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REAL-TIME AND CONTINUOUS MULTI-PATIENTS REMOTE HEALTH CARE MONITORING SYSTEM USING RELIABLE IEEE802.15.4 PROTOCOL

S. R. T Muda, N. M. K Nik Yusoff and B. Hassan
Faculty of Electrical and Electronic Engineering, Universiti Malaysia Pahang, Pekan, Pahang Malaysia
E-Mail: srasol@ump.edu.my

ABSTRACT

Healthcare industry has been blooming due to increasing health awareness among the modern communities where unlimited innovations are produced following demands ranging from small healthy tablets to big complicated health machines. With current technological development, advanced application such as continuous remote healthcare monitoring system can be proposed since an effective healthcare system assures the healthy and nurturing future of a nation. This paper presents the design and development of remote health monitoring for multi-patient in real-time environment. The paper begins with an overview of the system architecture and its components that constitute the system. It proceeds with the development of the software of the monitoring system. The communication subsystem employs IEEE802.15.4 protocol. Based on the tests results carried out on a faculty building, the author concludes that ZigBee communications between two rooms on the same floor can be acceptable for distances less than 15 meters, while for rooms on different floors the allowable limit is less than 5 meters. In the final conclusion the author suggested wider coverage alternatives as well as inculcating monitoring patient's health condition by employing IOS or Android based gadgets as future works for the project.

Keywords: ZigBee, network-based, health-care monitoring.

INTRODUCTION

In recent years, the advancement in medical care technology i.e. the miniaturization of biomedical sensors, the efficient wireless data transmission etc. has helped improving the average lifespan of a human being. The increase in the social development, on the other hand, leads towards the increasing number of patients being hospitalized (X.Lin *et al*., 2010). Therefore, an effective and efficient system is in immediate need to solve over-crowded hospitals with generally disorganized wards. This scenario indirectly affects patient recovery progress, especially without a proper multi-patients health monitoring system in use.

Currently available multi-patients monitoring systems for collecting physiological parameters in wards today are functional, but unfortunately, this equipment have some disadvantages. Firstly, most of these healthcare monitors are based on wired data transmission systems. Patient mobility is limited while being monitored. Relevant sensors for the patients are connected to real time complex monitoring equipment via wires and cables over a very long time periods. Thus, secondly, monitoring rehabilitation patients, to capture vital signals during physical therapy is becoming very inconvenient due to these very tedious long hours of immobility (Junho Park *et al*., 2007).

By reducing the usage of this wired equipment, if not eliminating them, the power consumption of the health centres can be drastically reduced. This will allow medical officers to continuously and remotely monitor the patients health conditions in real-time while at the same time the patients can move freely without uncomfortable wires attached all over their bodies.

This can be achieved simply by exploiting various health monitoring sensors e.g. oximeter, temperature sensor, accelerometer etc. and connect them to a wireless monitoring system. Simultaneously, further health diagnosis can be done regardless whether the patients are under treatment or undergoing rehabilitation process.

The proposed system features a portable version of the wireless sensor network for remote monitoring program applicable for self-diagnosed health at home where full-duplex communications between transceivers are achieved via IEEE802.15.4 protocol which also translated into a cost-effective solution for non-commercial uses. Equipped with a Global System for Mobile (GSM) module, the proposed system has been designed to automatically send messages to the program's authorized user of the patients current health status (D.Visan *et al*., 2010)(F.Wyne *et al*., 2009).

Additionally, the proposed system viability can be extended to rural areas to counteract the medical officer shortages, therefore, effectively reducing health care costs while helping the people to have good quality lifestyle.

This paper describes the development of the network-based wearable physiological parameters remote healthcare monitoring system for multi-patients. The paper begins with an overview on the architecture of the system and its components that constitutes the system. It proceeds with the description of the development of the software/firmware for the monitoring system. Results of the several tests are presented before the author concludes the outcome and suggested the future works for the project.

ARPN Journal of Engineering and Applied Sciences

SYSTEM ARCHITECTURE

The system hardware is conceptualized and designed based on star topology where the system consists of one central/master node and several remote/slave/patient nodes (K.K.Ho, 2009).The central/master node features a microcontroller, wireless module, LCD module, serial communication module and a PC as shown in Figure-1. Likewise, the remote/slave/patient node consists of microcontroller module, sensor module, and transceiver module as shown in Figure-2.

