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A Comparative Analysis of Single-Hop and Multi-hop transmission using EERDT Protocol in Mobile and Critical Scenario for WBAN

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Abstract

Wireless Body Area Network (WBAN) is a technology, used for remote monitoring of patients where the wired network is not available. The sensed data is transmitted via internet to doctors so that they can aid the condition of a patient. Sensor nodes are being planted inside or outside the human body keeping in mind that there should be less number of nodes as well as radio model transmitting and receiving frequency should be less, so that it may not interfere with human body. In this work, a routing technique is proposed that will transfer critical data to base station immediately. The concept of mobility has also introduced. M-ATTEMPT protocol is used for comparison. Simulation result reveals that using single-hop approach is much better than using multi-hop approach in terms of network lifetime and packet transmission.

Keywords: *ATTEMPT, Mobile WBAN, efficient routing, reliable routing*

1. Introduction

WBAN is a collection of wireless sensors placed around or in a human body that are used to exchange important information from a human body to remote stations [1]. Figure 1 depicts how sensor nodes can be used to sense data and transmit it through internet. In a WBAN system, very significant requirements have been placed on the sensor node [2]. The sensor nodes should be small, consume extremely low power and reliable [3, 4]. Therefore, it is very important to minimize the power consumption of a sensor node.

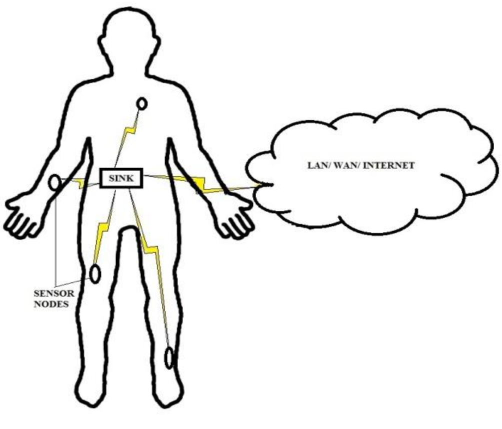

Figure 1. Deployment of Nodes in Body

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Due to varieties of components in WBAN, it is able to perform sensing work in military, healthcare, emergency, research, lifestyle, sports *etc*. Medical application of WBAN continuously monitor the patients, if any abnormal condition is detected, the information is immediately transmitted to doctor. In non-medical applications especially in military, WBANs are used to prevent sensitive information from being caught by enemies. Various applications have been discussed in [1-12]. Few of them are categorized and illustrated in Figure 2.

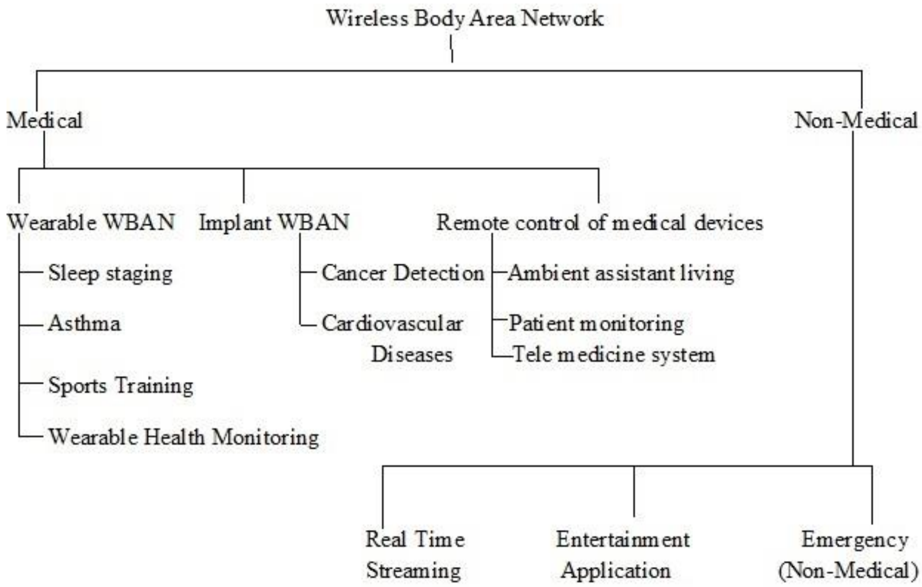


Figure 2. Applications of WBAN

2. Literature Review

Routing is one of the major concerns in WBAN due to its unique features. Various routing algorithms have been proposed to maximize network lifetime as well as mobility support in WBAN. In this section, we have discussed few routing protocols. They have considered different parameters for different routing techniques. Some of existing routing approaches are presented in this section.

