Design Of Dynamic Energy Efficient Multi-Hop Protocols For Wireless Body Area Network

Shaik Jhani Bhasha, Dr. Sunita Panda

Abstract: Technological and scientific improvement in wireless technology has led to the creation of a state-of-the-art health care wireless body network (WBANs). It facilitates remote monitoring by doctors and helps them continue providing patients with an appropriate diagnosis. Besides, each person has a WBAN, transmits body sensing data from different sensors, used on the human body, to sink node. Because these sensors are equipped with limited battery power, space, and processing instruments. The transmission of data via WBANs is a resource-hungry process, especially in terms of resources. While routing plays a significant role in the lifetime of WBAN activity. The implementation of an effective, multi-hop node selection process is one of the major challenges in the network. Therefore this paper provides an energy-aware link efficient routing approach for WBANs (EAALER-W) as a communication system. This paper also introduces the initial proposal to incorporate the efficient Time Access Module (E-TDMA) focused on WBAN technologies to establish a system that meets the criteria of real-time communication. It shows significantly improved lifetime, linking efficiency and efficient packet delivery and minimizes network latency.

Keywords: Wireless body area networks (WBANs); link reliability; residual energy; Cost Function

1. INTRODUCTION

For users, their machines have been easily wired to sensors and connected to the Internet in recent days. As the smartphones are based on their operating systems and manufacturers of different data interfaces, such as USB or earphone links, there is no common wire interface between smartphones and the sensor network [1] in terms of the wire link. Nonetheless, the Wireless Sensor Network (WSN) incorporates common wireless technology IEEE 802.15.4 that does not include phones as well as other wireless technologies such as Bluetooth Low Energy (BLE) or WLAN. The Internet network can also be attached to the mid-station system when the machines are wirelessly wired to iPhones. Currently, sensors and actuators can be connected to software applications and industry frameworks. Thanks to their multifunctional ability and versatility, Raspberry Pi [2] or Arduino [3] developers and investigators prefer to be their creation platforms associated with particular applications. For Raspberry Pi or Arduino boards, people often make great advancements; they still need time and resources to evolve, even though they have skilled programming experience.

For context, Raspberry Pi uses the Linux system, which can sometimes take extra effort to get new Linux users began. More relevantly, costs are of major importance in terms of global production in the industrial application. In comparison with typically used microcontrollers, Raspberry Pi and Arduino seem to be overqualified for minimal-cost, quickly-developed industrial final products. Similarly, the Medical Internet of Things is the community of internet-related tools that conduct healthcare procedures and facilities. MIoT has arisen as a modern e-healthcare application that captures patients’ critical body parameters and tracks their clinical data via smaller wearable technology or implantable sensors.

MIoT has also shown huge potential to provide a better guarantee of human health and supports a wide range of applications from implantable medical devices to the WLAN. The MIoT structure is generally comprised of three layers: the sensor layer, the network layer, and the application layer, as shown in Fig.1.

Wireless body area sensors are used with limited energy capital for human health tracking. Sensed patient data must be obtained accurately for more review by the medical professional. An opportunistic technique was provided in [4]. The proposed strategy facilitates mobility at low-performance costs and additional relay node hardware costs. They use a sink at their wrist. So when the sink node is relocated from the node-set, it uses a relay node that collects data from sensor nodes.

Fig. 1. Structure of Medical Internet of Things

Fig. 2. Classification of WBANs Routing Protocols
In an opportunistic protocol, the wireless link between the sink and sensor nodes disconnects whenever the patient moves his hands. Link failure absorbs more sensor node power and the relay node often utilizes more packets, leading to a loss of sensitive and essential data. We are proposing a new system to reduce energy consumption and increase throughput. Routing protocols were classified for WBANs into different types, namely MAC layer protocols, QoS-aware, etc. Fig. 2 shows the WBAN protocol categorization. The main contributions and organization of this paper are summarized as follows: In section 2 we describe background works of routing protocol. The section 3 methods and methodology. The section 4 Results and discussion work, finally in section 5 we concluded the paper.

