unfortunately, the current network management technologies focus on collecting management information and manually manage the network using platform-specific products. Furthermore, as the size and complexity of networks grow, even the type of information collected is not comprehensive enough to diagnose the operations of complex interacting systems. There has been little research toward the development of intelligent, efficient, proactive end-to-end management of large networks and their applications.

The main approaches of network and system management have been influenced by three standards organizations – the Internet Engineering Task Force (IETF), open system interconnection/International Telecommunication Union (OSI/ITU) and the Desktop Management Task Force (DMTF). The first management standard, the OSI/ITU systems management standards and its associated protocol, Common Management Information Protocol (CMIP) focuses on a extensive and fastidious approach to network management, protocol architecture, and resource-specific information models for network management functions – configuration, fault, performance, security and accounting. Nevertheless, CMIP is a complex architecture and it is difficult to implement. The Simple Network Management Protocol (SNMP) was introduced to provide an alternative approach to CMIP and it emphasizes simplicity of implementation. The management information bases (MIBs), which express a core set of attributes, are defined to describe the managed environments. But there is little effort to support various common abstraction form of data model such as inheritance or association; it requires the data modeler to capture these abstractions on the top of SNMP and causes inconsistency among the vendor-specific data models. Recently, DMTF introduced Common Information Model (CIM), which provides information-modeling framework that encompasses networks, applications and systems, and extends traditional management information; but does not focus on communication protocol aspect[Patrick98].

As the complexity of network management grows because of diversity of networks, systems and applications, the notion of a centralized manager- multiagents principle over communication protocols (i.e. CMIP and SNMP) has been shown their limitation of capacity and their overhead over large-scale networks. The increased importance of network management for large-scale networks has stimulated research on novel approaches to reduce the management complexity and cope with dynamic management change. Instead of a centralized manager, multi-managers and their communication protocols are proposed. As a decentralized and dynamic management, Management by Delegation (MbD)[Gold95] and Code Mobility [Baldi97] approach have been proposed to show how today's network devices are capable of managing themselves. A management station specifies a set of commands for agents and delegates its actual execution to the devices. It reduces traffic around the management station, deals with less link failures among the management station and devices and distributes the processing loads to perform the task.

Instead of manger-agent relationship among managers and agents, peer-to-peer relationship using the Common Object Request Broker Architecture (CORBA) has been studied in the area of Telecommunications Information Networking Architecture (TINA) framework [Pavon98]. A few web-based approaches to network management have emerged recently. The Java Management API (JMAPI) is another management solution for current heterogeneous networks with plentiful set of extensible objects and methods for developing seamless system, network and service management. The main direction of the Web-Based Enterprise Management Architecture (WBEM) is to combine and integrate the data provided by existing management techniques to manage the problem from the application level through the systems and networks [Patrick98].

However, distributed network management of applications over heterogeneous has not fully studied and is becoming increasingly important. Recently, Application Management MIB [AM98] and MIB for Application [Appl98] have been proposed to collect and store common application management information in IETF. Common Information Model (CIM) by DMTF is proposed a similar process information definition for WBEM [Patrck98]. Still, there has been little work done to achieve programmable application management schemes and is not well understood.

To provide effective and intelligent management for an application, the concept of proactive management is introduced; it involves the anticipation of possible problems, which may occur in systems and networks, the detection before they occur, the avoidance of similar problems in advance. We found that intelligent support using Artificial Intelligence (AI) and expert system would help to achieve automation of network management tasks and make dynamic decisions with minimal involvement of human manager.

The main goal of our research is to develop a management system to achieve end-end proactive application-centric management. In this paper, we present our approach to design and implement a Proactive Application-centric Management System (PAMS) for large-scale network management. We apply delegation and intelligence schemes to reduce management complexity and get better application performance. In Section 2, we describe the PAMS architecture. In Section 3, we discuss our experimental results with PAMS prototype. In Section 4, we present concluding remarks and future research.

2. PAMS Architecture

The architecture of PAMS shown in Figure 1, utilizes the capabilities of the AnalysisWare The overall goal of PAMS is to develop programmable management services to ensure stable and secure operation of large-scale information systems and their applications or services. The main key components of PAMS(see Figure 1) include Application-centric Management, Intelligent Controller, Management Agent Template, Distributed Monitoring, System Baseline, Application baseline, and Predictive Analysis. The Agent-based Management Server creates, monitors and controls the application-centric management service to ensure that the application execution meets its operational and quality of service requirements. For each application or a service, we define an application centric management program that describes the management functions required to maintain its operational, security, fault and configuration requirements. The Management Agent Template generates the appropriate type of mobile agents (MA) required to control and manage that application operation.

