Efficient Patient Monitoring For Multiple Patients Using WSN

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***Abstract*— Real motivation of this research work is to develop an efficient system that can monitor multiple patients' health parameters simultaneously and can effectively deliver the data to a patient monitoring system where it is stored permanently. Current traditional health monitoring is accomplished by individual PCs attached to each patient's bed. The multiple parameters that are monitored are blood pressure, temperature, ECG, and EEG. Our research investigates the potential of WSN to reliably, wirelessly collect, send and process these multiple parameters of multiple patients simultaneously, in real-time. This research succeeds in transforming the traditional individual patient monitoring apparatus and its requirements into an apparatus that is capable of reliably monitoring the multiple parameters of up to six patients simultaneously, in real-time. Managing interference and ensuring the accurate delivery of the information to the monitoring system using the most effective wireless communication technique are the challenges taken in to consideration. This is achieved by identifying each patient's monitored parameter using a unique ID and employing a time scheduling scheme during data transmission. The system also alerts the doctor/nurse of some measured value cross threshold limits. A real time data storage mechanism employed here helps to look further into the recorded data by the doctor. This contribution succeeds in indicating where there could be huge savings in power consumption and cost for hospitals. Currently employed systems use a one patient monitoring system per patient which is expensive, whereas this system uses the same resources to monitor up to six patients, with more comfort to the patients and more convenience for the healthcare professionals.**

Keywords— multiple health parameters; patient monitoring system; real-time monitoring; sensors; wireless sensor network.

I. INTRODUCTION

Continuous monitoring of the health parameters of patients is one of the major problems faced by the hospital authorities nowadays. Monitoring should be accurate, precise and carried out in real time [9]. Current patient monitoring systems consist of single patient monitoring systems, where sensors are hardwired to a PC next to bed [7]. Human intervention is also needed frequently. That is, a nurse will have to frequently monitor the patient's health parameters. Employing a multiple patient monitoring system as oppose to a single patient monitoring system per patient, would be more cost and power efficient, and would allow the healthcare professionals to monitor many patients simultaneously without being in the same location. So a system that can overcome the above mentioned problems will really benefit developing countries like India.

The proposed system makes use of the idea of network technology with wireless applicability. Each patient is identified using an identifier makes it simpler for a doctor in identifying the patient's current health status. The monitored parameters are processed and compared with the individual threshold limits of each patient and is networked to the patient monitoring system in doctors room. It is also networked to the monitoring system in nurse room. Hence in case of doctor's absence since the monitored data being stored, an experienced nurse can convey the status of certain patient's parameter to doctor's mobile phone. Thus the necessary health aid can be provided and once the doctor arrives the results of concerned patients can be checked.

Section II describes the problem. Section III discusses the related work. Section IV explains the proposed system architecture. Section V presents a decision making algorithm for monitoring and detecting conditions of patients in hospitals. Section VI focuses on the implementation and results. Section VII describes the experimental setup. Section VIII describes theoretical calculations. Section IX and X contains the conclusion and future work respectively.

II. PROBLEM STATEMENT

The problem, that motivated us to develop this system, is the difficulties for monitoring multiple patients' health conditions faced by healthcare providers. In case of a large hospital where multiple patients need to be monitored simultaneously a separate monitoring system for each patient is inefficient. By employing a single system for multiple patients there will be a huge reduction in cost as well as power consumption. Data being recorded can be used for further research purposes if needed. It also provides flexibility to doctors.