2. BACKGROUND WORKS

In [5], the authors suggested a routing protocol that endures network changes. They use the processing and forward method to increase data packet count to the corresponding sink node with more reliability. Each node stores the data packet and transmits it to the following node from source to destination. Through processing a data packet and transmitting it, energy consumption is increased and the delay is extended. The authors proposed in [6] the Body Area Networks Self-Organization Protocol (Anybody). This protocol aims to directly reduce the rate of transmission in the network. This increases the level of performance with the associated CHs in the given network. In [7], the authors suggested a protocol more or less like a storage and forward scheme. They implement this transmission power adaptation (TPA) processing and forward strategy. Every node is aware of its neighbors to control the use of transmission power. Nodes transmit data with low power and constant connection performance. In [8] the authors proposed a routing protocol that often provides a lowering of the energy consumption in the network and thus extends the network’s lifetime. In Cluster Head (CH), data transfer from the cluster nodes remains constant. In [9], when the packet is transmitted with a weak node, the authors addressed the scenario and condensed the link between the source node as well as the target node in the network system. It is difficult to determine the false route when routing. The node in the given network sometimes intentionally misleads the forwarding mechanism to detect the wrong path. Such a node as that of the interruption attacker node will obstruct contact including its peer node on a different routing path. Besides, [10] each round has an energetically modified distance value with a different β factor that significantly reduces energy use and improves network existence. The proposed method also minimizes the rear transmission problem and perceiving of the sensor network at all points with stable energy savings. In [11, 12], the authors studied WBAN lag and various methods of media access. The authors suggest a delay-tolerant protocol in [13]. They contrasted their protocol with various other protocols.

3. METHODS AND METHODOLOGY

In this section, the proposed framework mainly relies on the radio energy model as mentioned in the [15].

Radio Energy Model:

In this model d, the distance between the transmitter and the receiver and d2, energy loss due to the transmitting channel, are listed. Equations of the first order radio model are given.

\[
E_{Tx}(k, d, n) = E_{Tx-elec}(k) + E_{Tx-amp}(n)k d
\]

\[
E_{Rx}(k, d, n) = ETx-elec \times k + E_{amp} \times k \times n \times d^2
\]

\[
E_{Rx}(k) = E_{Rx-elec}(k)E_{Rx}(k) = E_{Rx-elec} \times k
\]

Where \( E_{Tx} \) is the energy expended in transmission, \( E_{Rx} \) is the energy expended by the receiver, \( E_{Tx-elec} \) and \( E_{Rx-elec} \) are the energies essential to run the electronic circuit of transmitter and receiver, respectively. The energy needed for the amplifier circuit is \( E_{amp} \), while \( k \) is the packet size and \( n \) is the path loss coefficient. In WBAN the media is a human body that probably contributed to the attenuation of the radio signal. The energy parameters in Equation 1 are hardware-dependent. We take into account two generally used transceivers in WBAN technology. The Nordic nRF 2401A is a single chip, low-power transceiver and Chipcon CC2420 is another transceiver.

**Table 1 Radio Parameters**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>nRF2401</th>
<th>CC2420</th>
<th>ZL70102</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC current</td>
<td>10.5</td>
<td>17.4</td>
<td>9.5</td>
<td>mA</td>
</tr>
<tr>
<td>DC current</td>
<td>18</td>
<td>19.7</td>
<td>15</td>
<td>mA</td>
</tr>
<tr>
<td>Intake Voltage supply</td>
<td>1.9</td>
<td>2.1</td>
<td>0.8</td>
<td>V</td>
</tr>
<tr>
<td>( E_{tx-elec} )</td>
<td>16.7</td>
<td>96.9</td>
<td>13.1</td>
<td>nJ/bit</td>
</tr>
<tr>
<td>( E_{rx-elec} )</td>
<td>36.1</td>
<td>172.8</td>
<td>26.78</td>
<td>nJ/bit</td>
</tr>
<tr>
<td>( E_{amp} )</td>
<td>197e-9</td>
<td>271e-7</td>
<td>212e-9</td>
<td>j/b</td>
</tr>
</tbody>
</table>

Both transceivers have a frequency of 2.4GHz. We use the Nordic nRF 2401A transceiver energy parameter possess of less consumption of power than Chipcon CC2420. Table 1 displays the required parameters for the simulation purpose.