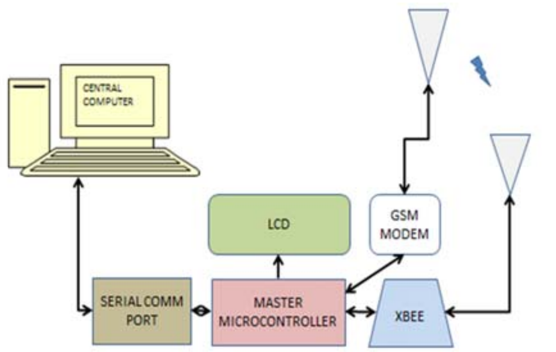

Figure-1. Master module.

The patient modules are equipped with several human body sensors such as temperature, oxygen saturation in blood (SPO_2) and heartbeats of patients. All these parameter are measured and collected by the microcontroller and transmit these vital parameters to the master module through ZigBee transceiver wirelessly.
The data transmissions are handled by ZigBee transceivers allowing full-duplex communication between remote location and central rooms. The IEEE 802.15.4 compliant solution is used as a transceiver as it offers unique needs for low cost and low power wireless sensor networks and the technology has put such a compromising enhancement into the sensor network in various fields (N.N.F.A. Hamid, 2012).

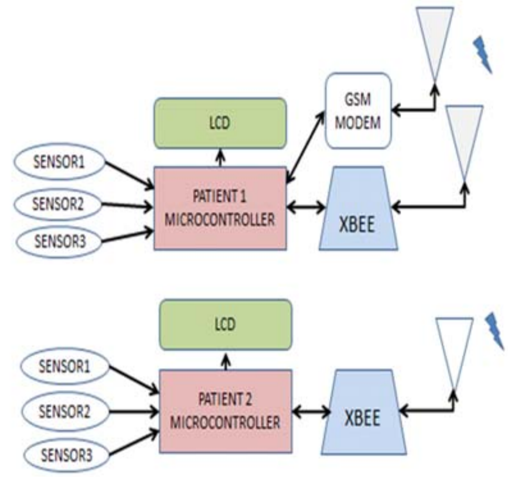

Figure-2. Patient module.

For experimental purposes, each remote is equipped with three types of sensors. They are temperature sensor, pulse sensor and heartbeat sensor. These sensors measure the patient conditions periodically. Then, this analogue information are sent to microcontroller through analogue input pin where the converting process are performed. 10-bit Analog-Digital Converter (ADC) is considered adequate for these levels of conversion. The condition of each parameter will be updated locally through the slave's LCD panel. At the same time, the information are encapsulated along with the slave's address and sent to master unit for analysis and storage purposes (Y.L. Ming, 2014).

Additional module, Global System for Mobile (GSM), is included in the design to relay the message automatically to authorized user for any critical condition of the patients. This GSM modem is automatically activated when the patient's parameter readings indicate abnormal value. A text which contains the detail of the patient is sent to the medical officer. The microcontroller-centric design is based on a simple 8-bit architecture industry-standard Atmel family.

FIRMWARE

In general, two sets of code in C-Programming language are written, one for the master and another for the slave, as highlighted in Figure-3. The codes are compiled into machine code format and burnt onto the Atmel internal flash memory as device firmware. The X-CTU software is used as a tool for ZigBee configuration and data reliability checking.

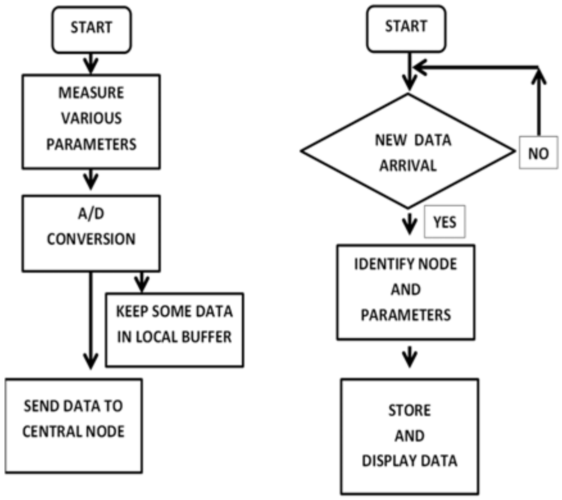

Figure-3. Flowchart for remote/slave node and central/master node functionalities.

