Modified SIMPLE Protocol for Wireless Body Area Networks

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Abstract – *Wireless body area network is a hot upcoming field in automatic patient monitoring. In WBAN sensors are placed on patient body, and these sensors collect patient's data and after aggregation data is send to base station, and finally to doctor sitting at distant place from patient. As sensor nodes sense data therefore their battery drains, and to save battery power various routing protocols are proposed. In the similar context recently SIMPLE protocol was proposed. In this paper further modification is suggested to improve its performance.*

Key Words: WBAN, SIMPLE, Throughput

1. INTRODUCTION

With the fast growth in the population of developed countries, the health-care is now one of the major issues for health-care authorities and government. In order to overcome this problem and to provide patient monitoring even from remote location, wireless technology is used which also provides reliable, cost effective, and fast services to patient. WBAN is the latest evolved technology which provides very effective health care services. It gives simple diagnostic monitoring [1]. In the WBAN technology, sensor nodes work on energy source constraints. The sensors must use power as low as could be for the transmission of data to sink. With the minimum use of energy source can extend the life of the battery over a long period due to the fact that recharging batteries in WBAN is not frequent. In WBAN, one of the prime issues is of recharging the batteries. To overcome this problem, an effective routing protocol is needed. WSNs have a number of routing protocols [2], [3], [4], [5] which makes use of energy efficiently. But WBANs and WSNs are of different architectures, applications and work in different situation. It is not possible to port WSN routing protocol to WBAN. Therefore, for WBAN we require an energy efficient routing protocol in order to monitor a patient for long time.

In this paper, we propose a reliable, high throughput and stable routing protocol for the purpose of patient monitoring. We place sensor nodes at their pre-decided place on the patient's body. Sensors for glucose level and ECG are put close to the sink. Sink is paced at waist. Both of these sensors contain important patient's data and need high reliability, less attenuation and long life as they have to transfer their data to sink continuously. The parent node is followed by other sensors and sends data to sink by means of multi hop. It conserves nodes' energy and network work for a long time.

In this paper a wireless body area network protocol will be designed. In this work, all the sensors located on body will transfer data to sink node (generally on wrist or waist) and sink node will transmit data to base station or to the server. The simulation results will be evaluated in terms of

1. No. of dropped packets
2. Remaining Energy
3. Throughput
4. Number of dead node

These results will be plotted with number of rounds.

2. RADIO MODEL

In past various radio model is proposed for WSN. In general first order radio is found suitable for WBAN as detailed in [6].

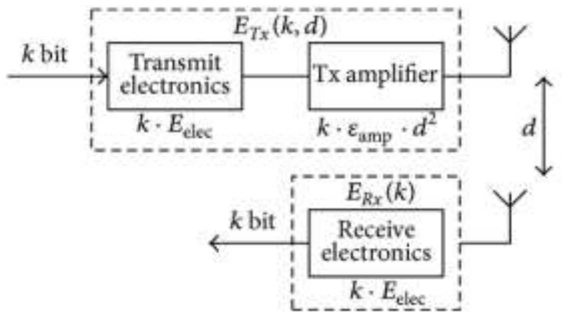

Figure 1: First order radio model

This radio model assume that d , is the separation between transmitter and receiver and d^2 , the loss of energy due to transmission channel. First order radio model equations can be summarized as

$$E_{TX}(k,d)=E_{TX-elec}(k)+E_{TX-amp}(k,d) \quad (1)$$

$$E_{TX}(k,d)=E_{TX-elec}\times k+E_{TX-amp}\times k\times d^2 \quad (2)$$

$$E_{RX}(k,d)=E_{RX-elec}(k)E_{RX}(k)=E_{RX-elec}(k)\times k \quad (3)$$

where E_{TX} is the energy consumed at the time of transmission, E_{RX} is the energy consumed during reception, $E_{TX-elec}$ and $E_{RX-elec}$ are the energies needed for the operation of the electronic circuit of transmitter and receiver, respectively. E_{amp} is termed as the measure of energy needed for the amplifier circuit, while k denotes the size of the packet.

The medium that is used for the communication in WBAN is human body which provides its contribution of attenuation to radio signal. Hence, path loss coefficient parameter is added by us in radio model. Equation 27 of transmitter can be rewritten as

$$E_{TX}(k,d) = E_{elec} \times k + E_{amp} \times n \times k \times d^{n} \qquad (4)$$

The parameters of energy provided in equation 6 rely on the hardware. In WBAN technology, two transceivers that are generally used for the analysis are Nordic nRF 2401A is a single chip, low power and Chipcon CC2420 transceivers. Both have the same bandwidth i.e. 2.4GHz.

