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A Hospital Healthcare Monitoring System Using Wireless Sensor Networks

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Abstract- It is necessary to constantly monitor the patient's physiological parameters in a hospital health care monitoring system it. For example a pregnant woman parameters such as blood pressure (BP) and heart rate of the woman and heart rate and movements of fetal to control their health condition. This paper presents a monitoring system that has the capability to monitor physiological parameters from multiple patient bodies. For this, a coordinator node has attached on patient body to collect all the signals from the wireless sensors and sends them to the base station. The attached sensors on patient's body form a Wireless Body Sensor Network (WBSN) and they are able to sense the heart rate, blood pressure etc. This system can detect the abnormal conditions, issue an alarm to the patient and send a SMS/E-mail to the physician. Also, it consists of several wireless relay nodes which are responsible for relaying the data sent by the coordinator node and forward them to the base station.

The main advantage of this system in comparison to previous systems is to reduce the energy consumption to prolong the network lifetime, speed up and extend the Communication coverage to increase the freedom for enhance patient quality of life. It has been developed in multi-patient architecture for hospital healthcare, simulated in OMNet++ and is compared with the other existing networks based on multi-hop relay node in terms of coverage, energy consumption and speed.
Keywords: Patient; Blood pressure; Hospital healthcare; Wireless body sensor network; Energy consumption; End-to-end delay; Pregnant woman.

Keywords – *Healthcare, wireless sensor network*

1. Introduction

Body sensor network systems can help people by providing healthcare services such as medical monitoring, memory enhancement, medical data access, and communication with the healthcare provider in emergency situations through the SMS or GPRS [1,2]. Continuous health monitoring with wearable [3] or clothing-embedded transducers [4] and implantable body sensor networks [5] will increase detection of emergency conditions in at risk patients. Not only the patient, but also their families will benefit from these. Also, these systems provide useful methods to remotely acquire and monitor the physiological signals without the need of interruption of the patient's normal life, thus improving life quality [6,7]. Present systems allow continuous monitoring of patient vital signs, but they require the sensors to be placed bedside monitors or PCs, and limit the patient to his bed. But now, there is no relation between the sensors and the bedside equipment due to the wireless devices and wireless networks [6]. These systems do not require the patient to be limited to his bed and allow him to move around but requires being within a specific distance from the bedside monitor. Out of this range, it is not possible to collect data. In most cases, health monitoring will be done by infrastructure-oriented wireless networks such as commercial cellular/3G networks or wireless LANs. But, the coverage of the infrastructure-oriented networks changes with time or location. Sometimes, the coverage of wireless network is not available, or the coverage is available but we cannot access to the network due to a lack of available bandwidth.

So, with these problems and restrictions, continuous health monitoring is not possible and emergency signals may not be transmitted from a patient to healthcare providers. Under these conditions, we can reach to continuous health monitoring by using ad hoc wireless networks that can transmit vital signs over a short-range [8,9]. Lai et al. [10] presented a WMHRN for reliable and real-time transmission. In most systems the health data from multiple patients can be relayed wirelessly using multi-hop routing scheme to a base-station in [11-13].

An example of the application of this system is controlling a pregnant woman. A pregnant woman's blood pressure should be the same as any other person's normal blood pressure. It is important to monitor the blood pressure during pregnancy, to watch for preeclampsia. These women need frequent BP checks. If BP goes too high, the patient may be hospitalized. But, the patient is limited to her bed in hospital. In the proposed system, the patient's physiological signals are acquired by the sensors attached on the patient body, and are then transmitted to the remote base-station and also a PC for storing and analyzing. According to table 1 [14], in indoor environments, the signal strength of access points can be weakened by 30-90% as it passes through the obstructions (for example, when the two wireless devices or relay nodes are in

different rooms, and the door which connects the rooms are closed). With the increasing number of obstructions between the nodes, we can observe more packet loss and more dead spot that will cause a communication disconnection between the patient and the network. So, we have to increase the number of relay nodes within the indoor environments to cover the whole environment, and enhance the reliability for wireless connectivity. In addition, an emergency alert service using short message service (SMS) messaging is also added to the proposed system for emergency responses and rescues.

