Enhancing Energy Efficiency in Wireless Body Area Networks: A Comprehensive Study of Algorithms

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Abstract

The fast advancement of wireless technology, particularly 5G, has accelerated the implementation of Wireless Body Area Networks (WBANs) to improve the quality of life for individuals with disabilities. This study looks at the most efficient energy-saving algorithms and tactics for medical and health monitoring apps. The research addresses issues in sustainable energy consumption caused by the limited battery life of wearable devices and categorizes energy-efficient algorithms as contention-based or contention-free solutions. The study emphasizes the significance of creating bespoke routing protocols for WBANs in order to save energy. It also outlines potential obstacles, such as lowering power usage and dealing with radiation absorption by the human body, all of which are critical for WBAN technological progress. The study continues by evaluating energy-efficient WBANs and emphasizing the need of ongoing innovation and interdisciplinary collaboration in order to overcome existing hurdles and reach long-term health monitoring solutions.

Keywords: Wireless Body Area Networks (WBANs), energy efficiency, algorithms, health monitoring, sustainability, and routing protocols.

1 Introduction

The use of wireless body area networks (WBANs) and wearable technologies has grown significantly in popularity in recent years. [1]. Due to the aging population, more people need medical care from doctors/specialists. The most useful and economical method of monitoring medical equipment and various other applications is via wireless body area networks, or WBANs. Small, energy-efficient, intelligent, and portable sensor devices that can communicate information wirelessly and operate on or near the body create a wireless body area network (WBAN). [2]. Previously, it served the purpose of evaluating physical attributes and documenting any unusual or crucial conditions in the body of an individual [3]. ECG stands for electrocardiography, in which the electrical activity of the heart is monitored using a specific technique. Following the completion of the data collection process, it is conceivable that it will be sent to remote monitoring stations for the purpose of achieving a variety of diagnostic goals [4], [5]. A wireless sensor network, also known as a WSN, is made up of components known as WBAN [6]. Implanted WBAN and wearable WBAN are the two types of WBAN that may be distinguishable from one another in terms of employment [7]. Data transmission between the implanted sensor nodes and the base station (BS) is feasible within the context of "implanted WBAN," a kind of body-wide wireless network. This is not the same as "wearable WBAN," which enables base stations (BS) and wearable devices to communicate [8], [9].

1.1 Importance of WBANs

WBAN, which stands for wireless body area network, offers a solution that is both practical and effective to these problems. As a result of the fact that patients may sometimes need assistance, the WBAN is beneficial. Wireless Body Area Network (WBAN) is a diagnostic and therapeutic method used in hospitals for home-based patient monitoring when physicians are unavailable due to factors like war losses, patient age, infirmity, or hospitalization fees. [10]. Remote monitoring permits continuous monitoring from anywhere and at any time, which assists disabled and elderly patients. The WBAN helps incident-free patients for free. Thus, WBANs are used in medicine for patient monitoring and assistance.

1.2 An overview of the sustainable energy-efficient WBAN

Since technology has made sensor devices smaller, Wireless Body Area Network (WBAN) has emerged as a desirable substitute since it is very cheap [11]. According to [12], in their study on Smart Grid and Renewable Energy Systems, WBAN sensors are able to communicate wirelessly because of their small size, low power consumption, and lightweight design. This is because of the combination of these three characteristics. WBANs [13] may be used to measure and quantify several human physiological characteristics, such as heart rate and breathing rate. According to [14], Because of this, patients are no longer need to visit the hospital for routine checkups since continuous and remote health monitoring has made this unnecessary of them. The use of WBAN enables customers to choose the location of their choice while simultaneously reducing the costs associated with healthcare [15].

