When Smart Home Meets Pervasive HealthCare Services Using Mobile Devices and Sensor Networks– Status and Issues

Ti-Shiang Wang

Nokia Research Center
5 Wayside Road, Burlington, MA 01803, USA.

Abstract: In this paper, to deliver healthcare service pervasively, especially to the home space, we first discuss the status and activities on healthcare infrastructures and systems using mobile devices and sensor networks. We also provide the information and illustrate the reasons why home healthcare will be even more hot space in the near future. With the advance of wireless network, mobile devices become more demanding for users to communicate each other either for voice or data service, or both. In addition, as medical record goes to digital form and will be available any where, any time and used by any kind of mobile devices, so that mobile healthcare becomes a hot topic and many issues are currently working on. From the user side point of view, advanced sensing devices and networks based on them provide rich context and seamless connection between users and mobile devices so that the personal data or medical record could be updated as needed and quality of services can be improved. With the help of smart sensors and sensor networks embedded either on body or in the home space, the quality of personal healthcare can be improved in lower cost as well. In this paper, we also address some issues to implement the home-based pervasive healthcare applications and provide a visionary scenario integrating smart home and healthcare services.

1 Introduction

Healthcare institutions today are attempting to respond to demands to reduce cost and improve the effectiveness of care delivery. Spurred by a combination of economic and regulatory pressures (such as Health Information Portability and Accountability Act, HIPPA) [1], hospitals and healthcare providers want new solutions that can address core business needs and manage the huge volumes of time- and security-sensitive data that they are involved.

With the popularity of mobile devices and pervasive deployment of wireless networks, the gateway of healthcare service become closer to patients so that the patients can control the autonomy and smart home/healthcare gets involved. In other words, patients and healthy people can do the basic control and monitoring by themselves. From mobile device's point of view, personal digital assistants and mobile phones are

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cheap and effective, and run a wide variety of applications. Many people simply bring their own PDAs to work. As technology continues to reshape the way hospitals deliver care, doctors, nurses, and other clinicians need access to patient information from any location and at any time. Although many hospitals have integrated their various information systems, delivering clinically relevant patient information, for example, electronic medical record (EMR) [2], to healthcare professionals – when, where, and how it is needed – still poses a major challenge. Services from caregivers to the patients or users are related to the data rate of the services, which is a key criteria used for both wired and wireless network and technology deployed in the healthcare environment. Even with patients (either sick ones or/and healthy ones) have them for well-being or daily monitoring. The range of data rates of typical devices used in the telemedicine can be scaled from several kbps up to tens of Mbps [3].

Mobile healthcare encompasses the range of mobile technologies as they are applied in healthcare, wireless network infrastructure, mobile devices and mobile applications. It is an extension of, but not a replacement for, desktop computing. The potential benefits of mobile healthcare include point-of-care communication, improve clinical decision-making, enhanced quality of care, reduced medical errors [4], improved information access and exchange, improved accuracy, diminished redundancy, diminished paperwork, increased time for patient care, and improved integration. In Addition, mobile healthcare supports public safety initiatives and reduces cost while improving efficiency. Mobile healthcare aims to give users (either patients or physicians) a more active role in the healthcare process while at the same time healthcare payers are able to manage costs more directly. The benefits of mobile healthcare computing are to provide point-of-care communication, to offer information access and exchange, to diminish paperwork, to improve accuracy and efficiency, to improve clinical decision-making, and to promote integration. XML and web service technology [5, 6] have also been consider to apply in healthcare sectors to provide sharing, interoperability and availability of medical data or records.

On the other side, the pervasive computing technologies can be of use on the user sides not only to support healthcare, health and wellness management, but also to make healthcare available everywhere and any time, pervasively, especially in the home. It is envisioned that this concept of computing anywhere can be applied to support users in their own home environment, so that the activities around the home can be monitored, under control and make proactive decisions to better serve the occupants by enabling context-awareness instead of being solely reactive to their commands. For home-based healthcare, personal wellness systems are not meant to replace the mainframe system of hospitals, clinics and physicians but rather to put seniors and activities of daily living more squarely into the healthcare mix. Especially, systems that encourage seniors to maintain physically fitness, nutrition, social activities, and cognitive engagement so they can function independently in their own home for as long as possible can help address the social and financial burdens of an aging population.

To make the home to be smart to provide suitable services, sensors and sensor network will play an important role to make it happen. Basically, pervasive healthcare techniques consist in embedded sensors to continuously monitor people's home activity, which is analyzed to provide global health information. Nevertheless, in such systems, support is limited to a closed environment, and sensing of vital signals is not

possible. These signals sensed mostly are physiological information. In the future, both of physiological rhythms and behaviors of the own of the house will be considered in the pervasive healthcare. The sensed data can be integrated in the database and arrange it in a generalized XML format, which allow the exchange with medical institutions where a system manages the database for each patient's vital signals, so that the advanced web service technologies can be applied.

