IM-REAST: AN IMPROVED RELIABLE, ENERGY AWARE AND STABLE TOPOLOGY FOR WIRELESS BODY BIO-SENSOR NETWORKS IN HEALTH-CARE SYSTEMS

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ABSTRACT
Rising medical expenses and increased life expectation impose big issues for proper health care and monitoring. Wireless Body Bio-Sensor Networks (WBBSNs), a set of tiny bio-sensor nodes attached within, on and/or around the patient body, were placed to meet this requirement. Due to patient body postural change, ultra short range radio links and random RF attenuation lead to on-body topology disconnections occur, which results more energy consumption and network lifetime is reduced. To address these issues we propose an IMproved Reliable, Energy Aware and Stable Topology (IM-REAST) protocol to maximize network stability period and minimize energy consumed by bio-sensor nodes on-body topology for WBBSNs. This algorithm applies the mixed mode communication between bio-senor nodes and the sink, which employs a new forwarder function for selection of forwarder node. This mixed mode communication reduces the energy consumption of the network and maximizes the network lifetime. This paper provides a comparison of three of the routing protocols, SIMPLE, ATTEMPT and proposed. The comparison is performed at the 2.4 GHz frequency (IEEE 802.15.4) on-body bio-sensor set-up. The proposed protocol performances are compared in terms of stability of network, residual energy, packet received at sink and path loss and simulation results shows that performance of overall network is improved by 25% as compared with SIMPLE and ATTEMPT protocols.

Keywords: WBBSNs, IM-REAST, stable topology, forwarder function, link parameters, forwarder node.

1. INTRODUCTION
The population growth and the increased cost of medicare in developed and developing countries have opened more and more challenges in the healthcare sector. With the growth in elderly populations, the value of medical services would presumably drop, ensuing raise in medicare and health care expenditures. According to [1] Several Millions of people in the world die due to heart attacks and suffer from diabetes every year. In [2] advancements in wireless technologies empowered to support patient health monitoring in cost effective way. WBBSN is one of emerging trend which allows, monitoring a person’s health and providing services to patients at their doorsteps. In [3] the Wireless Body Area Network(WBAN) is a communication standard optimized for battery operated devices on, in or around the human body to serve as a different applications like medical, consumer electronics, sports, entertainment and other. Usually in health care systems bio-sensors are attached to the patient body with wires. In [4] the comfort level of patient is increased with emergence of WBAN, which introduces wireless communication among bio-sensors. WBANs create a wireless network by employing radio links among the bio-sensors on human body to screen critical signs such as temperature, glucose level, blood pressure, EMG and position. In WBSNs, the bio- sensors are entrenched inside the body or wearable to monitor health condition in real-time and sends this information to central sever and the doctor. In [5], the WBAN is compatible to communicate with existing wireless technologies like Bluetooth, Wi-Fi, ZigBee, WSNs, Wireless Personal Area Network (WPAN), Wireless Local Area Networks (WLAN), and the internet. Figure-1 shows the architecture of WBAN with 3 communication-tiers.
Figure-1. Communication Tiers in a WBSNs.

In [6], communication Tier-1 is an Intra-WBAN which monitors the patient body through body sensors and collects the vital information like temperature, heartbeat, blood pressure, etc., and send to the coordinator node using Bluetooth or Wi-Fi technology. Communication Tier-2 is an Inter-WBAN, which comprises of a body coordinator that consolidated the data and transmits to the sink node. Tier-1 to Tier-3 data can be transferred through this gateway. In [7], the communication tier-3 is an extra WBAN where the sink transmits the gathered information to the remote medical centre and doctor through internet. The main problem that arises in WBSN topology is battery recharging cycle and not feasible to detach batteries from body parts for charging them from time to time. Since each bio-sensor node continuously transmits their information to central device which is done at the cost of their energy consumption. Which result in stability of network and network lifetime is reduced, hence, energy distribution among the nodes is major factor for designing the WBSN. By concentrating on this factor in mind, we propose IM-REAST for WBBSNs. In this proposed topology, we adopted mixed mode communication between sink and the bio-sensor nodes. Eight bio-sensors are deployed on patient body out which two of Bio-sensors are deployed near the sink to collect the emergency information of patient with low attenuation; these sensors continuously transmit their information to sink. Other sensors follow indirect communication to transmit their information via forwarder node which is elected by Forwarder function defined in this protocol. It minimizes the energy of nodes and stability of network is enhanced.

