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Hierarchical energy efficient secure routing protocol for optimal route selection in wireless body area networks

A. Roshini *, K.V.D. Kiran

Department of Computer Science and Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, AP, India

1. Introduction

Wireless Body Area Networks (WBAN) is an evolution of wireless sensor networks (WSN) that comprises of tiny self-sustained nodes equipped with a special criterion for transport interfacing and control unit communication. WBANs are used for telemedicine to regularly quantify the physiological signals like EEG, EMG, ECG, blood pressure, heart beat rate, thermal body reading and blood glucose level checks. The abnormality sensed in these signals will be forwarded immediately to the care centre located nearby to provide necessary treatments. The telemedicine services have taken its identity for the reduced dimension of the sensor devices with affordable cost considerations [1]. Wireless Body Area nodes deployed in or on the human body possess minute low powered sensors with wireless mode of communication, if either implanted or placed on the body or placed in the surrounding. The unhealthy and lethargic living style of humans like frequent food intake, increased stress levels, lack of physical exercise and increased exposure to medication for a normal health issue. The reasons witness increases in vulnerability of developing chronic diseases that requires continuous treatment throughout the lifetime. The growing rate of flu or fever caused for a common man has outreached the COVID-19 virus and now it is resulted due to the epidemic Monkey pox virus, as suggested by the World Health Organization (WHO). The asymptotic nature of these diseases lacks early treatments resulting in boomed mortality rate. This cause has given rise to WBAN that lessens the health care expense. A complete efficient WBAN health care system still possess challenges like fluctuated battery power of sensor nodes, instant network topology due to node mobility, narrow QoS requirements, hot-spot problem, compromised data security, limited transmission power [2]. Hence it is highly advisable to address the challenges to ease the utilization process.

Efficient energy management sensor nodes can be attained when a ubiquitous routing algorithm is used during inter BAN and intra BAN scenario. A distributed network topology in BAN follows multi-hop data forwarding method using Zigbee technology to the central body co-ordinator or sink node. When multiple nodes are involved in carrying the physiological data, the security in handling the data by the

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* Corresponding author.
E-mail addresses: roshinicse22@kluniversity.in (A. Roshini), kiran_cse@kluniversity.in (K.V.D. Kiran).

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intermediate nodes and the thermal power granted by the sensor node increases hazardous effects on the subject’s health and life [3]. The sensor nodes deployed in various parts of the human body senses the physiological signals and based on the criticality of the sensed data, the data will be prioritized and forwarded to the Body Coordinator (BC). This node initiates the data forwarding process to the wireless devices to trigger the reception process from any part of the Universe. This remote health monitoring reduces the incidental expenditure by making frequent visit to the hospitals. The intra-body signal transmission challenges in terms routing and security are to be addressed for better energy efficiency and attack free critical data handling.

Unlike wireless sensor networks that monitors the environmental changes in the field of agriculture or domestic field, extended energy efficiency for data transmission is in need for WBAN to handle the critical data. This demand emerges as the body nodes are activated by the micro batteries in which replacement is a design issue. In addition, the emission of electromagnetic radiation influences the specific absorption rate by the human tissues which when exceeded beyond the threshold value initiates human tissue damage. In contrast the conventional methods to address the energy related challenges like open-source methods and throttling, an efficient routing algorithm can be designed to stabilize the energy efficiency and enhance the Network Lifetime rather than fragmenting the Network.

Routing in intrabody network is a challenge, as mentioned earlier in this paper. This work provides a method for data forwarding from the source node to the coordinator node under distributed topological structure, where each node has a wireless connection between all the remaining nodes in the BAN. The multi-hop routing pattern results in a non-optimized way results in high energy consumption by the body nodes. To optimize this, a hierarchical distribution of sensor nodes clustered together and controlled by a cluster head is responsible for efficient routing as shown in Fig. 1. The cluster allows categorizing the nodes with moderate energy levels [4]. In spite the non-uniform clustering issues are to be addressed to reduce the energy dissipation of sensor nodes. The flat networks cause flooding which requires high bandwidth levels to handle the duplicate messages thereby increasing the delay rate.

