A Framework for End-to-End Proactive Network Management

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ABSTRACT

Current advances in networking, computing, software and web technologies have led to an explosive growth in the development of networked applications. Management of large-scale networks and their applications is an extremely complex task due to factors such as centralized management architectures, lack of coordination and compatibility among heterogeneous network management systems, and dynamic characteristics of networks and application bandwidth requirements. We do need to develop an integrated network management paradigm that is proactive, scalable and robust. In this paper, we present a framework for end-to-end proactive management of global heterogeneous networks and their applications. Our framework consists of a three-level hierarchy: Network and Protocol Management (NPM), Management Computing System (MCS), and Application-Centric Management (ACM). The NPM layer addresses the issues of utilizing existing network management tools, abstracting their collected management information, and providing proactive management services to manage networks and protocols. The MCS layer addresses the core system management issues and provides system management services to enable the development of efficient proactive management of a wide range of network applications. The ACM layer addresses the issues required to develop application specific management techniques, and manage applications so they can meet their requirements in real-time.

1. Introduction

The emerging high speed networks and the advances in computing technology and distributed software tools are important driving forces to merge the communications and computing technologies that will result in an explosive growth in network complexity, size and applications. In fact, it is becoming even more difficult to distinguish between computing and communication technologies. For example, a high performance switching system (ATM switch) applies all the advances in parallel processing and system software to achieve its communications functions. 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 global networks and applications has become increasingly complex and unmanageable. Unfortunately, the current network management techniques have not addressed effectively the research issues that could lead to the development of intelligent, efficient, proactive end-to-end management of large networks and their applications.

Most of the current research and available network management technologies focus on collecting management information and manually manage the network (passive management). Furthermore, even the type of information collected is not comprehensive to achieve end-to-end robust management functions. There has been little work done to make network management systems proactive and intelligent. By making network management systems proactive, all management functions will be improved and the network can respond in a timely manner to any changes in application requirements and available resources. The concept of management system and programmable application management schemes has not been investigated thoroughly and is not well understood. The main goal of our research is to develop a management framework to achieve end-end proactive management starting down from the network

level (bitsway level) and moving upward to the application level.

In this paper, we present a framework for a global network management system that provides management services to bridge the gap between application development and network management as well as build management ready applications. Our approach for the implementation of the framework is hierarchical and consists of three layers: Network and Protocol Management (NPM), Management Computing System (MCS), and Application Centric Management (ACM). The NPM is responsible for the collection of management information not only about the network devices, but also information related to computer processes, file systems, user access information and patterns, and protocols. The NPM will also perform tasks to manage the network devices, protocol functions, computer processes and file systems. The MCS provides the core management functions to manage system-wide resources from a system perspective rather than component perspective as is done in NPM. The ACM provides the capability to program MCS functions to control and proactively manage a given network application during all the life cycles of any network application.

The organization of the paper is as follows. In Section 2, we present a brief literature review of current network management techniques and identify their limitations to address global end-to-end network proactive management services. In Section 3, we describe our network management framework and the main software modules to implement this framework. In Section 4, we present a summary and concluding remarks.

2. Overview of Network Management Schemes

Network management products have taken a long road to the current state. They started with the Simple Network Management Protocol (SNMP) version 1 and then version 2, followed by the Management Information Base (MIB) version I and then version II, and Remote Monitoring (RMON) version I and version II. Recently, there has been an intensive effort to use web-based technologies to build network management tools. In this section, we review these management techniques and highlight their limitations to achieve global end-to-end network management for a wide range of network applications.

SNMP is an application layer protocol that allows network managers to access management information data that resides in network devices such as computer hosts, routers, printers, and hubs [1]. The SNMP agents maintain management information about network and make them available to SNMP managers on demand. Network managers can use SNMP to manage network performance and deal with network problems. Since SNMP must run in a diverse network environment, it must assume the lowest common denominator management software to solve incompatibility [3].