Distance- obstructions	Packet lost rate
3 m	0.13 %
5 m	0.19 %
5 m-1 door	0.32 %
10 m	0.85 %
10 m-1 door	1.08 %
10 m-2 doors	1.23 %
Moving patient	20.15%

Table 1: Loss rate values for the in-house patient [14].

Multi-Patient Body Sensor Network System Design

A healthcare prototype system for hospitals is designed to place wireless sensors on a person's body to form a wireless network which can communicate the patient's health status with base station connected to the monitoring PC. The architecture of the system consists of four parts:(1) The WBSN includes four sensors which are responsible for collecting the physiological signals from patient.(2) The WMHRN (Wireless Multi-Hop Relay Node), consist of a number of wireless relay nodes which is in charge of forwarding the health data to the base station.(3) A BS (Base Station) receives the relayed data and sends it to the PC through a cable.(4) The graphical user interface (GUI) which stores, analyze and presents the received data in graphical and text format, and sends SMS to the healthcare provider or patient's family in emergency conditions through the GPRS or GSM modem.

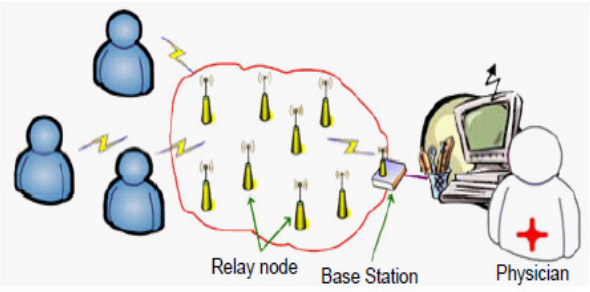

Figure 1: Architecture for proposed healthcare system in hospital.

Coordinator Nodes and Sensors Nodes

This section describes the components that make up the WBSN and their functionality.

Sensor Nodes:

All the sensors are wireless and sense different physiological parameters in a given interval and simultaneously, determine the sampling interval by the physician. For example sensors for pregnant woman can be:

1) Motion Detection-Accelerometers: To measure blood pressure, the patient should be seated or lying [15]. So, these sensors can detect patient's position. If the patient is placed in a proper position, it will allow the other sensors to sense.

2) Blood Pressure and Heart Rate: These sensors can return blood pressure and heart rate.

3) Heart rate and Movement of the fetal: Detection of the heart rate and the movement of the fetal used by medical practitioners to assess the health of the fetal.

Coordinator Node:

The coordinator node is a wireless node in the WBSN which is in charge of collecting and packaging the arrival signals from the other sensors, and send them to the base station. This node attaches on the patient's body and it works with battery. Each coordinator node is identified by a unique ID which is used to identify each patient in the network.

GPS:

GPS is a space-based satellite navigation system that provides location information about the patient in the hospital which helps the hospital staffs to find the patients in emergency conditions. It is always attached to the patients body.

WBSN Design:

To measure blood pressure, the patient should be seated or lying. So, these sensors can detect patient's position. If the patient is in a proper position, the motion sensors by sending a SENSE_START packet will allow the other sensors to sense. To reduce energy consumption, all the sensors wake up simultaneously and wait for a specified time until they receive the SENSE_START packet. If they receive it, they will send their readings to the coordinator node and then turn off their radio. Which can be observed by the state diagram of the Blood Pressure (BP) sensor in figure 2.

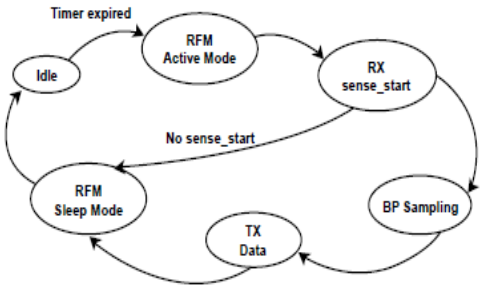

Figure 2: State transmission diagram of the BP sensor

If each sample of data (such as the heart beat, BP etc.) is immediately encapsulated into a frame and transmits, the overhead will be increased and will cause excessive energy consumption. So to decrease the overhead, the burst transmission mechanism [10] is used as shown in figure 3. Woman heart rate, woman blood pressure, fetal heart rate and fetal movement encapsulate in one frame. In this way, more energy conservation is achieved.

