



Improved Energy-Based Temperature Aware Routing Protocol (IE-TARP) for Wireless Body Area Network (WBAN)

¹Abdulrasaq Rakiyat Oluwatoyin, ²Evans C. Ashigwuike, ³Ibrahim Abdulkareem Bebeji

^{1&2}Department of Electrical and Electronics Engineering, University of Abuja,

³National Space Research and Development Agency, Abuja

ABSTRACT

This research presented the development of an Improved Energy-Based Temperature Aware Routing Protocol (IE-TARP) for Wireless Body Area Network (WBAN) that considers the nodes current energy level, number of hops, current temperature and expected temperature rise as metrics for efficient choice of route. During communication in WBAN, increase in packet injection rate increases the temperature of nodes which leads to the reduction of packet delivery and low network lifetime because high temperature nodes are not considered for routing as they damage body tissue and reduce the performance of WBAN. In this research work, a routing protocol for Wireless Body Area Network (WBAN) was developed which is Improved Energy Temperature Aware Routing Protocol (IE-TARP) to enhance WBAN performance using Packet Delivery Ratio, Network Lifetime and End-to-End delay as performance metrics. A WBAN consisting of 20 nodes was simulated using MATLAB to test the efficiency of the developed scheme (IE-TARP) in comparison with Hotspot Preventive Routing (HPR) protocol and Enhanced Temperature Aware Routing Protocol (ETARP) with the threshold temperature set as 410C (Celsius) and reactive energy threshold as 0.3J (Joules). From the Simulation result, the developed scheme IE-TARP packet delivery outperforms HPR and ETARP by 13.63% and 4.05% respectively. IE-TARP network lifetime outperforms HPR and ETARP by 28.44% and 7.10% respectively. IE-TARP end to end delay outperforms ETARP by 2.89% and HPR outperformed IE-TARP with a slight improvement of 0.59%.

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INTRODUCTION

Based on the report by the World Health Organization (WHO), Cardio Vascular Disease (CVD) is the prime cause of the deaths in the world (Samaher, Ibrahim, Mohammed, & Shamshirband, 2017). It is estimated that the number of CVD related deaths, mainly from heart disease and heart stroke will reach up to 23.3 million by 2030. Wireless Body Area Network (WBAN) is a network that is used for remotely monitoring the patient's health and gathering the related information from the embodied sensors (Samaher, Ibrahim, Mohammed, & Shamshirband, 2017). Health monitoring is the key focus of WBAN to check urgently needed data

like data about blood pressure, temperature level of the body, heart beating, increase or decrease of glucose level of the patient inside the hospital or maybe in the remote areas. Small nodes (sensor nodes) are deployed on the body or fitted inside the body. Advancement in WBAN for the better care of patient decreases the expenses much more for the patient inside the hospital (Bahrul, Najeeb, Sheeraz, Muhammad, & Abdul, 2017).

Communication in WBAN, from the nodes near the patient body or inner the body are complicated as compared to the other scenarios (where these node are not placed in or on the human body) because the human or patient body have a complex body parts within their own nature

Corresponding author: Abdulrasaq Rakiyat Oluwatoyin

✉ rakiyata@gmail.com

Department of Electrical and Electronics Engineering, University of Abuja.

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of conduction (Nadeem, Javaid, Mohammad, Khan, Sarfraz, & Gull, 2013). Due to the critical requirement of WBAN and in order to solve wide application of WBAN, it is needed to support low power consumption sensor nodes. High data rate schemes are required for better care and performance evaluation. Quality of Service (QoS) has the key role in WBAN environment (Attaphongse, Alberto, Matti, Jani, & Jari, 2008).

