THERMAL AWARE LINK ENERGY EFFICIENT SCHEME FOR BODY AREA NETWORKS

M. Javed¹, Asim Zeb², M. Shahzad³, Asif Nawaz⁴, Ahmed Ali Shah⁵
Naveed Jan⁶, Zeeshan Rasheed⁷, Atif Ishtiaq⁸, Sheeraz Ahmed⁹

¹,²Qurtuba University of Science and I.T, Peshawar, Pakistan
³Deptt of Electrical Engg, MNS University of Engg and Tech, Multan, Pakistan
⁴ETS, Higher Colleges of Technology, Dubai, UAE
⁵Deptt of Electrical Engg, Institute of Business Administration, Sukkur, Pakistan
⁶Deptt of Information Engg Tech, University of Technology, Nowshera, Pakistan
⁷Deptt of Computer Science, Mir Chakar Khan Rind University, Sibi, Pakistan
⁸,⁹Department of Computer Science, Iqra National University, Peshawar, Pakistan

Corresponding Author: Sheeraz Ahmed
Email: sheeraz.ahmad@inu.edu.pk

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Abstract

A daunting task in Wireless Body Area Networks (WBANs) is still to develop effective routing techniques. Small-sized nodes are installed on or within the human body to monitor human health conditions which then deliver the data to servers for analysis. During sensing and data transfer, biomedical sensors work continuously and the temperature of the nodes may rise beyond the threshold limit. This temperature rise may damage the human body issues as well as the routing mechanism in terms of path losses. To keep the temperature at its normal working value, a priority-based selection of routes is required to prevent data loss during transmission. This will ensure safe and accurate data delivery at the destination.

A protocol called "Thermal Aware Link Energy Efficient Scheme for WBANs" (TALEEBA) for workers is proposed to monitor the health of workers in factories. One of the four sinks will collect the data of the nearest worker in the field. As the body temperature of any worker is detected to rise, an alarm will be generated and the supervisor of the workplace will ask the worker to be replaced by some other worker. The same mechanism will continue till the task ends. Our proposed TALEEBA (Thermal Aware Link Energy Efficient Scheme for WBANs) scheme is aligned with current LAEEBA and THE-FAME WBAN schemes. In simulations, we analyze our protocol in terms of stability period, network lifetime, residual energy, a packet sent, packet dropped, and throughput. Hence, the results show stability and network life 50%, a packet sent 20% and throughput 23% are improved in comparison with LABEEA and THE-FAME protocols.

Keywords: Wireless Body Area Networks, Delay, Thermal aware.

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I. Introduction

Wireless Body Area Sensor Network is proposed to be implemented in 2001 [XX]. This incorporates various devices and network types with a more recent term. This allows for remote control of operations. The Healthcare monitoring system is the best example of WBASN [XVI], which can be seen in Figure 1. Small-sized sensors in a WBASN can be invasive or no-invasive. Invasive means that these sensors can insert into the human body while non-invasive means that these sensors are placed on the human skin. A person’s physiological parameters can be recorded during any particular activity by these devices without disturbing a person’s activity. With the help of these devices the following monitoring can be done:

1. A patient’s blood pressure, heartbeat, temperature, etc. can be monitored during daily routine works without any disturbance or giving trouble to a person [VIII].
2. During a game a player may be observed.
3. A soldier's safety can be noticed on the battlefield or during the training session.

![Figure 1: Structure of Wireless Body Area Sensor Networks in health care.](image)

WBASNs can track the physiological parameters continuously. For this purpose, WBASNs has been designed to be easily applied around the human body, without disturbing a person. The sensors can do sensing, processing and communication [XXIII]. The function of sense is to monitor or sense the parameter with the help of the sensors.

Design issues for WBAN routing protocol

The IEEE 802.15 task force formed a TG6 committee for WBAN in 2007 to research the uniformity of WBAN technology. IEEE802.15.6, the world's first proposed WBAN standard, was officially released in 2012. This standard of formulation also allowed WBAN to evolve rapidly. WBAN technology is basically applied to human bodies, and it has a very complex network framework. As the physiological data gathered have a direct impact on human health and life, it is very

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important to design routing for the body area network. The following issues and difficulties in routing architecture need to be discussed based on the above review [I].

