Role of Agents in Distributed Network Management: A Review

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Abstract

Today's network management systems, mostly based on SNMP or CMIP management protocols, suffer from scalability and flexibility problems as it involve the transmission of large amount of management data towards the centralized management station for processing. In the event of network stress (e.g. generation of lots of fault data or performance monitoring data) it overloads the management station. A distributed paradigm is a viable solution to perform management functions when network start growing significantly. In this sense, use of mobile agents offer many possibilities for designing the next generation of distributed network management systems. They decentralize processing and control thereby reducing the management traffic around the management station and distribute processing load. This paper discusses and analyzes the key advantages and application of mobile agents in the distributed network management systems.

Keywords: *Mobile agents, Network Management, Distributed, SNMP, Scalability*

1. Introduction

Modern day telecommunication industry is facing ever increasing demand for more sophisticated services, higher quality and shorter times to market. Network operators and service providers in the telecommunications industry must meet these demands at a commercially viable cost and should have plans in place for any unforeseen change. This flexibility must be achieved in an environment that is complicated by distributed, often mobile, data, resources, service access and control [1], especially when these networks are growing in size and complexity. Moreover, varied technologies, such as SONET, ATM, Ethernet, DWDM etc., present at different layers of the Access, Metro and Core (long haul) sections of the network, have contributed to the complexity in terms of their own framing and protocol structures. Thus, controlling and managing the traffic in these networks is a challenging task.

Network management system is a fundamental facilitator that typically gathers and analyzes huge amount of data from the network and makes decisions thereof for various functional areas of a management system. The real-time requirements for various types of traffic are also set instantly. Existing management models traditionally adopt a centralized, client/server (CS) approach wherein the management application, with the help of a manager, acting as clients, periodically accesses the data collected by a set of software modules, agents, placed on network devices by using an appropriate protocol as shown in figure 1.

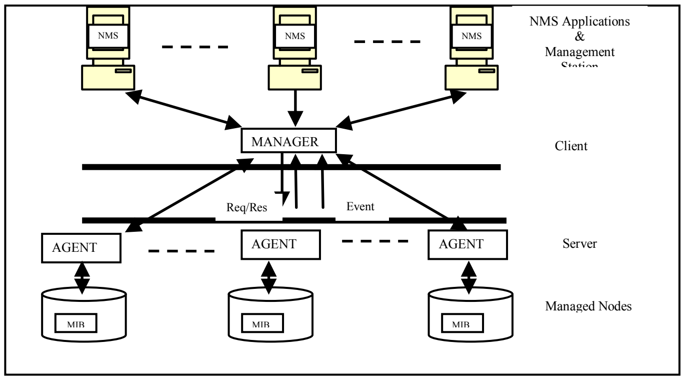

Figure 1. Centralized Manager/Agent interaction

The functionality of both managers and the agents where managers act as client and the agents as a server is statically defined at design time. Traditionally, the Network Management (NM) scene has been dominated by the Internet Engineering Task Force (IETF) simple network management protocol (SNMP) for data networks [2], and the OSI common management information protocol (CMIP) for telecommunication network [3], which are typically designed according to a centralized model and hence suffer from lack of distribution, a low degree of flexibility and fault tolerance [4]. They also require network operators at NMS level to make real-time decisions and manually find solutions for the series of problems in the network. These network management systems deal only with data gathering and reporting methods, which in general involve substantial transmission of management data thereby consuming a lot of bandwidth and computational overhead. Moreover it also causes a considerable strain on the network and significant traffic jam at the manager host [5]. Besides this centralized management activities are limited in their capability as they can not do intelligent processing like upfront judgment, forecasting, analyzing data and make positive efforts to maintain quality of service.

These problems have motivated a trend towards distributed management intelligence that represents a rational approach to overcome the limitations of centralized NM. As a result, several distributed management frameworks have been proposed both by researchers and standardization bodies [6] [7]. However, these models are typically identified by static management components that cannot adapt to the evolving nature of today's networks, with rapidly changing traffic patterns and topology structures.