RMON is a standard monitoring specification that allows a variety of network monitors to exchange network monitoring data. It is a mechanism to enhance efficiency and productivity in network management tasks because it can provide comprehensive network fault diagnosis, planning, and performance tuning information to enable network managers to perform network utilization analysis and network trend analysis. RMON has a distributed architecture, where embedded agents communicate with central station via SNMP. Though RMON MIB provides a rich source of network information, collection of these data is quite a CPU and memory intensive task.

The two main web-based management schemes are the JavaManagement API (JMAPI) and Web-based Enterprise Management (WBEM). JMAPI is the management solution for current heterogeneous networks with plentiful set of extensible objects and methods for developing seamless system, network and service management. This set of Application Programming Interfaces (API) can be utilized across a

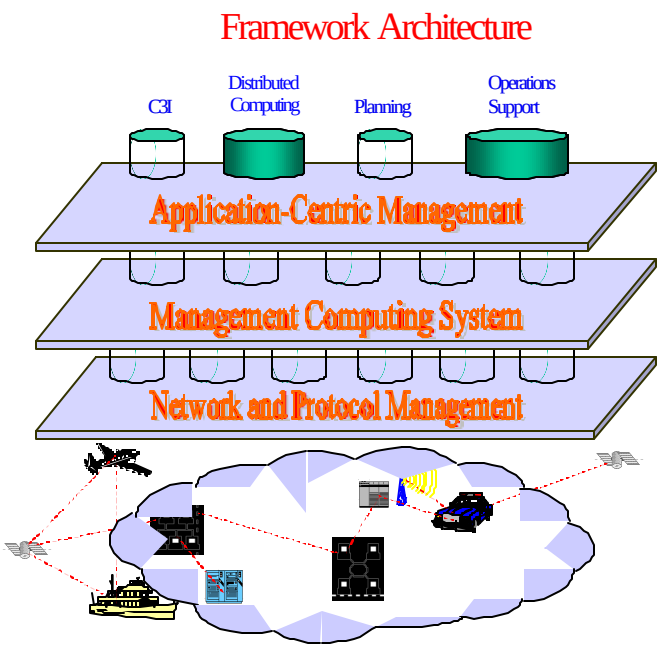
variety of computing environments involving diverse operating systems, systems architectures, networks protocols, and heterogeneous software [6]. The main direction of the WBEM initiative is to combine and integrate the data provided by existing management technologies. The point of convergence is on solving real enterprise issues by allowing problem areas to be tracked from end to end - from the user/application level through the systems and network layers to remote service/server instances [7].

The current limitations and problems with network management are:

- Most of the current commercial network management systems collect management information about packet throughput, delay, and packet errors at input and output of network interfaces. For end-to-end proactive network management, we need more information about the current loads on computers, the types of processes accessing file systems, types of users and their access pattern profiles, security information, and so on. Furthermore, we need to have the ability to program the type of information to be collected and for what period in order to dynamically collect in real time any required management information.
- The amount of information collected for large networks (enterprise networks) is huge. It is very difficult for network managers to efficiently utilize the overwhelming amount of management information to improve network performance, utilization and applications. This problem becomes extremely complex when the size of the network increases to hundreds or thousands of nodes spanning several organization domains or countries. We need to develop techniques that can process raw management information (management information filters) that can lead to efficient and robust analysis of large-scale networks and their applications.
- The literature is rich with algorithms and techniques to dynamically route packets, automatic reconfiguration, adaptive scheduling of resources, dynamic fault tolerance, etc. However, very little is done to integrate these algorithms/techniques in the real-time management of networks and their applications.
- Most of the management functions such as configuration, resource allocations and scheduling are done manually by network managers. This makes the management process slow, not scalable, and not cost-effective. Furthermore, this manual management scheme can not meet the stringent real-time requirements of some critical applications.

We do need to investigate management research issues that eliminate these problems and provide scalable management capabilities to efficiently, intelligently, and cost-effectively manage any network application running on any network of any size and at any time.

