Performance Enhancement Strategies for Routing Protocols During Mobility in Wireless Body Area Networks

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Abstract*— People who are at danger of chronic or deadly conditions such as cardiac arrest or heart disorders, to name a few, might benefit from timely intervention. These are the leading causes of mortality and disability in the world. Continuous monitoring of important bodily indicators may aid in prompt intervention, potentially saving the lives of patients with life-threatening chronic conditions while also improving their quality of life. WBAN is an autonomous network that uses battery-powered heterogeneous sensor nodes. The purpose of these nodes is to continually monitor bodily parameters. Data from sensor nodes is sent to the sink, which is the destination node, via routing procedures. During routing operations, the nodes might also act as intermediary nodes. Much of the network's energy is used by this routing activity. Due to bodily movement, this network may experience problems such as packet congestion or connection failure. We need to create a system that can address all of these difficulties and reliably transmit data. Robust strategies to prevent packet loss at different stages during transmission must be addressed. This work proposes performance enhancement strategies to improve the performance of WBAN routing protocols.

***Indexed Terms*— emergency data, mobility support, placement of nodes in WBAN, routing protocols**

I. INTRODUCTION

Sensor technology and low-power and intelligent hardware advancements in the past several years have revolutionized healthcare, the military, sports, interactive gaming, and other disciplines. They continually monitored physiological parameters like health and mobility with small sensor devices implanted in the body or worn on clothing. The Wireless Body Area Network (WBAN) is a collection of micro-networks created on the human body and linked through wireless media (WBAN) [1], [2]. A small wireless network of sensor devices, either implanted in the body or worn on clothing, continually monitors human physiological variables like blood pressure and cardiac rate and transmits the data to a central server far off by a wireless channel. In addition, they track the health of the individual in question when the data reaches the central server[3].

A person with WBAN is always on the go. This has to be taken into consideration while designing WBAN applications monitoring health parameters of a patient. WBAN routing has seen a significant amount of prior study, however the current state of the art research in WBAN routing handling mobility is restricted [4]. To address these issues, new methods have been proposed to reduce packet loss and improve energy efficiency during the mobility of patients. These methods enhance the performance of routing protocols designed for WBAN applications. The methods have been used to improve the performance of the routing protocols: Energy Efficient Routing for Wireless Body Area Networks (EER-W) and Energy Efficient Routing with Reliability and QoS (EER-QR).

II. LITERATURE SURVEY

Dalal Abdulmohsin Hammood,, et al. [5] proposed Emergency Data based cooperative communication protocol for WBAN ED-TMS which optimizes network performance using cooperative communication. Relay nodes retransmit dropped packets. Nodes pick the optimum destination through cooperative transmission. Protocol optimizes network performance and latency. A path selection mechanism which uses 3 stages was proposed by Manickavasagam, et al. [6] using Software Defined Network (SDN) for handling data with is critical information about the body vitals. For transmitted time critical packets, SDN controller chooses optimal path between source and destination using greedy approach. Here the path selection is divided into 3 stages with the best path between the source and destination being selected based on node delay and the available bandwidth in the link.

Placing the sink node strategically can improve the overall performance of the network. Abdullahi Abdu Ibrahim, et al. [7] had contributed to improving reliability of routing protocol for transmission of emergency data. This was achieved by the proposed routing protocol EN-NEAT (Enhanced Energy Efficient threshold based Emergency Data Transmission). The proposed protocol uses single hop for transmission of high emergency data and multi hop communication for transmission of low emergency data. The authors have reported an improvement in the packet delivery ratio, network lifetime and reduced energy consumption in the network.

The emergency data should be transmitted with high reliability. Yating Qu, et al. [8] proposed reliable and energy efficient routing protocol by using cost function to select the forwarder node. The sensor nodes are distributed on the human body and are identified with their own ID. The initial energy of all the nodes is same. The cost function takes the residual energy, network bandwidth and the number of hops to the sink to select the best next hop node. Shanmugapriya, et al. [9] proposed DP-PCC scheme for QoS in WBAN. The data sensed from the sensor nodes are classified as emergency or normal data based on the QoS requirements. Authors have proposed Pearson Correlation Coefficient which computes the positive or negative correlation that is used to classify the data packet into normal or emergency data. The correlation measures and establishes the relationship between the type of data packet and bandwidth availability. The channel is allocated for high priority emergency data. Authors have also considered elliptic curve cryptography for secured communication using public key cryptography.

