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Reconfigurable Wireless Sensor Network: With Auto Reconfigurable Routing and Power Optimization

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Abstract: In this paper, we present Reconfigurable Wireless Sensor Network (R-WSN), which will improve the reliability of wireless links in health monitoring system in case of failure or fault at the default router i.e. Personal Data Processing Unit (PDPU), by automatically reconfiguring data routing. Along with re-configurability, we also present a power optimization algorithm to be implemented in standby router.

Keywords: PDPU, Re-configurability, Standby Router, Central/Medical server.

1. INTRODUCTION

IN roads into coordinated, intelligent computing are enabling sensor networks to monitor environments, systems, and complex interactions in a range of applications. Wireless Sensor Network (WSN) system, for example, promises novel uses in health-care, fitness, military and other purposes. Each WSN system consists of multiple interconnected nodes which together provide sensing, processing, and communication capabilities.
One of the most promising applications of sensor networks is in health monitoring. A number of minute sensors strategically placed on the human body connect wirelessly to the PDPU, which in turn connects with the central server to create a wireless Body Area Network (BAN) that can monitor various vital signs, providing real-time feedback to the user and the medical personnel.
On the off chance, if the PDPU fails for some reason, the standby router takes its place and connects the sensors with the central server. This seamless integration into the wireless BAN makes network reconfigurable and more reliable. Considering the limitations of power consumption to drive the network, the standby router is put in sleep mode during the time when the PDPU is operational. Once the PDPU fails the standby router is powered on to work as an acting PDPU for the time the PDPU is repaired.

2. SYSTEM DESCRIPTION

In order to establish an effective and reliable network, the entire system is divided into three tiers. Each tier is running independently and is performing certain task.

- SYSTEM ARCHITECTURE:

The proposed three tier health monitoring system consist of the microcontroller based Sensor Unit at the bottom tier, Personal Data Processing Unit (PDPU) along with the Standby Router (SR) in the middle, and a central server at the top as shown in Fig.1.

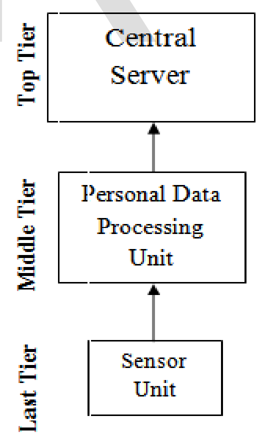

Fig.1 Overview of System Architecture

The top tier, centred on a medical server, is optimized to service hundreds of individual users, and encompasses a complex network of interconnected services provided to medical personnel, and healthcare professionals [1].

The medical server keeps electronic medical records of registered users. It is the responsibility of the medical server to authenticate users, accept health monitoring session uploads, format and insert this session data into corresponding medical records. It also analyses the data patterns, recognize serious health anomalies in order to contact emergency care givers, and forward new instructions to the users, such as physician- prescribed exercises and medication.

The patient's physician can access the data from his/her office via the internet and examine it to ensure that the patient has his/her health metrics (for e.g. heart rate, body temperature) within the normal range. A server agent may inspect the uploaded data and create an alert in the case of a potential medical condition. Based on the database of the collected data, the analysis of conditions and patterns would help researchers to link symptoms and diagnosis with changes in health status and other parameters such as gender, age and weight.

The second tier or middle stage composes of the Personal Data Processing Unit (PDPU) acting as the link between the BAN at the patient end and the central server at the hospital. The PDPU processes data from different sensors, frames it into a packet and sends it to a medical server to which the patient is registered.

The third and the last tier is composed of the sensor unit which forms the BAN. The sensors are small size, low weight devices available at the patient end. There are several such sensors which touch the patient body & gather all the relevant health related parameters. Any kind of portable biomedical sensors can be used.

Each user wears a number of sensor units whose primary functions is to unobtrusively sample vital signs and transfer the relevant data to a personal server through wireless BAN implemented using Zigbee protocol which is IEEE802.15.4 standard. Different types of topologies can be formed in a Zigbee based network. Here we are using a tree network where all data from small sensor nodes are collected by a central node PDPU or SR which has a better range to transmit data to medical server over through different available channels.

- RECONFIGURABLITY

Re-configurability was the main challenge of our implementation. The communication protocol that we have used is the Zigbee communication protocol in the IEEE 802.15.4 Standard, which has features which include support for different network topologies such as mesh, tree etc.

For our implementation, we consider a well-equipped facility such as a hospital or a high risk working environment such as underground mine. The patient/mine worker will have the sensor units placed over their body which would send data to the medical server located at a secure location via the PDPU. The central server keeps a log of data of different patients/mine workers based on the unique ID given to each sensor node.

