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Performance Evaluation of Energy Efficient Optimized Routing Protocol for WBANs Using PSO Protocol

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Abstract—A Wireless Body Area Network (WBAN) is a network that may be worn on the human body or implanted in the human body to transmit data, audio, and video in real-time to assess how vital organs are performing. A WBAN may be either an inter-WBAN or an intra-WBAN network. Intra-WBAN communication occurs when the various body sensors can share information. This is known as inter-WBAN communication, which occurs when two or more WBANs can exchange data with one another. One difficulty involves getting data traffic from wireless sensor nodes to the gateway with as little wasted energy, dropped packets, and downtime as possible. In this paper, the WBAN protocols have been compared with WBAN under Particle Swarm Optimization (PSO), and the performance of various parameters has been analysed for different simulation areas. The WBAN under the PSO protocol reduces the energy consumption by 43.2% against the SIMPLE protocoldue to the effective selection of forwarding nodes based on PSO optimization. In addition to that the experimental WBAN testbed is conducted in indoor environment to study the performance of the routing metrics towards energy and packet reception..

Keywords- WBAN, Energy Efficiency, Routing Protocol, Intra-WBAN communication, PSO, Throughput

I. INTRODUCTION

Wireless technology has advanced so that information can be sent quickly between devices, independent of their physical location. Wearable, implantable, or subdermal sensors and controllers can communicate with one another over a Wireless Body Area Network (WBAN). Data transmission between the network's nodes can be conducted wirelessly, and the network can cover all or a portion of the body. Researchers in sectors as disparate as mobile health monitoring, health care, medicine, and various media, are exploring promising new applications for a WBAN [1]. Everyone takes advantage of the mobility a WBAN provides. Wireless body area networks can be used in the medical profession to monitor a patient's vital signs, including Heart rate, blood pressure (BP), Respiration, Temperature, electrocardiogram (ECG), and more. The good news is that the patient can stand up, walk around the room, and even go home for a short while [2]. The patient's condition improves while costs are reduced for the healthcare facility. Collecting data on a patient over a longer time frame and in their natural environments may provide more valuable insights, leading to a quicker and more accurate diagnosis.

WBAN was explicitly developed for use in medical and urgent care environments. The network's little wireless sensor nodes collect data from the human body and relay it to the hospital's medical server. A physician or doctor at the hospital looks at the data and decides. Using physiological characteristics (PVs) to identify people can help keep WBAN conversations safe [3]. Hence this provides cutting-edge medical treatment. Without safeguards, erroneous identification

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will occur, which might have fatal consequences for humans. Sensors with short battery lives, dynamic network topologies, stringent quality-of-service requirements, varying data production rates and sizes, and weak transmission power are some challenges WBAN technology must overcome.

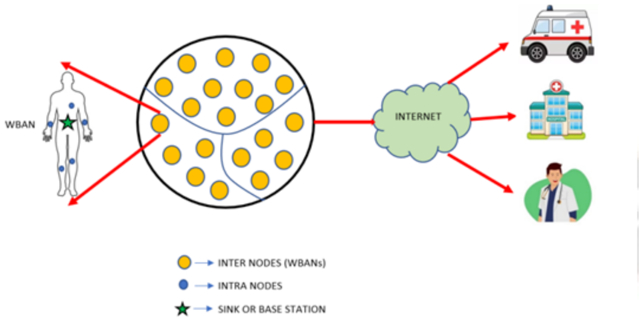

Figure1. WBAN Architecture

In WBAN there are two types of WBANs as shown if Figure 1, firstly. Intra-WBANs are private networks built around the need to monitor patients' vitals without intruding on their daily lives. In WBAN, a large number of wireless sensors are dispersed throughout a person to monitor their vitals in real time. These sentinel nodes (SNs) record and process data from sensors on a person's body and then send it to a base station (BS) or a sink. Secondly, Inter-WBAN connects different WBANs to networks, such as the Internet and cellular networks. This communication happens when two or more WBANs talk to each other. The sensor in the intra-network communicates with the sink and transmits data to it. The sink will be connected to the other WBANs on the inter-network [4]. The data is transmitted to the Internet through different WBANs and will be destinated to the specific emergency locations. In addition to that the MAC [5] layer based approaches is considered for improving QOS (i.e) to reduce energy with minimum wakeup interval forwarding data packets with network or routing approaches makes better network life time.

