3G NETWORK ORIENTED MOBILE AGENTS FOR INTELLIGENT DIABETES MANAGEMENT: A CONCEPTUAL MODEL

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Abstract- **With the development of technologies in wireless communication especially the third generation (3G) mobile network, Internet, software agent, it is possible now for hospitals to provide a seamless or ubiquitous virtual care environment for patients especially for those who have suffered with chronic diseases such as diabetes requiring high frequency patient-physician contact. Such an environment can provide intelligent and personalized monitoring services to patients, best-practice decision support to physicians, and wellness maintenance for cost control. In this paper, we present a new approach using 3G mobile agents for intelligent diabetes management. A conceptual model is presented and issues related to the implementation of the virtual environment are discussed.**

Keywords **-3G mobile network, software agent, intelligent diabetes management**

I. INTRODUCTION

Diabetes mellitus is now recognized as a major worldwide public health problem. At present, about 100 million people are registered as diabetic patients and the prevalence of diabetes mellitus is rising, especially in developing countries as they adopt a Western lifestyle [1]. It is estimated that 7% of the British population has Type I or II diabetes. Many clinical, social and economic problems occur as a consequence of the disease. Treatment attempts to prevent or delay complications by applying 'optimal' glycaemic control. Long term complications may affect the central or peripheral nervous system and give rise to nephropathy, neuropathy, or cause blindness. These complications are costly to the health system and contribute to loss of productivity. Therefore, there is a continuous need for effective monitoring of the patient. In many cases, this requires follow up treatment by a number of medical professionals for example the general practitioner, the specialized nurse and consultants such as diabetologist, endocrinologist, cardiologist, paediatrician for the case of children or obstetrician for the case of pregnant women. Hence, efficient communication between these professionals is of paramount importance for effective patient management and control.

The current explosion in telecommunication technologies and the use of the world wide web, demands that medical information becomes available and is processed in a distributed way over large scale networks. This is also rapidly making healthcare a consumer-oriented industry. According to [2, 10, 13], the emergence of personal mobile telemedicine systems using wireless links is imminent in next few years. The advances in the third generation (3G) mobile systems are encouraging the development of high technology computer devices to operate according to the wireless network standards. 3G will initially support data rates in the tens to hundreds of Kbps range, with possible future support for data rates as high as 2 Mbps. 3G mobile networks are seen as being the technology to bring the new broadband services being developed for the Internet to the mobile user: this will provide communications in any form, at any time and anywhere. These networks are exploiting the potential to provide users with added value, and help users navigate massive content and services through ubiquitous next generation mobile devices. Intelligent user interfaces will be provided to manage the interaction between users and these mobile devices. With the help of these technologies, it is possible for future hospitals to provide a seamless or ubiquitous virtual care environment for patients especially for those who have suffered with chronic diseases such as diabetes and require high frequency patient-physician contact. Such an environment can provide intelligent and personalized monitoring services to patients, best-practice decision support to physicians, and cost control. Hence, software agents will become an important technology in contributing to the effective patient care and improving communication among medical experts in such framework especially within the congested NHS services.

The remainder of the paper is structured as follows. Section II describes mobile agents in healthcare in general. Section III presents a conceptual model for intelligent diabetes management using mobile agents. Section IV concludes the paper and future work.

II. MOBILE AGENTS IN HEALTHCARE

A. Software Agents

The current shift in medical practice towards health promotion, shared patient-provider decision making and managed care has created a greater demand for on line services and information, mainly through the Internet.

In order to ensure high quality of healthcare, the following requirements are to be satisfied: reduce errors in diagnosis and prescriptions; deliver healthcare to remote locations; improve medical training and education; and, make healthcare information more accessible to consumers. In order to effectively support these requirements of the medical practice, it is necessary to develop new paradigms, environments, tools and techniques to: (1) proactively anticipate the information needs of users and deliver it on a periodic basis; (2) support synchronous and asynchronous communication, co-ordination and co-operation between the various people such as clinicians, nurses and laboratory staff who are involved in the process of managing and delivering health care services; (3) enable co-operative decision making among the various people involved in managing

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health care by sharing of distributed information and knowledge sources. In recent years, the field of agent technology is seen to provide some suitable solutions to these requirements especially for chronic disease management. A software agent is a self-contained computer program that is capable of controlling its own decision-making and acting based on its perception of its environment, in pursuit of one or more objectives [3]. An agent possesses a number of attributes: acting on behalf of others, autonomy, ability to perceive, reason and act in its environment, learn from experience, and socially interact and communicate with other agents.