2 Mobile Healthcare Projects/Programs

Mobile healthcare activities have been very active because wireless network is pervasively deployed and mobile devices are mature enough to provide an important component in healthcare sectors. Mobile healthcare application can be viewed an extension of the use of telemedicine [7, 8] to support the healthcare in mobile manner and remotely. In other words, mobile healthcare can be considered the first step towards pervasive healthcare application, since it is mainly focused from the healthcare or caregiver side. In this section we list some projects (but not an exhaustive list) that have been proposed in the area of mobile healthcare applications. In general, sensor based network with mobile devices (such as mobile phones or PDAs), Internet, wireless networks and medical record center are major network components. Fig. 1 is shown for network domains for mobile healthcare projects discussed in this section.

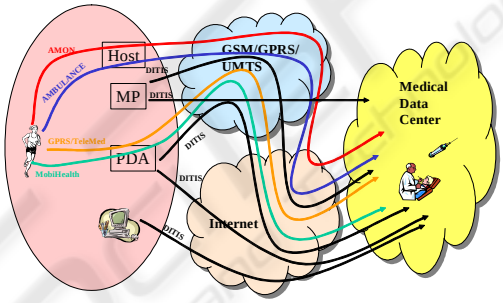

Fig. 1. Architectures of proposed mobile healthcare projects

Advanced care & alert portable telemedical MONitor (AMON) [10] system is a wearable personal monitor medical device that evaluates human vital signals using several kinds of advanced biosensor. The system gathers and analyzes the vital information and transmits the data to a remote telemedicine center for further analysis and emergency care, using cellular infrastructure.

MobiHealth project [9] funded by European Commission aims at introducing mobile value-added services in the healthcare using 2.5G (GPRS) and 3G (UMTS) technologies. A sensor-based network, called body area network (BAN), enabling the integration of different sensors and actuators, is presented and has been prototyped in the first phase of the project. The BAN was connected to the public GPRS and UMTS networks, using iPAQ and Ericsson mobile phone as gateway to connect to Internet.

In [11], this project was partially supported via the Cyprus Telecommunication Authority (CYTA), the Research Promotion Foundation of Cyprus (project IASIS), and the University of Cyprus. In this project, a practical evaluation of the performance of the GSM and GPRS systems in the transmission/reception of X-ray images and videos in emergency orthopedics cases was carried out. The results presented in this study were carried out using the Compaq iPAQ 3870 handheld PC equipped with GSM/GPRS expansion pack modem.

In AMBULANCE project [12], it consists of mobile unit and consultation unit. GSM link was used to connect these units. The device uses GSM links and allows the collection and transmission of vital bio-signals, still images of the patient, and bi-directional telephoning capability. The mobile unit mainly consists of two components, a Johnson&Johnson Dinamap Plus III bio-signal monitor used for bio-signals acquisition and a portable PC. The consultation unit mainly consists of a dedicated workstation as a processing terminal in the hands of the acting expert doctor to support an emergency case.

DITIS [13] is a member of the MEMO cluster project. DITIS is an Internet (web) based Group Collaboration system with secure fixed and mobile (GPRS/GSM/WAP) connectivity. It employs mobile agents, web databases with Java database connectivity for storage and processing of information.

MOMEDA [14] project was focused on the development of a compact personal information terminal for hospital and home care environment that could be used by patient and a demonstrator that allows the consulting physician to access electronic patient record data from outside the hospital, using a handheld companion device connected to GSM network. This project was sponsored by Nokia, and the Nokia 9110 communicator was used in the test-bed and demonstration.

3 Home-Based Healthcare Services

Compared to hospitals, home is the more comfortable and favorable to the patients or occupants, and the expense of healthcare services can dramatically be reduced if this service can be delivered to the home, without interrupting their daily activities. With Internet, wireless LAN and personal area network technologies, pervasive healthcare applications at home applications include patient monitoring, mobile/fixed telemedicine, location or proximity services, emergency response and management, and wellness fitting/tracking, have been widely deployed and discussed. To break the boundaries in time, space, and organization that healthcare service may face, mobile device based healthcare application could be one of the candidate solutions thanks to widely deployment of wireless network.

To bring health care to the home, motivation and availability of technologies to be used can be seen unchanged, however, the scenarios at home space are different from the cases in mobile healthcare mentioned above. Depending on the severity of their diseases, occupants do not need to stay at hospitals, but they will lead a normal life while their medical data are monitored and analyzed by healthcare professionals. This situation leads the popularity of smart health at home or called smart home for healthcare services, such as elder care services [15, 16, 17]. Home-domain healthcare envi-

ronment gives residents as much autonomy and even responsibility for themselves and their environment as possible. Pervasive sensors can be used to monitor vital signs and health indicators. These sensors also include some position sensor to sense the position of patient and monitor their activities. In other words, pervasive computing as well as computational technologies will let adults age in place. But few of them bring the use of mobile phone to the discussion and this remains to future investigation. Home-based sensor and diagnostic technologies can be installed in the home space to fit occupant's need, and could help establish "disease signatures" that show up physiologically and behaviorally before severe symptoms become readily apparent.

