Dedicated Portable Real Time Multiple-Patients Monitoring System using Zigbee

Omar S. Alwan, K. Prahald Rao, Ahmed S. Balamesh

Abstract*: Telemedicine for multiple patients monitoring has been developed as a monitoring system to monitor the status of patient's health. Real time multiple patients monitoring system (RTMPMS) is applied in areas where real-time vital function analysis takes place. A state-of-the-art, PC and arduino based, integrated, low-cost, small, portable, low power consumption, ZigBee communication with health monitoring system and alarm system has been studied in this paper. Human's body temperature, electrocardiogram (ECG) and heart rate information have been acquired and sent to a computer using ZigBee communication. The system in this paper will monitor three patients simultaneously by one computer through multiple Xbee transceivers. The graphical user interface (GUI) has been set up to display/store the body temperature reading, ECG data, pulse rate information in real time and patients records using LabView. The user interface has alarm system which will be activated if one parameter increased the range. The open architecture system design offers scalability, standard interfaces, flexible signal interpretation possibility and effective monitoring system. This system shows how arduino with the computer through ZigBee can be feasible in patient monitoring and patient data retrieval. Through this way, real-time remotely monitoring is achieved.

Index Terms*: Cost, Health Care, Real Time, RTMPMS, System, ZigBee.

I. INTRODUCTION

Patient monitoring system (PMS) is a continuous measurement of patient parameters such as heart rate and rhythm, temperature, ECG, blood-oxygen saturation, respiratory rate, blood pressure, and many other parameters have become a common feature of the care of critically ill patients [1]. It is a very critical monitoring system. It is used for monitoring physiological signals including invasive and non-invasive blood pressure, electrocardiograph (ECG), respiration, body Temperature, oxygen saturation in human blood (SpO2) and other gases [2].

Speedy detection and reporting of changes in the vital signs are essential and delays in initiating appropriate treatment can detrimentally affect the patient's outcome [3]. One of the traditional roles of nurses involves monitoring. This might include watching patients for changes in their condition, recognizing early clinical deterioration and protection from harm or errors [4].

Wireless transmission data technology in the medical field is the most important application that any organization in the health sector needs it. As well as this technology is often characterized by the speed, safety and easy installation of hardware at lower costs. Patient monitor systems which are used in hospitals are used for continuous monitoring of patient's physiological values. The limitation of these systems is that the sensors are 'hardwired' to the monitors or PCs nearby the patient. In spite of wired connectivity with the monitoring devices, nursing staff should keep track of all vital values by making note the records either manually or entering into the computers which would sometime tend to make human errors that may lead to serious consequences on the patient [5].

Real time monitoring worthwhile to investigate its possible use in telemedicine. The ultimate goal of telemedicine is to provide a quality health care to anyone for medical diagnosis, treatment, and patient care.

Patient monitoring system may be performed for diagnostic purposes in the emergency room and ICU or for therapeutic purposes in the operating room. So this system recommended being integrated, small, with low cost and low power consumption. So the physician can monitor the vital signs of the patient from his office in the hospital.

Remote patient monitoring is having its day, and there is no letup in sight on this evolving trend. It could fundamentally improve patient outcomes and quality of care across the medical field. This includes onsite in hospitals and clinics, for at-home care, and for remote care in less populated areas of the country and in developing countries.

Due to increasing medical technology, delivery of health care services also increased day by day. Wireless body area network is the most widely used sensor networks used in the hospitals for monitoring the patients' medical conditions [6]. ZigBee is a low cost, low complexity and low power technology that exhibits the following characteristics which makes it more beneficial to use in the medical applications [7]. Zigbee has some characteristics that recognize it among other technologies. It can be very responsive particularly when it is compared to other technologies like Bluetooth. It is designed with low power which makes smaller batteries last longer. Zigbee can provide multiple options of network communication e.g., peer to peer network, point to multipoint network and mesh network. It is simple technology that was designed with a cost less than other wireless personal networks and uses a variety of power-saving modes to guarantee [8]. As compared to Bluetooth, Zigbee is low cost, large range and low power technology which have not any connectivity issues [6].

