Dealing with Challenges in Managing Heterogeneous Networks by Using Mobile Agent Technology

Shamila Makki, Subbarao V. Wunnava

Department of Electrical and Computer Engineering
Florida International University, U.S.A.

Summary
In recent years managing and supervising heterogeneous networks that include different types of networks have become a challenging task. In addition, interactions between network components have affected various on-line activities and this is due to the increase of transfer of data between manager and agents which this can cause network traffic/congestion. The centralized network management system can not manage different system administrations and traffic control tasks since it involves with the management of the transmission of a substantial data which causes to consume a lot of bandwidth, and creates computational overhead and traffic jam at the manager's host. This results in a considerable strain on the network's resources at all the times. Therefore, instead of having one centralized and huge system for managing a network, several smaller systems along with agents will use for better handling of data and reducing the congestion in the network. Thus, this new management paradigm can carry out the scalability, flexibility, and robustness expected from the current network management system. This paper discusses and analyzes the general advantages of having decentralized management system and addresses how mobile agent technology deals with the challenges of managing heterogeneous networks.

Key words:
Mobile agent, network management, heterogeneous, distributed systems, scalability, flexibility, robustness.

1. INTRODUCTION

The next generation telecommunication networks consist of heterogeneous networks both wired and wireless as shown in Figure 1.1. The ubiquity and complexity of these modern networks make the management of today's telecommunication networks a complex task, especially by the increase of users' expectations in regard to Quality of Service (QoS) and reliability. Hence, these parameters make the management of such networks even harder and require an automated management and control to provide the requested reliability, reduce the congestion and improve the QoS.

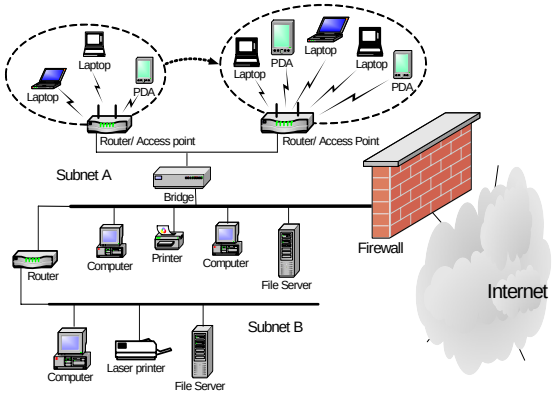

Figure 1.1: Heterogeneous network both wired and wireless.

Network management is a process of the monitoring, analyzing, controlling and planning of activities and resources of a telecommunication network not only to provide services to users but also maximizing the efficiency and productivity of the network. This process involves collecting, processing and analyzing data from a variety of devices in the network, in order to effectively manage the network traffic and its resources [1]. Simple Network Management Protocol (SNMP) is an application layer protocol for the management of TCP/IP network. SNMP is based on client/server model where the functionality of both clients (managers) and distributed servers (static agents) is defined at the design time [2], as shown in Figure 1.2.

In the traditional network management system the tasks are regularly static and they use the major part of the network significant resources (network bandwidth and latency) of the large scale networks, instead of using the common and inexpensive resources in the network elements (such as processing capability and memory) [3]. In addition, centralized network management system is not regularly able to distribute the computational load successfully. Moreover, the SNMP agents provide a limited and fixed set of functions.

Manuscript received October 5, 2007
Manuscript revised October 20, 2007

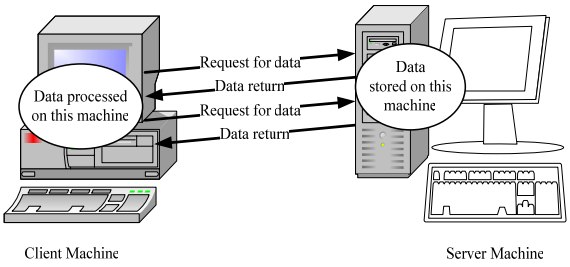

Figure 1.2: Traditional network management system based on client/server.

Thus, due to the growing complexity of telecommunication networks and extension of computers, it is require a logical framework that can support automated and more intelligent end-to-end management results [4]. The other draw back of the existing centralized management system is lack of flexibility, scalability, performance and also the network administrators must persistently control user activities at different nodes. Therefore, it is better to use distributed network management system with mobile agents (MAs).

