Health Care Process Management Supported by Wireless Technology

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***Abstract* — In this paper we propose a system architecture for smart healthcare based on an advanced Wireless Sensor Network (WSN). It particularly targets for hospitals and other applications that may benefit from remote health monitoring. We will discuss about our objectives and then the achievable advantages. Finally we present the current status of the system architecture design. Early results suggest a strong potential for WSNs to open new research perspectives for low-cost, ad hoc deployment of multimodal sensors for an improved quality of medical care. How to shift work load from the supporting activities to the patient-centric care, and make the patient passage through hospital processes more convenient are discussed in this paper. Some examples on the hardware implementation related to the topic are also discussed.**

***Index Terms* — 6LoWPAN, Smart Healthcare, Wireless Sensor Network, Wireless Body Area Network.**

I. INTRODUCTION

This paper reviews the wireless healthcare sector research activities at the University of Oulu, contribution to the WILHO[1] project, and extension to the work presented in [1].

Wireless technology provides unique and novel ways to optimize and enhance the existing medical systems. ISG-WILHO aims at the wireless transmission of both diagnostic medical activities and clinical information, as well as wireless positioning of people and medical equipments. Emerging applications for wireless sensor networks involves their use in medical care. In hospital or clinic, outfitting every patient with tiny, wearable wireless vital sign sensors would allow doctors, nurses and other care givers to continuously monitor the status of their patients. Recently, lots of scientific and technical contributions have been received in the literature to bring the smart healthcare system to the reality [2 – 8]. For instance, some efforts have been devoted to continuous medical monitoring for degenerative diseases such as Alzheimer, Parkinson and similar cognitive disorders [4]. In addition, other projects such as “CodeBlue” at Harvard University extend WSNs for medical applications in disasters [5].

The core idea of a wireless hospital concept is deployment of a wireless network, which can be connected to the database systems, as well as to the various wireless healthcare related applications. Principally the database systems are able to reach the deployed wireless network through a set of standardized data transmission protocols. On the other hand, the healthcare related application can be connected to the wireless network through a standardized RF interface. Our vision is that wireless technology will become a permanent part of the data networks, data systems and logistics of hospitals. It significantly improves the quality of diagnostics as well as personal data and medical information.

The following discussion is based on the ideas and work carried out by the WILHO Consortium in Oulu region in Finland. Besides the Centre for Wireless Communications (CWC), the other key contributors for the research comprise the *Intelligent Sensor Group* (*ISG*) at the Computer Engineering Laboratory and the *Optoelectronics and Measurement* (*OEM*) Techniques Laboratory at the University of Oulu and *Oulu University Hospital* (*OUH*). In addition to the academic contributors, the consortium in oulu region has three SME's: *ODL Health Ltd*. (*ODL*), Whealth Ltd. and Sensinode Ltd. All these parties have formed the WILHO Consortium to improve the utilization of wireless technologies in hospitals and promote the concept globally.

II. OBJECTIVES OF WIRELESS HEALTH

We are developing a sensor network architecture for smart healthcare that will open up new opportunities for continuous monitoring of assisted medical staff in their daily routines. While assisting both medical staff and the system privacy, the aforementioned network manages the medical history in a continuous fashion.

One of the main goals of the project is to enhance and streamline the internal healthcare processes. Using the wireless healthcare system, the number of staff required to take care of patients is reduced considerably. As a consequence, the hospital staff is able to deal with more imperative medical activities. It has been reported that the use of wireless technology has made it possible to boost medical processes by up to 20 percent[1]. The achieved enhancement of the medical processes is based on the following factors:

A. Portability

Small devices (i.e., wireless sensors) collect minimal data from the patients, and at the same time, are able to communicate wirelessly with rest of the system. These small portable devices can be either carried by the human body or deployed in the environment. Unobtrusiveness feature of the proposed wireless healthcare system improves the patient

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[1] http://www.wilho.net

acceptance procedure and minimizes confounding measurement effects at the same time. Since remote monitoring is performed in the hospital environment, the patient travels less often and therefore, it is indeed safer and more convenient.

B. Scalability and Flexibility

Wireless devices can be deployed in larger scales and with dramatically less complexity and cost in comparison to their wired counterparts. Existing structures, particularly devices which are difficult to integrate, can be easily augmented with a WSN network whereas the equivalent wired installations would be definitely expensive and impractical. The above devices are configured and placed in the living space. They are self-organized and calibrate with the network automatically. The system is designed in such a way that it can be integrated into existing network, either wired or wireless, to offer better flexibility and mobility.

C. Real-time Management

Physiological and environmental data can be monitored continuously, allowing real-time response reception from the emergency or healthcare staff. The collected data forms so-called health database server that can be used for filling the patient history reports automatically. In addition, the stored information can be utilized in the future to diagnose the same patient whenever he/she needs medical care. Even though the network as a whole is always active, individual sensors still must conserve energy through smart power management and on-demand activation.