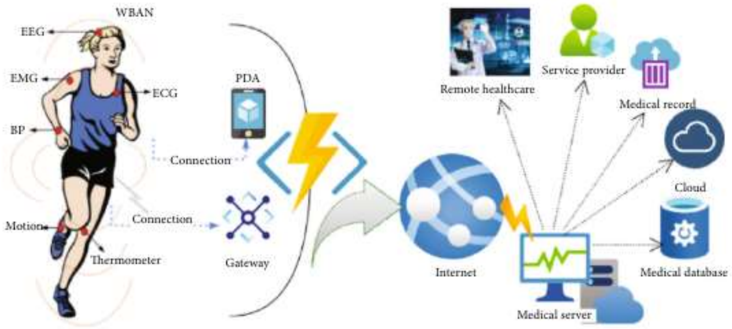

Figure 1 Architecture of WBAN

The increasing popularity of applications connected to the Internet of Things (IoT) has led to a significant increase in interest in developing wireless body area networks (WBANs). This group of components includes, for instance, the local processing unit (LPU), personal terminals, networking devices, and sensors [16]–[18]. Through the use of wireless networks, the sensors send the data that they have gathered to the LPU [19]. Furthermore, this data might be sent to distant computers for further analysis [20]. While wireless body area networks (WBAN) as well as wireless sensor networks (WSN) have distinct lifetimes, they share a number of aspects. WBAN technology encounters many problems, including restricted sensors' battery recharging, shifting network architecture, rigorous QoS requirements[15], and varying file creation and storage rates [21]. The longevity of WBANs relies on energy consumption, rendering it a prevalent issue inside the network [22]. In order to ensure the proper implementation of the WBAN, it is crucial to solve these difficulties, as stated by [23].

There are several methods to enhance the performance of a network across multiple network domains [24]. Ultimately, these benefits result in enhanced network performance [25]. The data included inside an individual's vital signs is very sensitive. Security and privacy methods are crucial in WBAN [26]. The secrecy and authenticity of data packets rely on the security and privacy features that are included into the routing protocols [27].

2 Energy-Efficient Algorithms and Techniques

2.1 Contention-Based Algorithm

Wireless Body Area Networks (WBANs) energy economy, latency, and delivery probability require improvement, among other issues. Several methods have been offered. This is crucial when channels change often and resources are few. Since we have many goals, including improving network performance, the researchers chose contention-based channel access. [28]–[33]. Specifically, the crucial node was determined to be the sensor node that had the greatest criticality index [28]. To enhance its delivery probability, this node's MAC frame length has been increased from its previous value. The data in [29] were classified based on the condition of health of the patient. Further contributing to the decrease of conflicts brought on by biological sensors is the reduced contention adaptive slots allocation carrier-sense multiple access with collision avoidance (RCA-CSMA/CA) system. For this reason, it is recommended. In [30], The Liu et al. MAC protocol's contention orientation mechanism distributes resources uniformly across all contention levels. The Liu et al. MAC protocol's contention orientation mechanism distributes resources uniformly across all contention levels. CSMA/CA was used in the beginning to reduce control message conflicts. The second phase incorporated standby mode to address over- and idle-listening issues.

2.2 Contention-Free Algorithm

The references look at a range of time-division multiple access (TDMA) based channel access techniques [34]–[38]. In their study, [27] introduced hybrid methods that included prolonged and mixed period techniques. After connecting the LPU and sensor nodes, the author provided the most effective approach for determining the interbeacon interval (IBI). The adaptive interbeacon interval (IBI) approach was the name given to this particular field of technology. This choice is taken considering the available data packets and the appropriate priority level. The purpose behind creating this assignment was to make use of the time.

2.3 Analysis of Energy consumption in WBAN

Because of its finite energy supply, the WBAN's uses are limited by its operational length. The network's focus on human health data requires high data processing capacity and dependability. However, increasing throughput requires higher network activity and energy consumption, which opposes the WBAN's plan. [9]. When building a solution for WBAN, it is important to limit Specific Absorption Rate (SAR) in order to prioritize human health.

