Temperature aware variable time-slot assignment priority-based routing algorithm for WBANs in IoT based eHealthcare systems

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Abstract. The wireless body area networks are an integral part of the Internet of Things for eHealthcare applications. These networks suffer from two major problems such as energy consumption and lifetime of the overall network. To address these problems, a temperature aware priority-based routing algorithm for WBANs is proposed. This algorithm employs temperature aware routing, priority-based routing, and variable time-slot assignment. The temperature-aware routing enhances the stability of the overall network by providing an alternate route. The priority-based routing facilitates reliable data transmission among the sink and the sensor nodes which will enhance the lifetime of the overall network. The variable time-slot assignment in the scheduling phase prevents the collisions by employing a new synchronization scheme which will minimize overall network energy consumption. The performance proposed algorithm was analyzed with three network parameters and the results showed improved performance as compared with the traditional routing protocols

Keyword: Variable time-slot assignment, Internet of Things, Priority-based routing, Temperature aware, eHealthcare.

1. Introduction
The Internet of Things (IoT) is a network of interconnected objects or devices that are supervised or controlled through the internet. Wireless sensor networks (WSN) includes a series of sensor nodes spread around a wider area. Which monitor and store environmental and device information for different applications. The applications of WSNs include weather monitoring, emergency mitigation, object tracking, biomedical systems [1]. IoT functions in a wider context analogous to a brain, which is responsible for data acquisition, storage, retrieval, interpretation, and decision-making. Through utilizing WSN, IoT links the real world digitally [2]. In addition, WSN is often responsible for the dissemination of monitored knowledge to the Public. However, sensor nodes have limited battery
energy, which require heavy processing, and computing to extract the required data from the internet. Therefore, a range of operational, transmission, and resource restrictions; these restrictions must be optimized [3]. These restrictions limit the overall network lifetime and the cumulative path energy expended must be reduced by using an optimal route to maximize the network lifetime in WSN. Wireless Body Area Networks (WBANs) is a subdivision of the WSN. In which small bio-sensor nodes deployed on the human body to track various physical conditions. The applications of WBANs include Electronic healthcare (ehealthcare) and wellness tracking, sports, culture, bio-medical and IoT applications. It must, therefore, conquer a range of difficulties such as connectivity, safety, the lifetime of the network, and resource efficiency [4].

2. Related Work
The WBANs primarily focus on two significant elements including reducing power usage and extending the lifetime of the network. WBANs characteristics vary based on the transmission energy limitations, propagation medium, and human organ/tissue security requirements from traditional wireless communication systems [5]. For enhancing the quality of human lives, health IoT is one of the most promising methods. This is achieved by monitoring healthcare and remote telemedicine support systems, which enable data collection, communication, and visualization through the internet in real-time. The first global standard for wireless transmission is developed by the Institute of IEEE 802.15.6 task group that optimizes energy usage and offers security for healthcare and non-healthcare systems in or around the patient body [6]. The idea of telemedicine under the health IoT has shifted from remote medicine to personalized universal healthcare on the move. Concerning home or hospital Medicare surveillance situations, wireless implanted Medicare surveillance equipment considerably enhances patient convenience and mobility in contrast to wired healthcare systems. Radio Frequency can cover enhanced operating distances and allow wireless communication with on-body devices by interactive implanted sensors and devices [7].

Besides, enhancing Radio Frequency modules energy efficiency is a main aspect in the in-to-out body channel owing to the practical limitations of batteries and can be achieved by employing miniaturized embedded transceivers. The wireless routing protocols were established for the discovery and testing of the most energy-efficient path. The relay node approach leads to the minimized energy utilization of the implanted sensor nodes by selecting the shortest route. A two-relay node approach trade-off with reliable transmission and energy efficiency as contrasted to the single relay approach and direct transmission. Two-way communication technique mainly focuses on wireless fading channels to get significant attention to improve spatial diversity and energy efficiency [8].

3. Proposed Algorithm for WBANs
In this paper, a proposed Temperature aware variable time-slot assignment priority-based routing algorithm (TA-VTSA-PBR) for WBANs is proposed. For deployment of sensor nodes and data transmission, the ehealthcare architecture including WBANs is illustrated in Fig.1. Eight sensors nodes are fixed on the patient's body, two sensor nodes are in proximity to the sink which gathers on-demand data with negligible loss. The rest of the sensor’s nodes are far proximity to the sink which gathers normal data from the various parts of the patient's body. This algorithm uses priority-based routing (PBR), variable time-slot assignment (VTSA) and temperature aware routing. The PBR facilitates reliable data transmission among the sink and the sensor nodes which will enhance the lifetime of the overall network. The VTSA in the scheduling phase prevents the collisions by employing a new synchronization scheme which will minimize overall network energy consumption. The temperature-aware (TA) routing enhances the stability of the overall network by providing an alternate route. The proposed algorithm involves four stages: such as the initial, routing, scheduling, and data transmission stages. The proposed algorithm is concentrated on the routing stage and scheduling stage. In the routing stage, a priority-based routing and in the scheduling stage variable time slot assignment are employed. Following pseudo code explains the route selection according to the priority of the sensor by considering...
the distance, residue energy, temperature, and the hop count within that route. The notation used for the pseudo-code is presented in Table 1.

```
for (i=1, i<n, i++)
if (dr_i < dr_i+1) then
    dr_i = optimal route
else
    dr_i+1 = optimal route
endif
if ( Tr_i< Tr_i+1) then
    dr_i = optimal route
else
    dr_i+1 = optimal route
endif
if ( HCr_i < HCr_i+1) then
    dv estimation & timeslot assignment
else
    dr_i+1 = optimal route
    dv estimation & timeslot assignment
endif
```