Due to the high demand of data packets needed in the WBAN technology, communication of packets consumes energy which results to increase in the temperature of sensor nodes. If the routing management in WBAN is efficient, energy consumption will be less and battery life will be long for this type of technology, that's when it will fulfill the requirements of WBAN applications (Attaphongse, Alberto, Matti, Jani, & Jari, 2008). Quality of Service (QoS) has a key role in WBAN and as such, recent works has been done on QoS. In any schemes or model developed for WBAN, the researchers give more attention to QoS of WBAN in order to ensure efficient operation (Attaphongse, Alberto, Matti, Jani, & Jari, 2008).

Wireless Body Area Network (WBAN) is a new trend in wireless technology that provides remote mechanism to monitor and collect patient's health data record using wearable sensor nodes and actuators. The sensor nodes are placed directly either on the body or under the skin of a person to compute and transmit certain body parameters. It is widely recognized that a high-level data delivery, network lifetime and low end-to-end delay play a key role in improving the performance of WBAN. Node temperature is another great concern to prevent damage of tissue by WBANs. The routing protocol affects the temperature of nodes as heat generated by these nodes is majorly due to increase in the packet injection rate of the system or energy dissipation during data transmission etc.

Some researchers proposed a new enhanced temperature aware routing protocol to assign the temperature of node by considering current temperature and expected rise caused by the packets in the buffer. This was done to improve the data delivery and network lifetime of these sensor nodes. However, node energy factor

which also affects the WBAN performance was not considered as a metric for route choice. Thus, a low temperature node route that is however made up of low energy sensor nodes may be selected in the routing path. This will reduce the performance of WBAN in data delivery, network lifetime and end-to-end delay.

This paper presents the development of Improved Energy –Based Temperature Aware Routing Protocol for WBAN that considers the nodes energy level, number of hops, number of packets in buffer, current temperature, and expected temperature rise will be used as metrics for the calculation of cost function. The route with minimum cost function and has nodes with energy beyond the threshold energy is considered an efficient route for packets.

RELATED WORKS

Over the last decade, several researches have been done on WBAN routing protocol in order to improve its performance and efficiency. (Bag & Bassiouni, 2008) presented a Hotspot Preventing Routing (HPR) algorithm that can be used for in-vivo biomedical sensor network. The algorithm helped to reduce the rise in temperature of the nodes in the network and hence prevented the formation of hotspots having extremely high temperature. This reduced the possibility of tissue damage due to overheating of embedded sensor nodes. In HPR algorithm, the nodes overheard the transmissions of the neighbors and the number of packets transmitted by the neighbor nodes within a certain interval of time. Based on that estimate, the nodes computed the change in temperature of the neighbor nodes in that time-interval. The sum of the change in temperature of a neighbor and its previously computed temperature gave the neighbor's current temperature. This helped the node to maintain updated temperature values of the neighbors. If it was above a certain threshold value, the packet was discarded.

Simulation results showed that the HPR algorithm was highly scalable, increased the operational life of the network and helped to reduce the number of packets dropped during communication. However, HPR algorithm was



based on current temperature, it cannot deal with rapid increase of temperature which naturally led to packet loss or long delay. In the HPR algorithm, temperature rise prediction was not possible. Hence two-hop ahead nodes might just be a hot spot node which led to a sudden change of route. It implied that more hops ahead algorithm might be required. This would further increase end-to-end delay transmission of packet.

Saha and Anvekar (2017) developed an efficient message routing approach through multiple hops and node classification so that energy consumed by individual sensors can be less. To enhance communication reliability in WBAN, the work proposed a scheme that classified transmitted data so that more security could be provided to the crucial messages compared to regular messages. The proposed poly hop message routing approach through node and data classification showed an improvement over conventional message transmission approach in WBAN. Also, the proposed hybrid security protocol reduced the overhead imposed by asymmetric encryption. The poly hop approach provided comparatively better results in terms of energy consumption, packet drop rate and thereby improved the overall reliability of WBAN communication.

