iBTTA: IMPROVED BODY TISSUES TEMPERATURE AWARE ROUTING SCHEME FOR WBANs

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https://doi.org/10.26782/jmcms.2019.02.00003

Abstract

Wireless Body Area Sensor Network (WBANs) are used to measure the biological parameters of a human body in a critical health situation. Sensors use an antenna and electromagnetic radiations to drive the response towards the sink node. Our research focuses on the overheating problem of body tissues due to the electromagnetic field generated by electromagnetic radiations. When sensor nodes continuously send and receive the data, it not only influences the communication between the nodes by stimulating high attenuation for signal transmission, but also conduits various health problems. These health issues may include reducing blood flow, affecting the enzymatic reactions, brain tumor, damaging the sensitive tissues and leading to tissue cancer. The exposition of such issues are addressed in our research called iBTTA (Improved Body Tissue Temperature Aware) routing scheme, where not only the temperature of a body tissues is controlled under the threshold value but significantly improves the performance in terms of its throughput, end-to-end delay and transmission loss. The scheme is an extension of our previously published scheme BTTA. The validation of our scheme iBTTA is done through comparison with already existing techniques SIMPLE (Stable Increased-throughput Multi-hop Protocol for Link Efficiency in WBANs) and LAEEBA (Link-Aware and Energy Efficient scheme for WBANs). In iBTTA we have improved the problem of the body tissues temperature, utilization of battery power and load balancing techniques in WBANs.

Keywords: Tissues temperature, Attenuation, WSNs, Load balancing, Network Lifetime, residual energy
I. Introduction

According to one of the prediction currently the world population is 7.6 billion, 8.6 billion in 2030, 9.8 billion in 2050 and 11.2 billion in 2100. Every year 83 million people are added to world population. Health care will be one of the major issues in the coming era. About 30% of bereavements are because of cardiovascular. 17.5 million People die each year due to heart disease, while 246 million people suffered from diabetes and the number of people will reach 280 million by 2025. Hence, it is indispensable to utilize the advanced technology in healthcare, hence real-time healthcare monitoring and biofeedback of a humans body lead towards the development of a dynamic arena known as WBANs, and one of the emerging technologies with immense utilities and benefits. WBANs brought revolution in the field of healthcare and implemented in various countries. Improvement has been seen and life expectancy increased. Some facts and figure about life expectancy are given in table 1 for two countries Australia and America.

| Table 1: Life expectancy increased analysis |
| :------------------------------------------|
| **Country** | **Tenure** | **Expected age** | **Age improvement** |
| :-----------: | :--------: | :-------------: | :----------------: |
| **Australia** | 1960 | 70.4 | 10.9 |
|              | 2010 | 81.7 |         |
| **United State** | 1960 | 69.8 | 8.4 |
|              | 2010 | 78.2 |         |

WBANs is a branch of a wireless sensor network used to monitor intelligently vital signs of a patient remotely under the critical situation, transfer it to the sink node and then to the medical server for supplementary practice. One of the challenging tasks in WBANs is the development of energy-aware routing protocol i.e. to deliver the data packets efficiently from intra-tier to inter-tier with minimum energy consumption [I, II, III].

WBANs are one of the emerging technologies with gigantic advantages. WBANs are used in healthcare, but also a part of some non-medical applications such as public safety, defense, lifestyle and sport, non-medical emergency and environmental monitoring. Heaps of works have been done in WBANs to devise superior scheduling algorithms and power management protocols to bargain with these power issues. Various energy-aware routing protocols have been intended to improve the efficient power consumption in wireless sensor nodes, but body tissues temperature was not addressed in detail. The sensor node lifetime is directly proportional to the sensor battery, which leads to many challenges and issues in design and development, especially in implanted WBANs. Diagrammatically the structure of WBANs is defined in figure-1 [III, IV].
Figure 1: Architecture of WBANs

The WBANs network is not static in nature, humans body habitually change its sentiments. The topology and the link quality are changed when the human body changes its posture. A human body is the combination of tissues and organs. Due to the multifaceted arrangement and some postures of the human body, affects the transmission of the data packet to sink node results in delay, lost or blockage of radio signals, which not only degrade the network lifetime but also pangs the network performance [IV, V].