- **Stability Period**
  Duration begins with the initialization of the network and lasts until the death of the first node in the network is called the stability period.

- **Throughput**
  The throughput is the number of packets received successfully per unit time at the sink.

- **Bandwidth**
  Bandwidth is calculated as the amount of data that can be transmitted within a network from one point to another in a specified amount of time.

- **Network lifetime**
  The time starting with the initialization of the network and ending the last node in the network is called the network lifetime.

- **Path loss**
  The difference between energy consumption to transmit and receive data is referred to as path loss.

### II. Literature review

A large number of routing schemes has been proposed for WBAN in literature. These routing protocols can also be categorized as single-hop or multi-hop communication protocols. In WSN, single-hop communication is applied where central management is crucial. Whereas, in WBAN, it provides poor results, as the energy-limited sensors are over-burdened due to the transferring of data to a far-off sink, which exhausts the nodes earlier. Multi-hop communication, in comparison to single-hop, is considered more favorable in scenarios of WBANs, because on-body sensors transmit information to the relay node(s) which, then transmit data to the external network for monitoring purposes. Hence, reduces the distance traveled by the data and reduces the energy consumption of the nodes. In this section, we present some proposed routing protocols for WBAN.

In paper [III], a routing protocol is proposed named Link-aware and Energy Efficient Scheme for Body Area Networks. The major parameters of LAEEBA are more throughput, reliability and path loss efficiency. The lifetime of single-hop and multi-hop communication networks is increased and the effects of path-loss are minimized. The selection of the forwarder node is made using two main factors (less distance to sink and residual energy). In paper [IV], a suggested scheme is introduced called THreshold based Energy-efficient FAatigue MEasurement (THE-FAME). In this protocol, more than one parameter is used to observe the accumulation of lactic acid and covered distance for a specific player. A player is to become in fatigue condition when the value of any parameter is greater than the threshold. Another routing protocol is presented in paper [XIII] called Mobility-supporting Adaptive Threshold-based Thermal-aware Energy-efficient Multi-hop Protocol (M-ATTEMPT). Direct communication is used for sensitive data, and multi-hop is implemented in normal delivery. Basically, it is a thermal aware protocol, which monitors the hot-spot links and switches the packets to other links and keeps away the data from these links.

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The key objective parameters of this protocol are to reduce energy depletion and enhance network lifetime.

In paper [V], a routing scheme called Path-loss and Energy Efficient Model (PLEEM) is proposed to reduce the path-loss in both communications (e.g. on-body and off-body). Two off-body relays are deployed in this protocol to reduce the path-loss while the body is in motion. Two types of communications are implemented; for regular data direct communication and for normal data indirect communication is implemented. PLEEM protocol shows the best performance with the contrast of other routing protocols in terms of throughput, latency, network lifetime, stability duration. Stable Increased-throughput Multi-hop Protocol for Link Efficiency (SIMPLE) is a scheme that is proposed in paper [XVIII]. Minimize energy consumption and increase the lifetime of the network, multi-hop topology is implemented in this scheme. With cost function to a forwarder or parent node, two parameters of residual energy and minimum distance are used.

Another routing protocol is proposed in paper [XXII], named Distance Aware Relaying Energy-efficient (DARE), which focuses on reducing sensor energy consumption during the transfer of data from nodes to sinks. In this protocol, the focus is given to reduce the consumption of sensor energy during transferring data from nodes to sink. Here seven normal and one relay node deployed for each patient, while one sink is used to cover all wards in the hospital and each ward contains eight patients. The researchers presented various schemes that focus on reducing node energy depletion. The authors proposed a protocol for WBASNs called Reliability Enhanced-Adaptive Threshold-based Thermal unaware Energy-efficient Multi-hop Protocol (RE-ATTEMPT) for WBASNs in paper [II].

III. Motivation

The detailed literature reviewed on wireless body area networks (WBANs) and two papers are selected named FAME and LAEEBA as reference papers related to my proposed work. In LAEEBA protocol proposed for channel modeling with energy conservation. It is a trustworthy protocol based on higher throughput and least path losses. Single-hop and multi-hop characteristics are widely used to improve network life. Maximize the time of network stability and keep the nodes alive for longer. So the path losses decrease with less packet loss during data transmission. The thermal aware concept is not introduced in the LAEEBA paper [III]. In THE-FAME protocol having better throughput, longer lifetime, more residual energy and less delay. People performing strenuous activities in their daily life especially solder players and factory workers. Patients with chronic muscle fatigue are monitored. Thermal awareness and Path losses are not discussed in the THE-FAME paper [IV]. In this work, we want to design a new WBANs routing protocol, which has a thermal aware concept and also enhances the performance of parameters in both protocols (LAEEBA, THE-FAME).