Mobile agent technology is a fast developing area of research in the field of distributed network and management systems. Mobile agents can manage rapid changes and increase scalability of complex networks. Once a central processing entity is replaced by mobile agents, the computational load can be divided between different nodes, thus the network traffic and bandwidth requirements will be reduced. This causes increase in scalability and moreover supports fault tolerance behavior [5].

The remainder of this paper is organized in the following way: after reviewing related work in the following section, then we describe network management functions and advantages of distributed network management system in section 3. We discuss the use of mobile agent technology and advantages of its mobility and intelligence in network management in section 4. Finally, the paper concludes in section 5.

2. RELATED WORK

Mobile agents have become active and remarkable applications in heterogeneous networks. The common advantages of decentralized and agent-based approaches to network management systems and telecommunications have often been concentrated on mobile agents. In the area of network configuration management for the heterogeneous asynchronous transfer mode (ATM) environments Pagurek et al [6], improved the existing ATM's configuration management system based upon the use of mobile agents and the Java programming language. They have chosen configuration management of Permanent Virtual Connections (PVCs) in ATM networks to show the applicability and suitability of mobile agents for management purposes. In addition, Java was used for the implementation because of its platform independence, portability and robustness.

Corley et al [7] have investigated the practical implications and profits of applying agent technology to the management of problems related to service application software. In these cases, agents are seen to play a central role in enhancing flexibility, and productivity, both for the end users and the support engineers. Reference [8] shows as the capacity of web increases, it gets more difficult to retrieve the information that is not indexed. Furthermore, if indexing is done from time to time, then it makes it hard to get regularly changing information in a timely manner. With the mobile-agent based approach, agents could be launched to the source of the data to index and report. This will result in a finer grain model of information retrieval than the existing solutions.

The use of mobile agents has been discussed in [9]. They described a mobile-based approach for supporting coordination of user activities in distributed collaborations. They use XML to specify a collaboration plan in terms of different participants' role, access rights based on roles, and the coordination actions to be executed when certain events occur. By using this plan an agent-based distributed middleware system provides for each user an interface to execute the tasks that affect the collaboration. The actions of a user transparently create and dispatch coordination agents to other users.

3. NETWORK MANAGEMENT

Network management is the execution of the set of tasks for increasing availability, performance, security and control of network resources [10]. The major task of a network management system is to gather and analyze data from a diverse underlying network devices and depending on the activities of the network, some decisions must be made at different times to set the real-time requirements for various types of network's traffic. This requires the advancement of existing centralized management models into an intelligent distributed management model which puts forward a decentralized scalable network management system.

A network management system has a network management stations that can interact with management agents running on the network elements. They use network management protocols and exchange management information [11]. A network management station is a computer system, typically a workstation, which executes network management applications. It

offers the basic functionality of network management for a variety of different devices [12], as shown in Figure 1.3.

Generally network management systems are prepared according to the centralized model, and intelligence and control are placed in one centralized network management station, or the platform-centric model, where network management applications are made based on a single management platform. These can solve the problems of interaction and interoperation between different management components [13]. Nevertheless, the lack of scalability, flexibility and reliability causes these models unable to manage large heterogeneous networks effectively [14].

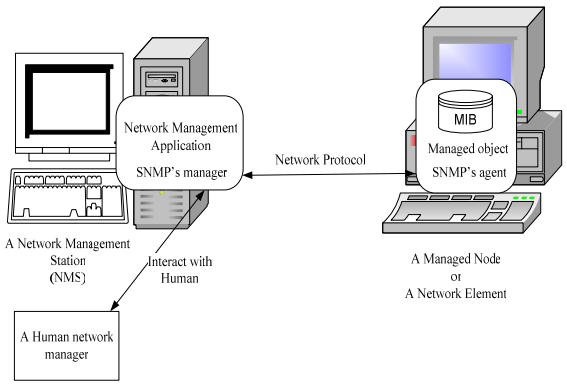

Figure 1.3: An SNMP based manager/agent model and its components.

In addition, centralized management activities are limited since they can not do intelligent processing such as judgment, decision making, forecasting, analyzing data, and making positive efforts to maintain quality of service [15]. Furthermore the traditional network management systems have been seriously disapproved because of their centralized characteristics, static managements and simple-minded models. Therefore, the model of distributed network management considered as a possible solution for these networks, and the centralized management function will distribute into multiple management entities all over the network.