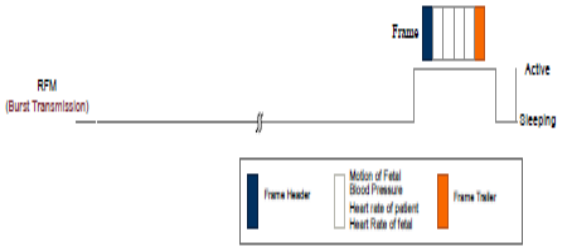

Figure 3: Burst transmission.

Among various existing MAC protocols, here Time division Multiple Access (TDMA) protocol for media access is used because there is a constant number of nodes between sensors and the coordinator node. TDMA divides the channel into individual time slots, which are then grouped into frames. In each time slot, only one node can transmit. TDMA is energy-efficient. A sensor node can turn off its radio during all time slots in a frame.

Moreover, when the number of nodes in a cluster changes, it is difficult for a TDMA protocol to dynamically change its frame length and time slot assignment [17]. To control data transmission and reduce collisions between data sent, CSMA/CA MAC is used. In this design the RTS/CTS (Ready to Send/Clear to send) is used. When a coordinator node wants to send data to a relay node first it will check the transmission channel. If the channel is free then the relay node will send a CTS packet to the coordinator node. This simple MAC protocol allows multiple coordinator nodes to reliably transmit their data to a relay node without any significant delay.

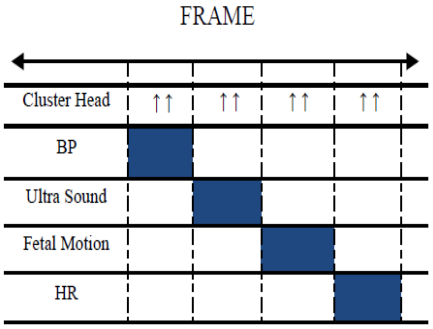

Figure 4: Time slots allocation to the sensors.

WMHRN design:

The WMHRN consists of several wireless nodes. Relay node has only routing capability to transfer physiological signals, such as heart beat, BP, and other biomedical signals to the base station or to surrounding other relay nodes. Hospitals have fluorescent lights in the hallways that are always on, so the relay nodes are operated by light energy. To save huge cost and to eliminate the need of batteries. The operation of the WMHRN is divided into two phases:

1. To find the minimum path from the coordinator node to the base station.
2. The data transmission stage through the minimum path.

By these nodes and the first phase, the end-to-end delay will be decreased.

End-to-End delay is the time taken for a packet to be transmitted across a network from source to destination.
By reducing it, the speed will be increased. Due to high speed, system can detect abnormal physiological parameters and issue alarm rapidly. Also, several nodes in an indoor environment can reduce the dead spots and extend the patient's freedom. To find the minimum path, an algorithm is used which is shown in figure 5.

```
After receiving an FMP packet checks and turns on the timer
If (current hop count > previous hop count)
        Drop the packet
Else If (current hop count < previous hop count)
        Keep it in routing table.
        Increase the current hop count by 1.
        Add the ID to the Next Hop
        And send it to the neighbors.
Else IF( the timer is expired)
        send an FMP_END to the BS
```

Figure 5: The proposed algorithm to find the minimum path.

The first phase begins with sending a FMP (Find Minimum Path) packet from the BS. FMP consists of <hop count, source, node ID> to find minimum path. When a node receives an FMP, it checks the hop count. If the hop count is smaller than hop count in the previous FMP, will record the packet to its route table. Then the node adds its ID to the "node ID" field and then sends it to its neighbors.

After a specified time, the minimum path from nodes to BS will be found and each node returns an FMP_END packet which is similar to FMP and then sends the packets to the BS through the path in their route table. When a node receives an FMP_END, it records the ID in its route table, to determine the minimum path from the BS to nodes. The second phase starts with broadcasting a TRANS_MODE packet in the network from the BS. When the coordinator node receives this packet, it can transmit the data packet into the network.

Design of GUI and Monitoring System

The installed software in the remote computer receives real-time patient's data from the base station and processes them to detect anomalies. Table 2 shows a partial list of physiological conditions that cause alerts.

Table 2: Alert detection parameters [13].

