A MOBILE AGENT FRAMEWORK FOR REMOTE PATIENT MONITORING

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ABSTRACT

Healthcare service delivery is currently shifting from “Doctor-Patient Contact Base” to “Anywhere-Anytime Service Based” paradigm due to technological advancement in pervasive computing, the widespread of the Internet and wireless mobile communication systems, which has given rise to tele-medicine, tele-monitoring and tele-health. Unfortunately these are widely distributed and fragmented with high degree of heterogeneity, strong local autonomy, lack of adequate technical capacity, poor bandwidth, expensive software components and few numbers of experts hindering the adoption and acceptability of this mode. In this paper, a framework is proposed, the potentials of ICT and intelligent mobile agent were harnessed in electronic healthcare service delivery to improve the monitoring of patients within specific contexts, which ultimately resulted into more efficient and accessible healthcare services.

Key Words: Mobile agent, Wireless sensors, Remote Patient monitoring

1. INTRODUCTION

Mobile agents are software abstraction that can move from host to host on a network to perform specialized services. Apart from providing mobility, agents possess the unique characteristics of adapting to changes in their execution environment and hence have a higher chance of survival and achieving application objectives over a large, distributed and heterogeneous network when compared against traditional techniques which make its adoption for the present research a viable option in this local context (Danny and Mitsuru, 1999). Mobile agents have also proved very effective in supporting asynchronous execution of client’s request with weak connectivity (Spyrou, Samaras, Pitoura, and Evripidou, 2004) especially in the health care sector which is not only widely distributed and fragmented but it also exhibits a high degree of heterogeneity with strong local autonomy (Grimson, Stephens, Jung, Grimson, Berry, and Pardon, 2001). In addition to these, the data intensive nature of patient monitoring systems and dynamic nature of both care givers and patients in terms of physical mobility have made researchers to accept mobile agent paradigm as a better approach to context-aware services delivery in patient monitoring (Juan, Dante, Jesús, and Óscar, 2010). Health care applications can take outstanding advantage of the intrinsic characteristics of multi-agent systems because of notable features that most health care applications share.

The present technological advancement in pervasive computing and the widespread of the internet and wireless networks and mobile communication systems can be harnessed by E-health to bring better monitoring of patients to obtain a more efficient health care delivery and reduction in medical errors. In this work a novel remote patient monitoring framework is presented. It exclusively focussed on modelling a remote patient monitoring space in which mobile agents transfers vital signals from patients to care givers and also automatically replicate the same data for back up purpose.

The outline of this paper is as follows: An overview of the remote monitoring system is presented in Section 2. Related works in remote monitoring are given in Section 3. Section 4 discussed the framework design and Section 5 discusses the implementation of the mobile agent monitoring framework with a scenario. Concluding remarks was given in section 6.

2. REVIEW OF REMOTE MONITORING SYSTEMS

The field of home telehealth, remote monitoring and disease management is one of the fastest growing areas within the field of telemedicine(Koch, 2006). Most of the early
telemedicine programs used interactive video to bring patients, referring providers, and consultants together. From 1959 until the 1970s, telemedicine was tested in medical schools, state psychiatric hospitals, municipal airports, jails, nursing homes, Native American reservations, and other settings. Most of these early programs proved too costly to be self-sustaining and were terminated when external funding ran out (Jim and Jay, 1998). Until recently, it was necessary to have at least a personal computer physically linked to a fixed wired network, a fact that severely restricted the mobility of users of telemedicine applications.

Like many other fields, telemedicine has benefited from the ubiquitous access to (medical) knowledge granted by the Internet. Nowadays, a patient can be monitored without needing to be moved to a health-care centre (Loke, Rakotonirainy, and Zaslavsky, 2000). There has been an accelerating movement towards the adoption of remote patient monitoring (RPM) systems, particularly in the treatment of chronic conditions. As more sophisticated technologies have become available, more complex forms of RPM have emerged, including remote monitoring of medical devices and remote consultation and assessment.

Remote patient care and telemedicine platforms have been proved during the last years to be significant tools for the optimization of patient treatment in isolated areas (Lin, 1999; Doukas, Moulos, Maglogiannis, and Kormentzas, 2005). Transport, accommodation and medical personnel related costs are reduced, and a full time 24 hours per day, 7 days per week patient status monitoring is provided (Traver et al., 2003). Health monitoring may be delivered not only in a hospital environment but at home as well, through the establishment of modern patient telemonitoring systems. Chronic diseases such as asthma, diabetes and congestive heart failure (CHF) carry high costs of care and, as a result, are often the focus of RPM initiatives, the latest advances in wireless and mobile technologies such as Bluetooth, WI-Fi, GPRS and UMTS have overcome mobility limitations. Furthermore, the availability and popularity of small mobile devices such as PDAs, mobile phones, GPS and medical devices have created plenty of opportunities for increased user mobility in the field. It is therefore not surprising that telemedicine is one of the fastest-growing application fields for intelligent mobile services. Nevertheless, a significant number of new challenges have come up. In particular, certain technological and domain constraints (computational and bandwidth limitation, security and privacy concerns etc) must be taken into account in order to successfully build open, large-scale, pervasive applications for the health-care domain (Zaslavsky, 2002).

