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Effective Energy Efficient Routing Algorithm for WSN/WBAN

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Abstract: **Wireless body area network is a new emerging field in WSN. WBAN is a wireless network of wearable computing devices. The most important application of WBAN is health monitoring. In WBANs the wireless sensors are deployed in the human body and these sensors are used to monitor the various human body parameters such as blood pressure, glucose level, heart rate etc. WBANs capture accurate and quantitative data from a variety of sensors. In this work we propose a energy efficient routing protocol for WSN/WBANs that uses a combination of multi-hop and single-hop topology. We use the concept of cost function in order to select the forwarder node. The calculation of cost function takes into consideration the residual energy parameter into account thus making sure that the energy consumption of the network is balanced. MATLAB simulations of proposed routing algorithm have been performed to obtain the simulation results. The simulation results show that our proposed protocol increases the network stability and the nodes stay alive for a longer duration, which in turn contributes to higher packet delivery to the sink.**

Index Terms— **Wireless Body Area Network, cost function, residual energy, stability, network lifetime, delay**

I. INTRODUCTION

The Body Area Network field is an interdisciplinary area which could allow continuous health monitoring with a real-time updates of medical records [1]. As sensors are available in various sizes, they can be worn on, attached or implanted into the human body. The main objective of WBANs is to simplify and improve the speed and accuracy of data collection from nodes, thus providing reliable communication. WBANs also control actuators for in-time release of medication. The sensors used in WBANs are battery driven units. These sensor nodes have limited battery resources, due to which the sensor nodes are unable to collect all information stored in the network.

The most important application of WBANs is the patient monitoring. The sensors deployed in the human body record the various physiological conditions of the patients under supervision and can provide us real-time feedback. The sensors collect the patient data and then send it to the physician in a hospital through Metropolitan Area Network (MAN) or Local Area Network (LAN).

As frequent charging of the batteries is a tedious process, the deployment of WBANs requires a novel solution towards power-efficient communication. Higher power consumption leads to increase in electro-magnetic radiations. Additionally, the electro-magnetic radiations have negative impacts on the human body. Power efficient communication ensures the significant decrease in the electromagnetic radiations. Thus energy efficient routing is of great importance.

The routing protocols in WBANs are classified as follows [5]-

Temperature Based Routing Protocols: The objective of these protocols is to avoid routing on hot spots by maintaining low temperature among sensor nodes.

Cluster Based Routing Protocols: These protocols divide the various nodes in the WBAN network into different clusters and assigns one Cluster Head for each cluster and routes the data from sensor nodes to the sink through Cluster Heads.

Cross Layer Routing Protocols*:* These protocols are mainly reactive and need to gain knowledge of the connectivity of all Nodes in the network and their other features which leads to significant overhead.

Cost-Effective Routing Protocols*:* These protocols introduce the concept of cost function. Periodically the cost function is updated based on the cost-effective information and the node with the minimum cost function is selected for the transmission of data.

QoS-Based Routing Protocols**:** These protocols provide separate modules for various QoS metrics, hence providing higher reliability, lower end-to-end delay and higher packet delivery ratio.

The rest of the paper is organized in the following order. In section 2 the radio model is presented. Energy efficient protocol is proposed in section 3. Existing protocols are discussed in section 4. Performance metrics and simulation results are presented in section 5. And finally section 6 presents conclusion.

II. RADIO MODEL

We use first order radio model proposed in [3]. Single-hop communication is used to minimize delay. This radio model considers d, the separation between transmitter and receiver and d2, the loss of energy due to transmission channel. We calculate energy consumed in Single-hop communication as:

Es-hop = Etransmit ....(1)

where, Etransmit is the transmission energy and is calculated as:

Etransmit = Eelec + Eamp ....(2)

where, Eelec is the energy consumed for processing data and Eamp is energy consumed by transmit amplifier.

$$\text{Etransmit} = k(\text{Eelec} + \text{Eamp}*d2) \ldots\ldots\ldots\ldots (3)$$

Where, k is number of bits in a packet.