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Omar S. Alwan, Department of Electrical and Computer Engineering, KAU, Jeddah, SA.

K. Prahlad Rao, Department of Electrical and Computer Engineering, KAU, Jeddah, SA.

Ahmed S. Balamesh, Department of Electrical and Computer Engineering, KAU, Jeddah, SA.

II. RELATED WORKS

Real-time monitoring of human can provide an automated system of supervising functional status over extended time periods [9]. Previous studies have also demonstrated using similar units to monitor the patient conditions. Although mobile devices are always considered a promising tool to monitor and manage patients' own health status, these devices have some inherent limitations in computation or data intensive tasks. A new hybrid mobile cloud computational solution has been proposed in [10] to overcome these limitations. The authors have introduced a mobile cloud based electrocardiograph monitoring system. The experimental results show that the proposed system can significantly enhance the conventional mobile based medical monitoring system in terms of diagnostic accuracy, execution efficiency, and energy efficiency.

To monitor the health of a pregnant woman with preeclampsia a novel health monitoring system has been proposed in [11]. The system has been designed for the community based health care providers so that they can collect symptoms and perform clinical measurements at the patient's home. The clinical data are used to predict the risk level of a patient. Based on the risk level the system provides recommendations for treatment, referral, and reassessment. The proposed system also uses an Oximeter connected to a smartphone to measure oxygen saturation level of the patient in order to predict her risk level.

Wireless electrocardiogram (ECG) monitoring system based on Bluetooth Low Energy (BLE) technology has been reported in [12]. The system consists of (i) a single-chip ECG signal acquisition module, (ii) a Bluetooth module, and (iii) a smartphone. The system is able to acquire ECG signals through two-lead electrocardiogram (ECG) sensor. The system is also able to transmit the ECG data via the Bluetooth wireless link to a smartphone for further processing and displaying the ECG signals. The results show that the proposed system can be operated for a long period of time due to low power BLE technology.

A system to monitor the blood pressure of a hypertensive patient using mobile technologies has been proposed in [13]. By using the system a doctor can carefully monitor the patient and can perform diagnosis. The system is implemented on the Java platform and it can reside in a small capacity device. The system is also able to communicate with a server via Internet. The server is used for storing and displaying patient data graphically.

Mobile device based healthcare system for monitoring the patients with Alzheimer's disease has been developed and presented in [14]. The system is able to provide caregivers and medical professional with the ability to be in contact with the patients all the time. This system has been field tested by the Alzheimer's disease caregivers and the initial results show that the system is very effective for them.

Cloud computing has been incorporated in a healthcare system in [15]. The authors have proposed a cloud based intelligent healthcare monitoring system (CIHMS) for providing medical feedback to a patient through cloud. The proposed system can obtain adequate data related to patient's disease and deliver the data to a remote location by using cloud computing devices.

In order to monitor the breathing disease called Obstructive Sleep Apnea Syndrome (OSAS), occurs due to sleep disorder, has been introduced in [16]. This disease not only interrupts normal sleep pattern but also causes hypoxemia and hypercapnia. In this work a smartphone based wireless e-health system has been introduced for monitoring a patient with OASAS. The authors show that the proposed system is very energy efficient due to the use of Bluetooth.

A smart shirt has been designed in [17]. The shirt can measure electrocardiogram (ECG) and acceleration signals for continuous and real time health monitoring of a patient. The shirt mainly consists of sensors and conductive fabrics to get the body signal. The measured body signals are transmitted to a base station and server PC via IEEE 802.15.4 network. The wearable devices consume low power and they are small enough to fit into a shirt. To reduce the noise associated with the ECG signal an adaptive filtering method has also been proposed in this work.

III. METHODOLOGY AND PROCEDURES

Real time multiple patients monitoring system (RTMPMS) consists of the following stages: (1) System Architecture, (2) Hardware and (3) Software.