The nodes on the human body can be arranged based on their transmission rate. Relay nodes can be introduced to provide alternate path option if the chosen path between the source to the sink fails with no other paths available. Smita Singh, et al. [10] proposed a modified NEW-ATTEMPT which takes into consideration the heterogeneous nature of the WBAN network. Authors have used the cost function to determine the next hop node. The sink node has information about the complete network using which the cost function is computed. Ashwini Umare, et al. [11] used genetic heuristics to optimize the routing process in WBAN network. Clustering technique has been proposed with genetic algorithm which uses evolutionary approach to arrive at the most feasible solution. Authors have reported improvement in the lifetime and stability period of the network using genetic algorithms compared to other optimization techniques.

Frequent forwarding and placement of sink node can influence energy consumption and packet transfer in the WBAN network. Vahid Ayatollahitafti, et al. [12] proposed Energy Efficient Next Hop Selection Algorithm (ENSA-BAN) The experimental setup involves two scenarios. The first scenario where the sink node is placed at the waist region of the patient. In the second scenario the sink node is placed at the ankle region. The authors have reported more packet loss when the sink is placed in the ankle region because of frequent forwarding. The nodes with low energy levels should be avoided from being part of data forwarding in the WBAN network. This is to conserve energy of the nodes. The nodes with high energy levels can be used to transmit packets. Nedal Ababneh, et al. [13] proposed Adaptive Routing and Bandwidth Allocation protocol (ARBA), an adaptive protocol for streaming emergency data to the sink node. Authors have proposed mixed Integer Liner Program model for adaptively finding routing paths. The nodes with high energy levels are used to transmit emergency packets. ARBA gives more emphasis to adapt to the context of the application environment where the network is deployed. Author reports this to be the most prominent feature of this protocol.

In one hop communication, far-away nodes lose energy quicker. In multihop, frequently utilised next-hop nodes waste energy quicker. Yousaf, et al. [14] proposed CE Mob, Critical Transmission in Emergency with Mobility support in WBAN. To prevent frequent data transmission, a threshold-based technique is utilized, where data is only sent if the prior value is different. This conserves energy in nodes, extending the network's life.

III. METHODOLOGY

3.1 Strategic Nodes for Mobility Support

WBAN's energy efficiency and connection are two of the most difficult issues to solve. As noted in the survey, the state-of-the-art algorithms designed for mobility in WBAN do not account for the requirement to improve efficiency and reduce data loss and dead nodes during mobility of the subject. This result may be attained by a unique method that employs additional nodes strategic nodes. Strategic nodes have increased data and energy rates [15]. The strategic placement of extra nodes ensures that, regardless of body position, at least one additional node is always in line of sight for the transmission of packets from sensor nodes. The extra nodes are positioned so that the sink node is accessible at all times, regardless of body posture.

Strategic nodes do not take data directly from a patient's body, but rather utilize the data they get from the previous nodes to transfer it to the next node. In addition to conserving energy, it extends the life of the wireless body area network. It also aids with data routing, ensuring that irrespective of postural changes, transmission of data is uninterrupted. In constructing a WBAN, strategic nodes assist reduce packet loss and also make the system more energy efficient, ensuring the network's long-term viability.

An essential consideration in the design of an energy efficient and reliable wireless body area network is where strategic nodes are placed. Data routing and the placement of strategic nodes are intertwined in this challenge. Reduced costs, energy consumption, and load distribution on relay nodes are the primary goals of this challenge. Reduce costs, energy consumption, and load distribution on strategic nodes are the primary goals of this challenge. As well as using less energy, the suggested approach is expected to spread the load equally across all of the strategic nodes as well. In order to extend the lifespan of WBSNs during mobile scenarios, strategic nodes are added. These nodes have more powerful batteries and a greater range of use. As a result, the amount of energy required to carry data from one node to another is greatly reduced. Adding strategic nodes reduces the amount of power needed to send data from sensors that are far away from the destination, it also increases the quantity of data packets that may be sent to the strategic node.