2. ROUTING PROTOCOLS AND CHALLENGES IN WBBSNs

From last decade, changes in lifestyle of people and our life expectation, the prevalence of long-term diseases has increased, and these physiological disorders often need a real-time monitoring of vital signs. The portable health care system will give opportunities and precious support for both patients as well as doctors to [9]. In [10] authors presented the direct communication may raise the temperature of the sensor nodes which affect the human body tissues. So, they used indirect communication for communication from root nodes to sink. But these authors’ also presented storage and congestion delay increase overall delay in indirect communication, hence indirect communication is not best choice for emergency data. And also, previously established link may disconnect due to versatility of patient’s body. After disconnection, to setup a new connection it takes time and causes delay. The authors proposed a new Energy management scheme to outlay the problem of disconnection and to minimize the delay.

In [11] the authors proposed iM-SIMPLE, a routing protocol for WBANs. Indirect transmission is used to optimize the energy consumption and employed higher cost function node as forwarded node. This will further improve the packet delivery and reduces the path loss. An energy aware routing protocol (EAR) [12] is considered to medical applications and hospitals. Change in network topology results in rapidly batteries to deplete, which consequently destroys efficiency of the network. Uniform load distribution is the plays important role while designing a routing protocol, such that energy consumption must be even at every iteration. Direct transmission leads to more load on distant nodes and indirect communication rapidly deplete battery energy of nearer nodes quickly.

Authors in [13] use direct transmission to send information directly to the sink from the all sensor nodes. This approach is helpful to beat the delay; however, far away nodes of consume more energy. In [14] authors highlighted the indirect transmission from sensor nodes to the sink. But, delay and consumption of energy are major
concerns in routing selection. In [15] authors proposed EAR scheme which uses both direct and indirect transmissions from sensor nodes to the sink. However, indirect transmission is not reliable for emergency data because it results in delayed delivery of data. Authors in [16] employ priority-oriented tree structured protocol for WBASNs. They use specific paths for critical data delivery and if it is successful, then normal data is put forward for transmission. However, frequent loss of accessible resources due to dedicated channels. Authors in [17] propose adaptive route selection based on remaining energy at the node. Dynamic route selection assurances equal load distribution on the nodes and extend the lifetime of the network.

The network topology design issues for WBANs are presented in [18], [19]. The first issue is that number of forwarder nodes in the topology and it must be predetermined. The second issue is that placement of forwarder node in architecture of WBAN. In addition, total network establishment expenditure is depends on relay nodes, since cost is another issue of the network topology.

From the observation of above routing protocols, the basic aim of a routing protocol is to maximize the network lifetime and minimize the energy by uniform distribution of load, such that energy utilization at every iteration is even. Single-hop communication causes increased load on distant nodes and multi-hop communication drains the battery power of nearer nodes quickly. However, some of deficiencies of routing above protocols are as follows:

- Deployment of bio-sensor nodes is not according to energy levels.
- Unbalanced energy of bio-sensor nodes results in of high data rate nodes quickly deplete energy than lower data rate nodes.
- Unbalanced energy consumption due to non-uniform load on the nodes causes reduction in stability period.
- There is no alternative route selection in case of dead nodes.

3. PROPOSED SYSTEM MODEL

In this proposed algorithm eight sensors and one sink are placed on the human body. The positioning of bio-sensor nodes and sink on patient body is shown in Figure-2(a). The proposed protocol employs two paths for transmission from bio-sensor nodes to the sink. These paths are shown in Figure-2(b).

The first path is employed for emergency (ECG and heart rate) data. The second path is utilized for remaining bio-sensor data transmissions, in which the data is transmitted via a less number of bio-sensors. First path results in increased load on faraway nodes and second path leads nearer nodes quickly consume their battery energy. These deficiencies are already addressed by SIMPLE and ATTEMPT protocols in [20]. Almost SIMPLE and ATTEMPT followed the same protocol I. In both the protocols for selection of forwarder node the authors followed Minimum hop-cunt in that path or residual energy of a particular node.