A. System Architecture

The system design is the most important stage to build any system. It should be cohesive and integrated. Smart systems assist users at the right places and get out of the way to empower people in order to increase the system efficiency and limit the future problems and errors as much as possible. Real time multiple patients monitoring system (RTMPMS) is a state-of-the-art, PC and arduino based, integrated, low-cost, small, portable, low power consumption, ZigBee communication with health monitoring system and alarm system. This system design is based according to the following characteristic: circuits, technologies, total cost, parameters, components and software. The essential vital signs indicates the status of the body's vital functions which give clues to possible diseases, help assess the general physical health of a person and show progress toward recovery. Primary parameters that will be observed from the patient will be applied in this system. These parameters are temperature, ECG and pulse rate. The main components are the temperature sensors for measuring the temperature, ECG sensor (AD8232) for measuring ECG signals, pulse sensor for measuring heart rate, the embedded system that connected with the sensors and process all signals, OLED for displaying the sensors outcomes before transmission, the transmission modules that transmit and receive the signals, external power supply, and the computer which process and display the received signals.

The system architecture which is based on wireless transmission of medical data is composed of four stations. Three stations of them represent the modules that will be connected to the patients.

These stations are called the routers (transmitters) which transmit the sensed data to the last station which called receiver. Each module of the transmission station consists of the embedded system (arduino nano), temperature sensor, ECG sensor, pulse rate sensor, OLED display, Xbee transceiver and 9V battery. On the other side, receiving station composed of computer, Xbee receiver and usb to serial converter. All data will be manipulated and displayed on the computer through a graphical user interface using LabView. The block diagram of real time multiple-patients monitoring system (RTMPMS) is shown in Fig. 1.

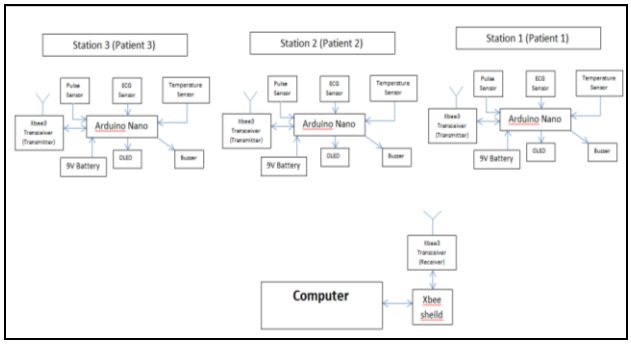

Fig. 1 Block Diagram of RTMPMS

B. Hardware

The systems generally are made up of combination of two components, which is hardware and software. Both components are important and have their own functions and meaningful usages. According to hardware, it is important that the hardware meets the needs of the system requirements. The hardware are now updating and the technology is improving frequently and speedy, and hence affected its price. Therefore, it is very important to choose and buy the most appropriate and cost-effective hardware. Selection of hardware can have a deep impact on system performance. There are some characteristic should be considered when choosing the hardware such as IC quality, cost, power compatibility, acclimation with system, advantages and limitations, size and modernity. The system hardware that will be applied are arduino nano, MAX30205 temperature sensor, AD8232, OLED, active buzzer module, xbee3 pro and micro xbee3 and Xbee shield. The modules of transmission station which attached to the patients will be portable so all components of each module will be combined in a single wrist strap as shown in Fig. 2.

Fig. 2 Portable Patient Transmission Station Module

1. Arduino Nano

The Arduino Nano is a small, complete, and breadboard-friendly board based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller [18]. In this system, RX0 pin is connected to TX (pin 3) of micro xbee3 and TX1 pin to RX (pin 4) of micro xbee3. A0 pin is connected with ECG output and D10, D11 pins are connected with LO+, LO- (lead off detection) respectively of the same sensor. A4 and A5 pins are connected with SDA and SCL respectively of MAX30205 and AD82323 sensors. Arduino will be supplied by a portable battery (9V) through VIN pin. VCC, VDD and ground pins are connected according to the sensors power supply. Table 1 shows the pins connection details of system hardware.