Gill R. Tsouri proposed a global routing protocol in [5], with a novel link cost function to increase the lifetime of network in the WBANs. To compute the link cost function, Dijkstra's algorithm is used, which helps to balance the energy. In this work, all nodes deplete their energy at the same time due to balancing the energy of nodes in the network. In [7], to reduce the packet loss, hierarchical routing is used. While single hop routing is used to improve the quality of services and directly transmit the critical data to the base station. Cluster head is selected with maximum cost function after first round. To maximize the stability period and through; put of the network, cost function is evaluated using residual energy of the nodes and threshold value. A reliable, power efficient and high throughput multihop routing protocol is proposed in [8], in which, consumption of energy is minimum and stability period of network is increased, through multihop topology. A parent node (forwarder) is selected with minimum cost function, based on the maximum residual energy of nodes and minimum distance to the sink. A time slot is assigned to each child node to transmit the sensed data to forwarder node in its own time. In this way, consumption of energy is minimized and stability period of the network is increased. In [9], cross layer optimization performance is investigated based on real life example, by Samiya and others. The best route is selected, to transmit the data at the network layer, based on the channel state information from the physical layer. Shortest path routing and cooperative multipath routing are the two dynamic routing techniques, which are used for reliable data transfer and less packet error rate in WBANs. An extension of SIMPLE [8], which support mobility nature of human body called iMSIMPLE, is proposed in [13] by Nadeem Javaid and others. Linear programming is introduced to reduce the energy consumption and higher data transfer to the forwarder node. At first, energy consumptions of forwarder and child node is analysed and then a mathematical linear programming model is used for less energy consumption of nodes in the WBANs. In paper [14], a probabilistic store-forward packet routing protocol is designed using a stochastic link cost and supporting human body mobility. The main aim of this algorithm is to be end-to-end packet delays and end-to-end hop count, so that the transmitted energy is minimized. In [15], an energy efficient network coding approach for cooperative solution is proposed using decode and forward relays sensor nodes. The different messages coming from different sources are combined and generate one message for whole messages by relay node. And then, generated messages are transmitted to the destination, this scheme is called decode and forward-network coding (DF-NC). Here relay node works in half-duplex mode. This approach uses TDMA (Time Division Multiple Access) to send the messages at source node, like in SIMPLE [8]. Using this approach, minimum energy is consumed over other existing non network coding approach, because DF-NC requires only one time slot to forward the message and use direct transmission for WBANs. So, maximum energy is utilized and less time is required to transmit the sensed data from source to destination. In [16], authors N. Javaid and others proposed LAEEBA and COLAEEBA routing protocols to improve the network lifetime, energy consumptions as well as path loss of network in WBANs. There is a forwarder node in LAEEBA (Link Aware Energy Efficient Routing for Body Area), which is selected on the basis of residual energy of the sensor nodes. While, COLAEEBA (Cooperative Link Aware Energy Efficient Routing for Body Area) works on the basis of cooperation, and source nodes are utilized more than one link at the same time. In [17], authors proposed a dynamic resource allocation scheme to avoid the interferences amongst coexisting WBAN, using a table in which activity of nodes interference are updated. Authors also provide a mathematical analysis to validate its efficiency and a probabilistic approach to reduce the interference level. To avoid interferences among WBANs, a complete orthogonal channel is assigned to all sensor nodes in the network and at the same time, other sensor nodes re allowed to use the whole time slot until all are occupied. So this proposed scheme is efficient to reuse the channel and as well as maintain the interference level among sensor nodes in WBANs. In [18], a priority based energy aware routing is proposed, that effectively transfer the information to the sink node with supporting the mobility nature, in WBANs. A parent node is selected based on the cost function, considering priority, residual energy and distance of node. The distance factor helps in packet delivery from child to forwarder node and priority helps to select the best path to forward the critical data. In [19], a cluster based routing protocol is proposed by author to increase the stability of network and decrease the energy consumption of sensor nodes in WBANs, inspired by modleach protocol of WSNs. Single hop and multi hop communication is used to send the emergency and normal data respectively to the sink node. Threshold value is used to select the cluster head. It will remain cluster head for next round, if energy of cluster head is greater than threshold value. So, there is no need to select the new cluster head and in this way, energy is saved. In [20], authors design an improved routing protocol for effective data transmission and consider even energy consumption called 'Even Energy Consumption and Back Side Routing Protocol' (EECBSR). The main objective behind this routing technique is to increase the lifetime of network, energy efficiency and path loss of node located at the back side of body. Its aim to reduce the problem arises in M-ATTEMPT, like not support the mobility and operation runs parallel in this work. Author uses the standard deviation function instead of cost function used in SIMPLE [8] and select minimum; standard deviation value for forwarder node. In this work, to achieve the higher connection probability sensor nodes are also implanted on the back side of the body.

2.1. Research Gap

Although, WBANs have to face many demanding requirements in terms of delay delivery of data packet, low powered sensor nodes and network lifetime. A lot of routing techniques is proposed to achieve these demanding requirements. From the above review of papers, it can be concluded that, not a single routing protocol is sufficient to meet the basic requirements and quality of services of WBAN. Almost all the authors focused on the energy efficient routing technology for WBANs, based on the cost efficient function. Mobility nature of human body and effect of radiation on tissues heating are the two major concerns to design an energy efficient routing protocol.

2.2. Need of Study

The literature aptly enunciates that there is still need for some efficient routing technique which can work on mobile nodes as well as it can transfer critical data directly to Base Station.

2.3. Objective

An energy efficient and reliable routing approach which can be used with mobile nodes and for critical data transfer to base station.

3. Algorithm for Mobile Nodes (Based on Movement of Human Body)

In this algorithm, human body is lying on the bed is assumed for simulation. Six nodes are implanted in or outside the human body. Movement of legs and hands are considered in this case. The algorithm used for data transfer is shown in the Figure 3. In this proposed technique, six sensor nodes are deployed on human body. All nodes have equal initial energy and similar processing and computation capabilities. Sink node is placed around waist. Movement of legs and hands are considered in this case.

