Critical Issues and Solutions in Network Management Architectures

Manohar Lal
School of Computers & Information Science
New Academic Complex, IGNOU,
Maidangarhi, New Delhi – 110 068, INDIA.
Email: lalmanohar03@yahoo.com

Sunil V. K. Gaddam, Ram Chakka
Dept. of Computer Science & Engineering
RGM College of Engineering & Technology
Nandyal – 518 501, INDIA.
Email: sunilvkg, ramchakka@gmail.com

Abstract

With the emergence of the gigabit high speed next generation networks (NGN) and the next generation Internet (NGI), intended to support a wide range of services, applications and mechanisms based on service building blocks, with stringent QoS requirements, sharply increasing demands and usage, there is undoubtedly an urgent and enormous need to develop much more efficient network management techniques. It is all the more significant since the technologies concerning computing and communication hardware are sharply outgrowing those in network management. This paper is a critical review on the existing network management techniques and architectures with some discussion on further research ideas.

Keywords: Next Generation Networks, Centralized Network Management, Hierarchical Management, Distributed Management, Integrated Management

1. Introduction

Since, networks are growing rapidly in size and complexity due to increased services, demands, users, diversification in the underlying hardware technologies and QoS related constraints, they are exposed to problems such as failure, performance inefficiency, resource allocation, security issues etc. With the ever-increasing complexity and heterogeneity in the area of networking, there arises a need to satisfy the QoS requirements and keep the network running consistently at all times [1, 13]. Thus the Network Management must be realized to manage and maintain the network alive for ever. Network Management (NM) means deploying and coordinating resources in order to plan, operate, administer, analyze, evaluate, design and expand communication networks to meet service-level objectives at all times, at a reasonable cost, with maximum flexibility, and with optimum capacity [14]. Network Management used to be simple and empirical when most networks were homogeneous. With further technological advancements, the situation prevalent today with ubiquitous heterogeneous networks, needs more standardized, ordered, integrated, and acceptable ways to manage rapidly changing, converging, and evolving Next Generation Networks (NGN) [15]. To carry out the Fault, Configuration, Accounting, Performance and Security (FCAPS) functional areas for Network Management, new approaches would be required. Stringent QoS requirements exist for services especially, on the NGN. Thus, there is a need to develop new and more efficient network management techniques. This article briefly reviews various types of Network Management approaches and finally discusses critical issues in proposing new approaches for NM of NGNs.

2. Next Generation Networks

Next-Generation Network (NGN) is a general term which is being widely used in recent days for new technologies that are being brought into fixed networks. NGN can mean different for different parties. NGNs are characterized by the use of Internet Protocol (IP), fiber optics and software-based platforms that deliver the services, rather than specialized switching units that create a service [16]. Over the years the basic nature of networks is changing from separate services, separate networks and separate service providers to converged wireline voice, wireline data, wireless and cable services [15].

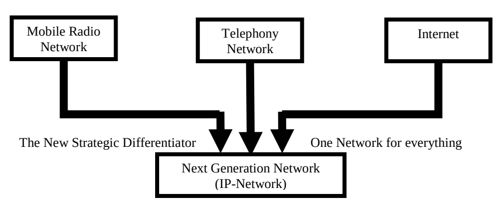

Figure 1: Convergence of Mobile Radio, Telephone and Internet

The growth of Internet and other IP-based networks with their requirements for bandwidth and capacity has driven rapid innovation in telecommunication access and transport networks. Due to the convergence, the Next Generation Networks (NGN) will offer high-speed transport and switching of voice, fax, data and video in an integrated packet-based manner (Figure 1).

Thus NGNs are going to be highly complex, distributed, mission critical networks to deliver data and voice services besides integrating legacy systems with emerging technologies. These networks need to manage a host of diverse and incongruous technologies and deploy flexible, platform independent applications with minimum staff. The NGNs will integrate fixed, mobile, fully mobile and Ad-hoc networks [15].

