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The Evolution of E-Health – Mobile Technology and mHealth

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Abstract— **This paper presented a multi-agent network architecture for monitoring human health conditions based on new wireless mobile technologies. This architecture provides the basis for the use of intelligent agents to provide better health care to patients, particularly in the case of home care for chronic illnesses, the cost increases because of an aging population in the world.**

Index Terms—**Multi agent, E-Health, m-Health.**

I. INTRODUCTION

Medicine has always been an information intensive field from the first days of practice, when pearls of wisdom were passed along the generations as word of mouth. Throughout history, informatics has been an integral part of medicine, facilitating the storage and accession of vast amounts of data. This has come to the culmination of present day medical practice, which is built on the foundations of Electronic-Health (E-Health)[1], [2]. New information is rapidly disseminated through electronic access to medical journals and other relevant sources of information. Patient data is increasingly stored electronically, and reference information including textbooks are stored electronically in websites. The E-Health revolution digitized the world, and medicine has benefited immensely.[3], [4] Whilst having this information available electronically has numerous benefits, the delivery of this information to medical staff has been less than ideal, requiring doctors to be tied down to devices such as immobile desktop computers.

The next stage in digital informatics is to gain rapid access in both storing and creating material in a convenient manner; and smartphones have been an instrumental tool in this evolution. Smartphones have a number of characteristics which give them an advantage over other technologies, such as portability, constant internet connectivity, enough computing power to run complex applications and the simple fact that the majority of doctors have one in their pocket[5].

In June 2011, the penetration of wireless devices amongst the US population was recorded at 102%, meaning that there were more wireless devices than the total population.1 Whilst smartphones do not account for all wireless devices, it is estimated over 75% of medical staff use a smartphone.2 Varied clinical uses of smartphones are being increasingly documented in the medical literature[6]. The assessment of wounds by picture messaging has become ubiquitous amongst plastic surgeons, and studies have found promising results. 3 Communication between medical staff and hospitals has also been facilitated greatly with the use of 'push email' and notifications; in addition to certain hospitals integrating paging systems with smartphone notifications.4,5 With the advent of custom designed applications, smartphone use has rapidly expanded and a number of specialties are producing innovative applications relevant to their own specialty, such as orthopaedic decision support applications6 , offsite radiology access7 , anaesthetic techniques8 or infectious disease physicians tracking epidemics9 to name a few.

With continued innovation, medical applications will continue to be developed at an exponential rate. Storage of reference materials is another area which has become popularized, with many a medical student's heavy textbooks being traded for electronic textbooks accessible in the palm of their hand.10 Whilst the smartphone has been the catalyst for the transition of E-health to mobile health (mHealth), various other mobile technologies have been introduced to the market which show promise[7].

Tablets are now becoming mainstream with the advent of the Apple iPad, which finally took tablets from a specialist item, to something that many people find essential. According to [8] medical uses of iPads are rapidly expanding, with examples such as patient education material, reference material storage, medical education11, and even use in research projects (as exemplified in a case report in this issue of our journal). Advances in technology have allowed specialized devices to be produced which are either mobile equivalents of large cumbersome pieces of equipment, such as ultrasound scanners, devices for deep venous thrombosis (DVT) prophylaxis12, or devices which interface with smartphones, such as blood sugar level (BSL) monitors which can monitor and transmit results to physicians13 Whilst all of these developments amongst mobile technology show great promise, it is of utmost importance that the rigors of evidence based medicine are applied [9]. Without a strong evidence base to support a product or application, one needs to be cautious about its use. New pharmaceutical products undergo demanding testing, and their efficacy needs to be proved through appropriate studies.

Similarly, new technologies should also be tested through the scientific process, and their value needs to be carefully documented. Currently, there exists a gap in the literature, and no medical journals focus on documenting developments in the field of mobile technology[10]. The launch of the Journal of Mobile Technology in Medicine represents an opportunity for doctors to be kept up to date with quality peer reviewed research articles, and provides an avenue for researchers to publish articles which will shape the field of mobile technology and its application to medicine.

II. NETWORK ARCHITECTURE OF MOBILE HEALTH MONITORING SYSTEM

Our system architecture consists of Java-based agents of each human role (e.g. doctors, patients) residing on the gadget

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(e.g. PDA or PC). We needed to design the system for a more generic many-to-many (multiple patients assisted by multiple doctors and specialists) scenario[11]. Therefore we defined the network architecture consisting of clients (for doctors and patients) and servers that would provide communication and coordination between these clients. Although many users have personal computers (PCs) at home, getting these PCs to connect to body sensors would require patients to come to a fixed location and many users are not comfortable with that. Also PCs are still expensive for some sections of the population. Hence we decided to use mobile phones/portable digital assistants (PDAs) as the patient-side network client. Within the frame-work, the agents reside in three areas: the patient's mobile device (e.g. smart phone or PDA with Internet connectivity), the healthcare personnel's mobile device (e.g. for nurses or paramedics) and the mobile and static servers (which may be a wirelessly connected notebook or an enterprise server computer).