The energy consumption during Multi-hop communication can be computed using the following equations:

$$\text{EM−HOP} = \text{Etransmit} + \text{Ereceived} \ldots\ldots\ldots\ldots (4)$$

where, Ereceived is the energy consumed for receiving data. If *k*-bits are transmitted to a distance of *n*-hops the transmission energy will be *n***k**Etransmit and receiving energy will be (*n*−1)**k**Ereceived . So the energy consumed for Multi-hop is:

$$\text{EM−HOP} = n*k*\text{Etransmit} + (n-1)*k*\text{Ereceived} \ldots. (5)$$

From (3) and (5), taking Ereceived = Eelec since the receiving energy is equal to energy consumed to process received data we obtain

$$\text{EM−HOP} = n*k*(\text{Eelec} + \text{Eamp}*d2) + (n-1)k*\text{Eelec} \ldots\ldots\ldots(6)$$

$$\text{EM−HOP} = n*k*\text{Eelec} + n*k*\text{Eamp}*d2 + n*k*\text{Eelec} - k*\text{Eelec}.(7)$$

$$\text{EM−HOP} = [2*n*k*\text{Eelec} + n*k*\text{Eamp}*d2 - k*\text{Eelec}]\ldots\ldots.(8)$$

III. PROPOSED PROTOCOL

Energy efficient Routing Protocol:

1) System Model

In this protocol, sink is placed at center of the human body. Sensor nodes are deployed on a human body; having equal power and computation capabilities. The sensor nodes used to detect ECG and glucose transmits data directly to sink. Single-hop communication is used during emergency conditions [2] and multi-hop scheme is used for normal data delivery as proposed in [4]. The relay nodes are used so that they can easily forward the received data to sink due to higher energy levels.

2) Initial Phase

Three tasks are performed in this phase. Firstly each node is informed with its neighbors; the location of sink on the body is identified and finally all the possible routes to sink are also evaluated. Each of the sensors updates location of neighbors and sink, when each node broadcasts an information packet containing its node ID, its own location and its energy status. Fig 1 shows the flow chart for the implementation of energy efficient protocol.

3) Selection of forwarder node

The sink node knows the ID, distance and residual energy status of all the nodes in the network. It computes the cost function of all nodes and transmits this value to all members. The cost function is calculated as follows:

$$C(i) = \frac{\sqrt{d(i)}}{R.E(i)}$$

Where d(i) is the distance between the node i and sink, E(i) is the residual energy of node i and is calculated by subtracting the current energy of node from its initial energy.

The node with the minimum cost function value becomes the forwarder node. This becomes the selection criteria for forwarder node. All the neighbor nodes stick together with forwarder node and transmit their data to it. Forwarder node aggregates collected data and forward to the sink. Nodes transmitting ECG and glucose do not participate in forwarding the data. Nodes are awake only at the time of transmission.

4) Routing Phase

Consequently, route selection is done using radio model. Only such routes are selected which are at fewer hops to the sink. As the nodes have information of all nodes and sink's location, so selected routes are steadfast and consume less energy. In case of emergency, all the implanted nodes on the body can communicate directly with the sink.

IV.OTHER PROTOCOLS

The existing protocols that will be used for comparison with the proposed protocol are discussed in this section.

A. *Mobile-adaptive threshold based thermal aware energy-efficient multi-hop protocol (M-ATTEMPT)*:[6]

In M-ATTEMPT, both single hop communication and multi-hop communication is used. Single hop communication is used for real-time traffic (critical data) or on-demand data while Multi-hop communication is used for normal data delivery. In WBANs it is important to sense the heat generated by the implanted sensor nodes. The M-ATTEMPT protocol is thermal-aware and it senses the link Hot-spot and routes the data away from these links. This protocol considers the concept of mobility, in order to keep the established links intact.

In this protocol, the sink is placed at the center of human body and the sensor nodes are deployed on the human body. The nodes with high data rate send data directly to the sink node and can easily forward the received data from low data rate sensors.

Initially, all nodes broadcast Hello messages. This Hello message contains neighbors information and distance of sink nodes in the form of hop-counts. In this way all nodes are updated with their neighbors, sink position and available routes to the sink node. Using Radio model, routes with fewer hops to sink are selected from available routes and the selected routes are steadfast and consume less energy. In case of emergency, all processes are lagged until critical data is successfully received by sink node.