IV. Methodology for TALAEEBA protocol

In our proposed protocol health node wakeup from start-up and sense the body temperature of the factory worker as shown in figure 2. When the threshold limit of the biosensor reached, as a result, an abnormality was detected. Otherwise, the worker can continue their normal duty. After abnormality is sensed, locate the
nearest sink node with its minimum delay. When the nearest sink is found transfer the data otherwise try to locate the next nearest distinct sink. Supervisors and medical staff members continuously monitor the activities of the worker. The supervisor receives the thermal aware status of a worker busy the duty. When the supervisor wants to call another worker to replace with tired worker and go to health node wakeup from start-up otherwise worker can continue its normal duty. The flow chart of the whole scenario is represented in figure 3.

It is suggested that a cost function select the forwarder node because it has high residual energy and a small distance to sink and path loss. The residual energy parameter balances energy consumption and the distance parameter is used to ensure the packet is transmitted effectively to sink, while the path loss parameter reduces the path losses during transmission of data.

**Figure 2:** Supervisor and Health Officials monitor the health status of workers.

**IV.i. Algorithm for TALEEBA**

1. Start
2. Initialization of Network components
3. Health node wakeup from start-up
4. Sense the temperature information
5. If the limit exceeds the threshold value
6. Abnormality detected
7. If the nearest sink with minimum delay is located
8. Go to Step 11.
9. Else
10. Locate the next nearest distinct sink
11. Data transfers
12. End if
13. Supervisor receives the thermal aware status of worker
14. If the supervisor wants to call another worker
15. Worker Replaced
16. Go to step 3
17. Else
18. Go to step 21
19. End if

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IV.ii. Flow Chart for the proposed methodology

![Flow Chart for TALAEEA](image)

**Figure 3: Flow Chart for TALAEEA**

IV.iii. Mathematical Modelling for TALEEBA

A detailed mathematical model will be formulated for our TALBEEA scheme covering the aspect of energy consumption, successful packet delivery ratio, path loss and above all the Cost Function which will be the driving force of our scheme. The mathematical formulation will be further validated through simulation in MATLAB and comparison will be done with LAEEBA and THE-FAME protocols of WBAN.

IV.iii.a. System Model

Electrical and magnetic fields are produced by radio signals used in wireless communication. When exposed to electromagnetic fields, the human body absorbs radiation and experiences a rise in temperature [XXII]. Even with moderate heating,
some organs are vulnerable to thermal damage, which is extremely susceptible to temperature rises due to lack of blood supply. The constant activity of sensor circuits also increases the temperature of the tissue [XI]. Specific absorption rate (SAR, unit is W / kg) is a measure of the rate at which the tissue can absorb the radiation energy per unit mass.

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

Where \(E\) is the electrical field caused by radiation, tissue density is represented by \(\rho\), and tissue's electrical conductivity is \(\sigma\). Some countries and organizations, for example, describe specific SAR maximum values. Tests demonstrate a concentration of 8W / kg SAR in any gram of tissue in the head or torso for 15 minutes that could cause a high risk for damage of tissue [VII].

![Figure 4: Nodes Deployment for TALEEBA protocol.](image)

As shown in Figure 4, the sink in our proposed model is situated in the middle of the human body. Eight sensor nodes, with equivalent power and computational capabilities, are mounted on a human body. Node 1 can be a sensor for ElectroCardioGraphy (ECG) detection while node 2 can be a sensor for measurement of glucose levels. Such two nodes directly forward data to sink. The other of the nodes are transferring data down to sink by relay nodes.

**IV.iii.B. Initialization Phase**

Throughout the initialization process, all nodes within the body send to each other nodes a specified message called "HELLO." This message includes important information, such as identification of nodes, i.e. ID of the node, place of a node in the human body, intake of the energy status of the surrounding node and sinks distance from the node. When these HELLO messages are exchanged in this way the sensor node updates its routing table.

