Modified PSO Based Reactive Routing for Improved Network Lifetime in WBAN

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Summary
Technological advancements taken the health care industry by a storm by embedding sensors in human body to measure their vitals. These smart solutions provide better and flexible health care to patients, and also easy monitoring for the medical practitioners. However, these innovative solutions provide their own set of challenges. The major challenge faced by embedding sensors in body is the issue of lack of infinite energy source. This work presents a meta-heuristic based routing model using modified PSO, and adopts an energy harvesting scheme to improve the network lifetime. The routing process is governed by modifying the fitness function of PSO to include charge, temperature and other vital factors required for node selection. A reactive routing model is adopted to ensure reliable packet delivery. Experiments have been performed and comparisons indicate that the proposed Energy Harvesting and Modified PSO (EHMP) model demonstrates low overhead, higher network lifetime and better network stability.

Keywords:
WBAN, Reactive Routing, PSO, Energy Harvesting, Network Lifetime.

1. Introduction

Wireless Body Area Networks (WBAN) are a special sub domain of Wireless Sensor Networks (WSN) which specialize in health care systems [1]. They aid in remote monitoring of the necessary vitals from human body. The advantage of remote monitoring has made these networks gain huge prominence in healthcare industries. WBAN networks contribute to healthier and safe human life [2]. These networks are constructed by placing heterogeneous sensors on various strategic locations in the human body. The sensors used in these systems are small lightweight components that are low cost and low powered devices. They measure physiological and non-physiological parameters from the human body [3]. Multiple sensors are usually placed in the body. These sensors tend to be heterogeneous in nature, as each sensor is aimed to measure a different parameter. As they are embedded in the human body, they are size constrained. These constraints result in the sensors containing only limited energy levels. However, difficulty lies in the fact that they cannot be easily replaced [4]. Replacement requires complex and intrusive surgeries. The sensors collect the vital parameters and transmit them to other sensors within the network, intra communication, and also to devices outside the network, intercommunication. Intercommunication is usually done through the sink node. These communications results in loss of energy, and eventually node depletion.

Software Defined Networking (SDN) is identified to be a simple and flexible form of managing complex heterogeneous networks like WBAN [5]. Software based management of WBAN has become mandatory due to the limited energy levels contained in the sensors, and the higher difficulty levels required to replace them [6, 7]. In software defined networking networks are managed from a central point rather than being distributed in nature. Routing plays a major role in software define networking [8]. Effective routing techniques is important to conserve energy. Several factors like packet loss, delay, charge and temperature play a significant role and should be considered along with the distance factor for routing in WBAN [9, 10]. These factors, however, vary overtime. Hence, reactive decision making is the most appropriate technique to be used during the routing process. This work focuses on developing a metaheuristic based routing model for effective load balancing, and an energy harvesting mechanism to improve lifetime of a wireless body area network.

The remainder of this paper is structured as follows; Section 2 presents the related works, Section 3 presents the proposed EHMP model, Section 4 presents the research and discussions and Section 5 presents the conclusions and future work.

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2. Related Works

Software defined networking has become the go to solution in electronic health care systems. This section presents the existing works in the domain of software defined networking.

An energy efficient software defined networking based routing model for wireless body area networks was proposed by Cicioglu et al. [11]. This work uses fuzzy based Dijkstra technique for the routing process. It uses centralized and on demand approach for the routing process. Several factors like battery level and hop count add included in the decision making process. Other works proposed by the same author includes software defined networking based model [12] and the energy harvesting technique [13] that can be used for improved routing and extending the lifetime of wireless body area networks.

A next hop selection model that uses link quality and energy level of nodes was proposed by Qureshi et al. [14]. This work performs an analysis and considers multiple criterion like node energy, and link quality during the selection process. Further, the remaining energy level and energy utilization levels are also considered prior to the transmission process. Hence, the model is considered to perform the entire transmission successfully without any intermediate breakdowns. Reinforcement based routing model for WBAN routing was proposed by Liang et al. [15]. This model analyzes and records the parameters of other nodes for better decision making during the routing process. The downside of this model is that it exhibits high network overhead. Energy efficient data routing process has been proposed by Khan et al [16]. This work mainly concentrates on handling indoor WBAN applications. The routing table is incorporated with additional information such as communication cost and residual energy to ensure better routing system. Other similar routing based techniques include works by Jamali et al. [17] and Khan et al. [18].