3. Basic Network Management Architecture

Most network management architectures use the same basic structure and set of relationships. End stations (*managed devices*), such as computer systems and other network devices, run software that enables them to send "alerts" when they recognize problems (for example, when one or more user-determined thresholds are exceeded). Upon receiving these alerts, *management entities* are pre-programmed to react by executing one, several, or a group of actions, including operator notification, event logging, system shutdown, and automatic attempts at system repair.

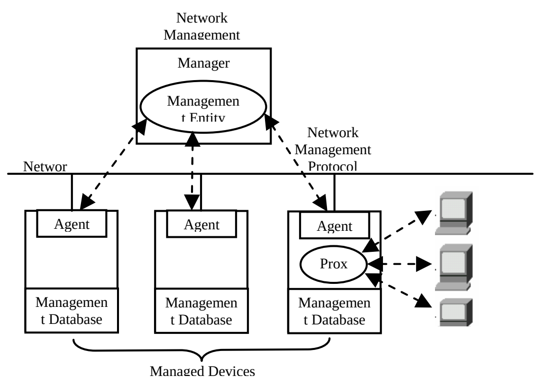

Figure 2: Basic Network Management Architecture

Management entities also can poll end stations to check the values of certain variables. Polling can be automatic or user-initiated, but *agents* in the managed devices respond to all polls. Agents are software modules that first compile information about the managed devices in which they reside, then store this information in a *management database*, and finally provide it (proactively or reactively) to management entities within *network management systems* (NMSs) via a *network management protocol*. Well-known network management protocols include the Simple Network Management Protocol (SNMP) and Common Management Information Protocol (CMIP). *Management proxies* are entities that provide management information on behalf of other entities. Figure 2 depicts typical network management architecture that maintains many relationships.

4. Network Management Approaches

The architecture of a NMS is a complex entity. There are no specific rules that can be applied to the architecture development [2, 4]. There are various approaches in designing NMS. Depending upon operation and designing issues, we can have the following types.

4.1 Explicit management

If human beings initiate management operations, we can call it as '*explicit managemen*t'. With this form of management, the decision to initiate management functions will explicitly be taken by (human) *operators* during the operational phase. It should be noted that even this form of management requires the inclusion of a number of management functions during the design. The purpose of these functions is to support the operator while performing his task.

4.1.1 Pros and cons of explicit management:

An advantage of explicit management is that it is not necessary to elaborate all management functions during the design phase. This is particularly true for the functions that determine at which moment a particular management operation should be initiated and which values should be selected to achieve a specific goal (such functions may be considered as the management 'intelligence' or the management 'decision process'). As a result of this, the design process will be less complicated and requires less time. Explicit management is particularly useful for solving the unexpected problems that show up during the operational phase and require the invention of novel solutions. Explicit management is thus well suited (when it comes) to fault management.

Since explicit management will be performed by human beings, response time may be poor when compared to implicit management. Other disadvantages of explicit management are its limited capacity and the potential high number of errors. If we compare the costs associated with both forms of management, we can conclude that in case of explicit management the management functions that are elaborated *during the design phase* will be less complex and therefore *less expensiv*e. On the other hand, explicit management requires human intervention during the operational phase, and as such it will be *more expensive during the operational phas*e.

4.2 Implicit management

When the system itself initiates operations, the management can be called *implicit management*'. With this form of management, all management functions will be performed by hard and software modules automatically, therefore operator intervention is not needed. Here, the design process will be less complicated and requires less time as would the case with explicit management.

It should be noted that the distinction between both types of management is primarily a matter of realization. In principle it is possible to perform the same kind of functions with both types of management. With the advent of Artificial Intelligence (AI) and expert systems, the distinction between both types diminishes. Real world examples usually show a combination of both forms: some management problems are solved via implicit, while others require the use of explicit management.

In principle, it is also possible to realize primary functions in an explicit way or to concentrate major parts of the primary functionality within a small number of central systems. The fact that functions are performed in an explicit way or the fact that functions are concentrated within a few number of systems, does not necessarily imply that these functions should be considered as management functions.