3. RELATED WORKS

Figueredo and Dias (2004) presented a telephone care system using mobile telephony for remote patient monitoring. Their system takes advantage of the serial port available in new mobile phones to implement a generic interface for patient monitors. Vital signals are acquired from electro medic devices using RS232 interface and transmitted through the internet.

Alessandro Copetti, Loques and Leite, (2008) developed intelligent context-aware monitoring home health care system. In this system sensors are used to collect data from patient and then sent to a centre for supervision. They introduced intelligence to the system by using fuzzy logic model and rules based on medical recommendations to analyze and identify critical situations of the patient locally at home. The identification of patient abnormal situation can activate a local device or start interaction with the person or issue on emergency message.

Vassis, Belsis, Skourlas, and Pantziou, (2008) proposed and consequently implemented a policy based architecture that allows autonomous and continuous monitoring of patient thereby providing continuous necessary medical information to hospital personnel by utilizing software agents and wireless sensor technologies.

Walker, Praveen, Bhatia and Dinesh, (2009) developed a web based framework for patient monitoring comprising of a worst models called Biote which houses an accelerometer and different bio-potential sensors interfaces, a invero controller and RF communication transceiver. This hardware receives patient’s medical signals and transmits to their website which is integrated to Microsoft Health vault. Care providers we able to view these patients reading by navigating to the desired patients reading page.

Bhattacharyya et al. (2011) developed a context-aware system that helps in monitoring patients diagnosed with brain tumor health care application. They used a button up approach to collect data from various hardware, sensors and notifications are generated by the system to doctors
whenever there are deviations from the expected medical recommend actions.

Non of the cited frameworks included logging and replication which servers as the novelty of this work. Logging describes the concept that patient sensor data are not only delivered to designated readers (care givers) but are also persisted for patient history analysis. Replication adds reliability and availability to the system. The agent on the central Server forwards received patient sensor data to designated agents on other servers (alternate servers) for the purpose of backup and recovery. These agents on successful configuration on the alternate server, sends messages to the base agent on the server to subscribe as a replication agent, and wish to henceforth receive patient sensor data. In the next section we present our framework for remote patient monitoring with highlights of all functional components and how it has achieved logging and replication for effective patient monitoring.

4. PROPOSED MOBILE AGENT FRAMEWORK

Figure 1  Framework of Remote Patient Monitoring (RPM)
The framework is made up of participating human actors and components as shown in Figure 1.

4.1 Participating human actors

These are patient(s), Emergency Services / Care Givers, Personal Medical Personnel and Readers.

4.1.1 The Patient

Our definition of patient is someone in a remote location (out of hospital) whose medical state requires constant monitoring, dynamic prescription and possible emergency care. The patient is assumed to have registered with a health care administering body or health insurance providers that will then place him on the system.

The patient serves as a constant information source as his body vitals are constantly read using bio-sensors and other body vital measuring device. These devices will connect to a smart phone and the data they provide will be transported to an online central server. Upon registration, the application developer using the framework provides mechanisms for “Calibrating” the patient.

Calibration: This process involves defining ranges for measured values such as: body temperature, blood pressure which will class them into severity levels of

**Emergency:** Values within this range indicate that immediate medical attention is required. Values in this range are life threatening and fatal.

**High:** Values in this range indicate a severe medical state that may not cost the patient his life. Values in this range often imply that the patient needs the attention of a medical personnel even if his condition becomes better.

**Medium:** Values in this range indicate average medical situations that can often be handled by prescriptions that can be administered by the patient himself. The medical personnel give suggestions and prescriptions that would handle the situation. A typical example is when all a patient needs is to take a few pills and a lot of rest.

**Low:** Indicate subtle medical situations that may result from activities, environmental conditions of the kind of food taken by the patient. Values in this range are often temporal and can be handled by the patient himself.

**Info:** Values in this range are normal body values for the patient, they are sent for history and record purposes only.

The calibration process is done by or in collaboration with a trained medical personnel after basic inspection and analysis of the patient’s body vitals. These values are used by the framework to decide on actions to perform based on values read from biosensors on the patient.

4.1.2 Emergency Services / Care Givers

These are public/corporate health-care emergency response providers. They respond to emergency situations triggered by the system.

4.1.3 Personal medical Personnel

This is a trained medical practitioner that is registered with an health care administering body or health insurance provider. A medical personnel is primarily and immediately responsible for a patient, responds to body readings, provide prescriptions and essential medical attention with a principal goal of keeping the patient in the best medical state possible. A medical personnel may be assigned to more than one patient.