An information agent, based on a user profile, can proactively perform the role of locating, assessing, retrieving, filtering and presenting information from many distributed sources on a periodic basis [4]. A multi-agent system is a composition of multiple autonomous components (agents) that interact with each other in order to solve the problem. Such a system is expected to possess the following characteristics: each component (agent) has incomplete capabilities to solve the problem, there is not a global system control, data and knowledge is decentralised, and communication is asynchronous. A co-operative multi-agent framework can support the heterogeneous transaction workflow process among the people involved in patient care management. A distributed decision support system based on the multi-agent paradigm can support co-operative medical decision making [5].

It is, therefore, no surprise that a number of researchers have successfully attempted to satisfy the requirements of medical practice through the development and implementation of software using the agent paradigm. These attempts have been in different areas which include; general patient care management [6], intensive care monitoring and decision-making [7] and elderly care management [8].

B. Mobile Agents

Mobile agents are a special category of software agents that can migrate through many nodes of a heterogeneous network of computers, under its own control, in order to perform tasks using resources of these nodes [10]. It travels from a node to another performing tasks in behalf of its owner. There are many advantages of the mobile agent paradigm. Some of them include the reduction of the network bandwidth use, distribution of processing and loading through the hosts of the network, support for a more flexible peer-to-peer model, scalability and decentralization of control. In terms of processing and network bandwidth consumption, the use of the mobile agent paradigm is justified when the cost of the use of some remote resource, using traditional approaches as the client/server paradigm, overcomes the use of the agent.

Mobile agents can be used to overcome the network latency. Consider a distributed environment composed by a big number of machines connected by a slow network, for example, a LAN connected to another LAN using a slow Internet link [9]. Suppose a client on one LAN wants to make a complex query in a Database server in the other LAN. In the mobile agent paradigm, agents can move to the place where the data is stored, performing queries and filtering relevant information before sending this data to the client. In this context, it is shipper to transport a small agent to the source of the data, than to bring the entire query results back to the node in order to be processed. Moreover, as the interaction between the agent and the resource (after moving) is performed in the same host, without the transmission of messages through the network, this paradigm is indicated for some kinds of real-time distributed applications. Such applications will have a critical impact on future medical wireless management systems.

Mobile agents can also be used in a situation where agents are launched by an appliance - for example, shipping a mobile agent from a cellular phone to a remote server. The server may be a weather server which is continuously updated with current weather data; that agent can warn you by phoning whenever a pre-specified weather condition has occurred [9].

A conceptual model targeted specifically for 3G mobile network is to be presented in the next section. It also describes how to makes use of mobile agents for intelligent diabetes management.

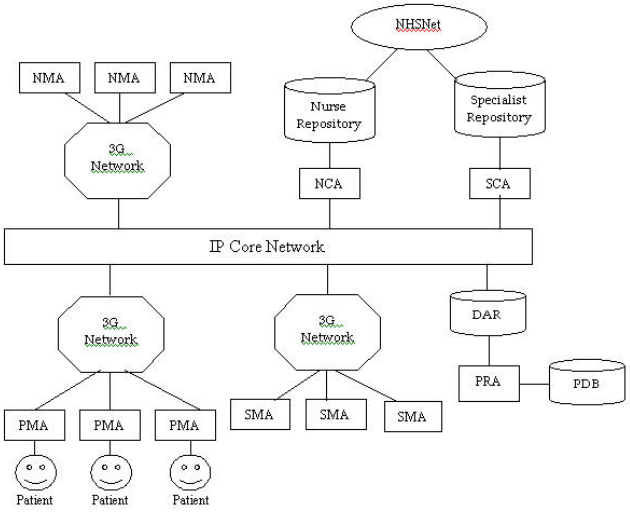

Fig.1. A conceptual model for a 3G wireless diabetes management using mobile agents.

