Characterization of a Novel Intelligent Information Management Architecture based on Autonomous Mobile Agents

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ABSTRACT

Information Systems have progressed from stand-alone platform-centric systems to network-centric intelligent systems with the rapid advancement in Information and Communication Technology. This is an evolutionary process embedded with new challenges and rewards for the users of new information systems. The migration of these systems towards network centric computing has made these systems susceptible to networking paradigm problems opening a whole new avenue of research to address the typical problems of these information systems. The user demand on information service systems is never predictable and is always changing, creating new challenges for the designers and managers of these systems. Autonomous mobile agents employed in a networked environment have shown a lot of potential to inject intelligence and to handle the heterogeneous user demands of such systems under constantly evolving conditions. This paper investigates the employment of faded information field architecture employing mobile agents to address the constantly evolving condition of an information service system. The proposed architecture was simulated with promising results in unison with predicted behavior.

Keywords

Mobile agents, information systems, information management, artificial intelligence.

1.0 INTRODUCTION

Recent times have seen a quantum leap in the advancement of Information and Communication Technologies (ICT). Not only the technologies to store huge volumes of raw knowledge have improved but the delivery mechanisms of knowledge transport have progressed tremendously through networking technologies. Knowledge repositories used to be isolated and distributed in the past with inefficient modes of retrieval and deposit and with inefficient mode of distribution. Information systems are now shifting from platform centric to network centric systems which solely depend on networks for their performance. Although the rapid advancements in ICT have given new impetus to knowledge retrieval and distribution, the whole paradigm is undergoing an evolutionary process of transformation into a new era. This era is loaded with challenges and rewards. Some of the most significant challenges facing the ICT community are the design, integration, upgrade and maintenance of information (Ceruti, 1998). 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 where as 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 method of information sifting on the Internet by search engines in vogue is highly inefficient.

Although efforts have been made to standardize and offer different platform based systems (ADL, 2001; ARIADANE, 2001; GESTALT, 2001; CEN, 2001; Wai and Qing; Cloete, 2001), these efforts have failed to address the basic issue of information service management for optimum efficiency under evolving user requirements. A knowledge management system being a data repository in nature has to rely on a network for it to be useful in terms of new usage; it is vulnerable to the shortcomings and problems of networking in the context of congestion, fault tolerance and assurance.
This paper investigates using a new technique (Ahmad et al., 2001) of information fading to be employed in a knowledge management system. Faded information field architecture holds the potential to alleviate the current problems in networking. The technique was simulated and the results are promising.

2.0 A TYPICAL KNOWLEDGE MANAGEMENT ARCHITECTURE

Knowledge/Information management systems (IMS) have been keeping pace with the advancement in information and communication technology (ICT) for their evolution. The evolution of ICT has witnessed a direct impact on IMS. This impact has given rise to a technological environment where the user has all the support to retrieve the information with gadgets coupled with human support as depicted in Figure.1. Currently, a variety of such systems are in existence ranging from information service systems to proprietary electronic-learning systems that use technologies, which originally have not been developed for the purpose (Cloete, 2001; Cortes;

Vrettos and Stafylopatis, 2001). These systems generally employ Artificial Intelligence for data retrieval/management and ICT for service utilization. A typical generalized knowledge management system architecture is shown in Figure 2. The knowledge 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 knowledge 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 knowledge management system. A knowledge management 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. Thus it can be concluded that the ultimate performance of a knowledge management 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 knowledge management systems are centralized systems. They are operated through centralized servers and therefore are susceptible to centralized service problem syndrome. One of the most prominent is 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 knowledge management systems.

