INTEGRATING RADIO FREQUENCY NETWORK AND INFORMATION TECHNOLOGIES FOR WIRELESS COLLECTION OF MEASURED PHYSIOLOGICAL DATA

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ABSTRACT
In this moment, measuring of physiological data is performed at hospitals or laboratories where patients are trapped with many electrodes attached on the body. Application of information technologies (IT) and wireless networking will liberate people from such confinement and enable continuous real time monitoring of physiological data, which is vital for medical care. To achieve this goal, it is necessary research and development on wearable intelligent sensor devices, sensor miniaturization, signal processing, wireless transmission, and databases for these vital data. Our goal is to design and construct a system that can be put into practical use and prove the benefits and potential of this vital data monitoring system. We describe an experimental system from which, we could evaluate the problems facing practical use.

KEY WORDS

1. Introduction
To provide human healthcare support with a better quality, we should be able to collect a very large amount of people’s vital signs and monitor it efficiently. Current welfare system is based on medical doctor regular consultation, on behalf of our own feeling. The idea is not to replace the current system, but to augment it by an environment using information technologies (IT) and wireless networking, to provide continuous monitoring of one’s physiological information, perform simple diagnosis and communicate all that with medical institutions.
Recent advances in miniature devices, as well as mobile and ubiquitous computing, have fostered a dramatic growth of interest for wearable technology. Wearable sensors and systems have evolved to the point that they can be considered ready for clinical application. Stable trends showing a growth in the use of this technology suggest that soon wearable systems will be part of routine clinical evaluations.

The interest for wearable systems originates from the need for monitoring patients over extensive periods of time. This case arises when physicians want to monitor individuals whose chronic condition includes risk of sudden acute events or individuals for whom interventions need to be assessed in the home and outdoor environment. If observations over one or two days are satisfactory, ambulatory systems can be utilized to gather physiological data. An obvious example is the use of ambulatory systems for ECG monitoring, which has been part of the routine evaluation of cardiovascular patients for almost three decades. However, ambulatory systems are not suitable when monitoring has to be accomplished over periods of several weeks or months, as is desirable in a number of clinical applications.

Wearable systems are totally nonobtrusive devices that allow physicians to overcome the limitations of ambulatory technology and provide a response to the need for monitoring individuals over weeks or even months. They typically rely on wireless, miniature sensors enclosed in patches or bandages, or in items that can be worn, such as a ring or a shirt. They take advantage of hand-held units to temporarily store physiological data and then periodically upload that data to a database server via a wireless LAN or a cradle that allow Internet connection. The data sets recorded using these systems are then processed to detect events predictive of possible worsening of the patient’s clinical situation or they are explored to assess the impact of clinical interventions.

Park and Jayaraman [1], demonstrates the great impact on the clinical potential of wearable systems of the Georgia Tech Wearable Motherboard, the result of a revolutionary idea that allowed Dr. Jayaraman’s team to develop a garment (i.e., a shirt) that actually functions as a wearable health monitoring system. This concept has been developed into a product that is now commercially available and allows one to record heart rate, body temperature, motion, position, barrier penetration, and the like in a totally nonencumbering manner. Park and Jayaraman [1] point out a number of clinical challenges...
that can find a response in technological advances and they discuss future possible developments in wearable systems as well as the resulting transformation of healthcare and positive impact on the quality of life of individuals.

Jovanov et al. [2] present their approach to develop personal health monitors based on a wireless body area network of intelligent sensors. Body area networks of wireless intelligent sensors are linked to a personal server via a mobile gateway, i.e., a PDA-based device that allows easy access to standard wireless technology such as Bluetooth and IEEE 802.11b. With the proposed approach, several subjects can be monitored simultaneously by integrating individual wearable devices into a distributed wireless system. This is a key characteristic of the wireless system for the application presented in this article. In fact, the objective of the study is to evaluate responses to a stressful training situation in a group of individuals simultaneously involved in the experimental procedures. Data analysis is based on heart rate variability observations that correlate with the outcome of psychological tests and hormonal responses.