The reason behind the use of the energy parameter of The Nordic nRF 2401A transceiver is its less consumption of power as compared to Chipcon CC2420. The energy parameters for this transceiver are given in Table 1.

Table 1: Network Parameters

Parameter	Value
E_0	0.5 Joule
E_{elec}	5 nJ/bit
E_{fs}	10pJ/bit/m^2
E_{amp} E_{da} Packet Size	0.0013 pJ/bit/m^4 5 pJ/bit 4000 bits

3. SIMPLE PROTOCOL

The constant quantities of nodes in WBANs offer chance to relax limitations in routing protocols. With the inspiration of routing constrains, we enhance the period of stability and throughput of the network [41]. Following subsections throws a light on the features of the system model along with the detail of SIMPLE protocol.

A. System Model

Eight sensor nodes are placed on the body of the person in this scheme. Each sensor node consists of same power and computation capabilities. Sink node is deployed at waist. Node 1 which is around heart area is ECG sensor while node 2 in waist is Glucose sensor node. Data is transmitted directly to sink by these two nodes. The deployment of nodes and sink on the human body is shown by the fig. 3.2.

The typical sensor node parameters are detailed in Table 3.1.

Table 2: Radio Parameters

Parameters	nRF 2401A	CC2420	Units
DC Current (Tx)	10.5	17.4	mA
DC Current (Rx)	18	19.7	mA
Supply Voltage (min)	1.9	2.1	V
$E_{TX-elec}$	16.7	96.9	nJ/bit
$E_{RX-elec}$	36.1	172.8	nJ/bit
E_{amp}	1.97×10^{-9}	2.71×10^{-7}	J/bit

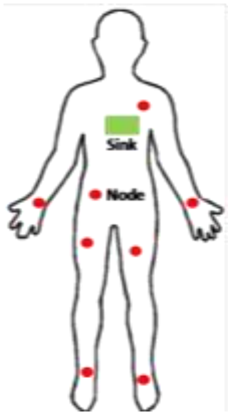

Figure 2: WBAN Body Area Network with Eight Nodes

B. Initial Phase

In this phase, Sink broadcast a small information packet in this phase which comprises the position of the sink on the person's body. Each sensor node, after getting this control packet, stores the position of sink. An information packet is broadcasted by each sensor node which has the following information: position of node on body, node ID and its energy status. Thus, each sensor node is updated with the information about the location of neighbours and sink.

C. Selection of next hop

In order to save energy and to enhance network throughput, a multi hop scheme is proposed for WBAN. In this part, we explain the criteria of selection for a node to turn out parent node or forwarder. With the end goal of balancing consumption of energy among sensor nodes and trimming down energy consumption of network, new forwarder is being selected by SIMPLE protocol in each round. Sink node is aware of the information of the nodes such as distance, ID and residual energy status. Sink processes the cost function of each node and this cost function is transmitted to all nodes by sink.

Each node makes the decision on the basis of this cost function whether to be a forwarder node or not. If i is number of nodes than cost function of i nodes is evaluated as:

$$C.F(i) = \frac{d(i)}{R.E(i)} \qquad (5)$$

Where the distance between the node i and sink is represented by $d(i)$, $R.E(i)$ is the residual energy of node i and is estimated by extracting out the present energy of node from initial total energy in the initial. We prefer a node with least cost function as a forwarder. Each one of the neighbour node get affixed together with forwarder node and transfer their data to forwarder. This data is collected and forwarded to sink by the forwarder. This (forwarder) node has highest residual energy and least distance to sink; hence, minimum energy is consumed by it in the process of forwarding data to sink. Nodes for Glucose and ECG monitoring establish direct communication with sink and do not get indulge in forwarding data.

D. Scheduling

As far as this phase is concerned, a Time Division Multiple Access (TDMA) is assigned by forwarder node to its children nodes on the basis of the time slots. Each one of these children nodes transmit the data which is sensed by them to forwarder node in its particular predefined time slot. In the case when a node does not contain any data to be sent, it switches to idle mode. Nodes wake up just at the time of its transmission. The dissipation of energy of particular sensor node could be minimized by scheduling of sensor nodes.