III. High Level System Architecture

The medical sensor network system integrates heterogeneous devices including wearable and indoor equipments. All together, they inform the health care provider about the physical condition of the patient. Data is collected, aggregated, pre-processed, stored, and utilized with the help of a variety of sensors in the proposed architecture (temperature sensor, RFID tags [9], environmental sensor, etc.). Following, we present the architecture of a wireless hospital area network for mobile health care monitoring.

The network comprises a set of smart sensor nodes and a control entity which is responsible for the management of a sensor network communication with a remote database as depicted in Fig. 1. In the considered scenario, either a *personal digital assistant* (*PDA*) or the Nokia 770[2] type device can be used as a control entity. It will communicate with smart sensor nodes using standard wireless technologies. The smart nodes are equipped by one or more sensors, such as electrocardiogram (ECG), blood pressure, body temperature, etc., and are capable of processing and storing the collected data. The observed data is forwarded to either the remote users or a database using, for example, ZigBee [14], 6LoWPAN [15] or WLAN in the hospital environment.

Using the aforementioned wireless network, the patient information can also be automatically transferred into the PDA device of the hospital staff when he/she is approaching the patient. Due to the automated mechanism, all the latest information related to the patient is always available.

[2] http://www.nokia.com

IV. Technologies

A. Wireless Body Area Network (WBAN)

This network comprises tiny portable devices equipped by a variety of sensor types (such as heart-rate, heart-rhythm, temperature, oximeter, accelerometer), and performs biophysical, monitoring, patient identification, and other desired tasks.

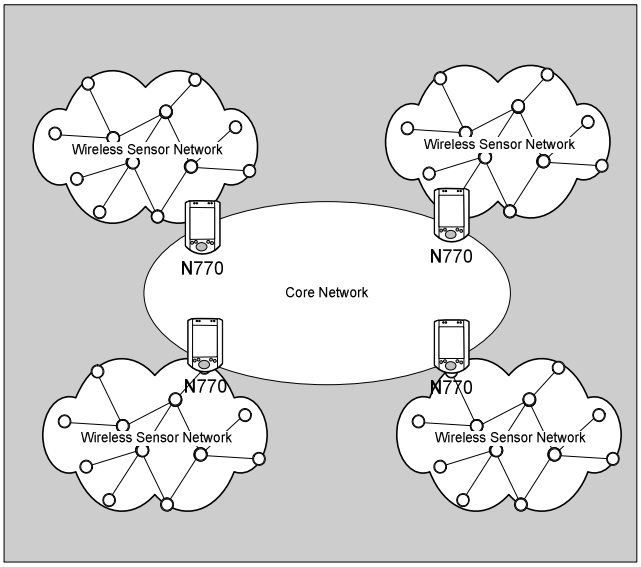

Fig.1. System Architecture

These devices are small enough to be worn comfortably for a long time. The data from non-invasive sensor or monitoring node can be directly transferred to the access point, which is passing the message to the core network. The other option is to collect the data in a centralized manner from all nodes controlled by a *portable base station* (*PBS*). The latter option utilizes point-to-point communication between the sensor nodes and PBS, in addition to the connection between a PBS and the fixed infrastructure. The heterogeneous idea is only valid inside a WBAN which allows the utilization of different radio protocols in the system. The general idea of WBAN is shown in Fig. 2.

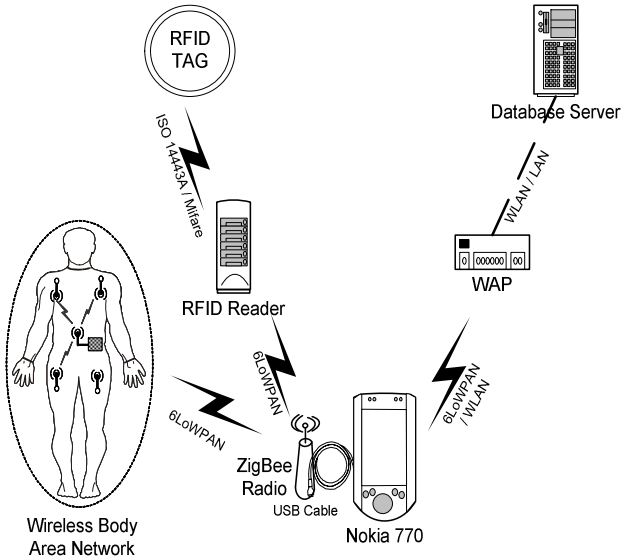

Fig. 2. Network Architecture

B. Radio Frequency Identification (RFID)

Nowadays, Radio Frequency Identification (RFID) [9] technology is a hot topic both in terms of its potential benefits and misuses. RFIDs are low powered radio devices that do not necessarily need any battery power and thus have potential uses in storage areas. RFID tags are used in hospitals to keep track of equipments, doctors and patients inside the hospital. They can be also deployed for monitoring of the hospital supply stocks.

An RFID tag is attached to an object, e.g., equipment, patient, doctor, etc. An RFID reader can read data from a tag over the wireless channel when the tag is inside the reading distance. The reader in turn communicates with a central server in the hospital. Then, the server can take action or forward that information to other mobile devices such as Nokia 770 or hospital database system.