Protocol I
Forwarder selection
In each round
For each node
Calculate Hop_count
For (i=0; i<n; i++)
if (Hop_Count(i)<Hop_Count(i+1))
select node(i)=forwarder node
else
if(S(i).E>S(i+1).E)
select node(i)=forwarder node
else
i=i+1
select node(i)=forwarder
endif
endif

But still SIMPLE and ATTEMPT are having deficiencies [21]. To address these deficiencies, we presented protocol II in this paper. This protocol is extends the network lifetime, residual energy and reduces path loss of overall network. In protocol II for selection of forwarder node, we employed forwarder function which is based on distance of the node and the residual energy of the node. Several number of radio models are presented in literature. We use basic 1st order radio model used in this paper. In this model, d is the distance from sender to the receiver and $d^2$ energy loss from the channel. The 1st order radio model is characterized in (1) and (2) are given as.

\[
E_f(p,d) = E_{f\text{-elec}}(p) + E_{f\text{-amp}}(p,d) \\
E_f(p,d) = E_{\text{elec}} x (p) + E_{\text{amp}} x p d^2 \\
E_g(k) = E_{g\text{-elec}}(K) E_{g\text{-amp}}(K) = E_{\text{elec}} x p \\
E_g(p) = E_{g\text{-elec}}(p) E_{g\text{-amp}}(p) = E_{\text{elec}} x p \\
E_g(p) = E_{\text{elec}} x p
\]
Where $E_T$ is the transmitter energy consumption, $E_R$ is the receiver energy consumption, $E_{T\text{,elec}}$ is the transmitter electronic circuit energy and $E_{R\text{,elec}}$ is the receiver electronic circuit energy, $E_{\text{amp}}$ is the required energy for amplifier circuit and $p$ is the size of packet. In WBSN, human body is the communication channel which leads to attenuation of radio signal. So, we add path loss coefficient (n) parameter in radio model of transmitter can be rewritten as in (3).

$$E_T(p,d) = E_{\text{elec}} x (p) + E_{\text{amp}} x p d^n$$  \hspace{1cm} (3)

In Equation (3) based on the hardware, the energy parameters may be varied. We considered two most frequently use hardware transceivers in WBBSNs.

**Protocol II**

Forwarder selection

For each node

Calculate Forwarder function (i)= $1/(S(i).E^2 \times \text{distance}(i))$

For (i=0; i<n; i++)

if (Forwarder function(i) >min Val && S(i)>Threshold Energy)

select node(i) =forwarder node

else

Direct transmission to sink

endif

**4. PERFORMANCE ANALYSIS**

The performance analysis of SIMPLE, ATTEMPT and the proposed IM-REAST are performed at the 2.4 GHz frequency (IEEE 802.15.4) on body bio-sensor set-up. The simulated results of these protocols performance are compared in terms of stability of network, residual energy, packet received at sink and path loss. The network topology shown in Figure-2 and radio link parameters used for simulation by considering of collision-free channel are shown in Table-1 are used for the simulation. The network is simulated for $10^4$ iterations.

<table>
<thead>
<tr>
<th>Link Parameter</th>
<th>nRF 2401A</th>
<th>CC2420</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmitter current</td>
<td>$10.5 \times 10^{-3}$ A</td>
<td>$17.4 \times 10^{-3}$ A</td>
</tr>
<tr>
<td>Receiver current</td>
<td>$18 \times 10^{-3}$ A</td>
<td>$19.7 \times 10^{-3}$ A</td>
</tr>
<tr>
<td>$E_{T\text{,elec}}$</td>
<td>$16.7 \text{ nJ/bit}$</td>
<td>$96.9 \text{ nJ/bit}$</td>
</tr>
<tr>
<td>$E_{R\text{,elec}}$</td>
<td>$36.1 \text{ nJ/bit}$</td>
<td>$172.8 \text{ nJ/bit}$</td>
</tr>
<tr>
<td>$E_{\text{amp}}$</td>
<td>$1.97 \times 10^{-9}$ j/b</td>
<td>$2.71 \times 10^{-7}$ j/b</td>
</tr>
</tbody>
</table>