Winters et al. [3] provide the readers with their vision of issues related to integrating wearable technology into neurorehabilitation and consumer-centered mobile telerehabilitation. Their approach is centered on the concept of intelligent telerehabilitative assistants. These provide multimedia teleconferencing and wireless communication tools, means to perform collection of sensor data and user-based information associated with events to be monitored, and expert system modules to provide support to clinical decisions are discussed.

Pervasive healthcare techniques consist in embedded sensors to continuously monitor people’s home activity, which is analysed to provide global health information. Nevertheless, in such systems, support is limited to a closed environment, and sensing of vital signs is not possible. Other approaches use a portable multichannel physiological sensing device, connected to a computer system on which a software components library allows access to device’s functionality.

Part 4: Programmable, portable recording modules
Part 3: PC-based base station (including data processing)
Part 2: Analogue measurement modules
Part 1: Radio frequency data transmission network

The main goals of the design are lightweight, minimal power consumption, modular design and robust circuitry. The Network in between the measuring modules and the base station is realised as a bi-directional multi-point, single master RF-link, operating in the LPD-frequency range (868MHz) on a single channel. The RF measuring network consists of several measuring (slave) modules (a maximum of 31 slaves is possible) and of one master module.

The structure of the network is fully dynamic and in operation reconfigurable and scaleable. The configuration process of the RF-network is fully automatic in conjunction with the control program, running on the PC or the Base station. The initialisation process and the required communication in between the master and the module’s give the possibility to control the network dynamically. It is therefore necessary to initialise a slave module to a dedicated master. The function of master is slave polling and acquisition of data. The function of slave is recognition of control package and sending data to master (Fig. 2). The master acts in direct conjunction with PC by USB or RS232, collecting information from RF link and sending to database by PC application. User
action by PC application master translates to slaves by RF link. It is possible to operate several masters in parallel using different channels. The base station collects the data stream of the modules operating in parallel and feed them together. The bandwidth of the whole system is 19200 Baud. The bandwidth of each slave is dynamically controllable by the master.

For each slave is also given a back directional configuration channel. Its purpose is to configure the slave and to control hardware functions of measuring device. The basic concept of the data transmission is packet oriented data sequencing. As a result the output data are restored to give them the original time relationship and to ensure the time-sequenced data fields given to the PC-application. The total delay to the system is less then 100 ms.

The channel selection by the master is managed by a collision detection algorithm to ensure the usage of the channel with the minimum radio strength signal. Individual slave (measuring) modules (Fig. 2) are controlled by, and communicate with, the master module (PC) using a custom wireless protocol. We use standard 868 MHz RF modules (RF Transceiver TRF6900) because the available Bluetooth technology requires three to five times greater power consumption. In addition, we reduce power consumption by using a custom, power-efficient communication protocol. The core of our wireless modules consists of a low-power Texas Instruments microcontroller MPS430F149. The controller features a 16-bit architecture, ultra-low power consumption (less than 1 mA in active mode and ~1 µA in standby mode), 60-KB on-chip flash memory, 2-KB RAM, 12-bit A/D converter, and dual UART. Internal microcontroller analog channels monitor battery voltage and temperature. Therefore, slave module is capable of reporting the battery status and temperature to the upper level in the system hierarchy.

Master and slave modules form a personal area network, which communication system is wireless, mid-range (up to 500 meters) and consume little energy, for practical usability. Under these requirements, it is constructed transmission circuits using weak radio frequency.

On vital data reception, master module automatically records it in a local database. It is designed database architecture centered on measurement sessions and time-based classification. The environment also provides functionalities to display multiple physiological data on graphs, carry out graph manipulation (zoom, slide), and access information about sensors (maker, serial number, picture...).

After the data have been saved, it is coupled with sensor information (sensor id number, name) and saved into PC database. It is designed to manage patients’ daily monitoring individual data, provide tools to support medical doctors diagnosis process, and a meta-data framework to make easier processes like correlation analysis and data-mining.