The detail of the paper is structured as follows: In section 2 the recent existing WBAN routing protocols are discussed with respect to metrics, setback. The detailed working of proposed WBAN routing with optimization mechanism is discussedin section 3. The performance evaluation of both simulation and real-time testbed is presented in section 4, and finally the conclusion and future work is presented in section 5

II. Related Works

In [6], Haseeb Ur Rahman et al., stated that enhancing network efficiency in WBANs using dual forwarder selection technique and new method called the Dual Forwarder Selection Technique (DFST). DFST has been designed to boost the stability of the network and throughput and make it last longer by using less Energy. The DFST behaves by aggregating sensor nodes on a human body, on another hand a fitness function has chosen both next hop or forwarder nodes to send packets to the base station. The effectiveness of the proposed work in terms of throughput, and network stability has been judged using simulation results. Most of the WBANs have three levels of architecture. The first level is called "intra," the second level is "inter," and the third level is called "extra" or "outer" BAN. In this paper, a new energy-efficient algorithm is made to choose the best forwarder node (FN) based on DFST instead of only single FN selection in WBANs. The wireless sensor nodes are classified as either as Group A or B nodes, and different FN is chosen among the sensor nodes in each cluster group. Security techniques can also be studied in WBANs because they are so important; most of the time, human lives depend on them.

In [7], M.Ambigavathi et al.,stated that the Energy efficient and load-balanced priority queue algorithm for WBANs to show better throughput, PDR, latency, and energy consumption than conventional approaches. MAC protocols use different standards like IEEE 802.11 (WLAN) and IEEE 802.15.4 (Zigbee stack) to send data, but they limit data rate, end up wasting Energy, aren't suitable for busty traffic, and take too long. This paper describes a new algorithm called the Energy Efficient and Load Balanced Priority Queue Algorithm (ELBPQA) that uses the IEEE 802.15.6 standard to send crucial data with as little delay as possible. The Two-Round Reservation Medium Access Control (MAC) protocol was developed to separate sensor data into bursts and periodic data. There are four separate queue types: high-priority lines, medium-priority lines, low-priority lines, and normal-priority lines. This indicates that the results of the analysis show a significant improvement in network throughput, packet delivery rate, energy efficiency, and latency. This will make it simpler to send sensitive data without worrying about it being intercepted.

In [8], HojjatollahEsmaeili et al., stated that A multi-objective function such as distance, energy, route loss, and the evolutionary-based multi-hop routing protocol presents expected energy consumption for WBANs for selecting forwarder nodes. They proposed the flexible Evolutionary Multi-hop Routing Protocol (EMRP) to solve these problems. According to the IEEE 802.15.6 standard draught, WBANs can only send data in one hop (directly) or two hops (through a forwarder node). The genetic algorithm can be used to adapt how EMRP is tuned (GA). WBANs are like MANETs in that nodes can move around. A Thermal Aware Routing Algorithm (TARA) is one-way data packets are sent away from hot spots. Energy-efficient Power-and Thermal-Aware (EPTA) is a protocol that decidebased on an objective function for routing towards residual energy, temperature, and power received from one hop neighbors. The simulation results show that the new

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technology is much more reliable than the current ones concerning throughput, lifetime, path loss, and energy usage.

In [9], Nadeem Javaid et al., stated that the enhanced maximum throughput multi-hop link efficient routing protocol for WBANs to minimize the energy consumption of the network utilizes a multi-hop mode of communication In contrast to wireless sensor networks (WSNs), WBANs often use star topology as their architecture. In this topology, an access point (AP) is placed at the centre of the body to get data information from sender nodes up to 1.5 m away. The M-ATTEMPT (thermally aware) routing protocol adopts multi-hopping to send data from sensor nodes to the sink. CICADA uses the TDMA scheme to plan when nodes will send data. To handle both normal and life-critical traffic, the priority-guaranteed medium access control (PMAC) protocol was created. PMAC utilizes 2 contention access periods and one contention-free period to send a large number of data packets. The simulation output shows that iM-SIMPLE performs better than current protocols for increasing the network's throughput and period of stability.

In [10], N. Javaid et al., stated the New Energy-Efficient Routing Protocol for WBANs. A prototype has been made for using different kinds of sensors placed on the human body. While multi-hop communication is exemplary for transferring huge amounts of data, it cannot be used for real-time traffic (critical data) or on-demand data transmission. The suggested routing strategy prioritized thermal efficiency during its development. Data packets may be diverted to avoid the "hot spot" on the connection using this feature. Given that node in WBASNs can be located anywhere on the human body, much forethought is essential before deployment. It can be fixed by moving the nodes with the slowest data rates closer to the sink. All other processes must cease while data is sent to a sink node. All of the embedded nodes can communicate with the central hub in the case of an emergency. The low-throughput sensors will send data once the most crucial data has been delivered, thanks to a prioritization system. The outcomes prove that the suggested routing approach is more effective and reliable than multi-hop communication.