4. PROPOSED MODEL

In order to achieve the target of enhancing the throughput and reliable communication between sensors and sink, we propose a new scheme. Principle benefits of our proposed protocol are as follows:

The less energy consumption of nodes, contribute to a high throughput. The proposed model is very much similar to the simple protocol with following forwarding function:

$$FF(i) = \min\left[\frac{\sqrt{d(i)}}{\left[E_0 - E(i)\right]}\right] \qquad (6)$$

In this function we consider that the energy lost which is defined as difference in the energy of initial energy and left over energy after each round. Also the nodes with lesser energy should not be considered as forwarding node.

5. PERFORMANCE METRICS

The protocol is discussed in terms of the following parameters.

1) *Throughput:* Throughput is a fractional value and it is the total number of generated packets that are correctly received at sink. This is also equal to the difference of total generated packets and loss packets.

2) *Residual Energy:* Residual energy represents the energy left with the nodes with each subsequent round. This is helpful in evaluating the energy consumption in the network.

6. SIMULATION RESULTS AND ANALYSIS

With keeping in mind the end goal of evaluation of the proposed protocol, we have carried out an extensive set of experiments using MATLAB R2010a. In this section, results of proposed model are compared with SIMPLE protocol. In figure 3, number of dead nodes vs. Number of rounds is plotted. In ATTEMPT protocol at the round 2161, all of sudden 3 nodes become dead. However in case of SIMPLE protocol till round 4436 number of dead node remains as zero. With SIMPLE protocol, the numbers of dead nodes become 6, around the round 5945. In proposed protocol till round 2775 number of dead nodes remain zero, and from 2275 to 7200 rounds the number of dead node is one only. From round 7200 to 7215 numbers of dead nodes are two. There after it catches other protocols.

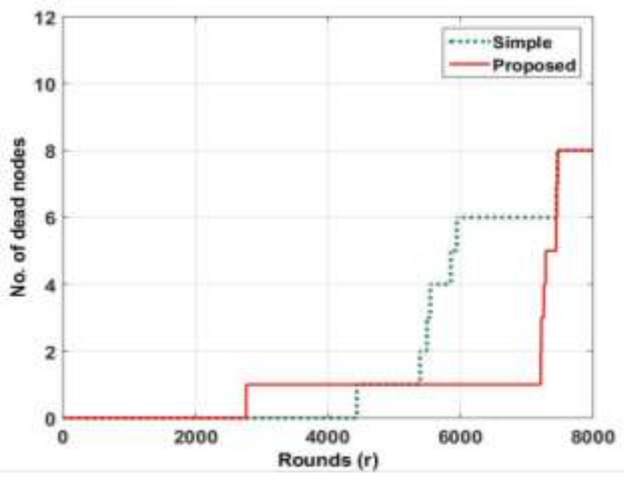

Figure 3: No. of dead nodes vs. rounds

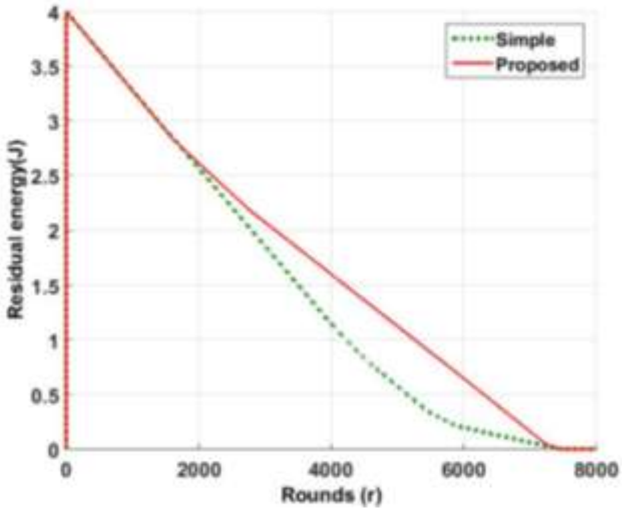

Figure 4: Residual Energy vs. Rounds

In figure 4, residual energy vs. Round is plotted. Here the residual energy curve for SIMPLE and proposed protocol is shown. However, the proposed protocol has better saving of energy due to lesser number of dead nodes.