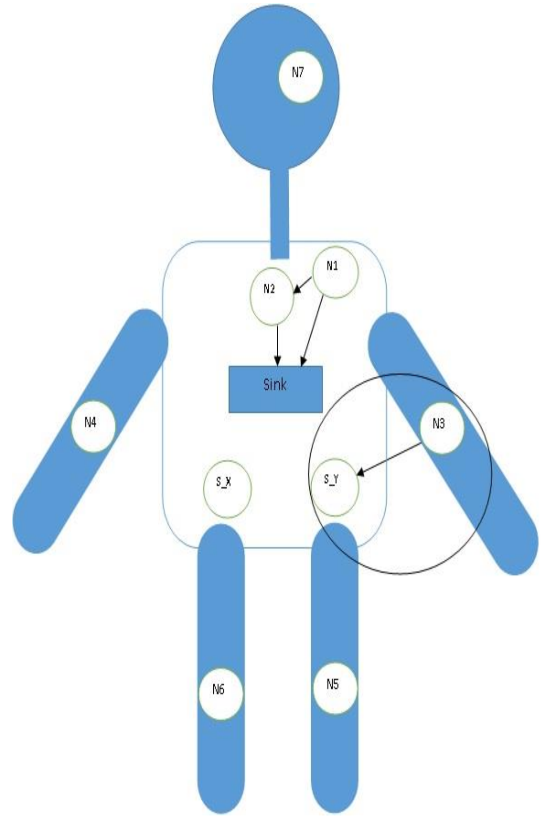

Fig 1 (a) Node 3 associated with S_Y

As shown in the above Fig 1 (a), Node 3 has been associated with the strategic node S_Y which is the current parent to node 3. As depicted in Fig 1 (b), because of the mobility (hand movement) node 3 is out of reach with respect to S_Y. If node 3 does not find a new parent to send the data to sink it data may be lost. The Node S_X which has been strategically placed in such a way that it can be a parent to any of the nodes.

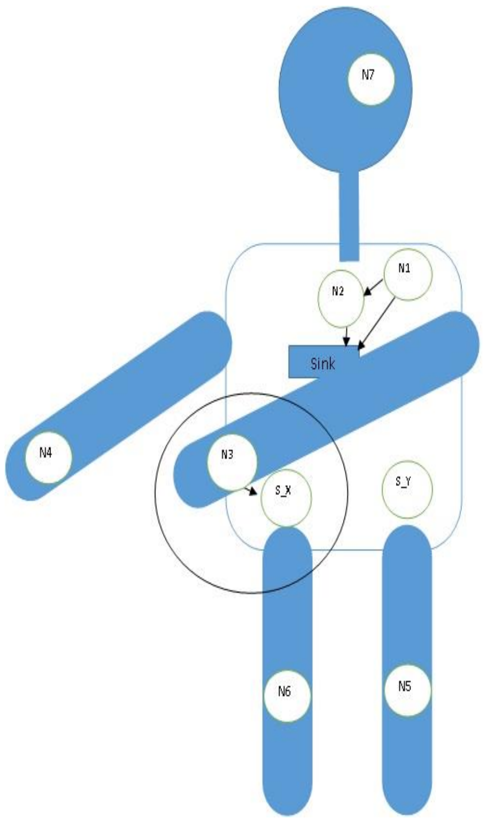

Fig 1 (b) Node 3 with the change of association during mobility.

As depicted in Fig 1 (b) because of the mobility (hand movement) node 3 is out of reach with respect to S_Y. If node 3 does not find a new parent to send the data to sink its data may be lost.

Performance assessment of protocols in wireless networks with node mobility requires a suitable mobility model. High mobility is one of the hallmarks of a WBAN's sensor nodes. Changes in posture and movement even within a certain posture may totally alter the WBAN structure. Consequently, it is critical to use an appropriate mobility model while evaluating performance.