The physiological signals extracted and reaching the care centre is more essential for life. Hence safeguarding these data until it reaches the destined receiver with high security and confidentiality techniques must befoold in WBAN. Synthesis of a secure routing protocol integrated with data security yields better confidentiality, integrity and authentication of data [5]. Therefore, a contemporary approach for optimum route selection from a hierarchical distributed network that exhibits energy efficiency, reliability, throughput and security necessitates WBAN for highly secure data transmission.

Sensor nodes used in agriculture field for the benefit of the farmers witness aggressive energy consumption by the nodes under abnormal environmental changes. Hence the sensor nodes are regularly energized by replacing the batteries. The proposed protocol is a novel approach derived from the drawbacks of the existing protocols like Energy aware Peering Routing (EPR), compressed and secure energy efficient routing protocol (CSEER), reliable Adhoc on-demand distance vector routing (Rel-AODV), optimized energy efficient secure routing protocol (OEESR) and other standard protocols like Adhoc on demand distance vector (AODV) and cooperative Adhoc on-demand distance-vector (C-AODV) with reference to throughput, packet dropping rate, energy efficiency and security.

The remnant contribution in this article includes a detailed literature survey on the existing routing protocols in section 2. The research gaps identified in the literature and the novelty of the proposed protocol in section 3. The working of the proposed protocol in terms of optimal route selection in section 4 and security in section 5. A detailed analysis and the outcome of the results in section 6 followed by conclusion and future enhancement in section 7.

2. Literature review

An energy-aware clustering algorithm and cluster-based routing algorithm EADC under a non-uniform node distribution scenario is framed where in a uniform cluster, the current cluster head selects the next data forwarding node with high energy level and stabilizes the load among all the nodes in the cluster [6], to increase the network lifetime. Complete cluster based Low Energy Adaptive Clustering Hierarchy (LEACH) exhibits distributed clustering technique that reduces the impact of random cluster head selection [7] and the node with higher energy levels will be selected as the cluster head.

Application-specific data acquisition process focussing on energy efficiency and media access, through LEACH-centralized protocol that go along with self-organisation of the sensor nodes and spinning cluster head positions for efficient load handling that out performs the lifetime [8] of the Network. Reducing network congestion to improve data reliability and enhance the data transmission with security [9] using an Optimized Energy Efficient Secure Routing Protocol (OEESR). The protocol evaluates data throughput and energy consumption by 90% and 8.8% with diminished packet drop rate of 13%. The thermal emission among the body nodes dissipates high energy, resulting in reduced Network Lifetime and creates impact on human tissues by inducing damages [10]. Thus, a Temperate Aware and energy optimized (TAEO) routing protocol is created to reduce the hot spot problem and to stabilize the load on the network. The protocol reduces the cardinality of the heated nodes by 30% and transmission takes place with remaining

![Fig. 1. WBAN Topology based Routing Classification.](image-url)
70% of the nodes.

The threshold values for the extracted data from the human body is fixed to a normal range to reduce the energy consumption. Threshold-based energy efficient routing of critical data parameters for emergency scenarios outperforms in increasing the throughput and reducing the packet drop rate, but the data categorization is least considered in routing process [11]. A generic survey on wearable sensors and its effects on human body is analysed, that intimates the health status of an individual. Hence a lightweight sensor [12] monitoring the physiological values and activities reduces the exasperating feel among the individual.

An economic, on body and user-friendly sensors and actuators to monitor the important physiological sensors [13] with minimal human resources. The system includes assimilation of sensors, modes of communication and intelligent retrieval to identify health information under various postures like walking, sleeping and running. The IEEE standards to secure the data communication is included in IEEE 802.15.6 for Local Area Networks (LAN) and Metropolitan Area Networks (MAN). Coordination of destined hubs for medium access [14] and power management with a single hub in BAN where the number of body nodes range from 0 to MaximumBAN_Size. Secure communication in MAC goes through the stages like orphan state-where the hub security is void, associated state – where the hub holds the master key for pairwise temporal key creation, secured state-nodes are secured and emphasize only on security parameters and finally the connection state to forward the data packets.