Another noteworthy issue in WBANs is the energy exhaustion of node battery. As sensor nodes are wearable or implanted in nature, cannot be swap often. The nodes transmit and receive the vital data of human body continuously, which leads to drain the node battery quickly [V].

In WBANs, numerous sensor hubs are embedded within the human body to gather momentous information using Radio Frequency (RF) channels i.e. between 850 MHz and 2.4 GHz. When the antenna absorbs the radiation i.e. radio signals and node consume the power electric, then a magnetic field is generated which leads to increase the sensor temperature. Overheating of the sensor reduces the blood flow and can damage the human sensitive tissues. Mathematically the energy absorption rate per unit time is calculated as in equation (1).

\[ \text{SAR} = \sigma |E|^2 P \ (\text{W/kg}) \]  

(1)
where, in equation (1), $\sigma$ is used for electrical conductivity of tissues, $E$ shows magnetic field by radiation and $P$ is the density of tissue. Mathematically the SAR can be defined as

$$\text{SAR} = \frac{d(\Delta w)}{dV} x^2$$

(2)

where, $\Delta w$ is mass of discretized volume and $dV$ is the volume incremented and maximum SAR value within the 10g tissues is considered. The ICNIRP limitation was introduced i.e. pulsed transmission was measured by using equation

$$SA = \text{SAR} \times T_p$$

(3)

where, $T_p$ is the pulse duration.

Temperature in the humans head is measured by the equation known as bio heat equation

$$C_p \frac{\delta T}{\delta t} = \Delta.(K \Delta T) + p.SAR + A - B(T - T_B)$$

(4)

$K$, known as the thermal conductivity $C_p$ defined the specific heat, $B$ is the Blood perfusion, $P$ is the tissue density measured in (kg)$/(m^3)$ and $\Delta.(K \Delta T)$ is a diffusion term used for heat transfer. The bio heat equation in (4) solve by means of a boundary condition mention in equation (5)

$$K \frac{\delta T}{\delta n} = -h. (T-T_a)$$

(5)

Security and integrity have been a significant issue in all ages of digital communications. In wireless channel radio, the interface is configured at the same frequency band, open for everyone to access and partake in the communication. So it becomes easy for the attacker to break. It is obligatory and one of the challenging task to ensure the secure transmission of information and access only by authorized users. Hence all the above issues direct us to contrive such a routing scheme which helps to prolong the WBANs network life.

II. RELATED WORK

The author focused on the energy efficiency in the paper [I], and introduced a new protocol in WSNs (Wireless Sensor Networks) name as advance LEACH. According to the author this scheme helps to extend the sensor node life and reduce the probability of sensor node failure. The author approach is to introduce a new routing protocol for WBANs to acquire the task of minimizing energy consumption in WBANs. The name of this protocol is BEC stands for Balance Energy Consumption in paper [II]. In this protocol the next hop is selected through cost function from source node to the sink node.

The author suggested a new thermal-aware multi hop routing protocol in the paper [III]. This protocol has better transmitting power and packet delivery rate compared to other. According to the author, fix sensor nodes are added manually to
the WBANs network, were these fixed sensor nodes are used as a forwarding nodes. The best path to the sink node is elected through the cost function. The author tried to improve the path loss, throughput, and energy utilization of a sensor node in the paper [V], by introducing a new scheme named as LAEEBA for WBANs. The next hope is decided through cost function. The child node collect the information and send these information to the parent node and then to sink node.

The author compared different protocols in the paper [VI], in this paper different routing protocols are analyzed and the author gives an overview of these protocols. The author classified the various protocols in different categories i.e. temperature-aware, cluster-based routing protocols, pastoral-base routing protocols, cross-layer base protocols and QOS-based routing protocols. The author gives an idea about a new routing scheme for WBANs in the paper [X]. The protocols define two ways of communication i.e. single hop and multi hop. Single hop communication is used for emergency data, while multi hop communication is used for normal data. In paper [XI], a new routing scheme is introduced for WBANs named as a cooperative communication. In this protocol, the author introduced the idea of WBANs nodes cooperation with the purpose of energy optimization to elongate the network life. In the paper [XIII], the author proposed a new routing protocol named ELA-RP (Energy and Link Aware Routing Protocol). The main theme of the routing protocol is to calculate the different parameters of the neighbor sensor node including energy level and link quality.