Using algorithmic models may have a significant influence on the accuracy of sensor network simulations. Node movement patterns are characterized in mobility models in an attempt to match real-world behavior. An algorithmic model relies heavily on the context in which it will be used. Because the sensors in a WBAN are placed on the user's body, the network's topology is constantly changing. The quality of the channel and the connection between the nodes is highly dependent on the location of the sensor nodes relative to one another. It raises the importance of a WBAN's mobility model [16]. Without a proper model of mobility, a WBAN protocol simulator cannot be relied upon at all. Sensor nodes on separate parts of the body are able to move independently, as well as the whole body as it moves around the surroundings. All of these elements should be included in a mobility model. Furthermore, it should be able to be adapted to the WBAN domain's unique application situations.

Algorithm 1 Managing Mobility in WBAN using Strategic Nodes

Nodes X and Y are strategic nodes placed on locations which are less mobile in human body. These node posses high data rates and are directly connected to the sink node.

```
1. define Nodes {N1, N2, N3, N4, N5....}
2.define Strategic_node_X ,Strategic_node_Y;
3.if(change_in_node_location and connection_parent_lost)
then
4.search  new Strategic_node;
5.else dead_Node;
6.endif
7.if(new_node_found) then
8.Send Join_request
9.endif
10.if(Number_of_nodes_with_parent <4) then
11.Accept Join_request
12.add new_child to tree
13.endif
```

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3.2 Algorithmic Modeling for Mobility support

A typical WBAN network system includes sensor nodes positioned on the human body. This is an independent network with its own topology. Typically, sensor nodes are linked using a star architecture. Vital bodily parameters will be communicated or transferred to a medical server over WBAN in enhancing support for decision making by the medical personal. Routing becomes the core of the network in order to reduce energy loss and maximize network longevity. The WBAN network's sensor nodes rely on one another to function .A WBAN network on the patient's body should be able to control movement at various levels. The patient's movement when walking, running, sitting, bending, and resting modifies the patient's posture, which changes the topology of the network. The mobility support by the routing protocol is crucial for any WBAN application [17]. This is because of changes in posture during mobility, the WBAN network's network topology changes regularly. As a consequence, the link between the sensor nodes may be severed. The chances of packet loss during these situations are high compared to patient being static. The connection must be restored, taking into account the network topology at the time.

Using mobility models may have a significant influence on the accuracy of sensor network simulations. Node movement patterns are characterized in mobility models in an attempt to match real-world behavior. Choosing the correct mobility model relies heavily on the context in which it will be used. Because the sensors in a WBAN are placed on the user's body, the network's topology is constantly changing. The quality of the channel and the connection between the nodes is highly dependent on the location of the sensor nodes relative to one another. It raises the importance of a WBAN's mobility model [18], [19]. Without a proper model of mobility, a WBAN protocol simulator cannot be relied upon at all.

Basic Assumptions:

- General Mobility Model has been taken into consideration.
- The WBAN is made up of N nodes, each of which serves as a routing forwarder.
- Except for the sink node, all sensor-nodes (homogeneous) have the same communication range (heterogeneous).
- The communication range of a sensor-node allows it to connect directly to all other sensor-nodes within that range.

3.3 Transmitting time critical data in mobility

Mobility is a critical limitation to deal with in WBAN. It’s challenging to design a mobility-based routing protocol since varied human postures must also be addressed. People can move in different ways, such as by sitting, standing, walking, lying down, or running. Because both the sender and the receiver move around, the throughput efficiency of a routing protocols are lowered. Patients' postural mobility may disrupt the network for a short time or permanently due to link or node failure, with the effects reflected in data transmission. Because of changes in posture during mobility, the WBAN network's network topology changes regularly. As a result, nodes and connections are vulnerable to a variety of threats, increasing the likelihood of failure, and multiple nodes in the WBAN may become disconnected. As a consequence, the link between the sensor nodes may be severed. The connection must be restored, taking into account the network topology at the time. This may have an influence on network performance measures such as energy consumption, packet delivery, throughput, and reliability. Along with the issues stated above, the protocol should consider energy usage, packet loss, and network longevity.

Algorithm 2 Routing Time Critical Packets (TCP’s) during mobility.

1:Set-up phase- All sensor nodes are ready to transmit their data to destination node.

