A Model for Scalable and Autonomic Network Management

Amir Eyal and Robin Braun*

Institute of Information and Communication Technology, Faculty of Engineering,
University of Technology, Sydney
{Amir.Eyal,Robin.Braun}@uts.edu.au
Tel.: +61 2 9514 2460; Fax: +61 2 9514 2435

Abstract. Current telecommunication network management systems rely extensively on human intervention. They are also prone to fundamental changes as the managed network evolves. These two attributes, combined with the growing complexity of networks and services, make the cost of network management very high. In recent years, we have witnessed the emergence of artificial intelligence applications. Some are aimed at the creation of autonomic network management systems. This paper offers a novel approach to the design of a network management system that incorporates intelligent agents. As a benchmark to this model, we use two approaches most widely in use in network management systems today. The focus of this paper is on synchronization issues, service discovery and policy enforcement.

Keywords: Autonomous Network, Network Management, Scalability, Information Model.

1 Introduction

Telecommunication networks are by definition complex systems [5]. They consist of large numbers of components and the number of services and activities taking place is even larger. The behaviour of the network is according to a changing set of rules that is hard to accurately predict. Given the complexity, it is a difficult task to maintain and manage these systems. Moreover, the complexity has been growing and is expected to grow vastly with the introduction of new types of devices, new services and networks, and with the standardization of service differentiation [4, 6].

Substantial efforts are being put into automating management tasks. This includes the development of algorithms, protocols and management tools. By having some of the labour done automatically, the network operator can cut down on the resources spent on maintenance and management [1, 2]. It will still

* The authors are with the Institute for Information and Communications Technology, Faculty of Engineering, University of Technology, Sydney. They are members of the Teleholonic Systems Research Group. http://teleholonics.eng.uts.edu.au. Amir Eyal is a doctoral candidate. Robin Braun is Group Leader.

D. Hutchison et al. (Eds.): IWAN 2005, LNCS 4388, pp. 194–199, 2009.

be required for network managers to perform some manual tasks, and to coordinate and supervise the automated tasks. By definition, the managed component has to behave in a certain pattern in order for the management algorithms to be effective. Any deviation from this pattern would mean efficiency degradation or a malfunction. To overcome that, the algorithm needs to be *adaptive.* This attribute in the management system would *transform it from automatic to autonomic* [5, 4].

A central part of the network management system (NMS) is the information layer (IL). The IL's purpose is to represent the state of the network. Parameters in the information layer correspond to settable parameters in the network. The meta-tructure is an information model. It consists of two parts, informational, containing the network status, and operational, which has the ability to affect the status of the network.

We use two opposite approaches in network management as benchmarks - the distributed model and the centralized model. The distributed model with a distributed information base is epitomized by SNMP to control and monitor network devices like switches. The CIM [3] is a comprehensive example for the centralized model. This paper offers a novel model for the information layer that enables a strong binding by utilizing autonomic agents that perform the synchronization tasks. We show that it bridges over the differences between the standards in use to utilize the best suited standard for each component in a natural way. It also enables the use of intelligent agents that perform several duties.

The paper proceeds as follows: section 2 is a survey on current management systems and models. Section 3 describes the autonomic network management system model. Section 5 describes our model, followed by a detailed description of the information layer (IL) and how it addresses the challenges presented above.

2 The Information Model

Information models divide to two groups or models. One model is the distributed information model. It can be seen in management systems like SNMP [7], where each network element contains its own parameters. A management system can perform a "SET" operations to change the state of the network, and a "GET" in order to check a certain parameter. Due to the differences between network elements, the structure, the hierarchy, of the information may differ from one element's storage to another's. Thus, it is also required of the system to know the structure of the informatio n model contained in each network element. Another constraint of this model is that information must be related to the physical element it exists on. This means that a parameter that cannot be associated with a specific network element does not get the appropriate representation. On the other hand, this approach is scalable, since the larger the network, the more distributed the MIB is.

With centralized model, network management tools like CIM provide more versatile capabilities. CIM is a common definition of management information for systems, networks, applications and services [3]. Since its a centralized database (or distributed between a set of management stations) we can map logical entities properly. However, issues like synchronization and scalability rise, since all the weight of the network management falls on a small number of management stations and its corresponding databases.