A profusion of network structure with opportunistic routing protocol ensuing source-neighbour node communication in a relay mode and multi-hop pattern of data forwarding depending on the position of the relay nodes [15], the Line of Sight (LoS) varies depending on time that yields better throughput and reduces the packet drop rate. An energy efficient routing protocol for increased reliability on data, in which the next hop node is elected in an influential manner [16] by assuming the maximum benefit function as one of the parameters like residual energy, transmission efficiency, available bandwidth and number of hops to reach the sink node. The cost of the routes varies based on the priority of the data. However, the protocol does not follow a standard mechanism for weight (or) cost computation.

Wrong selection of cluster head is overcome with Enhanced Developed Distributed Energy Efficient Clustering EDDEEG. The protocol categorizes the nodes into typical nodes, advance nodes and super nodes. The cluster head selection is based on the node’s residual energy [17], which is then compared with Low Energy Adaptive Clustering Hierarchy (LEACH), LEACH-C (clustering) and PEGASIS on efficient energy consumption. Photoplethysmography (PPG) -a congenital instrument to monitor the blood flow that is an alternate to electrocardiography to estimate the heartbeat rate [18]. The existing models discussed as of now requires the subject to be in a static motion for fewer duration, but the framework in this contribution is entrenched on mobile node deployment [19]. Hence a power efficient method [22] for secure transmission efficiency in the proposed protocol a data compression model and cost-based function is considered. The model assumes the QoS parameters like delay and residual energy. The compressed and secure Energy Efficient Routing Protocol (CSEER) outperforms RelAODV by RSA and Arithmetic data Compression techniques [23], yielding 10–11% more energy efficient.

3. State of art

The literature review strongly reveals two important issues about the routing and network lifetime of WBAN. Most of the available protocols restrict the network to monitor the regular activities whereas patients or subjects who are completely bedridden for various reasons like undergone a surgery, person affected by stroke and other issues like autism. The positioning of the body nodes on the subject at various locations create issues on data forwarding process and mobility. The prioritized critical data handling techniques overlook the intra clustering issues and inter routing processes to stabilize the load in the communication channels with the enhanced Lifetime. The clustering and routing processing of the physiological signals compromise the security issues in handling the critical data before it reaches the base station. To add with the acquired raw data must be compressed to acquire confidentiality and authentication from the care taker end [24]. Hence to attain the QoS parameters, An Energy Efficient Secure Hierarchical Routing protocol (EESHR) is proposed to select an optimal route in a hierarchical network clustering of the deployed sensor nodes on the body with confidentiality.

The definite contribution are as follows:

1. Structure the sensor nodes using Low Energy Adaptive Clustering Hierarchy-Media Access Control (LEACH-MAC) routing algorithm to select the cluster head (CH) on constant intervals.
2. A secure data compression technique called Huffman data compression to reduce the number of data extracted to increase the speed of data transmission and select the optimal route selection.
3. The mobility of the body nodes (BN) cause a diversified data acquisition, which is prioritized based on the substantial value, after which identifies the next nearest node through the MAXIMAL, GAIN FUNCTION that considers the clustering parameters like residual energy, CH selection and multi-hop data transmission.