A tree based energy efficient routing technique has been proposed by Liang et al. [19]. The technique uses multi hop based routing process and adaptive power control to ensure low overhead during the routing process. The transmission nodes are also chosen adaptively during the routing process to ensure fail safe delivery. A location based routing model that considers body shadowing was proposed by Quwaider et al. [20]. This work considers location changes occurring in sensors due to body shadowing, hence uses dynamic routing to avoid packet loss. An opportunistic routing scheme that considers change in body movements while walking has been proposed by Maskooki et al. [21]. This work considers an additional fixed node that can act as a relay node. The reload is relay node is considered to be at the vicinity of all the other nodes ensuring successful routing. Other similar energy harvesting based techniques for effective routing was proposed by Ullah et al. [22, 23].

An energy efficient routing process for smart wearable patches in wireless body area networks has been proposed by Raj et al. [24]. This work uses an energy efficient opportunistic routing mechanism along with load balancing techniques for better transmission. Further, the model also reduces the need for data aggregation which in turn avoids routing loops for energy conservation. Reliable routing scheme for energy efficient routing has been proposed by Ullah et al. [25]. This work aims to enhance the stability period of the network and reliability of the transmission. The work uses two mechanisms; forwarder node selection scheme and forwarder node rotation scheme to ensure reliability. It also uses an adaptive static clustering routing technique to maximize reliability. Other similar energy maximizing techniques include works by Kaur et al. [26], Sandhu et al. [27] and Jan et al. [28].

3. **Energy Harvesting and Modified PSO based Routing (EHMP)**

Enhanced network lifetime is a significant and most important requirement in WBAN. Routing of information is the component that requires highest amount of energy in any sensor network. However, routing is a very important process that is used for communication of information, and has to be performed frequently. This automatically leads to overall reduction of charge in WBAN sensors. Nodes in WBAN network are usually embedded in the human body and hence cannot be easily replaced. Effective routing mechanisms the can perform load balancing is required in WBAN. Even with effective routing techniques, charge in the sensors tend to reduce rapidly as communication progresses. Incorporating techniques to replenish charge can provide long term advantages. Energy harvesting plays a vital role in extending the lifetime of nodes in WBAN networks. This work presents modified PSO based routing technique and an energy harvesting mechanism, EHMP, that can be used to effectively improve the lifetime of nodes in WBAN.

3.1 Modified PSO based Routing

The process of routing is performed using the modified Particle Swarm Optimization (PSO) algorithm. Original PSO algorithm uses the location information to identify the fitness of nodes for routing. PSO is modified by altering the fitness function to include other additional factors like charge, temperature, payload and location of the sensors. The process of transmission is performed in three phases. Transmission initiation is performed during the initialization of the network, particle dispersion and node selection are performed prior to every route request. This work operates by selecting single nodes, until the destination sink node is reached.

3.1.1 Transmission Initiation

The process of transmission initiation is performed once when the network is initialized. Charges in each of the nodes, location of the nodes, wavelength, frequency and temperature in the nodes are standardized. Every node transmits hello packets along with the location information. These packets are broadcasted, as during the initial phase the nodes are not aware of the neighboring nodes. All nodes in the range receive the hello packets and sends acknowledgements. The acknowledgement packets are composed of location details of the acknowledging node. The hello and acknowledgement messages helps to build the routing table. Every node maintains its own routing table. All one hop nodes and their location information are stored in the routing table. This is used as the base for the route creation process. At the end of this process, the network is considered to be operational.

3.1.2 Particle Distribution

Transmission requests arise when a sensor node wants to transmit information to the sink node. The destination is usually the sink node. The search space for PSO is created using the location information from the network. The particles are agents that determine the next node for transmission. PSO operates by distributing the particles in the search space. The distributed particles identify the fitness of nodes and move towards the node with the highest fitness. Speed of movement of the nodes is determined by the velocity component. During the initial movement, the velocity component is determined by the following equation (1).