Of-late, the Mobile Agent (MA) paradigm has emerged within the distributed computing field. The term MA refers to autonomous programs with the ability to move from host to host to resume or restart their execution and act on behalf of users towards the completion of a given task [8]. One of the most popular topics in MA research community has been distributed NM, wherein MAs have been proposed as a means to balance the burden associated with the processing of management data and decrease the traffic associated with their transfers (data can be filtered at the source). Network management based-on Mobile agent refers to equipping agents with network management intelligence and allowing them to issue requests to managed devices/objects after migrating close to them as depicted in figure 2.

The independence and mobility of mobile agents reduce client server bandwidth problems by moving a query from client to the server. It not only saves repetitive request/response handshake but also addresses the much needed problems created by intermittent or unreliable network connections. Agents can easily work off-line and communicate their results when the application is back on-line. Moreover, agents support parallel execution (load balancing) of large computation which can be easily divided among various computational resources.

1.1. Conventional Network Management System

The activities involving, operation, administration, maintenance and provisioning of network resource and services, is called network management [9].

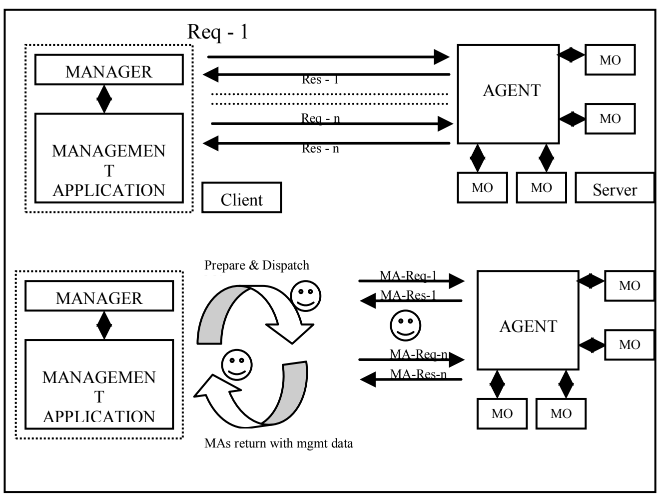

Figure 2 : Client/Server v/s Mobile Agents

The relevant data from various agents, sitting on the network devices, is gathered, analyzed and then employed to perform the appropriate management tasks. The decisions thereof are taken either manually by the operators monitoring the networks or in an automated fashion by various management applications.

A typical organization model of a network management system is based on SNMP two-tier architecture. It consists of two major components: network agent process and the network manager process. The network agent process resides on the managed network devices such as routers, switches, servers etc. The network manager is housed on the NMS station from where it manages the various devices, by accessing the management information, through the agents residing on them as shown in fig. 3. The management information consists of collection of managed objects, stored in Management Information Base (MIB).

Various management applications such as configuration management, fault management etc. resides on the NMS stations whereas manager/agent paradigm procures the needed data for respective management application. The agents have very simple interfaces by means of which they provide information to the requesting applications on granular basis gathered from the target devices. As they lack the needed intelligence and global view, agents don't perform management actions on their local data. Management data has to be transported to managers for taking any management decision. The management protocols provide the primitives for exchanging the management information among the agents and managers. Inherently it leads to centralized model of network management.

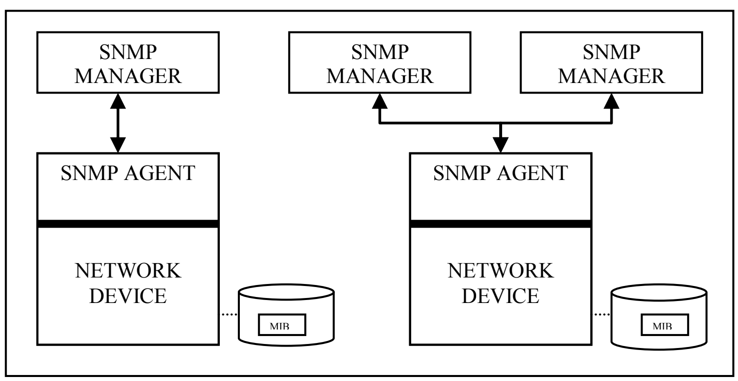

Figure 3. Two-tier Manager/Agent models

A centralized architecture suffers from the lack of scalability and flexibility. Furthermore, the staleness of gathered data (due to network latency involved) and probable error in the selection of management task being carried over (owing to the staleness of data) reduces the reliability of the management applications.