List of symbolic representations in this paper is listed in Table 1.
cluster head (CH), where the threshold is given by:
\[ r = \frac{1}{e_r} \quad \text{where } 0 < r < 1 \] (26). The nodes then yielding a random transmission. The elected node is controlling the other nodes known as warding in wireless networks. The protocol originally handles multiple clusters in which a collection of nodes constitutes forming a cluster, the clusters in which a collection of nodes constitutes forming a cluster, the

4.1. Cluster head selection

The conventional LEACH protocol, elects the cluster head dynamically in a randomized way, where each node generates a random value ranging between 0 and 1 [26]. The nodes then yielding a random number and falling below the threshold \( T_h(BN) \) will be elected as cluster head (CH), where the threshold is given by:

\[ T_h(BN) = \begin{cases} I_p(CH) \\ 1 - I_p(CH) \left( \left\lfloor \frac{r}{\text{mod} \left( \frac{1}{I_p(CH)} \right)} \right\rfloor \right) \end{cases} \]

\[ \text{if } (BN_i \in BN) \]

The CH then selects the nodes to constitute the cluster based on the received potential levels of the signal (PLS) [25]. The randomness in the CH election is enhanced as the WBAN is distributed Network that follows Mesh topology with Optimized Low Energy Adaptive Clustering Hierarchy-Media Access Control (OLEACH-MAC) by considering the message priority based on the physiological value, node’s residual energy and node’s hierarchy such as relay or direct nodes.

Consider that WBAN is comprised of five location specific sensor nodes to monitor the Heart Beat Rate (HBR) of a person who is under medical surveillance. The following assumptions are considered in the Network Model:

- All the deployed five body nodes follow varied power levels depending on the PLS.
- Nodes are mobile and distributed in the positions from where the HBR could be monitored efficiently.
- Sink or the base station (BS) is placed outside the human body and each body nodes can acquire the data with an energy consumption of \( E_n \) (\( nJ/\text{bit} \)).
- The residual energy of all the nodes is uniform at the beginning.

The proposed OLEACH-MAC protocol allocates the cluster head in the rolling pattern based on the residual energy and to maintain uniform node utilization for better lifetime. Suppose that the ideal number of cluster heads are \( n \), then mean value of nodes in a cluster is \( \frac{N}{n} \). The combined energy consumption for a single TDMA cycle by a cluster is:

\[ E_{ci} = E_{Ch} + \frac{N}{n} E_{nClusH} \]

\[ \text{Followed by the energy consumption of the cluster head and non-cluster node is based on the response, data acquisition and data transmission to the sink or Base station:} \]

\[ E_{Ch} = \text{len} E_{\text{msg}}/N + \text{len} E_{\text{msg}}/n + \text{len} E_{nCh} \]

\[ E_{nClusH} = \text{len} E_{\text{msg}} + \text{len} E_{\text{msg}} = E_{\text{msg}} \]

The sum of the energy consumed in a frame is given by:

\[ E_{\text{sum}} = n E_{ci} \]

This total energy is then passed to the threshold generator where the priority of the messages is verified based on the Heartbeat Rate and the traffic priority like Critical-medical data (CMD), Periodic-Medical Data (PMD), Regular-Medical data (RMD) and Non-Medical Data (NMD). The energy calculated in the above equation (6) will also return the unconsumed energy \( E_{net} \), of the nodes given by:

\[ E_{net} = E_{initial} - E_{ci} \]

The unconsumed energy level of a node evaluates which node must be elected as CH and which will remain as member nodes in WBAN. If the unconsumed energy is less than that of the threshold then the node is elected as the cluster head and the network follows the multi-hop data transmission pattern called as relay mode, else the networks used direct mode of data transmission called as direct mode and will be labelled as non-cluster head. Next, the data transmission need to be initiated from the member nodes following an optimal route for the data to reach the destination.

