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Power Efficient and Reliable Routing Protocol for Wireless Body Area Networks

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Abstract*: Our aim is witnessing an increasing pressure on quality and quantity of healthcare due to the increase of aging population, chronic diseases, and health consciousness of people. People put more attention in prevention and early risk detection. A system that can continuously monitor the health condition of elderly people and share information with remote care providers or hospitals will be in great demand. As Wireless body area network, WBAN, is a network designed by low-power devices that are located on, in or around the human body and are used to monitor physiological signals and motion for medical, personal entertainment and other applications and purposes. IEEE has launched the IEEE 802.15 BAN to develop a communication standard optimized for low power devices, and operating on, in or around the human body to serve a variety of applications including medical and consumer electronics. In more common terms, a Body Area Network will be a network containing sensor nodes in close proximity to a person's body monitoring vital signals of the human body and a more intelligent node capable of handle more advanced signal processing. We propose a reliable, power efficient and high throughput routing protocol for wireless body area networks (WBANs). We use hierarchical routing to minimize energy consumption and maximizing network lifetime. Selection of cluster head is based on distance and residual energy to maximize network lifetime. Simulation results shows that proposed protocol named Power Efficient and Reliable Routing (PERR) to enhance the network stability period and nodes stay alive for longer period. Longer stability period contributes high packet delivery to sink which is major interest for continuous patient monitoring. Simulation has been done in MATLAB and results are compared with existing hierarchical protocol such as M-ATTEMPT.*

Keywords*: WBAN, Hierarchical routing in WBAN, wireless body area network, reliable routing, energy efficient routing.*

1. INTRODUCTION

Improvement in wireless technology born a new generation of WSN which is suitable for networking on the human body or in the human body. For data transfer among sensor nodes a point to point topology or multi-hop topology is used in these networks. In wireless body area network, only few sensors are used which are implanted in body or positioned on the body. These tiny sensors placed on patient's body measure vital signs like blood pressure, Glucose level, and pulse rate etc. These measured values are then forwarded to the medical server or doctor to further analyze the patient's condition. Wireless sensors provide continuous monitoring of patient at remote place. Use of topology depends on the application, for example to measure the postures of an athlete require a multi-hop topology. The sensed data is exchange among sensor nodes and then it reaches to base station or sink. Sensors can be implanted or placed on the athlete's body. One of the major applications of WSN technology is monitoring of human health [3]. Wireless body area network, WBAN, is a network formed by low-power devices that are located on, in or around the human body and are used to monitor physiological signals and motion for medical, personal entertainment and other applications and purposes [2], Fig.1. Healthcare applications have attracted researcher's attention because of the increasingly aging population prone to age-related diseases and could often benefit from continuous monitoring of physiological signals [3]. The use of WBANs may enable ubiquitous healthcare and could lead to proactive, and even remote, diagnostic of diseases in a nearly stage. Moreover, a WBAN may contain an actuator, which based on measurements and settings, can automatically release medicine or other agents. An example being an actuator to supply insulin to a patient with diabetes under the appropriate conditions. Additionally, WBANs provide health monitoring without interfering the patient's everyday activities. For real-time applications where the caregiver needs to receive information about the patient's health on a continuous basis, the WBANs should provide, among other characteristics, reliable communications that are relatively insensitive to link or node failures [4]. However, patient mobility increases the probability of packet loss, and it is preferred that the packet error rate should be kept less than1% [5]. Moreover, the WBANs must transmit at low power to protect the patients against harmful health effects associated with the radiofrequency (RF) emissions. Thus, the specific absorption rate (SAR) should be low [6]. SAR is the rate at which the RF energy is absorbed by a body volume or mass. Due to this limitation on the specific absorption rate, it is not possible to increase the transmission power beyond a certain level to overcome the transmission loss of the packets. To increase the network's throughput and reliability in the presence of packet losses and avoid single points of node or link failures, the author extend Cooperative Network Coding (CNC)as proposed in [7] to networks where there are many sources, many relay nodes and many sinks/destinations. The relays and sinks act as multiple-input-multiple-output (MIMO) nodes [8].

