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An Enhanced SIMPLE Protocol for Wireless Body Area Networks

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ABSTRACT

Wireless Body Area is hot area of research, as it can be used in healthcare application in chronic diseases. WBAN, technology is based on tiny sensors which consume less power and highly reliable. In this paper, an enhancement in SIMPLE protocol is proposed, while considering both distance and residual energy. A set of forwarding functions are proposed and optimal forwarding function is searched using the simulation results. The obtained results are compared with recent proposed protocols, and it has been found that the proposed forwarding function provide better results.

Keywords: *AWG, TWC, re-circulating buffer*

1. INTRODUCTION

The applications of wireless sensor/body area networks comprise a wide variety of scenarios. In most of them, the network is composed of large number of nodes deployed in an extensive area in WSN or in body in case of WBAN in which not all nodes are directly connected. Then, the data exchange is supported by multi-hop communications. Routing protocols are in charge of discovering and maintaining the routes in the network. However, the appropriateness of a particular routing protocol mainly depends on the capabilities of the nodes and on the application requirements.

In WBAN, the single hop communication is presented in [2], to deal with the issue of the single hop communication. As far as multi-hop communication is concerned, it is proposed by Sue et.al. in [3]. A Secure Low-Delay Protocol is proposed by Latre *et al*. for Multi-hop Wireless Body Area Networks. The structure of this routing protocol is like a spanning tree [4]. Parent nodes drain out their energy at a much rapid pace because of the additional traffic load of children nodes.

Quwaider *et al*. in [5] suggested a routing protocol which endures to variations in network. Store and forward mechanism is used by them to improve the probability of a data packet to achieve effectively to sink node. All sensor nodes are capable to make storage of a data packet. In source to goal course, every node makes storage of the data packet and transmission to following node. With the storage of a data packet and after this retransmission results more consumption of energy and extend end to end delay.

In [6], A Self-Organization Protocol is proposed for Body Area Networks (ANYBODY). The purpose of this protocol is to limit the transmission of sensor nodes directly to sink. It upgrades the effectiveness of network by varying the selection grounds of CHs.

Nabi *et al*. in [7] proposed a protocol which is more or less similar to store and forward system. They incorporate this store and forward plan with Transmit Power Adaption (TPA). In order to have control on the consumption of transmission power, each node is aware of its neighbours. Nodes make the transmission of data with least power and with a steady quality of link.

In [8], Transmission Power Control (TPC) method as proposed by Nabi *et al*. is applied. At the point when link quality of a node diminished, an Automatic Repeat Request (ARR) is generated and sent back thus it enables the re-retransmission of drop packet. Retransmission of lost packet enhances the network throughput with the cost of consumption of energy.

In [9], [10] Tsouri *et al*. applied creeping waves to relay data packet. This protocol was proposed by them to reduce the energy consumption of nodes at the time of maintaining the reliability on body link.

In [11], [12] authors make the analysis of the delay in WBANs and various medium access methods for WBAN. A delay tolerant protocol is proposed in [13] by author. They made the comparison of their protocol with various protocols of present.

2. SIMPLE PROTOCOL

In WBANs, the constant quantities of nodes offers chance to loosen up limitations in the case of routing protocols. With the inspiration of routing constrains, SIMPLE protocol enhance the period of stability and throughput of the network. Following paragraphs throws a light on the features of the framework model along with the characteristics of SIMPLE protocol [14].

System model

Fig. 1 illustrates that eight nodes are placed on the body of the person.

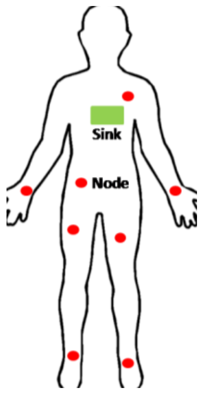

Fig. 1 Body area network with eight nodes.

Each sensor node consists of same power and computation capabilities. The Sink node is placed at chest. ECG and Glucose sensors nodes are Node 1 and Node 2 respectively. Data is transmitted directly to sink by these two nodes.

The typical sensor node parameters are detailed in Table 1.

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Table 1: Radio Parameters [18].

Parameters	nRF 2401A	CC2420
$E_{TX\text{-}elec}$	16.6 nJ/bit	96.89 nJ/bit
$E_{RX\text{-}elec}$	36.2 nJ/bit	173.78 nJ/bit
E_{amp}	1.96 nJ/bit	270.9 nJ/bit

Initial phase

A small measure of information packet is broadcasted by sink in this phase which comprises the sink's position on the person's body. Each sensor node, after getting the control packet, makes the storage of the sink's position. An information packet is broadcasted by each sensor node which has the following information: position of node on the human body, node ID and the status of the energy. Thus, each sensor node is updated with the information about the location of neighbours and sinks.