2. Assume: 0 for Normal packet and 1 for Time Critical Packet.

3. Each source node transmits its data by setting the flag to 0 or 1
4. Initialize flag=0.
5. if(critical data && sensor_value>threshold) then
6. flag = 1
7. if(flag==1)
8. if(sink in range)
9. next_hop= SingleHop to sink
10. endif
11. else
12. X= StrategicNode(in range)
13. next_hop=X
14. else
15. hop=multihop.

For WBANs, robust techniques for transferring essential medical data are necessary since packet loss is common during mobility. The patient's life might be put in danger if vital information isn't sent on time. In the event that crucial data is transferred via the typical multiple-hop technique, data packets may be delayed or even lost. A single hop to the sink or direct transmissions to strategic nodes have been suggested as an alternative. A single-hop technique or strategic nodes may be used by any node N that may have time-critical data. A single hop or transmission to strategic nodes approach is used to prioritize and convey vital data, resulting in higher energy consumption.

Due to the fact that each intermediary node receives, processes, and transfers data to the next node before sending it on, the latency in multi-hop communication is substantially higher than in direct communications. A delay occurs because of the time it takes for each intermediary node to receive, process, and transmit received data. Some severe situations may need a delay of more than a few minutes owing to congestion. Single-hop communication or transmission to strategic nodes is utilized in order to reduce the delay caused by this.

3.4 Energy efficiency with mobility support

Sensor nodes in an intra-WBAN network may need to operate without being recharged for extended periods of time. This is due to the difficulty of replacing the batteries in the sensor nodes. If the sensor nodes are implanted into the human body, as in some circumstances, the situation will become more challenging. The network should be designed in such a way that the energy consumption is minimized with the help of the routing protocol. Much of the energy in a WBAN network is spent during network initialization or reestablishing a lost connection. Connections are regularly lost in mobility-based scenarios, and reestablishing the connection becomes a routine in the network. This can deplete the network's total energy.

Reducing the number of control messages sent during postural movement can aid in energy conservation.

Algorithm 3 Energy Efficiency with Mobility Support

1: Sending the packets from source to sink node
2: if (path1< path2) then
3: selected=path1
4: else
5: selected=path2
6: if (path2< path1) then
7: selected=path2
8: else
9: selected=path1
10: if (path1== path2) then
11: EC1 ← Energy consumption in path 1
12: EC2 ← Energy consumption in path 2
13. if (EC1 < EC2) then
14: selected=path1
15: else
16: selected=path2
17: end if
18: end if
19: end if
20: end if

The distance between the node and the sink can have a significant impact on the energy levels of sensor nodes. If the node is further away from the sink and single-hop transmission is utilized for data transfer, the sensor node's energy can drain at a faster rate, resulting in the node turning dead. If the network transfers data via a multi-hop strategy involving forwarder nodes, the energy levels of nodes near the sink may be depleted. The key to conserving energy during postural movements is to strike a balance between the two approaches. If an end to end reliable path is not available for immediate transmission of emergency data, the algorithm uses direct transmission. The availability of reliable path results in using multi-hop approach which conserves energy. When the normal packets are transmitted to the sink, a multi-hop approach can be used.

Applications built using WBAN network typically use continuous transmission of data or transmission of data during regular intervals. This can result in draining the energy of sensor nodes which can become more critical during mobility scenarios. Novel mechanisms have been devised for avoiding repeated transmission. The techniques include transmitting data (i) if changes in the sensor readings are noticed (ii) if the reading crosses a specified threshold. Ex: Heartbeat reading in the range of 40-100 is normal. Apart from the above situations, the sensor nodes transmit the readings when requested by external source.

3.5 Network Simulator for modeling Mobility support
Several open source frameworks for modeling WSN and WBAN protocols exist. There is a sophisticated toolkit for modeling wireless networks like this in the MiXiM framework on top of the OMNeT++ discrete event simulator. OMNeT++'s mobile network simulation capabilities are bolstered by the architecture it provides for mobile device mobility.In addition to the OMNeT++ framework, Castalia focuses on mimicking WBAN protocols. It contains a radio model based on actual radios for low-power communication and a sophisticated channel model based on experimentally observed data for the human body as the propagation medium. Other network simulators, such as NS-2/3, have their own frameworks on top of them.