2. RELATED WORK

In [1], the author presents a new energy efficient MAC Protocol targeted at wireless body area sensor networks focused on pervasive healthcare applications. The protocol exploits the attributes of this type network to implement a very low power architecture which is still capable of fast reaction to sporadic Alarm events. The novel concept of 'wakeup

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fallback' time is also presented as a means of reducing the complexity of time-slot management in the presence of link failures resulting from Alarm events or other interference. The MAC has been implemented as part of a larger SoC (Sensium™), and measured results have validated the effective operation of the new MAC protocol.

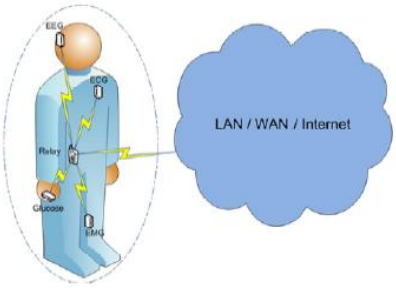

Figure 1: Wireless Body Area Network

In [2], the author implant devices are used to measure biological parameters and transmit their results to remote off-body devices. As implants are characterized by strict requirements on size, reliability and power consumption, applying the concept of cooperative communications to wireless body area networks (WBANs) offers several benefits.
In [3], Author describes Wireless body area networks (WBANs) offer many promising new applications in the area of remote health monitoring. An important element in the development of a WBAN is the characterization of the physical layer of the network, including an estimation of the delay spread and the path loss between two nodes on the body. This paper discusses the propagation channel between two half-wavelength dipoles at 2.45 GHz, placed near a human body and presents an application for cross-layer design in order to optimize the energy consumption of different topologies.
In [4], the emerging of wireless body area network has profound impacts on our daily life, such as pervasive medical supervision and outdoor exercises, and the large scale application of wireless body area network can effectively reduce higher cost burden owing to the aging society and long term healthcare for the chronic illness.
This paper presents [5] the WBAN transceiver that satisfies all of the requirements for IEEE 802.15.6 applications. The transceiver is optimized to the WBAN sensor nodes by removing the XO and any off-chip external components for reducing the cost, size, and power consumption by efficient duty cycling.
In paper [6] The author's addressed the topology design problem for Wireless Body Area Networks, proposing a novel and effective model based on mathematical programming that determines (1) the optimal number and placement of relay nodes, (2) the optimal assignment of sensors to relays, as well as (3) the optimal traffic routing, taking accurate account of both the total network cost and energy consumption. The model can be used to minimize both the total energy consumption and the network installation cost, while ensuring full coverage of all sensors.
In this paper [7], author addressed the reliable topology design problem for WBANs, taking into account the movement and different body postures. To this end, they proposed a reliable and dynamic topology design and energy-efficient resource provisioning approach (RTDP-WBAN), focusing on three specific scenarios (Stand, Sit and Walk). The RTDP-WBAN approach is based on a 3D coordinate system (3D-IBPS), which is able to calculate the (x; y; z) coordinates of sensors and relays in different body postures and movements. They evaluated the performance of the RTDP-WBAN approach, comparing it to two other relaying approaches, in the Stand, Sit and Walk scenarios. The performance metrics adopted in this work were the total energy per bit consumed by the WBAN and by each sensor, and the number of relays deployed on the body. Numerical results of this paper showed that approach is reliable and energy-efficient, and it offers an interesting and flexible trade-off between the number of relays deployed in the WBAN and the total energy consumption.
In this paper [8] presents a novel low power reliable MAC protocol. Energy model which was proposed and validated through measurements. Here WBAN with MAC protocol can be used in the EEG monitoring scenario. Reducing the power requirements for the communication part of the system allows allocation of more energy to more accurate DSP for seizure detection. In this paper this proposed scheme also results in very reliable data transfer, which is crucial in medical applications.
MAC Protocol was also compared with two other recently reported protocols, and results showed improvements in communication power consumption and duty cycle. If the need for the more flexible network should arise, various solutions for network forming and management will be investigated like CSMA solutions for network forming and TDMA protocol proposed in this paper for data transfers.
This [9] paper demonstrates the use of Wearable and implantable Wireless Body Area Networks as a key infrastructure enabling unobtrusive, constant, and ambulatory health monitoring. This new technology has potential to tender a wide range of assistance to patients, medical personnel, and society through continuous monitoring in the ambulatory environment, early detection of abnormal conditions, supervised restoration, and potential knowledge discovery through data mining of all gathered information. We have described a general system model for the biosensor network implanted inside the human body and some important issues and challenges that a WBAN can face. This paper proves that wireless sensor networks can be widely used in healthcare applications. We believe that the role of wireless sensor networks / Body sensor networks in medicine can be further enlarged and we are expecting to have a feasible and proactive prototype for wearable / implantable WBAN system, which could improve the quality of life.
In this work [10], authors designed and an implement a three-tier sensor network solution with energy efficiency for home application. The network is considered to be constituted of communicating heterogeneous sensors: medical, environmental, and video/audio sensors. To save nodes