Figure1 The Diagram of Management Framework



3. Framework for Global Network Management

The management framework we are developing can be viewed in terms of three systems: Network and Protocol Management (NPM), Management Computing System (MCS), and Application-Centric Management (ACM). The NPM is responsible to collect management information not only about the network devices, but also information related to computer processes, file systems, user access information and patterns, and protocols. The NPM will also perform tasks to manage the network devices, protocol functions, computer processes and file systems. The MCS provides the core management functions to manage the whole system resources from system perspective rather than component level perspective. In order to achieve that, the management information collected at the lower level (NPM) will be analyzed and abstracted into suitable data structures or format to perform efficient system level management functions. The MCS design concept is analogous to the operating system in computer system design. The operating system manages the computing system resources (memory, I/O, CPU, and processes). Similarly, the MCS will act as an automatic system manager and provides management functions to achieve application centric management tasks. The ACM provides two main functions: Assist in the development of application management routines, and provide intelligent proactive management for a wide range of network applications. Figure 1 shows a block diagram of the proactive end-to-end management framework that is currently developed at the USAF Rome Laboratory and Syracuse University. In what follows, we describe the main components of each layer in this framework.

NETWORKS and PROTOCOLS MANAGEMENT (NPM)

Most of the current research and available network management technologies focus on collecting management information and manually manage the network resources and functions (passive network management). Furthermore, even the type of information collected is not comprehensive to achieve end-to-end robust management functions. Very little is done to analyze the collected management information and perform in real-time or near real-time anticipatory management to improve the utilization of the network resources and the performance of network applications. The NPM layer will attempt to remedy this limitation by utilizing the services of current network management systems (SNMP, WBEM, JMPAI, etc.) to build scalable, proactive network management capabilities. The NPM management functions are: 1) assist in the design and planning as well as the deployment of NPM management functions; 2) management of heterogeneous active networks; 3) programmable monitoring services that enable NPM to monitor only the required events and for the appropriate time period; and 4) programmable runtime support that enables other higher layer management functions to dynamically control and manage the network resources. As a result, the NPM layer consists of four important software modules (see Figure 2): NPM Design and Planning, Management of Active Networks, Programmable Monitoring Services, and Programmable Runtime Support.

Figure 2 The main Component of NPM

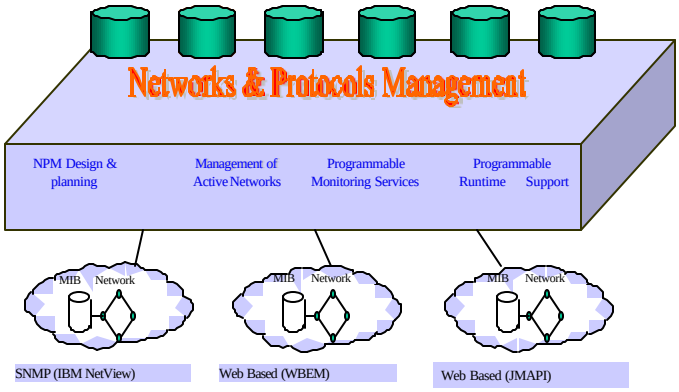
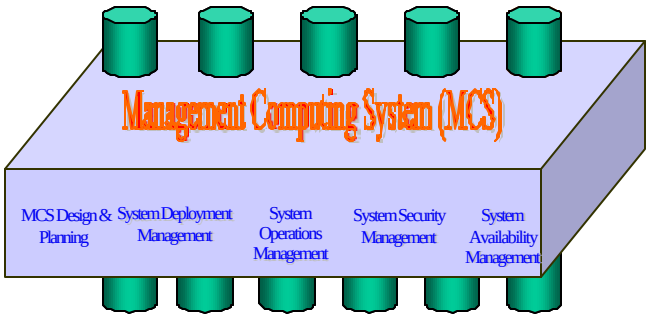


Figure3 The Main Component of MCS



MANAGEMENT COMPUTING SYSTEM (MCS)

Organizations worldwide are in a race to deploy enterprise-wide network applications. However, as the network computing environments become more integral to business operations, the management of such applications becomes more complex, costly and critical. Furthermore, the size of the network and the large number of resources involved in next generation network applications, make the current network management systems (network management products) unsuitable to manage such complexity. The MCS main goal is to remedy this problem an make the management functions scalable, efficient and proactive. The MCS layer receives the management information collected about the network and computing devices and transform them into formats that reduce significantly the amount of management information that needs to be processed to maintain and manage the requirements of the currently supported network applications.