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IV. ENERGY MODELING FOR SINGLE HOP AND MULTI HOP COMMUNICATION

(1) The energy used for Single-hop communication is given as:

$$SH_E = T_E \quad (1)$$

Where SH_E is the energy consumed for single hop communication
T_E is the energy used for transmitting the data.

Here $T_E = EC_{DP} + EC_{AMP}$ (2)

where, EC_{DP} is the energy spent for processing data and EC_{AMP} is the energy used by the amplifier for transmitting the packets.

(2) The amount of energy needed to transmit K bits across N number of hops considering energy loss during transmission is given below

$$T_E = N \times K\,(EC_{DP} + EC_{AMP}) \times E^2_{LT} \quad (3)$$

Where E^2_{LT} is the energy lost during transmission

If a node detects an emergency or a request for on-demand data is given, the node checks the availability of strategic node. If the strategic node is available and meets the delay requirements, the same is used, else the node goes with direct transfer of data to the sink using Single-hop communication. If the data is normal, it is sent to the sink node via Multi-hop communication, which uses less energy. However, sending data over longer distances causes the use of more energy. As a result, Multi-hop communication uses a small amount of energy, but with more delay.
(3) The energy used for Multi-hop communication is given as:

$$MH_E = T_E + R_E \quad (4)$$

Here MH_E is the energy consumed for Multihop communication.
T_E is the energy used for transmitting the data.
R_E is the energy used for receiving the data.

$$MH_{E=}\ 2 \times N \times C \times EC_{DP} + N \times C \times EC_{AMP} + E^2_{LT} - C \times EC_{DP}$$
(5) [20]

V. RESULT ANALYSIS

An experimental network with OMNet++ based Castalia simulator was setup to use the above performance enhancement strategies with the following protocols(i)Energy Efficient Routing with

Reliability and Quality of Service(EER-QR) (ii)Energy Efficient Routing in WBAN(EER-W) [21]. Simulations results show an improvement in the performance of EER-W and EER-QR protocols in terms of achieving energy efficiency and also reliable transmission of time critical packets.

Table 1 Metrics with Configuration information

	Area	8M × 8M
Deployment	Deployment type	Nodes are dynamic.
	Nodes Deployed	8 nodes(6 BANs,2 Strategic Nodes)
	Size of the Buffer	32 packets
	Transmission rate at the Link Layer	250kbps
	Transmission power used	-25dBm
Task	Type of Application	Event driven
	Maximum size of packet.	32 Bytes
	Type of traffic.	CBR Traffic.
MAC Layer	IEEE 802.15.4	Values which are default.
Simulation	Time	2000 Sec with set uptime as 3 seconds. Result of simulation is the average of three rotations.

The following strategies have been adopted to improve the performance of EER-W and EER-QR during mobility based scenario.

1. Considering various body postures and mobility factor for placing strategic nodes.
2. Data may be sent to the sink via a single hop or a multi-hop strategy, depending on the network topology changing due to the user's mobility and the packet requirement. With an average of 3 runs simulated for every experiment, the overall performance of EER-W and EER-QR is analyzed for.

(i) Energy consumption of EER-W and EER-QR protocols for with and without performance enhancement strategies (PES).
(ii) Reducing waiting time and packet timeout for time critical packet resulting in faster delivery, saving lives of patients with chronic conditions.

5.1 Energy consumption by EER-QR

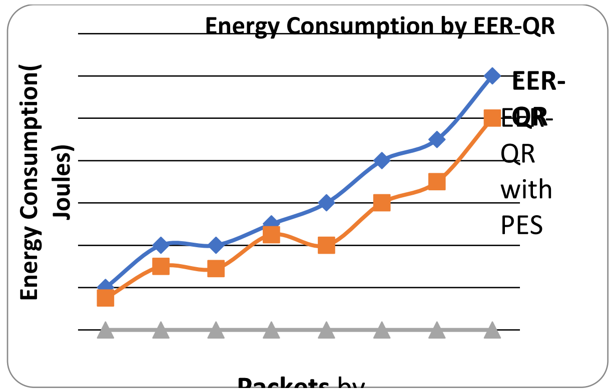

Fig 2 Energy consumption by EER-QR with and without PES

From the graphs in Figure 2 to 5, we can infer that introduction of strategic nodes in the network and a mechanism to hybridize the use of single hop and multi hop approach has resulted in reduced energy consumption of almost 10-25%, also the numbers of packets lost have reduced by 40 to 50%. This can result in reliable delivery of packets to the medical personnel ensuring early intervention.

