Ubiquitous Monitoring Environment for Wearable and Implantable Sensors (UbiMon)

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ABSTRACT

Body sensor network (BSN) is an upcoming technology for providing ubiquitous healthcare monitoring. Despite the technological developments of sensing and monitoring devices, issues related to system integration, sensor miniaturization, low-power sensor interface circuitry design, wireless telemetric links and signal processing are major technical challenges. The aim of this paper is to address issues related to using wearable or implantable sensors for distributed mobile monitoring. A proposed system architecture, including a preliminary demonstration prototype, is described.

INTRODUCTION

Wireless Sensor Network is becoming a significant enabling technology for a wide variety of applications. The rationale behind the distributed sensor network is for detecting, identifying, localizing, monitoring, or tracking one or more subjects of interest. One of its potential deployments is in the form of BSN for measuring physiological/context parameters [1]. The aim of having a ubiquitous monitoring environment for wearable and implantable sensors (UbiMon) is to provide continuous management of patients under their natural physiological states so that transient but life threatening abnormalities can be detected and predicted. The use of these sensors for post surgical care, especially in conjunction with minimal access surgery, is a promising area of research.

The concept of ubiquitous monitoring has found extensive clinically related applications [2-4] in recent years. In fact, the last decade has witnessed a rapid surge of interest in these sensing and monitoring devices for healthcare. The technological advancement of these devices will inevitably reshape the general practice in clinical medicine. We present herewith several key issues in the development of wearable/implantable sensors in BSNs that necessitates the implementation of wireless telemetry system for multi-sensory data fusion and decision-support.

SYSTEM ARCHITECTURE

The UbiMon system, as depicted in Figure 1, consists of five major components, namely the BSN node, the local processing unit (LPU), the central server (CS), the patient database (PD) and the workstation (WS).

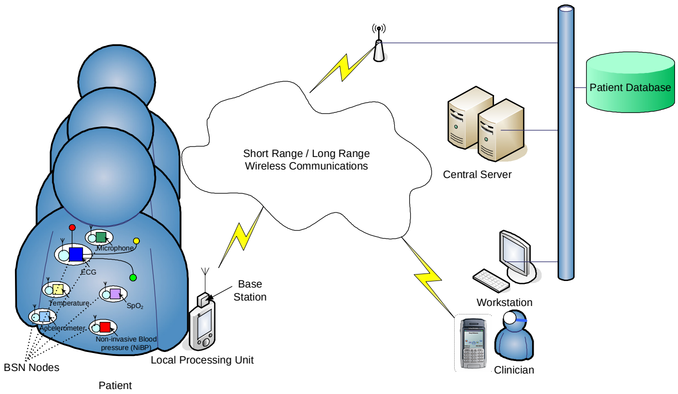

Figure 1: UbiMon system diagram.

BSN Node - To provide monitoring of the patients, a miniaturized battery/batteryless wireless intelligent module, referred herein as the BSN node, is to be designed. Each node is integrated with a wearable or implantable physiological biosensor such as the ECG, SpO2, temperature sensors. The context awareness sensors, such as the accelerometers, can also be fitted together with the BSN node for recognizing the activity of the patient.

Local Processing Unit (LPU) - With near distance transmission through free space (for wearable sensors) or through the skin layer (for implantable sensors), all the sensor data collected by the BSN nodes are gathered by the LPU via the base station. The LPU can be any portable devices, such as a PDA or a mobile phone. Apart from gathering all the sensor data, the LPU is also designed to detect abnormalities and provide immediate warnings to the patients. In addition, it also acts as a router between the BSN nodes and the central server via short-range wireless communication standards such as Bluetooth/WIFI or other long-range mobile network such as 3G/GPRS.

Central Server (CS) - Upon receiving real-time multi-sensory monitoring information from the LPU, the CS will store the data to the patient database, and also perform long-term trend analysis. Through deriving the pattern and trend from the physiological data, the CS is able to perform a prediction on the patient's condition so as to prevent any potential life-threatening abnormalities.

Patient Database (PD) - As continuous data will be fed into the system, the patient database is designed to cope with the real-time storage demand, and the constant queries from the workstations.

Workstation (WS) - Monitoring terminals, via portable handheld devices, personal computers or others, are utilized to allow clinicians to analyze the patient data. The patients' real-time sensor information, as well as historical data, can also be retrieved and playback to assist the diagnosis.

