PROACTIVE NETWORK MANAGEMENT BASED ON MOBILE AGENTS AND FUZZY LOGIC

Arnoldo Nunes da Silva[1]
Center of Informatics
Federal University of Pernambuco
Recife-PE, Brazil
E-mail: ans@cin.ufpe.br

Carlos André Guimarães Ferraz
Center of Informatics
Federal University of Pernambuco
Recife-PE, Brazil
e-mail: cagf@cin.ufpe.br

Geber Lisboa Ramalho
Center of Informatics
Federal University of Pernambuco
Recife-PE, Brazil
E-mail: glr@cin.ufpe.br

José Neuman de Souza
Department of Computer Science
Federal University of Ceará
Fortaleza-CE, Brazil
E-mail: neuman@ufc.br

ABSTRACT

Networks with complex topology require applications that adopt a decentralized model of management and an automation of activities that aid administrators in the network's diagnosis. This work proposes a model implemented by a prototype that adopts mobile agents as technology for distribution of tasks. The technique of artificial intelligence based on fuzzy logic is added in mobile agents, giving the system a proactive behavior.

1. INTRODUCTION

The increase of the complexity and heterogeneity of the topology of computers networks demands an automation of tasks in network management. It contributes to an overload in the traffic generated in the network and consequently there is an increase of its answer's time. These problems have been found in the centralized model of network management.

Most of the network management systems still follow the centralized model that is based on the client-server model. OSI/CMIP [8] and IETF/SNMP [9] are the models used by these systems, where a manager analyzes the data collected by agents located in the managed devices in a centralized way. Centralization presents some problems, such as: 1) it could cause an traffic overload and processing at the side of the manager, affecting its performance; 2) it doesn't present scalability in the increase of the complexity of the network; 3) the fault in the central manager of the network can leave it without management.

In this context, the need for decentralization of the management tasks appears. Alternative models based on a hierarchical management [18] proposed the division of tasks among sub-managers for the control of groups of sub-networks, defining a hierarchy of managers controlled by a central manager. Therefore, this model still doesn't show the reduction of processing in the main manager. Other decentralized models were proposed, standing out the Management by Delegation[6] whose approach is based in the upload of management scripts to be executed in the managed device and the use of CORBA that facilitates the cooperation among distributed objects.

The use of mobile agents is the approach of this work as an alternative for the decentralization of the management tasks. The mobile agents are programs that migrate among the machines running tasks delegated to them. They allow the decentralization of the processing and of the control, reducing the load of the management station, turning asynchronous the communication with that station. They also permit a balancing of processing load and increasing the flexibility of the behavior of management agents.

In order to the management system come more efficient, it is necessary that it aid the administrator in the process decision taking. Starting from this premise, possible behaviors of the computers network management systems were defined. The management system can present a reacting behavior, through the emission of alarms and events following the occurrence of some problem in the network. However, the proactive behavior has been adopted in network management, where the eventual problems in the network can be anticipated[13]. These prevision are made through the analysis of the management network information collected in the managed element. The proactive behavior is reached through the use of techniques of Artificial Intelligence.

Fuzzy logic is the technique of Artificial Intelligence adopted in this work. It smoothly translates the network behavior in the common sense into a mathematical approach and a semantics richer than the traditional Expert Systems approach, relieving the problem in the knowledge acquisition, due to the facility to construct rules, inherent to the linguistic process itself[11].

[1]Msc Student at Federal University of Pernambuco, Brazil. Supported by CNPq.

A series of models based on mobile agents has been proposed. Baldi et al. [4] develop a prototype of a management infrastructure with mobile agents and SNMP. Pagurek et al. [5] apply mobile agents in the functional areas defined by OSI and they implement an infrastructure and a number of tools that interrelate with the agents. Babacar[10] proposes a model defining a hierarchy of cooperative mobile agents with differentiated functions and classified in different management levels. In Gavalas et al. [17] a management infrastructure based on mobile agents is proposed, defining two ways of data collection: time real and in off-line. However, all of them adopt a reactive behavior in its management models. Moreover, an automated analysis of the data was not included for the emission of the diagnosis. Other works proposed the use of artificial intelligence in proactive management through fuzzy logic [11], neural networks [12] and expert systems [13][14][15]. But these are not based on mobile agents.