2.1 SYSTEM EVALUATION

System operation loop is tested to evaluate the data flow process: measurement, transmission, integration, and standard formatting. System experiences are carried out at Clinical-Hospital Center of Kragujevac.

The system supports multiple gateways. In each contact with the individual slave module, the gateway creates a separate communication session file containing data downloaded from the device. The same application is responsible for communication protocol implementation, data collection, file creation, data consistency checking, automatic repeat requests, and graphical user interface. The next picture (Fig 4) shows simple application and transmitted sine wave from sine generator. Frequency band is from 1Hz to 20Hz and it means that it is possible to transmit wide spectrum of measured signals: temperature, pressure, EKG, etc.

In addition to data collection, this application also monitors characteristics and the quality of the wireless channel (number of retransmissions, bit error rate, number of loss packets, etc.). We want to use that data to further improve the wireless communication protocol and to decrease power consumption of the slave modules. All communication session files from multiple gateways are aggregated into a session file on a central PC workstation.
We developed and tested analogue modules for measurement of temperature and heart rate. A screen shot of a program used for temperature and heart rate aggregation, processing, and archiving is given in Figures 4 and 5.

Figure 4: Measuring of body temperature

Figure 5: Measuring of heart rate

Also, our RF network is capable for SMS messaging. It is used in case when emergency situations arise at patient, for example high body temperature, heart rate abnormalities, etc. In such situation an SMS message is sent to sentry medical doctor (Fig. 6).

Figure 6: SMS messaging in case of medical emergency

Transmitted data are terminated by check sum. It is simple total of all bytes in transmitted information. The microcontroller can be capable to receive data, evaluate check sum of received data and compare it with information of check sum that sends slave module. If check sums does not equal, master sends to PC information: “Communication error”, ignores that packet and receives another.

We performed experiment when patient walked up and down. Communication is failed in a couple cases. Communication frequency is 868 MHz and it is very close to GSM network frequency. If patient use mobile phone or some other near the patient uses it, we have noises and check sum error. Other problem is GSM base station based at roof near the Clinical Center and it produce noises. We predicted possibilities for acquisition of data in memory and then transmit large packet of measurement data in blocks of 32, 64 and 128 bytes. A large block of data produces more mistakes at master side. It is experimental work and we have not realized holder box for slave module at patient side. As a consequence we had many other mechanical disturb, damages, electrostatic electricity. Many of that would have removed if holder box had realized.

3. Conclusion

Wireless intelligent sensors have made possible a new generation of noninvasive, unobtrusive personal medical monitors applicable during normal activity. Sensor intelligence allows implementation of real-time processing and sophisticated encryption algorithms. On-sensor data processing decreases the amount of energy spent on communication and allows implementation of power-efficient communication protocols. Decreased power consumption will significantly increase battery life and even enable externally powered intelligent sensors. The current technological trend will allow wider use of wireless intelligent sensors, lower power consumption, and smaller sensor sizes.

Intelligent medical monitors can significantly decrease the number of hospitalisations and nursing visits by acting as a personal “guardian angel” that can warn the user of a medical emergency or contact a specialised medical response service. In case of medical emergency master module can send an SMS message to the sentry medical doctor.

Daily monitoring of patient’s vital signals will make possible a broad range of healthcare application services. It allows enhancing accuracy of diagnosis, networked system allows several doctors to monitor the same patient and detect pathological change in its early stage, evaluate behaviour of elderly people with dementia, quantitatively estimate human physiological condition in daily life, and support interactive home care.

Developed system is based on wearable sensors to enable continuous monitoring of patient’s physiological information. A wearable controller collects wirelessly sensor data, integrate it into a database, which allow the exchange with medical institutions where a system
manages the database for each patient’s vital data. Improvements of the physiological information integration system concern simultaneous sensor communication management method, and algorithm evaluation to detect simple abnormalities. Simultaneous use of several wearable sensors allowed performing correlation analysis, which is the source of sensor system simplification (information redundancy). The determination of minimum sensing environment, size and energy consumption improvements are critical to adapt the system to practical use.

References: