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ROLG: Delay Sensitive And Fault Tolerant Hybrid Mobility Model For Wireless Body Area Network

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Abstract
In recent years, WBAN has been one of the most used networks in the field of healthcare. Along with its uses, it comes along with a lot of challenges to manage to get the maximum outcome from the network. The most significant challenges of all time involve the location of the sink node and the identification of lost nodes during movement. The proposed mobility model named ROLG which is delay sensitive and fault tolerant hybrid mobility model for WBAN environment. ROLG inherits the benefits of both group and individual mobility patterns and thus allows a realistic modeling of the body movements and ensure minimal communication delays and higher network resilience. The model also incorporates predictive mapping of mobility and localized recovery that ensures data flow even in the event of node or link failure. The proposed approach utilizes the grey wolf algorithm for achieving the tremendous growth in the network performance of WBAN. The simulation results revealed that with optimized 25 sink nodes, the performance of PDR performs well with no packet loss, enhances the throughput to 34.61 kbps, and reduces the delay to 0.001226 seconds which proves superior efficiency in comparison to random sink movement. At 50 nodes, PDR functions well with no packet loss and reduced delay to 0.002563 seconds, throughput stays at 28.94 kbps with optimized sink movement whereas, with random sink movement throughput lowers to 19.48 and increased the delay. The ROLG mobility model has successfully localized every lost node in the network and has achieved high proficiency in the overall network performance.
Keywords *WBAN, RPGM, RVGM, Fault Tolerance, Sink*

1. INTRODUCTION

Wireless body area networks (WBANs) are a distinctive type of sensor network that is employed to monitor a person's health-related metrics without disrupting their daily activities [1]. WBANs are one of the most cost-effective medical solutions for this issue. It consists of biological sensor nodes (SNs) that are both lightweight and compact, and can be easily and comfortably implanted within the human body [2]. The key drawback with these compact SNs is their tiny resource capacity, particularly the battery capacity which drains rapidly. In contrast, a WBAN necessitates a significant level of dependability due to its direct correlation with the quality of patient monitoring [3], [4]. Even a little negligence can result in death. So, the major objective is to properly monitor the data. Therefore, error tolerance, security, and operational efficiency are three criteria that the protocol must handle to cope with high levels of reliability and data accuracy. Error forbearance and operational efficiency to give an effective and consistent resolution correlating WBAN; both parameters should be examined simultaneously [5]. Security needs to be the third component of the same. Error, inaccuracy, and letdown are the three separate characteristics that need to be addressed to cope with the concept of fault tolerance. Many problems arise as errors; they may be related to current hardware or software impairment. Both purposeful and unintentional factors might lead to an event. Active fault is the abbreviation for notifiable problems, such as a sensor's dead battery. Passive errors, such as code bugs, will never be simple to detect. A problem can harm the system if it goes unfixed for a certain amount of time, which could result in system failure. Data loss occurs during data transmission as a result of path-loss/path dis-connectivity issues caused by the increased mobility of SNs resulting from human body movement. Routing protocols that rely on clustering mechanisms are suitable for use in WBAN-related applications. In WBAN, transmission delays and interference with data integrity and smooth communication are significant issues due to node isolation and network partitioning. These issues may lead to decreased network performance and various network Quality-of-Service (QoS) metrics. Additionally, the intentional placement of numerous anchor points throughout the network ensures a robust framework that minimizes network splitting. This approach enhances WBAN's resilience to physical weaknesses and ensures a more reliable and efficient data transfer mechanism, rendering it an appealing solution to these urgent issues.

WBANs represent a considerable technological advancement that has a wide range of applications in both the medical and non-medical sectors [6], [7] [8]. WBANs are communication devices that are designed to monitor the human body from the inside out. They collect health data from patients and transmit physical or vital information from biosensor nodes to a server for evaluation. The issue with WBAN is the movement of sensor nodes, which renders them susceptible to isolation. This movement also results in a variation in topology over time. Prior models had fixed the sink, which resulted in data loss due to movement and node isolation from the central node during data transfer. The proposed model will assist us in solving the following issues.

i. The proposed work will solve the problem of node isolation by introducing multiple anchor points in group mobility models.
ii. Sink mobility will improve the model's overall performance in terms of fault tolerance and delay by being incorporated into already-existing mobility models.
iii. The work will help in eliminating the problem of existing empty groups in the region along with the checkpoints for redundant data to save extra computing and hence more efficient mobility models for WBAN.

The paper is structured as follows. Section 2 summarizes the existing studies of WBAN. Section 3 outlines the materials and methodologies employed in this work. The research findings are presented in Section 4, and the conclusion is presented in Section 5.

2. Related Work

The ever-changing field of healthcare technology relies heavily on WBANs to monitor and analyze physiological data in real-time. Regardless, there exist substantial obstacles to the efficient functioning of WBANs in healthcare environments, specifically about guaranteeing prompt data transfer and resilience against any malfunctions. Researchers have developed several fault-tolerant and delay-sensitive schemes that are specially designed for WBANs to overcome these issues [9]. Young Rok Jang et al. focused on two elements that are essential for WBAN nodes: increased longevity and minimum loss of important physiological data. However, by dynamism accumulating information to extend the battery-operated lifetime of the nodules, these aspects may be brought to light. The Minimum Distance Adaptive Allocation (MDAA) queue management mechanism was used by the suggested approach's authors to ensure the dependability of both the statistics line and the energy line simultaneously. The two-dimensional plane is used to model the energy queue and data queue. Then, MDAA modifies the timing of energy gathering and statistics transmission to reduce the Euclidean distance between the optimal pass and the subsequent pass. The data queue and the energy queue operate at their optimal levels when they are both empty and fully charged. To mitigate the Euclidean difference between real and ideal states, the MDAA is implemented. The hub transmits radio frequency (RF) signals that can be converted to energy upon obtaining data from the node. In contrast, the data node acquires RF signals from the hub and transmits them. The longevity and data overflow of the MDAA output are contrasted with that of the Deterministic Allocation (DA) control group [5]. Two remote authentication methods were employed by Jingwei Liu et al. to provide secure and lightweight certificates for remote WBAN users. These authentication methods are based on a novel certificate-less signature (CLS) mechanism that has been demonstrated to be highly effective in the random database model and secure against existential fabrication on adaptively chosen transmission assaults. Furthermore, these protocols ensure that neither facility sources nor applications are capable of disclosing individuals' real identities.

Additionally, it is forbidden for the system administrator to pose as an authorized user to aid in the certification processes as a covert key maker. The outcomes of simulations demonstrate the efficacy of these methods [10]. The work in [11] has introduced an efficient Poll-based MAC protocol (PMAC) that prioritizes energy conservation and delay factor in order to circumvent the limitations of IEEE 802.11 and 802.15.4. The implementation of a polling-based channel access approach surmounts the restriction of 802.15.4, which employed CSMA-CA and TDMA mode for channel usage in the beacon-enabled and contention-free time. The proposed work has divided the whole volume of traffic into four categories.

Scheduled, postponed, and unexpected polling are also distinct types of polling. Though the method proposed is effective in terms of channel access, it fails to account for node mobility. MAC layer protocols significantly influence the overall efficiency of WBAN. similarly, the work in [12] [13] has worked on Energy harvesting in WBAN and various data transmission techniques has been compared in work done by[14] where multiple routing techniques has been evaluated with different node positions of the sensor nodes in WBAN. For WBAN longevities in [15] suggested a uniform energy intake and bottom direction-finding to increase network longevity, increase the likelihood of effective broadcast, and promote postural body motions. This approach recommends two separate direction-finding methods, one for the back node and the other for the front—as well as consistent energy use. Using the Selection-Optimal-Route protocol and route data in a multi-hop fashion, the Backside Node Procedure selects the best route. Records are immediately redirected to the base station in a crisis. The intermediate node with the lowest standard deviation value is chosen by the algorithm for uniform energy ingesting after it checks residual energy and regular aberration for each node. However, the approach has a large overhead because forwarding nodes are selected for each cycle. The temperature of the sensor node keeps rising as the data is being broadcast, which is a major issue for WBAN. K.S. Kathe and Deshpande proposed a thermal-aware routing system that prioritizes patient vital information (such as high blood pressure and low blood sugar) above other traffic to resolve this issue [16]. This investigation emphasizes the importance of numerous sensor node parameters, such as the distance of the transmitting module from a washbasin and the current temperature of the surrounding node, to reduce unplanned hotspots during the transfer of emergency data. The limitation of this work was that the sensor nodes' mobility has not been considered in this study. In [17], authors have investigated the primary obstacles that WBAN faces when implementing a fixed slot allocation mechanism in IEEE 802.15.4. The author suggested a dynamic time slot allocation method for medium access control that improved the presentation of devices in terms of energy consumption and network lifetime. Recommended for data packet routing is the lowest-cost parent selection strategy, which is energy efficient. Utilizing a dynamic slot allocation system in conjunction with a fog-aided network is essential for the secure and efficient transfer of data. Even though the system functions flawlessly, security remains a significant concern due to the cloud's storage of data. In [18], the author has proposed (E-HARP) protocols for WBAN. The proposed protocol has two primary responsibilities: the selection of an ensemble leader from a list of candidates based on their calculated Cost Factor (CF) and Signal to Noise Ratio (SNR) and the subsequent routing of data using E-HARP with cooperative routing. The proposed method has a relatively low operational energy consumption. The investigation in [19] concentrated on the detrimental effects of electromagnetic radiation on human tissues and the subsequent decrease in the network lifespan of (BDN). To surmount this obstacle, the author devised the OPOT algorithm, which assists sensor nodes in determining the optimal path by considering temperature and collision rate. The proposed method reduces the total energy consumption and network latency. The primary focus of Mehmood, G. et al. was the effects of body fading in WBAN, which disturbs node relationships and elevates network latency. The author has suggested a fault tolerance technique that is energy-efficient and utilizes the accommodating message and system coding policy to reduce the overall delay and node failure caused by body fading [20]. The study's geographic scope, which covered a limited geographic area, and the number of WBAN nodes precluded the consideration of scalability. However, the primary goal of the study was to develop surveillance indicators that would utilize cooperative communication to reduce hospital readmissions and, as a consequence, lower mortality rates. The study aims to guarantee the reliability and efficacy of WBAN routing [21]. The authors developed the blockchain-based (ATEAR). Thermal energy, temperature rise, and throughput have been the primary areas of investigation in this investigation. The proposed research posits that the network's overall throughput may be increased by conserving residual energy and refraining from using overheated nodes as forwarders. The research has assessed the performance of the Castalia simulation tool by incorporating implanted nodes and utilizing the hyper ledger Caliper tool. For implanted nodes, the proposed approach is effective; however, there is currently no research on wearable nodes and node mobility.

3. PROPOSED METHODOLOGY

The proposed methodology entails the development and implementation of a ROLG Group Mobility Model with a movable sink node within the context of WBANs. Initially, the model's design and parameters are specified, encompassing key variables such as node density, group size, movement speeds of sensor nodes, sink node trajectories, and communication ranges. Using a NS-2 network simulation tool, a virtual environment is created to facilitate the integration of both sensor node and sink node mobility patterns. Node grouping is established based on density and proximity, with synchronized movement orchestrated within each group, guided by a designated leader node. The network is divided into several logical subnetworks, or clusters, using the clustering technique. Each cluster is comprised of one cluster head (CH) and other cluster member nodes. Each cluster member node transmits their detected data to the cluster via a single hop. In each cluster, the CH compiles the received data into a single packet known as a data packet. Subsequently, CH transmits this compressed data to the BS/Sink. The clustering technique optimizes data transmission and ensures end-to-end latency, resulting in minimum energy consumption. The CH consumes a greater quantity of energy than the member nodes because it aggregates and transmits data to the sink. Each transmission round involves the dynamic selection of new CHs to ensure that energy consumption remains balanced. Dynamic CH selection throughout the network's lifespan guarantees consistent energy consumption by distributing the load among multiple nodes [10]. The selection of dynamic CHs is a difficult task that requires the consideration of numerous factors. Multi-attribute decision-making methodologies are highly influential in the selection of an appropriate node for the CH position. These methods identify high-ranked nodes as potential candidates for CH by analyzing the essential node properties. The CH is the node with the highest rank value following the network criteria, which include leftover energy and proximity to the sink. When selecting the CH, a few of the current methods consider a variety of node features, such as the four SN parameters of transmission power required, predicted total network energy loss, Signal to Noise ratio (SNR), and current/residual energy of the SN [18].

A. Development of ROLG Mobility Model

The proposed ROLG group mobility model has three different aspects viz., grouping of sensor nodes, localization of lost nodes and the inclusion of mobile sink node with optimized traversal for the same.

Step 1: Clustering of Nodes and choosing Cluster Head

Clustering of nodes in WBAN is performed using geographical division of the simulation environment. General clustering algorithms are not considered because in WBAN sensor nodes position are not fixed and so is the cluster head's position so every time while sensing and transmitting the data the actual coordinates of the sensor nodes and cluster heads might come out to be different [22]–[24]. The diagrammatical view of the clustering nodes is shown in Fig. 1.

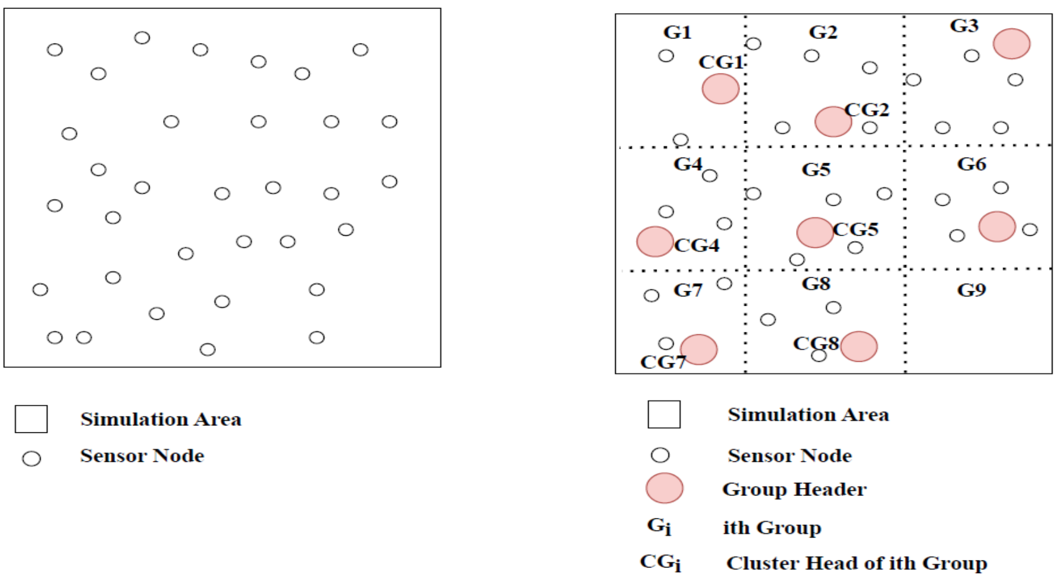

Fig. 1. Clustering of nodes and choosing group heads

The flow diagram to represent the above schema is shown below in Fig. 2.

Step 2: Planned Optimized Sink Movement

Problem Definition: WBAN is one of the best suited networks supported by most healthcare applications to collect and transmit vital body information to medical servers and get assistance for further course of action. In many circumstances, the sink node's position is fixed, which affects data collection for distant nodes. Occasionally, the delay is so great that patients do not receive medical treatment in a timely manner. The sink movement proposed so far in WBAN environment is very limited and not optimized to get better outcome, some of the sink movements are defined below:

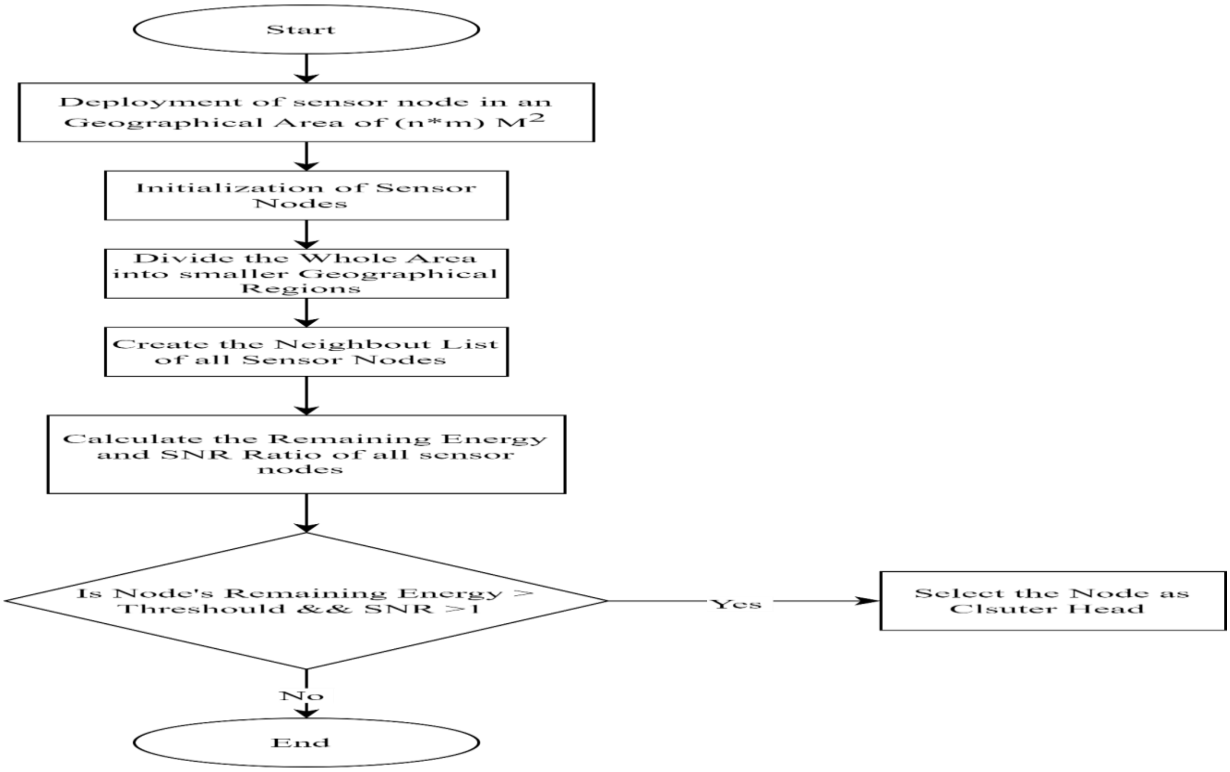

Fig. 2. Flow diagram for the selection of cluster head

Fixed path: In this type of sink movement, the trajectory of the sink path is always fixed [25]. This type of sink movement is supported by the networks where after deployment there is no change in the actual position of the sensor nodes and due to which this is not suitable case in WBAN environment where sensor nodes change its position frequently.

Random Path: In this type of movement, Sink exhibits a random movement in WBAN network i.e., sink nodes start from fixed potion, follows a random Trajectory in the network and returns to the initial position [26]. While movement sinks node visits the random coordinates in the network and collects the sensed data from nearby (In Range) Nodes.

Controlled Path: This type of sensor movement is controlled by the user and therefor an extra arm is needed to control the actual trajectory in this type of scenario a manual position of sink is decided depending upon the movement of sink nodes in the network. This type of movement is also not supported by the network because it always must keep an eye on the changed coordinates of sensor nodes [27]. WBAN sink is the major data collection node and sink position is the biggest challenge in the network. The general sink movement (Random) and fixed scenario are demonstrated in Fig. 3.

Case 1 (Left Side): The position of sink node is fixed in case 1. Let as assume node A want to send data to sink node. Because of the smaller transmission range of sensor nodes in WBAN it is not possible for node A to transmit data directly to the sink so it will choose its next neighbor for data forwarding with destination address of sink node. Similarly, B will choose C, further D and E node will be comes in picture to make sure that data have reached Sink. From above case it can be clearly seen that even though

B, C, D and E nodes Does not have any data to send but still their energy got depleted for transmission of data and because of this as the time passes these nodes will be lacking in energy level and hence get disconnected from the network which further causes unreachability of sink node for far away sensor nodes. This problem is called the sink hole problem.

Case 2 (Right Side): The movement of sink is random in case 2. In this scenario, the sink node is allowed to move inside the WBAN area with random coordinates and speed. Sink node starts from (X0, Y0) and moves till (X3, Y3) and then returns to original position. During its travel sink collects information from all sensor nodes that come into the range. Even though this scenario performs better than the former one but still we have a possibility that several nodes are left out during the sink movement in the network.

B. Proposed algorithm for optimal path selection for sink movement (Delay minimization)

The task is broken down into three steps: grouping the nodes and choosing the group head nodes; figuring out each group head node's access order; and figuring out where each ideal stop point is located. Once the group head node has been identified, the algorithm uses the Grey Wolf set of rules to plan the track of each group head node based on its position. At this point, the procedure optimizes the average path distance and final collection of iterations for the given group head nodes.

Algorithm:

1. Initialize N identified group head nodes inside the communication range (R) and Movable Sink
2. Compute Distances between all Cluster heads (H0, H1, H3, H4……. Hn)
   Where H0 is the section of the path between cluster head 1 and 2, H1 is the section of the Between Cluster Head 2 and Hn is the section of the path between cluster head n and 1.
3. Apply Grey Wolf algorithm to plan the path of the all-group head nodes according to the position of the all-group head nodes and the optimized average path distance.
4. Bisect the angle (the inferior angle) which is formed by two paths across the CG's and extend to the intersection until it reaches the distance equivalent to the circular range of cluster head which will be the best stop point for sink node to collect the data.
5. Collect the data and return to the initial position

Step 1: In Step 1 we must initialize all the sensor nodes and perform the clustering of the Nodes along with the selection of cluster head**.** The clustering of sensor nodes is performed by dividing the whole simulation area and smaller subdivisions are abbreviated as groups as shown in Fig. 1.

Step 2: Once the cluster heads are selected the next step is to find out the traversal path for sink node in the simulation environment. Grey Wolf algorithm is used to find the optimized traversal path with minimum distance to be covered during traversal. Let us assume the H0 be the distance between sink node and CG1 in Traversal Path. Similarly, H1 be the distance between CG1 and CG2 and so on. The grey wolf algorithm will find the traversal path such that H0+H1+H2+………. Hn is minimum as shown in Fig. 3. CG's Being the cluster head are found at P1, P2, P3 ……. Pn. Let x0, y0 be the coordinates of P0 and x1, y1 be the coordinates of P1 distance between these two nodes can be defined as:

$$H_0 = \sqrt{(x_1 - x_0)^2 + (y_1 - y_0)^2} \qquad \text{Eq. 1}$$

Similarly, we can calculate the distance between P1 to P2 and so on i.e., H1, H2, H3 …… Hn.

Step 2 will come out with traversal order which in general cases is covered by a moving sink which will start from P0 and travel back to P0 but after covering all group header as per the traversal order given by grey wolf algorithm. Grey wolf algorithm is facilitated with two different inputs.

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Inputs for Grey Wolf algorithm:

a. Number of Group Headers (Count, n=1,2, 3,)
b. Current location coordinates of group Header (xi and yi of the Group Header)

Step 3: Based on the current location of group header and total number of group headers grey wolf algorithm will find out the best possible traversal path which will be an optimized path in terms of distance.

Step 4: To Fig. out the best stopping coordinates for sink node angular bisection technique is used in this scenario. Here, the angle formed between the cluster heads of two nearby Groups as per the traversal order provided by grey wolf algorithm are divided into two equal parts and the straight line is formed until we get the distance equal to the circular range of cluster head i.e., its radius.

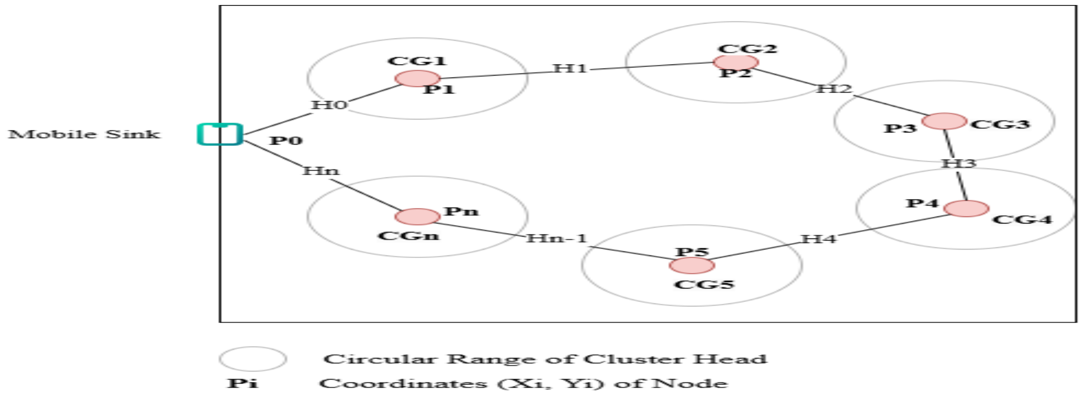

Fig. 3. Diagrammatic scenario of showcasing the actual distance between cluster heads.

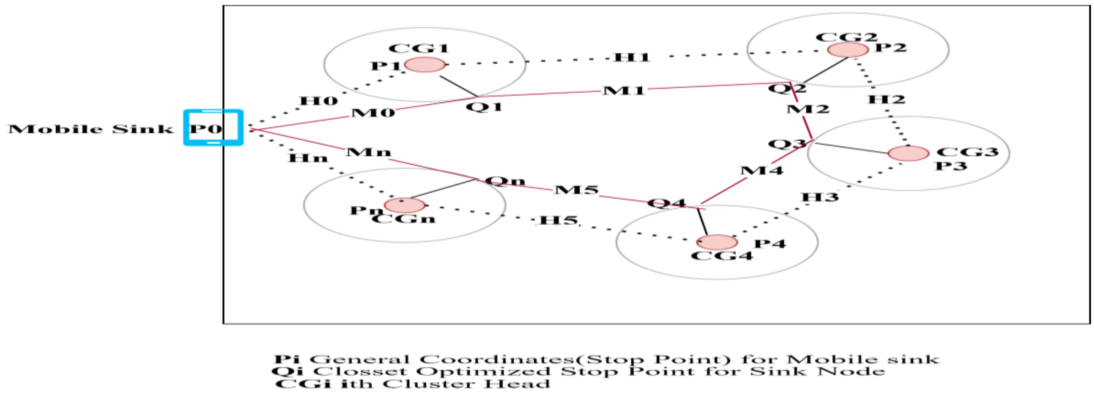

Fig. 4. Diagrammatic representation of clusters using angular bisection method

Optimized Path: Let us apply the angular bisection on the angle formed between consecutive group header as shown in Fig. 4 and stretch the distance till it reaches the circular range of group header and let us say new coordinates are found to be Q1, Q2, Q3……. Qn. Now, the new traversal coordinates of the mobile sink are found to be P0>>Q1>>Q2>>Q3……. Qn>>P0 When compare the distance travel by sink node during normal traversal and optimized traversal the distance (P0>>Q1>>Q2>>Q3……Qn>>P0) is found out to be very smaller than that of (P0>>P1>>P2>>P3>>……Pn>>P0)

Step 5: Once we have the optimized path the mobile sink will travel to the evaluated coordinates and collect the data and come back to its original position.

C. Result Analysis for the proposed approach

In the analysis, the outcomes are focused on the ROLG mobility model with the random sink and optimized sink movement. At the lower number of nodes (N= 25, and 50), the PDR achieves significant performance without packet loss. Additionally, for node size (N=75), the random sink movement achieves a PDR of 93.52%, whereas the analysis shows 96.38% of PDR in optimized sink movement. Conversely, the optimized movement efficiently managed the increased traffic and guaranteed increased reliability. Fig. 5 showcases the outcome of ROLG mobility model for different QoS parameters with random & optimized sink movement and varying number of nodes i.e., from 25 to 75.

At N=25, random sink movement achieves 23.57 kbps throughput, but optimized sink movement has significantly better throughput with 34.61 kbps. As the density increases to N=50, random sink movement's throughput drops to 19.48 kbps, whereas optimized sink movement's throughput stays at 28.94 kbps. The rate of random sink movement decreases to 15.23 kbps at the highest density, N=75, while optimized sink movement keeps the throughput at 22.24 kbps. Fig. 6 depicts the comparative analysis of throughput for ROLG mobility model with random and optimized sink movement.

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The study findings show that optimizing sink movement is the better option to reduce delays by strategically positioning the sink, especially in dense networks with high traffic. The delay for random sink movement at N=25 is 0.003212 seconds, but optimized sink movement achieves a significantly lower delay of 0.001226 seconds, which is a testament to its efficiency. When the node density increases to N=50, the delay for random sink movement is reduced to 0.002563 seconds, but optimized sink movement decreases to 0.001139 seconds. In case of 75 nodes, random sink movement exhibits 0.003358 seconds and 0.001088 seconds with optimized sink movement Fig. 7 depicts the comparative analysis of throughput for ROLG mobility model with random and optimized sink movement.

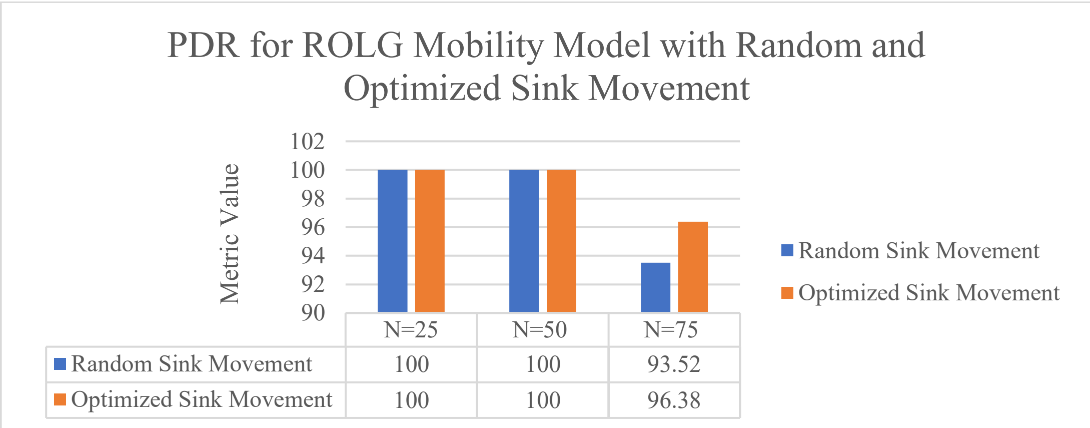

Fig. 5. Comparative analysis of PDR of ROLG mobility model with random sink and optimized sink movement

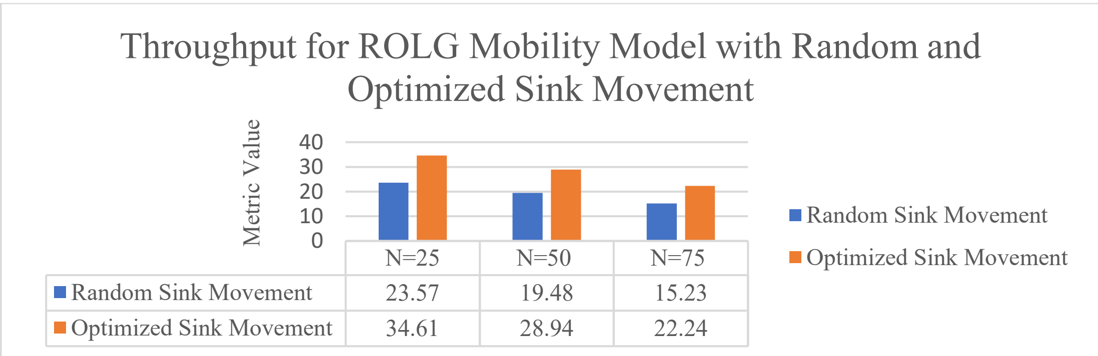

Fig. 6. Comparative analysis of Throughput of ROLG mobility model with random sink and optimized sink movement

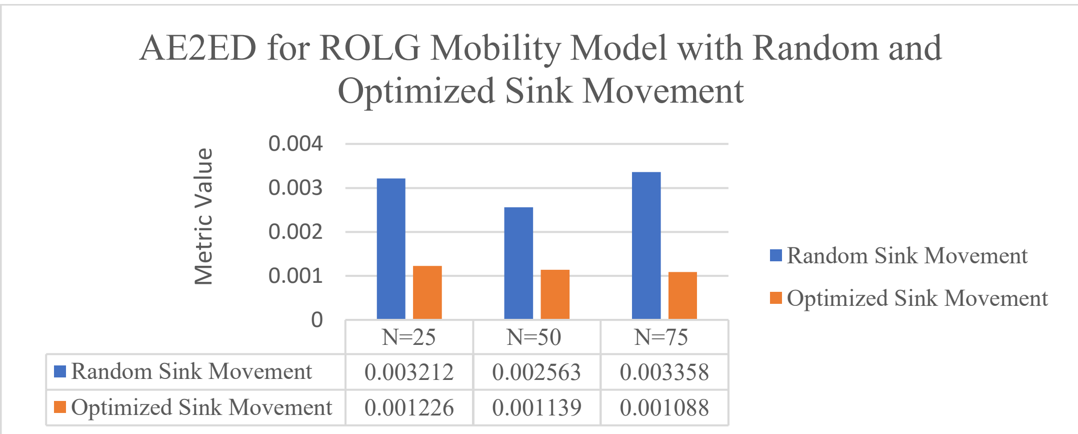

Fig. 7. Comparative analysis of AE2ED of ROLG mobility model with random sink and optimized sink movement

4. Localization of nodes with error estimations using multiple anchor points

Localization is a problem that necessitates estimating the locations of nodes which can be accomplished globally by utilizing altitude, latitude, and longitude data, or locally, by utilizing position data in context with other nodes. Once any node switches the group, there can be two possibilities which can happen (i) node can join another group (ii) node becomes isolated from the group and is no longer a part of any group. Hence, the network cannot identify data without location data because the network loses all the information when receiving data from the sink node. Therefore, localization in WBAN is necessary for efficient routing and minimizing delay to have a fault and delay tolerant network [28]–[30]. This helps to reduce energy consumption, optimize resource allocation and improves the routing by selecting nearby or more reliable nodes for data forwarding. In this process, the grey wolf optimization has been proposed to achieve a multi anchor point optimization. The evaluation tool used is MATLAB, which computes localization results to assess the effectiveness of the proposed approach. Tool used for the evaluation is MATLAB and compute the localization results in directions to assess the usefulness of the suggested approach. The radio array of the device nodes (R) is fixed at 25 m, and the testing area is a square measuring 125 by 155 m2. As shown in Fig. 8 and 9, the network's size increases from 25 to 100, by the total of anchor nodes and mobility nodes set at 4 and 5, respectively. Furthermore, the following cases are considered to identify the estimated error in localizing the node, and the one with the minimum error is used to fix the location of the last node. The three different location indicators are considered including i) red one is Anchor point location, ii) blue one is mobile node's true location and iii) green one is the estimated location of mobile node.

Case - I: (a) Let us consider first scenario, when the network is of 25 nodes and assume that 5 nodes are lost due to some malfunction as shown in Fig. 8. In the initial plot (a), the localization algorithm estimates positions with a moderate level of accuracy, with an estimation error of 1.0773 meters. In the second plot (b), the estimation error is reduced to 0.91133 meters as a result of improved precision between the true and estimated locations. The algorithm exhibits highest accuracy in the third plot (c), which has an estimated error of 0.45717 meters. In all three cases, the network's performance was satisfactory, with an average estimated error of 0.815 meters. The error reduction's progression indicates that the network's accuracy has increased and proving its capacity for more accurate localization.

Case – 1: (b)When the network is 25 nodes and assume that 10 nodes are lost due to some malfunction. In the initial plot (a), the localization algorithm estimates positions with a moderate level of accuracy, with an estimation error of 0.67376 meters. In the second plot (b), the estimation error is slightly increased to 0.85386 meters as a result of reduction in accuracy. The algorithm exhibits highest accuracy in the third plot (c), which has an estimated error of 0.39151 meters. In all three cases, the network's performance was satisfactory, with an average estimated error of 0.63904 meters indicating the improved in performance.

Case - II: (a) Let us consider the second scenario, when the network is of 50 nodes and assume that 5 nodes are lost due to some malfunction as shown in Fig. 9.

In the initial plot (a), the localization algorithm estimates positions with higher accuracy and an estimation error of 0.50147 meters. In the second plot (b), the estimation error is reduced to 0.29058 meters as a result of improved localization. The algorithm exhibits a rise in estimation error in the third plot (c), which has an estimated error of 1.8989 meters. In all three cases, the network's performance was satisfactory, with an average estimated error of 2.69095 meters. The progress of error reduction implies that the network's accuracy slightly increased, demonstrating its ability for better localization.

Case – II: (b) When the network is 50 nodes and assume that 10 nodes are lost due to some malfunction. In the initial plot (a), the localization algorithm estimates an estimation error of 2.2537 meters. In the second plot (b), the estimation error is slightly increased to 2.719 meters which deteriorates the performance of localization. The algorithm exhibits a lower in estimation error in the third plot (c), which has an estimated error of 0.69067 meters. In all three cases, the network's performance was satisfactory, with an average estimated error of 5.6933 meters. This results in gradual improvement of the network.

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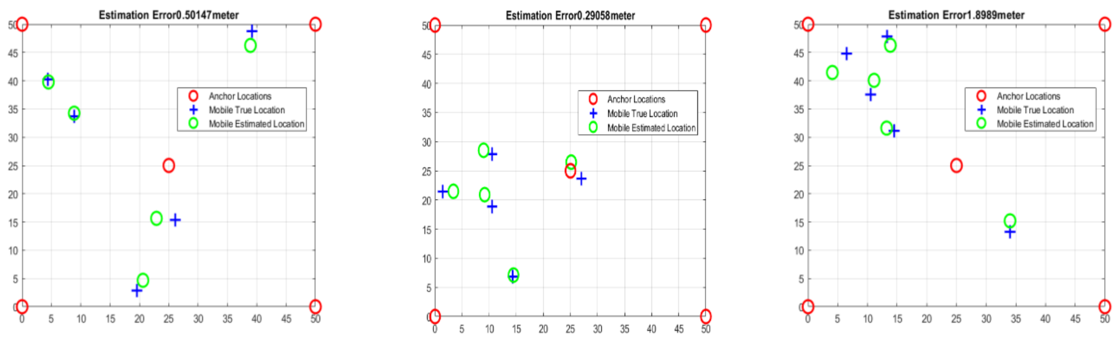
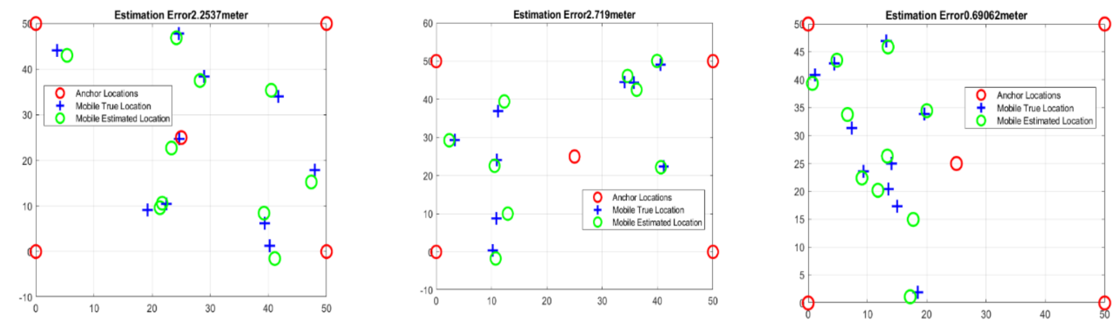
Node localization comes into picture when a mobile node goes out of its own group. Once any node switches the Group, there can be two possibilities which are possible (i) node can join another group (ii) node becomes isolated from the group and is no longer a part of any group in both the mentioned cases localization is must so that services for that node remains active. The Grey Wolf optimization algorithm is proposed to achieve multi anchor point optimization. For example, in the case of mobile communication if we got stuck at a location where we connect to three different vendors and do not have full strength of signals for any, we generally get connected to the one which shows minimum error of correction. Here multiple anchors point either fixed on the corner nodes of the simulation area of movable inside the network area are used to localize the nodes. Below are the five different cases considered for identifying the estimated error in localizing the node and the one with minimum is used to fix the location of lost node.
Fig. 10 shows the values of calculated location for lost nodes with the help of anchor points. Several nodes considered are 25, 50 ,75 and 100. Location for lost nodes are calculated, and average is considered the one with minimum error is taken for localizing the node.

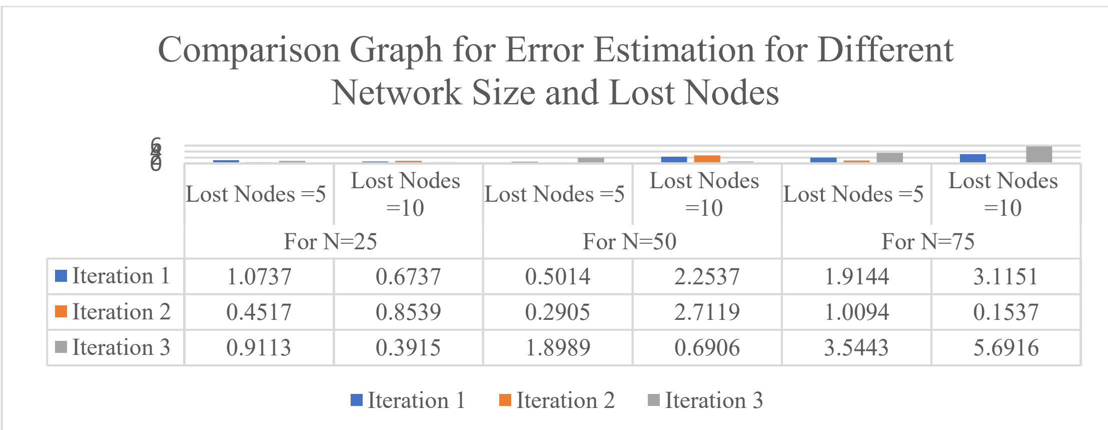


(a)



(b)

Fig. 9. Screenshot for Network Size =50 (a) assumed lost node: 5 and (b) assumed lost node: 10



	For N=25		For N=50		For N=75	
	Lost Nodes =5	Lost Nodes =10	Lost Nodes =5	Lost Nodes =10	Lost Nodes =5	Lost Nodes =10
Iteration 1	1.0737	0.6737	0.5014	2.2537	1.9144	3.1151
Iteration 2	0.4517	0.8539	0.2905	2.7119	1.0094	0.1537
Iteration 3	0.9113	0.3915	1.8989	0.6906	3.5443	5.6916

Fig. 10. Comparison graph for estimation errors for different network sizes and lost nodes

5. CONCLUSION AND FUTURE SCOPE

Healthcare is being transformed by WBANs which enable wearable sensors to integrate seamlessly into the human body, allowing for real-time physiological data monitoring and analysis. The proposed architecture aims to improve overall performance and quality of service by efficiently connecting body sensor nodes with a moving sink in one region. According to simulation results, the use of a mobile sink results in a significant increase in throughput, packet delivery ratio, and AE2ED delay. The paper presents a Grey Wolf technique, which utilizes the closest anchor to address the localization issue. The algorithm resulting in additional processing costs, the recommended approach still delivers favorable outcomes without requiring additional equipment. The proposed method has an average estimation error of 13.923, which is lower than the old method's average error of 2.2318. The study demonstrates that the proposed approach is superior to the existing algorithms. To summarize, the proposed framework for WBANs is a significant advancement in healthcare technology. The integration of fault detection algorithms, adaptive routing protocols, and effective error recovery strategies allows the system to sustain dependable communication despite changing network conditions and possible sensor failures. The system improves service quality in healthcare applications by prioritizing delay-sensitive data packets, which allows for prompt diagnosis and intervention. The focus of future work will be on using soft computing techniques to decrease computational costs and enhance the system's performance and efficiency.

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Conflicts of Interest

We, the authors, hereby declare that we have no conflicts of interest related to this work

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REFERENCES

[1] R. Goyal, R. B. Patel, H. S. Bhaduria, and D. Prasad, "An Efficient Data Delivery Scheme in WBAN to Deal with Shadow Effect due to Postural Mobility," Wirel. Pers. Commun., vol. 117, no. 1, pp. 129–149, 2021, doi: 10.1007/s11277-019-06997-5.

[2] B. S. Kim, K. H. Kim, and K. Il Kim, "2. A survey on mobility support in wireless body area networks," Sensors (Switzerland), vol. 17, no. 4, pp. 1–18, 2017, doi: 10.3390/s17040797.

[3] R. Singla, N. Kaur, D. Koundal, and A. Bharadwaj, Challenges and Developments in Secure Routing Protocols for Healthcare in WBAN: A Comparative Analysis, vol. 122, no. 2. Springer US, 2022.

[4] N. M. M. Shindhja and A. Varshney, "Hybrid βΩ-Indexing Fractal Slotted Multiband Antenna for Electronics Wireless Sensor Applications," J. Electron. Electromed. Eng. Med. Informatics, vol. 5, no. 2, pp. 59–68, 2023, doi: 10.35882/jeeemi.v5i2.283.

[5] Y. R. Jang, Y. Kim, J. W. Lee, D. Hong, and S. Choi, "Adaptive queue management scheme for body area network with energy harvesting," BODYNETS 2013 - 8th Int. Conf. Body Area Networks, pp. 201–204, 2013, doi: 10.4108/icst.bodynets.2013.253666.

