Turkish Online Journal of Distance Education-TOJDE October 2005 ISSN 1302-6488 Volume: 6 Number: 4 Article: 10

An Autonomous Mobile Agent-Based Distributed Learning Architecture-A Proposal and Analytical Analysis

Dr. I. Ahmed M. J. SADIIG

**Department of Electrical & Computer Engineering
International Islamic University Gombak
Kuala Lumpur-MALAYSIA**

ABSTRACT

The traditional learning paradigm invoving face-to-face interaction with students is shifting to highly data-intensive electronic learning with the advances in Information and Communication Technology. An important component of the e-learning process is the delivery of the learning contents to their intended audience over a network. A distributed learning system is dependent on the network for the efficient delivery of its contents to the user. However, as the demand of information provision and utilization increases on the Internet, the current information service provision and utilization methods are becoming increasingly inefficient.

Although new technologies have been employed for efficient learning methodologies within the context of an e-learning environment, the overall efficiency of the learning system is dependent on the mode of distribution and utilization of its learning contents. It is therefore imperative to employ new techniques to meet the service demands of current and future e-learning systems. In this paper, an architecture based on autonomous mobile agents creating a Faded Information Field is proposed. Unlike the centralized information distribution in a conventional e-learning system, the information is decentralized in the proposed architecture resulting in increased efficiency of the overall system for distribution and utilization of system learning contents efficiently and fairly. This architecture holds the potential to address the heterogeneous user requirements as well as the changing conditions of the underlying network.

Keywords: **Mobile agents, Electronic learning, Information systems, Web-based learning.**

INTRODUCTION

The ability to instruct from a distance can hardly be termed as new. Several correspondence schools in Europe engaged in teaching shorthand and foreign languages by mail in mid-1800s. However, the traditional face-to-face instructional style is being complemented by the distant instructor through e-learning technology. Information and Communication Technology (ICT), having the Internet and network-centric computing as its backbone, has laid a firm foundation for experimentation with e-learning. As a result, the traditional learning paradigms have been stretched through electronic and web technologies into new learning models that are dynamic in nature (Geyeret et al 1997, Rafaeli et al 2004, Abbatsita et al 2004, Houtsonen et al 2004). The rationale behind the advancing importance of e-learning into educational institutions and training centers can be broadly categorized as the impetus of market forces, the availability of technology and customer pressure.

Electronic learning is booming by any measure. The demand for e-learning in the USA leapt from 5 percent of all students in higher education in 1998 to 15 percent by 2002, whereas the on-line content of employee training budget went up to 40 percent of the total (Ubell 2000). Efforts are continuing worldwide to standardize the e-learning systems resulting in several specifications for e-learning and learning objects. Among pioneers are groups such as Learning Technology Standards Committee of the Institute of Electrical and Electronics Engineers (IEEE LTSC) and the IMS Global Learning Consortium (Mohan et al 2003).

The Internet is a heterogeneous data repository that is constantly changing, with its users increasing at the rate of 20% annually (Roberts 2000). New information services are added and modified regularly whereas the legacy services are dropped. It is therefore a tedious task to search for the required information on the Internet. This is so as the current method of information sifting on the Internet by search engines is highly inefficient. Although various architectures are being developed to make the e-learning systems efficient and meaningful compared to traditional methods, the ultimate efficiency of an e-learning system is dependent on the network to which it is connected for service provision. As ICT advances, the e-learning systems tend to be more data intensive. The efficiency of service provision and utilization of such learning systems cannot be effectively enhanced through conventional means alone since the dynamics of distance learning are increasingly becoming similar to the dynamics of the underlying communication network. A demand-oriented information service architecture employing mobile agents has been reported recently (Ahmad et al 2001). The architecture termed as Faded Information Field Architecture (FIF) holds the potential to handle the high throughput data rates involved in the current information services. We propose an integrated learning architecture that employs FIF as the underlying mechanism of information distribution and utilization in a distributed learning environment. With reference to the architecture of a typical e-learning system, the mechanism of service provision and utilization has been specifically taken into consideration in this work The evolved architecture holds the potential to handle the high rate of service provision and utilization requirement of a modern e-learning system. The information provision is decentralized in the proposed system resulting in comparatively less user access time and high fault tolerance. It distributes the most accessed information contents around the service provider with equal access to the users. The congestion avoidance strategy of the proposed system was evaluated by simulations. The results verify the potential of the proposed system to reduce congestion during peak service times. It may be pointed out that the term web-based learning will be used in the context of e-learning throughout the text. The paper is organized as follows: The next section looks at the general form of an e-learning system followed by an overview of the FIF architecture employing mobile agents. Section 5 will illustrate the proposed e-learning system. Simulation results will be presented in section 6. The paper will be concluded in section 7.