III. RELATED WORK

A two-tier clinical warning system, for hospitalized patients, was described in [1], which incorporates preventing clinical deterioration in patients, through early detection and intervention. Their system consists of an Early Warning System (EWS) which identifies at-risk patients from existing real-time Electronic Medical Record (EMR) data, using machine learning algorithms. A key challenge that they noted had not been overcome for such applications was to be able reliably deliver sensor data from mobile patients. This system focuses on a solution for this problem. Whereas the proposed system is capable of overcoming this limitation. A novel

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wireless sensor network structure to monitor patients, with chronic diseases in their own homes, through a remote monitoring system of physiological signals assessment is discussed in [2]. They present a new design which eliminates the need for a PC to send patients' data to a hospital. Mobile patient monitoring systems, which integrates current personal digital assistant (PDA) technology where used in [3] and [4]. [4] used PDA in conjunction with wireless local area network (WLAN) and discussed the possibility of using Bluetooth technology, in the future. However disadvantages of Bluetooth are that is in capable of multiple hopping and its range is limited. [5] looks at currently used wireless techniques in hospitals. The technologies of wireless sensors and data transmission, and their ability to meet the needs of patient monitoring in the operating room and the intensive care unit, are reviewed.

IV. PROPOSED SYSTEM

The proposed system, as shown in "Fig.1", monitors the parameters of multiple patients such as their blood pressure, temperature, ECG, EEG. These are processed and are compared with the threshold limits and are wirelessly transmitted to the patient monitoring system held at doctor's room. The data is also networked to the monitoring system in nurse room. Each patient is identified using their Unique ID and thus doctors will get a detailed report of each individual patient's current status and state. In case of doctor's absence since the monitored data being stored at the nurse system, the monitored values along with their status can be send to the doctor's mobile phones [6] or make use of internet facility. Thus our system helps in the simultaneous monitoring of the multiple parameters in multiple patients.

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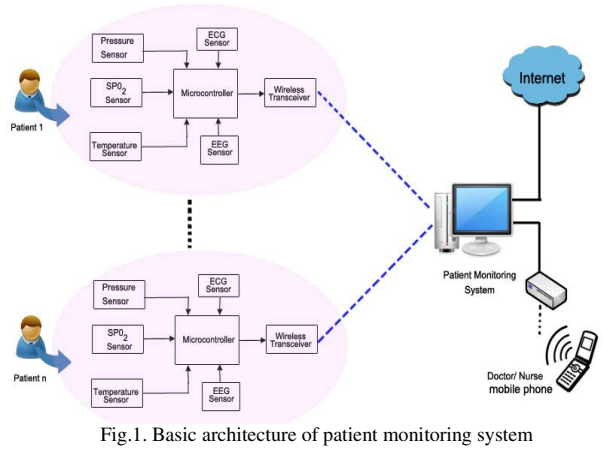

Fig.1. Basic architecture of patient monitoring system

The various components of proposed system consists of

a) Sensors attached to the body of patient.
b) Signal conditioning section.
c) Patient monitoring system.
d) Doctors/nurse mobile phone.

The various sensors used are blood pressure sensor, temperature sensor, SPO_2 (pulse oximeter), ECG and EEG sensor. In this paper, we concentrate on the blood pressure monitoring of multiple patients.

V. DECISION MAKING ALGORITHM

A decision making algorithm shown in "Fig.2" is proposed based on the risk factor of patients. The risk factor can be obtained from the current status of patient. In the case of critical patients the system can collect data continuously whereas in the case of patients with a low risk factor an option of transmitting data after some duration of time is provided. Thus power usage can be reduced. The parameter, we focus on in this paper, is blood pressure. A monitored patient's condition can be classified into three blood pressure values: Normal, Mild Hypertension and Severe Hypertension. Normal person's blood pressure ranges between 80 and 120. A person whose blood pressure value is between 120 and 140 is referred as having Mild Hypertension. A person whose blood pressure value lies above 140 is referred as having Severe Hypertension. By observing the monitored results we can classify the patients into safe or critical zones and alert the doctor/nurse to come to the patient's aid if necessary.