The proposed protocol, at the first stage, performed encryption for messages transmitted between the sensor and mobile device. Encryption was achieved by using simple XOR and NOT operations along with a predefined key at the sensor. The process of encryption and initialization of logic scheme required a lot of mathematical processes that required high sensor node processing which led to an increase in the node temperature. This made these nodes unqualified to participate in routing process because its temperature is higher than the level of temperature that sensor nodes in WBAN can accommodate. This increased temperature of nodes would reduce the packet delivery rate of data in WBAN as only non-high temperature (below the acceptable body threshold) nodes were usable in WBAN technology.

Ahmed, Danish, and Saful (2019) developed a thermal and energy-aware routing

protocol for Wireless Body Area Networks (WBANs) to address the dual challenge of managing energy consumption and temperature rise in sensor nodes. The proposed protocol ensured that the energy consumption of nodes was minimized, and the temperature was maintained within acceptable levels by utilizing thermal-aware mechanisms. This contributed to enhancing the network's lifetime and reducing potential tissue damage caused by overheating. However, the protocol's limitation lay in its inability to handle real-time dynamic changes in node temperature and energy levels, which could lead to increased delay and packet drops in scenarios with high mobility or sudden workload surges.

Jaimal, Muhammad, Rashid, and Dohyeun (2019) introduced an adaptive thermal-aware routing protocol for WBANs that aimed to balance energy consumption while maintaining thermal safety. The protocol adapted dynamically to network conditions, ensuring efficient energy usage and avoiding hotspots through real-time monitoring and route adjustments. It demonstrated improved throughput and reduced packet loss compared to conventional thermal-unaware protocols. Nevertheless, the frequent adjustments in routing to adapt to dynamic conditions increased computational complexity and processing delays, which contributed to higher energy consumption and reduced overall efficiency in energy-constrained environments.

Beom-Su, Ki-Il, and Babar (2018) developed a new Enhanced Temperature Aware Routing Protocol (ETARP) to assign the temperature of node by considering current temperature and expected rise caused by the packets in the buffer. To overcome the problem of single hop exchange, two hops ahead algorithms were implemented while considering short distance between each sensor node and sink. The ETARP employed temperature rise prediction as cost and two hops ahead scheme. While the former was used to measure the impact of further communications on the node, the latter was used to ensure forwarding, where hot spot high temperature node above a given threshold was far from two hops. ETARP was performed by constructing temporary nodes set S_i which

included one hop neighbor nodes with temperature lower than threshold. If this set was empty or only one element existed, the next hop was selected to be the lowest temperature node.

Otherwise, a packet was forwarded to the next hop which was selected according to the weight of node's temperature. Simulation results showed that ETARP led to short end-to-end delay and high packet delivery ratio. The use of the two hops ahead algorithm as a process for route selection led to uneven energy distribution amongst the node as only a node with minimum temperature was considered in the routing process. This was because a high temperature (almost equal to the temperature threshold) node at an instant might just have enough energy to sustain the network which could have resulted to longer network lifetime. The ETARP selected a minimum temperature (far below the threshold) part not minding if the sensor nodes on that part had the energy to sustain packet transmission. Due to this drawback, the general performance of ETARP in terms of packet delivery ratio and network lifetime was degraded.

From the reviewed literatures, it was observed that all the researchers focused on improving the performance of WBAN by either improving the packet delivery rate and not taking note of the node temperatures or putting more emphases on the node temperature/energy and not taking note of nodes throughput/end-to-end delay. These tradeoffs mitigate the performance of WBAN. In order to further improve the performance of WBAN, an Improved Energy-Based Temperature Aware Routing Protocol (IE-TARP) for WBAN is developed. A cost function that considers the nodes energy level, number of hops, packet delivery, current temperature, and expected temperature rise will be used as metrics for the calculation of the efficient route with minimum cost in the WBAN.