Our approach is based on using delegated agents to implement the management functions required by an application. We have investigated and designed the delegation of management activities from the managing system to the managed systems by means of remote execution of mobile software agents. This will enable the execution of dynamic mobile agents, which contain management controls, i.e. sequences of management operations. Hence the network elements can act autonomously of the operations system for performing specific management tasks. The management controls could be activated based on time, management actions, or occurrence of monitored events that cross certain thresholds. One strength of this approach is that different mobile agents could be sent to different managed systems according to the desired application management tasks. Furthermore, cooperation between mobile agents located at different managed systems or the managing system is possible, if the agent technology used in the implementation supports agent cooperation.

Knowledge-based approach is used because of its automatic evaluation of the system conditions, recognition of complex impact chains and ability to offer recommendations. We use intelligent agent scheme; it is a self-contained software element responsible for performing part of a programmable process. Therefore, it contains some level of intelligence, ranging from simple predefined rules to self-learning AI inference machines. It acts typically on behalf of a user or a process enabling task automation.

In application-centric management, we do need to develop programmable management services to ensure stable and secure operation of large-scale information systems and their applications or services.

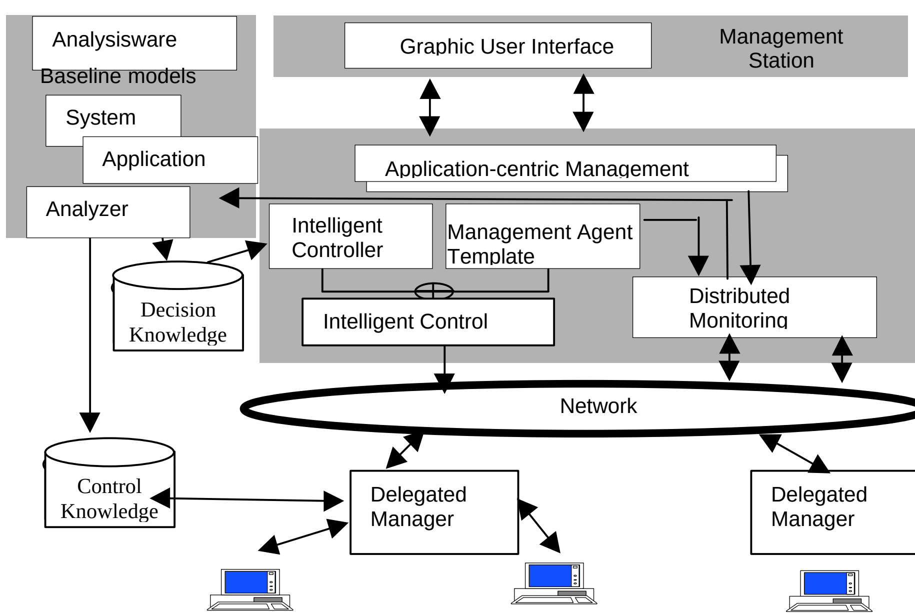


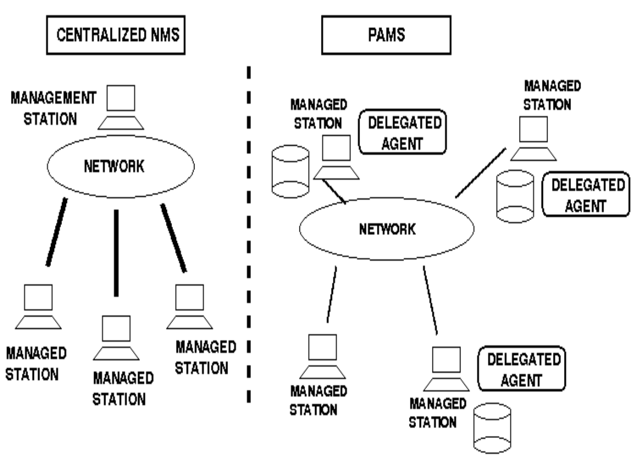
Figure 1: An Architecture of PAMS

For each application or a service, we define an application-centric management program that describes the management functions required to maintain its operational, security, fault and configuration requirements. The Management Agent Template generates the appropriate type of mobile agents (Delegated Manager) required to control and manage that application operation. The intelligent controller receives alarm events from the network monitoring module as well as the management requirement and issues an alarm and/or reconfiguration management task once the operational resources of the distributed information system or a managed application behavior deviates from an acceptable range of operation.

3. Experimental Results

In this section, we evaluate the bandwidth and response time of some management functions (traffic analysis and evaluation, error management, and application fault) using PAMS delegated agents and a centralized management system. Figure 2 shows the resources used in our experimental environment.