Flowchart in Figure-4 shows a little bit detail software functionalities that may be employed in the slave firmware. The flowchart clearly marks the wait for an event process that is always waiting for any of the three basic known event types. Two of the events are local, namely exit, and measure while other set of events are commands from central node, such as, stored data retransmission request which is requested and originated by the Central /Master Node.

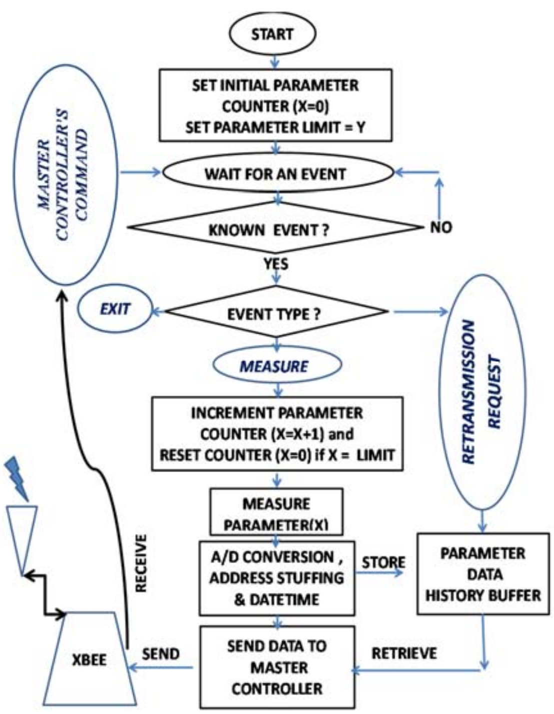

Figure-4. Expanded flowchart for a typical software functionalities embedded in the patient module.

Once the system is powered up, the patient body parameters at remote room location are sensed by respective sensors. These signals are sent simultaneously to microcontroller for internal 10-bit ADC conversion and manipulation purposes. The output of this internal processing is then displayed in proper unit on at the local LCD. At the same time, these parameters are encapsulated and sent to ZigBee transceiver for transmission to the central node through radio wave.

At the central node, transmitted data from remote rooms are received by the ZigBee transceiver in the central node, extracts the information and examines the received transmitted data by comparing upper and lower 32 bits of the 64 bit destination address to distinguish between several remote rooms. Personal Area Network (PAN) ID for each ZigBee is crucially significant to ensure data broadcasting of the network is highly secured and noise-free. Once the mutual authentication is identified and resolved, the parameters of measurements are stored in the respective database and listed on the PC screen display.

Additionally the display screen can be configured to create an alarm to attract the attention of the medical officer for parameters that are not within the normal range. When this happens immediate action should be given to the respective critical patient that requires serious attention.

RESULT AND DISCUSSIONS

Preliminary testing

Initially, the strength of wireless signal is measured in different conditions using X-CTU software. Figure-5 shows the Received Signal Strength Indicator (RSSI) versus Distance in outdoor condition. Based on the figure it is obvious that the RSSI value gradually decreases from -40 to -82 dBm as the distance increases from 0 to 115 meter. This result is obtained at the vicinity of Faculty of Electrical and Electronics Engineering (FKEE), University Malaysia Pahang (UMP) building. It is noticed that at distances ranging from 30 to 50 meters, the signal strength faces interference, from other signals, believed to be due to Wifi transceivers within the compound proximity.

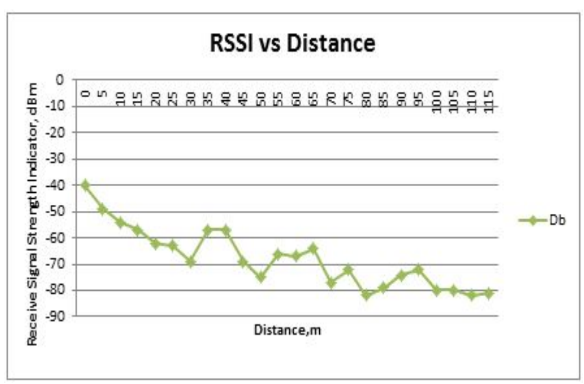

Figure-5. Outdoor RSSI vs distance.