A TYPICAL E-LEARNING SYSTEM

E-learning has evolved over the years in unison with the advancement in information and communication technology (ICT). The evolution of ICT has witnessed a direct impact on e-learning systems.

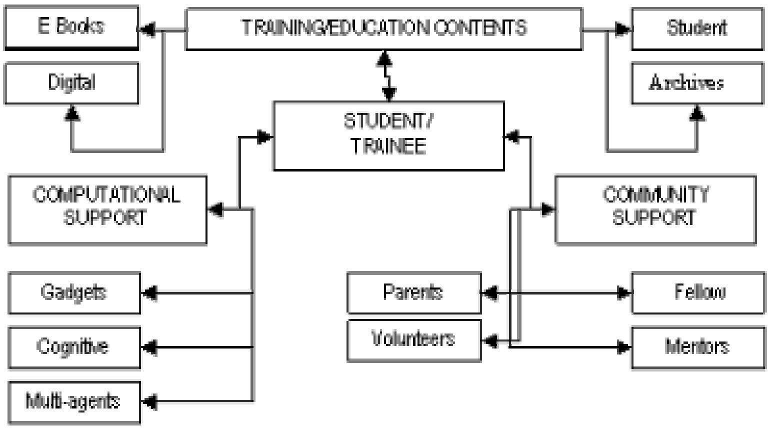

Figure: 1 The student/learner at the hub of a modern e-learning system

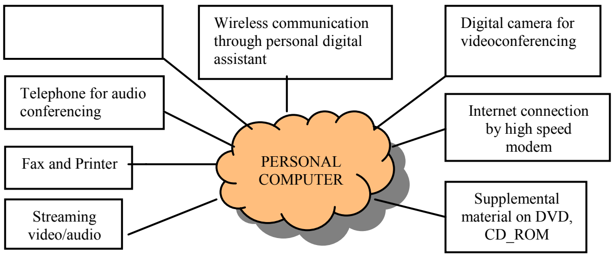

Figure: 2 The personal computer acting as the nerve center of technical innovation in e-learning.

This impact has given rise to a technological environment where the learner has all the support to learn with gadgets coupled with human support as depicted in Figure 1. The personal computer as the nerve center of an e-learning system is depicted in Figure 2. Currently, a variety of e-learning systems are in existence ranging from proprietary solutions to systems that use technologies that originally had not been developed for teaching and learning e.g., the World Wide Web (WWW) (Cloete 2001, Cortes 1999, Vrettos et al 2001, Leung et al 2001). These systems generally employ Artificial Intelligence for data retrieval/management and ICT for service utilization. A typical generalized e-learning architecture is shown in Figure 3. The learning contents are traditionally stored on a central location in the system. Various schemes are employed to service user requests and interaction with the system through the network.

The educational content of the central server ranges from text data to multimedia presentations. The WWW is an essential component of such a system. No matter how localized the architecture may be, it has to be interfaced with the Internet for it to be a useful distributed learning system. An e-learning system is essentially an information service system. Therefore, the quality of service (QoS) of such a system is a function of the QoS of the Internet. It can therefore be concluded that the ultimate performance of an e-learning system is determined by the QoS of the network environment to which it is hooked up for communication in addition to its own attributes.The current e-learning systems are centralized systems. They are operated through centralized servers and therefore are susceptible to centralized service problems, one of the most prominent being the overloading of the server owing to the popularity of its contents. Such machines have low

reliability and have a single entry point on the web in the form of a URL. It is therefore imperative to address these problems and adopt/develop efficient techniques to optimize the service provision and utilization of present e-learning system.

MOBILE AGENTS IN INFORMATION SYSTEMS– AN OVERVIEW

The details of mobile agents and their employment in a distributed environment can be found elsewhere (Karmouch et al 1998, Perdikeas et al 1999, Lange et al 1999). Here, a brief introduction of mobile agents and their role in a network-based information system will be discussed.

The term mobile agent is often context-dependent and has two separate and distinct concepts: mobility and agency.