The distinctive behaviour of the proposed protocol lies in the delay of the CH advertisement to the neighbouring nodes in the WBAN. A random interval time \( Time_{CHrandom} \) is used to compute the data trans-
mission time \((T_s)\) and time to receive the acknowledgement \((R_{ack})\) for the data sent which is given by:

\[
T_s = \frac{(8B_{\text{size}} + 8)}{BW} \tag{7}
\]

\[
R_{ack} = T_s \times (P_{\text{size}} + 4) \tag{8}
\]

Therefore,

\[
Time_{\text{CHrandom}} = R_{ack} \times 1 \times 4 + 1 \tag{9}
\]

The total transmission time \((Time_{\text{CHrandom}})\) required for a CH to transmit a data packet based on the network traffic and priority of the messages, allows the CH with higher unconsumed energy levels to transmit the CH announcement. At regular intervals the node analyses the number of announcements through the \(CH_{\text{ann}}\) variable. If the variable value falls below the prime value i.e., within the total number of nodes in the network, then the node forwards the CH advertisement else it is declared as the normal node.

### 4.2. Data compression with optimal route selection

Energy efficiency during data transmission is very important in WBAN, as the network handles physiological data, which must be triggered during abnormalities during the heartbeat rate surveillance. The energy dissipation rate will be a considerable issue if not addressed leads to frequent replacement of body nodes. Hence it becomes essential to efficiently utilize the service of body nodes and the CH. Increase in network traffic during multi-hop data transmission and the restricted repository of body nodes are added challenges that need to be addressed using data compression techniques [29].

Huffman encoding is used to store data more optimally in a compressed manner and in encrypted way. During compression, the probability that the data gets lost is high and it could be acceptable only to a certain level when dealing with image or video data but not acceptable in WBAN. This pitfall is overcome by reducing or fragmenting the data into smaller units and regularize the energy utilization. The approach reduces the transmission and reception duration, time and space complexing and increases the network Bandwidth and throughput. The following process is followed to evaluate the compression and encryption techniques:

\[
\text{Ratio of compression} = \frac{Len_{CD}}{Len_{ID}} \tag{10}
\]

Compression Parameter is given as the converse of the compression given by,

\[
\text{Compression Parameter} = \frac{Len_{ID}}{Len_{CD}} \tag{11}
\]

Amount of data compressed from the original data is the Sustained energy and is given by,

\[
\text{Sustained Energy} = \frac{Len_{ID} - Len_{CD}}{Len_{CD}} \% \tag{12}
\]

Data efficiency rate is computed as follows,

\[
\eta = \frac{S(z)}{Len(z)} \times 100 \quad \text{where} \quad 0 \leq \eta \leq 100 \tag{13}
\]

where \(S(z)\) and \(Len(z)\) is the entropy and average length of the code-words in Huffman encoding. Assume the Heartbeat rate occurrence probabilities are given by the CH at regular intervals are given by \(P(b1), P(b2), P(b3), \ldots, P(bn)\) for \((b_i = 1, 2, 3, \ldots, n)\). The entropy \(S(z)\) is calculated as:

\[
S(z) = \sum_{i=1}^{n} P(b_i) \log P(b_i) \tag{14}
\]

Average length of the codeword \(Len(z)\) is given by

\[
Len(z) = \sum_{i=1}^{n} P(b_i)Len(b_i) \tag{15}
\]

The compression and decompression momentum are calculated from the time taken for the message to compress and decompress.

The critical data collected from the human body through the WBAN is also vulnerable as they are transmitted through the network and strict security policy must be followed. Security compromise in this data may harm the life of the subject and lead to complications leading to mortality. The attacker may intrude to these systems and monitor the patient’s data for illegal purpose. Hence a lightweight secure and privacy technique is in demand to handle the security risks in these systems. The privacy policy in such systems rely on the asymmetric encryption technique that uses both private and public key maintained by all the deployed nodes in the BAN. The private key of the sensor nodes consists of two large prime numbers that will not allow the attacker to decrypt the physiological data.