The author investigated in the paper [XIV], and developed the energy-aware routing protocol for WBAN such that it can efficiently send data to sink node without increasing the SAR (Specific Absorption Rate) value beyond the threshold. The author addressed in the paper [XV], about new protocol name as ESR for WBANs, where ESR stands for Energy Aware and Link Stable Routing protocol. According to the author, the source BANs coordinator broadcast the route request message to all his directly connected sensor nodes and catch the information about the sensor node residual energy and stability of a link of a neighbor to discover multiple possible paths to the destination.

Various authors suggested lots of schemes and algorithms to protract the lifetime and reliability of WBANs network under the threshold value of body tissue temperature. The author projected an idea in the paper [XVI], named “Priority Based Energy Aware” (PEA) routing scheme for WBANs. In PEA routing scheme the sensor nodes are divided into three categories i.e. child nodes, parent nodes and sink nodes. The selection of the parent node in PEA routing scheme pedestal on cost function and cost function is itself an energy consumption process. The author deals in the paper [XVII], with the power absorption, characteristics and thermal effects on human body tissues during the packet transmission from one node to another in WBANs.

The author projected a new energy-aware routing protocol in the paper [XVIII], name as HMEAT stands for “Horizontal Moveable Energy-Efficient Adaptive Threshold-Based Routing Protocol” for WBANs. The proposed protocol
help to utilize efficiently the battery charges to prolong the network lifetime. The author addressed a scheme PSO (Particle Swarm Optimization) algorithm in the paper [XIX], we know that during packet transmission EME radiation is generated, which create a negative effect on the human body. The Author defines the SAR stands for “Specific Absorption Rat”, and can be defined as “The quantity of the radio frequency absorbed by the human body tissue”.

The author gives an idea about a new routing scheme for WBANs in the paper [X]. The protocols define two ways of communication i.e. single hope and multi hope. Single hope communication is used for emergency data, while multi hope communication is used for normal data. The author give a new idea and presented new routing protocol in the paper [XX], named as Co-CEStat stands for Cooperative Critical Data Transmission in Emergency in Static WBANs). The main purpose of this protocol is to improve WBANs performance using the cooperative routing in the heterogeneous network.

III. Motivation

WBANs sensor battery life is too short, and sensors are overheating when sending and receiving the data constantly. As we know that, it is uncomfortable for a patient to change or recharge the batteries in wearable sensor nodes and impossible in implanted sensor nodes. In paper [V], a new routing protocol LAEEBA has been proposed for WBANs, where the author addressed the problems path loss, throughputs, and battery utilization very efficiently by selecting the best path from source to destination through cost function. Similarly, in the paper [XVI], the author pays attention towards the efficient utilization of battery power to prolong the WBANs life. He groups the entire sensor nodes in three categories i.e. CN (Child Nodes), PN (Parent Nodes) and SN (Sink Node). According to the author, CN select the PN through cost function, while PN acting as a relay node between the CN and SN. When the relay node battery power less than threshold power value, then the child nodes select another relay node among the available.

The sensor nodes are using a small antenna for sending and receiving information. When child node collect the human body information i.e. blood pressure, sugar value, heartbeat, temperature etc, process it and then send it to parent node. The parent node receives the data from child node and forwards it to the sink node. During the packet transmission between the sensor nodes electric and magnetic field radiations are produced, some of the radiations reached to the receiving end antenna, while some of the radiations are lost and absorbed by the human body. As parent node continuously receives data from child node and then send to the sink node, due to which parent node get overheated, which lead to raising the temperature of body tissues. If the temperature of the body tissues raises more than the threshold value defined by the IEEE and ICNIRP i.e. 1.6 mW/g, 2 mW/g for any 1g and 10 g of tissues, respectively, it will cause a serious problems, including reducing the blood flow, damage the sensitive tissues, brain tumor and cancer etc. Both the above-mentioned authors of paper [V] and [XVI] addressed the utilization of battery power efficiently, but did not pay attention towards the overheating problem of human body tissues in WBANs while sending and receiving data among the sensor nodes.
Hence our goal is to design such a routing scheme, that forward the critical patient data from the child node to the parent node and then to the sink node with minimum battery power consumption and keeping the temperature of body tissues under the threshold value. We considered and deploy sensor nodes on a human body randomly and placing a sink node in the middle of the body chest as shown in figure 2.