Figure 2: Experimental Environment



Experiment 1: Traffic Analysis and Evaluation

In this experiment, it is continuously required to evaluate and monitor the amount of traffic between consecutive interval, and displays the amount of traffic changes between the consecutive intervals. In a centralized NMS, the management station needs to obtain traffic for each interval for all the managed machines, i.e.

```
for each managed resource i do
        obtain fraffic_value(t)
        difference between traffic_value(t) and
        traffic_value(t-1)
End for
```

For n resource, the time of SNMP messages required to obtain these information is $n * (S * msg)$, where S is number of SNMP messages, and msg is network time to transfer a message and to get the summary of traffic of each machine, n* comp is required, where Comp is the computation time required to obtain the summary of traffic for a machine.

To achieve the same using a delegated agent in PAMS, the following is required.

- Load a management agent on each management resource
- Each agent computes the following simutaneously
    - traffic_difference(t) = traffic_value(t) – traffic_value(t-1)
    - Send traffic_difference(t) to management station

The transfer time of messages is $n* msg$ in the worst case (sequential communications).

$$Speedup = \frac{n*(S*msg+Comp)}{n*msg+Comp}$$

In addition, the processing time on the server is much faster since the computation is done distributively at each managed resource. Figure 3 shows the response time for two approaches.

Experiment 2: Error Management

In this experiment, it is required to monitor the amount of error rate at each interface. We compare the bandwidth required to achieve this managed task using our approach and compare against the centralized approach.

```
For each managed machine i do
        - Obtain the error rate at machine i's
        interface
        - if Error_rate (i) > Error_threshold then
                send a message to the machine to
                disable interface over network
End For
```

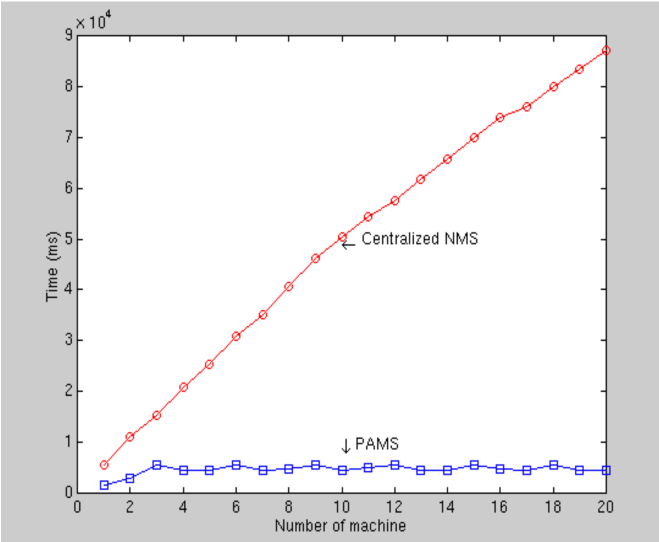


Figure 3 the comparison of response time for Centralized NMS and PAMS

Using PAMS approach, the agent will perform the following routine:

- monitor error_rate
- if error_rate > Error_threshold then
  disable the interface locally

The number of messages required in SNMP approach is n * S * msg since checking for errors is performed in the centralized management station. In PAMS approach, the number of messages is n * msg when the error rate meets the threshold. In delegated agents, there is no traffic overhead when there is no error detected in the system. In addition, the processing time is much less in our approach because the computation are performed locally at each node rather than being implemented on the management station.

Experiment 3: Automation of Application Fault Management

In the experiment, we focus on the automation of application fault management. Currently, we are building up the architecture of the management system, which allows users to design management tasks to support a specific application requirement (e.g., fault-tolerance capability). The task has intelligence to cope with any unexpected events and provide transparent management to the application execution. Like Application MIBs [Appl98][AM98], we define simple AIB (Application Information Base) to hold user requirement, system requirement, execution and management. We monitor the execution of a given application and when the application is crashed/killed, the manager provides proactive action by assigning a new machine to maintain the fault tolerance requirement. The average recovery time after detecting application fault is 50 milisecond. As it is impossible to implement with existing NMS, we claim that it is a significant experiment to manage an application fault.

4. Conclusion

In this paper, we presented a novel approach to implement end-to-end proactive application-centric network management system. Our approach is scalable and utilizes delegated agent approach to implement distributed management services. We have also compared our approach with the traditional NMS approach when applied to analyze traffic, error management and application fault management. Our preliminary results show superior performance gain in our approach. We are currently extending PAMS capability and developing generalized models for networks and applications.

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