PROTOTYPE SYSTEM

With Ubimon, preliminary clinical evaluation of the prototype is developed for patients with ischaemic and arrhythmic heart disease. Based on the Berkeley mote, Mica 2 Dot, a miniature and light-weighted BSN node is developed with an Electrocardiogram (ECG) sensor, together with the base station interfacing with the PDA, as shown in Figure 2.

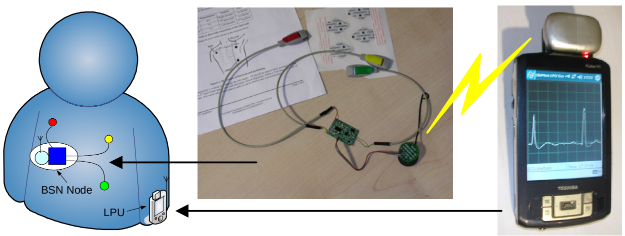

Figure 2: An ECG module (BSN Node) communicating with the base station en-slotted to the PDA (LPU).

The software for the BSN node is developed based on TinyOS. Instead of using the TinyOS protocol and radio stack, a lightweight protocol and special TDMA (Time Division Multiple Access) is developed to deal with the high data rate requirement of the ECG signal. The base station, on the other hand, is developed using the MICA2 Dot with a serial interface connected to the PDA.

The PDA is employed here as the LPU. By gathering the data from the BSN node, real-time ECG signals and its corresponding heart rate information can be displayed on the LPU. In addition, inference mechanisms are developed in the LPU for recognizing its associated activities based on the collected context-aware sensor data. By using the WiFi link, all the data gathered by the LPU can then be routed to the server for storing into the patient database.

A graphical user interface is developed at the WS for retrieving the sensor data from the database, as illustrated in Figure 3. To assist the clinician in patient management, subjects with the highest risk are listed at the top of the patient table, which can be interactively interrogated. In addition, the historical record of the sensor readings can also be playback for any specific episodes.

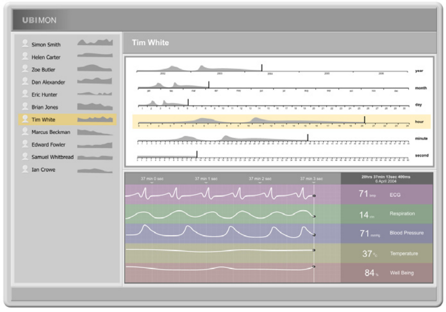

Figure 3: Workstation GUI.

In addition to using the WiFi link, a GPRS version of the LPU in conjunction with a mobile phone version of the WS have also been developed. The sensor data collected by the LPU are transmitted to the mobile phone so that real-time ECG data can be displayed on the phone, including the retrieval of the patient record from the database.

CONCLUSION

A ubiquitous monitoring system is presented for continuous monitoring of patients under their natural physiological states. The system provides the architecture for collecting, gathering and analyzing data from a number of biosensors. Particularly, the concept of BSN node is implemented which could form the basis for wireless intelligent modules for wearable and implantable sensors. In addition to the physiological parameters, the context awareness aspect is also included in the system to enhance the capturing of any clinical relevant episode.

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REFERENCES

1. Baldus H., Klabunde K. and Müsch G. Reliable set-up of medical body-sensor networks. *European Workshop on Wireless Sensor Networks (EWSN)*, LNCS 2920 (Jan 2004), 353-363.
2. Jovanov E., Raskovic D., Price J., Chapman J., Moore A., and Krishnamurthy A. Patient monitoring using personal area networks of wireless intelligent sensors. *Biomedical Sciences Instrumentation*, 37 (2001), 373-378.
3. Wilson L. S., Gill R. W., Sharp I. F., Joseph J., Heitmann S. A., Chen C. F., Dadd M. J., Kajan A., Collings A. F., and Gunaratnam M. Building the hospital without walls – a CSIRO home telecare initiative. *Telemedicine Journal*, 6(2) (Jun 2000), 275-281.
4. Koval T. and Dudziak M. Medilink: A wearable telemedicine system for emergency and mobile applications. *Studies in Health Technology & Informatics*, 64 (1999), 93-107.