IV. iBTTA PROPOSED PROTOCOL

This segment presents our proposed routing protocol iBTTA for WBANs which not only defines a technique to control the body tissue temperature under the threshold but also improve the lifetime of WBANs network.

A. Network Topology

In WBANs the deployment of sensor nodes and sink node at patient body is a challenging task. If they are not placed in proper positions, it fatally affects the overall performance of a network, because human body not static in nature and continuously changing his postures. In first phase, we considered and deployed 11 sensors nodes on a human body randomly and placing a sink node in the middle of the human body chest. These sensor nodes are divided into two groups. Among eleven sensors nodes, three of them are sensing an emergency data, while eight sensor nodes are sensing normal data. Different parameters for simulation are defined in table 2.
B. Initialization Phase

In this phase, the entire sensor nodes unicast their own residual energy, distance to the sink node, position of the sensor node and nature of the sensor node to sink node through hello message. The node hoarding an emergency data directly sends the data to its sink node. While nodes having normal data participate in the election process, conducted for selection of child node and parent node based on the residual energy of sensor node and distance between sensor nodes to the sink node. The sensor node with maximal residual energy and merest distance between source node and sink node is selected as parent node, while all the other nodes considered as child node.

Table 2: Parameters for simulation

| S/No | Parameters                  | Values   |
|------|-----------------------------|----------|
| 1    | DC current (RX)             | 18 mA    |
| 2    | DC current (TX)             | 10.5 mA  |
| 3    | Minimum supply voltage      | 1.9 V    |
| 4    | Energy- elec                | 36.1 nJ/bit |
| 5    | Energy- elec                | 16.7 nJ/bit |
| 6    | Eamp                        | 1.97 nJ/bit |
| 7    | EDA                         | 5 nJ/bit  |
| 8    | Wavelength (k)              | 0.125 m  |
| 9    | Frequency (f)               | 2.4 GHz  |
| 10   | Initial energy (Eo)         | 0.5 J    |

C. Path selection phase

In the 3rd step, the best path between the child nodes, parent nodes and then to the sink node are selected based on a minimum number of nodes from the child node to sink node, minimum body tissue temperature and minimum path loss. As we know that distance and frequency are the two key factors of path loss. According to the Co-LAEEBA [3], two path loss models are defined, while data sending from the child node to the parent node. If node transfers data to personal node, then distance $d_2$ is calculated. In case $d_1 \geq d_2$, then suitable path loss model for sensor nodes from source node to the sink node i.e. $PL_1(d, f)$ having an equation.

$$PL_1(d, f) [dB] = a \times \log_{10}(d_1) + b \times \log_{10}(f) + N_{d,f}$$

(6)

While if $d_2 \geq d_1$ then node follow the path loss model
PL\(_2(d,f)[dB]\) = \(PL_0 \times 10n\log_{10}(\frac{d^4}{\lambda^2}) + \alpha\)

where,

\[PL_0 = 10n\log_{10} (4\pi + d_0 f)^2 \times C\]

Henced\(_0\), is the selected reference distance, while forwarding the data from source node to sink node. When the temperature of body tissues increased then threshold value along that path, then alternative path from source to the sink node is selected.

The main premise of this research is, as the parent node receives the data from the child node, sends to the sink node constantly. Due to electric magnetic wave radiation, the nodes get warm. The generated heat by the sensor nodes will absorb by the body tissues. The body tissues temperature incessantly measured along the path from child node to the parent node, when the body tissues temperature increased and crosses the threshold limit, sending the data along that path from child node to the parent node is yield. The child node selects an alternative forwarder and parent node using cost function and threshold body tissues temperature to the sink node. As each child node select his parent node based on the cost function and threshold body tissues temperature which proficiently distribute the traffic load between the parent nodes. In this way not only we can make a secure communication under the threshold value of body tissues temperature, but also can perform load balancing among the parent nodes, which not only save a humans body tissues from savior disease but also can efficiently utilize the sensor battery power. The flow chart of the proposed iBTTA protocol is given in figure 3:
Figure: 3iBTTA flow chart
D. Data Transfer

The collected data of sensors nodes are checked. If the nature of the data is an emergency, then it will send directly to the sink node via shortest path with minimum sensor nodes. While the normal data are sent to the parent node and then to the sink node using the best path having a minimum distance, maximum residual energy to the sink node. If body tissues temperature is increased with a selected best path from source to destination, alternative best path is calculated hence that the body tissues remain under threshold value.