Another potential usage for RFID technology is to implement physical user interfaces. When the reading distance is short, touching an RFID tag with a mobile terminal (equipped with an RFID reader) can be interpreted as a command to, for example, show information on the mobile terminal's display or read a sensor.

In hospital environment, RFID tags can be installed on a patient's wristband, medication, devices, name tags, and so on. Touching a tag can bring information about a patient or device to the mobile terminal's display, or configure the mobile terminal to become a device's remote controller, for example. Furthermore, when each tag is marked with an icon, a nurse can recognize the points in the environment that can be touched with the mobile terminal and actions that the system performs when those points are touched [10].

The advantages of this approach are that the commands related to the nurse's current situation are easily available as the nurse does not have to browse the mobile terminal's user interface or to enter text manually. Furthermore, as the reading distance is short, the nurse stays in control.

C. Wireless Sensor Network (WSN)

Embedding wireless sensor networks into the environment or good monitoring further to vital parameter monitoring increase all the utilization of WBAN in healthcare or welfare sector. Sensor Network technologies such as Zigbee [11] and 6LoWPAN [15] are being combined with WBANs [12] to form small scale networks that can be placed on human clothing (or other objects) and provide unobtrusive access to their health information.

Sensor networks are also increasingly being used in natural sciences, for example, in monitoring wild life or other natural phenomenon. Due to lower power requirements they can be deployed for a long period of time. Due to limited range, they have to be deployed in large numbers and thus they form a distributed network covering a large portion of space. Therefore they can be programmed over the air, making their management very easy. Wireless sensor network are used to integrate the medical sensors into the suggested system.

D. Wireless LAN (IEEE 802.11)

Most hospitals, universities and corporate offices these days provide wireless LAN access. Some benefits include untethered access to the Internet. Hospitals can use the wireless LAN channels to transfer patient data from portable device to the hospital database system. Communication between different medical devices can be also possible using wireless access points (WAP). Nowadays, IEEE 802.11 standard is also universally utilized in healthcare [16].

V. Challenges and Issues

Basically, the medical applications have strict quality and assurance requirements due to the fact that patients' sensitive information brings new challenges on how to deal with the abovementioned issues. In this section, we will talk about the challenges that are faced when deploying wireless networks for the medical applications.

Some of the challenges faced when deploying wireless network based solutions include in engineering issues, social issues, and patients well-being issues. An implementation related challenge is interoperability among various devices. For example, wireless devices are developed by different companies which follow different standards or proprietary solutions. Therefore, making sure that all these devices work reliable together would be a challenge. For instance, different wireless medical devices can work at different frequencies.

In medical fields, strict guarantees are needed since patients' well-being may depend on it. In applications where there are real-time requirements, it can be challenging to guarantee real-time services.

Wireless devices can behave differently at different times and locations, due to natural and artificial issues as well as power requirements and power availability. Some devices may also fail during operation that can cause harm to the patient health. Guaranteeing a seamless service during bandwidth jitters and handling total disconnection can be quite challenging in medical applications. On the other hand, reliability is one of the most important issues in medical applications. Hospitals are not willing to use a wireless devices or solutions that can not guarantee reliability due to the fear of lawsuits and other health related issues in the case of failure. For patients, one of the most important issues is how their daily life will be affected by using these new applications. Thus, designing the applications that can be useful while being unobtrusive is another challenge for wireless networks based application/solution developers.

Since most wireless networks based devices are battery operated, one of the major challenges for developers is the issue of power limitations. Sometimes they have to guarantee that the device will work for a year or two without changing the battery [13]. This could include devices such as heart pacemakers [13]. The developers have to design better scheduling algorithms and power management schemes to deal with these power issues. Also we know that wireless channels are slower than their wired counterparts. Developing applications/devices that can deal with traffic congestion and other performance issues is a major issue.

Some main issues that arise due to the use of wireless network devices include security, privacy and the learning curve for new technologies. Ensuring patient's information security can be a major issue when deploying these applications. Privacy of the user data over wireless channels can be another major issue. Wireless networks based medical devices can be very limited in terms of power

availability and processing strength. Thus, ensuring privacy without using complex encryption algorithms can be a big challenge for developers of medical applications. With the new technologies taking hold in our daily lives, new users can find it challenging to use these devices to full extent. Hence, it can be an imperative concern for the developers/hardware engineers to create the best fit solutions without forcing the customers to make unnecessary effort regarding the way by which the equipment should be used.

VI. Future Trends

Although wireless technologies in the field of medical applications are still relatively new, commercial products are being developed by several companies to solve wide ranging problems. In some cases, these new applications are designed purely social health benefits i.e. reducing interference to daily life when dealing with long term patient care. Advanced data communication systems are allowing real-time video conferences but also remote operations are possible. These technologies are already used in developing countries. However, the technology can be brought available for the people all around the world.

VII. Conclusions

This paper reviews the recent research activities from WILHO consortium from Oulu, Finland, toward the wireless hospital concept. New hospital concept will utilize advanced wireless technologies to improve the cost efficiency and quality of care, as well as hospital processes and logistic. The project findings will shift nurse's work load from supporting tasks to nursing and patient care activities.

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