These problems have motivated a trend towards distributed management intelligence that represents a rational approach to overcome the limitations of centralized NM. Gathering and analysis of the management data from agents of managed devices is partitioned and spread over the various computing platforms in the network (sometime the managed devices act as computing platform) thereby breaking the centralized paradigm. Mobile agents allow more and more of the network management intelligence to move closer to the devices unlike the centralized model. Some micromanagement operations could be performed locally avoiding the need to transfer large amount of data generated at management nodes to the central management station thereby reducing the workload for the management station and the overhead in the network.

2. Related Literature

The disadvantages of a totally centralized architecture as described before lead researchers and industry experts to look for a form of decentralization in the network management system design and architecture. In this context, the use of approaches based on mobile agents for network management allows to overcome many limitations of current centralized management systems.

Early work in the field of mobile code, carried over by Goldszmidit et al [6], introduces the concept of management by delegation. Herein, the management station can extend the capability of the agents at runtime thereby invoking new services and dynamically extending the ones present in the agent on the device. Further work in the field of mobility of code established three major paradigms, a. Code on demand, b. Remote evaluation, c. Mobile agents, introduced by Baldi et al[10]. Mobile agent based strategies have distinct advantages over the others as it allowed for easy programmability of remote nodes by migrating and transferring functionality wherever it is required. Bellavista et al.[11] proposed a secure and open mobile agent environment, MAMAS (Mobile Agents for the Management of Applications and Systems) for the management of networks, services and systems. Sahai & Morin [12] introduce the concept of mobile network managers (MNM), which is a location independent network manager and assists the administrator to remotely control his/her managed network, through launching MAs to carry out distributed management tasks. In [13], Oliveira and Lopes propose how the integration of MA-based sub-system could be carried out in the IETF's DISMAN framework. Manoj Kumar Kona et al. [14] described an SNMP based efficient mobile agent network management structure, in order to cooperate with conventional management system; For transferring less network monitoring data and managing devices more effectively, Damianos Gavalas et al.[15] adopted the methods of calculating Health Functions of MIB variables and polling SNMP tables to deploy management agents; Chi-Yu Huang et al. proposed a clustering mobile agent based network management model aiming at large enterprise entrant network in [16]. Liotta et al. [17] have suggested an MA-based hierarchical and dynamic management architecture which deploys static middle managers who in turn can launch MAs. Pualiafito et al. [18] introduce the Mobile Agent Platform (MAP), used for monitoring the systems state by calculating aggregation functions combining several MIB values (*health* functions). Damianos Gavalas et al.[19] proposed a hierarchical and scalable management model where middle managers are themselves mobile and based on certain policies they dynamically segment the network and deploy other mobile middle managers for data collection.

2.1. Mobile Agents Based Network Management Model

Damianos Gavalas et al. [19] have discussed number of mobile agent-based network management models in their research work. Few important ones have been discussed and compared against certain design parameters in this section.

1. ***Flat Bed Model:*** For a particular management task a single mobile agent is launched from a management station which then traverses the network topology in a sequential manner, visiting each managed device and carrying out the assigned task. Though the model relives the network from the flood of request/response messages, it introduces the issue of roundtrip delays as the network size grows. This leads to scalability issue if data has to be collected very frequently from managed devices. The size of MAs grows considerably in large networks. The model is shown in Figure 4.

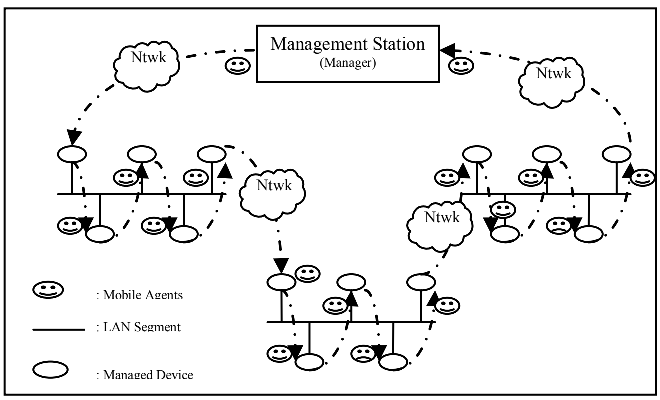

Figure 4: Flat Bed Model

2. ***Segmentation Model:*** Here the scalability issue is addressed by partitioning the network into many administrative or geographical domains and assigning a single MA entity to each one of them. This brings high degree of parallelism in the data collection architecture and brings the response time down by many folds. The model is shown in Figure 5.