3 The Hybrid Model

Our model's contribution is twofold. Firstly, it remaps the network components into the TMF 4 layer structure [4], combining it with a 3 columns (vertical layers) of the management system. Secondly, it adds the concept of intelligent agents performing most of the duties in the management system. The usage of artificial intelligence concepts and tools, like JADE, which provides mobile agents, can alleviate accuracy and scalability issues, reduce delays and spare most of the effort done by the human network administra tor. It may also reduce the development cost of network management tools. The block representation of our two-dimensional autonomic network management model is presented in Figure 1. By dividing the network into 4 layers, the network can be fully represented in the information layer [4]:

- Resource Layer - storage devices and available bandwidth.
- Services Layer - services offered by the system.
- The services rely on use resources in the layer below.
- The products and their components are mapped to the uppermost layers.

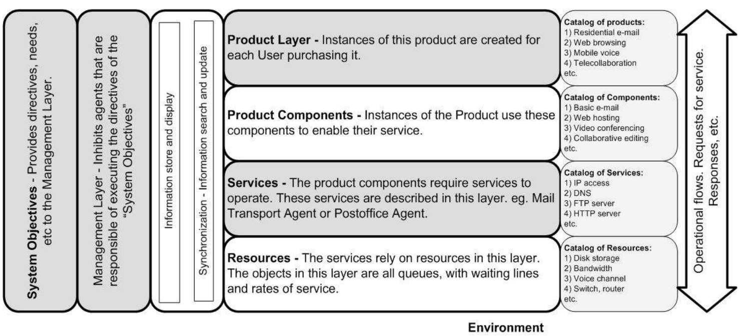


Fig. 1. Block Diagram of the Layered Model

In addition to the 4 horizontal layers, there are 3 vertical management layers. The first provides objectives to the system. An objective is an ambition that produces management actions. The middle layer translates those objectives into network activity. The rightmost layer is split in two parts. One stores the state of the network, corresponding to the 4 horizontal layers, while the other is in charge of maintaining integrity between the information storage and the network.

4 Issues with the Information Binding

4.1 Requirements

The flow of commands in the management systems is as follows. Any activity initiated by the *o*bjectives layer and translated by the *m*anagement layer into changes in the *i*nformation store, has to be reflected correctly in the network. It has to happen with as little delay and as much accuracy as possible. This is the **IL** $\Rightarrow$ **Network** binding.

On the other hand, any event that changes the state of the network needs to be visible to the management and objective layers. This means we need a binding in the other direction, **IL** $\Leftarrow$ **Network**. The following discusses the inner structure of the synchronization block and the ways to achieve the **IL** $\Leftrightarrow$ **Network** goal.

In order for a network management system to become autonomous, it needs a number of prerequisite.

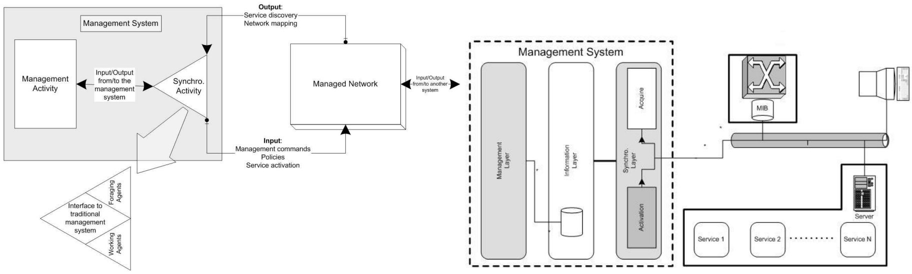
– It has to be capable of incorporating specially tailored artificial intelligence algorithms.
– It has to interface with intelligent agents.
– It has to have a strong binding between the management systems information layer and the network parameters.

4.2 Structure

As shown in the logical representation in Figure 2(a), the management system has two parts, the management activity and the synchronization activity. The management activity is making and carrying out management decisions. This may be done by an autonomous decision making process or by a network administrator. Figure 2(b) shows the actual layout of the network management system with a physical network. The network consists of both physical elements (resources) and logical ones (services and products). Furthermore, the physical elements can be of any type.