III. A CONCEPTUAL MODEL FOR INTELIGENT DIABETES MANAGEMENT USING 3G WIRELESS MOBILE AGENTS

In this section, a conceptual model proposed in this paper is presented for intelligent diabetes management, and a brief description of the functionality of each agent is also given. In addition, a scenario of multi-agent interaction for a diabetes patient to get some medical help from specialists is described.

A. The conceptual Wireless Model

Fig. 1 shows the block diagram of the model.

The conceptual model involves patients, nurses and specialists. These people communicate with each other through 3G mobile devices such as mobile phones, PDAs, pocket PCs via a 3G wireless communication network running on top of Internet. There are five kinds of software agents in the model. The functionalities of each kind of agents are briefly described below.

- Patient Mobile Agent (PMA). There are many PMAs in the model. Each PMA is a mobile agent that can be shipped from a mobile device to the Internet via a 3G network. The PMA can carry a patient data and move to a patient database serve in which it interacts with a Patient Record Agent (PRA) to retrieve the patient's medical history records from a Patient Record Database (PDB), to store a new medical record to the PDB. The PRA can detect if the patient's situation is critical based on the medical data and the criteria set in a Diabetes Alarm Repository (DAR). The PRA can interact with a Nursing Center Agent (NCA) to alarm a Nurse Agent (NA) if the situation is critical.
- Nursing Centre Agent (NCA). There could be one or more NCAs in the model. Each NCA represents a nursing center in a hospital. The NCA is a static software agent that receives requests from outside departments and then alarms a related Nurse Mobile Agent (NMA) for a specific task. It can make a decision to choose which NMA for a particular situation based on the information related to each nurse such as time schedule, which is stored in a Nurse Repository.
- Nurse Mobile Agent (NMA). There are many NMAs in the model. Each NMA is a mobile agent that can be shipped from a mobile device to the Internet via a 3G network. The NMA can make a query about a patient's medical history records from the PDB by interacting with the PRA. It can provide some advice to the PMA based on the patient's current medical data or make an alarm to the Specialist Center Agent (SCA) if the patient's situation is urgent.
- Specialist Center Agent (SCA). There could be one or more SCAs in the model. Each SCA represents a specialist centre in a hospital. The SCA is a static software agent that receives requests from outside departments and then alarms a related Specialist Mobile Agent (SMA) for a specific task. It can make a decision to choose which SMA for a particular situation based on the information related to each specialist such as time schedule, which is stored in a Specialist Repository. Or it can choose a specialist team if a patient's situation is urgent.
- Specialist Mobile Agent (SMA). There are many SMAs in the model. Each SMA is a mobile agent that can be shipped from a mobile device to the Internet via a 3G network. The SMA can make a query about a patient's medical history records from the PDB by interacting with the PRA. It can provide some advice to the PMA based on the patient's current medical data or work with other SMAs in a Specialist Center to make a decision if the patient's situation is urgent.

The Nurse Repository and Specialist Repository can be linked to the National Health Services Network (NHSNet) [12] for further access of medical data and patient records.

B. A Scenario of Multi-Agent Interaction

The following steps show the interaction between multiple agents in the conceptual model.

1. A patient's PMA is shipped from a wireless terminal to a PDB carrying the patient's medical data.
2. The PMA contacts the PRA in a database server.
3. The PRA finds the patient's situation is a little bit critical and then alarms the NCA for the situation.
4. The NCA contacts a nurse available and passes the task to her/him for a solution.
5. At the same time, the PMA moves to the nursing center carrying the patient's medical history record and current medical data.
6. The nurse sends a NMA to the nursing center server where the NMA meets the PMA to get the needed data from the PMA and reports to the nurse.
7. The nurse feels that patient's situation is urgent and she can not make a decision. Then she/he sends an alarm to a SCA and asks help.
8. The nurse's NMA informs the PMA to move to a specialist center carrying the needed data.
9. The SCA contacts two specialists for a solution.
10. The two specialists send their SMAs to a server in the specialist center where these two SMAs will meet patient's PMA to get the needed data and then report to the two specialists respectively.
11. After a careful consideration, the two specialists make a decision to inform the patient through his /her PMA and ask him/her to take an insulin injection.
12. After the injection, the patient feels much better.