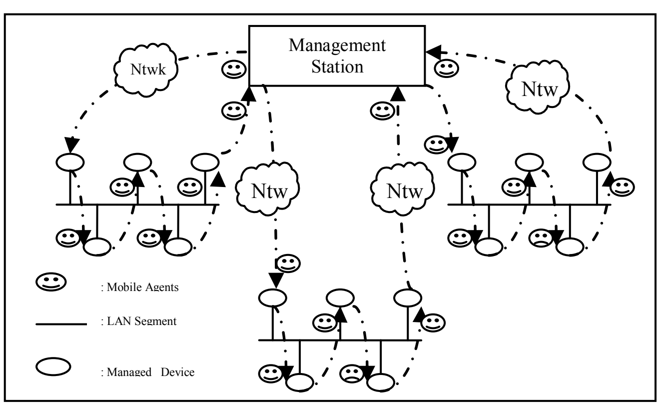

Figure 5: Segmentation Model

3. ***Hierarchical Static Middle Managers Model:*** The scalability problem is more adequately addressed by deploying hierarchical models wherein NM tasks are delegated to MAs. They migrate to remote subnetworks/domains where they act as local managers and takes over the responsibility of local devices from the central manager. These models suffer from automatic adaptation of management system to changing network configurations, i.e. mid level manager do not change the location where they execute. The model is shown in Figure 6.

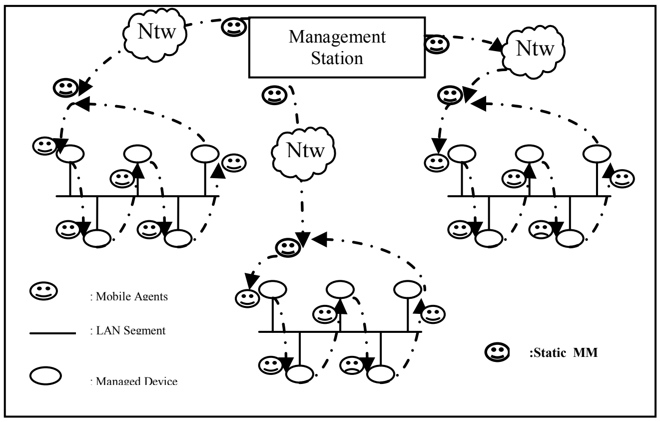

Figure 6: Hierarchical *Static Middle Managers* Model

4. ***Hierarchical Mobile Middle Managers Model:*** In search of more flexible solutions, a concept of Mobile Middle Manager (MDM), referring to a management component that operates at an intermediary level between the manager and the management end points, is introduced. The mobility feature of the MDMs allows the management system to adapt dynamically to a changing network conditions. MDMs can be deployed to or removed from a given network segment in response to change in network traffic or move to a least loaded host to optimize local resource usage. The model is shown in Figure 7.

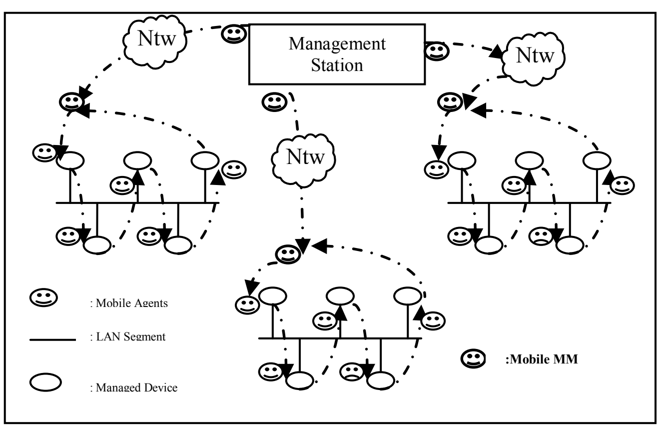

Figure 7: Hierarchical *Mobile Middle Managers* Model

2.2. Comparison Analysis of C/S and Various MA-Based Management Models

All the MA-based management models enumerated in the previous section and conventional client/server model (SNMP client/server model) are compared for five typical design parameters, i.e. scalability of management functions as the network grows, load balancing amongst participating entities, fault-tolerance of the management model, dynamic adaptation to the changing needs of network topology & traffic patterns and easy integration of new management services in the management model. Table 1 summarizes the comparative study.