Temperature-Based Routing Protocol

During communication in WBAN, radio signals are generated by invasive or non-invasive sensors which raise the overall temperature of the human body that usually results in sensitive tissue

damage if it is above Specific Absorption Rate (SAR) or temperature threshold.

$$SAR = \frac{\sigma |E|^2}{\rho} \left(\frac{W}{Kg} \right) \quad (2.1)$$

where:

σ is the tissue conductivity

E is the induced electric field

ρ is the density of the tissue

The ETARP technique from the work of (Beom-Su, Ki-Il, & Babar, 2018), takes into consideration the current temperature as well as temperature rise caused by transmission of packets in the buffer. The temperature of a node i is calculated using equation (2.2).

$$T_i = Cur_T_i + Exp_T_i \quad (2.2)$$

where:

T_i is the temperature of node i

Cur_T_i is the current temperature of node i

Exp_T_i is the expected temperature rise of node i

The expected temperature is given by (Beom-Su, Ki-Il, & Babar, 2018):

$$Exp_T = Num_Trans \times Avg_Temp_Rise_pkt_i \quad (2.3)$$

where:

Num_Trans is the total number of packets transmitted

$Avg_Temp_Rise_pkt_i$ is the average measured temperature rise for each packet

The total number of packets transmitted is given by (Beom-Su, Ki-Il, & Babar, 2018):

$$Num_Trans = (no_pks_bf_i + no_pks_bf_i \times Retrans_Prob_i) \quad (2.4)$$

where:

no_pks_bf is the sum of packets in the buffer

$Retrans_Prob_i$ is the transmission probability of node i

The temperature threshold that qualifies a node to participate in the routing process is given as (Beom-Su, Ki-Il, & Babar, 2018):

$$Th = 0.5 \times C1 \times C2 \quad (2.5)$$

where:

$C1$ is a component which is a function of the average temperature of the neighbor nodes

$C2$ is a component which is a function of the node's own temperature.

The proposed algorithm will use a reactive energy threshold as a metric for route choice. The model equation for the reactive energy threshold value is given as:

$$E_{th,t} = Avg_{RE} - Net \quad (2.6)$$

The reactive energy threshold value will enable the network to only evaluate the average energy of nodes in the network at an instant of transmission by a source node S_i .

where:

$Avg_{RE} - Net$ is the current average network energy at time t_i

$$Avg_{RE} = \frac{E_1 + E_2 + E_3 + \dots + E_i + \dots + E_N}{N} \quad (2.7)$$

t_i is the current transmission time of source node S_i

N is the maximum number of nodes.

E_i is the current energy of node i

E_N is the current energy of last evaluated node

The model equation for the cost function of the proposed algorithm will be given by:

$$C_i = \left[(Cur - T_i + Exp - T_i), Cur - E_{th,t} \right] \quad (2.8)$$

where:

$Cur - E_{th,t}$ is the current energy threshold value of the network at time t_i

MATERIAL AND METHODS

This section describes the detailed procedures and methods that were employed for the successful completion of this research. The list

of materials that were used in this research includes:

1. MATLAB 2020b
2. Laptop (hp Intel (R) Core (TM) i5-2520M CPU)

The steps of the methodology that was adopted for this research, towards the development of an Improved Energy-Based Temperature Aware Routing Protocol (IE-TARP) for WBAN is given below:

1. The following steps will be adopted in the replication of enhanced temperature aware routing protocol in WBAN
 - a. Initializing temporary node set S_i
 - b. Evaluating node temperature threshold
 - c. Nodes exchange information about their current temperature
 - d. Predicting temperature rise with packets in the buffer where hot temperature node is excluded
 - e. Nodes exchange expected temperature information and take into account temperature rise caused by transmission of packets in the buffer.
 - f. Forwarding packet to the next hop which is selected according to the weight of node's temperature W_i .
2. The following step will be adopted in the development of the proposed Improved Energy-Based Temperature Aware Routing Protocol (IE-TARP) for WBAN
 - a. Repeating steps (a) and (b) of methodology 1
 - b. Evaluating each node energy threshold
 - c. Nodes exchange information about their current temperature and energy status
 - d. Predicting temperature rise with packets in the buffer where hot temperature node is excluded
 - e. Nodes exchange expected temperature information and take into account temperature rise and possible energy depletion caused