During the design and the operational phase different views of network management may exist. After the operational phase has been entered, it may be difficult, however for network users and operators to distinguish between the primary functions and those management functions that are performed in an implicit and distributed way. For this reason several people restrict their view of management to only those functions that are performed from a central location in an explicit way. Implicit Management can be of many types.

Network Management Architectures: The Network Management Platform can use various architectures to provide functionality. The 3 most commonly used are:

- Centralized
- Hierarchical
- Distributed

4.2.1 Centralized management

In this approach there is a single management machine, which collects the information and controls the entire network, i.e., all information related to applications is stored on a single (centralized) managing system (Figures 3 & 4). It implies, management decisions will be taken from a limited number of central locations. The management functionality that takes these decisions is called the *manage*r. It represents what can be considered as the management intelligence and is sometimes referred to as the management 'application'. This architecture is ideal for an organization having centralized administration at one location. Currently, most network management systems are centralized [2].

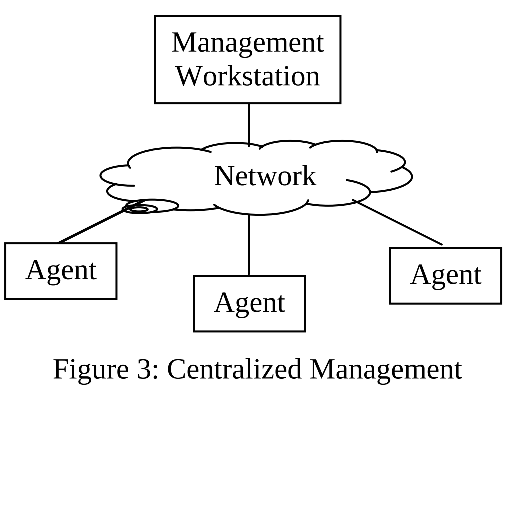

Figure 3: Centralized Management

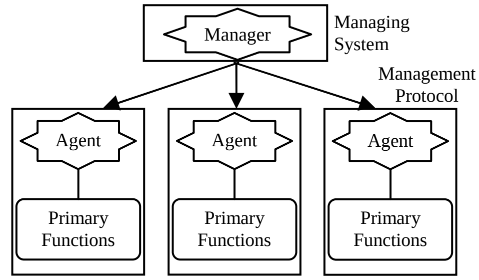

Figure 4: Centralized Management

To manage the operation of the primary functions, *agents* should be added to the systems that perform primary functions. Such agents represent the management support functionality through which manager(s) initialize, monitor and modify the behavior of the primary functions. As compared to managers, agents are usually simple. To allow managers to communicate with their agents, a management information protocol is necessary [2], such as the SNMP and the CMIS/CMIP.

The manager, implemented typically on a workstation, is a single point of failure, and if it fails, the entire network could collapse. In case the management host doesn't fail, but a fault partitions the network, the other part of the network is left without any management functionality. Also, a centralized system cannot easily be scaled up when the size or complexity of the network increases [5].

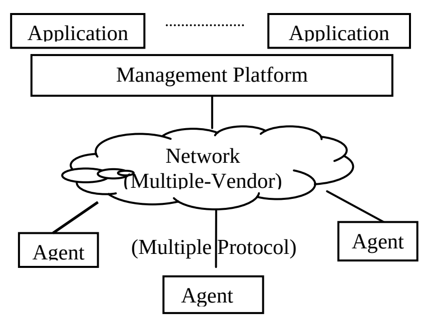

Figure 5: Centralized Platform-based Management

A variation of centralized systems is the platform approach [6] (Figure 5), in which a single manager is divided into two parts: the management platform and the management application. The management platform is mainly concerned with information gathering and simple calculations, while management applications use the services offered by the management platform to handle decision support and higher functions [7]. The advantage of this approach is that applications do not need to worry about protocol complexity and heterogeneity. The drawback is that it still inherits the limited scalability from its centralized architecture. In centralized approach,