Now a problem can arise, if for some reason, the PDPU of one patient fails to operate, the data generated by the bio-sensors will fail to reach the server, and hence there will loss of data and monitoring of critical data of that patient will be disabled. This is a hazardous situation as the monitoring system for that particular patient gets paralyzed.

Here, the re-configurability of the firmware prevents loss of data and enables continuous monitoring of patient even in the event of failure of PDPU of a particular patient. In this case the sensor node will automatically switch the data routing through a standby router ensuring no data loss.

In the event of failure of PDPU, the standby router will be

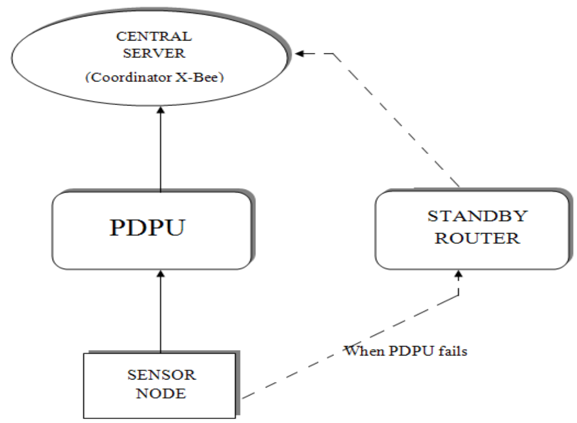

Fig 2 End-Device re-configurability

powered on. It will send the data of the sensor nodes to the central server. Based on the address in the data packets, the operator at the server side in the hospital/mine field would recognize that the PDPU has failed and would undertake steps to ensure that PDPU is repaired. On the PDPU is repaired, the PDPU will send data of sensor nodes to the server and the standby router will go in sleep mode.

3. IMPLEMENTATION DETAILS

The front end has been implemented using Visual Basic 6.0., Visual Basic (VB) and Microsoft access have been used together to create a Graphical User Interface (GUI) which will help patients and doctors to get a live update of the data in the form of chart.

- GUI consists of a login page, and there are separate options for patient and doctors like patients are allowed to see only their data while doctors have access to the data belonging to his patients only.
- Each patient has his own database table along with unique ID to avoid any loss of data.
- Patient by default is shown his latest data records but an option has been provided where-in he can view data belonging to any time span hence, giving full access to patients.
- VB is used to display the data whereas Access is used to log the data obtained from the sensors.
- The data sent by the sensor also consists of the time stamp which helps in deciding the exact time at which a data was logged and so helps in effective monitoring of a patient's vital parameters.

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The backend involves Arduino platform (Atmega-328P based Arduino UNO) for processing of sensor data and Zigbee protocol for communication purpose. The Arduino IDE (Integrated Development Environment) is used for programming the ATMEGA microcontroller and XCTU is used to configure the X-Bee.

A tree network topology is implemented using the X-Bee, with the Central server being at the top of the hierarchy, the PDPU comes in the middle stage and the end-devices or sensor nodes form the end-user stage, completing the hierarchy. The X-Bee is used in API mode to implement software re-configurability.

The implementation involves the sensor node, comprising of temperature sensor and accelerometer, linked to the PDPU which in turn is linked to the central server, here the coordinator X-Bee. There is a standby router that will route data to server in the event of failure of the PDPU.

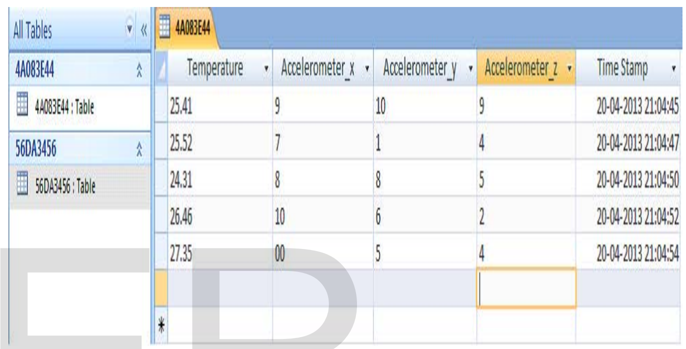
Under normal operation, the sensor node sends data to the server through the PDPU. Now, the PDPU is switched off to represent failure of the same. This will be sensed by the respective sensor node of the patient, since no acknowledgment for sent data is received. It will start scanning for nearby devices or PDPUs that are connected to the server. On finding the standby router, the end device or sensor node reconfigures itself to send data to the new device. Thus, end device re-configurability has been achieved as shown in Fig.2.