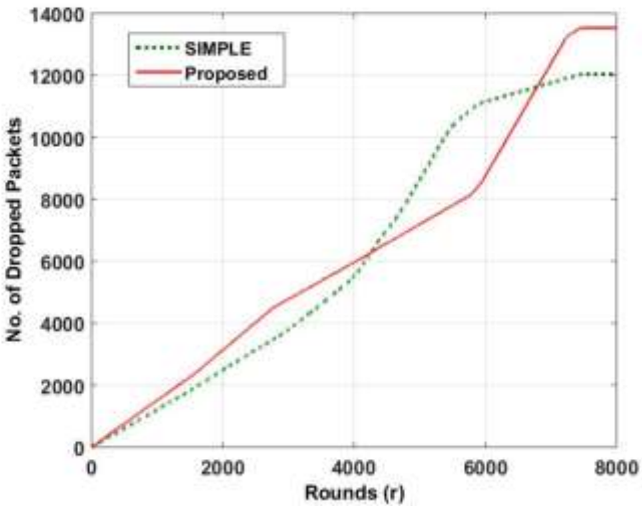

Figure 5: No. of dropped packets vs. Rounds

In figure 5, number of dropped packets vs. Round is plotted. Here the curves for simple and proposed protocols are shown. In case of simple protocol the numbers of dropped packets are 1.203×10^4, while in case of proposed protocol the numbers of dropped packets are 1.353×10^4.

In figure 6 packet received at the sink vs. Round is plotted, it is clear from the figure that the performance of the proposed protocols are better in comparison to the SIMPLE protocol. After 6000 rounds a significant difference in the packet received at the sink can be observed. In case of proposed protocol the total packets received are 3.134×10^4, while for SIMPLE protocol; the numbers of received packets are 2.807×10^4. Therefore, a rise in the packets received and in terms of percentage it is 11.64%.

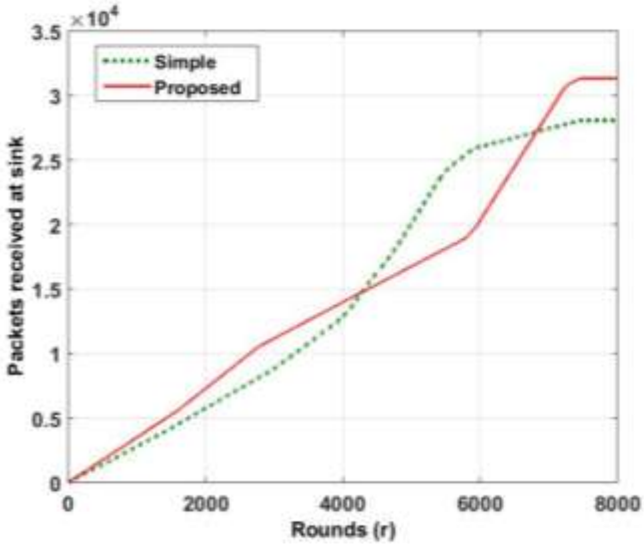

Figure 6: Packet Received at the Sink vs. Rounds

5 LINK FAILURE PERFORMANCE

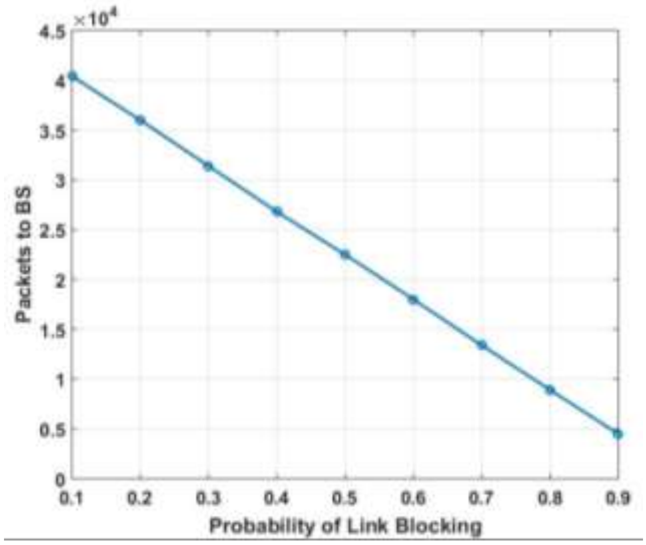

Figure 7: Packets to BS vs. probability of link failure

The packets transferred to BS, drops due to the link failure. In the above results the probability of link failure is considered to be 0.3. Next in figure 7, probability of link failure vs. packets to BS is plotted. For link failure probability of 0.1, the packets transmitted to BS is 4.04×10^4, while for link failure probability of 0.5, the packets transmitted to BS is 2.25×10^4.

7. CONCLUSION

In this work an energy efficient wireless body area network protocol is presented. The selection of forwarding nodes is based on the cost function which is dependent on the distance and energy. It is found that the proposed protocol works well in comparison to earlier proposed protocol

SIMPLE. The throughput of the proposed protocol is nearly 11.64% more than the SIMPLE protocol.

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