4. THE EFFECTS OF MOBILTY AND INTELLIGENCE

Distributed systems and distributed algorithms have become obvious as a way to deal with the size and the complexity of the heterogeneous networks. The two best recognized methods for implementing distributed algorithms in these networks are active networks and agent-based systems [16]. In both cases, systems across the network are improved with some level of programmability. In the case of the agents, this usually occurs at the application layer, while in the active networks the entire network itself becomes programmable, including the network layers using active packets.

The term mobile code describes any program that can be sent un-changed to a heterogeneous collection of processors and execute with the same semantics on each processor. A richer functionality can be given to the interaction among processes by allowing the code to be sent among them. Sending code closer to a resource can also reduce the network bandwidth because the point of interaction moves with it. A mobile code supports a flexible form of distributed systems, where the desired non-local computations do not have to be known in advance at the execution site [17]. Mobile codes are classified as Code on Demand, Remote Evaluation, and mobile agent [18].

Mobile agent (MA) is a program (encapsulating code, data, and state) sent by a client machine to a server. Then it can continue its execution in the server machine, thus fulfilling its mobility's properties and finally it will return to the client machine with some results as shown in Figure 1.4. A mobile agent can create clones to visit several server machines in parallel in an asynchronous manner to execute certain distributed tasks [19].

Mobile agents do not statically be located in network devices, and they can be created on demand and destroyed when they are no longer required. The agent platform allows agents to travel in a heterogeneous environment. The mobility of the agent is the capability of transporting objects (which include code and state) to a network element and it can be used to reconstruct the system at run-time [11].

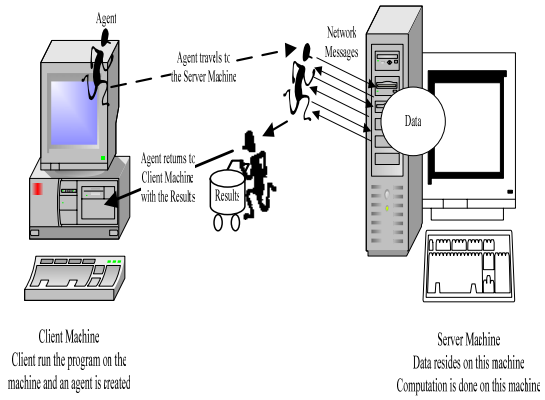

Figure 1.4: A mobile agent's model.

Agents in traditional network management systems are very big, hard to modify, static, and often require extensive resources. Mobile agents are usually smaller in size, and they normally execute a single task. MAs offer many possibilities for designing the next generation of

network management. They allow a better management of the networks and help them to utilize their full potentials and they are the best choice for developing the different network management applications.

MAs help to control the tasks to be completed in an actual distributed manner. This idea enables telecommunication services to be offered and adapted directly at the locations where the intelligence is needed [15]. A key advantage of using mobile agents is the provision of dynamic services in network elements that have been pre-programmed with such conveniences [20]

Mobile agents offer a number of special abilities to deal with the challenges in managing heterogeneous networks. They are autonomous, reactive, and proactive programs. These features are suitable for solving the problems brought by distributed systems [21].The autonomy indicates that the agent has the intelligence to work independently of the manager and does not need to report back until the task is completed [14]. Thus, by dividing management tasks into mobile, autonomous and intelligent computing entities many of the problems with network and service management can be addressed.

A mobile agent's model is more flexible and dynamic than client/server model for large-scale distributed heterogeneous network. In the mobile agent model the program moves to the data and reduces bandwidth consumption significantly in many applications, without transmitting any intermediate data across the network and creating network traffic/congestion. Instead, they minimize the volume of network traffic exchanged between distributed systems, while maintaining relatively low task execution time, especially for time-critical tasks [22]. An agent can react to user actions rapidly and thus improving the latency requirements [23].

In addition, the usage of the MAs can prevent the need for long and costly network connections between remote computers, since an MA needs only to move to its destination which requires just a short and thus less costly connection time and hence it is suitable for the users of mobile computers, since it makes an application less sensitive to the unstable communication links [24]. Therefore, the usage of the mobile agents can provide a much cheaper option for the network usage as we pay increasingly more for networks' bandwidth and time.