Selection of next hop

With the end purpose of saving energy along with the improvement in the network throughput, a multi hop procedure is proposed for WBAN. This section of the paper details about the grounds of selection for a node to turn out to be a parent node or forwarder. The main objective is of creating the balance of the energy consumption among sensor nodes of network. In SIMPLE protocol in each round new forwarder is chosen. Sink node is aware of the information of the nodes such as distance, ID and residual energy status. Sink processes each node's cost function and transmission of this cost function is done to all nodes by sink.

Each node makes the decision on the grounds of the below discussed cost function whether to be a forwarder node or not. Considering '*i*' represents the number of nodes than the evaluation of cost function of node '*i*' is done as follows:

$$CF(i) = \frac{d(i)}{RE(i)} \tag{1}$$

In the above equation, the distance between the sink and node '*i*' is represented by $d(i)$ and $RE(i)$ is the residual energy of node '*i*' and is estimated by extracting out the present energy of node from whole energy at the initial phase. We prefer a node with least cost function to be as a forwarder. Each one of the neighbour node get affixed along with the forwarder node and transfer the data possessed by them to forwarder. This data is collected and forwarded to sink by the forwarder. This (forwarder) node contains 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 straightforward communication with sink and do not get indulge in the process of forwarding data.

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, of the event that a node does not contain any data to be sent, it switches to idle state. 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.

3 RADIO MODEL

Radio model is used to consider the behaviour of the wireless medium. In past various radio model is proposed for WSN. In general first order radio is found suitable for WBAN as detailed in [36-37].

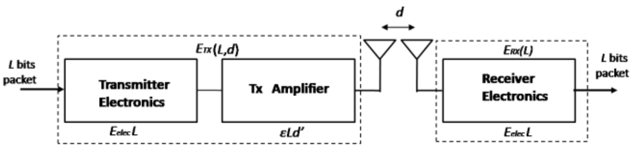

Fig. 2 First order radio model.

The above mentioned radio model assume that *d*, is the separation between transmitter and receiver and, d^2 represent the loss of energy because of the transmission channel. We can define the first order radio model equations as

$$E_{TX}(L,d) = E_{TX-elec}(L) + E_{TX-amp}(L,d) \tag{2}$$

$$E_{TX}(L,d) = E_{TX-elec} \times L + E_{TX-amp} \times L \times d^2 \tag{3}$$

$$E_{RX}(L,d) = E_{RX-elec}(L) E_{RX}(L) = E_{RX-elec}(L) \times L \tag{4}$$

Where E_{TX} is the energy consumed at the time of transmission, E_{RX} is the energy consumed during reception, $E_{TX\text{-}elec}$ and $E_{RX\text{-}elec}$ 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. On the other side, *L* denotes the size of the packet.

The platform 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. We can rewrite the equation 3 of transmitter as follows

$$E_{TX}(L,d) = E_{elec} \times L + E_{amp} \times L \times d^n \tag{5}$$

The parameters of energy provided in equation 5 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. 3.4GHz.

Table 2: Simulation parameters.

Parameter	Value
E_0	0.49 Joule
E_{elec}	5.0 nJ/bit
E_{fs}	10.0pJ/bit/m^2
E_{amp}	1.3 *f*J/bit/m^4
E_{da}	5.0 pJ/bit
Packet Size	4000 bits

Performance Metrics

The protocol is discussed in terms of the following parameters.

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

2) Number of dead nodes: This is the process where we count the number of dead/alive nodes after each rounds. It is desirable that nodes should remain alive for longer duration.

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4. FORWARDING FUNCTION ANALYSIS

The above discussion is based on the protocol forwarding functions. Still a careful analysis is needed which investigates the effect the distance and energy. In order to achieve the target of enhancing the throughput and reliable communication with more reliability between sensors and sink, latest schemes are proposed by us. The various forwarding functions with their nomenclature are detailed in Table 3.

Table 3: Forwarding Functions Comparison.

Nomenclature	Forwarding Function
CF1	$F.F(i) = \frac{d(i)}{R.E(i)}$
CF2	$F.F(i) = \frac{1}{d(i)}$
CF3	$F.F(i) = \frac{1}{R.E(i)}$
CF4	$F.F(i) = \frac{1}{d(i)[R.E(i)]^2}$
CF5	$F.F(i) = \frac{1}{d(i)[E - R.E(i)]^2}$

The CF1 depends on distance and residual energy, CF2 depends on distance only, CF3 depends on residual energy only, CF4 relies on distance and scaled residual energy and CF5 depends on distance and dissipated energy. Form Fig. 3, it is clear that, the performance of CF1 is poorest, and the performance of CF5 is best among the chosen forwarding functions. The performance of CF1 and CF3 is nearly same, and on the other side the performance of CF2, CF4 and CF5 is nearly same.