The term agency implies having the same characteristics as that of an agent. These are self-contained and identifiable computer programs that can move within the network from node to node and act on behalf of a user or other entity. These can halt execution from a host without human interruption (Cao et al 2001).

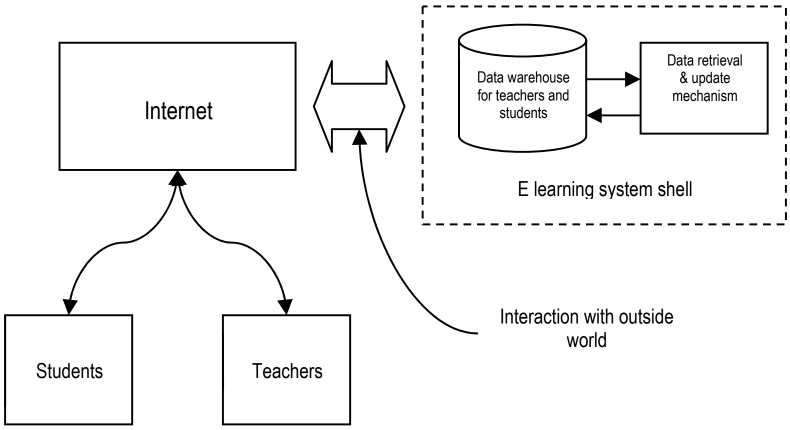

Figure: 3 The basic general architecture of a web-based e-learning system.

The current network environment is based on the traditional client/server paradigm. However, in the case of mobile agents employed in a network, the service provision/utilization can be distributed in nature and is dynamically configured according to changing network performance metrics like congestion and user demand for service provision (Ahmad et al 2001).

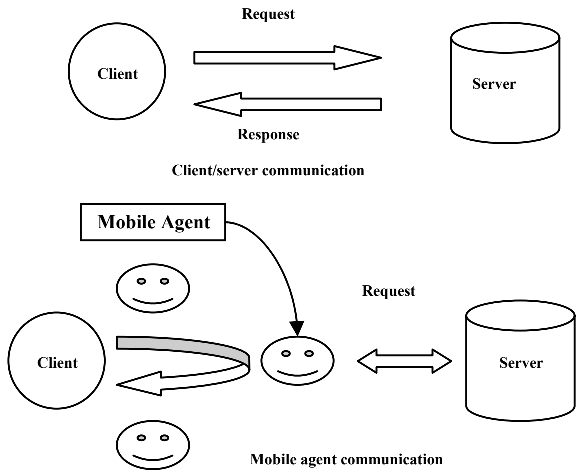

Figure: 4 Bandwidth can be conserved by using mobile agents in a complex adaptive information system environment.

Mobile agents are typically suited to applications requiring structuring and coordinating wide area network and distributed services involving a large number of remote real time interactions (Funfrocken 1998). Mobile agents can decide how best to handle a user's request based on past data or history of a similar request. These programs are therefore capable of learning from user behavior to some extent.

THE FADED INFORMATION FIELD ARCHITECTURE – AN OVERVIEW

Faded Information Field (FIF) Architecture has been proposed recently to optimize the service provision parameters on the network. The details of this technology can be found elsewhere; only essential features will be reviewed here. The goal of FIF is the effective provision of information in a network. This architecture is based on demand-oriented replication of information service to assure service availability and utilization. In a FIF system, the information is distributed on a number of nodes in the network rather than a localized node. The FIF architecture is depicted in Figure 5.

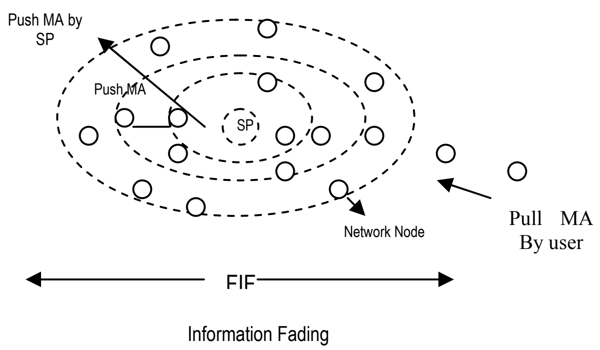

Figure: 5 The layout of a Faded Information Field Architecture.