Alert Type	Detection Parameter
Tachycardia of woman	>100 bpm
Bradycardia of woman	<80 bpm
Tachycardia of fetal	>110 bpm
Bradycardia of fetal	<100
BP of woman	> 139/90 (systolic/diastolic)
movements	From past 4 readings>=3
Moving patient	20.15%

Figure 6 shows an alert in the software application when the BP is out of the threshold.

Figure 6: An alert when the patient's blood pressure level is critically low.

By detection an alert, a SMS/E-mail will be sent to the patient's family or the healthcare provider through the GSM modem/GPRS. card, and operates over a subscription to a mobile operator, just like a mobile phone. When a GSM modem is connected to a computer, this allows the computer to use the GSM modem to communicate over the mobile network. While these GSM modems are most frequently used to provide mobile internet connectivity, many of them can also be used for sending and receiving SMS and MMS messages.

Performance Evaluation and Discussion:

One way to analyze the performance of WBSN system is to measure the end-to-end delay, energy consumption, coverage range. So, the simulation of the proposed system is done in OMNet++. OMNeT++ is an extensible, modular, component-based C++ simulation library and framework,for building network simulators. Network here can be wired and wireless communication networks, on-chip networks, queueing networks, OMNeT++ is a simulation framework.

Coverage Range:

Data can be transmitted through a short-range frequency module (RFM) inside the coordinator node and wireless relay nodes with minimum energy consumption. Medical bands such as MICS (Medical Implant Communication Service) with 10 meters coverage and 402-405 MHz frequency band is used for body-area network applications because of its low transmitter power [18]. To cover a hospital with 50 m×20 m dimensions without any obstacles in it such as doors and walls,7 relay nodes are required. Therefore, there is not any dead spot in this environment. Whereas, with several obstacles on the way of signals to prevent of weakening signal and loss signals more relay nodes are required (figure 7).

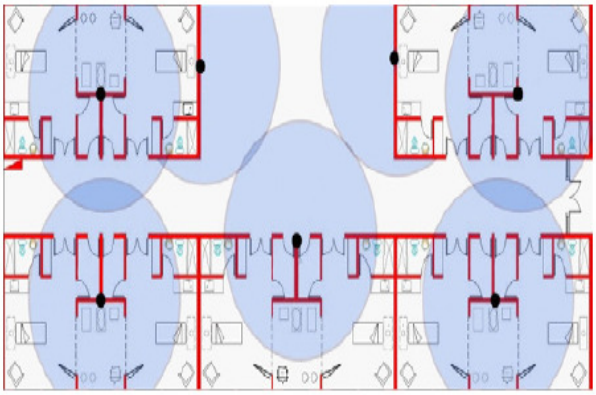

Figure 7: A hospital with 7 relay nodes for coverage of the whole environment.

Energy Consumption:

There is a relation between energy consumption and lifetime of the network. So, quality is provided by reducing energy consumption in coordinator node. Coordinator node has an important role in the network such as aggregation of sensory data, data packaging and transmitting them to the base station. If the lifetime be short, the patient has to recharge the battery of coordinator node in short intervals, and if the patient forget to recharge the battery, it may be dangerous for the patient. In normal case, the battery can work for 3 days and can be recharged. In, burst transmission, the battery lifetime is upgraded to 9 days.

End-to-end Delay:

When the delay is high, it seems the speed is low which is very dangerous for the patients with blood pressure because unusual signs are diagnosed late. Due to this it needs an acknowledgement (ACK) for each data packet.

There are two scenarios for ACK delivery:

1. In the first scenario, when the BS receives a data packet, it will return an ACK to the coordinator node.
2. In the second scenario, when each intermediate node receives the data packet, it will return an ACK to the sender.

Therefore, end-to-end delay and energy consumption in coordinator node will be reduced in the second scenario as shown in figure 9.

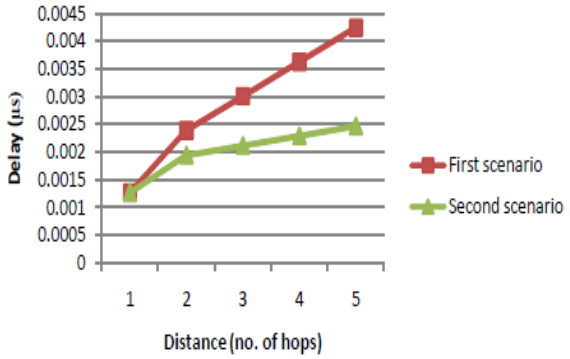

Figure 9: The relation between distance (no. of hops) and the end-to-end delay.