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energy, the solution was based on organizing them into groups according to their role and functionalities and also on affecting them intelligent behaviour. Communication at the same time and activity duration were reduced to allow better use of nodes component resources. The solution was based on even-driven behaviour which gives good results than single tier architectures. It was shown that intelligent behavior guarantee several months for the sensors autonomy than single tier architectures.

3. METHODOLOGY

1. Initially, we have set base station a fixed position at human body and nodes are setup in a particular region on different parts of body like on legs, hands, heart etc. and each have equal energy i.e. 0.5 J. We propose here a Hierarchical Routing Protocol to reduce packet loss and we also use one-hop routing to improve quality of service. One hop routing is used for nodes that will transfer important data for the human body like heart rate and ECG. Initially, all nodes have equal energy. So, there is no cluster head.
2. In round 1, Cluster Head will be created according to probability condition i.e. according to minimum distance from base station and residual energy. The residual energy is the energy that a nodes must have to send the aggregated data to the Base Station which can be calculated as,

Residual Energy: (1.5*((ETX+EDA)*(b) + Eamp*b*(distance * distance)))

(1)

where,
ETX: Energy consumed by Transmitter to send data.
EDA: Data Aggregation Energy
Eamp: energy consumed by transmit amplifier.
b= Data Bits need to transfer
Distance: Distance from a particular cluster head or base station

3. After election of cluster heads, remaining Nodes will find out their respective cluster head according to the minimum distance. Nodes will elect a node as their cluster head if it is nearest as compare to other cluster heads.
4. Then, Nodes sends the data to their respective cluster heads and energy consumption will be calculated according to equation.

ETX*(b) + Eamp*b*(min_dis * min_dis);

(2)

where,
ETX: Energy consumed by Transmitter to send data.
Eamp: energy consumed by transmit amplifier.
b= Data Bits need to transfer
min_dis: Distance from a particular node to cluster head.

5. Cluster Head will aggregate the data and send it to the base station and energy consumption will be calculated for each node and cluster heads according to following equation:

1.5*((ETX+EDA)*(b) + Eamp*b*(distance * distance))

(3)

Where, ETX: Energy consumed by Transmitter to send data.
EDA: Data Aggregation Energy
Eamp: energy consumed by transmit amplifier.
b= Data Bits need to transfer
Distance: Distance from a particular cluster head or base station

6. In round 2, the nodes will become cluster heads according to cost function i.e. according to minimum distance from base station and threshold energy.

Cost Function (i) = distance (i) /Residual Energy (i)

(4)

Cost function value ensures new forwarder in each round

7. After selection of cluster heads, Nodes sends the data to their respective cluster heads, that will be selected according to the minimum distance of a particular node from cluster heads and energy consumption will be calculated according to above equations.
8. Cluster Head will aggregate the data and send it to the base station and energy consumption will be calculated according to above equations.
9. This process will be repeated until the whole network gets down or number of rounds finished.
10. Performance will be evaluated according to parameters like network lifetime, energy dissipation, no. of data packets sent etc.

4. IMPLEMENTATION AND RESULTS

Due to the fact that clustering protocols consume less energy, these protocols for WSNs have gained extensive acceptance in many applications. Many on hand WSN protocols use cluster based scheme at manifold levels to minimize energy expenditures. CH in most cluster based protocol is selected based on a probability. In this report, our goal is to design a routing protocol named PERR (Power Efficient and Reliable Routing) that will reduce packet loss as well as energy consumption. Figure 2(a) and (b) have showed the plotting of nodes.