The service providers sense the demand trend of information and the most accessed segment of that information is allocated to a storing node. From the storing node the information service is further distributed to adjacent nodes, however, with less information content.

The process continues in a recursive fashion and the information contents are distributed to more storing nodes away from the service provider (SP). The so called information field created by this pruning process has the following key characteristics:

- **The information content stored on a node is inversely proportional to the distance of storing node from the SP.**
- **Information update frequency on a storing node is inversely proportional to the distance of storing node from the SP. Thus nodes adjacent to the SP are easily and frequently updated compared to the nodes farther away from the SP.**

By allocating the most frequently accessed information to the nodes and by concentrating the majority of the information closer to the SP, the cost of service utilization (user access time) and cost of service provision (information update) are balanced.

FIF Components

The system essentially consists of logically connected nodes through which users and service providers correspond. Mobile agents are used by both parties to acquire and provide information respectively, under evolving/changing situations. The mobile agents (MA) generated by service providers are termed as push mobile agents (Push MAs). Push MAs carry out the function of autonomous coordination and negotiation with other nodes for information fading according to network situation and the level of importance attached to the information.

The level of importance of particular information content is based on its popularity, determined from a high hit rate of query. The pull mobile agents (Pull MA) are generated by users and they autonomously navigate in search of the required information on the network nodes in a step by step fashion. Once the required information is located, these agents report back to the source. The push and pull MAs have no direct correspondence with each other.

The third important subsystem of a FIF is the node itself. It is a platform for both storage of information and program execution. It monitors the local information-based system conditions and autonomously makes decisions for allocation requests by the SP. Each subsystem is autonomous in terms of control to execute its operations and coordination with other nodes under evolving network conditions.

Communication Format in a FIF Architecture

The conventional communications techniques cannot cope with the evolving conditions in a heterogeneous network environment where the state of nodes, the status of the SPs and the stability of connections are highly unpredictable as the user demand to access the information is dynamic in nature.

FIF therefore employs a different technique referred to as content communication technique (Ahmad et al 2001). An example of content code communication is depicted in Figure 6 where the information about a distance learning course is structured according to the degree of importance. CM1 specifies the course nomenclature followed by CM2 indicating the type of degree program under which it is offered.

The information contents in a FIF are uniquely defined by their content codes (CCs). These are further elaborately specified by their characteristic codes (CHs). Push MAs are sent out in the FIF by SPs specifying Content Codes (CMs) of information to the nodes using the message format shown in Figure 6. The selection of information storage/allocation is autonomously carried out by the nodes based on CCs. Similarly the Pull MAs sent out by the users search for the required information based on CCs.

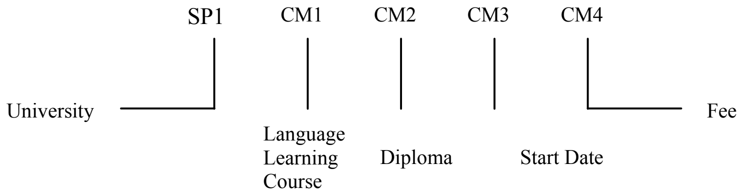

Figure: 6 The message format in FIF architecture.

THE PROPOSED AUTONOMOUS E-LEARNING SYSTEM

The proposed architecture based on FIF technique is shown in Figure 7. The e-learning server where all the necessary learning material is placed is referred to as a SP for the purpose of reference.

The SP generates mobile agents that are essentially network conscious programs. These agents autonomously navigate through the network, from node to node. These are referred to as push MAs. The Push MAs carry the educational/learning contents of the system (on a server) located at SP to the adjacent network nodes. Contrary to the traditional method of making the information accessible to the users, the SP radiates the important contents of information to its nearest nodes.

As the power of a radiated electromagnetic wave fades away from the transmitting antenna, so does the information content fade away from the SP on various nodes. The degree of fading is negotiated by the Push MA with the node and is a function of network operating condition and is inversely proportional to network congestion.

The user looking for the educational/learning information on the other hand generates Pull MAs that navigate the nodes in search of required information. Instead of searching for a fixed URL as in the current system, the pull MA navigates the nodes in search of the required information. Since every client may not require the same degree of information complexity the pull agent may not be required to navigate all the way to SP to access the information contents which may be accessible closer to its source.