- by transmission of packets in the buffer.
- f. Forwarding packet to the next hop which is selected according to the weight of node's temperature W_i and energy E_i

The flowchart for the developed IE-TARP algorithm is given in Figure 3.1. The simulation parameters are also given in table 3.1. The pseudo code for the node energy and temperature information sharing for eligibility during transmission is given as follows:

BEGIN: PSEUDO CODE F

Input:

$N \rightarrow$ Total number of nodes in the network
 $T_{\text{ambient}} \rightarrow$ Ambient body temperature (e.g., 37°C)
 $T_{\text{max}} \rightarrow$ Maximum allowable node temperature
 $E_{\text{th}} \rightarrow$ Energy threshold computed from network's average energy
 Each node i has:
 $E_i \rightarrow$ Current energy level of node i
 $T_i \rightarrow$ Current temperature of node i
 $P_{\text{tx}_i} \rightarrow$ Transmission power of node i
 $T_{\text{tx}_i} \rightarrow$ Transmission duration of node i

Output:

Updated status of nodes (safe/unsafe for transmission)

Steps:

1. Initialize network and set threshold values $\{T_{\text{max}}\}$ and $\{E_{\text{th}}\}$.
2. For each node $\{S_i\}$ in the network:
 - a. Retrieve current energy level $\{E_i\}$.
 - b. Compute updated energy level after recent transmission:

$$\{E_i(t) = E_i(0) - \sum_{j=1}^n P_{\text{tx}_j} \cdot T_{\text{tx}_j} - \sum_{k=1}^n P_{\text{rx}_k} \cdot T_{\text{rx}_k}\}$$
 - c. Compute temperature rise due to recent transmissions:

$$\{T_i(t) = T_{\text{ambient}} + \alpha \sum_{j=1}^n P_{\text{tx}_j} \cdot T_{\text{tx}_j}\}$$

d. Broadcast $\{(E_i, T_i)\}$ to all neighboring nodes.

3. Each node receives information from its neighbors.

4. Determine node status:

a. If $\{E_i > E_{\text{th}}\}$ AND $\{T_i \leq T_{\text{max}}\}$, then:

- Node is **SAFE** for data transmission.

b. Else:

- Node is **UNSAFE** and temporarily excluded from forwarding packets.

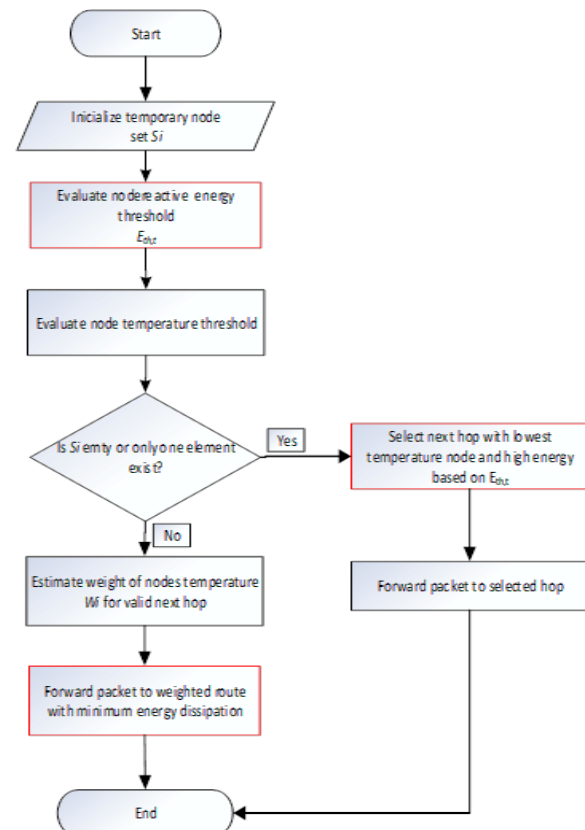


Figure 3.1: Flowchart of the Developed IE-TARP Algorithm

The flowchart in Figure 3.1 represents the decision-making process in the Improved Energy-Based Temperature Aware Routing Protocol (IE-TARP) for Wireless Body Area Networks (WBANs). It ensures efficient packet