Path Loss Model:

During the propagation of a signal in WBANs, it suffered from long term shadow and fading on the body area of a person. Table 2 shows frequency bands which are presented as channel models for each channel model in this document. This quantity of signal is directly proportional to the distance \( d \) with associated exponent term \( \gamma \). At a certain distance \( d \), the direction loss in dB is:

\[
PL(d) = PL_0 + 10 \times \log_{10}\left(\frac{d}{d_0}\right) + S(d); \quad d > d_0 = 1 \text{ m}
\]

When path loss (i.e., \( PL_0 \) in dB) is \( d=1\text{m} \), \( PL_0 \) is an intercept point, \( 10\gamma\log_{10}(d/d_0) \) each is the intercept point of the mean path loss, referenced to 1m; \( \gamma \) the path loss exponent; and \( S \) the lognormal shadow fading at dB is called a path loss exponent. The shadow fading term \( S \) has rms value of dB,
and PL0 and \( \gamma \) are selected so that \( \Delta P \) is reduced. The selection of frequency of the carrier is a significant transceiver factor. For industrial, scientific and medical (ISM) radio frequencies, the two options available are 2.4GHz or sub-GHz.

**Table. 2 channel models**

<table>
<thead>
<tr>
<th>Channel Model</th>
<th>Description</th>
<th>Frequency band(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CM2</td>
<td>Implant to Body Surface</td>
<td>400 MHz</td>
</tr>
<tr>
<td>CM3</td>
<td>Body Surface to Body Surface (LOS)</td>
<td>400, 600, 900 MHz</td>
</tr>
<tr>
<td></td>
<td>Body Surface to Body Surface (NLOS)</td>
<td>2.4 GHz</td>
</tr>
<tr>
<td>CM4</td>
<td>Body Surface to External (LOS)</td>
<td>UWB</td>
</tr>
<tr>
<td></td>
<td>Body Surface to External (NLOS)</td>
<td>UWB</td>
</tr>
</tbody>
</table>

Some benefits of sub-GHz over 2.4GHz are revealed:
- Range and quality signals. The message weakens when radio waves travel across walls and other barriers. The 2.4GHz propagation can be degraded quickly in highly congested areas, impacting the signal quality adversely.
- Biological tissues as a feature of frequency consume RF power. Without being absorbed, lower frequencies will easily penetrate the skin, indicating improved RF connection compared to the 2.4GHz frequency.
- Radio waves, while they propagate, turn when reaching a solid edge. When frequencies decline, the diffraction angle decreases, helping sub-GHz signals to curve around an obstruction and increasing the blocking effect.

As shown in Fig.3, the usage of power consumption in WBS indicates the payload data rate on the x-axis and power on the y-axis. After payload data reaches 10Mbps, the power has exponential growth shows the goodness of the transceiver.

**Fig. 3. Average Power versus Payload Data Rate of a Wireless Sensor Using the ZL70102 Transceiver**

A 100 kbps limit is often seen as a means of improving energy efficiency. Attempting to compare RF transceivers means energy is better per bit than energy consumption. But, high-data radios sometimes have higher peak levels. They are strongly undesirable for most small batteries, as they produce significant, leaky storage condensers, typically several hundred \( \mu F \). Fig. 4 shows a WBAN application block diagram that has a ZL70102 ZARLINK Semiconductor device built [14]. By having wake-up mode, this chip can operate in ISM band thus, allowing a higher power wakeup to be broadcast, and the primary radio is functioning on the MICS band (400 MHz).

**Fig. 4. A simple WBAN using ZL70102 transceiver system**

Because of node deployment, on the human body, they have to consume less power so that it does not harm them. Nevertheless, there can be substantial signal attenuation, because all organs of a person possess particular dielectric constant and signal absorption happens accordingly. We present a new routing protocol for WBANs in this section. The limited number of nodes in the WBANs enables the routing protocols to be relaxed. Taking into account routing restrictions, we increase the network stability time and network performance.