This work proposes a decentralized approach for a proactive network management using mobile agents endowed with intelligence. Through fuzzy logic, the agents will have the reasoning power for automated generation of the diagnosis of the managed resource.

2. MODEL FOR PROACTIVE MANAGEMENT BASED ON MOBILE AGENTS AND FUZZY LOGIC

The proposed model is shown in the fig. 1 through its information flow diagram. When the agent visits a host, it gets the data provided by the SNMP agent referring to the network interface of the machine executing the GET request command together with parameters that identify the host and the OIDs (object identifier). This identifier represents a characteristic data of the device, for example, the number of output trafficked bytes on network interface. These objects are stored in a database called MIB (Management Information Base) of the network element.

The fuzzy system, present in the mobile agent, runs the reasoning process. If a critical value is diagnosed for the situation of the interface, the system suggests a solution in agreement with the type of traffic that caused this abnormality.

The task that verifies the situation of degradation occurs through the monitoring of one or more parameters of the network (eg: input non unicasts packages rate), observing if they exceed or not certain values limits called thresholds. When one or more of these thresholds are exceeding, the fuzzy system infers a value, previously deduced, for the linguistic variable that represent the interface situation. That value is determined starting from inferences of the fuzzy module using simulated values.

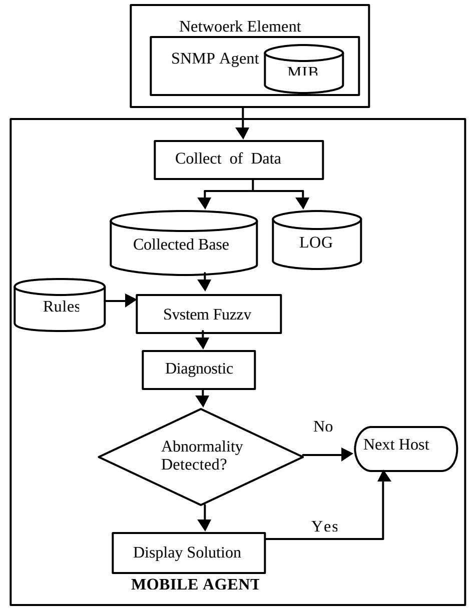

Figure 1: Flow diagram of information of the management platform based on mobile agents.

2.1 MOBILE AGENTS IN NETWORK MANAGEMENT

Network management using mobile agents is an alternative to the centralized management model. The tasks delegated to the mobile agents distribute the central manager's activities. The mobile agent visits each one of the managed machines. Successive requests are executed in each host to collect of MIB information, substituting the pollings sequence from the manager such in the model client/server.

The fundamental condition to execute an application that uses mobile agents is the existence of an infrastructure in each device of the network that supports code mobility. This infrastructure should provide services in the transport layer that support the execution and the movement of mobile codes. In this work the used infrastructure was the platform ObjectSpace Voyager 2.0 for mobile agents in Java.

Besides that infrastructure, each network element to be managed should be configured to execute codes written in Java (i.e. to have installed a JVM - Java Virtual Machine) and it should have a process executing, in this case supported by Voyager, to support the reception of mobile agents. This process "listens" certain TCP and UDP ports and it links with codes coming from manager or from another process. Each device has SNMP (Simple Network Management Protocol) and its resident agent (SNMP agent) that will provide the necessary information to the management. to the mobile agents.

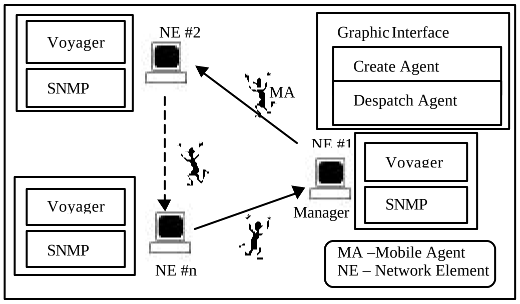

Figure 2: Overview of the platform

In fig. 2, it's shown an overview of the proposed management platform. The manager, through the graphic interface, creates and sends the mobile agents to the network elements (NE). The mobile agent (MA) visits each managed device to collect the data in the defined time interval. Inside this interval, the mobile agent calculates the function that finds the traffic rate of each package to be analyzed and it verifies its status.