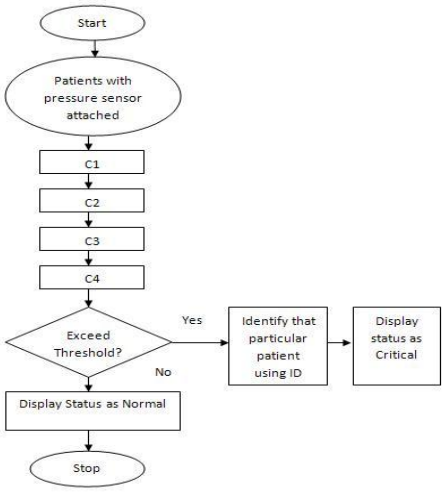

Fig.2. Decision making algorithm

These are the blood pressure monitoring algorithm steps:
C1: Collect sensed pressure values from the multiple patients.
C2: Transmit the sensed pressure values to the microcontroller module.
C3: Transmit the signal conditioned information to the central server for further processing.
C 4: Compare the received values with threshold limits
i)If the threshold limit has been exceeded then identify that particular patient using their ID and display status as "Critical".
ii) Else display status of patient as "Normal".
The complexity of proposed algorithm depends on the number of patients under monitoring say $\mathbf{n_P}$ and the time period of sampling $\mathbf{T_S}$.

VI. IMPLEMENTATION AND RESULTS

A reliable patient monitoring system that can monitor multiple patients' parameters simultaneously in an indoor scenario is proposed. The parameter taken for experimentation is blood pressure. Blood pressure readings from multiple patients are wirelessly transmitted to a central monitoring system using ZigBee technology. At the server each patient is identified using the Unique ID and thus doctors will get a detailed report of patient's current status and state. The system architecture is modified as shown in "Fig.3".

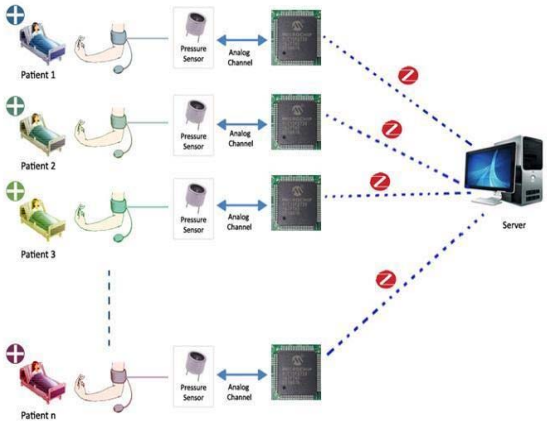

Fig.3. Architecture of pressure monitoring system

VII. EXPERIMENTAL SETUP

The blood pressure readings of three patients were monitored simultaneously. The actual pressure sensor was attached to one of them and the other two patients were monitored using variable potentiometers. The monitored values were successfully transmitted and displayed in real time, in the HyperTerminal of a personal computer using an USART interface. The system architecture is shown in "Fig.4".

VIII. THEORETICAL CALCULATIONS

The health statuses of patients, with a high risk factor, are monitored using biomedical sensor networks. Therefore the performance of these networks is of the utmost importance as human lives are potentially threatened if the performance of this technology fails. The performance of the IEEE 802.15.4 standard in the network is analyzed in terms of packet delivery rate, propagation time, and transmission delay. The packet delivery rate increases when the data payload becomes large, but a large size packet suffers as it requires a larger transmission time.

From the data frame format of the IEEE 802.15.4 the following calculations are made:

Maximum MAC Packet Size acceptable to IEEE 802.15.4 =127 Bytes.

MAC Header size = 11 Bytes

MAC Footer = 2 Bytes

Hence, Data Payload = 114 Bytes.

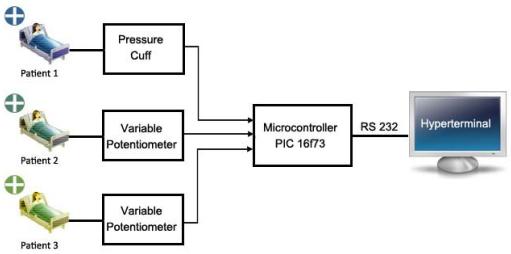

Fig.4. Experimental Setup

The following results were obtained.