**A. System Model**

We deploy eight sensor nodes on the human body in this system. Both sensor nodes have almost the same capacity and processing resources. Sink node is on the hip. Node 1 is a sensor ECG, while Node 2 is the sensor node Glucose. Such two nodes immediately send data to the sink. Fig. 5 illustrates the positioning of the human body of the nodes and sinks.

**Fig. 5. (a) Proposed WBAN Node deployment (b) ATTEMPT and SIMPLE Node deployment**
B. Initial Phase
Hello, packets are used in this phase to keep adjacency among neighboring nodes. Through circulating HPs periodically, BSNs exchange their modified residual capacity, required hops, distance and channel link strength. It maps both sensor nodes to neighbors' and sink positions. With the help of Eq 4, we can compute the residual energy \( E_{\text{res}} \) of the node and emptiness in the queue \( Q_{\text{empty}} \) when the node is open. Then the required hop count to reach the sink can be achieved by placing in the last fragment. The interpretation of \( HOP_{\text{min}} \) is as follows:

\[
HOP_{\text{min},i} = \min \left( HOP_j \right) | j \in N_i + 1
\]

Where \( HOP_j \) is the minimum hop counts of node \( s_j \) to the sink node. In this Eq 4 is added to the minimum hop counts of the neighboring nodes because the hop count of node \( s_j \) to its neighboring nodes is 1.

Link reliability:
Link stability among two nodes impacts quality of service needs and energy consumption, as the poor connection among the nodes increases, that results in frequent packet retransmission. This role involves \( s_j \) node residual resources, \( S_j \) node queue length emptiness and the strength of communication with \( S_i \) and \( S_j \) nodes. \( Cost_{ij} \) has the following definitions:

\[
Cost_{ij} = \frac{E_{\text{res},j}}{E_{\text{init},j}} + \frac{Q_{\text{empty},j}}{Q_{\text{total},j}} + \frac{\gamma \cdot \text{LinkR}_{ij}}{T_x}
\]

Where \( E_{\text{res},j} \), \( E_{\text{init},j} \), \( Q_{\text{empty},j} \), and \( Q_{\text{total},j} \) are residual energy, initial energy, vacant queue length, and maximum queue size of node \( s_j \) respectively. \( \text{LinkR}_{ij} \) is the link reliability between two nodes \( s_i \) and \( s_j \). Additionally, \( C_E \), \( C_Q \) and \( C_L \) denoted constant coefficients. Also link reliability of the nodes increases the reliability of the network. The objective link cost function for node \( S_i \) is defined by

\[
\text{maximize} \left( Cost_{ij} \right), \forall j \in SN_i
\]

where SNi is obtained from the Eq 8

\[
SN_i = \left\{ j | \forall j \in N_i, HOP_{\text{min},j} = HOP_{\text{min},i} - 1 \right\}
\]

where \( N_i \) prepared list of neighbor nodes \( s_j \) and \( HOP_{\text{min},j} \) denoted as hop count of minimum for node \( s_j \) to the sink node.

C. Selection of next hop and routing algorithm
The process of choosing best next hop node that acts as forwarder for packet transmission with less energy resources. When a node receives a HELLO packet from its next node, the node changes the previously mentioned neighbor list. The node regularly chooses the next hop address. The process of choosing best next hop node can be summarized in pseudo code as:

**Pseudo code for next hop node:**

- **Input:** \( N_i, HOP_{\text{min}}, SN_i \)
- **Output:** \( NH_i \)

1. for (Gather entire nodes in list \( N_i \)) do
2. Calculate \( \text{Cost}_{ij}, j \in N_i \)
3. end for
4. \( j = \) first element of \( N_i \)
5. while (Not end of list \( N_i \)) do
6. if \( (HOP_{\text{min}}+1 == HOP_{\text{min},j}) \) then
7. add \( j \) to \( SN_i \)
8. end if
9. \( j = \) next element of \( N_i \)
10. end while
11. Sort \( SN_i \) (in descending order of \( \text{Cost}_{ij} \))
12. \( NH_i = \) First element of the list \( SN_i \)