[6] I KOMANG YOGI MAHARDIKA, Bambang Guruh Irianto, Torib Hamzah, and S. Misra, "Central Monitor Based on Personal Computer Design with SpO2 and Body Temperature Parameters Using Wireless Xbee Pro," J. Electron. Electromed. Eng. Med. Informatics, vol. 3, no. 1, pp. 35–43, 2021, doi: 10.35882/jeeemi.v3i1.6.

[7] Trie Maya Kadarina and R. Priambodo, "Performance Evaluation of IoT-based SpO2 Monitoring Systems for COVID-19 Patients," J. Electron. Electromed. Eng. Med. Informatics, vol. 3, no. 2, pp. 64–71, 2021, doi: 10.35882/jeeemi.v3i2.1.

[8] M. Asam et al., "Challenges in wireless body area network," Int. J. Adv. Comput. Sci. Appl., vol. 10, no. 11, pp. 336–341, 2019, doi: 10.14569/IJACSA.2019.0101147.

[9] M. H. Anisi, A. H. Abdullah, S. A. Razak, and M. A. Ngadi, "An overview of data routing approaches for wireless sensor networks," Sensors, vol. 12, no. 4, pp. 3964–3996, 2012, doi: 10.3390/s120403964.

[10]J. Liu, Z. Zhang, R. Sun, and K. S. Kwak, "An efficient certificateless remote anonymous authentication scheme for wireless body area networks," IEEE Int. Conf. Commun., pp. 3404–3408, 2012, doi: 10.1109/ICC.2012.6363786.

[11]A. Bhatia, "PMAC : A Poll-Based MAC Protocol for Wireless Body Area Networks (WBANs)," 2016.

[12]H. S. Sangha and H. Sohal, "Power challenges in wireless body area network for mobile health powered by human energy harvesting: A survey," Indian J. Sci. Technol., vol. 9, no. 46, 2016, doi: 10.17485/ijst/2016/v9i46/106912.

[13]H. Li and J. Tan, "Heartbeat driven medium access control for body sensor networks," Heal. Proc. 1st ACM SIGMOBILE Int. Work. Syst. Netw. Support Healthc. Assist. Living Environ., pp. 25–30, 2007, doi: 10.1145/1248054.1248062.

[14]R. Goyal, N. Mittal, L. Gupta, and A. Surana, "Routing Protocols in Wireless Body Area Networks: Architecture, Challenges, and Classification," Wirel. Commun. Mob. Comput., vol. 2023, 2023, doi: 10.1155/2023/9229297.

[15]I. Ha, "Even energy consumption and backside routing: An improved routing protocol for effective data transmission in wireless body area networks," Int. J. Distrib. Sens. Networks, vol. 12, no. 7, pp. 1–11, 2016, doi: 10.1177/1550147716657932.

[16]K. S. Kathe and U. A. Deshpande, "A Thermal Aware Routing Algorithm for a Wireless Body Area Network," Wirel. Pers. Commun., vol. 105, no. 4, pp. 1353–1380, 2019, doi: 10.1007/s11277-019-06148-w.
[17]S. Pushpan and B. Velusamy, "Fuzzy-based dynamic time slot allocation for wireless body area networks," Sensors (Switzerland), vol. 19, no. 9, 2019, doi: 10.3390/s19092112.
[18]Z. Ullah et al., "Energy-efficient harvested-aware clustering and cooperative routing protocol for WBAN (E-HARP)," IEEE Access, vol. 7, pp. 100036–100050, 2019, doi: 10.1109/ACCESS.2019.2930652.
[19]B. Banuselvasaraswathy and V. Rathinasabapathy, "Self-heat controlling energy efficient OPOT routing protocol for WBAN," Wirel. Networks, vol. 26, no. 5, pp. 3781–3792, 2020, doi: 10.1007/s11276-020-02303-5.
[20]G. Mehmood, M. Z. Khan, S. Abbas, M. Faisal, and H. U. Rahman, "An Energy-Efficient and Cooperative Fault-Tolerant Communication Approach for Wireless Body Area Network," IEEE Access, vol. 8, pp. 69134–69147, 2020, doi: 10.1109/ACCESS.2020.2986268.
[21]Z. Shahbazi and Y. C. Byun, "Towards a secure thermal-energy aware routing protocol in wireless body area network based on blockchain technology," Sensors (Switzerland), vol. 20, no. 12, pp. 1–26, 2020, doi: 10.3390/s20123604.
[22]M. K. Singh, S. I. Amin, and A. Choudhary, "Genetic algorithm based sink mobility for energy efficient data routing in wireless sensor networks," AEU - Int. J. Electron. Commun., vol. 131, no. June 2020, p. 153605, 2021, doi: 10.1016/j.aeue.2021.153605.
[23]S. Ahmed, Z. A. Khan, A. Wahab, Z. W. Mufti, and A. Mahmood, "DSAB: Dual sink approach in WBans," ITT 2017 - Inf. Technol. Trends Explor. Curr. Trends Inf. Technol. Conf. Proc., vol. 2018-Janua, no. Itt, pp. 78–83, 2017, doi: 10.1109/CTIT.2017.8259572.
[24]R. Sharma, "Clustering Based Routing Protocol to increase the stability in WBAN," vol. 6, no. 1, pp. 119–125, 2015.
[25]X. Xu, W. Liang, and T. Wark, "Data quality maximization in sensor networks with a mobile sink," 2011 Int. Conf. Distrib. Comput. Sens. Syst. Work. DCOSS'11, 2011, doi: 10.1109/DCOSS.2011.5982160.
[26]A. K. Gupta, H. Sadawarti, and A. K. Verma, "18. Performance Analysis of MANET Routing Protocols in Different Mobility Models," Int. J. Inf. Technol. Comput. Sci., vol. 5, no. 6, pp. 73–82, 2013, doi: 10.5815/ijitcs.2013.06.10.
[27]S. Wang, X. Mao, S. J. Tang, X. Y. Li, J. Zhao, and G. Dai, "On movement-assisted connectivity restoration in wireless sensor and actor networks," IEEE Trans. Parallel Distrib. Syst., vol. 22, no. 4, pp. 687–694, 2011, doi: 10.1109/TPDS.2010.102.
[28]M. Peyvandi and A. A. Pouyan, "An improved DV-Hop localization algorithm in wireless sensor networks," 2015 Signal Process. Intell. Syst. Conf. Sp. 2015, vol. 7, no. 10, pp. 153–158, 2016, doi: 10.1109/SPIS.2015.7422331.
[29]W. Tranter, V. Tech, and J. Gibson, Node Localization in Wireless Sensor Networks Synthesis Lectures on Communications Editor. .
[30]R. Stoleru, J. A. Stankovic, and S. H. Son, "Robust node localization for wireless sensor networks," Proc. 4th Work. Embed. Networked Sensors, EmNets 2007, pp. 48–52, 2007, doi: 10.1145/1278972.1278984.

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