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

Where the upper and lower boundaries of the search space is represented by b_{up} and b_{lo}.

After the completion of initial movement, every node every particle will have information about the particle (*pbest*) and the global best (*gbest*) solutions. These components are also added to the velocity function to improve performance. The pbest and gbest components are determined by identifying the fitness values for each particle. Fitness of a particle is determined by next week

$$F_{m,n} = \frac{n_{ch}}{d_{m,n} \times n_{temp}} \quad (2)$$

Where n_{ch} and n_{temp} are the charge and temperature of the node *n* and *d* is the Euclidean distance between the source node *m* and the destination node *n*

Higher fitness represents better solutions. The particle with best fitness is considered to be the gbest. Every particle maintains the best solution that has been visited by itself. This is maintained as the pbest solution. After the identification of pbest and gbest values, the velocity function is given by,

$$V_{i,d} \leftarrow \omega V_{i,d} + \varphi_p r_p \left(P_{i,d} - X_{i,d}\right) + \varphi_g r_g \left(g_d - X_{i,d}\right) \quad (3)$$

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

This process is repeated until all the particles converge into a single solution or until the number of iterations (*nc*) reaches the maximum limit. Here, the maximum number of iterations (*nc*) is set to 100.

3.1.3 Next Node Selection Using Particle Traversal

After conversion convergence, are the maximum number of iterations, the global best solution is identified. This solution corresponds to the best node that can be traversed for the optimal path. The data packets are transmitted to the selected node. Transmission of data results in reduction of charge and increase in temperature for both the sender and the receiver nodes. The level of reduction of charge and increase in temperature is given by,

$$PLoss = \left(-27.6 * \log_{10} d_{m,n}\right) + \left(-46.5 * \log_{10} f_m\right) + 158$$

$$TransmissionLoss = E_{Tr} \quad p_m + E_A * PLoss * p_m * d_{m,n}$$

$$ReceptionLoss = E_R \quad p_m$$

Where $d_{m,n}$ is the distance between the nodes *m* and *n*, f_m is the frequency of node *m*, p_m is the payload, E_{Tr}, E_A and E_R are the energy consumed by transmission unit, amplifier and reception unit.

The current node is considered as the base node, and the process of node selection is repeated by particle distribution and *gbest* selection. The process is continued till the packet reaches its destination or sink node.

3.1.4 Algorithm -1 Modified PSO based Routing

Input: Node coordinates, start node and end node

Output: Route between start and end nodes

1. Network configuration and Routing table construction
2. Search space creation for PSO
3. If transmission initiated
4. Particle Distribution in the search space
5. For each particle p
    a. Calculate Fitness based on charge, distance and temperature
6. Velocity initialization for each particle and particle movement

7. Fitness identification of particles
8. For each particle p
    a. Determine pbest of p
9. Determine gbest based on the pbest values
10. Velocity calculation using pbest and gbest
11. Particle traversal to new nodes
12. If stagnation is not reached go to step 7
13. Consider gbest as the next node for traversal

3.2 Energy Harvesting

As discussed in the previous section, transmission of packets results in reduction of charge in both the sender and the receiver. Further, the transmission loss should also be considered. Most transmissions are multi-hop in nature. Hence, the intermediate nodes are required to both receive and transmit packets. This results in a higher loss in the intermediate nodes. One hop transmissions are very rare. Although, the proposed modified PSO model performs load balancing, overall reduction in charge is expected. Energy harvesting is mandatory to maintain nodes live for a longer period. This work considers the energy harvesting scheme proposed in [22] to ensure higher network lifetime. For every regular time interval, the reduction in temperature in nodes and a small increase in the charge due to the energy harvesting mechanisms is considered in this work.

4. Results and Discussion

4.1 Simulation Setup

Results from EHMP architecture is compared with the E-HARP model proposed by Ullah et al. [22], and EH-RCP model proposed by Ullah et al. [23]. The simulation setup from E-HARP model has been adopted in this work to enable comparison.

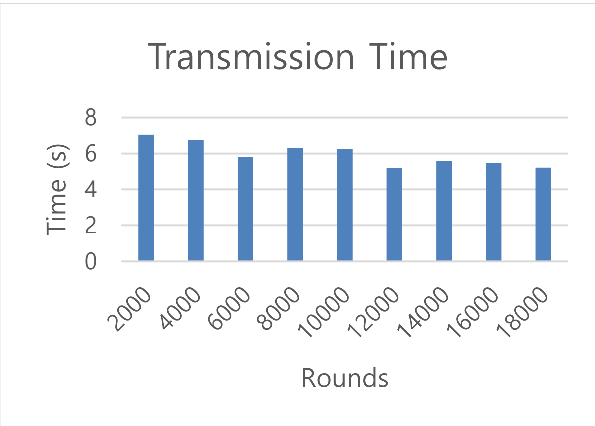

Figure-1 Transmission Time Requirement for EHMP

Time taken for transmission has been recorded for every 2000 iterations and is shown in figure-1 . It could be observed that the first two iterations require higher time of 7 seconds, while the other iterations average to 6 seconds. Higher time requirement for the initial iterations can be attributed to the network setup time, and the time required to build the routing table. Standard requirement of 6 seconds for every 2000 transmissions indicate that every transmission requires an average of 3 milliseconds. This shows the very low overhead required for the node prediction during the routing process.

5. Comparative Study

A comparison of the network lifetime and stability analysis as shown in figures 2 and 3. Network lifetime represents the time period required for depleting all the nodes in the network. As every transmission requires reduction of charge from the sender and the receiver, analyzing the network lifetime is mandatory for identifying the efficacy of the routing model and its load balancing component. It could be observed that the proposed EHMP model and the EH-RCP model exhibits the first node depletion. However, the rate of depletion of EHMP model is observed to be very low. The EH-RCP and E-HARP models exhibit complete node depletion during the 16,000 cycle, while, even after the 18,000 cycle the EHMP model contains several live nodes. This shows that the proposed routing model exhibits better load balancing techniques.

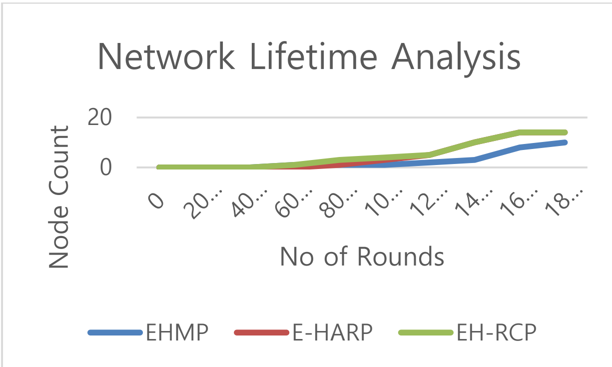

Figure-2 Comparison of Network Lifetime Analysis

A tabulated view of the network lifetime analysis is shown in table 1. The initial depletions of EHMP and EH-RCP occurred during the 6000th iteration, while the E-HARP model exhibits its first depletion in the 8000th iteration. The next node depletion in EHMP model was observed to be at the 12,000th iteration, while the other models exhibit five depleted nodes during the same time period. During the end of the observation period, 18,000th iteration, EHMP exhibits 4 live nodes, while all the other models get depleted during the 16,000th iteration. This shows that the EHMP model has extended network lifetime due to the appropriate routing technique and the effective energy harvesting mechanism.

Table 1: Network Lifetime Analysis

	0	***2000***	4000	6000	8000	10000	12000	14000	16000	18000
EHMP	0	0	0	1	1	1	2	3	8	10
E-HARP	0	0	0	0	1	3	5	10	14	14
EH-RCP	0	0	0	1	3	4	5	10	14	14

	0	***2000***	4000	6000	8000	10000	12000	14000	16000	18000
EHMP	14	14	14	13	13	13	12	11	6	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

Table 2: Stability Level Analysis

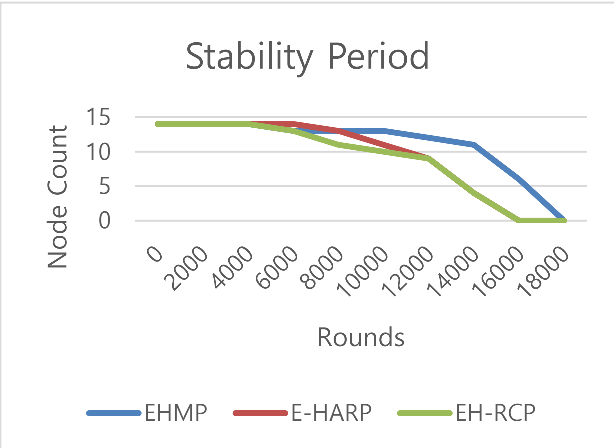

Figure-3 Comparison of Stability Levels

An analysis of the stability period of the nodes is shown in figure 3 and table 2. Stability refers to the number of nodes that are live during the transmission periods. The initial decrease in stability levels were observed after the 4000th iteration by EHMP and EH-RCP, while E-HARP remains stable till the 6000th iteration. However, the E-HARP model and EH-RCP model loses the stability levels faster and exhibit complete depletions during the 16,000th cycle. The proposed EHMP model exhibits stability even after this point, showing better stability levels.

Conclusion

Energy conserving and extending the network lifetime are two of the most significant processes in maintaining a wireless body area network. Limited resources and inability to replace batteries and components in wireless body area network ensures that WBAN requires effective routing strategies. This work presents and energy harvesting and modified PSO based routing scheme EHMP. Regular PSO model has been modified to include energy based and temperature components of the sensors in its fitness function to ensure better node selection.

Reactive routing technique is adopted so that the selection process is always up to date. Experimental results indicate that the proposed EHMP technique exhibits low overhead, and also exhibits a higher network lifetime and better stability levels. Although the proposed model exhibits better stability levels, initial node failure occurs at an earlier cycle compared to the existing models. Future works will concentrate on improving the network lifetime by postponing the initial node failure time.

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References

[1] I.F. Akyildiz, A. Lee, P. Wang, M. Luo, W. Chou, A roadmap for traffic engineering in SDN-openflow networks, Comput. Netw. 71 (2014) 1–30, http: //dx.doi.org/10.1016/j.comnet.2014.06.002.

[2] M. Cicioğlu, A. Çalhan, HUBsFLOW: A novel interface protocol for SDNenabled WBANs, Comput. Netw. 160 (2019) 105–117, http://dx.doi.org/10. 1016/j.comnet.2019.06.007.

[3] K. Kondepu, C. Jackson, Y. Ou, A. Beldachi, A. Pagès, F. Agraz, F. Moscatelli, W. Miao, V. Kamchevska, N. Calabretta, G. Landi, S. Spadaro, S. Yan, D. Simeonidou, R. Nejabati, Fully SDN-enabled all-optical architecture for data center virtualization with time and space multiplexing, J. Opt. Commun. Netw. 10 (2018) B90, http://dx.doi.org/10.1364/JOCN.10.000B90.

[4] I.F. Akyildiz, P. Wang, S.-C. Lin, SoftAir: A software defined networking architecture for 5G wireless systems, Comput. Netw. 85 (2015) 1–18, http: //dx.doi.org/10.1016/j.comnet.2015.05.007.

[5] A.-C. Anadiotis, L. Galluccio, S. Milardo, G. Morabito, S. Palazzo, SD-WISE: A software-defined wireless sensor network, Comput. Netw. 159 (2019) 84–95, http://dx.doi.org/10.1016/j.comnet.2019.04.029.

[6] J. Mu, X. Liu, X. Yi, Simplified energy-balanced alternative-aware routing algorithm for wireless body area networks, IEEE Access 7 (2019) 108295–108303, http://dx.doi.org/10.1109/ACCESS.2019.2925909.

[7] Optimizing Quality of Service for Sensor enabled Internet of Healthcare Systems

[8] Md. Taslim Arefin1*, Mohammad Hanif Ali1, A. K. M. Fazlul Haque2.(2017) Wireless Body Area Network: An Overview and Various Applications, Journal of Computer and Communications, 5, 53- 64, doi: 10.4236/jcc.2017.57006.

[9] Z. Ullah, I. Ahmed, T. Ali, N. Ahmad, F. Niaz, Y. Cao, Robust and efficient energy harvested-aware routing protocol with clustering approach in body area networks, IEEE Access 7 (2019) 33906–33921, http://dx.doi.org/10.1109/ ACCESS.2019.2904322.

[10] [15] A. Çalhan, K. Gündoğdu, M. Cicioğlu, M.E. Bayrakdar, Energy harvesting unit design for body area networks, Sakarya Univ. J. Comput. Inf. Sci. 2 (2019) 1–8, http://dx.doi.org/10.35377/saucis.02.01.512210.

[11] Energy-efficient and SDN-enabled routing algorithm for wireless body area networks

[12] M. Cicioğlu, A. Çalhan, SDN-based wireless body area network routing algorithm for healthcare architecture, ETRI J. 41 (2019) 452–464, http://dx.doi.org/10. 4218/etrij.2018-0630.

[13] [15] A. Çalhan, K. Gündoğdu, M. Cicioğlu, M.E. Bayrakdar, Energy harvesting unit design for body area networks, Sakarya Univ. J. Comput. Inf. Sci. 2 (2019) 1–8, http://dx.doi.org/10.35377/saucis.02.01.512210.

[14] Link quality and energy utilization based preferable next hop selection routing for wireless body area networks

[15] X. Liang, I. Balasingham, and S.-S. Byun, "A reinforcement learning based routing protocol with QoS support for biomedical sensor networks," in Applied Sciences on Biomedical and Communication Technologies, 2008. ISABEL'08. First International Symposium on, 2008, pp. 1-5.

[16] Z. Khan, N. Aslam, S. Sivakumar, and W. Phillips, "Energy-aware peering routing protocol for indoor hospital body area network communication," Procedia Computer Science, vol. 10, pp. 188- 196, 2012.

[17] M. A. J. Jamali, "A multipath QoS multicast routing protocol based on link stability and route reliability in mobile ad-hoc networks," Journal of Ambient Intelligence and Humanized Computing, pp. 1-17, 2017.

[18] [27] R. A. Khan, K. H. Mohammadani, A. A. Soomro, J. Hussain, S. Khan, T. H. Arain, et al., "An Energy Efficient Routing Protocol for Wireless Body Area Sensor Networks," Wireless Personal Communications, pp. 1-12, 2018.

[19] A low overhead tree-based energy-efficient routing scheme for multi-hop wireless body area networks

[20] M. Quwaider, S. Biswas, On-body packet routing algorithms for body 932 sensor networks, in: Proc. IEEE International Conference on 933 Networks and Communications (NETCOM), 2009, pp. 171–177.

[21] A. Maskooki, C.B. Soh, E. Gunawan, S.L. Kay, Opportunistic routing for body area network, in: Proc. IEEE Consumer Communications and Networking Conference (CCNC), 2011, pp. 237–241.

[22] Energy-efficient Harvested-Aware clustering and cooperative Routing Protocol for WBAN (E-HARP)

[23] Z. Ullah, I. Ahmed, T. Ali, N. Ahmad, F. Niaz, and Y. Cao, "Robust and Efficient Energy Harvested-Aware Routing Protocol With Clustering Approach in Body Area Networks," IEEE Access, vol. 7, pp. 33906- 33921, 2019.

[24] Energy efficient routing algorithm in wireless body area networks for smart wearable patches

[25] An Energy Efficient and Reliable Routing Scheme to enhance the stability period in Wireless Body Area Networks

[26] AMERP: Adam moment estimation optimized mobility supported energy efficient routing protocol for wireless body area networks

[27] M. M. Sandhu, N. Javaid, M. Akbar, F. Najeeb, U. Qasim, and Z. Khan, FEEL: forwarding data energy efficiently with load balancing in wireless body area networks, in Advanced Information Networking and Applications (AINA), 2014 IEEE 28th International Conference on, 2014, pp. 783-789.

[28] B. Jan, H. Farman, H. Javed, B. Montrucchio, M. Khan, and S. Ali, Energy efficient hierarchical clustering approaches in wireless sensor networks: A survey, Wire. Comm. and Mob. Comp., vol. 2017, 2017.

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