D. Improved Scheduling
When the nodes have successful interaction, with that of the main controller, it sends time slots as requests to query several TDMA slots from the controller. The initial number of TDMA slots to be requested is one of the network configuration parameters and should be set as soon as the network is set. The TDMA system should also be allowed to fill all slots throughout the TDMA with nodes that do not allow any additional free-time slots to be used to achieve a maximum degree of accuracy. In comparison, the TDMA device slots must be evenly distributed here between nodes at the end of network services. After acquiring the TDMA slots order, the controller registers the necessary number of slots for each node in a control frame that determines the TDMA framework. The above control system controls the network and specifies the parameter values for the TDMA cycle. Such a mechanism helps nodes to access the channel whenever the TDMA slot query is issued by the controller. If the request is first accepted, the resulting node utilizes the channel before anyone else. The controller also provides multiple timeslots equal to the number of slots available for each node. It announces the events list being responsible for all the aspects with a framework. Also, during its time slots, a node wakes up and begins to relay the packets. For every successful packet transmission, there should be an acknowledgment of the corresponding node from the controller end. If the node does not obtain the acknowledgment tag, the node concludes that its connection is strongly fading and thus does not retransmit a packet. Therefore, the node shuts down the transceiver and sleeps until the latest TDMA round comes to an end. New nodes will start to use the channel as planned.
4. RESULT AND DISCUSSIONS

The simulations are carried out in 11 BSNs and a sink is placed on the human body as shown in the figure. 5(a) is not allowed. All BSNs produce constant CBR traffic. All the simulations are carried on ZL70102, which is a low power chip most suitable for BAN, so, we regarded simulation parameters with several evaluations employing Matlab 2013a that have been conducted to determine the efficiency evaluation of the current EALER-W Protocol. Also, the findings are comparable to standard SIMPLE protocols and ATTEMPT as shown in the figure. 5(b).

Fig. 6. WBAN network lifetime analysis

Fig. 6, showing comparison in various forms of dead nodes of the proposed EALER-W with traditional SIMPLE. The analysis shows that the very first three nodes of traditional SIMPLE died 2800 times because of heavy loads on those nodes. The first node dies accordingly at 2780 and 5500 rounds in traditional SIMPLE and EALER-W.

Fig. 7. WBAN throughput analysis for transmitted packets to SINK

As shown in Fig.7, the EALER-W protocol achieves high performance than the traditional SIMPLE. The number of packets that are sent to the sink depends on the number of nodes. More alive nodes transmit more packets to drop, which improves network performance.

Fig. 8. WBAN throughput analysis for received packets at SINK

Fig. 8 shows that conventional SIMPLE collect numbers of packets efficiently at sinks, and EALER-W is almost 18500, 37500 respectively. Because of the longer reliability of individual BSNs, the EALER-W protocol obtained an increased value of active packets received. The BSNs died in the conventional SIMPLE in the early stages, resulting in a lower number of BNC packets.

Fig. 9. WBAN remaining energy Analysis

Fig. 9 The evaluation of EALER-W's energy consumption with existing protocols demonstrates that EALER-W energy consumption is lower than traditional SIMPLE. It also shows that residual energy is more stable than competitive protocols. Results indicate that the energy consumption of the ELR-W is 14% to 45% smaller than traditional SIMPLE.
Fig. 10. Path loss (dB) Vs Rounds

Fig.10 shows that EALER-W initially works well with a 380dB Path Loss. After 2000 rounds, indeed, the path loss of traditional SIMPLE decreased dramatically to 260 dB because certain topology nodes die. The lowest possible number of live nodes in the lowest cumulative loss of path. By having more stability timeslot for EALER-W it can achieve less path loss compared to simple protocol.

5. CONCLUSION

In this paper, we suggest a process for WBAN routing data. The proposed scheme uses a cost function to select a suitable sinking route. By introducing new route costs based on residual resources like required hops, link quality, and distance for selecting the best next-hop node for transmitting the packets successfully. The simulation results reported a reduction in consumption of energy among two nodes decreased a lot with minimal delay and higher throughput. The proposed EALER-W routing protocol maintains a longer network lifetime as related to the traditional SIMPLE protocol. It often demonstrates that the proposed routing system increases the stability in the network and the number of packets transmitted to the sink.

6 REFERENCES


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