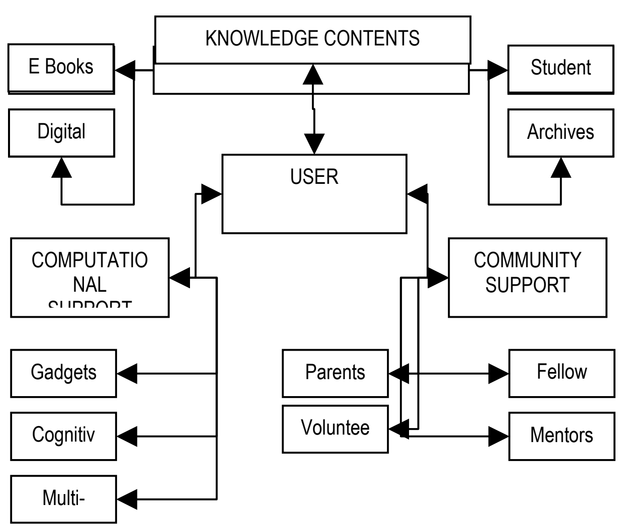

Figure 1: User at the central focus in a typical knowledge management system

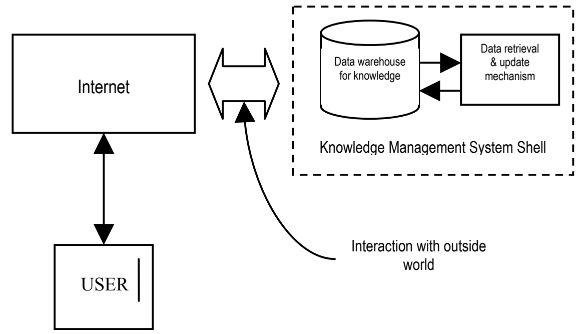

Figure.2: The basic general architecture of a Knowledge Management System

3.0 THE FADED INFORMATION FIELD ARCHITECTURE – AN OVERVIEW

Faded Information Field (FIF) Architecture has been developed recently to optimize the service provision parameters on the network (Vrettos and Stafylopatis, 2001). The details of this technology can be found elsewhere (Vrettos and Stafylopatis, 2001), however, only essential features will be reviewed here. The goal of FIF is the provision and effective utilization of information. In FIF system, the information is distributed on a number of nodes in the network rather than a localized node. From the central node (SP node implying service providing node) the information decreases/fades away in content away from the SP. This implies that the nodes adjacent to the SP richer in information content than those away from it.

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 situation. The mobile agents (MA) generated by service providers are termed as Push MAs and these negotiate with nodes for information fading according to network situation and the level of importance attached to the information.

The pull agents are generated by users and they autonomously navigate in search of the required information on the network nodes. This scheme helps to reduce the access time for the user to access the required information stored at the nodes located closer to the user. Similarly the SP can avoid the network congestion.

4.0 THE PROPOSED INTELLIGENT INFORMATION SYSTEM

The proposed architecture based on FIF technique is shown in Figure 3. The information contents 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 information 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 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 current system, the pull MA navigates the nodes in search for the required information. Since every client may not require the same degree of information complexity, the user 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 own node. 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 the information search a difficult task, the mobile agent technology proposed for the implementation of the intelligent autonomous information system architectures is one of the solutions to the current problem of access to a central data base. Following advantages are envisaged for the proposed 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 up gradation of e-learning contents can be coped efficiently.
- Fault tolerance of the architecture is improved as the information availability is decentralized.

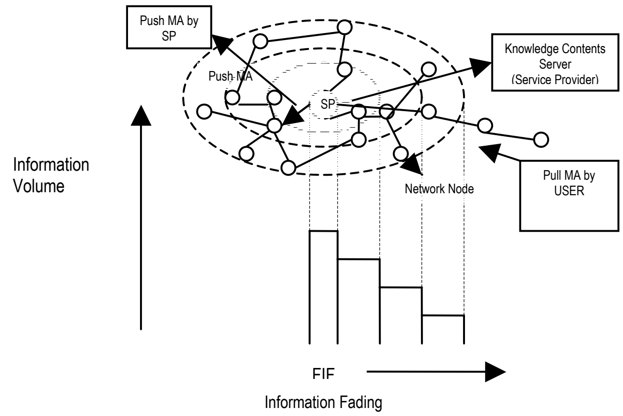

Figure 3: The concept of the proposed autonomous mobile agent-based intelligent Information System Architecture.

5.0 MOBILE AGENT PERFORMANCE SIMULATION

The system was simulated in a network environment. Following parameters were used to characterize the system:

- ✓ *All servers possess the same processing capability (it was not included as a variable).*
- ✓ *Total number of information providers: 50*
- ✓ *Servers each provide up to 8 categories of information.*
- ✓ *Nodes can store indefinite amounts of information, since disk space is no longer a concern in modern databases.*
- ✓ *Servers update their information every 100 seconds.*
- ✓ *Mobile agents allow themselves to travel 20ms distance before deciding that further distance exceeds the permitted faded field size.*
- ✓ *Nodes choose how much information they store depending on distance the incoming push MA has traveled. The further it has traveled, the further is the source, so less information is chosen from the push MA to be stored.*

The congestion strategy is built into the fading strategy of the simulated mobile agent system. Push-MAs have a certain transport lifetime that they are allowed to maintain. This represents the time they are allowed to travel the network, but does not include the time spent waiting for service at information storage servers. Thus, the mobile agent will travel a certain 'distance' on the network, and this distance is represented by the time spent on the network. During congestion, a push-MA will spend more time on the network in router queues, so it will be able to traverse less actual distance on the network due to its limited lifetime as assigned in design time.

Congestion at a server is represented by congestion in the links leading to the server for purposes of 'distance' calculation. Congestion is varied by multiplying the time taken to travel to be serviced at the server by a certain percentage.