1) Algorithm of EERDT Protocol: The algorithm of EERDT protocol is as follows:

1. Initially, we have set base station a fixed position at human body and nodes are setup in a particular region on different parts of body like on legs, hands, heart *etc.* and each have equal energy *i.e.* 0.5 J and sink is considered to be a node that is having unlimited energy supply. We propose here a direct routing protocol to reduce packet loss as well as to improve quality of service.

2. In round 1, All nodes will transmit the sensed data directly to base station.

3. Energy consumption will be calculated according to (1).

$E_{TX}*(b) + E_{amp}*b*(\text{ min\_dis}^2)$ (1)

where,

E_{TX}: Energy consumed by Transmitter to send data.

E_{amp}: energy consumed by transmit amplifier.

b= Data Bits transfer to base station.

min_dis: Distance from a particular node to cluster head or base station.

4. This process will be repeated until the whole network gets down or number of rounds finished.

5. Performance will be evaluated according to parameters like network lifetime, energy dissipation, no. of data packets sent *etc.*

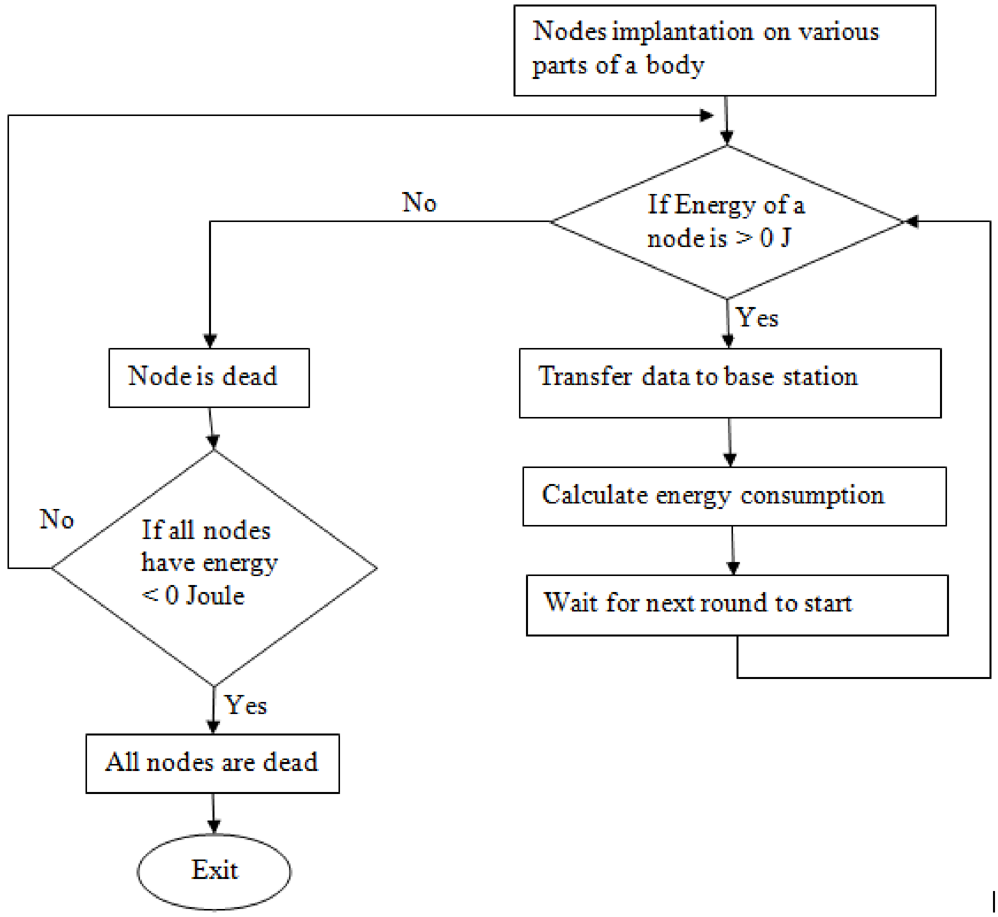


Figure 3. Flowchart of Data Transmission for Mobile Nodes

3.1. Implementation

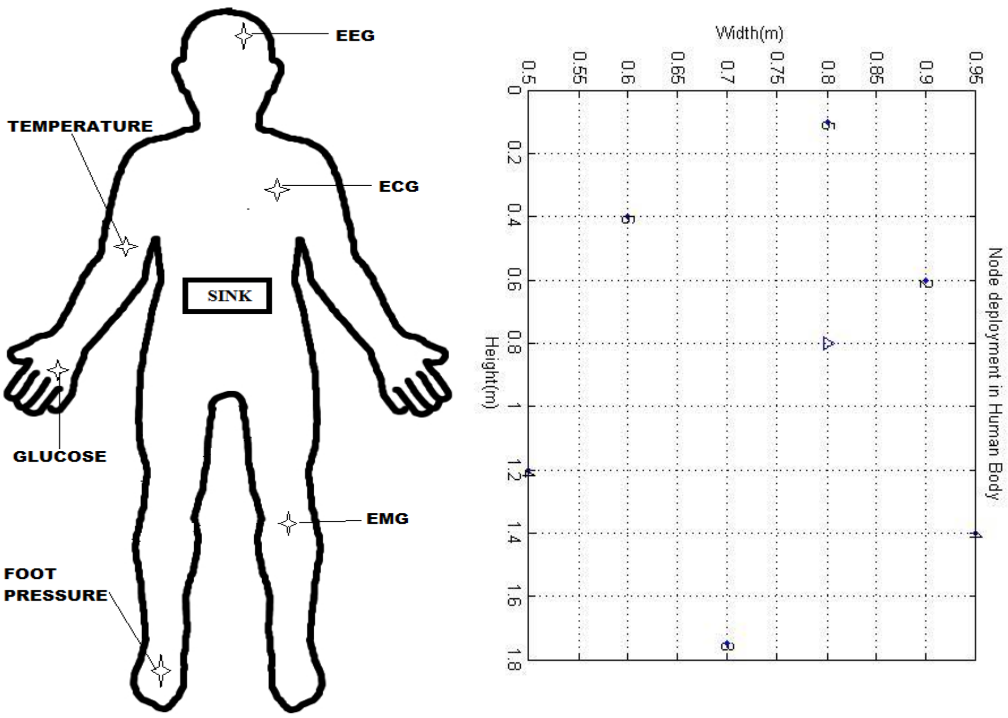
Table 1. Radio Models Used in WBAN [7]

Radio Model	nRF 2401A	CC 2420
E_{TX}(elec)	16.7nJ/bit	96.9 nJ/bit
E_{RX}(elec)	36.1nJ/bit	172.8 nJ/bit
E_{amp}	1.97 nJ/b	$2.71e^{-7}$ J/b

Table I shows various radio models used in WBAN. Table II shows various network parameters used for simulation. We have used radio model nRF2401A for simulation purpose because it consumes less transmitting, receiving and amplification energy as compared to CC 2420 which consumes six times more energy than nRF2401A.

Table 2. Network Parameters

Parameter	Value
Initial Energy, E_o	0.5 J
Amplifier energy, E_{amp}	1.97nJ/b
Transmitting Energy E_{tx}(elec)	16.7nJ/bit
Receiving Energy E_{rx}(elec)	36.1nJ/bit
Data Aggregation Energy(E_{DA})	5nJ/ bit
Packet size (b)	4000 bits
No. of Nodes(n)	6
Implementation tool	MATLAB 7.6
Radio model used for simulation	nRF 2401A



(a) (b)

Figure 4. Nodes Deployment on Human Body

Figure 4 (a) shows deployment of various nodes on the human body. Sink is placed at the center of the body and nodes are placed to measure EEG, ECG, temperature, foot pressure *etc.* Simulations part is also shown in Figure 4 (b).

3.3. Results when Nodes are Mobile (Based on Movement of Human Body)

Two nodes (node on right hand and feet) in each routing technique will change their position due to body movement as simulation rounds increases. Initially, the nodes will be placed as shown in Figure 4. But after 50 rounds, nodes will start changing their position. For *e.g.* after 50 rounds, node on the right foot will change their position. After 100 rounds, hand will change their position and so on.

The communication technique in M-ATTEMPT is multi-hop and we have implemented here single-hop communication technique.

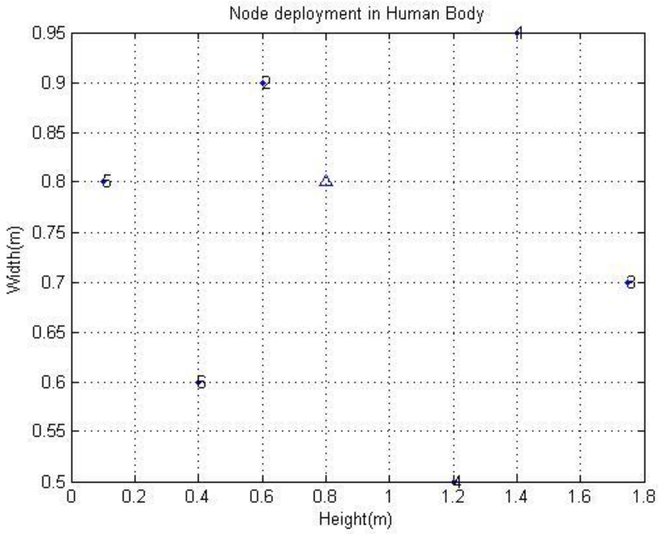


Figure 5. Initial Deployment of Nodes

Figure 5 shows deployment of nodes in or outside the human body. Movement in body posture will change node position. Here, we have considered movement of arms and legs. Mobility of nodes is considered for both protocols. Node 3 which is implanted on the foot of human body has changed its position after 50 rounds and communicates from the new position as shown in Figure 6(a). After 100 rounds, node 4 has a new position and communicates from the new position as shown in Figure 6(b). Similarly, in Figure 6(c) – Figure 6(f) shows the movement of nodes after a specified number of rounds.

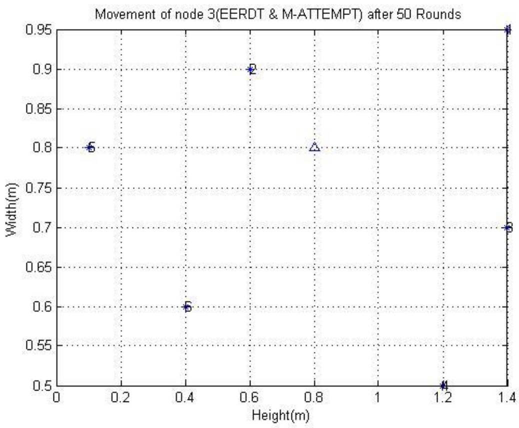


Figure 6(a). Movement of Node 3 after 50 Rounds

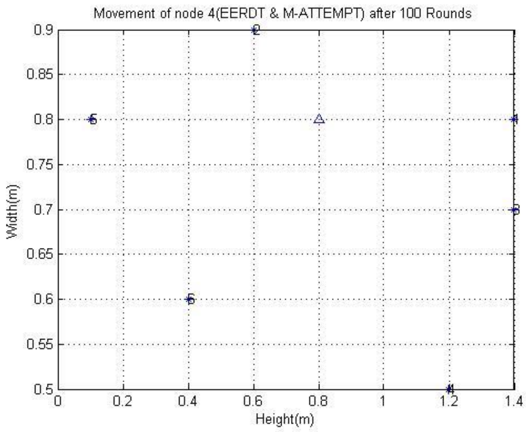


Figure 6(b). Movement of Node 4 after 100 Rounds

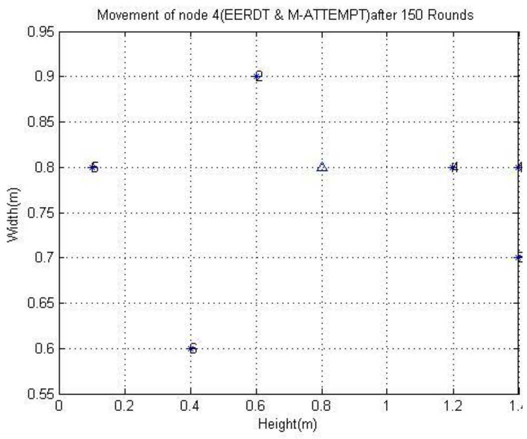


Figure 6(c). Movement of Node 4 after 150 Rounds

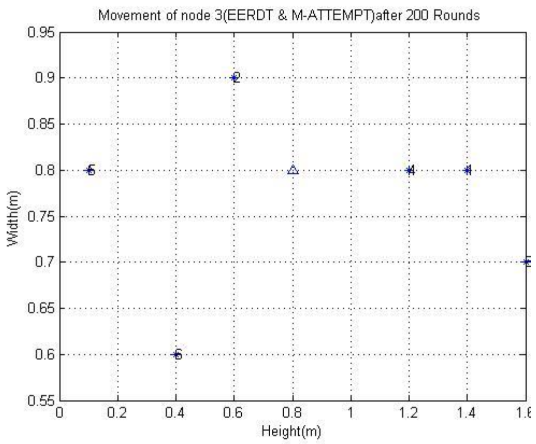


Figure 6(d). Movement of Node 3 after 200 Rounds

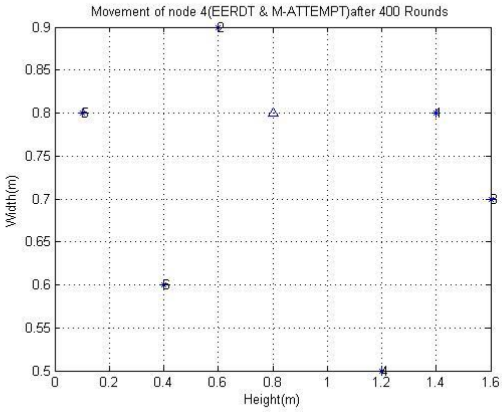


Figure 6(e). Movement of Node 4 after 400 Rounds

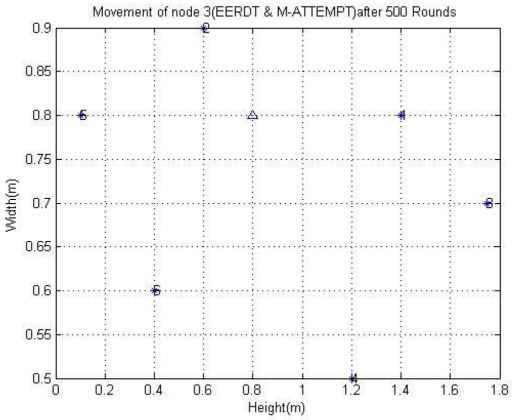


Figure 6(f). Movement of Node 3 after 500 Rounds

Figure 6. Movement of Nodes Due to Change in Body Posture after Specified Rounds

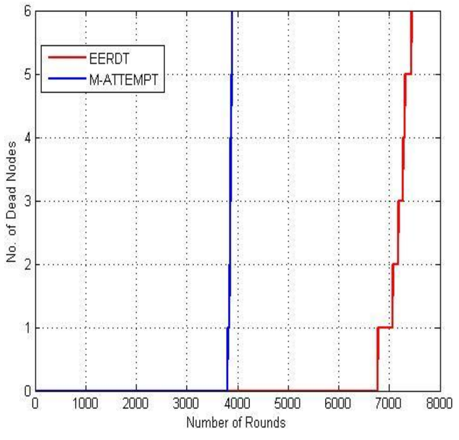


Figure 7. Number of Nodes Dead in EERDT and M-ATTEMPT

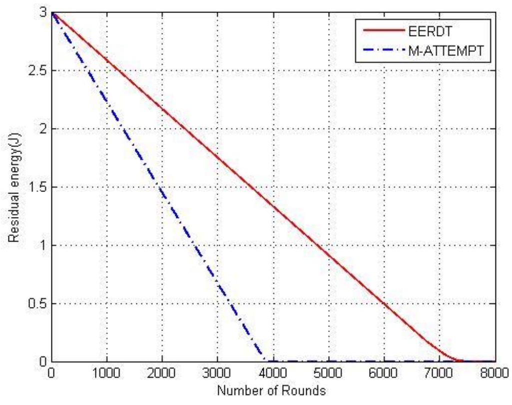


Figure 8. Residual Energy Comparison between EERDT and M-ATTEMPT

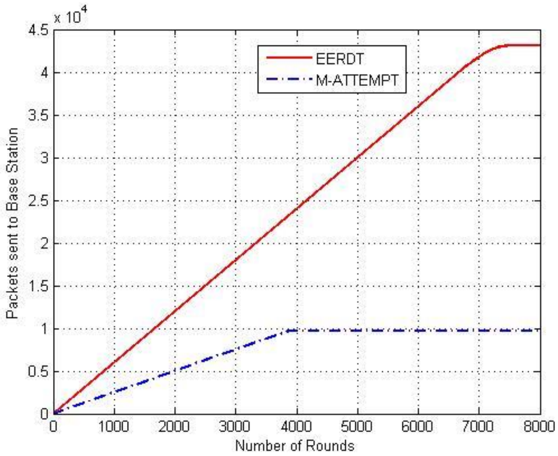


Figure 9. Packet Sent to Base Station in EERDT and M-ATTEMPT

As the number of rounds increases, node will lose their energy by transmitting data to other nodes or to base station. In M-ATTEMPT protocol, all the nodes are died very quickly as compared to EERDT protocol as shown in Figure 7. EERDT have much more stability than M-ATTEMPT protocol. In EERDT, mobility of nodes does not affect the routing algorithm and hence nodes will increase the overall network lifetime. Figure 8 showed the remaining energy of the whole network with respect to number of rounds. As number of rounds increases, node's energy gets depleted after each round due to data transmission. In M-ATTEPT, whole energy of the network reduced to zero around 4000 rounds but in case of EERDT, energy of the network reduced to zero after 7000 rounds. EERDT has showed much more stability in energy consumption than M-ATTEMPT.

In each round, nodes have to transmit the data to base station. Network lifetime is directly proportional to packet sent to base station. The lifetime of nodes using EERDT protocol is longer than M-ATTEMPT so higher numbers of packets are transferred to base station as shown in Figure 9.

4. Proposed Algorithm for Data Transfer in Critical Conditions

The proposed algorithm in case of data transfer in critical is following.

1. Sensing Phase: If data sensed by sensor node is not critical. Transmitting will not be done. Data will be sensed again after a period of time If data sensed by sensor node is critical. Transmitting phase will be initiated.
2. Transmitting Phase: Data will be transmitted and energy consumption will be calculated.