V. RESULTS AND DISCUSSIONS

This paper contains on a series of simulation results to defend the efficiency and performance of our routing scheme iBTTA. We contrast our iBTTA scheme with two well-known existing routing protocols LAEEBA and SIMPLE.

A. End-to-End Delay

The total time taken by a data packet from source node to the sink node in WBANs is known end to end delay. Minimizing end to end delay is important and considered a key element in WBANs. Sensing the body symptoms, select the best path from source to sink node and delivered the data from the source node to the sink node in propose time. End-to-end delay is measured in millisecs. Figure 4 illustrates that the achievement of iBTTA protocol is more sophisticated compared to LAEEBA and SIMPLE routing protocols. The result shows that delay of iBTTA is 0.8 at 5000 second and 1.25 at 10000 seconds, while the delay of LAEEBA protocol showing 1.3 at 5000 and 1.6 at 10000 and a delay of SIMPLE protocol showing 1.5 at 5000 and 2 at 10000 secs. The achieved performance is due to selecting of best path from the source node to the SN based on body tissue temperature, path loss and the minimum number of nodes.

![Figure 4: End-to-End Delay Vs Time](image)
B. Throughput

Throughput can be defined as “moving of data bit/s from the source node to the sink node”. In the iBTTA protocol, data is divided into two categories i.e. emergency data and normal data. According to the iBTTA emergency data is sent from the source node to the sink node directly through a path having a minimum number of nodes to the sink node. While the normal data are forward through next hope, and the best path is selected using multiple criteria which help to improve the throughputs of iBTTA protocol compared to SIMPLE and LAEEBA. The result in figure 5 shows that iBTTA routing protocol is quit better and stable compared to LAEEBA and SIMPLE routing protocols.

![Throughput Vs Time](image)

Figure 5: Throughput Vs Time

C. Transmission Loss

The voltage of a signal loss, during the transmission from the source node to the sink node in WBANs is known as transmission loss. As sending the normal data from the source node to the sink node, BTTTA routing protocol using the two path loss models. The path loss model of iBTTA due to the induction of temperature awareness shows much better results compared to LAEEBA and SIMPLE routing. The transmission loss of iBTTA is 185, while LAEEBA and SIMPLE transmission loss is between 400 to 480 db. Whole of the energy is consumed by 7000 rounds, hence we can see that all the three transmission losses have come to a zero value at that point.
D. Energy Tax

Energy tax is the energy consumed by the nodes at a particular time interval after sufficient rounds have elapsed. Figure 6 indicates the energy tax at various time slots of the three under consideration routing WBAN schemes. Again the energy tax of iBTTA is comparatively less than the LAEEBA and SIMPLE schemes. The more energy utility in SIMPLE scheme is non-consideration of transmission losses in its scheme whereas LAEEBA and iBTTA both consider the path-losses in their schemes modelling. The initial energies assigned to all the schemes is 4 joules and all of them drop to zero after 7500 rounds.

Figure 6: Transmission Loss Vs Time

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{transmission_loss.png}
\caption{Transmission Loss Vs Time}
\end{figure}

Figure 6: Energy Tax vs Time

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{energy_tax.png}
\caption{Energy Tax vs Time}
\end{figure}
VI. CONCLUSION & FUTURE WORK

In this paper, the body tissues temperature is the main theme of our research. The body tissue temperature increased while sending continuous data from the source node to the sink node along with a single path. When the body tissue temperature crosses the threshold value it will not only influences the blood flow, enzymatic reactions, brain, and sensitive body tissues, but also causes problems in data transmission from the source node to the sink node i.e. increasing end to end delay, transmission loss and decrease the throughputs. Hence, in this paper, we have defined a mechanism which helps to overcome the entire above-mentioned problems. We have simulated the proposed mechanism by considering 11 sensors and measure the results of iBTTA protocol in term of throughputs, end to end delay and path loss. We found that iBTTA has a better response compared to LAEEBA and SIMPLE schemes. Our future work is to implement our idea on more complex, large and emergency networks.

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