The proximity of the nodes often fall within the communication range as the number of body nodes are limited [27] in WBAN. Reliable and stable data transmission between two nodes is derived from a value-based function that is given by equation (16). The proposed OLEACH protocol, selects the optimal channel with to minimize the energy consumption and maximize the throughput.

\[
\text{Minimum}_{\text{ann}} = c_1 \times \frac{\text{Dis}_{\text{src}}}{\text{Dis}_{\text{net}}} + c_2 \times \frac{\text{Len}_{ID} - \text{Len}_{CD}}{\text{Len}_{ID}} + c_3 \times \left| \frac{\text{Energy}_{\text{init}} - \text{Energy}_{\text{ann}}}{\text{Energy}_{\text{init}}} \right| \tag{16}
\]

where

\[
c_1 + c_2 + c_3 = 1 \tag{17}
\]

The optimized weights \(C_1, C_2\) and \(C_3\) influence on the parameters like displacement, length of the data and the value-based function. The distance between the sending host and receiving host is computed as follows:

\[
\text{Dis}_{\text{src}} = \sqrt{(a_d - a_i)^2 - (b_d - b_i)^2} \tag{18}
\]

### 4.3. Normalization of QoS parameters

The optimal route selection process is characterized by two-three hop communication to reduce the average energy dissipation caused during direct communication. A MAXIMAL_GAIN FUNCTION parameter allows to firmly select the next-node that lies in the optimal route or to adjust the cost of the MAXIMAL_GAIN FUNCTION based on the network traffic data extracted from the human body. This proposed word achieves a firm routing alternative routed for reliable and efficient data transmission. The normalized form of transmission efficiency, residual energy, bandwidth and number of hops are computed using the weighted coefficients.

The finite state of the node’s energy is required for efficient energy consumption. The node with maximum unconsumed energy is selected as the next optimal node to stabilize the energy consumption of the network. The normalized form of the unconsumed energy \(E_{\text{net}}\) is given by:

\[
Y_i = \frac{E_{\text{net}} - E_{\text{th}}}{E_{\text{init}} - E_{\text{th}}} \tag{19}
\]

The lower the unconsumed energy than the threshold value then only the current node’s data is forwarded rather than the received data. Successful transmission rate of the packets returns the transmission efficiency. The higher number of successful transmissions per second yields higher transmission efficiency that depends on the number of data
packets successfully received and successfully transmitted by the node. This results in selecting the next optimal node for data forwarding which is given by:

$$\eta_i = \frac{Data_{success}}{Data_{receive}}$$  \hspace{1cm} (20)$$

The normalized transmission efficiency is given as:

$$Y_i = \frac{\eta_i - \eta_{min}}{\eta_{max} - \eta_{min}}$$  \hspace{1cm} (21)$$

The bandwidth used for current transmission must be broader enough for better data transmission. Assuming that the available bandwidth is sufficient for efficient data transmission and increased the reliability of the network. The normalized bandwidth rate and its efficiency is given by:

$$Y_3 = \frac{Ban_i}{Ban_{max}}$$  \hspace{1cm} (22)$$

The network enabled now selects the next hop node to reach the sink node, for enhanced real-time transmission. The next hop of the node in normalized form is represented as $$Y_4$$ given by:

$$Y_4 = \frac{Hop_i}{Hop_{max}}$$  \hspace{1cm} (23)$$

The MAXIMAL_GAIN FUNCTION is given by the sum of equations (19), (21)–(23), where the calculation of the next hop node allows to select the best next hop node.

### 5. Hierarchical Energy Efficient Secure Routing Protocol (HEESR)

The proposed protocol Hierarchical Energy Efficient Secure Routing Protocol (HEESR) targets to accomplish better reliability, throughput, energy efficiency and security by following the hierarchy among the body nodes deployed as relay nodes and direct nodes. The protocol is compared with Optimized Energy Efficient Secure Routing Protocol (OEESR) that reduces the network congestion and improves the security of the BAN by selecting the optimal route for data forwarding. The enhancement factors in the proposed protocol includes optimal CH selection among the deployed body nodes based on the threshold values and comparing the energy consumption levels with non-CH node. The collected data is then compressed and encrypted and then forwarded to the nodes in the optimal path as shown in Fig. 4. The protocol is described as follows:

#### 5.1. Node advertisement phase

The proposed protocol receives Hello message from the sink or body coordinator to the body nodes of the WBAN, which includes the location and identification number of the sink node as shown in Fig. 2. The body nodes upgrade the information in their routing table for later forwarding of physiological signal. The body nodes now start to elect the CH node by setting the threshold value and verifying the residual energy of the nodes. The reply node’s frame format is shown in Fig. 3. The node transmits the data based on the network traffic; hence the neighbour node table consist information about the priority of the data either critical or non-critical data.