The approach of management based on mobile agents presents several advantages [7], such as:

- reduced cost: inasmuch as management functions require the transfer on the network of a great volume of data, it may be better to send an agent to perform the task directly on management agents, where data are stored.
- asynchronous processing: an agent can be sent through the network, performing its tasks on other nodes. While the agent is out of its home node, this node can be out of operation.
- distributed processing: low capacity computers can be efficiently used in order to perform simple management tasks, distributing processing previously concentrated on the management station.
- flexibility: a new behavior for the management agents can be determined by the management station, which sends a mobile agent with a new execution code, substituting the old one dinamically.

Techniques of artificial intelligence are adds to the mobile agents, giving to the management system a proactive behavior. It allows the anticipation of a probable abnormality in the devices or in the network. The technique used in this work is fuzzy logic.

2.2 FUZZY LOGIC IN MANAGEMENT NETWORK

The fuzzy logic is an extension of the classical mathematics to keep track the partial trust concept, like, trust values between “completely false” and “completely trust”[16].

A fuzzy system can be represented according to Fig. 3 the numerical information is translated into a fuzzy number in the fuzzification module that gives a linguistic interpretation by the grammar use. The inference machine process a rule application of the type IF-THEN formed by prepositions that use terms of linguistic variables. The rule processes the result in a fuzzy value defuzzificated to a numerical output.

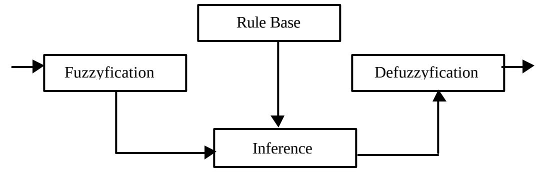

Figure 3: Fuzzy System

Binary Fuzzy Relations are fuzzy sets of the cartesian product $X\times Y=\{(x,y) \mid x\in X, y\in Y\}$, which is characterized by the membership function $\mu_R(x, y)$ that matches each (x, y) pair in R, a real value in the interval [0,1].

The Composition Rule max-min combine fuzzy relations from different spaces. Let $R1 =\{(u,v) \mid (u,v)\in UxV\}$ and $R2 =\{(v,w) \mid (v,w)\in VxW\}$ relations from U to V and V to W, respectively. The R 1°R 2 composition is given by the following fuzzy set:

$R1°R2 = \{ ((u,w), \mu_{R1 ° R2}(u,w)) \mid \mu_{R1 ° R2}(u,w)$
$= \sup \min[\mu_{R1}(u,v),\mu_{R2}(v,w)] \}$

Where $u\in U$, $v\in V$ and $w\in W$.

The work uses fuzzy logic to diagnose an abnormality situation in the device's network interface that can affect the network operation. A group of seven fuzzy controllers is created, each one regarding a characteristic type of package. In each controller, the rate of a specific traffic on a network interface is analyzed in relation to the rate of utilization of this interface.

For each type of TCP/IP traffic in the device's network interface, the fuzzy system is responsible to infer the referring values to this traffic in one of the controllers implemented. The result of this inference returns a numeric value in the interval [0, 10], quantifying the weight that this type of traffic has on the network in a certain instant of time. The input linguistics variables are associated to the following type of traffic evaluated on the network interface: Input Non-Unicasts Packets, Output Non Unicasts Packets, Input Discards Packets, Output Discards Packets, Input Error Packets, Output Error, Interface Utilization. The Situation of Interface represents the output linguistic.

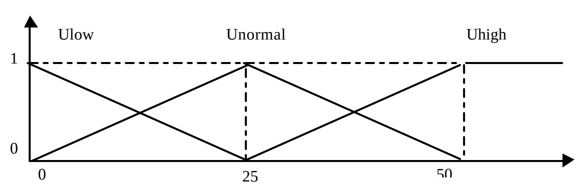

Figure 4: Relationship Degree Functions from Linguistic Terms of the Network Interface Utilization

Each linguistic variable uses three terms (low, normal and high) represented by its membership functions in fig. 4.