After route selection the sink node assigns Time Division Multiple Access (TDMA) schedule for communication between sink node and nodes. Sink node allocate time-slots to nodes, thus enabling a node to communicate with the sink node at the allotted time. Finally, the sink node receives the data from the nodes and aggregates it.

B. *Stable Increased-throughput Multi-hop Protocol for Link Efficiency in Wireless Body Area Networks (SIMPLE)*:[7]

In this protocol, the sensors of equal power and computational capabilities are deployed on human body. The sink node is placed at the waist. The sensors carrying the ECG information and the glucose information continuously transmit the data to the sink directly.

Initially, the sink broadcasts a short information packet which contains the location of the sink on the body. After receiving the control packet, each sensor node stores the location of sink. Consequently, sensor node broadcasts an information packet which contains node ID, location of node on body and its energy status. In this way, all sensor nodes are updated with the location of neighbors and sink.

Multi-hop communication scheme is used in order to save energy. In order to balance energy consumption among sensor nodes and to trim down energy consumption of network, this protocol elects a new forwarder in each round.

The sink is aware of the ID, distance and residual energy status of the nodes. Thus, this feature enables the sink to compute the cost function of all nodes and transmits this cost function to all nodes. On the basis of this cost function, the forwarder node is elected. The cost function is computed as follows[8]-

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

Where d(i) is the distance between the node i and sink, R.E(i) is the residual energy of node i and is calculated by subtracting the current energy of node from initial total energy.

A node with minimum cost function becomes the forwarder node. The forwarder node has maximum residual energy and minimum distance to the sink. All the neighbor nodes stick together with forwarder node and transmit their data to it. Forwarder node aggregates collected data and forward to sink. Nodes transmitting ECG and glucose do not participate in forwarding the data. Nodes are awake only at the time of transmission.

The forwarder assigns time slots to the children node with the help of Time Division Multiple Access (TDMA) scheme. The children nodes transmit their sensed data to forwarder node in its own scheduled time slot. This minimizes the energy dissipation of the individual nodes.

V.SIMULATION RESULTS

We used MATLAB for performance analysis. A network size of 0.8m x 1.6m is considered here, where eight nodes are deployed on the human body and sink node is placed at the co-ordinates location of (0.25m, 1m) of the network. 8000 number of rounds was taken and nodes with initial energy of nodes 0.5J and radio range of 10m selected. The protocol was executed 5 times and the average results with graphs are provided. The simulation results are compared.

The metrics used for performance analysis are:

1. *Stability Period:* The time interval from the start of network operation until the death of the first sensor node.

2. *Residual Energy:* The energy remaining in a sensor node after each round.

3. *Network lifetime*: The time interval from the start of operation of the sensor network until the death of the last node.

4. *Throughput:* The total rate of data sent over the network.

5. *Delay spread*: is a measure of the multipath richness of a communication channel or the arrival time difference between the earliest multipath component and the latest multipath component of the received signal.

Parameters	Value
DC Current (Rx)	18mA
DC Current (Tx)	*10.5*mA
Minimum DC supply voltage	*1.9*V
E_{rx} – elec	36.1 nJ/bit
E_{tx} – elec	16.7 nJ/bit
Amplification energy for long distance *Eamp*	1.97 nJ/bit
EDA	5 nJ/bit
Wavelength (λ)	0.125m
Frequency (f)	2.4GHz
Initial Energy (E_0)	0.5J

Table1: Parameter setting

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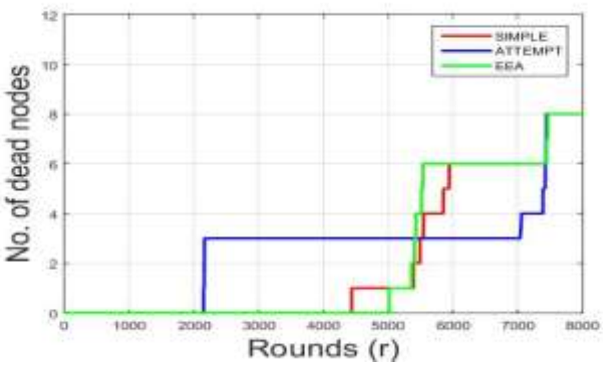