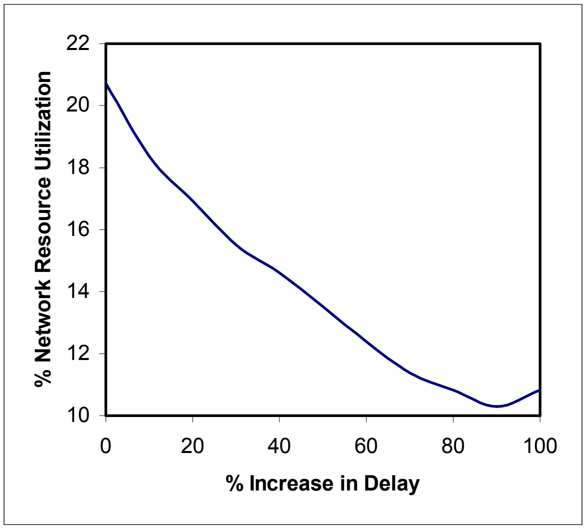

Figure 4: Network resource utilization vs increase in delay.

Figure.4 represents the network resources that the push MAs use at various levels of congestion. Congestion is represented by increase in delay in traveling through the network. As can be seen, push-MAs can help reduce the load on the network during congested times by reducing the time spent on the network. The actual lifetime of a push-MA has not been changed, but the effect of the fixed lifetime strategy is that the MAs actually distribute shorter distances, reducing the network utilization.

The above mentioned parameters were changed for a second 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 service providers (SP) on the simulated network each having stored information content that is faded outwards to the neighboring nodes. The amount of information fading is a function of network congestion. Thus the nodes adjacent to the SP will be more affected by congestion and therefore will fade more information compared to the nodes further away from the SP. 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 so called IF with the SP in the center.

In order to offset the disadvantage of a centralized SP, the size of the defined IF 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 node of the processing overhead required to maintain a large field. This effect was simulated using the same data as above.

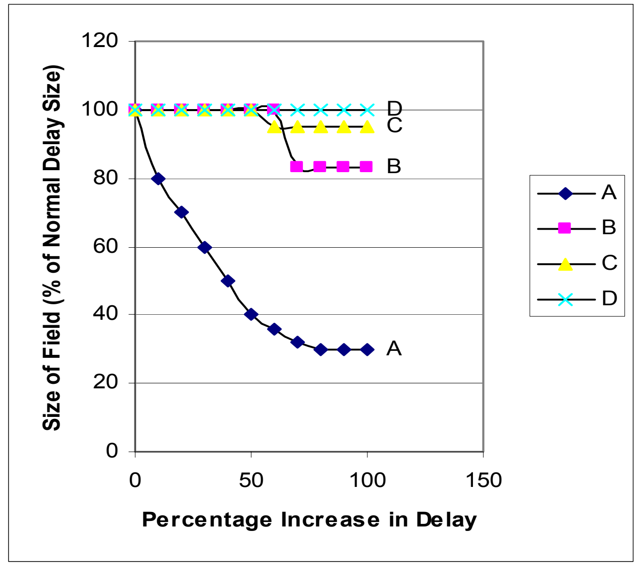

Figure 5: Size of faded information field vs. congestion

The simulation results are depicted in Figure 5. As the delays are incurred in the network and a node gets congested the field size around the congested node decreases autonomously whereas the field size around nodes far from the congested nodes is less affected. In Figure 4, node A is heavily congested and drops its field size as the network delay increases. Node B is the adjacent node, and it drops its size by a lesser magnitude, around 80% of its original size followed by node C. Node D being the farthest remains relatively unaffected in this consideration. Thus the autonomous mechanism embedded in the nodes keeps the information field size dynamic resulting in high assurance.

The information distribution function on a particular node being dynamic in nature is a function of congestion. This implies that the node sheds its information contents when congested resulting in less number of pull MA queries being directed to the node. The congested node thus becomes less informative and the information contents on the adjacent nodes increases away from the congested node. With the given data above, the simulation result of information fading is depicted in Figure 5. The results are in unison with the theory. Node A being the congested node drops its information contents up to 57%. Node B is an adjacent node in the simulated network that exhibits an information shedding behavior at a smaller scale. Node C is still further from node A and the redistribution content is very little as that of node D whose information contents remain intact. The occasional bumps in the curves relate to occasional impulses in the network traffic.

5.0 Conclusion

A new autonomous information management architecture based on mobile agents capable of handling the future Information Provision and Utilization has been proposed and demonstrated based on FIF architecture. The knowledge management systems have been identified to be essentially Information Service Providing Systems. Since the feasibility of FIF technology has already been reported, the proposed system holds a lot of potential to handle the large throughput requirements of future Information Providing Systems. The user access time and fault tolerance of the system improve in addition to assurance.

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