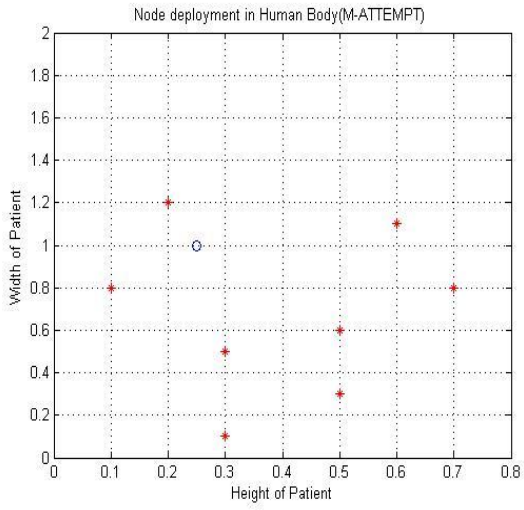

Figure 2 (a) Node deployment in Body during M-ATTEMPT protocol

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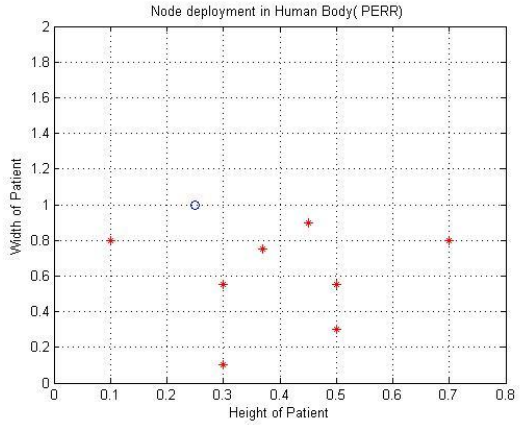

Figure 2 (b) Node deployment in Body during PERR protocol

The energy required to transmit a data packet of k bits to a distance d and to receive a data packet of d bits the radio consume, respectively, the following energies:

$ETx(b; d) = Eelec \times b + Eamp \times b \times d^2$ (5)

$ERx(b) = Eelec \times b$ (6)

b is the data-bits and d is the distance between nodes and cluster head or cluster head or base station. Network parameters values for calculating energy consumption are given in table 1.

Table 1: Network Parameter Value

Initial Energy,Eo	1 J
Amplifier energy,Eamp	2.71e-7 J/b
Transmitting Energy,Etx(elec)	96.9 nJ/bit
Receiving Energy, Erx(elec)	172.8 nJ/bit
Data Aggregation Energy, Eda	5nJ/ bit
Packet size(b)	4000 bits
No. of Nodes	8
Implementation tool	MATLAB 2008a

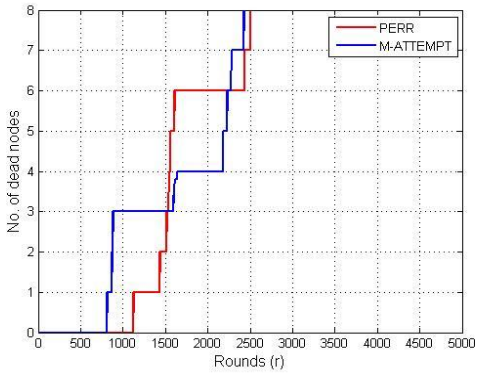

Figure 3: No. of Rounds vs No. of nodes dead

Figure 3 shows comparison of M-ATTEMPT and proposed routing technique in terms of number of nodes dead. From figure 3 it is observed that, initially M-ATTEMPT protocol loses its nodes quickly as compared to proposed protocol. The proposed protocol PERR will utilize energy much better as compared to M-ATTEMPT. The first node in M-ATTEMPT protocol is died in 812 rounds, but the first node in PERR is died at 1125 rounds. All nodes in M-ATTEMPT protocol are dead in 2428 rounds, but in PERR all nodes are dead in 2503 rounds. So, PERR will survive more numbers of rounds and hence enhances network lifetime as well as packet sending.