**IV.iii.c. Routing Phase**

One of the main issues that need to be discussed in a WSN is energy conservation. Multi-hop makes routing especially for WBAN more energy-efficient and high.
throughput in this protocol. Select a forwarder node by applying a selection criterion to balance the energy consumption between the nodes. In every round, the TALEEBA protocol elects the new forwarder. Because the sink node has maximum node information it calculates for all nodes the cost function. Then, this cost function used the node to find the forwarder.

\[
\text{cost function}(i) = \frac{R.E(i)}{d*q}
\]  

(2)

Where i is a number of nodes, R.E is node residual energy, d is the distance between the sink node and other nodes, whereas q is the average data rate for nodes. As a forwarder, select a node with the highest cost function value and start data transmission to the WBAN.

IV.iii.d. Scheduling phase

Since the route selection, it is the responsibility of the prime sink node to manage the scheduling for the remainder of nodes. Uses a simple communication time slot between the sink and root node. The interaction is entirely on TDMA. Therefore, the node transmits the sensed data to the forwarder. When no data is sent, it switches into inactive mode.

IV.iii.e. Energy consumption phase

The multi-path approach decreases energy usage, as nodes prefer relay nodes that are less distant from data transmission. The consumption of energy is proportional to the distance between one node and another node called \( n \) and \( j \) respectively \( d_{ij}^n \). \( n \) is a path loss exponent that depends on the transmission framework. The energy consumption of a node in the Transmission depends on whether the node transmits data directly into the sink or through neighboring nodes as relays in cooperation. All nodes are aware of their neighbors and the position of the sink so that the route chosen uses less energy. Delay is much lower for direct communication than in multi-communication, each intermediate node collects data in multi-hop and then delivers it to the next node. This induces delay and increases significantly due to congestion which can become unacceptable in some critical scenarios. Therefore the single-hop interaction is used to reduce the delay. Energy used in single-hop communication is given by [XIV].

\[
E_{S-HOP} = \frac{P_{amp,SD} + P_D}{R_b}
\]

(3)

Where \( P_{amp,SD} = (\zeta/n)P_i \). It is the power used by the transmit amplifier, depending on the maximum point-to-average ratio (\( \zeta \)) of the modulation scheme used and the drain output of the transmit amplifier (\( n \)). \( P_S \) and \( P_D \) are the power usage for the transmitting and receiving RF circuits, respectively. In bits /s for a bit rate of data is \( R_b \) used. \( P_i \) is the power required by a node \( i \) to transmit data which depends on the distance between source \( i \) and destination. A further factor for determining the use of multi-hop contact energy is the use of a feedback system. Multi-hop energy consumption varies because there is a feedback channel there. If no response is available, the relay always retransmits the message to the sink in the second time slot, regardless of the initial transmission performance. The overall energy usage can be expressed in [IX].

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\[ E_{S-HOP} = \frac{P_{\text{amp},SR} + P_S + 2P_R}{R_b} + \frac{P_{\text{amp},SD} + P_S + P_D}{R_b} \]  

(4)

Here, the first term is a transmission between S and R while the second term is a transmission between S and D. Since both R and D listen to S’s first slot transmission, the relay node consumes extra energy of 2PR. On the other hand, if the multi-hop scheme uses a feedback channel from the destination such that the relay is only retransmitted if the destination fails to correctly interpret the message, it typically leads to more energy. The energy usage can then be expressed in [XIV].

\[ E_{S-HOP} = \frac{P_{\text{amp},SR} + P_S + 2P_R}{R_b} + P_b \frac{P_{\text{amp},SD} + P_S + P_D}{R_b} \]  

(5)

Where \( P_{SD} \) represents the probability of incorrect receipt of a message at D from S after the first time slot.

**IV.iii.f. Path-loss selection phase**

Usually partially conductive is the characteristic of the human body, and there are embodied different substances of varying thicknesses, impedance properties and dielectric constants. The communication protocol adopted for nodes can result in high losses, depending on the operating frequency band. WBANs currently use a range of standards for interaction. Among those, however, are the most widely used IEEE 802.15.1 (Bluetooth), MICS, ZigBee, and IEEE 802.15.6 (UWB) [XV]. When devices communicate, the losses between them result in system performance monitoring degrading. Path loss involves all the effects related to the distance and interaction of the propagating wave with physical artifacts in the transmitter-receiver framework. Hence, it is the reduction of an electromagnetic wave’s power density. In the case of WBANs, distance and frequency depend on the path loss.