Table 1: Pins Connection of Arduino Nano with the System

PIN NO	PIN	MICRO XBEE3	ECG	PULSE SENSOR	OLED	BUZZER	MAX30205
2	GND		GND	GND	GND	GND	OS pin3+4.7kΩ
4	5V			VCC	VCC	VCC	
5	A7					I/O	
7	A5				SCL		SCL pin2+4.7kΩ
8	A4				SDA		SDA pin1+4.7kΩ
10	A2			Signal			
11	A1		OUT				
14	3.3V	2	3.3V				VDD+0.1µF
17	D11		LO-				
18	D10		LO+				
26	D2	INT+4.7kΩ					
27	GND	1					GND+A0+A1+A2pin(4,5,6,7)
29	RX0	3					
30	TX1	10KΩ to RX of Xbee3 (pin4) + 10KΩ to GND					

2. ECG Sensor (AD8232 Breakout)

The AD8232 Single Lead Heart Rate Monitor is a cost-effective board used to measure the electrical activity of the heart. This electrical activity can be charted as an ECG or Electrocardiogram and output as an analog reading. ECGs can be extremely noisy, the AD8232 Single Lead Heart Rate Monitor acts as an op amp to help obtain a clear signal from the PR and QT Intervals easily. The AD8232 is an integrated signal conditioning block for ECG and other biopotential measurement applications.

The AD8232 breaks out nine connections from the IC that pins, wires, or other connectors can be soldered to. SDN, LO+, LO-, OUTPUT, 3.3V, GND provide essential pins for operating this monitor with an arduino or other development board. Also provided on this board are RA (Right Arm), LA (Left Arm), and RL (Right Leg) pins to attach and use custom sensors. Additionally, there is an LED indicator light that will pulsate to the rhythm of a heartbeat. Biomedical sensor pads and sensor cable are required to use the heart monitor. This module will be interfaced with arduino nano and ECG signal will be displayed on the computer through the transceivers in a graphical user interface using LabView. In addition, the power supply will be connected to 3.3V and GND to GND of arduino nano. The output of AD8232 will be connected to the analog input 0 pin. D10, D11 pins are associated with LO+, LO- separately which identify lead-off detection.

3. Xbee3 (802.15.4)

Generally, there are many wireless technologies that can be used for the transmission of medical data such as Wi-Fi, Bluetooth, ZigBee, Bluetooth Low Energy (BLE), LoRaWAN, etc. Data rate, power consumption and the range are the main characteristics that have been considered before designing the system. In comparison, ZigBee is more suitable technology can be applied for the transmission of the patient's signal according to the following specifications:

- The data rate in ZigBee (250kbit/s) is low which is suitable for measuring and sensing the vital signs.
- Power consumption of ZigBee is very low.
- The cost is low.
- Supports up to 65,000 nodes connected in a network [19].
- Many medical applications for monitoring the patients have been applied using ZigBee.
- The range of ZigBee is large. It starts from 200ft (60m) until 2 miles (3200m) for ISM 2.4GHz frequency band [20] and it can be extended until 40 miles for 900MHz frequency band [21]. So Zigbee protocol is an essential feature to monitor the patient within healthcare facilities (e.g. hospitals and clinics) or out the scope of the healthcare facilities (e.g. ambulance).

Xbee3 devices which are last version of Zigbee RF modules have been released with three form factors. These forms are through hole, surface mount (SMT) and micro. Each form has two options which are Xbee3 and Xbee3-Pro. Generally, they are similar but Xbee3 differ than Xbee3-PRO in indoor/outdoor range, transmission power and transmit current. Table 2 describe the comparison between Xbee3 and Xbee3-PRO. The release of Digi XBee3 allows hardware to be compatible with multiple protocols including Zigbee, Thread, 802.15.4, DigiMesh, Wi-Fi and Bluetooth, which is available on a single hardware platform.