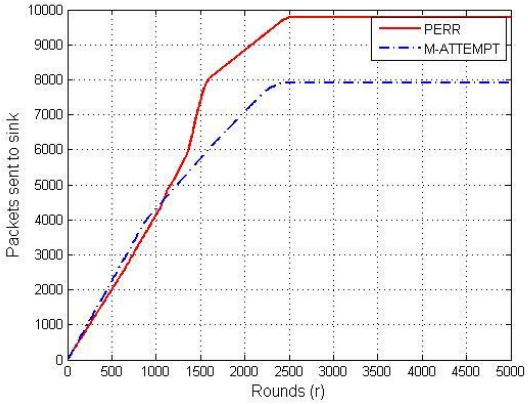

Figure 4: No. of Rounds vs Data sent to Base Station (SINK)

Figure 4 shows how much data will be sent from nodes to base station. As the network lifetime is increased with in PERR protocol so it will send more data to base station (sink) as compared to M-ATTEMPT protocol. From figure 4 it is observed that, in M-ATTEMPT protocol data sent to base station is relatively less as compared to PERR. PERR survives more numbers of rounds so it will send more data as compared to M-ATTEMPT.

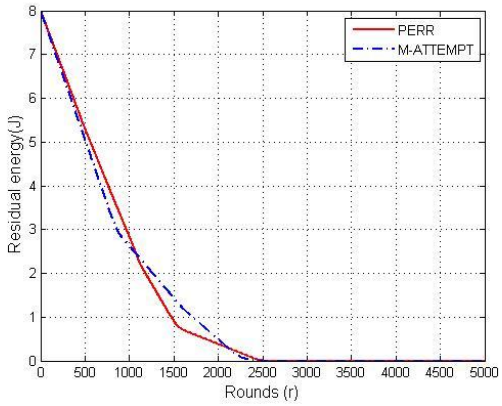

Figure 5: No. of Rounds vs Residual Energy

Figure 5 shows the comparison between M-ATTEMPT and proposed routing technique in terms of residual energy of the network. Initially, the proposed routing technique shows better stability in terms of energy consumption. M-ATTEMPT loses its energy quickly in initial rounds as compared to PERR. Around 1100 rounds, both techniques are relatively equal in amount of energy consumption or residual energy, but after

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that PERR loses its energy quickly till 1500 rounds. Finally, PERR shows more stability after 1500 rounds and total energy is consumed in 2503 rounds and M-ATTEMPT total energy is consumed in 2428 rounds.

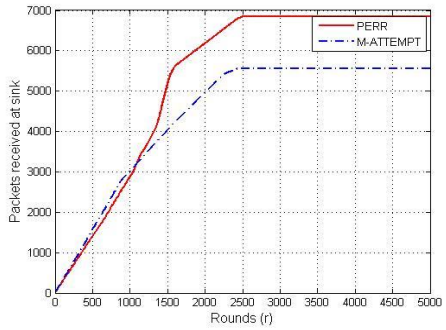

Figure 6: No. of Rounds vs Data received at Base Station (SINK)

Figure 6 shows how much data is received by base station. From figure 6 it is observed that, in M-ATTEMPT protocol data received at base station is relatively less as compared to proposed protocol. If the link is good, data will transfer to base station. The link is selected based on a random number ranges from 0 to 1. If value is less than 0.3, then link is bad otherwise it is good. PERR sends more data to base station as compared to M-ATTEMPT.

5. CONCLUSION AND FUTURE WORK

In this work, the Power Efficient and Reliable Routing (PERR) which is hierarchical routing as well as single-hop routing with the whole control to the base station. In PERR routing technique, the base station first collects information about the logical structure of the network and residual energy of each node. So, with the global information about the network base station does cluster formation better in the sense that it has information about the residual energy of each node. Finally, the PERR protocol is compared with already developed routing protocol M-ATTEMPT by the help of MATLAB. A comparison between two is done on the basis of energy dissipation with time, data packet sent and the system lifetime of network. System lifetime is basically for how long the system works. There are still some challenging issues we have to investigate for our prototype system to form a real medical supervision system. One important issue is to make the system more comfortable and easily portable, and the Android application must be implanted into the smart phone to carry out the actually test. Another important issue is optimization of network schedule mechanism for compounding medical data transmission.

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