Consequently, the management computing system hides all the component management information and provides system-wide management functions that enable the development of proactive management schemes to suit each class of applications. The MCS layer shields managers from the huge amount of management information about computing platforms, network devices and communication links, and operating systems by abstracting these information into formats that are concise and suitable to manage all the phases associated with application life cycle. In other words, the MCS provides all the system functions required to efficiently and intelligently manage applications during their deployment stage, operations stage as well as the functions to make them available and secure. MCS consists of the following modules: MCS Design and Planning, System Deployment Management, System Operations Management, System Security Management and System Availability Management.

APPLICATION-CENTRIC MANAGEMENT (ACM)

The number and type of network applications become increasingly large and their computing, storage, and network requirements differ widely. In addition to the difficulty that can be contributed to the complexity, heterogeneity, and size of the emerging network applications, the development of such applications do not take into consideration the management issues and requirements. Currently, the management of such applications follows force-fitting approach that attempts to rely on the current network management

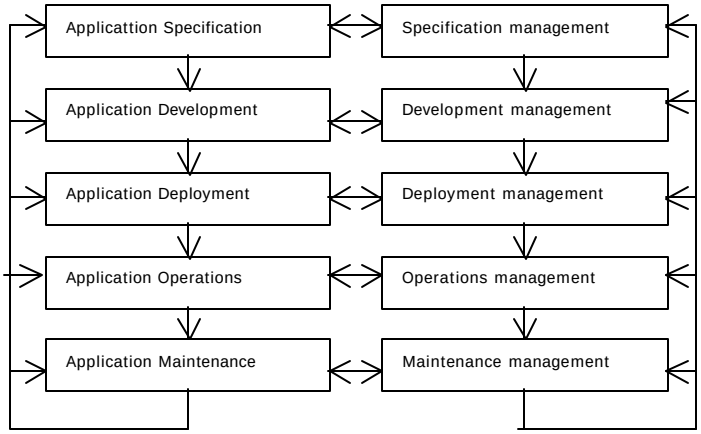
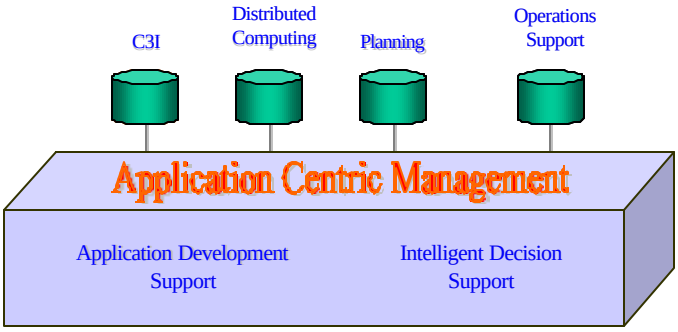


Figure 4 Software Development cycle with Management Activity

Our approach is to develop management functions that can be programmed by applications to meet their requirements during all the life cycles associated with

any networked application (specification, development, deployment, operations, and maintenance). Figure 4 shows our approach to integrate the software development of an application with the management activities of that application. In order to achieve this integrated environment, we do need software tools to help in the development as well as the management of the application when it is running as shown in Figure 5.

Figure 5 The Main Component of ACM



4. Summary and Concluding Remarks

In this paper, we presented the limitations and drawbacks of current network management systems to achieve proactive end-to-end network management services. We also presented a framework to achieve this goal and the main modules required implementing each layer of the presented framework. We are currently in the process of defining the main modules to develop and evaluate the performance of this framework to manage large-scale command and control applications.

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