#### 5.2. Hierarchical Routing algorithm

The selected CH node now identifies the direct or relay pattern transmission based on the unconsumed energy levels of the node and the type of messages. If a periodic message or non-medical data is sensed then the messages will not be transmitted immediately and will wait for a definite amount of time else if the critical medical data (CMD) is observed then those messages are transmitted with no delay through the multi-hop node. The distance between current node and the neighbour is computed to compare the shortest distance. The algorithm for the same is given below:

**Algorithm 1.** Node selection for data forwarding

![Fig. 2. Node Advertisement Frame format.](image)

**Fig. 3.** Neighbour node reply frame format.

**5.3. Encrypted message transmission**

The regular Heartbeat rate remains in the buffer till the contention period and then will be transmitted later, whereas the CMD will be immediately transmitted by resuming a copy of the message in the buffer. This information will be compressed and encrypted using Huffman coding and RSA (Rivest–Shamir–Adleman) asymmetric algorithm with the patient’s raw data using the private key to the source and the compressed data. Once the encryption process is completed the nodes routing table will automatically update the status by setting the flag = 1 else 0. This status will reduce redundant encryption and network traffic.

**5.4. Decrypted message receival**

The destination node verifies the encrypted message and decrypts using the public key to the destination. The ID of the destination is verified with the received message, if it matches then Huffman decoding algorithm is used to decompress the patient’s information and then
Table 2
Simulation parameters.

| WBAN Parameter | Value |
|----------------|-------|
| Number of nodes | 5     |
| Number of Sink  | 1     |
| Initial energy  | 1J    |
| Size of a packet| 75 bits|
| $E_{ClusH}$     | 0.9J  |
| $E_{ClusH}$     | 0.75J |

Fig. 4. Data transmission in HEESR protocol.

Fig. 5. Energy consumption levels.
forwarded to the care taker or physician for further medicaments as shown in Algorithm:2.

Algorithm:2. Optimum route selection

| Input: Heartbeat rate sensed by the sensor nodes |
|-----------------------------------------------|
| Output: Forward the data to the Base station   |
| 1. BN = Monitor the HBR                       |
| 2. If (data==CMD)                             |
| 3. Compress the data                          |
| 4. Encrypt the data                           |
| 5. Immediate transmission                     |
| 6. else                                       |
| 7. sleep (50)                                |
| 8. transmit the data                          |
| 9. end if                                     |
| 10. if (unconsumed energy==1)                 |
| 11. route the data to BN                      |
| 12. Flag=1                                    |
| 13. Forward the regular and critical          |
| 14. else                                      |
| 15. Forward the current data to base station  |
| 16. end if                                    |
| 17. Decrypt the data                          |
| 18. Action taken by the caretaker             |

6. Experimental results and analysis
The experiment results of the protocol are simulated in MATLAB environment. The routing process is carried out between the five pulse sensors deployed on the human body in five critical points like behind the ears, chest, right elbow, abdomen and near the left knee in a proximity of 1 m × 1 m. The limited network coverage area allows the node to determine the optimal path to transmit the physiological signal to the sink node. The five sensor nodes deployed on the body are prone to be mobile subjected to postural change. The Network parameters used during simulation are defined in Table.2. The proposed HEESR protocol follows direct or multi-hop pattern of data transmission depending on the residual energy of the sensor nodes, and the performance evaluation is carried out to verify the throughput, energy consumption and security of the Network.