4.1.4 The Reader

These are persons that require real-time access to measurements taken from the patient. They include relatives, supporting medical personnel who can define policies that notify them of medical situations they want to respond to. As a typical example, a care giver of an aged fragile man may want to get updates on the medical state of his protégé. The responses from the system may not be essentially medical prescription but it might trigger or source for help or simple check up on patient.

The different actors identified above need an effective and resilient network to communicate for effective collaboration and functioning. The framework solves the problem of unreliability and intermittence of the Nigerian network by using the proven JADE mobile agent platform. JADE is designed to handle and adapt dynamically to unstable networks.

As shown in the diagram, the framework passes messages using mobile agents (blue double dotted
lines), all messages leaving a software module is wrapped in a JADE ACL Message that conforms to FIPA standards. An agent at the other end receives the message and proper marshalling is done to deliver the message to recipient their party application(s).

4.2 Various component of the RPM diagram:

4.2.1 Body Network:

The body network component consists of the

i. **Sensor device**: the sensor device performs the patient monitoring by sensing vital details and sending it via a bluetooth to a mobile device. Attached to each of the patient is a sensor as shown in the component diagram. Each patient to one or more sensors and a mobile device.

ii. **Mobile Device**: The mobile device performs various operation. The data is sent via the network infrastructure to the central server. Notification details can be sent directly to remote centers. Residing on the mobile device is a middleware that hosts a mobile agent and various services as shown in the layer diagram.

iii. **Network**: This component consist of various network infrastructure that has been put in place so as to enhance data movement, communication and agent migration accross various agent platforms.

4.2.2 Central Server

The central server performs data storage operation and also hosts some services like the notification service. A firewall is displayed at the central server to show how mobile agents are blocked by the host mobile agent residing at the central server. So as to prevent a malicious agent from gaining access into the the server. An agent is also displayed to show the residing agent as the only agent that can access the service running on the server. The framework also allows for addition of backup servers where data can be backup without much additional work from the application developer and the middleware enforces integrity by making sure that all the data on all servers are in sink.

4.2.3 Software Actors

Four key software actors that operate in collaboration to achieve the objectives of the framework were identified. They are

i. Source Personal Digital Assistant (SPDA) Software

ii. Server Software

iii. Reader Software and the

iv. Data Backup and Replication

The **Source Personal Digital Assistant Software (SPDA)**

This is the software that will run on the patient’s personal digital assistant (PDA). It interfaces with sensors attached to the patient and obtains readings from them for simple on-PDA processing and onward forwarding to a central server.

**The Server Software**

This is the software that runs on the online central server. It collects patient data from various PDAs, which it will process, store and react to as appropriately decided by the application developer.

**The Reader Software**

This is the software that will be used by readers. It connects to the online central server and retrieve data as required by it’s user. It allows the creation of policies that automatically performs a predefined task based on retrieved patient body readings. This software may run on a mobile phone or on a desktop computer. Reader software on the mobile phone allows it’s user to interact with retrieved data while on the go.

**Data Backup and Replication**

This is an additional fail-safe mechanism to gird against server crashes. The possibility of a server crash cannot be ruled out. This software interacts with the server software to ensure that clone copies of the data on the server are transferred to other servers for backup. These are made possible by the mobile agent known as replicators on the framework.

5. APPLICATIONS

A simple scenario was implemented using the developed framework. A sample medical patient to be monitored is registered first on the server front end which mimics the process of registering a patient
as shown in Figure 2. On successful registration, the patient is given a unique id that will be used for future correspondence. Next, on the PDA that will be used for receiving sensor data, an application that uses the middleware is installed. The application on startup, checks if a patient has been previously registered on the phone. If no, the id of the patient is requested and the full information for the patient is retrieved from the central server. After confirmation of the retrieved information, the contexts registered for the patient is retrieved and persisted. After successful execution of these processes, the patient and his/her registered contexts are persisted on the phone and monitoring can commence. A reader, who could be the personal medical personnel or a next of kin, also installs an application that was developed, supplies the id of the patient of interest, the patient info is retrieved, confirms and can then get live readings from the patient. Figure 3 shows the activity diagram for the patient registration process on the source PDA. These data are automatically logged into the backup server.

Figure 2 Patient Info

Figure 3 Patient Real-time
We presented a framework that allows for easy patient monitoring using mobile agent technology, using this framework we successfully implement a platform for healthcare monitoring, the applications show that mobile agent can be used to remotely monitor patient in low poor areas and automatically replicate these data for backup purposes. In the future, we plan further to abstract the functionalities of the agent into a middleware layer so that application developers can concentrate on service logic of collecting vital physiological signals only.

7. REFERENCES