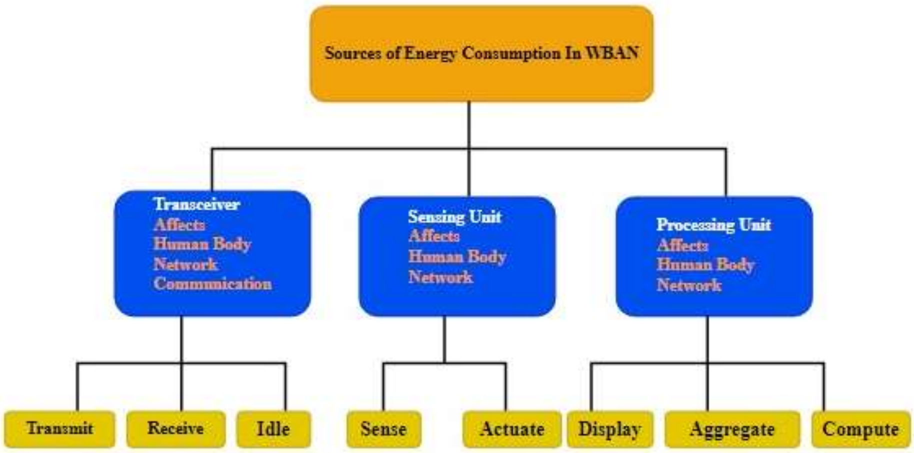

Figure 2 Sources of energy consumption in WBAN

Based on previous research, the primary causes of energy usage in WBAN may be shown in Figure 2. the influence that the WBAN system has had, not just on the system itself but also on its users is outlined Figure 3 includes a list of research that address one or more of these factors in the routing choice process. According to research, the transceiver (E_{tr}) consumes more energy than the combined energy requirements of the processing unit (E_{pr}) and sensing unit (E_{sn}) . Therefore, $E_{tr} \gg (E_{sn}\ AND\ E_{pr})$

Similarly, if we look at the transceiver's energy usage, we can see that transmission (E_{tx}) consumes more energy than reception (E_{rx}) or idle listening. Hence, $(E_{tx}) > (E_{rx}\ OR\ E_{idl})$. However, the energy used by the receiver is almost similar to that consumed during idle listening. Thus,

$$E_{rx} \approx E_{idl}$$

Most routing methods focus exclusively on transceiver energy use in their energy model. The body might have implanted or externally put sensor nodes. Since the body absorbs electromagnetic radiofrequency (EMRF) waves, high surface area ratio (SAR) causes tissue damage. A node that relays traffic or sends data continuously may run outside of energy, reducing the lifespan and dependability of the network. Furthermore, a node with little residual energy may interfere with or muffle signals, which would decrease the dependability of the connection. Since WBAN nodes are near humans, any mistake might be deadly.

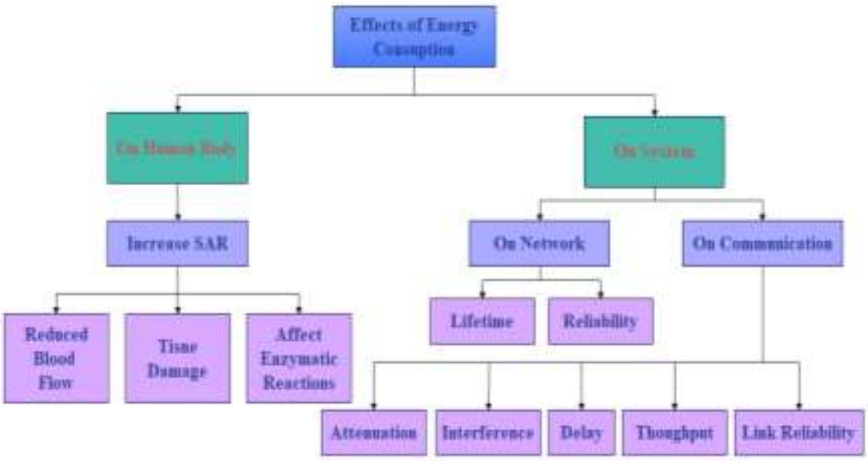

Figure 3 Impact of energy usage in WBAN

Here, they have made an effort to calculate a node's SAR based on its involvement in different network operations. For SARs, the unit of measurement is the amount of energy that is used given the amount of mass and the amount of time.

Thus, the quantification of SAR given mass M and time t:

$$SAR \approx \frac{E_{con}}{M \times t} \quad (1)$$

Equation 1 may be written as [2]

$$SAR = \frac{1}{M} \times \frac{dE_{con}}{dt} \tag{2}$$

Where $\frac{dE_{con}}{dt}$ indicates the pace at which energy is used. Using the previously established sources of energy use, equation 2 is rewritten as

$$SAR = \frac{1}{M} \times \frac{dE_{con}}{dt} + \frac{dE_{sn}}{dt} + \frac{dE_{pr}}{dt} \tag{3}$$

Since, $E_{tr} \gg (E_{sn}\ AND\ E_{pr})$ as stated before, equation 3 simplifies to

$$SAR \simeq \frac{1}{M} \times \left(\frac{dE_{tr}}{dt}\right) = \frac{1}{M} \times k \times \left(\frac{dE_{tx}}{dt} + \frac{dE_{rx}}{dt}\right) \tag{4}$$

Since relay nodes just transfer traffic, sensing and processing consume little energy. A bio-sensor node and a relay node may have their SAR (Specific Absorption Rate) computed using the same equation. Because the two nodes are designed similarly. The quantity of energy received is comparable to that sent., i.e.