In this protocol, one of the two path-loss models will be implemented when the nodes transfer their data to the sink or the relay nodes during the cycle. The distance of the two contact nodes is the key factor in this selection. It is calculated a certain threshold value which is the distance \( d_1 \) of the transmitting node \( n_1 \) from sink S. Now the distance \( d_2 \) is determined if \( n_1 \) transfers its data to another \( n_2 \) relay node.

If \( 1 \geq d_2 \), then the path loss model is implemented by nodes \( PL_1(d,f) \) given by [XIV].

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

(6)

In order to obtain coefficient values \( a, b \) and \( N_{d,f} \). It uses the Least Mean Squares (LMS) algorithm and calculates its values as \( A=\text{(-)}27.6, b = \text{(-)}46.5, \text{and} N_{d,f} = 157.\)

If \( d_2 \geq d_1 \), then the path loss model implemented for nodes is given by [XIV].

\[ PL_2(d,f)[dB] = PL_o + 10n\log_{10}\left(\frac{d_2}{d_o}\right) + \sigma \]  

(7)

Where \( PL_o \) is computed as follows:

\[ PL_o = 10\log_{10}(4\pi \cdot d_o f)^2 \times c \]  

(8)
Where \( d \) is 11 cm of the chosen reference distance. \( n \) is the path loss coefficient and its value ranges from 0.3 to 1.5 for LoS communication and from 1.8 to 2.8 for NLoS communication as for the protocol LAEEBA. \( \sigma \) is the default deviation, \( f \) is the operating frequency and \( c \) is the light level speed. Forwarder node is chosen in LAEEBA based on residual energy, while in TALEEBA relay nodes are used for synchronization that allows source nodes to use more than one connection at a time.

**IV.iii.g. Estimation of Temperature**

We consider two key sources that cause the heating effects: sensor node antenna radiation and sensor node circuit power dissipation.

**IV.iii.h.i The Antenna Radiation**

The sensor node is supposed to have a short dipole antenna consisting of a short wire \( dl \) conductive range with a sinusoidal drive current \( I \). They assume that the tissue is diverse, without hard edges or hard surfaces, to test the effect of radiation on the tissue. The area surrounding the antenna is divided into the near zone and far zone. The near-zone magnitude is given by

\[
SAR_{NF} = \frac{\sigma \mu_0}{p \sqrt{\sigma^2 + \omega^2 \varepsilon^2}} \left( \frac{ldl \sin \theta e^{-\alpha R}}{4\pi} \left( \frac{1}{R^2} + \frac{1}{R} \right) \right)^2
\]

and

\[
SAR_{FF} = \frac{\alpha^2 + \beta^2}{p \sqrt{\sigma^2 + \omega^2 \varepsilon^2}} \left( \frac{ldl \sin^2 \theta e^{-2\alpha R}}{4\pi} \right) \frac{\sin^2 \theta e^{-2\alpha R}}{R^2}
\]

For the distance between the source and the observation point \( R \) is used, while \( \theta \) represents the angle between the x-y plane and observation point, \( \gamma \) is the constant of distribution. We consider that our two-dimensional volume of the control is in the x-y plane and it is Perpendicular to the small magnetic field, Therefore we can safely conclude that the radiation pattern on the 2D plane is omnidirectional and \( \sin \theta = 1 \). The near or far zones radiation from the transmitter of the sensor induces tissue heating due to the radiation absorption. The Precise Absorption Rate is used to estimate the human tissue's possible heat effect.

**IV.iii.h.ii. Power dissipation by Sensor node circuitry**:

The temperature of the sensor nodes is increased due to the dissipation of the power of the sensor circuitry, which is the main heat factor for the tissue. \( P_c \) is the dissipation density, which is power absorbed by the sensor circuit is divided by sensor volume, which depends on their architecture and technology. In our analysis we found the normal power consumption to operate sensor circuits regularly.