- POWER OPTIMIZATION METHODS:

Algorithm implemented for reduction in power consumption by using sleep mode of the Standby Router (SR):
Step 1: PDPU and SR both are Powered On manually.
Step 2: SR checks its USART port for any data.
Step 3: If the data is available (which implies that the PDPU has failed) then it sends the data to the central server.
Step 4: If the data is not available then the counter starts in the SR. If the data is available on the USART port of SR before counter reaches the predefined maximum count value then the counter is reset and the data is sent to the central server.
Step 5: If data is not present before the maximum count value is reached then SR goes into sleep mode in order to save power. Even in the sleep mode the SR checks its USART port for any data. If data is available then the SR wakes up and Step 3 is followed else it would continue in the sleep mode.

Power optimization is achieved without compromising the reliability of the network by end device re-configurability through standby router as shown in Fig. 3.

Proposed method for reduction of power consumption through sampling frequency variation:
1) A significant amount of power is consumed in maintaining the sample rate at high frequency.
2) If the samples represent values that are almost identical and within the tolerance range of the critical values, then high sampling frequency would be unnecessary wastage of power.
3) Hence, the sampling frequency should vary based on the interpretation from the group of the samples.
4) It can be achieved by creation of an array that stores a specific number of samples. If all the samples are similar with some variation which are within acceptable limits, reducing current sampling frequency by some factor would save power. The reduction of sampling frequency is recursive until the frequency reaches its threshold.
5) For instance, if an array is created to hold 200 samples and current sampling frequency is 50 samples per second, then the frequency could be reduced to 25, 12, 6, and 3 and so on till it reaches the threshold rate and if the samples are well within the tolerance band. On the other hand, if any of the samples is found to be below critical value then the sampling frequency is increased exponentially to get as many real time samples as possible.



Temperature	Accelerometer_x	Accelerometer_y	Accelerometer_z	Time Stamp
25.41	9	10	9	20-04-2013 21:04:45
25.52	7	1	4	20-04-2013 21:04:47
24.31	8	8	5	20-04-2013 21:04:50
26.46	10	6	2	20-04-2013 21:04:52
27.35	00	5	4	20-04-2013 21:04:54

Fig. 3 Server side GUI using VB.

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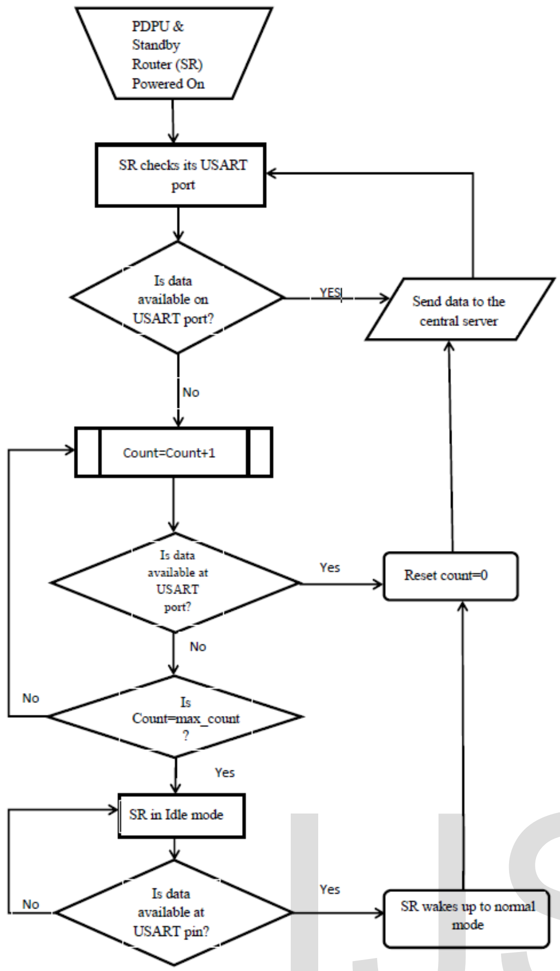

Fig.4 Flowchart for the algorithm using sleep mode of the SR to reduce power consumption

4. CONCLUSION

To conclude, we have implemented a three tier Reconfigurable Wireless Health Monitoring Network consisting of body area sensor network and mobile PDPU (Personal Data Processing Unit) communicating with the Server. In order to ensure the reliability of the network, the end device has been programmed to reconfigure its destination from PDPU to Standby Router so as not to lose any data in case of the PDPU malfunction. Power optimization has been achieved by putting the Standby Router in sleep mode when not in use. We have proposed a method to further reduce the power utilization of the network by variation of sampling frequency of end device.

The sensor network includes accelerometer and temperature sensor interfaced to Arduino microcontroller. The communication protocol we have used is Zigbee protocol and the Zigbee has been programmed to communicate in API mode. The entire data is seen on a GUI which has various login fields for doctor, engineer and patient. The data is processed and stored in a database which can be used for monitoring.

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