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ARPN Journal of Engineering and Applied Sciences

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RSSI against Displacement tests are also conducted for the indoor conditions. The result is shown in Figure-6. On analyzing the results, the acceptable signal strength for the ZigBee to communicate between two rooms is between -40 to -80 dBm. Therefore, the maximum allowable displacement for ZigBee to communicate between two rooms on the same floor is 15 meters. On the other hand, the maximum displacement for ZigBee to communicate between two rooms of different floors is 5 meters. This indicates the rooms are exactly above the ground floor or vertically adjacent to each other. Currently, practical modern communication system Grade of Service (GOS), for such a system is, 100% ability, 24 hours a day without failure. This is important so that access to patient data, within the interested communication range is assured. Thus for practical and commercial application it would be wise to have the RSSI versus Distance readings be flat at all locations within the boundary of the patient mobility. The solution to this is by installing repeaters at selected locations to ensure the RSSI versus Displacement readings, lie between the stipulated ranges of -60dBm to -40dBm. It is necessary to carry out additional tests within the boundary of the premises where the patients move after repeaters are put in place. This is to ensure subsequent adjustment on the repeaters placement can be carried out to have RSSI readings fall within the stipulated range and gradually optimized. .

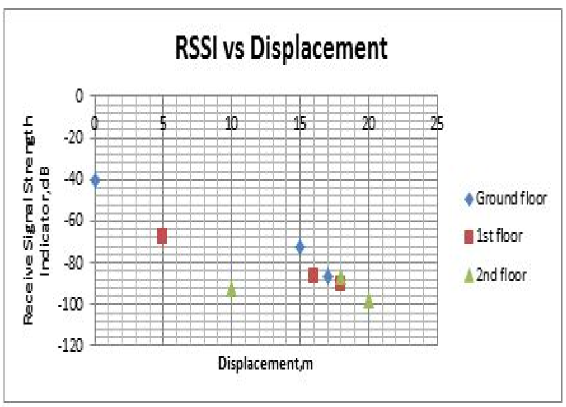

Figure-6. Indoor RSSI versus displacement.

System operation

Several tests were conducted to verify and validate the functionality of the system. The tests were conducted in a laboratory complex setting, where several laboratories were used to imitate remote locations. Two slave units and one master unit were built as prototypes for testing purposes as shown in Figure-7 and Figure-8 respectively. The slaves were placed in two separate laboratories while the master was placed in another laboratory centrally located between the two slaves. These laboratories are located several meters away from each other.

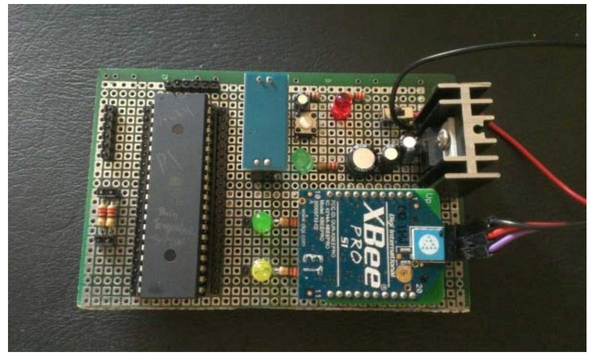

Figure-7. Patient module.

Figure-8. Centre module.

The results of several tests conducted revealed that the system has achieved the goals of monitoring two patients at different remote locations. When the units were powered on, the sensors on both slave units sensed the respective body parameter and displayed the values on the LCD of respective slave units. The data then was encapsulated and sent to the master via ZigBee radio signals. At the monitoring side where the master unit resided, the controller validated the received signal and extracted the data before they were stored and displayed on the PC. Figure-9 shows a snapshot of the output on master unit displaying the respective parameters of one of the slave unit continuously. These data were automatically stored, manipulated and plotted using spreadsheet. Figure-10shows another alternative of displaying the output.