\(
\gamma = +j\beta, \text{ phase constant } \beta \text{ is given as } [XXIV].
\)

\[
\beta = \omega \sqrt{\frac{\mu \varepsilon}{2}} \left[ \sqrt{1 + \left( \frac{\sigma}{\omega \varepsilon} \right)^2} + 1 \right]^{1/2} \text{ (rad/m)}
\]
IV.iii.1. Calculating Temperature Rise

The rate of temperature rise is determined using the bioheat equation Pennes \([XV]\) as follows:

\[
\rho C_p \frac{dT}{dt} = K \nabla^2 T + \rho SAR - b(T - T_b) + P_c + Q_m \text{ (W/m}^2\text{)}
\]

(12)

Here equation includes, \(\rho\) is used as mass density, \(K\) is the thermal conductivity of the tissue, \(C_p\) works as specific heat for the tissue, while \(b\) shows the constant blood perfusion which indicates how quickly the blood flow can carry the heat inside the tissue, and \(T_b\) is the blood and tissue temperature.

The left side of Equation has \(\frac{dT}{dt}\) is the rate of temperature rise of the volume control while the right side indicates accumulated heat in the tissue. \(K \nabla^2 T\) and \(b(T - T_b)\) are used as heat transfer due to the conduction and the blood perfusion, respectively. \(\rho SAR, P_c\) and \(Q_m\) are the heat produced through radiation, circuit power dissipation and metabolic heating, respectively.

Finite-Difference Time-Domain (FDTD) is an electromagnetic mapping technique that discrete the time and space differential form and can be used for heating applications as well [VI]. The whole space of the problem is discretized into small grids. Every grid has a pair of coordinates labeled with \((x, y)\). Because of space constraints, after some manipulations, we show only the out of the new bioheat equation.

\[
T^{m+1}(x, y) = \left[ 1 - \frac{\delta_b}{\rho C_p} - \frac{4\delta_x K}{\rho C_p \delta^2} \right] T^m(x, y) + \frac{\delta_x}{\rho C_p} SAR + \frac{\delta_b}{\rho C_p} T_b + \frac{\delta}{\rho C_p} P_c
\]

\[
+ \frac{\delta_x K}{\rho C_p \delta^2} \left[ T^m(x + 1, y) + T^m(x, y + 1) \right]
\]

(13)

Where \(T^{m+1}(x, y)\) is the temperature for the grid \((x, y)\) at the time \(m+1\), the discretized phase of time is \(\delta\) and \(\delta\) is the discrete phase of space (i.e. the grid size).

From (3.12), we can consider the grid point temperature \((x, y)\) at time \(m+1\), which is a function of the grid point temperature \((x, y)\) at time \(m\), as well as a function of the corresponding grid points temperature \((x + 1, y), (x, y + 1), (x - 1, y), \) and \((x, y - 1)\) at time \(m\).

If we know the characteristics of the tissue, the effects of the blood flow and the intensity of heat that the tissue absorbs, we can calculate the temperature at a given time and whether the heat effects can cause any damage to the tissue around us.

V. Results and Discussion

V.i. Performance Evaluation

TALEEBA’s efficiency is evaluated and contrasted with WBAN routing protocols THE-FAME and LAEEBA simulations in MATLAB. This evaluation aims to monitor the various major performance metrics such as residual energy, the lifetime of the network, period of stability and throughput. Table 1 has details the parameters used in the simulations. The findings are summed up in over five separate runs of simulations.

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Table 1: Simulation Parameters used

| Parameters                  | Value                                      |
|-----------------------------|--------------------------------------------|
| Quantity of nodes           | 8                                          |
| Position of Sink            | the center position of the body            |
| Opening energy ($E_i$)      | Advanced node: 0.3 j                       |
|                             | Normal node: 0.1 j                        |
| Size of Packet              | 1000 bits                                  |
| Rate for Data generation    | 4000 bits/round                            |
| $E_{elec}$                  | 50 nJ/bit                                  |
| $e_{fs}$                    | 10 pJ/bit/m²                               |
| $e_{amp}$                   | 0.0013 pJ/bit/m³                           |

V.ii Stability Period and Network Lifetime

These parameters are used to analyze the stability period and the network lifetime of the TALEEBA protocol. Duration begins with the initialization of the network and lasts until the death of the first node in the network is called the stability period, while the time starting with the initialization of the network and ending the last node in the network is called the network lifetime. TALEEBA’s stability period is higher than the LAEEBA and THE-FAME showed in Figure 5. The first node of LAEEBA dies at around 499 and of THE-FAME at 467. TALEEBA protocol shows the best improvement when the first node dies after round 1617, as shown in table 2. In terms of network life, TALEEBA performs much better and has the highest lifetime compared to both LAEEBA and THE-FAME protocols. 100% nodes of LAEEBA and THE-FAME protocols are died after 2000 rounds, while 50% nodes of TALEEBA protocol died after 2000 rounds. TALEEBA protocol uses a cost function to choose the forwarder node effectively, choosing the node with the lowest cost value as a data transmission forwarder node. Thus, Nodes display uniform power consumption that enhances network life and throughput.