And the relation between distance (no. of hops) and the end-to-end delay when a packet gets lost in the way and the coordinator node has to retransmit the data packet is shown in figure 10.

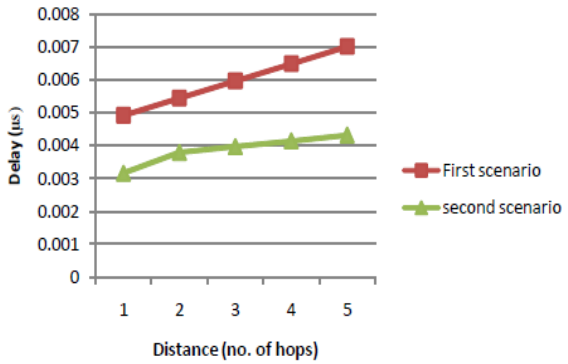

Figure 10: End-to-end delay based on retransmission of data packets.

Comparison of WBSN Systems:

Yuce [17] has presented a multi-hopping network for a multi-patient system that can be used in medical environments for remote monitoring of physiological parameters. But the coverage range by this system is 10 meters, and the patients cannot move around freely. Chung et al. [11] designed a multi-patient network using multi-hop routing scheme for transmission of data, shown in figure 11. It seems to be a good idea because the additional devices between the patient and BS have removed and it can reduce the cost. But, according to figure the figure 12 the end-to-end delay [11] is more than the proposed system, and the energy consumption has increased at the intermediate nodes and they need to be recharged more.

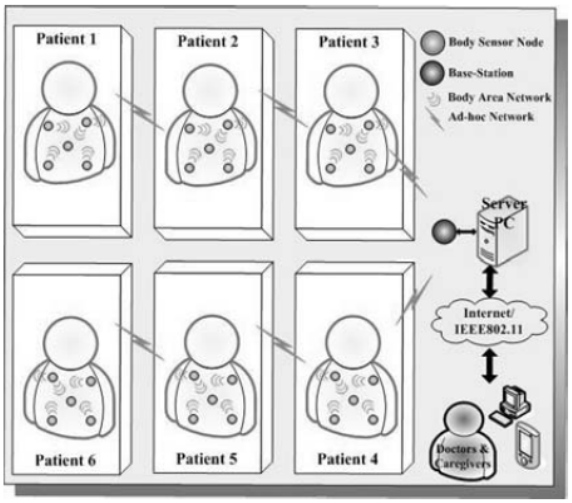

Figure 11: The presented architecture [10].

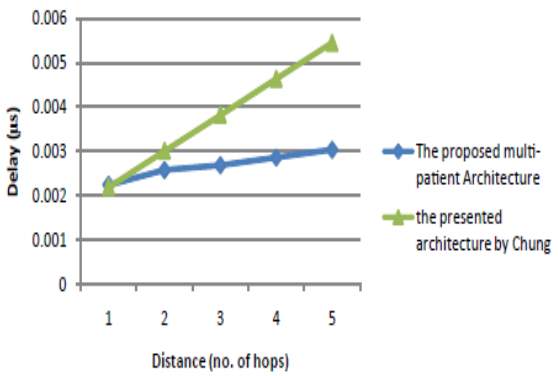

Figure 12: Comparison between the proposed architecture and the presented architecture by Chung [11] in term of delay.

Figure 13 shows the Energy Consumption at the closer nodes to base station is more than the other nodes. Another disadvantage is that the patient is dominated by signals and it is harmful for body of patients in the long time.

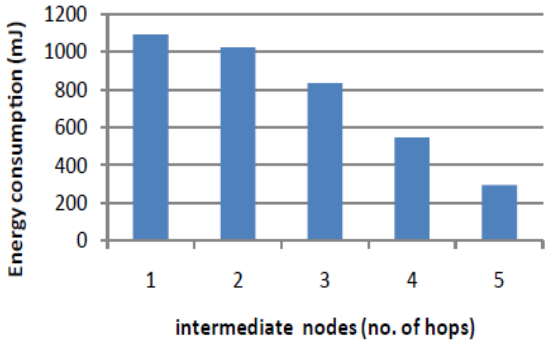

Figure 13: Energy consumption for one transmission at the intermediate nodes.