Each entity in this system is autonomous and is independent of other entities. Since the abundance of information available on the network and its evolving nature makes it difficult to be aware of the latest updates, the mobile agent technology proposed for the implementation of an e-learning architecture is one of the solutions to the current problem of access to a central database.

The following advantages are envisaged for the proposed architecture:

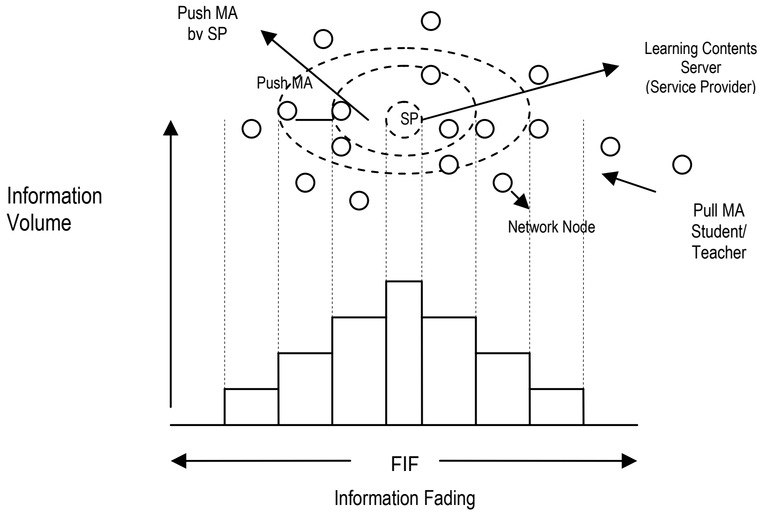

Figure: 7 The proposed autonomous mobile agent-based distance learning system architecture.

- **Enhanced reliability both for users and providers**
- **The access time for information is drastically reduced, as the required information is not centralized rather it is available on a number of nodes on the network.**
- **All the components in this architecture are autonomous. Nodes autonomously determine the amount of information to be stored.**
- **The issue of changing state of the network or the upgrade of e-learning contents can be coped with efficiently.**
- **Fault tolerance of the architecture is improved as the information availability is decentralized.**

SYSTEM SIMULATIONS

The simulation of a FIF has already been reported (Ahmad et al 2001). However, we programmed a distributed network to mimic a distributed learning environment. We carried out the simulation taking into account the physical field size and information content distribution as a function of nodal congestion. The information field is defined as the contents of information stored on a network node. It is assumed that there are 50 nodes on the simulated network. The amount of information fading is a function of network congestion. The nodes adjacent to the service provider (SP) will be more affected by congestion and therefore will store more information in order to relieve more burden of the SP. In comparison, the nodes further away from the SP store less information in order to relieve communication burden during network congestion at peak service times. There are two important issues here; the information field size fading and the information content fading. The size of the information field is defined as the nodes around the SP where the information content is loaded. The outermost nodes define the perimeter of the FIF with the SP in the center.

In order to offset the disadvantage of the conventional centralized SP, the size of the defined FIF must be made a function of the network congestion. This implies that in the absence of any congestion the field size is the optimum. However when congestion sets in the field size shrinks and the information contents are restricted to nodes occupying a smaller area thus relieving the congested SP of the processing overhead required maintaining a large field. This effect was simulated using the following data:

- 50 FIF nodes in the wide area network, shared by 4 SPs
- 200 routers
- The server sends push MAs every 100s (Figure 8. Size of information filed vs. nodal congestion)
- Distances between nodes can range from 20μs (for nearby nodes) to 250μs (for further nodes)
- Information fades as the push MA moves further away, but each node in the field is required to store at least one content code from each push MA that arrives