Table 1: Comparative Analysis of various Network Management Model

Design Parameters v/s Models	**C/S Model**	**FBM**	**SM**	**H-SMM**	**H-MMM**
Scalability	Poor. The network gets flooded with management request/response messages.	Becomes poor with increase in the size of network and if data has to collected very frequently.	Becomes poor with increase in the number of segments.	Better than the C/S, FBM & SM models as Static Manager takes over the management tasks from the central manager.	Better than the C/S, FBM & SM models as Mobile Manager takes over the management tasks from the central manager.
Load Balancing	Low as every management decision is taken on central manager.	Management tasks could be downloaded to mobile agents for which they can utilize the local resources available on the managed devices.	Management tasks could be downloaded to mobile agents for which they can utilize the local resources available on the managed devices.	Higher than FBM & SM as static manager can relieve the central manager from mobile agents generation and they intern can utilize local resources more efficiently.	Highest as Mobile middle manager itself can re-locate itself as the load on the host (on which it is running) increases.
Fault-Tolerance	Once the link between a subnetwork and central manager breaks, that subnetwork can't be managed	Mobile Agents, once dispatched, can carryout the management task manage the assigned even if the link between them and central managers breaks.	Mobile Agents, once dispatched, can carryout the management task manage the assigned even if the link between them and central managers breaks.	Static Managers can manage their own subnetworks even if the link between them and central managers breaks.	Mobile Managers can manage their own subnetworks even if the link between them and central managers breaks.
Dynamic Adaptation	No	No	No	No	Yes
Integration of new services	No	Yes	Yes	Yes	Yes

3. Role Of Mobile Agents In Distribution Of Managemet Tasks

3.1 Mobile Agent Technology

Mobile agents were introduced in the early 90's within the artificial intelligence research community, as semi-intelligent computer programs that assist a user with large amounts of complex information within a network environment. These are typically dispatched from one node in a network and transported to a remote node for execution. This concept of remote programming using mobile agents is considered as an alternative to the traditional client-server programming based on the remote procedure call or the static distributed object paradigm (e.g. CORBA). The primary goal of using mobile agents in management of telecommunication network is reducing network traffic by using load balancing and building scalable and reliable distributed network management system.

Some of the advantages of using agent technology in telecommunication networks are as identified and widely supported by a large number of researchers [20] are described below:

1. Reduce management data overflow. For very large amount of management data kept at remote hosts, it would be wise to dispatch a management entity to the managed hosts for taking the decisions rather than transporting all of the data to a central location and then processing it. To avoid overloading the network the data should be processed in its locality rather than transferred over the network. Mobile agents help decentralize management system by allowing independent remote programming.
2. Address network latency. Modern networks are quite big in size and spread over large geographical areas with different sections connected through back link WAN channels. Various mission critical applications needing real time monitoring runs on these networks. Size of these networks doesn't mitigate the need to respond immediately to important events as a result of significant latencies involved. These can be unacceptable for some real-time systems or systems involved with on-line processing of information. Mobile agents offer a solution because they can be dispatched from a central controller to act locally and execute the controller's directions directly.
3. Adaptation of management protocols. In a large, distributed and heterogeneous network it is a high likelihood that different devices/nodes adopt different management protocols (SNMP, TL1, CORBA etc.) as they come from different vendors and deploy different technologies. Mobile agents offer an excellent solution to be able to encapsulate these details from management stations and talk to visiting devices in their own native protocol language.
4. Off-line and independent execution. At times there are problems created by intermittent or unreliable network connections between the network management stations and managed devices. Agents can easily work off-line and communicate their results when the application is back on-line.
5. Dynamic adaptation. Mobile agents can sense their environment and react autonomously to changes. When a number of mobile agents are assigned to work with a common goal they can distribute themselves among hosts in the network to maintain the optimal

configuration for solving the problem. In the case of a mobile agent moving across a number of host nodes, it can adapt its future behaviour according to information that it has already collected and stored in its state.