ARPN Journal of Engineering and Applied Sciences

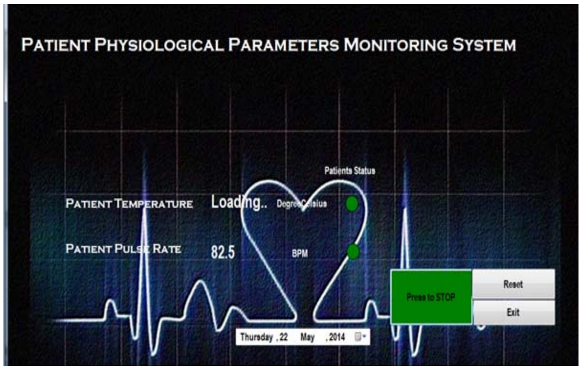

Figure-9. Measured pulse rate for patient with normal pulse rate.

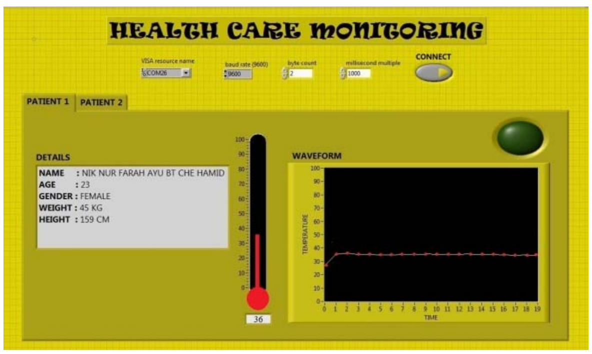

Figure-10. Another snapshot for body temperature.

Alternatively, a portable handheld master node was designed and the result is shown in Figure-11. Meanwhile, in an attempt to alert the authorized person for the respective patient critical condition, text message sent by a GSM module is shown as in Figure-12.

Figure-11. Handheld master node.

Abnormality is simulated by introducing hot air to body temperature sensor to test the system capability to react to abnormal temperature. In this simple test, the GSM module was used to send a SMS to authorized user when the patient body temperature exceeds the normal value. The SMS contains the detail of patient and the reading of body temperature. Test results show that the system is capable to response to abnormal condition of the patients as indicated in Figure-12.

Figure-12. Text message for abnormal outcome.

CONCLUSIONS

This project describes the development of the wireless network-based for Remote Health Care Monitoring. Testing of the wireless parametric monitoring system for in-door use has proven its capabilities to capture various forms of body parameters at two different locations and transmit the measurement to a central monitoring station. The system is also capable of sending the information to authorize person if the condition of the patient exceeds human comfort zone.

Data transmission between multiple remote units and the central room system is achieved without error and noticeable delay. In short, a simple remote health monitoring for multi-patient in real time environment system has been successfully developed. This system can be used to monitor a patient at home, hospital or even at rehabilitation center.

However, as one of the Key Performance Indicators (KPIs) or GOS for such a system is its ability to access and communicate patients data within the interested communication range without failures, 24 hours a day, any commercial design should comply to this GOS . Thus for practical and commercial application it would be mandatory to have the RSSI versus Distance readings be flat at all locations within the boundary of the patient mobility.

The solution to this is by installing repeaters at selected locations to ensure the RSSI versus Displacement always give readings between stipulated range of -60dBm to -40dBm. It is necessary to carry out additional tests within the boundary of the premises where the patients move after repeaters are put in place. This is to ensure subsequent adjustment on the repeaters placement can be carried out to have RSSI readings within the acceptable range and gradually optimized. This could be proposed as one of the future works for system coverage enhancement. In another attempt to explore wider coverage alternative, it is suggested that the ZigBee Pro module should replace ZigBee module as ZigBee provides coverage only within 100m compared to ZigBee Pro can offer up 1.6 km radius.

ARPN Journal of Engineering and Applied Sciences

However one should be careful with higher power radio transmission within the healthcare monitoring environment as high power may introduce more intermodulation which may trigger false alarm in the measuring processes. Interested parties should check on the radio regulatory matters with the relevant authority for a particular country (MCMC/SKMM for Malaysia).

Another future work for the system is to extend the sensor capability by incorporating several new sensors to enhance the function and application of the new system. At the same time, android-based or IOS application will be deployed for smart gadget operation in the system.

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