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ENERGY AWARE NODE ROUTING TO IMPROVE NETWORK LIFETIME IN WBAN

G. Sathya D.J. Evanjaline

Department of Computer Science, Rajah Serfoji State College, Bharathidasan University, Trichy, Tamil Nadu, India
rschlrsathya@outlook.com, drevanglin@outlook.com

Abstract- Increasing requirements for medical services and increase in technological development has mandated an integration that results in the usage of technological services in the medical industry. Timely treatment and diagnostics are the major need to ensure effective monitoring and safety for the patient. Wireless body area networks can aid in this process and can provide timely attention to the patient. Effective and energy efficient routing is the major requirement to ensure smooth functioning of the WBAN network. This work presents a metaheuristic-based model using particle swarm optimization algorithm for effective routing. The existing particle swarm optimization model has been modified to include several parameters like energy efficiency and node charge to improve the selection process in energy efficient manner. Further, the model also includes a node rotation best technique for load balancing and to improve the network lifetime. Experimental results and comparisons indicate improve network lifetime and improved stability in WBAN networks when using the proposed model.

Keywords: Wireless Body Area Network, Routing, Meta Heuristics, Particle Swarm Optimization, Network Lifetime.

1. INTRODUCTION

The World Health Organization (WHO) claims that, it was identified that proximately 17.5 million fatalities occur due to cardiovascular disease [1]. Although there are several other diseases causing fatalities, the major general factors observed as the cause for several fatalities is the poor medical service and absence of timely diagnostics [2, 3]. The increasing requirement for medical services and by increasing possibilities of providing medical services has triggered the inclusion of new technologies in this domain. Digital information collection, online consultation and technology assisted diagnostics are some of the major areas where technology is applied in the medical domain [4]. Embedding sensing devices with in body for ongoing monitoring is another significant field that is growing [5]. Wireless Body Area Networks (WBAN) are systems that incorporate these sensors within the body for regular inspection [6]. Sensors in WBAN are smart and intelligent and Eden monitoring and transmitting information within an outside body for medical analysis. Using advanced technologies like WBAN can provide better improvement in health care services and can also save countless lives.

Depending on the data to be gathered from the patient, WBAN sensors can be positioned within or outside of the human body. The sensors are small, and they are used for collecting and communicating vital parameters from the patient [7]. Since these sensors are small sized, and most of them are embedded inside the body, they contain small and low powered batteries [8]. This is to ensure that the patient does not have any physical hindrance due to the placement of these sensors. The embedded sensors perform intra communications within the sensors contained in the current network and also intercommunications between nodes inside and outside the body. Both the communication is directed by the IEEE 802.15.6 standard [9, 10]. This is the standard followed by all wireless communicating devices. WBAN devices have some special constraints such as size and battery limitations. Following the general communication standards which concentrate on providing the shortest communicating route will not be highly effective in such special scenarios [11]. Routing is the major cause for battery depletion; hence, energy efficient routing is the major requirement for WBAN networks [12]. This work presents a routing algorithm that provides high energy efficiency and also increases the network lifetime to the maximum extent.

2. BACKGROUND STUDY

Wireless body area networks provide an effective solution to several medical complications. Hence, these networks have become one of the goes to solutions in providing digitized healthcare service systems. This section discusses some of the existing works in providing effective routing solutions in WBAN.

In [13] an IoT-based WBAN model is proposed and it is utilized to build a surveillance system for pandemic conditions. To examine coronavirus symptoms including breathing rate, blood pressure, heart rate, etc., WBAN sensors are embedded. The routing algorithm is based on delay, delivery ratio and packet loss levels. The proposed geographic routing algorithm also monitors social distance and mask wearing status of people. Other similar applications include robotic based application for management of epidemics eating to serve patients food and medicine during quarantine has been proposed in [14], end a telemedicine best application that can be useful during the forward pandemic has been proposed in [15]. A multi criteria-based decision-making model that operates on identifying the next hop for transmission in WBAN networks has been proposed in [16]. The energy aware routing technique proposed in this work aims to reduce the energy utility levels by evaluating the link quality, the current energy level, the energy level remaining after transmission etc. Analysis of all these criteria ensures that this model provides better energy conservation.

Reinforcement routing-based model for routing in WBAN network has been proposed in [17]. this model operates by identifying a route that travels between regular nodes and the sink node. The work uses buffer cycle, traffic load and distance between as the major factors for the routing process. A QoS enhancement-based model for WBAN routing has been proposed [18]. This technique aims to improve latency and also maximize the energy consumption to provide better and reliable routing. This work generates multiple paths for kissing and classified these parts based on the routing metrics to identify the final optimal path. During the selection process energy is used as a major criterion in selecting the routes. Other similar techniques include appear routing based strategy [19], multipath routing scheme [20], and a multi objective QoS best routing strategy [21].

An energy efficient model that uses energy harvesting scheme to improve the lifetime of WBAN network has been proposed [22]. An extension of this model that uses a clustering approach for effective routing has been proposed [23]. In [24] an energy-efficient based routing strategy is proposed to increase the stability levels of WBANS. In order to enhance routing and offer better energy saving, this study employs forwarder node rotation and forwarder node selection approaches. Energy efficient routing technique that aims to improve the network lifetime by improving the routing model has been proposed [25]. This work uses the Fuzzy based Dijkstra technique for the routing process. Block considers several qualities and energy-based parameters like energy efficiency, throughput, packet delay and packet transmission rate for constructing the route selection mechanism. Other similar techniques concentrating on energy efficiency when routing in wireless body area networks (WBANS) include works [26-28]. The Wind Farm Layout Optimization (WFLO) problem is addressed in this approach [28] in three steps, with particle swarm optimization serving as the main strategy. This model's objective is to create a packet aggregation method that addresses the issue of inter-connection links between nodes while data routing [29].

3. ENERGY AWARE NODE ROUTING (EANR)

Wireless body area networks enable proactive health by using wearable devices. Challenges arise due to the critical placement of these devices and the limited power supply. To ensure energy conservation effective routing and load balancing are necessary. This work presents an energy aware reactive routing algorithm to handle these issues. The work is based on Particle Swarm Optimization (PSO) algorithm, which is metaheuristic in nature and provides optimal results. Algorithm for the EANR model is provided below.

Algorithm 1. EANR

Input: Node Coordinates, Start Node, End Node
Output: Route between start and end nodes
1. Network configuration and transmission initiation from the source node
2. Search space creation using available nodes and particle dispersal
3. For each particle p
   a. Identify its index in the rotation queue (r_i)
   b. Calculate Fitness using charge, distance and r_i
4. Identify p_{best} and g_{best}
5. Velocity calculation for each particle and particle movement
6. Fitness identification of particles after movement
7. If convergence is not achieved goto step 4
8. Consider g_{best} as the next node for traversal
9. If g_{best} is not contained in the rotation queue
   a. Add to the rear end
10. Else move the node to the rear end

3.1. Network Configuration and Transmission Initiation

Network configuration is the initial process that is to be performed when the nodes are deployed in several locations in the body. Some nodes are displaced internally, while others are externally placed. The location of node displacement is identified in advance and it is also determined by the type of measurements that are required for the patient. Every node is a different type of sensor obtaining a different measurement. All the nodes are wirelessly connected to each other and have the ability to communicate with each other. Based on the sensor contained in the node, the node gathers information and passes it to a specialized node called sink. The sink node this meant to collect all the information and transfer it to an outside node for further analysis. Most of the nodes are capable of collecting information and performing low level computations.

The nodes are in charge of gathering the data, and they send it to the sink node at the end of each time interval. When a transmission is initiated by a node, best path to the sink node is to be determined. Node communications are mostly limited to save battery, as every transmission and every reception leads to reduction in battery levels. The sink node is not directly connected to all nodes. Hence, most nodes are required to find an optimal path to the sink node in order to perform energy effective communications. Further, using the same routing path is not recommended, as it will lead to specific note depletions. Hence, this work proposes a PSO based energy aware routing model incorporated with rotational load balancing for effective communication.

3.1.1. Particle Distribution

Particle distribution is the first phase in the PSO algorithm. A graph is constructed using the deployed nodes in the network. Every sensor is considered as a node in the graph. Particles are distributed in the graph in random positions and the traversal is initiated. The best node is identified by the PSO algorithm. The best node identification is performed based on the fitness function of the nodes. PSO is based on identifying the particle best solution (p_{best}) and the global best solution (g_{best}). The initial p_{best} is set to current node. These values vary after particle traversal begins. Movement of particles is triggered using the velocity component. The initial velocity is given by [22].

$$V_i \sim U(-\left|b_{up} - b_{lo}\right|, \left|b_{up} - b_{lo}\right|) \quad (1)$$

where, the upper and lower boundaries of the search space is represented by b_{up} and bio .

After the moment is initiated, the particle best solutions (p_{best} are identified. The best of p_{best} values is identified and is considered as the g_{best} value. After the identification of p_{best} and g_{best} values, the velocity function is modified as [22].

$$V_{i,d} \leftarrow \omega V_{i,d} + \varphi_p r_p \left(P_{i,d} - X_{i,d}\right) + \varphi_g r_g \left(g_d - X_{i,d}\right) \quad (2)$$

where, $p_{i,d}$ and g_d are the particle and global best solutions, r_p and r_g are randomly generated values, $x_{i,d}$ represents the current position, and ω, φ_p, and φ_g depicts the significance of velocity component, p_{best} value and the g_{best} value.

This process is repeated until all the particles converge into a single solution. This is considered as the optimal solution, representing the sensor to which the particle has to travel next.

3.1.2 Fitness Identification based on Node Rotation for Load Balancing

Defining the appropriate fitness function is an important and the most significant part of detecting the most optimal node to be used for traversal. The general fitness function depends on the distance factor. The fitness function used in this work has been modified to provide equal significance for energy awareness and load balancing along with the distance factor. The fitness function for a node *n* from a node m is given by [23].

$$F_{m,n} = \frac{n_{ch}}{d_{m,n} \times n_{temp} \times Q_n} v \quad (3)$$

where, n_{ch} is the charge in the node *n*, $d_{m,n}$ is the distance between nodes *m* and *n*, n_{temp} is the temperature of the node n and Q_n is the index of node n in the rotation queue *Q*. Lower index (closer to 1) signifies that the node has been traversed earlier compared to the nodes occupying higher indexed positions. The rotational queue aids in load balancing by ensuring that a node is not frequently repeated in a path, unless it is mandatory and no other node is available.

3.1.3. Iterative Reactive Node Selection based Traversal

The previous sections discuss the fitness functions and the best node selection processes. This work follows the reactive node selection strategy. Reactive node selection signifies selection of node only on-demand. The entire route is not determined initially, instead, a single best node for the route is determined by each node in the path. Every node determines the next node to be traversed. This process aids in avoiding node depletions, as every node is determined based on the current charge, ensuring that nodes with very low charge levels are not prioritized will ensure the network is live for the longest period. Retransmissions are also avoided, as certain nodes might get depleted due to intermediate transmissions, leading to a break in the route. Since this work only identifies the next node, and charge of node is considered in fitness function, this issue is completely eliminated.

The process of traversal begins when the start node requires packet transmission. The start node selects the next node based on the modified PSO with the improved fitness function. The packet is passed to the selected node. The packet is examined to identify if the current node is the end node. If not, the next optimal node for traversal is determined, and the packet is transferred to the selected node. The process is repeated until the packet reaches the end node. The major advantage of using the metaheuristic based reactive routing strategy is that WBAN is not a huge network, and is comprised of limited number of nodes. Hence identifying the best path is not required. Instead, an optimal path will suffice until the transmission consumes less energy and performs load balancing those aids in extending the lifetime of network.

4. RESULTS AND DISCUSSION

The simulation setup and the sensor deployment coordinates from E-HARP model has been adopted in this work to enable comparison. Results from the proposed EANR technique is compared with the E-HARP model proposed [22], and EH-RCP model proposed [23]. The simulation has been executed for 18000 transmissions and network parameters have been recorded for every 2000 iterations. Time taken for transmission has been recorded for every 2000 iterations and the results are shown in Figure 1. The Figure shows that the transmission time for EANR varies between 15 seconds and 19 seconds. On average, transmission time requirement for EANR could be observed to be 17 seconds, which is a considerably low value, indicating that the EANR model is capable of performing real time transmissions.

This ESURF method detects one or more object in the given set of images and finds out the matching score using thresholds and accuracy measures under various conditions like rotation, orientation etc. This algorithm supports the accuracy for detection of objects in variant origin images from the dataset. By removing the outlying points, the distinction between the original image and the tampering image can be lowered. ESURF supports the real time images in the same way with the data set images. The enhanced method increases the speed along with maintaining the accuracy and the standard of its performance.

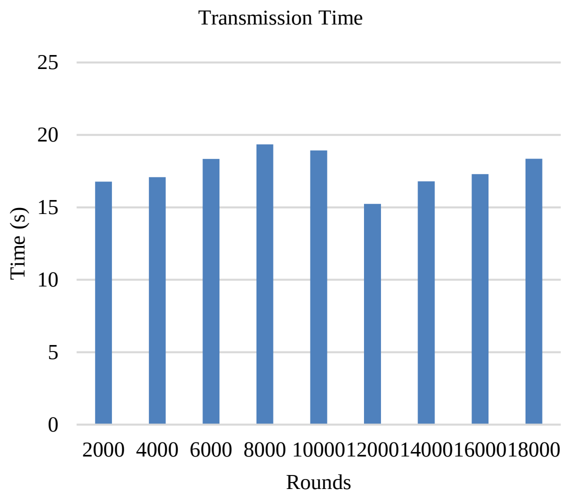

Figure 1. Transmission Time for EANR

5. COMPARITIVE STUDY

Comparative analysis of network lifetime and stability period of the network has been performed with E-HARP and EH-RCP models. The network lifetime analysis shown in Figure 2 indicates that the EH-RCP model experience is its first failure during the 6000th round, while the EANR model experiences its first failure during the 8000th round, which is similar to the E-HARP model. However, as the transmissions continue, the EANR model exhibits low failure rate compared to the other models. While the other two models experience an all-node failure at 16,000th iteration, the network using EANR model exhibits 10 node failures, indicating that the network is still in operation. A tabular analysis of the network lifetime is shown in Table 1. The table shows that the initial node failure occurs during the 8000th iteration in both EANR and E-HARP models. However, as the transmission proceeds, the proposed EANR routing scheme has lesser failures compared to the other models. Further, both the models exhibit faster failure levels compared to EANR, hence the networks using E-HARP and EH-RCP has complete network failures, while the network using EANR is live even after the 18000th iteration.

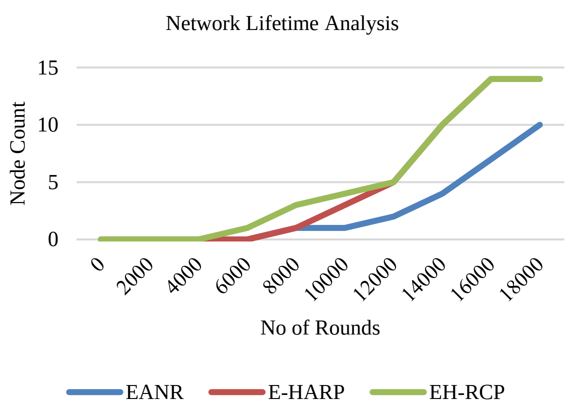

Figure 2. network life time analysis of EANR

Table 1. Analysis of Network Lifetime of EANR

	0	2000	4000	6000	8000	10000	12000	14000	16000
EANR (Proposed)	0	0	0	0	1	1	2	4	7
E-HARP	0	0	0	0	1	3	5	10	14
EH-RCP	0	0	0	1	3	4	5	10	14

Stability period of the proposed EANR model is compared with the existing models to analyze the stability levels of the models. The model is considered to be stable until live nodes are available in it. It could be observed from the Figure 3 that during the initial 8000 iterations the models remain stable, however the E-HARP and EH-RCP models fail rapidly after the initial failure, reaching a network depletion in 16000th iteration. This is mainly attributed to the routing strategy, as inappropriate routing leads to faster depletion levels.

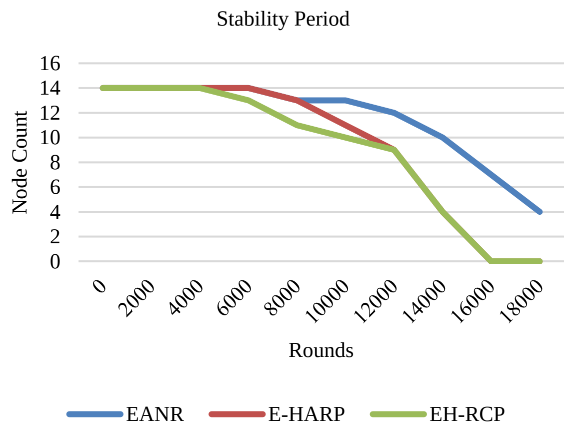

Figure 3. stability analysis of EANR

An analysis of the stability levels is tabulated in shown in Table 2. Stability levels represent the point up to which all the nodes in the network are live and running. For the EANR model and the E-HARP models, this point is 8000 iterations, while the EH- RCP model begins its failures at the beginning of the 6000 iterations. It should also be noted that the EANR model exhibits high stability levels owing to the effective load balancing technique and experiences low node failures. Ineffective load balancing results in entire network failure of the E-HARP model and the EH-RCP models during the 16000th iteration. This depicts the highly effective stability levels of the proposed EANR model.

Table 2. Analysis of Stability Levels of EANR

	0	2000	4000	6000	8000	10000	12000	14000	16000	18000
EANR (Proposed)	14	14	14	14	13	13	12	10	7	4
E-HARP	14	14	14	14	13	11	9	4	0	0
EH-RCP	14	14	14	13	11	10	9	4	0	0

5. CONCLUSION

Wireless body area networks effectively aid in providing qualitative and improved medical services. They are however, constrained by their size and battery limitations. Routing is the major cause for reduction in battery levels in WBAN networks. Effective routing can aid in the improvement of network lifetime to a large extent. This work presents an effective network routing model specifically designed for WBAN networks to enable energy efficient routing. The particle swarm optimization algorithm has been modified to ensure energy efficiency in the routing process. Further, a node rotation scheme is employed to ensure that same node is not frequently used for the routing process this also results in providing load balancing. Experimental results indicate improved network lifetime and improved stability levels when compared to existing models. The model however, exhibits initial node failure at an almost similar time as the compared model. Future enhancements will deal with increasing the time taken for initial node failure.

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BIOGRAPHIES

Ganeson Sathya was born in Thanjavur, Tamil Nadu, India in 1983. She received the M.Phil. degree in 2007 and pursuing the Ph.D. from Department of Computer Science, Rajah Serfoji State College, Thanjavur, Tamil Nadu, India. Now, she is working as Guest Lecturer in State Arts and Science College, Orathanadu, India. She has 14 years of teaching experience. Her area of research interest includes network security, data mining. She has published nearly 5 papers in national and international journals.

Daniel Jasmine Evanjaline was born in Cuddalore, Tamil Nadu, India in 1973. She received the Ph.D. degree from Mother Teresa Women's University, Kodaikanal, India in 2012. Currently, she is working as Assistant Professor at Department of Computer Science, Rajah Serfoji State College, Thanjavur, Tamil Nadu, India. She has more than 20 years of teaching experiences. She also guided 7 research scholars from Bharathidasan University, India. His area of research interest includes network security, data mining, and big data. She has published more than 25 research papers in top most Elsevier and Scopus indexed journal.