forwarding while considering both node energy and temperature constraints, thereby preventing node overheating and excessive energy depletion. The process begins with the initialization of a temporary node set S_i , which includes nodes available for packet forwarding. Following initialization, the algorithm evaluates the reactive energy threshold E_{th} to determine the minimum energy required for participation in the routing process. Simultaneously, the temperature threshold of nodes is assessed to ensure that overheated nodes are excluded from transmission.

At the next decision-making step, the algorithm checks if S_i is empty or contains only one element. If this condition is met, the algorithm directly selects the next hop with the lowest temperature and highest energy, ensuring that the packet is forwarded through a stable and energy-

efficient node. Once the optimal next hop is identified, the packet is forwarded to that node. However, if the node set S_i contains multiple elements, the algorithm proceeds to estimate the weight W_i of each node based on its temperature and energy status. A weighted routing decision is made, prioritizing nodes that contribute to minimum energy dissipation while maintaining safe operating temperatures. The packet is then forwarded to the best route based on this weighted selection. The flowchart efficiently integrates energy and temperature awareness in routing decisions, ensuring optimized data transmission, prolonged network lifespan, and prevention of node overheating. The use of threshold evaluation, node weight estimation, and selective forwarding helps improve the reliability and efficiency of WBAN communication networks.

Table 3.1: Simulation Parameters

Parameter	Value / Description
Simulation Tool	MATLAB
Packet Size	32 bytes (payload)
Packet Generation Interval	0.5 seconds
Beacon Message Interval	1 second
Sink Node Location	Center of the body
Number of Sensor Nodes	20
Node Placement	Grid-based, considering density
Routing Protocols Compared	Improved Energy-Based Temperature Aware Routing Protocol (IE-TARP) vs. Hotspot Preventing Routing (HPR)
Performance Metrics	Packet Delivery Ratio (PDR), End-to-End Delay, Network Lifetime

RESULTS AND DISCUSSIONS

This section discusses the results obtained by achieving the set objectives of this study. Here, simulation was carried out in MATLAB for HPR, ETARP and the developed IE-TARP protocols. Equations 4.1 were used to evaluate the percentage improvement of IE-TARP over other schemes. Key performance

metrics analyzed include packet delivery rates, network lifetime, and end-to-end delays under the three protocols. By analyzing these metrics, the simulation helps in determining the effectiveness of IE-TARP over HPR and ETARP in terms of energy efficiency, network reliability, and delay reduction.

$$\text{Percentage Improvement} = \frac{\text{Developed Scheme} - \text{Existing Scheme}}{\text{Existing Scheme}} \times 100 \quad (4.1)$$

PACKET DELIVERY RATIO (PDR)

Corresponding author: Abdulrasaq Rakiyat Oluwatoyin

✉ rakiyata@gmail.com

Department of Electrical and Electronics Engineering, University of Abuja.

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Figure 4.1 is a graph of packet delivery ratio over varying percent of sending nodes. It can be observed that the developed IE-TARP outperformed the other existing schemes ETARP and HPR with average improvement of 4.05 and 13.63 respectively as shown in table 4.1. The packet delivery ratio value in the table was gotten from the plot in Figure 4.1.