The processing power and storage of a local machine may be very limited, thus requiring the use of MAs in order to provide easier coordination, asynchronous computing, flexible distributed computing architecture and present an opportunity for attractive rethinking of the design process [25].

Furthermore, a mobile agent is executed only on one node at a time and other nodes do not run that agent until it is needed. This will help in reducing the usage of the Central Processing Unit (CPU) and other resources in comparison with the static agents [26]. Moreover mobile agents can be used in network management to eliminate the limitations that are available in the traditional network management systems by distributing and decentralizing network management tasks.

5. CONCLUSIONS

Network management is an important character in the configuration, proper functioning, and maintenance of a network. Since networks are becoming more complex through developing connections to many devices with different system architectures, they need new software for handling data, incorporating and integrating new and existing communication technologies.

In many cases, a centralized model of network management is unsuitable and incapable to serve large and different group of networks. Hence, there is a need to have a distributed network management for better managing and control the network. In addition, many of the problems with networks and service managements can be dealt with by dividing the management tasks into mobile, autonomous and intelligent computing entities. Mobile agents have a significant functionality in a distributed network management system and they can increase the, scalability, flexibility, reliability and power of telecommunication management systems and services.

Furthermore, there may be a lot of raw information that need to be searched and examined in order to determine their importance, thus, transferring these information across the network can be very time-consuming and may create congestion in the network. Since mobile agents have the ability to move towards the remote servers where the data are residing hence they can reduce network load/traffic congestion, communications' costs by optimizing the movement of data across the network and saving time.

6. REFERENCES

[1] S. S. Manvi, P. Venkataram, "Application of Agent Technology in Communications: a Review", Computer Communications Journal, Elsevier, Vol. 27, pp 1493-1508, 2004.

[2] Stallings, W., SNMP, SNMPv2, SNMPv3, and RMON 1 and 2, Third Ed., Addison Wesley, 1999.

[3] M. Ghanbari, D. Gavalas, D. Greenwood, M. O' Mahony, "Advanced network monitoring applications based on mobile/intelligent agent technology", Computer Communications Journal, Vol. 23, No.8, pp 720-730, 2000.

[4] M. L. Griss, "Software Agents as Next Generation Software Components", chapter 36, Computer-based Software Engineering: Putting the Pieces Together,

Gorge T. Heinemann, & William Council (Editors), Addison-Wesley, 2001.

[5] C. Tsatsoulis, L. K. Soh, "Intelligent Agents in Telecommunication Networks", Computational Intelligence in Telecommunications Networks, W. Pedrycz & A.V. Vasilakos (Editors), CRC Press, 2000.

[6] B. Pagurek, Y. Li, A. Bieszczad, and G. Susilo, "Network Configuration Management in Heterogeneous ATM Environments", in Intelligent Agents for Telecommunications Applications, Springer-Verlag, pp. 72-88, 1998.

[7] S. Corley, D. Magro, F. Malabocchia, J. Meinkohn, L. Sisto, S. Albayark, and A. Grosse, "The Application of Intelligent and Mobile Agents to the Management of Software Problems in Telecommunications", LNAI 1437, Springer, pp. 118-129, 1998.

[8] B. Brewington, R. Gray, K. Moizumi, D. Kotz, G. Cybenko, and D. Rus, "Intelligent Information Agents, in: M. Klisch (Ed.), Mobile Agents for Distributed Information Retrieval", Springer, New York, (chap.15), 1999.

[9] A. Tripathi, T. Ahmed, V. Kakani and S. Jaman, "Distributed Collaborations using Network Mobile Agents", in Second International Symposium on Agent Systems and Applications/Fourth International Symposium on Mobile Agents, pp. 126-137, 2000.

[10] T. M. Chen, S. S. Liu, "A Model and Evaluation of Distributed Network Management Approaches", IEEE Journal on Selected Area in Communications, Vol. 20, No. 4, pp 850-857, 2002.

[11] T. Magedanz, and A. Karmouch, "Mobile Software Agents for Telecommunication Applications," in Computer Communications, Elsevier Science, Vol. 23, no. 8, pp. 705-707. 2000.

[12] M. J. O' Grady, G. M. P. O' Hare, "Gulliver's Genie: Agency, Mobility & Adaptively", Computers & Graphics, Special Issue on Pervasive Computing and Ambient Intelligence-Mobility, Ubiquity and Wearables Get Together, Vol. 28, No. 4, pp 677-689, Elsevier, 2004.