The synchronization activities taking place in the management system are separated from the actual management activity. The synchronization block is divided into three parts. The upper part is responsible for collecting data from the network. It is home to foraging agents that roam the network performing service-discover y activities. The lower part of this block is in charge of enforcing those management decisions taken in the management block, on the network, the **IL** $\Rightarrow$ **Network** binding. It multiple types of agents and algorithms.

The middle part interfaces between the two former parts and the management block. In events of an initiative from the management block, the interface part has to translate it to input for the algorithms that run in the lower part. Whenever the higher part comes up with new discovered data, the interface will perform the corresponding changes in the information layer. It is important to say that parts of this block are likely to be mobile agents, swarming the network devices themselves. The combination of an information layer and a synchronization layer would form a "terrain" or "environment" for the agents in the management layer, which take on the role of inhabitants of that terrain.



(a) An overview of the synchronization layer (b) The interface of the management system to a hybrid network.

Fig. 2. The hybrid system

4.3 A Hybrid System

A comparison of the two leads us to the conclusion that in the hybrid model, we would want to include as many high-level parameters as possible, while having the bulk of the lower-level ones distributed. That way we can enjoy the possibility of optimization in the centralized management layer and leave the IL scalable.

The main performance issues we want to measure in the model for the autonomous management system is the bandwidth used for management. It is closely related to the number of messages passed between the IL and the network. In such case, the more centralized the model, the smaller the number of low-level commands and the total number of messages passed will be.

5 Possible Implementation

We need to implement two classes of intelligent agents. One class will contain agents capable of collecting the state of those parameters. The other class is of agents that affect the parameters within the domain. They synthesize changes in the information store and execute them on the network. Each class may consist of multiple agent types. In some cases, one type of agents may be responsible for more than one parameter or for both collecting a parameter's state and setting it. Finally, after establishing a kind of sandbox that is able to perform network management duties autonomically; we can set to out explore ways to transform the management itself into an autonomic process. We might end up using a 3rd class of intelligent agents, a genetic algorithm, or any combination of those.

At the this time, we have started with an email service. We mapped the email box into resources and services that it consists of, shown in Figure 2. We designed agents that perform the setting and the retrieving of parameters related to the service level of the email on multiple mail servers. For that particular service, we need to control on each server the list of users and passwords and be able to manage the quota allocated to each user.

We are going to evaluate the management system using numerous measurements. The most obvious parameter would be the integrity of the system. Here, we want to see that the network stabilizes in the right state and that changes in the network's state are reflected properly in the IL. Secondly, we will look at the delay, the period of time it takes the system to enter the state of stability. We will also notice the resources used in the process of performing a management act (i.e. number of messages, number of procedures, storage used, etc.).

An important issue to check is the scalability of the management system. The measurement will be done by experimenting with different scales of networks, growing number of operations and user requirements and checking the rate of growth in used resources and of performance degradation experienced.

6 Conclusions

We have discussed the different model structure options in the design of an autonomic network management system with the emphasis on the Information Layer. We suggested that the appropriate model might be of a hybrid nature between the distributed and centralized models. We are going to test the effectiveness and efficiency of the model for supporting autonomic algorithms according to a set of parameters that include the efficiency and grade of results.

References

[1] Bonabeau, E., Dorigo, M., Theraulaz, G.: Swarm Intelligence - From Natural to Artificial Systems, Santa Fe Institute (1999)
[2] Holland, J.H.: Hidden Order - How Adaptation Builds Complexity (1996)
[3] DMTF, Distributed Management Task Force
[4] Braun, R.: Towards a Management Paradigm for Autonomic Communications (2005)
[5] Ottino, L.A.N.A.,, J.M.: Complex Networks, Augmenting the Framework for the Study of Complex Systems. The European Physical Journal, B 38, 147–162 (2003)
[6] Magrath, S., Braun, R., Cuervo, F.: Policy Interoperability and Network Autonomics. In: 7th International Symposium on Autonomous Decentralized Systems (2005)
[7] Strauß, Klie, T., Frank: Integrating SNMP Agents with XML-based Management Systems. In: XML-based Management of Networks and Services in the IEEE Communications Magazine (2004)
[8] Bellifemine, F., Caire, G., Poggi, A., Rimassa, G.: JADE - A White Paper (September 2003)