$E_{tx} \approx E_{tx}$ hence, to make equation 4 simpler, we rewrite it as follows:

$$SAR \simeq \frac{2}{M} \times \left(\frac{dE_{tx}}{dt}\right) = k \times \left(\frac{dE_{tx}}{dt}\right) \tag{5}$$

Because 2/M is a constant, it is represented by the letter k in the equation that came before it. On the other hand, if a single bit requires e units of energy to be sent, then the transmission of q bits involves q units of energy.

$$SAR \simeq k \times q \times \left(\frac{de}{dt}\right) = k \times q \times \text{transmission power} \tag{6}$$

[39] WBAN's energy efficiency is a priority. WBAN concerns include greater throughput and network stability. Stable Enhanced Multi-hop Protocol Link Performance. This protocol was developed at the cluster level. An acronym gives it its name. It is sometimes called SIMPLE modified. M-SIMPLE allows single-hop and multi-hop operations, unlike other protocols.

2.4 A New Energy-Efficient Routing Protocol (ER-ATTEMPT)

A protocol called ER-ATTEMPT was introduced by Ahmad et al. [40]. The ER-ATTEMPT protocol is an advanced variant of the ATTEMPT protocol, designed to address route unavailability. It avoids high-temperature nodes and selects the path with the fewest hops. The protocol learns about available routes through HELLO messages, and in case of no route, the system chooses a suboptimal path for reliable transmission. The message format is represented in Figure 4.

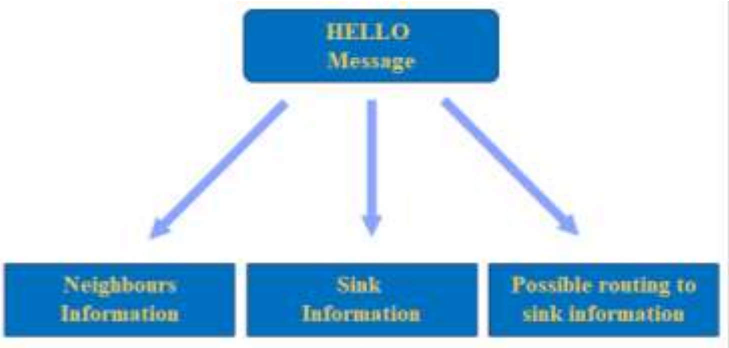

Figure 4 HELLO Message Format of the ER-ATTEMPT Protocol

2.5 Adaptive Transmission Power Control

Thoroughly discussed a new transmission system that is energy-efficient, using an APC algorithm. They carefully choose, alter, and conduct a proper theoretical study of the parameters to optimize the performance of WBAN (Wireless Body Area Network) [41]. The method in question utilizes eight primary parameters: The latest RSSI sample, denoted as R_{latest} , refers to the most recent received signal strength indicator measurement. The lowest RSSI sample, denoted as R_{lowest} , represents the minimum signal strength measurement obtained. The RSSI average, denoted as $\bar{R}$, is generated using a weighted average of the most recent and lowest RSSI samples. The RSSI target, denoted as R_{target}, is a number that is located between the lower threshold (TRL) and the upper threshold that is changeable TRH_{var}. The averaging weight α_1 is assigned to the good channel, while the averaging weight α_2 is assigned to the bad channel. Additionally, there is a fixed lower threshold (TRL) that applies globally.