5.2 Energy consumption by EER-W

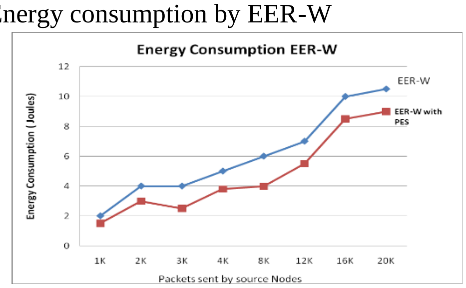

Fig 3 Energy consumption by EER-W with and without PES

5.3 Packet Timeout in EER-QR

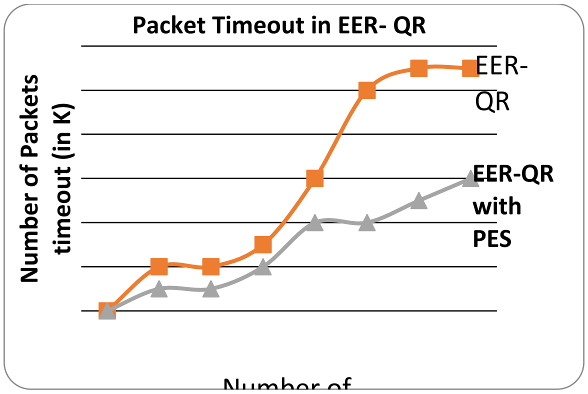

Fig 4 Packet Timeout in EER-QR with and without PES.

5.4 Packet Timeout in EER-W

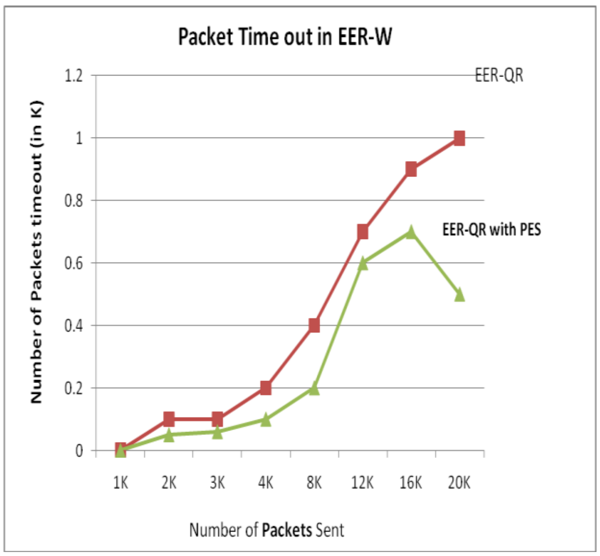

Fig 5 Packet Timeout in EER-W with and without PES

VI. CONCLUSION

In order to improve the overall efficiency of WBAN, strategic nodes must be used and placed in the right locations, taking mobility into consideration. Furthermore, of all the associated nodes that make up WBAN, the sink node is perhaps the most critical. Because of this, it is essential that the sink has the longest battery life. The location of the sink node affects this factor. The proposed strategies and algorithms can help applications that demand minimal latency. Patients who constantly walk, move, or play games may benefit from situating the sink node near the belly area to reduce the amount of time it takes for packets to arrive. The network's mobility performance may be improved by positioning the strategic node and sink node appropriately, decreasing retransmissions, packet drops, and network congestion, all of which help extend the battery life of sensor nodes. Depending on the user's mobility and the packet demand, the network architecture may require a single hop or a multi-hop approach for sending data to the sink. A reliable delivery of time-sensitive packets is also ensured through these mechanisms.

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