Table 2: XBee3 and Xbee3-PRO Comparison

SPECIFICATION	XBEE3	XBEE3-PRO
Indoor/urban range	Up to 60 m (200 ft)	Up to 90 m (300 ft)
Outdoor RF line-of-sight range	Up to 1200 m (4000 ft)	Up to 3200 m (2 mi)
Transmit power output (maximum)	6.3 mW (+8 dBm)	79 mW (+19 dBm)
Transmit current	40 mA @ +8 dBm	135 mA @ +19 dBm

In this project, a single through hole Xbee3-PRO module and three micro Xbee3 (xb3-24acm) have been used. Xbee3-PRO is the coordinator which is connected to the computer of the healthcare provider through XBee shield whereas micro Xbee3 is the router which connected to arduino nano. The size of new Xbee3 micro form factor is 13x19mm which is approximate 1/3 of arduino nano size can allows for more compact and portable applications.

Pin1 of xbee3 micro is connected to GND, pin2 to 3.3V, TX (pin3) of micro xbee3 to RX of arduino nano and RX (pin4) of micro xbee3 to TX of arduino nano.

C. Software

The software in any system is as important as hardware and sometimes it is more important. In this topic, we will discuss briefly about three aspects related to software, which have been applied in the patient monitoring system. These points are: Xbee configuration, Arduino IDE programming code and LabView User interface.

1. XBee configuration

Generally, each XBee module has its own MAC address which is a 64-bit address. There are several ways to configure the XBee module. X-CTU is the most common tool for Xbee configuration which can have a quick summary of all XBee's parameters.

The main parameters that have to be considered during Xbee configuration are in following:

- Function Set: set the radio module type.
- Firmware version: It is recommended to set the last firmware version of the radio module.
- Pan ID (ID): Defines the network that a radio will attach to. This must be the same for all radios on your network.
- Channel number (CH): Defines the frequency to use to communicate. This must be the same for all radios on the network.
- Serial Number High/Low (SH/SL): the MAC address of the module.
- Destination address high (DH): Defines the destination address to transmit the data to. The value of this setting should be the Serial Number High (SH) of the other module.
- Destination address Low (DL): Defines the destination address to transmit the data to. The value of this setting should be the Serial Number Low (SL) of the other module.
- Device Role (CE): Coordinator / End device Configuration. (CE=0 for End device) (CE=1 for Coordinator)
- API Mode Setting (AP): RF Packets received can be formatted into API frames to be sent out the serial port. AP=0 for transparent Mode (AT); AP=1 for API Mode without Escape; and AP=2 for API Mode with Escape
- Baud Rate (BD): The serial interface baud rate for communication between modem serial port and host.
- Node Identifier (NI): Defines the node identifier, a human-friendly name for the module.

- 16-bit Source Address (MY): The 16-bit source address for the device.

The main configuration that applied in this system is shown in Table 3.

Table 3: Main Configuration of Zigbee Transceivers in the System.

PARAMETER	XBEE-PRO (COORDINATOR)	XBEE (ROUTER1)	XBEE (ROUTER2)	XBEE (ROUTER3)
Function Set	Digi Xbee3 802.15.4 TH	Digi Xbee3 802.15.4	Digi Xbee3 802.15.4	Digi Xbee3 802.15.4
Firmware version	2002	2002	2002	2002
CH	C	C	C	C
ID	3332	3332	3332	3332
NI	Coordinator Station	Satation1	Satation2	Satation3
CE	Coordinator [1]	End Device [0]	End Device [0]	End Device [0]
SH	13A200	13A200	13A200	13A200
SL	4187DABD	417FE94E	417FE95F	417FE94F
MY	FFFF	FFFF	FFFF	FFFF
DH	0	13A200	13A200	13A200
DL	FFFF	4187DABD	4187DABD	4187DABD
BD	115200 [7]	115200 [7]	115200 [7]	115200 [7]
AP	API Mode With Escapes [2]	API Mode With Escapes [2]	API Mode With Escapes [2]	API Mode With Escapes [2]

2. Arduino IDE Programming Code

Arduino code which is using Arduino IDE program applied to process the data of the patients in the transmission station. It will sense the temperature, ECG and pulse rate from the sensors which connected to arduino, display the result in OLED, activate the alarm when the normal range have been exceeded and send them through the Xbee transmitter.