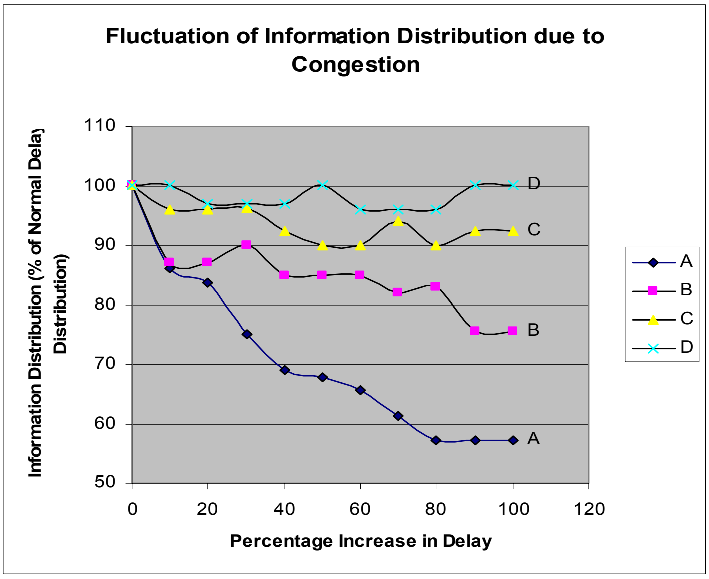

Figure: 8 Size of information filed vs. nodal congestion

The simulation results are depicted in Figure 8.

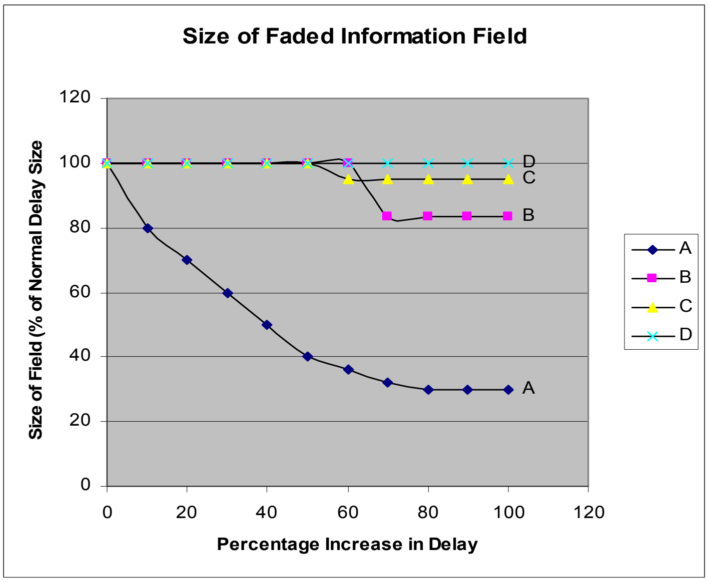

Figure: 9 Information distribution variations as a function of nodal congestion.

As the delays are incurred in the network and a node gets congested the field size around the congested SP decreases autonomously whereas the field size around SPs far from the congested SP is less affected. The field reduction mechanism is embedded in the push MAs. They are given a fixed time to live, or another internal time limit. When it exceeds this time limit, the push MA stops its distribution of information contents on the nodes. During congestion, it will achieve this time limit when it has traveled to less number of nodes, effectively reducing field size. In Figure 8, SP A is heavily congested and drops its field size as the network delay increases. SP B is the adjacent node, and it drops its size by a lesser magnitude, around 80% of its original size followed by SP C. SP D being the farthest remains relatively unaffected in this consideration. Thus the autonomous mechanism embedded in the push MAs keeps the information field size dynamic resulting in high assurance.

The information distribution function on a particular SP being dynamic in nature is a function of congestion. This implies that the SP sheds its information contents when congested resulting in less number of pull MA queries being directed to the SP. The SP in effect reduces its own information content by ensuring that all the adjacent nodes can handle a certain percentage of the information. The information contents on the nodes adjacent to the congested SP increase. With the given data above, the simulation result of information fading is depicted in Figure 9. The results are in agreement with the theory. SP A being the congested SP drops its information contents up to 57%. SP B is an adjacent SP in the simulated network that exhibits an information shedding behavior at a smaller scale. SP C is still further from SP A and the redistribution content is very little, and SP D's information contents remain intact. The occasional bumps in the curves relate to occasional impulses in the network traffic.

CONCLUSION

The e-learning systems have been identified to be essentially Information Service Providing Systems. A new e-learning architecture capable of handling future information provision in a distance-learning network setting has been proposed and characterized based on FIF architecture. Under evolving load conditions on the network, the autonomous fading mechanism of the FIF was observed to regulate the information field size dynamically in response to changing traffic load on the information network. The field size and information fading being the two key parameters of the information filed were simulated using a simulation engine and the results were observed to be in line with the predicted behavior of the system. The current research can be directed to further research into various aspects of the proposed architecture like the characterization of the system with respect to overlap of information provision by two service providers and the resultant behavior of the system.

Since the feasibility of FIF technology has already been reported, therefore the proposed system has a lot of potential to handle the large throughput requirements of distributed learning systems in addition to the provision of fault tolerance, timeliness and reliability.