Figure1:network lifetime

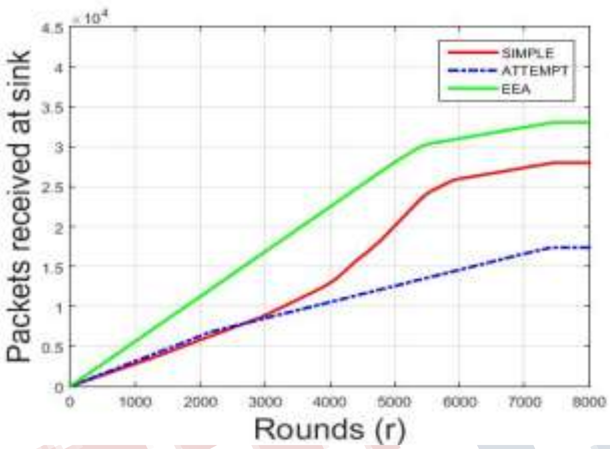

Figure 2: Throughput

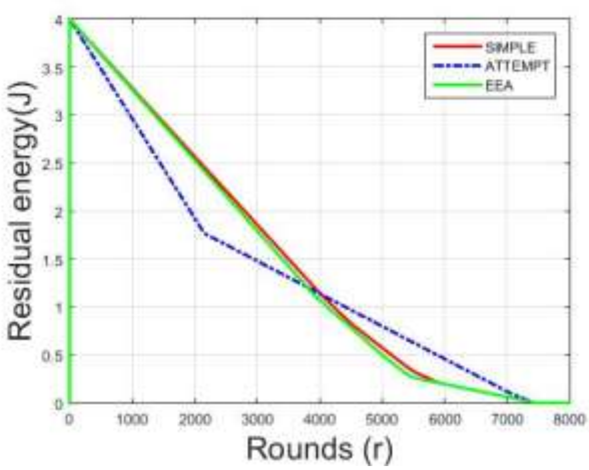

Figure 3: Analysis of remaining energy

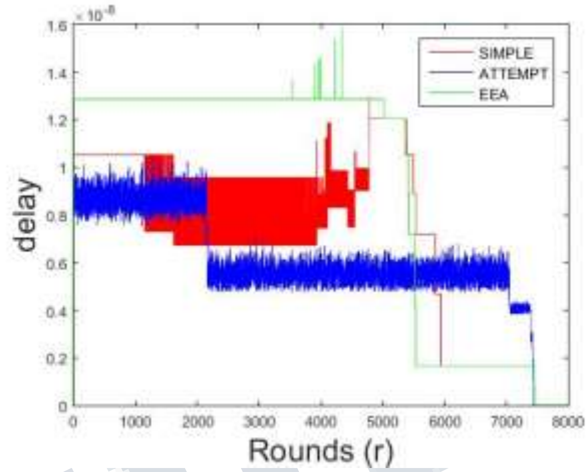

Figure 4:Delay

Fig 1, fig 2, fig 3, fig 4, shows the comparison between M-ATTEMPT, SIMPLE and Energy efficient routing protocol. From Fig 1 we can conclude that, stability period for Energy efficient protocol is much greater than those of SIMPLE and M-ATTEMPT. Increased stability period is seen in energy efficient protocol compared to SIMPLE and M-ATTEMPT is because of non-continuous data transmission. Fig 2 shows that the proposed protocol achieves higher throughput than SIMPLE and M-ATTEMPT protocols. Fig 3 shows that energy efficient protocol has approximately same residual energy when compared to SIMPLE protocol. Fig 4 shows energy efficient protocol has more delay since number of packets transmitted is more when compared to SIMPLE and M-ATTEMPT protocols.

VI.CONCLUSION

In this paper, we have proposed a mechanism to route data in WBANs in which both the merits of single-hop and multi-hop are utilized. The proposed scheme uses cost function to select the most appropriate route to sink. Our simulation results shows that proposed routing scheme has considerably enhanced the network stability period, it also has increased network lifetime and it reduces the power consumption of the WBAN network thus making it a power efficient protocol. In future work, we shall try to implement a probability function which determines the path through which the packets can be sent successfully to the sink.

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