- The Network Management Platform resides on a single computer system
- For full redundancy, the computer system is backed up by another system
- Can allow access and forward events to other consoles on network
- Used for:
  - All network alerts & events
  - All network information
  - Access all management applications
- Pros:
  - Single location to view events & alerts
  - Single place to access network management applications and information
  - Security is easier to maintain
- Cons:
  - Single system is not redundant or fault tolerant
  - As network elements are added, may be difficult or expensive to scale system to handle load
  - Having query to all devices from a single location

4.2.2 Hierarchical Management

In this approach, the system is divided into domains conveniently and also the management tasks and responsibilities, to form a hierarchical management system. The central forms the root of the hierarchy, and the distributed system comprises the leaves in the hierarchy. The central system has access to all parts of the network and it allocates tasks to each distributed system [2]. This implies that the hierarchical architecture uses the concept of “Manager of Managers” (MOM) and manager per domain paradigm [6, 4] (Figure 6). Each domain manager is responsible for the management of its domain, and is unaware of other domains. The manager of managers sits at a higher level and requests information from domain managers.

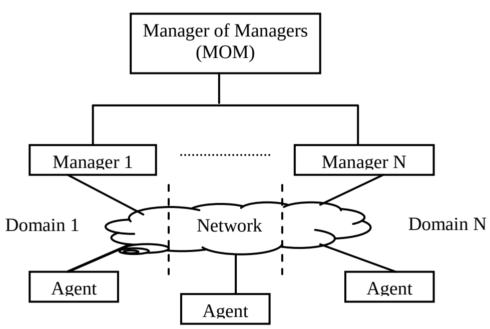

Figure 6: Hierarchical management

In this architecture, there is no direct communication between domain managers. This architecture is quite scalable, and by adding another level of MOM a multiple level hierarchy can be achieved. In this system,

- Uses multiple computer systems
  - One system acting as the central server
  - Other systems working as clients
- Central server requires backups for redundancy
- Key features:
  - Not dependent on a single system
  - Distribution of network management tasks
  - Network monitoring distributed throughout network
  - Centralized information storage
- Pros:
  - Multiple systems to manage the network
- Cons:
  - Information gathering is more difficult and time consuming
  - The list of managed devices managed by each client needs to be predetermined and manually configured

4.2.3 Distributed management

The distributed approach (Figure 7) is a peer-to-peer architecture [4]. It is just the opposite of centralized management. With distributed management there are no central systems from which management decisions are taken. Instead, multiple managers, each responsible for a domain, communicate with each other in a peer-system. That is, functions will be added to the systems that already perform the primary functions to take decisions. Whenever information from another domain is required, the corresponding manager is contacted and the information is retrieved. By distributing management over several workstations throughout the network, the network management reliability, robustness and performance increase, while the network management costs in communication and computation decrease [5]. Such distribution or addition of functions will usually be performed on a proportional scale, which means that all systems that perform the same kind of primary functions get equivalent management functions.

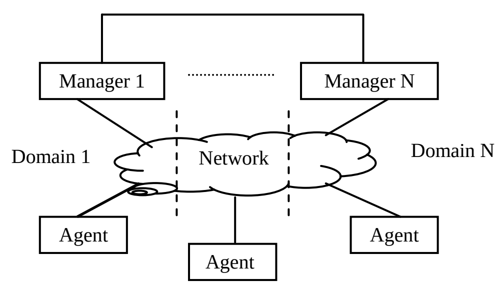

Figure 7: Distributed management

Characteristic for distributed management is that several peer network systems run simultaneously on the data network. In this set-up, each network management manages a specific part of the system i.e., subsystem takes its own management decisions. Because of the potential large number of systems, it will virtually be impossible to let human beings take these decisions. Distributed management must thus be realized in an implicit way. This architecture is ideal for an organization that is distributed over different geographical locations or has its administration distributed with many equal levels of management [2]. This approach has been adapted by ISO standards and the Telecommunication Management Network (TMN) architecture [8]. The management model for ATM networks, adapted by ATM Forum, is based on this approach [9]. Some examples of Distributed Management system are:

- Distributed Big Brother (DBB)
- Management by Delegation (MbD)

Advantages and disadvantages of Distributed Management System:

Fault tolerance and parallelism are key properties of a distributed management system [10]. A distributed system should use interconnected and independent processing elements to avoid a single point of failure. There are also several other reasons why a distributed system should be used. Firstly, higher performance/cost ratio can be achieved with distributed systems. Also, they achieve better modularity, greater expandability and scalability, and higher availability and reliability [11]. Distribution of services should be transparent to users, so that they cannot distinguish between a local or remote service. This requires the system be consistent, secure, fault tolerant and have a bounded response time.

A disadvantage of distributed management is that it will be difficult to change after the operational phase has started the functionality that makes the management decisions. This is because such changes require the modification of a large number of network systems, which will be expensive. In case the designer has little experience with a certain management solution, it may, therefore, be better to use the centralized management approach and concentrate the management functionality that makes the decisions within a single system. The motivation to use centralized management may thus be the same as the motivation to introduce Intelligent Networks (IN).

As opposed to distributed management, centralized management can be realized in an implicit as well as an explicit way. A disadvantage of centralized management is that the entire network may get out of control after failure of a single manager. Compared to distributed management, centralized management may also be less efficient. It is likely that more management information needs to be exchanged and the central managers may become performance bottlenecks.

With some management problems, for instance, in case integrity or fairness come into play, it may be better to rely upon centralized management. The determination of system priorities and token holding times, for example, can be better performed by an independent system and not by the systems to which the decisions apply. This approach,

- Combines the centralized and hierarchical architectures
- Uses multiple peer network management systems
  - Each peer can have a complete database
  - Each peer can perform various tasks and report back to a central system
- Contains advantages from central & hierarchical architectures
  - Single location for all network information, alerts & events
  - Single location to access all management applications
  - Not dependent on a single system
  - Distribution of network management tasks
  - Distribution of network monitoring throughout the network

4.2.4 Hybrid management

It is a combination of the hierarchical and distributed architectures (Figure 8). That's why some people call it as "Hierarchical-Distributed Management" or "Hie-Dist Management" and some people call it as "network architecture" [6].

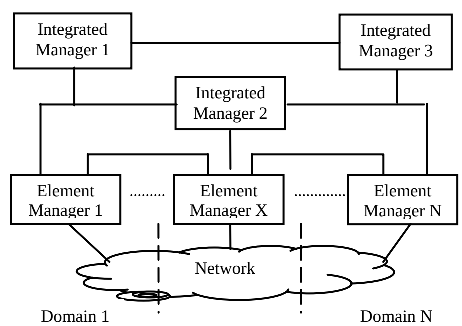

Figure 8: Hierarchical-Distributed ((Hybrid) management

This architecture uses both manager-per-domain and manager of managers (MOM) concepts, but instead of a purely peer-system or hierarchical structure, the managers are organized in a network scheme. Each domain manager is not only responsible for the management of its domain, but also very much aware of other domains. This approach preserves the scalability of both the systems and provides better functionality in diverse environments.

4.2.5 Object Oriented management

In this approach we assume (at a very high level of abstraction), that the management architectures proposed by the International Organization for Standardization (ISO) and/or the Internet Engineering Task Force (IETF). Figure 10 shows the high-level object communication of a distributed management system [12].

It is important to note that we have chosen to further specify the communicating objects. We do so in order to solve the specific problem of distributed resource management. ISO and IETF do this (solve the specific problem of distributed resource management) in order to create a common open management system enabling the monitoring and control of heterogeneous resources. The 'technologies prescribed to support the distributed computing objects are the CMIP in the case of ISO and the SNMP in the case of the IETE. Again, these technological choices are explicitly specified in order to allow for management system interoperability. The implementation technologies for all other parts of this specification are left up to the developer.

The major object sets in this object communications specification diagram are described in Figure 9.