Thus from CF1 and CF3 it can be concluded that, only with residual energy performance is poorer. The performance of CF2 and CF4 is overlapping and not visible in graph. It clearly concluded that the effect so residual energy will have little or no effect. This is very obvious as each of the node have same initial energy, thus their dissipation will also be nearly uniform. In CF5 we try to minimize the dissipated energy, and the performance of the protocol is best among the chosen one.

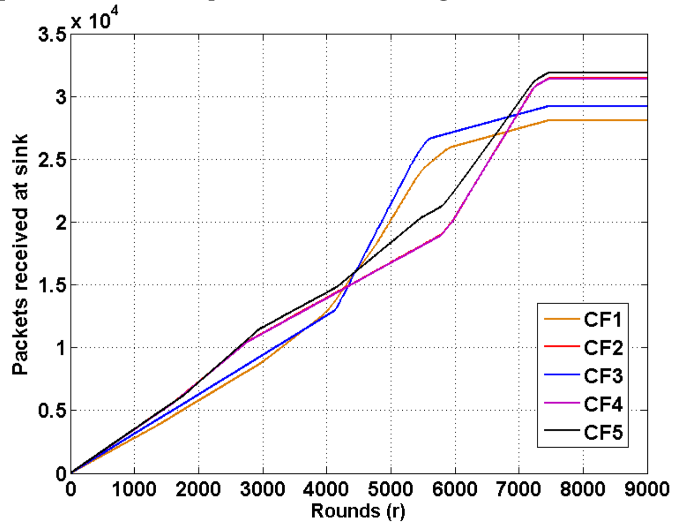

Figure 3: Throughput comparison of various forwarding functions.

As discussed above, the cost functions CF4 and CF5 have nearly same performance. To generalize the proposed model we modify CF4 forwarding function as:

$$FF(i) = \frac{1}{d(i)[R.E(i)]^p}, \quad p \geq 2 \qquad (6)$$

As it is useless to select a forwarding node which is far away from the data sending node therefore forwarding nodes are selected which are closest to transmitting node.

As a second modification we define forwarding function as

$$FF(i) = \frac{1}{d(i)[E - R.E(i)]^p}, \quad p \geq 2 \qquad (7)$$

We defined this protocol as CF5. 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.

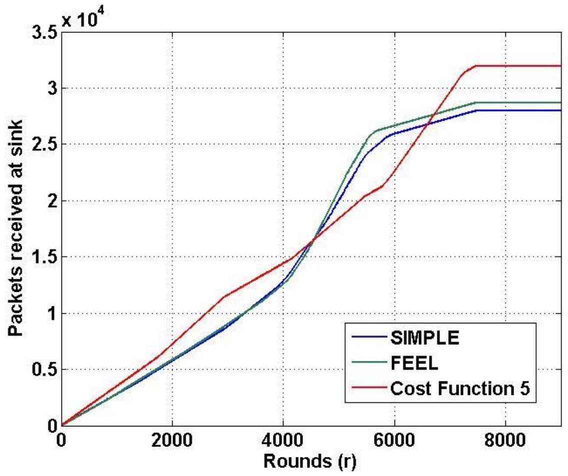

Figure 4: Comparison of FEEL, SIMPLE and cost function CF5

As defined above in SIMPLE protocol the forwarding function is defined as

$$F.F(i) = \frac{d(i)}{R.E(i)}. \qquad (8)$$

Recently FEEL protocol is proposed where the forwarding function is modified as

$$F.F(i) = \frac{\sqrt{d(i)}}{R.E(i)}. \qquad (9)$$

In figure 4, comparison of SIMPLE, FEEL is made with cost function CF-5. The maximum possible throughput in SIMPLE protocol is 27980, while for FEEL maximum throughput is 28690. Thus throughput improves by 3.5%. the obtained throughput with CF- is 31950. Thus performance with CF-5 is nearly 14.12% better than SIMPLE protocol. However, with FEEL the performance is improved by 11.36%.

7. CONCLUSIONS

In this paper, various forwarding functions are proposed, and performance comparison is made. Later sink position is optimized and it has been found that mean position of used node is best position for sink placement. Using simulation results are obtained under different protocols and it has been found that CF-5, with optimized sink provide an increase of more than 14.12% rise in throughput.

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