**Figure 1.** The priority-based routing algorithm for ehealthcare systems

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**Route selection Algorithm**

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For (i=1, i<n, i++)
if (dr_i < dr_i+1) then
    dr_i = optimal route
else
    dr_i+1 = optimal route
endif
if ( Tr_i< Tr_i+1) then
    dr_i = optimal route
else
    dr_i+1 = optimal route
endif
if ( HCr_i < HCr_i+1) then
    dv estimation & timeslot assignment
else
    dr_i+1 = optimal route
    dv estimation & timeslot assignment
endif

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Table 1. List of notations

| Parameter | Value |
|-----------|-------|
| n         | Number of sensor nodes |
| i         | Varies from 1 to n |
| dr_i      | distance for route i |
| dr_{i+1}  | distance for route i+1 |
| Tr_i      | Temperature at route i |
| Tr_{i+1}  | Temperature at route i+1 |
| HCr_i     | Hop-count of route i |
| HCr_{i+1} | Hop-count of route i+1 |
| dv        | Drift value |

4. Results and Discussions

For validation of the TA-VTSA-PBR, its simulation results are compared with traditional protocols such as REAST [11], SIMPLE [9], ATTEMPT [10] protocols. The 6 × 2.5 feet network area considered for the simulation within this area according to Table 2 coordinates all sensor nodes and the sink is positioned on the patient’s body with 400mJ of the initial energy. The radio transceiver parameters are shown in Table 2. The overall network is simulated in terms of rounds of about 10 thousand epochs.

Table 2. nRF24L01 Simulation Parameters

| Parameter      | Value | Units |
|----------------|-------|-------|
| Transmission Current | 10.5  | mA    |
| Reception Current       | 18    | mA    |
| Supply Voltage          | 1.9   | V     |
| ETx-Ele                  | 16.7  | nJ/bit |
| Eamp                     | 1.97  | nJ/bit/min |
| ERx-ele                  | 36.1  | nJ/bit |

**Stability period:** The stability of the network is defined as the rounds needed for first node death after the establishment of a network. In SIMPLE [9] protocol, due to the distribution of unbalanced energy; nodes with high data rates are depleted quickly than lower data rate ones, hence the stability period is restricted to 3500 rounds. In ATTEMPT [10] protocol sensor nodes do not arrange according to the energy levels; hence, the stability period is restricted to 45000 rounds. In REAST [11] protocol, due to unbalanced load on the sensor nodes restricts its stability period up to 7900 rounds. The TA-VTSA-PBR protocol achieves a maximum stability period of about 9200 rounds, balanced energy distribution, and arranging sensor nodes according to their data rates shown in Fig.2.

**Pocket received rate:** The proposed TA-VTSA-PBR protocol achieves improved data transmission/reception rate with VTSA. The improvement of pocket received at the sink is shown in Fig. 3. Numerically, the packets received a rate of TA-VTSA-PBR is about 8.5x10⁴ bits/s, REAST, SIMPLE and ATTEMPT are approximately 4x10⁴ bits/s. The TA-VTSA-PBR provides more reliable communication and efficient pocket delivery among the sensor nodes and the sink as a comparison with traditional protocols.

**Residual Energy:** The proposed PBR-VTSA protocol the periodic sleep mode minimizes utilization of the energy by avoiding inactive hearing. Further, energy utilization is minimized by integrating PBR and VTSA in the proposed algorithm. The TA-VTSA-PBR and ATTEMPT protocols have sufficient energy after simulation of 5000 rounds, but in the case of REAST and SIMPLE protocols, almost every sensor is depleted its energy as shown in Fig. 4. This depletion is mainly due to the non-uniform energy distribution unnecessary multi-hopping.
Figure 2. Rounds versus Number of dead nodes

Figure 3. Rounds versus packets received at the sink

Figure 4. Rounds versus residual energy
5. Conclusion
In this paper, a TA-VTSA-PBR algorithm is presented to achieve energy efficiency in WBANs that can support the IoT framework. This algorithm is simulated for $10^4$ rounds with four WBANs constraints such as network lifetime, data transmission rate, and residual energy. The simulation results clearly illustrate that the proposed algorithm enhances network lifetime by about 25%, the data transmission rate is about 12%, and the residual energy is about 10%. Finally, the overall network performance of the proposed method is 13% more efficient than traditional methods. The temperature aware routing will minimize the ration effects on the patient body. This study can even be expanded with the introduction of IoT to multiple WBANs in an ehealthcare applications.

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