Smartphones/PDA Phones (client-side) receive transmitted patient data from Bluetooth-enabled health monitoring devices connected to patients .

The network architecture for mobile health monitoring that we have developed consists of three levels on networks,namely the body area network (BAN), the personal area network (PAN) and the wide area network (WAN) as discussed below with a case study for cardiac monitoring [2]:

A. *Body area network (BAN)*

This involves a Bluetooth-enabled wireless network of various body parameter sensors [e.g. blood pressure, electrocardiogram (ECG) and blood sugar] that can communicate with the mobile device (cellular phone or PDA)[12]. We used an Alive heart monitor (with Bluetooth interface) that has two electrodes attached to the patient's body and it records ECG activity, body position and so on. The heart monitor is Bluetooth-compliant and transmits via the serial port profile (SPP) to the PAN, operating in a slave point-to-point configuration.

B. *Personal area network (PAN)*

The PAN component of the framework (based on GPRS/3G) connects the BAN to users who communicate through the local cellular network. The PAN includes intelligent agents as midlets on a Java-based Symbian smartphone to enable communication between body sensors and local nurses and doctors.

If the agent is to forward the patient's data to the hospital servers, the agent will commence the transfer via GPRS or 3G technology. To transfer data, the smartphone agent begins to encode data into a format which the server agent can understand. The message is then transmitted to the servers servlet as the body of an HTTP POST request.

The messages may also be transmitted via web services via SOAP messages encoded in XML.

C. *Wide area network (WAN)*

In this case, the WAN provides connectivity between the patient and remote healthcare personnel who might be geographically far apart. Through the operation of web application servers such as WebLogic running at hospital and mobile sites, we are able to program servlets (server agents) to collaborate with smartphone agents.

III. Scalability

Scalability is achieved with web-based applications running on the three levels of interconnected networks – BANs, PANs and WANs. This design is flexible enough to be used in a range of health monitoring situations including disasters.

The only drawback to this framework, however, would be the remote chance of Internet dysfunction altogether since it relies on the Internet as a data and information carrier. This would mean that communication to hospital servers would fail and data being transferred onto the smartphone would be temporarily stored locally. In summary, Fig. 1 shows the entire architecture of the network consisting of Bluetooth-enabled body sensors that are connected through Bluetooth (that work for very short distances) protocols to the smarthones on the client side (patients, doctors, nurses and so on). The mobile phone is connected to a GPRS-based gateway to a server that connects to the Internet and other remote devices through various types of wireless networking protocols, such as Wi-Fi and WiMAX. Service provider roles (e.g. doctors, nurses and paramedics) can connect to the network at various levels as shown in the diagram. We did come across some problems that will be discussed in the section on evaluation towards the end of this paper.

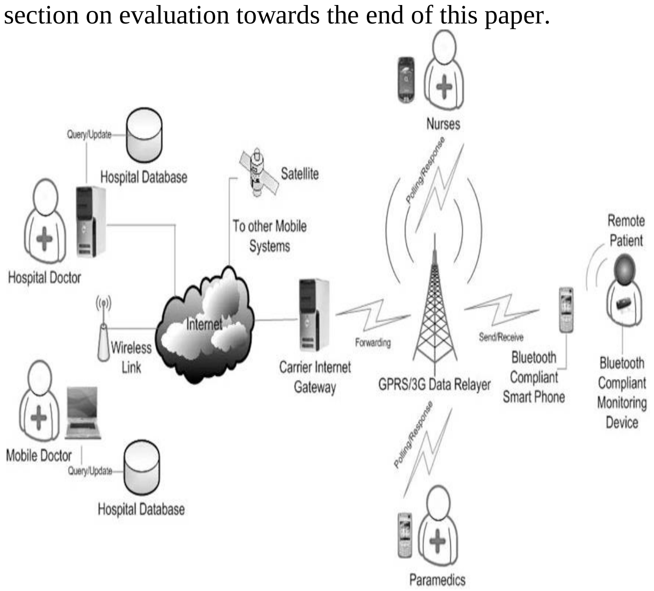

Figure 1: Architecture of mobile health monitoring system

IV. Conclusion

This paper has presented a networked multi-agent architecture for monitoring of human health conditions based on emerging wireless mobile technologies. This architecture provides the basis for the use of intelligent agents to deliver better healthcare to patients, especially in the case of home-based care of chronic illnesses, the cost of which is increasing because of the ageing population in the world. The application of this framework can be applied to many e-Health service scenarios[13]. This can range from

doctor-to-patient monitoring from a remote location for chronic illnesses such as diabetes, to responding to emergency situations such as earthquakes and tsunamis, and tele-consultations.

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