6.1. Energy consumption
The distance computation between two sensors nodes when there exists a posture change, enables to calculate the transmission time. The selection of optimal node using the OLEACH protocol, includes node initialization phase where each node identifies the presence of the neighbour nodes and elected the cluster head depending on the Threshold value. The CH selection among the nodes and the packet advertisement of the sink nodes to the WBAN and the reply nodes with the network priority in the frame format identifies an optimal route between the source and destination to route all the packets belonging to CMD, the residual energy levels of the nodes are also considered before data transmission. Hence, the energy levels of the proposed HEESR protocol maintains consistency in energy consumption for any data rate. The existing protocols Energy Aware Peering Protocol (EPR), Reliable Adhoc On-Demand Distance Vector (Rel-AODV), Compressed and secure Energy Efficient Routing Protocol (CSEER), Optimized Energy Efficient Secure Routing Protocol (OEESR) reduces by 2%–3%, where the proposed HEESR protocol consumes 1% of initial energy level as shown in Figure.(5).

6.2. Throughput
The reliability of the network is accessed by the successful data transmissions rate per unit of time. WBAN environment must maintain high throughput all the time as the data is related to the human body and the criticality in the subject’s physiological signals. The initial raw data generated is passed to Huffman coding algorithm where the data is compressed to reduce the number of bits to be transmitted, based on the traffic priority the number of packets will further be confined and the optimal routing path will be followed to maintain a reliable data transmission. Figure. (6) clearly shows that the initial throughput of HEESR protocol is reduced only by 8%, whereas it is reduced by 15% in OEESR, 30% IN CSEER,17% in Rel-AODV and 13% in EPR. In addition, the unconsumed energy levels of each node also will maintain the throughput for WBAN. Increased number of nodes results in buffer overflow which is controlled by the compression technique used to reduce the data. This process also reduces the collision rate and network traffic. Assuming the optimal selection of neighbour nodes enables all the data packets to be forwarded to the cluster head based on the data traffic and type of data like critical or non-critical data. Filtering of the data in to such category reduces the network traffic with maximum throughput.

The compression process is followed by the encryption of the data which is a significant feature of Huffman encoding and here the encryption process is carried out with the RSA algorithm, which is an Asymmetric cryptographic technique where the data is encrypted using private key to the sink node and decrypted using the public key to the CH node. The proposed algorithm outperforms the existing algorithms as the raw data is compressed and by applying the cryptographic algorithm the confidentiality in the message is maintained. The energy consumption, unconsumed energy levels, throughput and reliability of the network is increased as the compression is enabled with cryptographic algorithm to ensure security of the critical data to be free from vulnerability and untampered till the time it reaches the destination. The proposed HEESR protocol outperforms all the existing protocols by 1% and yields 93% of security whereas other protocols EPR (91.1%), Rel-
The proposed HEESR routing protocol’s unique nature adds energy efficiency and security under mobile nature of the sensor nodes caused out of the postural change to the existing protocols and improves the reliability of the data transmission in the deployed WBAN. The four parameters used for efficient data forwarding like CH selection based on the unconsumed energy levels and priority of the data. Implementation of compression techniques efficiently uses the buffer and thereby reduces the Buffer Overflow attacks.

7. Conclusion

The proposed HEESR routing protocol's unique nature adds energy efficiency and security under mobile nature of the sensor nodes caused out of the postural change to the existing protocols and improves the reliability of the data transmission in the deployed WBAN. The four parameters used for efficient data forwarding like CH selection based on the sink node advertisement, data compression using Huffman encoding and encryption using RSA asymmetric algorithm to return efficiency computation for data transmission, bandwidth utilization and multi-hop data transmission based on the residual energy and data priority has increased throughput rate with optimal energy consumption and reduced packet drop rate. The model considers only network parameters to evaluate the performance of the algorithm, which could be improved by using cloud platform, machine learning and Artificial Intelligence techniques to improve the data analytics of the physiological signals and the positioning and detection of the sink node in a distributed nature can be deployed as a future contribution.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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