Additionally, it is assumed that for the most recent and lowest RSSI samples, the TP and associated RSSI, both in dBm, are P_t, R_{latest} and $P_t - \Delta P_i$, $R_{latest} - 1$, respectively, where i = 1, 2,..., N indicates the ith TP level. After receiving the RSSI sample, the BS modifies the values depending on (1) and (2) for good and problematic channels.

$$\bar{R} = R_{latest} + (1-\alpha_1) \times R_{lowest} \tag{1}$$

$$\bar{R} = R_{latest} + (1-\alpha_2) \times R_{lowest} \tag{2}$$

The BS determines the TP levels by using (3) After comparing the figure to the set RSSI objective.

$$\Delta P = \arg\left\{\Delta P_1, \Delta P_2, ^{\min} ..., \Delta P_N \left(\sqrt{\left(R_{\text{target}} - \bar{R} - \Delta P_i\right)^2} \right)\right\}$$
$$s.t.\ \Delta P_i > R_{\text{target}} - \bar{R} \tag{3}$$

Investigation of the optimal TP value is required when N denotes Log 2(N) bits and the total amount of TP levels are small.

The suggested technique compares $\bar{R}$ with TRH_{var} and TRL, increasing or decreasing TP in the process. The channel state is astonishingly excellent if $\bar{R}$ exceeds TRH_{var} (step 6), In order to limit the amount of energy that is wasted, Step 7 is the reduction of the TP on demand. In contrast, if R drops below TRL (step 6), it indicates a poor channel condition. In order to prevent packet loss, the TP is swiftly adjusted upon request (step 7). By appropriately adjusting the TP level, TP will remain unchanged if R fulfills the RSSI threshold range $\left[TRL, TRH_{var}\right]$ (step 8). (step 9)

$$TRH_{var} = TRL + \sigma \tag{4}$$

$$\sigma = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(R_i - \bar{R}\right),} \quad i = 1, 2, ..., n \tag{5}$$

In equation (5), σ is the RSSI average, represents RSSI samples, It also shows the unit-expressed standard deviation of n RSSI samples. TRL is a lower threshold that has been specified. Their settings are R_{target} = -85 dBm, TRL = -88 dBm, and TRH_{var} = -83 dBm. Refer to Table 2 for further information.

Table 1 Simulation Parameters

Parameter	**Value**	**Parameter**	**Value**
TRH_{var}	−83 dBm	RSSI samples (n)	4000
TRL	−88 dBm	Channel model	real-time [24]
R_{target}	−85 dBm	data packet size	200 bytes
carrier frequency	2.4 GHz	data packet interval	200 ms
channel bandwidth	1 MHz	total time	300 s
ΔP index	{−31, …, −3, −2, −1, 0, 1, 2, 3, …, 31}	data rate	250 kbps
maximum transmit power level	0 dBm	noise figure	5 dB
minimum transmit power level	−25 dBm	noise PSD	−174 dBm/Hz
α_1	{0.6, 0.8, 1.0}	node speed	2.5 km/h
α_2	{0.2, 0.4, …, 1.0	number of packets	4000

$$E = \sum_{i=1}^{n} P_i \times t \tag{6}$$

E is the total amount of energy that is used in milliwatts, Pi is the total power that is consumed in milliwatts, in seconds, the variable t indicates how long transmission or reception take. N stands for 4,000 RSSI samples.

$$PLR = \frac{1}{8} \times 100\% \tag{7}$$

$$\Delta = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(R_i - R_{\text{target}}\right)^2}, \quad i = 1, 2, \ldots, n \tag{8}$$

where R displays RSSI samples and R_{target} represents the RSSI target value.

In order to guarantee consistent communication, the TP setting is also quite important. For example, if the computed TP adaptation level falls between 1 and 2 decibels, ΔP [in (3)] will be allocated 2 decibels, and the matching TP level will be added to the Transport Power Control index. Similarly, if the required level of determining the TP adaption ranges from -2 to -1 dB. The ΔP is given a value of -1 dB, and the corresponding power level is added to the TPC index. Lastly, confirmation that the power for every transmission must not surpass $P_{\max}$ or fall below $P_{\min}$. The suggested method exhibits respectable PLR, increased RSSI stability, average TP reduction, and energy efficiency. Thus, they might conclude that the study offers a thorough method for energy conservation in WBAN [41].

2.6 Data Aggregation Methods

Wireless Body Area Networks (WBANs) are expanding in the medical field due to their various applications. To address resource constraints, a reliable and energy-efficient Data Aggregation (DA) approach is sought. This method allows networks to operate without human intervention, increasing longevity. WBAN deployments must meet DA definition criteria, with clustering and mobile agent-based data aggregation options available. The Microsoft system receives vital information from the healthcare application in order to do analysis and take action in real time, which is made possible by the efficient real-time data transmission (DA) [42].