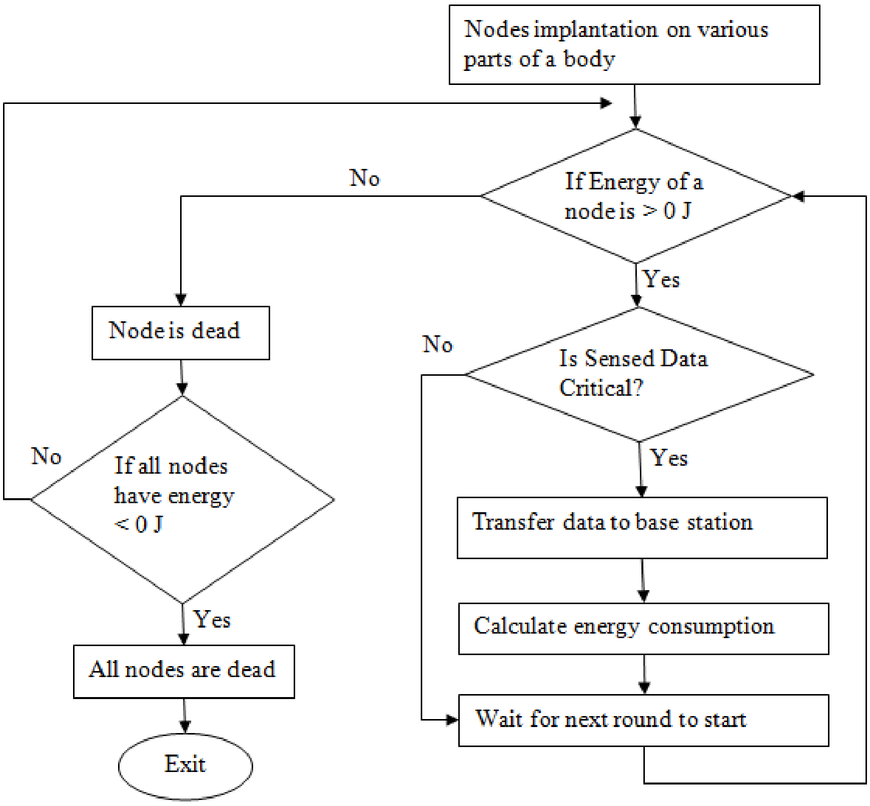


Figure 10. Algorithm for Data Transfer in Critical Conditions

4.1. Results

For implementation purpose, radio model and radio parameters are kept same as shown in Table I and Table II. The deployment of nodes is same as shown in Figure 4.

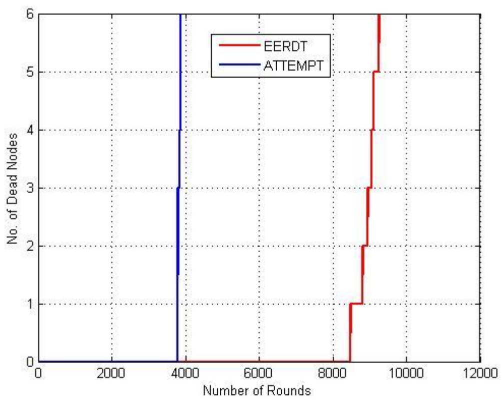


Figure 11. Number of Dead Nodes in EERDT and ATTEMPT

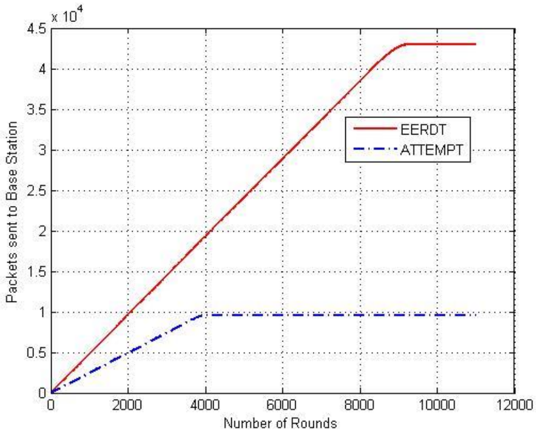


Figure 12. Packet Sent to Base Station in EERDT and ATTEMPT

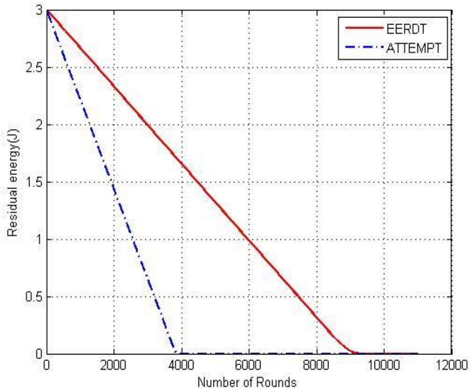


Figure 13. Residual Energy per Round in EERDT and ATTEMPT

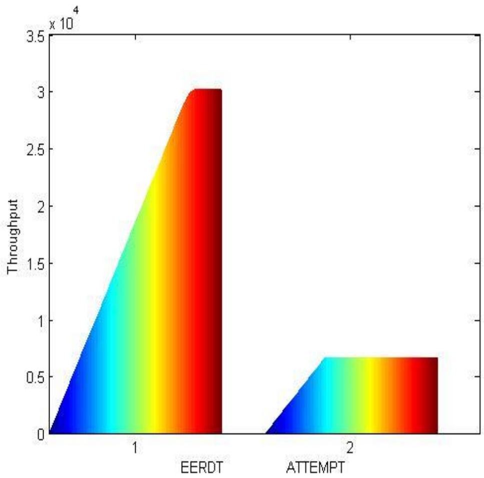


Figure 14. Throughput of the Network using EERDT and ATTEMPT Protocol

Figure 11 depicts the number of nodes dead w.r.t. number of rounds in ATTEMPT and EERDT (critical scenario). The lifetime of nodes using EERDT protocol is longer than ATTEMPT so higher numbers of packets are transferred to base station as shown in Figure 12. Figure 13 depict the remaining energy of the whole network with respect to number of rounds. As number of rounds increases, node's energy gets depleted after each round due to data transmission. Throughput defines the efficiency of a network in data transmission. Figure 14 illustrates the throughput of the network using EERDT and ATTEMPT protocol. EERDT has shown better throughput as compared to ATTEMPT while transferring critical data.

5. Conclusion

In this work, an energy efficient and reliable data delivery protocol is proposed while considering the fact of nodes mobility and critical time when data needs to be reported. As human body changes its posture, the node's position will also get changed. To avoid path loss in this situation direct routing technique *i.e*. nodes will directly transfer the data to base station is used. Direct routing will reduce packet collisions as well as packet loss at sink with the help of TDMA scheduling. Proposed routing technique enhances packet delivery and network lifetime. Further, the technique can also be used in critical time situations, in which data transfer will take place only when sensed data is critical. Simulations results depicts that the proposed technique improves the lifetime and throughput of the network.