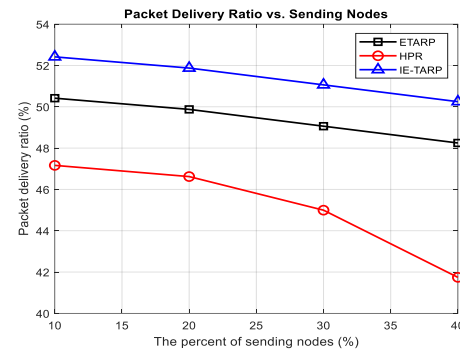


Figure 4.1: Packet Delivery Ratio for IE-TARP over HPR and ETARP

Table 4.1: Packet Delivery Ratio Percentage Improvement of IE-TARP over ETARP and HPR

Metrics	Percent of Sending Node	ETARP	HPR	IE-TARP	IE-TARP Improvement over ETARP (%)	IE-TARP Improvement over HPR (%)
Packet Delivery (%)	10	50.3	47.2	52.5	4.37	11.23
	15	50.1	47.0	52.1	3.99	10.85
	20	49.9	46.5	51.9	4.00	11.61
	25	49.6	45.9	51.5	3.83	12.20
	30	49.0	45.0	51.0	4.08	13.33
	35	48.6	43.4	50.5	3.91	16.36
	40	48.2	41.9	50.2	4.15	19.81
Average Percentage Improvement					4.05	13.63

NETWORK LIFETIME

Fig 4.2 is a graph of Network Lifetime over varying percent of sending nodes. It can be observed that the developed IE-TARP outperformed the other existing scheme ETARP and HPR with average improvement of 7.10 and 28.44 respectively as shown in table 4.2. The Network Lifetime in the table was gotten from the plot in Figure 4.2.

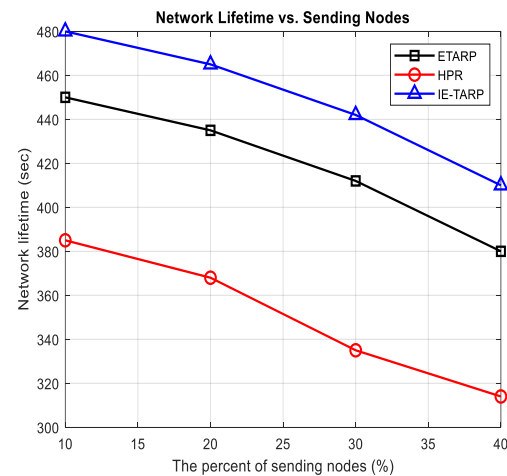


Fig 4.2: Network Lifetime for IE-TARP over HPR and ETARP

Table 4.2: Network Lifetime Percentage Improvement of IE-TARP over ETARP and HPR

Metrics	Percent of Sending Node	ETARP	HPR	IE-TARP	IE-TARP Improvement over ETARP (%)	IE-TARP Improvement over HPR (%)
Network Lifetime (%)	10	450	385	480	6.67	24.68
	15	442	376	473	7.01	25.80
	20	437	370	465	6.41	25.68
	25	425	350	454	6.82	29.71
	30	413	335	441	6.78	31.64
	35	395	325	427	8.10	31.39
	40	380	315	410	7.90	30.16
Average Percentage Improvement					7.10	28.44

END-TO-END DELAY

Fig 4.3 is a graph of end-to-end delay over varying percent of nodes. It can be observed that IE-TARP outperformed ETARP with average improvement of 2.89% and HPR outperformed IE-TARP with a slight improvement of 0.59% as shown in table 4.3. The end -to-end delay value was gotten from the plot in fig 4.3.