ACKNOWLEDGEMENT

This work was supported by the Research Center, International Islamic University, Malaysia. (When, something its budgetetc.)

BIODATA AND CONTACT ADDRESSES OF AUTHOR

Dr. I. Ahmed M. J. Sadiq
Department of Electrical & Computer Engineering
International Islamic University, Gombak, Kuala Lumpur, MALAYSIA
Tel: (03) 20564478
Cell: 016-6912464
Emails: imadg13@yahoo.com or jafars@iiu.edu.my

REFERENCES

Ahmad, H. F. and Helene Arfaoui, Mori, K (2001), Autonomous Information Fading by Mobile Agents for Improving User's Access Time and Fault Tolerance, *Proceedings 5th International Symposium on Autonomous Decentralized Systems*, 279-283.

Karmouch A. and V. A. Pham (1998), "Mobile Software agents: An Overview", *IEEE Communications Magazine*, 36(7), 26-37.

D. B. Lange and M. Oshima, (1999), "Seven Good Reasons for Mobile Agents", *Communications of the ACM*, 42(3), 88-89.

Eckert, A, Geyer, W. Effelsberg (1997), A Distance Learning System for Higher Education Based on Telecommunication and Multimedia: A Compound Organizational, Pedagogical and Technical Approach, *Proceedings: ED-Media/Ed-Telecommunication*, Calgary, Canada.

Elsabe C. (2001), "Electronic Education System Model", *Computers and Education*, 36(2), 171-182.

Elvis W. Chung L. and Qing .I (2001), "Agent-Based Approach to e-Learning. An Architectural Framework", W. Kim et al. (Eds): *Lecture Notes in Computer Science*, 2105, 341-2001.

Fabio A., Aldo P, Giovanni S. and Fabio Z. (2004), "An Agent that Learns to Support users of a Web site"*, Applied Soft Computing*, 4(1), 1-12.

F. Cortes, V. Darlayiannis, M. Herreo, G. Kyriakaki, R. Luling, Y. Maragoudakis, Y. Mavragains, K. Meyer, n. Pappas (1999), "The SCIMA Tele-teaching Trial on ADSL and Intranet networks", H. Leopold and N. Garcia (Eds): ECMAST; 99, *Lecture Notes in Computer Science*, 1629, 1-14.

H. F. Ahmad, H. Arfaoui and K. Mori (2001), Autonomous Information Fading by Mobile Agents for Improving User's Access Time and Fault Tolerance, *Proceedings, 5th International Symposium on Autonomous Decentralized Systems,* 279-283.

J. Cao, G. H. Chan, W. Jia, and T. Dillon (2001), Check-pointing and Rollback of Wide-Area Distributed Applications using Mobile Agents, *Proceedings, International Parallel and Distributed Processing Symposium*, San Francisco: IEEE Computer Society Press.

Lawrence G. Roberts (2000), "Beyond Moore's Law: Internet Growth Trends", *IEEE Computer*, 33(1), 117-125.

Lea H., Ilta-Kanerva K. and Antti R. (2004), "Web use in Geographical and Environmental Education: An International Survey at the Primary and Secondary Level", *Geo Journal*, 60(2), 165-174.

M. K. Perdikeas et al (1999), "Mobile Agents Standards and Available Platforms", *Comp.Net*, 31(19), 1999-2016.

Permanand M., Christopher B. (2003), "Engineering a future for Web-Based Learner Objectives", *Lecture Notes in Computer Science*, 2722, 120-123.

S. Vrettos and A. Stafylopatis (2001), "A Fuzzy Rule-Based Agent for Web Retrieval-Filtering", N. Zhong et al. (Eds): WI 2001, *Lecture Notes in Artificial Intelligence*, 2198, 448-453.

Sheizaf R., Miri B., Yuval D-G. and Eran T. (2004), "QSIA-A web-Based Environment for Learning Assessing and Knowledge Sharing in Communities", *Computers and Education*, 43(3), 273-289.

S. Funfrocken (1998), Integrating Java-based Mobile Agents into Web Servers under Security Concerns, *Proceedings 31st Hawaii International Conference on System Sc*iences, 34-43.

Ubell, R (2000), "Engineers Turn to E-Learning", *IEEE Spectrum*, 37(10), 59-62.