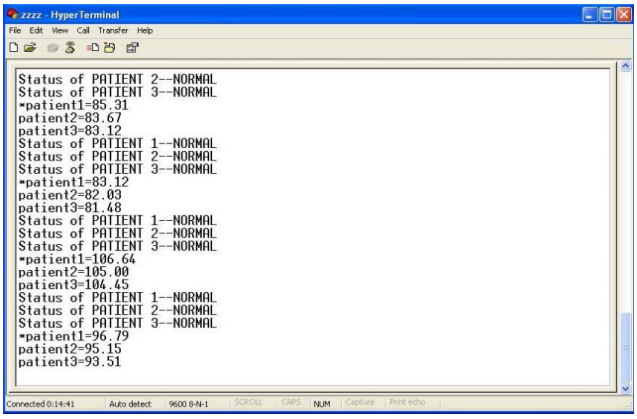

Fig.5. Output window at the server

The monitored blood pressure values from multiple patients after comparing with the threshold limits are classified into following states: Normal, Mild Hypertension or Hypertension. Thus the status of patients can be obtained based on these states. Patients having blood pressure values between 80 and 120 are in normal state. Blood pressure values between 120 and 140 are having mild hypertension. Patients having blood pressure values above 140 are having Hypertension.

The data rates of various biomedical signals are shown in TABLE I.

TABLE I. DATA RATES OF VARIOUS BIOMEDICAL SIGNALS

	Data Rates of Signals		
	Signal	***Data Rate***	***units***
1	Heart Rate	0.01-10	Kbps
2	Blood Pressure	0.01-10	kbps
3	ECG	10-200	kbps
4	EEG	10-200	kbps
5	Temperature	0.01-10	kbps

The maximum time limit to receive various measured medical parameters is listed in TABLE II.

TABLE II. MAXIMUM PERMISSIBLE TIME

	Maximum Permissible Time		
	Signal	***Time***	***units***
1	Heart Rate	5	sec
2	Blood Pressure	5-10	sec
3	ECG	10-20	sec
4	EEG	30-60	sec
5	Temperature	20	sec

Therefore the sampling time required for each signal can be calculated as given in "(1)"

Transmission time per frame = Data payload/Data Rate (1)

Data payload = 114 bytes.

The transmission time required for various signals is listed in TABLE III.

TABLE III. TRANSMISSION TIME PER FRAME

Data Rate chosen(kbps)	**Sampling Time**		
	Signal	***Transmission time per frame***	***units***
10	Heart Rate	0.0912	sec
3.2	Blood Pressure	0.285	sec
12	ECG	0.076	sec
10	EEG	0.091	sec
5	Temperature	0.1824	sec

From the theoretical calculations performed, the total time required to send all the frames for a single patient is around 0.8 sec only. Therefore at each second we can transmit each frame. Hence, if there are four patients then the total time required to transmit all their parameters will be around 3.2 seconds. Hence, we can transmit a maximum of six patient's parameters safely without a data loss to the patient monitoring system. This shows that multiple patients' multiple parameters can be sent efficiently to the single patient monitoring system using IEEE 802.15.4 standard.

IX. CONCLUSION

This patient monitoring system can monitor multiple patient parameters simultaneously in an indoor scenario. Experimentation was carried out by taking blood pressure readings of multiple patients' [8] .This system is so efficient, easy to use and handle and hence can be employed in hospitals. To obtain multiple monitored patients health statuses and values, doctors or nurses can login to a central server. It helps in ease of diagnosis. System also maintains the comfort to the patient as they will no longer need the traditional monitoring tools of wires and instrumentation. Wireless communication employed also enables rapid data transfer offering immediate real-time results in a critical situation for multiple patients.

X. FUTURE WORK

The work can be extended to the future by tking into account more parameters into consideration. Replace the use of cuff for blood pressure measurement and takes advantage of a technique called Pulse Wave Velocity. In this technique, blood pressure is calculated by measuring the pulse at two points [5]. Also how much data is send (bytes) for each signal is to be determined.

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