- **Mobile Agent-Based Data Aggregation**

The MA-Based DA approach involves installing a network, clustering biosensors, and selecting a clustering hub (CH). If a predefined path or node is incorrect, MA travel is performed over all CHs, followed by the construction of an alternate route. The flowchart, illustrated in Figure 5, illustrates the process.[43] Considering cloud-based Wireless Body Area

Networks (WBANs), an approach that is both quality-driven and energy-efficient has been developed for the purpose of aggregating vast amounts of data. Communications inside the BAN (Phase I) as well as communications between BANs (Phase II) may be undertaken with this method without incurring any additional expenses. Extensive simulation findings suggest that this strategy enhances network efficiency by 5-7 and 7-8% over conventional schemes, emphasizing the need of handling huge amounts of medical data in WBANs.

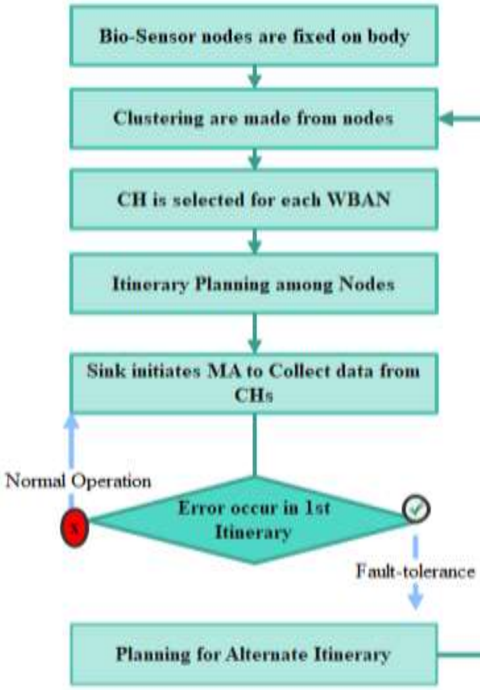

Figure 5 Flowchart For Proposed MADA Technique

- **Methodological pseudocode for data aggregation based on MA**

In stages, the algorithm that will be used for the proposed method is currently being developed. To begin, the network is established, and the CH is selected in the appropriate manner. After completing this stage, the schedule is created, and the MA begins with the BS assignment. Last but not least, in order to provide fault tolerance, alternative route planning is carried out in the event that a node or connection fails. All of the stages involved in the algorithm are shown below.

Table 2 Algorithmic pseudocode for MA-based data aggregation

Part 1 (Clustering and CH selection)
Step1: Deploy bio-sensors $\left(SN_1, SN_2, SN_3, ... SN_n\right)$
Step 2: Group of bio-sensors related to a WBAN are made into a cluster 'C', and a leader is elected for each know as CH
Step 3: Bio-sensor aggregated data transmission $\left(SN_i\left(Sen_{Vital}\right)\right) \rightarrow CH$
Step 4: Calculate $E_r\left(CH\right) > Th$ Continue

Step 5: Otherwise, Start from Step 1
Part 2 (Itinerary Planning)
Step 6: Initially, $Itinerary_{CH} = 0,$ then
Step 7: while $\exists(SN \in I_{CH})$ *do*
Step 8: Set $I_{CH} = I_i\left(CH_n\right)$ *end while*
Step 9: Sink node generated MA to collect the aggregated data
Step 10: $MA_i \underset{S-D}{\Rightarrow} I_i\left(CH_n\right)$
Step 11: Route $Data_{Aggr} \rightarrow Sink$
Part 3 (Fault-Tolerance itinerary planning)
Step 12: if $I_i\left(CH_n\right) \rightarrow Sink$
Step 13: if $V \leftarrow V_i\left(CH_n\right)$
Step 14: *find* $\mathrm{I}min_w\left(u,v\right)$
Step 15: Set $I_i\left(CH_n \leftarrow I_i\left(V\right)\right)$ *end if*
Step 16: end if

2.7 Routing Protocols for Energy Efficiency

- **Secured Routing Protocol for Energy Efficiency (SRPEE)**

To improve network security, performance, and energy efficiency all at once, a novel routing approach is being created. The protocol encrypts and compresses data using RSA encryption and Huff Mann Coding. Renewable Energy Systems and Smart Grid collaborate to achieve this goal, with the best node chosen via PSO routing.