C. *3G Wireless Network*

As the 3G mobile radio networks like Universal Mobile Telecommunication System (UMTS)[14] is now being launched, and will support bit rates of up to 144kbit/s in indoor scenarios that is much higher than presently available in 2G cellular systems, UMTS is considered as a wireless communication solution for the system proposed in this paper. In comparison with Satellite or ISDN, 3G wireless communication technology can provide a cheaper and more convenient medical services for the system.

IV. CONCLUSION

The current evolution of 3G mobile networks will allow software agents and the Internet to play a pivotal role in future wireless heath care management systems. It is necessary that a seamless or ubiquitous virtual care environment should be provided for patients especially for those who have suffered with chronic diseases such as diabetes requiring high frequency patient-physician contact. Such an environment can provide intelligent and personalized monitoring services to patients, best-practice decision support to physicians, and wellness maintenance for cost control. Currently, the work is ongoing to implement such framework based on the conceptual model proposed in this paper and test the operational performance of the system in a real NHS environment.

REFERENCES

[1] V. Ambrosiadou, M. Alevizos, G. Ziakas, "Decision Support in Diabetes Management for Optimal Glycaemic Control", in *IEEE Proc Systems Man and Cybernetics, Systems Engineering in the Service of Humans, Decision Making*, 5, pp. 391-397, 1993.

[2] R.S.H. Istepanian, "Telemedicine in the United Kingdom, Current Status and Future Prospects", *IEEE Trans. Information Technology in Biomedicine*, Vol. 3, 1, pp. 158-159, 1999.

[3] N. R. Jennings and M. Wooldridge, Agent-oriented software engineering, in J. Bradshaw, editor, Handbook of Agent Technology. AAAI/MIT Press, 2000.

[4] E. Lobato and V. Shankararaman, "PIRA: A Personalised Information Retrieval Agent", in the *Proceedings of the IASTED International Conference on Artificial Intelligence and Soft Computing,* August 9-12, 1999.

[5] G. Lanzoloa, L. Gatti, S. Falasconi and M. Stefanelli, "A Framework for Building Co-operative Software Agents in Medical Applications", *Artificial Intelligence in Medicine*, (16), pp223-249, 1999.

[6] J. Huang, N. R. Jennings and J. Fox , "An Agent-based Approach to health Care Management". *Int. J. of Applied Artificial Intelligence*, 9(4) pp. 401-420, 1995.

[7] J. E. Larsson and B. Hayes-Roth, "Guardian: An Intelligent Autonomous Agent for Medical Monitoring and Diagnosis", *IEEE Intelligent Systems*, pp. 58-64, 1998.

[8] L.M. Matos and W. Vieria, "Intelligent Mobile Agents in Elderly Care", *Robotics and Autonomous Systems,* (27) pp. 59-73,1999.

[9] David Kotz and Robert S. Gray, "Mobile Agents and the Future of the Internet", *ACM Operating Systems Review,* 33(3): pp. 7-13, August, 1999.

[10] L. Ismail, D. Hagimont, "A Performance Evaluation of the Mobile Agent Paradigm", in *Proc. of the ACM SIGPLAN Conference on Object oriented Programming, Systems, Languages, and Application,* Denver, USA, November 1-5, 1999.

[11] R.S.H. Istepanian and S. Laxminaryan, "UNWIRED, the next generation of Wireless and Internetable Telemedicine Systems-Editorial Paper", *IEEE Trans. Information Technology in Biomedicine*, Vol. 4, 3, pp. 189-194, 2000.

[12] http://www.nhsia.nhs.uk/nhsnet/pages/about/nhsnet.asp

[13] R.S.H. Istepanian and A. Tseng, "Diabetes Management using Advanced Mobile Technologies for Cost-Effective, Real-Time Patient Monitoring", in Proc. of eHealth, 3rd International Conference on Advances in the Delivery of Care, pp. 139-143, City University, UK, 2001.

[14] W. Yao and R.S.H. Istepanian, "3G Mobile Communication for Wireless Tele-Echography Robotic System", in *Proc. of the 6th World Multiconference on Systemics, Cybernetics ans Informatics,* Orlando, Florida, USA, pp138-142, July 2002.