4 Roles of Sensor Networks

Sensor networks have been established not only for sensing the data from the target environment or objects but also been designed to provide the services for them to meet some performance criteria or requirements. Especially, bio-signals have been used to offer health monitoring [18]. Several personal area networks using biosensors have been discussed to monitor some key or vital signals during the daily activities [19, 20, 21, 22, 23].

Traditionally, personal medical monitors have been used for data acquisition. With the developments of wireless and mobile technology, wireless sensor network with intelligence will provide more feasibility to the users. In addition, PDAs and/or mobile phones have been considered to be an important component as a gateway and they are portable, so that the sensed data from the sensor networks either can be relayed/transmitted to the medical database through Internet or can be processed/filtered to enhance these medical data for specific further medical activities around the users. In general, we observe that this type of architecture based on sensors is tree-type and can been seen the first or last hop of entire network. That is, for example, PDA or mobile phone is used as a central control node to its associated sensors and to process the sensed signals. The connection between sensors to these mobile devices could be designed using standardized protocol, for example, IEEE 802.15.1/bluetooth and IEEE 802.15.4/ZigBee.

Telemedicine and monitoring services provided by sensor networks also make sense to be installed for home-based healthcare services. These services include not only personal medical data recording but also occupants' physiological and behavioral monitoring [24, 25]. That is, home-based sensor network and diagnostic technologies could help establish disease signatures that show up physiologically and behaviorally before more severe symptoms become readily apparent. However, several challenging issues still remain using sensor network technologies. For example, how to translate the sensor data securely to context-awareness. In addition, based on the sensed data from the embedded sensors at home, how to estimate some key parameters confidently from occupants' behavioral manner and physiological rhythms at home to provide specific healthcare service is also one of the challenging issues. Furthermore, requirements will depend on the needs and attitudes of occupants, even

in the same home space. How to design a sensor network with an intelligent interface engine not only sense the data but also analyze the data as well remains to investigate.

5 Future Visionary Scenario: Smart Home plus Pervasive Healthcare

From home point of view, several smart home activities have been working for years. To make home be smart and services to be aware to the user/owner, there are several home network middleware schemes, such as Univeral Plug and Play (UpnP) [26], Java-based JINI [27], Open Services Gateway Initiative (OSGi), Home Audio/video Initiatives (HAVi) to control home networks that are composed of computers and various electronics appliances. In addition to electronic appliances as components of smart home, other objects, such as a cup or medicine refilled bottles, etc, should be also been viewed to provide data from healthcare's point. In other worlds, the user/owner shall feel confidently and comfortable use mobile devices for his/her daily life. To achieve this scenario of smart home integrating with pervasive healthcare services using mobile devices, several challenging issues should be tackled without the limit to the following. First, generic home network architecture of smart home to provide healthcare services is a must. That is, this home network architecture should be built not only by suitable sensors or sensor networks, but also probably with multiple different service discovery protocols (SDP) to meet the needs/requirements/services at home. Based on this, the physiological and behavioral data of user can be recorded and monitored as input to healthcare services. Second, interoperability is an issue too. Each existing service protocol and middleware scheme cannot meet all the requirements of this future scenarios. Thus, the interoperability of different SDPs at home to provide healthcare service remains as one of the challenges. Third, as the amount of appliances and objects increases at home, the scalability will be an unavoidable issue and should be considered. Especially coupled by the interoperability factor referred by different SDPs, network architecture and service connection built by some surrogate nodes at home should be carefully planned and design to meet the requirements of interoperability, scalability and robustness. Fourth, with mobile devices been used at home, security and user experience are worth to investigate. How to build a trust domain in a home to meet the requirements not only from services used at home point of view, but also from healthcare service point of view. In addition, how to make user be aware of the services around the home and live confidently and comfortably using his/her mobile devices is worth to investigate in the future.

6 Conclusion

With the need of electronic medical records and the deployment of pervasively-built wireless network including the mobile devices, mobile healthcare systems and services have brought more focuses and interests recently. There have been lots of ac-

tivities for mobile healthcare vendors to develop suitable products and services to satisfy their customers, either inpatients or outpatients, or both. These technologies will not only help physicians to work from any where, and collaborate with other physicians and specialists on line, it will also save them administrative time, which will translate into more value added time for healthcare provider and ultimately the patients. On the other side, as senor networking and pervasive computing technologies are getting more mature, the support for home based healthcare service will not be too far and brings the quality of life to the occupants, no matter they are of age or not. Moreover, emerging net-centric standards for service-registry like Universal Description, Discovery, and Integration and the standardized Web Services Description Language (WSDL) can be used to integrate the smart devices and services provided within a smart home with other community services. With the help of sensor based components and networks, the dream and flexibility of the mobile healthcare services getting closer to end users (for example, both patients and physicians) at any where, at any time and using any mobile devices will come true soon. It is conclusive that some of the current and successful telemedicine systems will be more geared toward emerging wireless solutions in healthcare scenarios that are not feasible with current generation of cellular telephonic and Internet services, so as to the user can also take the benefits and services support by the home to experience a comfortably daily life.

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