References

[1] L. H. X. Wang and T. Chen, "A Review of Protocol Implementations and Energy Efficient Cross-Layer Design for Wireless Body Area Networks.", Sensors (Basel, Switzerland), **(2012)**, pp.14730–14773.

[2] A. B. Waluyo, W. S. Yeoh, I. Pek, Y. Yong and X. Chen, "MobiSense: Mobile body sensor network for ambulatory monitoring", ACM Trans. Embedded Comput. Syst., vol. 10, no. 1, **(2010)**, pp. 1–30.

[3] B. Latré, B. Braem, I. Moerman, C. Blondia and P. Demeester, "A survey on wireless body area networks", Wireless Network, vol. 17, no. 1, **(2011)**, pp. 1–18.

[4] D. Cypher, N. Chevrollier, N. Montavont, and N. Golmie, "Prevailing over wires in healthcare environments: benefits and challenges", IEEE Communications Magazine, vol. 44, no. 4, **(2006)**, pp.56-63 .

[5] R. T. Gill, A. Prieto and N. Argade, "On increasing network lifetime in body area networks using global routing with energy consumption balancing", Sensors, **(2012)**, pp. 13088-130108.

[6] Z. Yang, "Beacon-based opportunistic scheduling in wireless body area network", 38th Annual International Conference of Engineering in Medicine and Biology Society (EMBC), IEEE, **(2016)**, pp.4995-4998.

[7] D. Sethi and P. P. Bhattacharya, "A Study on Energy Efficient and Reliable Data Transfer (EERDT) Protocol for WBAN", Second IEEE International Conference on Computational Intelligence & Communication Technology (CICT), Ghaziabad, **(2016)**, pp. 254-258.

[8] Q. Nadeem, N. Javaid, S. N. Mohammad, M. Y. Khan, S. Sarfraz, M. Gull, "SIMPLE: Stable increased-throughput multi-hop protocol for link efficiency in wireless body area networks", 8th IEEE International Conference on Broadband and Wireless Computing, Communication and Applications (BWCCA'13), **(2013)**, pp.221-226.

[9] Samiya M. Shimly, David B. Smith, Samaneh Movassaghi, "Experimentally-based Cross-layer Optimization Across Multiple Wireless Body Area Networks", arXiv: 1701.08605.

[10] Moosavi, Hussein, and Francis Minhthang Bui, "Optimal relay selection and power control with quality-of-service provisioning in wireless body area networks", Transactions on Wireless Communications, IEEE, **(2016)**, pp. 5497-5510.

[11] Movassaghi, Samaneh, "Enabling Interference- Aware and Energy Efficient Coexistence of Multiple Wireless Body Area Networks with Unknown Dynamics",IEEE Access, July **(2016)**, pp. 2935-2951.

[12] S. J. Marinkovic, E. M. Popovici, C. Spagnol, S. Faul, W. P. Marnane, "Energy Efficient Low Duty Cycle MAC Protocol for Wireless Body Area Network", IEEE Trans. Inf. Technol. Biomed, vol. 13, Nov. **(2009)**, pp. 915-925.

[13] Nadeem Javaid, Ashfaq Ahmad, Qaisar Nadeem, Muhammad Imran, Noman Haider, "iM-SIMPLE: iMproved stable increased-throughput multi-hop link efficient routing protocol for Wireless Body Area Networks", Computers in Human Behaviour, Vol. 51, **(2015)**, pp. 1002-1011.

[14] Muhannad Quwaider, Subir Biswas, "Probabilistic Routing in On-body Sensor Networks with Postural Disconnections", Proceedings of the 7th ACM international symposium on Mobility management and wireless access, ACM, October 2009, pp. 149-158.

[15] Samaneh Movassaghi, Mahyar, Mehran Abolhasan, "An Energy Efficient Network Coding Approach for Wireless Body Area Networks", 38th Annual IEEE Conference on Local Computer Networks, **(2013)**, pp. 468-475.

[16] S. Ahmed, N. Javaid, S. Yousaf, A. Ahmad, M. M. Sandhu, Z. A. Khan, N. Alrajeh and M. Imran, "Co-LAEEBA: Cooperative Link Aware and Energy Efficient Protocol for Wireless Body Area Networks", Computers in Human Behaviour, vol. 51, **(2015)**, pp. 1205-1215.
[17] S. Movassaghi and M. Abolhasan, "Smart Spectrum Allocation for Interference Mitigation in Wireless Body Area Networks", International Conference on Communication, IEEE, **(2014)**, pp. 5688-5693.
[18] S. Talha, R. Ahmad and A. K. Kiani, "Priority Based Energy Aware (PEA) Routing Protocol for WBANs", 82ndVehicular Technology Conference (VTC Fall), IEEE, **(2015)**, pp. 1-5.
[19] R. Sharma, H. S. Ryait and A. K. Gupta, "Clustering Based Routing Protocol to increase the stability in WBAN", International Journal of Innovations in Engineering and Technology, **(2015)**, pp. 119-125.
[20] I. Ha, "EECBSR (Even Energy Consumption and Back Side Routing): An Improved Routing Protocol for Effective Data Transmission in Wireless Body Area Networks", International Journal of Distributed Sensor Networks, **(2016)**.

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