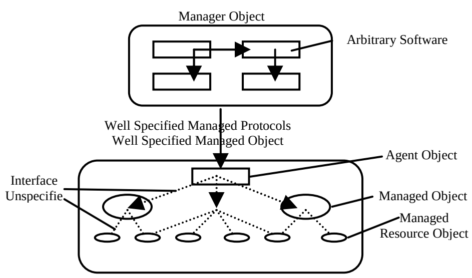

Figure 9: Distributed object oriented architecture for distributed resource

- **The Manager Object:** This object provides the management intelligence in order to exercise the command and control of distributed resources.
- **The Agent object:** This object provides a communication interface to the manager. This interface provides for the illusion to the manager of well specified and well-behaved computational entities called Managed Objects (MO). This interface is described for ISO Management in and for internet management in.
- **The Managed Objects:** These objects provide for the abstraction of managed resources to the Manager object. The interface as seen through the Agent Object is specified by the standards. A description of this interface can be found in. Briefly, this interface consists of generic methods to create and delete managed object instances (specified explicitly for ISO Management, by convention for Internet Management), as well as exercise a get of an attribute value or a set of an attribute values. Further more, a way of specifying new methods (specified explicitly for ISO Management, via convention for Internet Management0 and attributes for the object is prescribed, to essentially extend the basic managed object type.
- **The Managed Resource Objects:** This represents the actual managed entities. ISO and IETF purposely, do not specify this interface. They do not specify this interface because:
  - ➢ The infinite variety of managed resources do not allow them to and
  - ➢ These standards specify only system interfaces and not internal interfaces.

Example of such a protocol is: Distributed Management Environment (DME)

4.2.6 Integrated management

Here we want to propose a new paradigm, which is a combination of Hierarchical, Distributed and Object Management by applying CORBA to this architecture which is an Integrated Network Management Architecture as shown in the figure 10. Our model assumes the presence of physically distributed sets of software objects with potentially multiple threads of control, cooperating to solve a problem. (These objects may be the result of software development process using mainstream object oriented languages such as Smalltalk, Eiffel, CLOS, C++, or Java). We further assume that the software object sets may communicate via the use of object distributed technologies such as CORBA, or OLE.

In this approach, a SubManager, acting as an intermediary between Manager and Agent and is placed near the agents which are to be controlled. SubManager that can independently check management values of any MIB reachable either by SNMP, CMIP or DMI etc. SubManager is associated with a few agents, collects the primitive information from them, and performs some calculations and produces more meaningful values that can be used by a superior manager. This method significantly reduces the amount of management traffics because only high-level information is sent to the master manager [3].

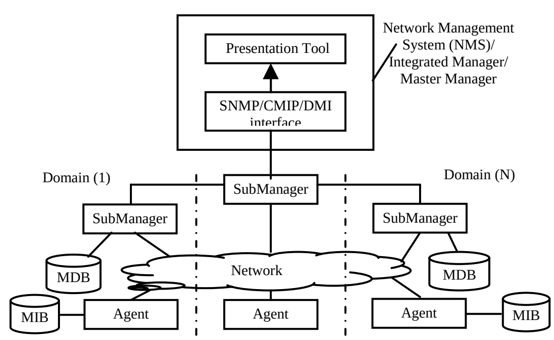

Figure 10: Integrated Network Management Architecture

Now if we apply CORBA to the above architecture we can now even improve the communication between NMS (Network Management System) and agent (whenever necessary). Here, since we consider every device either agent or SubManager as an Object, the main object (NMS) would be able to communicate with all other objects, which are on the network. But to avoid congestion this will be communicating through SubManager object only. If there is any abnormal event occurs, then the MasterManager (NMS) object can directly access information from any other object on the network [3]. This architecture is shown in figure 10.

5. Conclusion

In this paper, we have discussed about the various types of Network Management techniques / approaches / schemes and architectures. Their relative advantages and disadvantages are also discussed. There after we have given an Integrated approach (a proposal) for Network Management system which is possible by applying CORBA to the combination of distributed and hierarchical and object-oriented Network Management systems, to avoid all drawbacks, taking all the advantages.

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