![Figure 5](image_url)

Figure 5: Comparison of the number of dead nodes vs round (s).
Table 2: Death of nodes after equal intervals using mentioned protocols

| S.no | Name of Protocol | Death of first node at 8 seconds | Death of Nodes at one thousand seconds | Death of Nodes at two thousand seconds | Death of Nodes at three thousand seconds | Death of Nodes at four thousand seconds |
|------|------------------|----------------------------------|----------------------------------------|----------------------------------------|----------------------------------------|----------------------------------------|
| 1    | LAEEBA           | 499                              | 8                                      | 8                                      | 8                                      | 8                                      |
| 2    | THE-FAME         | 467                              | 5                                      | 8                                      | 8                                      | 8                                      |
| 3    | TALEEBA          | 1617                             | NIL                                    | 4                                      | 4                                      | 4                                      |

V.iii. Residual Energy

The parameter used to measure energy depletion within the network is called residual energy. In TALEEBA, nodes choose the parent node for transmitting data to sink, which helps to decrease energy usage. This minimizes the workload for a specific node. Therefore the maximum number of nodes has enough energy for transmitting the data to the main sink node, while in the case of LABEEA and THE-FAME several nodes exhaust near the beginning due to heavy traffic loads.

TALEEBA provides two types of sensor nodes in terms of the initial capacity. There are standard nodes with an initial energy of 0.1 J, while advanced nodes have initial energy of 0.3 J. The initial total energy was kept at 1.6 J of all the protocols. Figure 6 shows that the TALEEBA protocol consumes a minimum volume of energy as compared to THE-FAME and LABEEA protocols. A large number of nodes have ample energy to transmit the data to the central receiver node. Table 3 shows the relation of all the protocols analyzed with residual energy and that the TALEEBA displays a much stronger residual energy decay over time.

![Figure 6: Analyzing of residual energy vs round (s)](image)

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Table 3: Residual energy dropped (j) after equal intervals.

| S. no | Name of Protocol | Energy status after one thousand rounds | Energy status after two thousand rounds | Energy status after three thousand rounds | Energy status after four thousand rounds |
|-------|------------------|----------------------------------------|----------------------------------------|------------------------------------------|----------------------------------------|
| 1     | LAEEBA           | 0.20                                   | 0                                      | 0                                        | 0                                      |
| 2     | THE-FAME         | 0.20                                   | 0                                      | 0                                        | 0                                      |
| 3     | TALEEBA          | 1.11                                   | 0.71                                   | 0.47                                     | 0.23                                   |

V.iv. Packets sent for sink

The maximum number of packets can be sent to the base station in TALEEBA as compared with LABEEA and THE-FAME protocols due to network lifetime and efficient use of energy. Packets sent to sink in TALEEBA is 90%, THE-FAME 72%, and LABEEA has 55%. In the presented scheme, a 40% ratio is increased of a packet sent to sink in comparison with LAEEBA and THE-FAMES protocols. Figure 7 displays a comparison of data transmission mentioned protocols from node to base station. TALEEBA protocol sends the maximum number of packets as opposed to THE-FAME and LABEEA protocols to the base station. As observed from Table 4, the total number of packets sent by LABEEA is $1.94 \times 10^4$ and in THE-FAME $2.53 \times 10^4$ packets are sent. While in the TALEEBA protocol, the total number of packets are sent is $3.19 \times 10^4$. Due to the availability of alive sensor nodes, this successful result was obtained by the presented scheme.