6. Dealing with heterogeneous environments. Network computing is fundamentally heterogeneous, often from both hardware and software perspectives. Mobile agents are only dependent to their execution environment. Also, mobile agents are not coupled with other objects; instead they collaborate with other local agents and use the functionality they discover in each host.
7. Network fault tolerance. In order to perform the above properties, agents must communicate to find their peers, to cooperate and negotiate in open environments. It is significant that agent systems build on an interface with a diversity of existing and upcoming standards at the underlying network systems level.

3.2 Distribution of Network Management Tasks

Typical Network management systems have to deal with various functional areas in order to ensure availability of resources and services of the network to its end users. SNMP and CMIP require gathering and analyzing large amount of data from the network for various management tasks. SNMP manages and monitors only network elements and agents provide a limited and fixed set of functions [21]. Existing management models traditionally adopt a centralized, client/server (CS) approach wherein the management application (with the help of a manager), acting as clients, periodically accesses the data collected by a set of software modules (agents) placed on network devices by using an appropriate protocol. These systems regularly suffer from poor scalability due to an increase in the amount of communication and generate too much traffic in the network and the number of failures in nodes and channel.

Therefore, there is a need to employ mobile agents as an autonomous entity in network management and transfer the administration tasks to them. Also under this situation the network management tasks and computational load are distributed instead of being centralized towards and on the manager host. One of the important goals of the network management is to have balanced loading and reliable loading on the network such that connections in the network can be established quickly without noise, or several trails. Network management also aims to organize the networks in order to work professionally, successfully adjust to changes, and react to problems such as traffic patterns.

The OSI management model recognizes the following important network management functional areas. These are: Fault Management, Accounting Management, Configuration Management, Performance Management and Security Management. Besides these networks topology discovery is one of the fundamental functions of the management systems. Typically it involves finding the devices of the network and interconnection among those. A more detailed implementation would focus on construction of more detailed views that may include, for example, services available on a device or devices that satisfy certain constraints. If the constraints are functions of device status, then we approach problem discovery. As the complexity of discovery grows, it is harder to implement using classical client/server approaches.

The same principles as we saw in network modeling can be used to diagnose network faults. Detection of faults is a process of building a specialized model of the network. For example, a simple agent performing selective discovery of nodes with utilization that exceeds a certain threshold builds a model of over-utilized nodes. If the constraints on discovery describe violations of what is considered normal behavior of network elements, then the agents testing the constraints perform a fault detection function.

Another area of importance is performance measurement, which involves gathering statistical information about network traffic, methods to reduce, and present data. Measuring performance of networks using centralized SNMP based management is very difficult due to reasons like network delays and information traffic jam at the central management station.

It is now widely recognized that the use of decentralization in this kind of applications potentially solves most of the problems that exist in centralized client/server solutions. Hence applications can be more scalable, more robust, can be easily upgraded or customized and they reduce the traffic in the network.

In a distributed network, the network operator monitors the trend of network flow to assess network performance and identify unusual conditions. The analysis of data can be achieved from the management information base. The management information base preserves various data objects for network management. The information in management information base is ordered in clusters and maintained in a tree-like structure. Thus management information base manage the complex network tasks in the distributed network management environment.

4. Conclusion

Mobile agents offer an easy re-configurable, flexible and scalable solution to the management of today's complex telecommunication networks thereby reduces the number of necessary human interactions. Many of the complex management tasks can be delegated to agents whom agents can easily carry out without much intervention from the higher management layers. As discussed, the independence and mobility of mobile agents reduce bandwidth overloading problems by moving a processing of the management data and decision making from centralized management stations to the managed devices thereby saving many repetitive request/response roundtrips and also address the problems created by intermittent or unreliable network connections between the network management stations and managed devices. Agents can easily work off-line and communicate their results when the application is back on-line. Moreover agents support parallel execution (load balancing) of large computation which can be easily divided among various computational resources. Thus using agents network monitoring and other management tasks can be easily decentralized.

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