- **Phase 1: initialization**

Following getting hello messages from BC at certain times, the other sensors (N_{node}) , if they are situated between the Source $\left(S_{node}\right)$ and Destination (D_{node}) , reply with a hello packet. The routing table is updated by the S_{node} with N_{node} Information. Figure 6 depicts the least cost calculation for the second hop, as well as the flow diagram for the initialization step. Regular hello packets are sent by BC, and if more sensors (Nnode) exist in between the place of origin (Snode) and the place of destination (Dnode), they will reply with a hello packet as well. As a consequence of the Snode, the routing table obtains Node Information. The startup step determines the start and finish points of the hop by performing a least cost calculation.

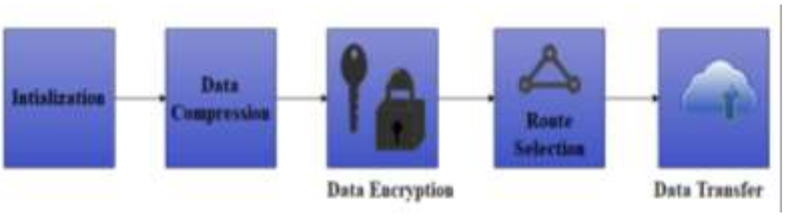

Figure 6 Flow diagram of SRPEE.

- **Data compression**

Sensor node storage capacity issues arise due to constant patient monitoring, necessitating more storage. Data compression can address these issues by using Huffman's non-uniform approach, increasing data packet speed, eliminating redundant sensing data, reducing storage hardware costs, and boosting network capacity.

$$\eta = \frac{H(z)}{L(z)} \times 100 \qquad 0 \le \eta \le 100 \tag{1}$$

where the entropy (S) computed using equation (2) is denoted by H (z).

$$H(z) = \sum_{i-1}^{n} P(m_i) \log P(m_i) \tag{2}$$

$$L(z) = \sum_{i-1}^{n} P(m_i) L(m_i) \tag{3}$$

Eq. (3) calculates the length of the data, L (mi), as well as the probability of the sensor data, P (mi), which reflect the length of the data.

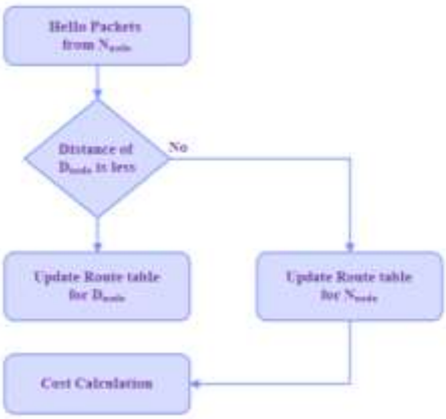

Figure 7 Flow Chart for Minimal Cost Calculation

- **Data encryption**

The suggested approach improves data security and privacy by using RSA, an asymmetric cryptography technology. Equation (4) yields the encrypted data.

$$E_{data} = P^e \bmod m \tag{4}$$

The equation (5) is a representation of the data that has been decrypted.

$$P_{data} = E^{d} \bmod m \quad (5)$$

E_{data} = Encrypted data to be transferred, P_{data} = Patient data obtained by the sensor, (m,e) = RSA Public key, and d = Private key shown in Eq. (6).

$$ed = 1 \bmod (p-1)(q-1), where\ p*q = m \quad (6)$$

- **Route selection**

The goal is to find the most efficient delivery method for energy-efficient data packets, using Equation (7) to estimate the cost for the next hop and Equation (8) to compute the distance between the source and destination.

$$MC_h = w_1 \left| \frac{D_{S,N}}{D_{S,D}} \right| + \left| \frac{L_{Pdata} - L_{Edata}}{L_{Pdata}} \right| + w_3 \left| \frac{E_0 - RE_N}{E_0} \right| \quad (7)$$

The $\frac{D_{S,N}}{D_{S,D}}$ represent the amount of distance that separates the origin and the destination. L_{Pdata} represents the length of the packet data, whereas L_{Edata} represents the length of the encrypted data. The router may use the net mask and network address to combine a packet and ascertain its eventual destination. This is accomplished via the use of routing table entries. When the IP address is matched, the packet will be sent to the first next hop that is available.

$$D_{S,D} = \sqrt{(x_D - x_S)^2 - (y_D - y_S)^2} \quad (8)$$

where x_D, $x_{S_{is}}$ are the x coordinates of the source and destination. y_D and y_S represent the origin and destination y coordinates, respectively. The distance formula is used in this equation in order to provide an approximation of the distance that separates two hops.