The inference rules are defined through a group of seven standardized rules for each type of analyzed packet. Each one of the groups corresponds to one diffuse controller. The rules were defined based on [11] with the following abstraction form:

If (*v1 is low*) and (*v2 is low*)
Then (*Status of Interface is low load*)
If (*v1 is low*) *and* (*v2 is normal*)
Then (*Status of Interface is low load*) and (*Status of Interface is normal*)
If (*v1 is normal*) and (*v2 is low*)
Then (*Status of Interface is low load*) and (*Status of Interface is normal*)
If (*v1 is normal*) and (*v2 is normal*)
Then (*Status of Interface is normal*)
If (*v1 is normal*) and (*v2 is high*)
Then (*Status of Interface is high load*) and (*Status of Interface is normal*)
If (*v1 is high*) and (*v2 is normal*)
Then (*Status of Interface is high load*) and (*Status of Interface is normal*)
If (*v1 is high*) and (*v2 is high*)
Then (*Status of Interface is high load*)

Where the variable v1 represents the percentage of network interface utilization and the variable v2 represents one of the several characteristic types of traffic. Each linguistic variable is defined in a scale of value that represents its percentage in relation to interface utilization. To homogenize those variables leaving them similar to the input linguistic variable Situation of Interface, they are mapped to a scale of [0,10] measured in unit of value (u.v.). The center of gravity method is used for the defuzzification.

3. PROTOTYPE AND RESULTS

The prototype was implemented in JDK 1.2, the platform Voyager [3] of ObjectSpace is used to allow the support to mobile agents. The set of classes of the API NRC Fuzzy Java [2] allows the construction of the fuzzy specialist system coupled with the mobile agents. The tool AdventNet SNMP [1] is used to support the management operations.

The *MoveMobget* class creates and dispatch the mobile agent to collect data in the hosts. The mobile agent is represented by the *Mobget( )* class that implements the *collect(String host, String oids[], String Community)* method and runs the get request command through of API AdventNet classes. It is shown below with its specification in the *IMobget* interface.

```
public interface IMobget
{
  void coleta(String host, String OID[], String Community);
}
```

```
public class Mobget implements IMobget, Serializable
{
public void coleta(String host, String oids[ ], String Community)
   {
     SnmpTarget target;
     target = new SnmpTarget();
     target.setTargetHost(host);
     target.setCommunity(Community);
     target.setObjectIDList(oids);
     try{
       ILog log = (ILog) Namespace.lookup("//c5c01:8000/LOG")

        String[ ] result = target.snmpGetList();
        if (result == null)
           System.err.println("Failed: "+target.getErrorString());
        for(int i=0; i<oids.length; i++)
            log.addLog(host.concat(oids[i]),result[i]);
       }
       catch( Exception exception )
       { System.err.println( exception );}
   }
}
```

For the creation and storage in the log, an ILog interface was defined, specifying the *Log(String host, String oids [ ])* and *AddLog(String host, String [ ])* methods.

The FuzzySystem class executes the methods that calculate the rates, calls the Inference class that implements the knowledge base and the inference machine and it concludes by calling the method Diagnostic( ), which verifies the possible abnormality in the host.

Through a graphic interface (fig. 5), the user defines the intelligent mobile agents together with the hosts group that each one will visit and the host's community. With these information, the agents can be created. After this process, the operator defines the OIDs of the MIB objects to be collected and the interval between each collection and dispatches the agents for the execution of the management tasks.

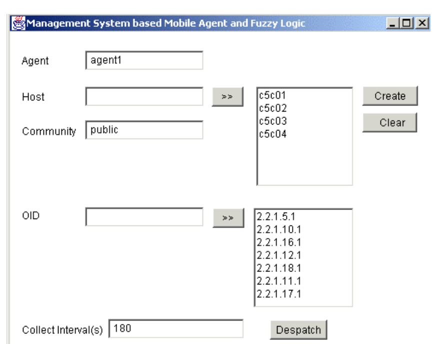

Figure 5: Graphic interface to create and dispatch agents

Fig. 6 examplifies the exhibition of a diagnosis for the case of a burst of output non-unicasts packets and its respective suggestion. The deduced threshold to interface situation was 7,5u.v. In this simulation, a sample of 20 collections in intervals of 3min showed the traffic of output non-unicast packets generated an averange output number for the interface situation of 7,8u.v. that is above the value of 7,5 for the profile of the managed network defined in the baseline.