3. Lab View Graphical User Interface

All data of the patients will be displayed in the graphical user interface which takes place in the receiver station (coordinator). After acquiring the data, this software will receive the frame packet and process it according to the address and display it. The user interface will be applied of 3 patients (persons) in this project.

The user interface will be divided into multiple tabs (sections) as follow:

A. Registration Tab

This tab includes Name, Age, National ID, Mobile No., Address, Company etc. which related to the patient. The system includes a database for the patients' data. After submission these data to the database, a special account number will be added for each patient. So the patient data can be extracted during search.

B. Add/Remove Tab

The physician can add the patient's account number that has been created in the registration tab into this tab. So he can monitor the vital signs for each patient in the main tab that will be described in the next subject. He also can add three patients in the same tab and monitor them simultaneously. For example, the patient's account will be added in the first icon when the first device is connected to the patient. In addition, the patient's account can be removed after completing the monitor by pressing on (Remove) icon. Then the patient's account will be removed from live monitoring, but the data will remain in the database until it is retrieved if the patient returns later.

C. Home Tab

This tab is the main page of the graphical user interface (GUI) and it will represent all patients' data that have been added in add/remove tab. This data consists of temperature, ECG and heart rate.

D. Patient Tab

In this tab, all patient-specific data will be shown separately. A tab will be created to choose the account number of one of the patients who connected to the system. These data contain (patient's account number, patient's name, age, nationality, mobile number, ID number, and previous patient's notes with their dates). The doctor can also insert any observations for each patient to read it later, such as (Isolated systolic hypertension, iron deficiency, Stage 2 hypertension, the patient uses certain drugs (with their names) and so on.

E. Historical Tab

This tab displays the previous diagnoses and patient-saved data for a specific period specified by the doctor, where the doctor assigns a specific date and time to view all notes that were recorded at that time. For example, all data will be displayed on 24/8/2018 from 12:30 to 1:30 pm.

F. Setting Tab

The custom settings for each patient are set on this tab. In these settings, the acquisition time range is adjusted or modified for the parameters which include temperature, ECG and heart rate.

IV. CONCLUSION AND RECOMMENDATION

Real time multiple patients monitoring system can monitor multiple patients with multiple parameters for each patient simultaneously. Temperature, ECG and heart rate are the major parameters indicated through graphical user interface and only temperature and heart rate have been shown through OLED. All parameters which vitally important are compactly displayed in one place making the doctor's work easy.

The whole module which include arduino, Xbee module, sensors, OLED, battery and buzzer has been compiled in a single wrist strap which makes the final system small and portable.

Temperature and pulse sensors will be fixed on the patient's finger using finger strap and 3 lead ECG electrodes will be fixed on the patient's chest. After sensing the parameters, arduino will process the results and send them using Zigbee communication. ECG signal need more filtration as there is a noise in the signal which affect the clarification of data as shown in Fig. 3.

Fig. 3 ECG Signal

In this paper, we recommend providing more parameters in a single module (Arduino, Raspberry etc.) that can send the useful information to the physician because Arduino can receive and process them simultaneously. We also recommend providing several devices using Zigbee modules for each department or room that can send the information to the physician. So the physician can monitor different patients from different sides in one monitoring system because Zigbee can be used to create personal area networks such as between rooms or departments in a hospital with long range and low power consumption. The project needs time. budget, hardware and programming to provide the complete system with communication depend on the number of devices and the parameters in each device.

As the technology is dramatically progressing, the electronic hardware component's quality is improving but the costs are decreasing. The components used in our proposed system for health care application are affordable which make the dedicated system cost effective.

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