Conclusion

Wireless BSN technology is emerging as a significant element of next generation healthcare services. In this paper a mobile physiological monitoring system is used, which is able to continuously monitor the patient's heart beat, blood pressure and other critical parameters in the hospital. The entire system consists of a coordinator node to acquire the patient's physiological data, a WMHRN to forward the data and a BS to collect the data. The system is able to carry out a long-term monitoring on patient's condition and is equipped with an emergency rescue mechanism using SMS/E-mail. Also, the simulation is done for WBSN in OMNet++ simulator and is compared this with existing WBSN systems in terms of coverage, energy consumption and delay time, it is observed that the proposed system has better performance than others existing WBSN systems.

References

1. Stanford V (2002) Using pervasive computing to deliver elder care. IEEE Pervasive Computing 1: 10-13.
2. Mcfadden T, Indulska J (2004) Context-aware environments for independent living, In Proceedings of the 3rd National Conference of Emerging Researchers in Ageing, Brisbane, Australia.
3. Anliker U, Ward JA, Lukowicz P, Troster G, Dolveck F, et al. (2004) AMON: a wearable multi-parameter medical monitoring and alert system. IEEE Trans Inf Technol Biomed 8: 415–427.
4. Cho G, Yoo1 SK (2009) Wearable ECG Monitoring System Using Conductive Fabrics and Active Electrodes, Proceedings of the 13th International Conference on Human-Computer Interaction, Berlin, Heidelberg.
6. Shnayder V, Chen B, Lorincz K, Fulford Jones TRF, Welsh M (2005) Sensor Networks for Medical Care, Proceedings of the 3rd international conference on Embedded networked sensor systems, New York, USA.
7. Alemdar H, Ersoy C (2010) Wireless sensor networks for healthcare: A survey. Computer Networks 54: 2688-2710.
8. Varshney U (2005) Using wireless networks for enhanced monitoring of patients. International Journal of HealthCare Technology and Management 6: 489-499.
9. Varshney U (2003) Pervasive healthcare. IEEE Computer 12: 138-140.
10. Lai CC, Lee RG, Hsiao CC, Liu HS, Chen CC (2009) A H-QoS-demand personalized home physiological monitoring system over a wireless multi-hop relay network for mobile home healthcare applications. Journal of Network and Computer Applications 32: 1229-1241.
11. Chung WY, Walia G, Lee YD, Myllyla R (2007) Design Issues and implementation of Query-Driven Healthcare System Using Wireless Sensor Ad-hoc Network. IFMBE Proceedings 13: 99-104.
12. Hande A, Polk T, Walker W, Bhatia D (2006) Self-Powered Wireless Sensor Networks for Remote Patient Monitoring in Hospitals. Sensors 6: 1102-1117.
13. Chung WY, Mo An S, Lee SC (2012) Real Time Multi-hop Routing Protocol for Healthcare System Based on WSN, 14th International Meeting on Chemical Sensors, Nuremberg, Germany.
14. Kyriacou E, Pattichis C, Hoplaros D, Kounoudes A, Milis M, et al. (2010) A system for Monitoring Children with Suspected Cardiac Arrhythmias Technical Optimizations and Evaluation. IFMBE Proceedings 29: 924-927.
15. Lowe SA, Brown MA, Dekker G, Gatt S, McLintock C, et al. (2008) "Guidelines for the Management of Hypertensive Disoders of Pregnancy". Society of Obstetric medicine of Australia and New Zealand.
16. Fahim M, Fatima I, Lee S, Lee YK (2012) Daily life activity tracking application for smart homes using android smartphone. Proceedings of 14th international conference on Advances Communication Technology (ICACT), Pyeong Chang.
17. Yuce MR (2010) Implementation of wireless body area networks for healthcare systems. Sensors and Actuators A: Physical 162: 116-129.
18. Keong HC, Yuce MR (2008) Low data rate ultra wideband ECG monitoring system. Proceedings of IEEE Engineering in Medicine and Biology Society Conference, University of Newcastle, Callaghan, Australia.