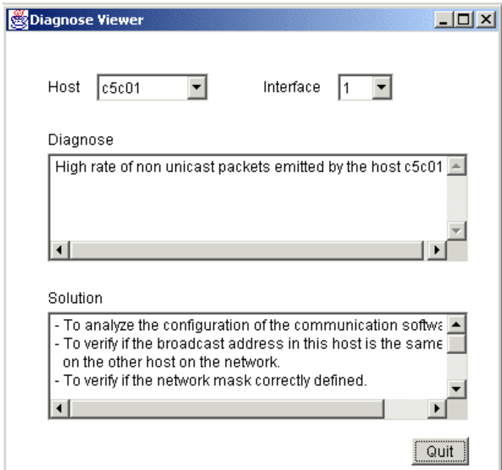

Figure 6: Diagnose viewer

4. FINAL REMARKS

The main contribution of this work is the investigation of the use of techniques of fuzzy logic in mobile agents applied in proactive network management. A prototype has been implemented using the performance management as the case study. A set of rules was built using several types of traffic as variables to show the network interface status in the managed device. As a future work the system will be applied to the other functional areas of network management.

5. BIBLIOGRAFIA

[1] Advent Network Management, Inc:, URL http://www.adventnet.com

[2] NRC Fuzzy Java Toolkit - http://ai.iit.nrc.ca/IR_public/fuzzy/fuzzyJavaToolkit.html

[3] ObjectSpace: "ObjectSpace Voyager Core Package Technical Overview", available at http://www.objectspace.com/voyager/VoyagerTechOviewNEWTAGLINE.pdf, Dallas, USA, 1997.

[4] Baldi, M., Gai, S., e Picco, G. P. Exploiting code mobility in decentralized and Flexible network management. In First International Workshop on Mobile Agents (Berlim, Alemanha, abril de 1997), pp. 13– 26.

[5] Bieszczad, A., Pagurek, B., e White, T. Mobile agents for network management. IEEE Communications Surveys 1, 1 (1998), 2–9.

[6] Goldszmidt, G. and Yemini Y.: "Distributed Management by Delegation", PhD Thesis, Columbia University, New York, NY, USA, December 1995.

[7] Nwana, H. S. Software Agents: an Overview. Knowledge Engineering Review 11, 3 (setembro de 1996), 1-40

[8] ITU-T Recommendation X.701: "Information Technology – Open Systems Interconnection – System Management Overview", 1992.

[9] Case, J., M. Fedor, M. Schoffstall, and J. Davin, The Simple Network Management Protocol", RFC 1157, University of Tennessee at Knoxville, Performance Systems International, Performance Systems International, and the MIT Laboratory for Computer Science, May 1990.

[10] Mané, B., Network Management with Mobile Agent – GRAM, Master Thesis, Federal University of Pernambuco, Recife, PE, Brazil – 1999. (In portuguese)

[11] Carvalho, E. V, Belchior, A. D. e Souza, J. N., Distributed Proactive Network Management based Fuzzy Logic. International Conference on Telecommunication – ICT'99, 15 a 18 de junho de 1999, vol. 2, pp. 308-312 Cheju, South Korea. (In portuguese)

[12] Nascimento, A., Franklin, M., Oliveira, M. Development Intelligent Agents for ATM Network Proactive Management. XVII Brazilian Symposium on Computer Networks (Salvador, Brasil, 1999), pp. 649–664. (In portuguese)

[13] Rocha, M. A., A Strategy to Implement the Proactive Management in Computer Network using System based in Knowledge, Master Thesis, Federal University of Rio Grande do Sul, 1996. (In portuguese)

[14] Artola, E. S. Life Eye: Inteligent System for Remote Proactive Management. Master Thesis. Federal Universidade of Rio Grande do Sul, 1996. (In portuguese)

[15] Filho, R. H. SAGRES – A System based in Knowledge for Suport to Fail Management in Computer Networks, Master Thesis, Federal University of Ceará, 1998. (In portuguese)

[16] Zadeh, L. A., Fuzzy Sets, Information and Control, 8, 1965, 338-353.

[17] Gavalas, D., Greenwood, D., Ghanbari, M., O'Mahony, Mike. Using Mobile Agents for Distributes Network Performance Management.-Proceedings of the 3rd International Workshop on Intelligent Agents for Telecommunication Applications (IATA-99), LNAI, Vol. 1699, pp. 96-112, Springer, August 9-10 1999.

[18] M.Siegl, G.Trausmuth. Hierarquical Network Management – A Concept ans its Prototype in SNMPv2. Vienna, University of Technology, February, 1995.