[13] M. D'Arienzo, A. Pescape, G. Ventre, "Dynamic Service Management in Heterogeneous Networks", JNSM: Vol. 12, No. 3, 2004.

[14] P. Zhang, C. Zhao, and Z. Li, "Agent-oriented Modeling Approach for distributed Network Management Applications", APOC 2001, Asia-Pacific Optical and Wireless Communications, 2001.

[15] M. Welzl, "Network Congestion Control: Managing Internet Traffic", Wiley, 2005.

[16] A. Acharya, M. Ranganathan, and J. Saltz, "Dynamic linking for mobile programs, In Mobile Object Systems: Towards the Programmable Internet", pp. 245-262, Springer-Verlag, 1997.

[17] T. Thorn, "Programming Languages for Mobile Code", in ACM Computing Surveys, Vol. 29, pp 213-239, 1999.

[18] A. Fuggeta, G.P. Picco, and G. Vigna, "Understanding Code Mobility", IEEE Transactions on Software Engineering, Vol.24, No.5, pp.436-361, 1998.

[19] R. Stephan, P. Ray, and N. Paramesh, "Network Management Platform Based on Mobile Agents", International Journal of Network Management, Vol. 14, pp. 59-73, 2004.

[20] H. Sanneck, M. Berger, B. Bauer, "Application of Agent Technology to Next Generation Wireless/Mobile Networks", in Proceedings of the Second World Wireless Research Forum (WWRF WG3) "Going Wireless-New Technologies", May 2001.

[21] P. Braun, W. Rossak, Editors, "Mobile Agents: Basic Concepts, Mobility Models & the Tracy Toolkit", Morgan Kaufmann, 2005.

[22] S. Papavassiliou, A. Puliafito, O. Tomarchio, and J. Ye, "Mobile agent-Based Approach for Efficient Network Management and Resource Allocation: Framework and Applications", IEEE Journal on Selected Areas in Communications, Vol. 20, No. 4, 2002.

[23] I. Satoh, "Network Processing of Mobile Agents, by Mobile Agents, for Mobile Agents", in Proc. Workshop on Mobile Agents for Telecommunication Applications, LNCS, Vol. 2146, Springer, pp. 81-92, 2001.

[24] M. Berger, H. Sanneck, and B. Bauer, "Application of Agent Technology to Next Generation Wireless/Mobile Networks", in WWWRF WG3: Going Wireless – New Technologies, 2002.

[25] M. Dalmejer, D. K. Hammer, A.T.M. Aerts, "Mobile Software Agents", Computer in Industry, Vol. 41, pp 251-260, 2000.

[26] A. Aneiba, J. S. Rees, "Mobile Agent Technology and Mobility", Proceeding of the 5th Annual Postgraduate Symposium on the Convergence of Telecommunications, Networking and Broadcasting, pp 14-20, PGNet 2004.

AUTHORS BIOGRAPHIES

Shamila Makki obtained her Masters degree in Information Technology from The University of Queensland, Brisbane, Australia in 2003. Currently she is a Ph.D. Candidate at the Florida International University, USA and her research interests are in Computer Networks, Data Communications, Wireless Communications, Databases, Intelligent Agent Technology and Network Security. She is currently a member of IEEE and ACM.

Dr. Subbarao V. Wunnava has been a Professor of Electrical and Computer Engineering at FIU since 1977. He areas of specialization are: Computer and Data Communications, Networking and Network Security, and Very Large Scale Integrated Circuit (VLSI) and Intelligent System Designs (ISD). His experience includes working as Graduate Advisor and Associate Chair of the Electrical and Computer Engineering Department. Also, he has been a consulting engineer for several years for AT&T Bell Laboratories and Bell Core operations, Motorola and Burroughs, and Cordis Corporations. He is author of nearly 160 publications in various conferences, seminars and journals. He is the author of 3 books on Micro processors and several tutorials on ISDN and Data Communications, Verilog and VHDL based VLSI designs. He has graduated 70 MS students in Electrical and Computer Engineering as the major advisor and 6 Ph.D. students during last 12 years. Currently he is the director of the VLSI and ISD research laboratories at FIU.