Eqs. (9) and (10) are used to calculate both the transmitted and received energies.

$$TE = kE_{Txb} + kE_{amp} D_{i,j} \quad (9)$$

$$RE = kE_{Rxb} \quad (10)$$

The proposed model exceeds earlier ones in terms of energy efficiency.

2.8 Comparison of energy optimization techniques for wireless body area networks

In this section we outline various comparison models related to the energy efficiency wireless body area network systems (table)

Algorithms	Network type	Communication mode	Thermal-aware	Energy-efficient	Emergency support
FPSS [44]	Homogeneous	Multihop	Yes	Yes	Yes

TARA [45]	Homogeneous	Multihop	Yes	No	No
OBSFR [46]	Homogeneous	Single hop	No	No	No
EAR [47]	Heterogeneous	Multihop	No	Yes	No
Tree [48]	Homogeneous	Multihop	No	No	Yes
DMQOS [49]	Homogeneous	Multihop	No	No	No
ATTEMPT [40]	Heterogeneous	Single hop/Multihop	Yes	Yes	Yes
RE-ATTEMPT [40]	Heterogeneous	Single hop/Multihop	No	Yes	Yes

The above table depicts the RE-ATTEMPT routing protocol for WBASNs, which combines the benefits of single-hop and multi hop routing, as well as priority-based route selection for regular and emergency data transmission. The initial worry with multi hop routing is latency, which is addressed by selecting routes depending on the least hop count. The second problem with multi hop routing is the high energy consumption of relay nodes; this is addressed by reducing the number of relay nodes and balancing them based on energy distribution. Furthermore, a time domain analysis of the proposed RE-ATTEMPT protocol in terms of route loss, as well as problem formulation and solution using linear programming-based mathematical modelling, is presented. The suggested RE-ATTEMPT protocol performed better in terms of network lifespan and throughput than existing protocols.

3 Future Directions and Open Challenges

Achieving a private, secure network with great stability is one of WBANs' primary criteria. It is also crucial to meet other needs including minimal latency, high energy efficiency, and minimal radiation absorption by the human body. The most urgent issues are listed in this section along with some suggestions for future study to address them.

3.1.1 Power consumption

Scientists are developing power-saving strategies for implanted devices, improving sensor sleep and collisions to prevent data retransmission, and developing body-powered wireless sensors for efficiency and reliability. Additionally, a research study in [55] suggests a schedule-based charging algorithm that charges implanted sensors in WBAN by using wireless power transfer technology.

3.1.2 Absorption of radiations by the human body

The human body may be negatively affected by radiofrequency radiation absorption, particularly in sensitive organs. For example, exposure to infrared radiation in the eyes is a serious concern because, as noted in [56], Radiation at eight watts per kilogram for 15 minutes may harm tissue in the head or chest. Europe limits exposure to 2W/kg, but the US limits it to 1.6W/kg. Thus, WBAN's main challenge is reducing radiation. Keeping sensors' power absorption low limits, the body's energy intake. WBAN devices must run for shorter periods and with less transmission power. LPWAN technologies, with their low transmission power and regulated duty cycles, may be one of the solutions.

4 Conclusion

The research explores various algorithms and strategies for enhancing energy economy in Wireless Body Area Networks (WBANs), a crucial technology for medical and health applications. It highlights the need for sustainable energy consumption due to wearable devices' short battery life and differentiates between contention-based and contention-free techniques. The study evaluates energy usage trends in WBANs and presents novel solutions, such as the ER-ATTEMPT routing protocol, and enhanced data aggregation algorithms. These solutions optimize energy consumption while maintaining network stability and performance. The research also emphasizes the importance of establishing customized routing protocols for WBANs to improve energy saving. The report also addresses potential paths and open issues, such as reducing power consumption and addressing radiation absorption by the human body. The study emphasizes the need for continuous innovation and multidisciplinary collaboration to overcome challenges and achieve long-term, reliable health monitoring systems.

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