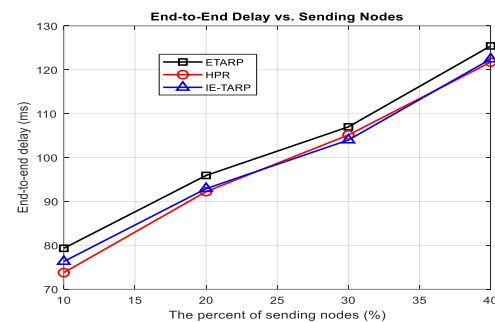


Fig 4.3: End-to-End delay for IE-TARP over HPR and ETARP

Table 4.3: End-to-End delay Percentage Improvement of IE-TARP over ETARP and HPR

Metrics	Percent of Sending Node	ETARP	HPR	IE-TARP	IE-TARP Improvement over ETARP (%)	IE-TARP Improvement over HPR (%)
End-to-End delay (%)	10	80	75	77	3.75	-2.67
	15	88	83	85	3.41	-2.41
	20	96	93	93	3.13	0
	25	102	99	99	2.94	0
	30	108	106	105	2.78	0.94
	35	116	113	113	2.59	0
	40	125	123	123	1.60	0
Average Percentage Improvement					2.89	0.59

From the Simulation result, the developed scheme IE-TARP exhibits:

1. Increase in Packet Delivery Ratio (PDR) than ETARP and HPR because IE-TARP ensures that the selected nodes used for routing are better suited to handle transmission without overheating or depleting their energy

too quickly to avoid retransmission unlike ETARP which routes data through nodes with just low temperature and HPR which uses hop count to determine routing path for packets.

2. Increase in Network Lifetime than ETARP and HPR because it prioritizes nodes with high energy levels and low

Corresponding author: Abdulrasaq Rakiyat Oluwatoyin

✉ rakiyata@gmail.com

Department of Electrical and Electronics Engineering, University of Abuja.

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temperature for routing thus preventing the use of a particular node repeatedly for data transmission which causes depletion of energy levels hence reducing the lifetime of the node.

3. Increase in End-to-End delay than ETARP because IE-TARP puts in consideration the nodes energy before selecting the routing path i.e. it selects node with energy sufficient to transmit packets from source to destination successfully without retransmission which reduces end-to-end delay. HPR demonstrated a very slight performance better than IE-TARP because it takes into consideration the hop count (shortest distance between source and destination) when choosing the routing path. Consequentially, as the percent of sending nodes increases, we can observe that the end-to-end delay of IE-TARP and HPR are similar in the sense that the routing path of HPR considers hop count and not node energy thereby a routing path might involve a node with insufficient energy which can lead to retransmission of packets causing increase in end-to-end delay.

CONCLUSION AND RECOMMENDATION

In this research work, a routing protocol for Wireless Body Area Network (WBAN) was developed which is Improved Energy Temperature Aware Routing Protocol (IE-TARP) to enhance WBAN performance using Packet Delivery Ratio, Network Lifetime and End-to-End delay as performance metrics. IE-TARP replicates ETARP to compute the node temperature using the packets in the buffer. IE-TARP uses two hops ahead algorithm to select nodes which have temperature less than threshold temperature and energy greater than reactive threshold energy. A WBAN consisting of 20 nodes was simulated using MATLAB to test the efficiency of the developed scheme (IE-TARP) in comparison with HPR and ETARP with the threshold temperature set as 41°C (Celsius) and reactive energy threshold as 0.3J (Joules). From the Simulation

result, the developed scheme IE-TARP exhibits: Increase in Packet Delivery Ratio (PDR) than ETARP and HPR, Increase in Network Lifetime than ETARP and HPR and Increase in End-to-End delay than ETARP but HPR demonstrated a very slight performance better than IE-TARP.

Wireless Body Area Network performance enhancement requires dealing with multiple Quality of Service (QoS) such as network lifetime, end-to-end delay, packet delivery ratio and so on. Hence, the routing decision must take into consideration multiple factors to have better QoS. Consequently, while the IETARP take into consideration the energy and temperature of the node, it could still be inadequate for some cases. Therefore, the following recommendations are made:

1. To develop and formulate a multi-factor routing algorithm that takes into consideration energy and temperature of the node as well as the hop count.
2. Data Security and Encryption techniques in Wireless Body Area Network.

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