Figure 7: Maximum packets sent to base station vs rounds.
Table 4: Comparison of Numbers of packets sent to the base station

| S.no | Name of Protocol | at 1000 | at 2000 | at 3000 | at 4000 | at 5000 |
|------|-----------------|---------|---------|---------|---------|---------|
| 1    | LAEEBA          | 1.94x10⁴ | 1.94x10⁴ | 1.94x10⁴ | 1.94x10⁴ | 1.94x10⁴ |
| 2    | THE-FAME        | 2.48x10⁴ | 2.53x10⁴ | 2.53x10⁴ | 2.53x10⁴ | 2.53x10⁴ |
| 3    | TALEEBA         | 1.98x10⁴ | 1.76x10⁴ | 2.25x10⁴ | 2.73x10⁴ | 3.177x10⁴ |

V.vi. Packets Dropped

This parameter is used to evaluate the number of packets dropped from nodes to sinks when traveling. Figure 8 shows a list of packets dropped for network protocols LABEEA, The-FAME and TALEEBA before reaching to sink. As observed from Table 5, the total number of packets dropped by LABEEA is 2597 and 4028 packets are dropped in THE-FAME. While TALEEBA protocol dropped 3187 number of packets. The result of figure 8 is shown, more packets dropped in The-FAME than TALEEBA. This is due to the correct scheduling of data in the TALEEBA protocol, which is to differentiate between emergency data transmission and regular data transmission. In addition, multi-hopping increases the number of packets in transit, which means more contention, increasing the risk of collision or, instead, decreasing more packets. But, this is a trade-off parameter for the TALEEBA protocol, due to the high ratio of dropped packets as compared with the LABEEA protocol. Even though TALEEBA has a low packet dropped ratio in comparison with the The-FAME protocol.

Figure 8: Comparison Number of packets dropped vs round
Table 5: Number of packets dropped after rounds interval

| S.no | Name of Protocol | at 1000 | at 2000 | at 3000 | at 4000 | at 5000 |
|------|-----------------|---------|---------|---------|---------|---------|
| 1    | LAEEBA          | 2597    | 2597    | 2597    | 2597    | 2597    |
| 2    | THE-FAME        | 3964    | 4028    | 4028    | 4028    | 4028    |
| 3    | TALEEBA         | 986     | 986     | 2253    | 2733    | 3187    |

V.vii. Throughput

This parameter has the function of analyzing a network’s throughput. The throughput is the number of packets received successfully per unit time at the sink. Throughput depends on the number of nodes that are alive or active in a network. The number of packets sent to the sink is directly proportional to the number of active or alive nodes.

![Throughput Graph](image)

**Figure 9:** Throughput comparison of LAEBBA, TALEEBA and The-FAME

Throughput in presented protocol 23% increased in comparison with LEEBA and THE-FAME protocols. The TALEEBA protocol uses energy effectively, leading to the longer service life of the network. For longer times, the nodes are alive and send more packets resulting in increased throughput. Minimizing the packet loss and optimizing the throughput is important. As shown in Figure 9, the TALEEBA protocol has more throughput than protocols THE-FAME and LABEEA.

VI. Conclusion and Future Work

The latest routing protocol for WBANS is developed called TALEEBA. In this scheme, we considered the performance metrics in terms of the already available schemes THE-FAME, LAEEBA and saw the effects in terms of energy efficiency, stability period and networks lifetime.

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The proposed protocol was compared with existing protocols to verify the performance of TALEEBA. The emphasis was on generating photovoltaic energy with the least resource consumption and proper network resource supervision. The effective option of forwarder node is made on the approach with the least amount with hop counts. When the distance between nodes is greater than more energy is wasted and therefore less distance between node is selected for energy saving. The other parameters are to improve throughput, routing and energy-producing to provide an efficient solution in WBAN. In TALEEBA, there are two modes of communication. For those sensors that are in direct contact with one of the sinks 1 or 2 direct mode of communication exists. Multi-hop communication mode for those nodes that aren't in direct range would be possible. In direct mode, the energy consumption is higher than in multi-hop. In the case of direct transfer, more energy is needed for transmitting data packets over longer distances; as a result, we go for the multi-hop transfer method.

The dropped packet ratio is high in this scheme with a comparison of the LABEEA protocol. So dropped packet is a trade-off parameter in this work. We did not work on congestion control and intra-wan communication in this scheme. Congestion control and intra-wan communication are future work for my proposed protocol.

Conflict of Interest:
All authors have no conflict of interest

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