The performance evaluation of proposed IM-REAST is compared with SIMPLE and ATTEMPT protocol with the help of MATLAB simulations. We considered $6 \times 2.5$ feet network area for deployment of network topology, where wearable bio-sensor nodes are deployed at immobile places and which are initially energized with 0.4Joules and sink is deployed at centre of the human body. The number of iterations required for first node death after establishment of network is known as network stability period. Here span is presented in terms of iterations and in single iteration the protocol operation is completed once. First bio-sensor node death occurs at $0.23 \times 10^4$ iterations in SIMPLE, at $0.35 \times 10^4$ iterations in ATTEMPT and in IM-REAST after $0.615 \times 10^4$ iterations. Similarly, initialization of the network to the death of all nodes is the network lifetime is shown in Figure-3. More than half the network lifetime period the IM-REAST is stable as compared with SIMPLE and ATTEMPT.
Figure-3. Comparison of Stability periods of SIMPLE, ATTEMPT and IM-REAST.

Figure-4 shows the throughput of IM-REAST as related with SIMPLE and ATTEMPT protocol. This throughput in IM-REAST protocol somewhat reduces due to even load distribution and optimized energy of the biosensor nodes. Numerically, the throughputs of SIMPLE and ATTEMPT is $4 \times 10^4$ while that of IM-REAST is about $2.9 \times 10^4$ respectively. But, which makes REAST is more reliable in terms of successful packet delivery in comparison with the SIMPLE and ATTEMPT protocol due to proper scheduling.

The non-uniform of energy distribution in SIMPLE and ATTEMPT may results forwarder nodes consume more energy. This deficiency in IM-REAST avoided by unnecessary multi-hopping of data hence it is having uniform energy distribution. Numerically, at half of the network lifetime the residual energy in IM-REAST
approximately double compared with SIMPLE and ATTEMPT. The comparison of residual energy for SIMPLE and ATTEMPT and IM-REAST protocols are depicted in Figure-5.

The attenuation of every path is a function of frequency and distance \(d\) and is given by (4). The attenuation of bio-sensor node is computed form its distance from sink by keeping the wavelength is constant. For simulation of path loss, human body path loss coefficient is 3.38 is considered with 4.1 as the standard deviation. This protocol is having stable and less path loss as comparison with the SIMPLE and ATTEMPT protocol and is shown in Figure-6.

\[
PL = PL_0 + 10 \log_{10}(d/d_0) + \sigma_s
\]  
(4)

Figure-5. Comparison of residual energy of SIMPLE, ATTEMPT and IM-REAST.

Figure-6. Comparison of Path loss of SIMPLE, ATTEMPT and IM-REAST.
The overall performance comparison of proposed IM-REAST, SIMPLE and ATTEMPT are shown in Table-2.

Table-2. Overall performance comparison of SIMPLE, ATTEMPT and IM-REAST protocols.

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Network Stability(i)</th>
<th>Throughput (Packet/i)</th>
<th>Residual Energy(J)</th>
<th>Path loss(dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIMPLE</td>
<td>0.23x10^4</td>
<td>4x10^4</td>
<td>.75</td>
<td>275</td>
</tr>
<tr>
<td>ATTEMPT</td>
<td>0.35x10^4</td>
<td>4x10^4</td>
<td>.75</td>
<td>375</td>
</tr>
<tr>
<td>IM-REAST</td>
<td>0.61x10^4</td>
<td>2.9x10^4</td>
<td>1.5</td>
<td>275</td>
</tr>
</tbody>
</table>

5. CONCLUSIONS
For heterogeneous WBBSNs, we presented an improved reliable energy aware and stable topology. In this topology we deployed eight bio-sensors for monitoring patient health conditions and one sink for collecting the data from these sensors. Out of these eight sensors two are for demand data transmission and remaining six sensors for normal data transfer. For communication between sink and sensor nodes we employed mixed mode communications. In mixed mode communication the forwarder node selection decides the energy consumption and the network stability. In this paper we presented new approach for selection of forwarder node. In this approach, we considered forwarder function and residual energy of the bio-sensor node to elect a node as a forwarder. This makes transmission to be successful by optimizing the energy consumption of the overall network. The improvement in performance of network is computed based several parameters such as dead nodes, residual energy, packets received at sink and path loss. The MATLAB simulation results show that improvement of the overall network performance by 25% as compared with SIMPLE and ATTEMPT protocols. Still there is a research scope to improve the network performance by considering mobility and hot-spot detection of bio-sensor nodes.

REFERENCES