In[11], Q. Nadeem et.al., stated that the Stable Increased-throughput Multi-hop Protocol for Link Efficiency in WBANs use multi-hop fashion to achieve less power consumption and increase in network lifetime. It suggests utilizing a fitness function to select a forwarder or parent node. The recommended cost function chooses a parent node that is near the sink and has a high residual energy. While the distance parameter assures successful packet reception to the sink, the residual energy parameter maintains the balance energy consumption among the neighbouring sensor nodes. WBAN sensor nodes only need a little power. The transfer of data from sensor nodes to sinks uses the least amount of power. The need to recharge the batteries is one of WBAN's main challenges. To solve the battery charging issue, an effective routing strategy is required. An efficient, stable, and high-throughput routing approach for WBAN. Set up sensor nodes on the body in the predetermined locations. The SIMPLE protocol increases node longevity while maximizing network stability. It's essential to give the sink more packets over a longer period of time in order to maintain patient monitoring.

From the existing study we noticed that the researchers predominantly employ on improving packet reception, network lifetime and minimum energy consumption. For smaller WBANs, this is trivial, but larger networks require deep review on choosing the nodes to forward to reach sink under multi-hop. Hence in this paper we place our work under two fold approaches: First, the selection of node is based on PSO optimization and secondly based on the fitness function with respect to routing metric. Hence the proposed WBAN in optimization leads to best selection of forwarded node makes an increase in network lifetime, minimum energy consumption under smaller and larger WBANs.

III. PSO Optimization used in WBAN Mechanism

Forwarding a large number of packets in a network can result in network congestion and performance degradation. In order to determine the correct and best path and enhance network performance, optimization techniques are used.

A. Particle Swarm Optimization (PSO)

First, Particle swarm optimization assigns positions, velocities, and fitness values to each individual particles or nodes. It has two equations namely velocity and position. These equations are used to discover the maximum or minimum of a function based on requirement. The fitness function is calculated based on these two equations. Every particle records its best fitness position and best fitness velocity. It is called as personal best or pbest. A record of the position and value of the global best or gbest fitness is also kept [12-13].

The velocity of kth particle for the gbest PSO is determined by the formula as given in equation (1),

$$v_{(k+1)} = w(k)v(k) + c_1 r_1 \left[p^b(k) - x(k)\right] + c_2 r_2 \left[p^g - x(k)\right] \tag{1}$$

PSO defines two positions, referred known as the personal best position and the global best position, to update the velocities and direct the swarm. The position of kth particle is given by equation (2),

$$X_{(k+1)} = X(k) + v(k+1) \tag{2}$$

where 'k' is the iteration number, r1, r2 are random numbers between 0 and 1, w(k) is the inertia weight, c1, c2 are correction factors, x(k), v(k) are position and velocity at kth

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iteration, P(k)b is the p_{best} position at k^{th} iteration, Pg is the g_{best} position.

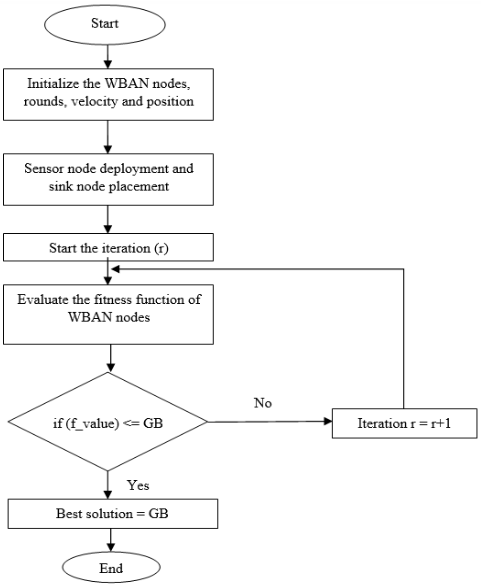


Figure 2 Flowchart of protocol

In Figure 2, the sensors nodes are deployed in various position in a human body with a position respect to sink. The nodes are considered as particles and their position and velocity are initialized respectively. The values of sensor node position and velocity are updated based on the evaluated fitness function. The current values of velocity and position is compared to the previous values and updated. The iterations will continue until the best forwarder nodes are found. In Algorithm 1, identifies the best forwarded node in WBAN networks. Line 1, 2 represent the parameter initialization and Line 4-7 represent the deployment of nodes based on distance (d). Line 8-18 calculation of fitness function is done and the solution is classified as best and worst, based on the best solution the position of nodes will be updated

ALGORITHM 1. Algorithm for best WBAN forwarded node

```
1.   Start
2.     Initialize the WBAN node (Ni), iteration (r), f_value, Global best (GB), local best
       (LB), position (p), Velocity (V)
3.     //deployment of WBAN sensor and sink node position
4.     for i in Ni
5.     Dx,y = x(i) y(i)
6.       X(i) = rand()
         Y(i) = rand()
7.     end for
8.     for i in Ni
9.       Calculate f_value of the WBAN particles
10.      LB[i] ← P[i]
11.    end for
12.    for i in r   /* max rounds*/
13.      Calculate the fitness function and update the position
14.      if (f_value(i) ≤ GB(i))
15.         GB = LB(i)
16.      End if
17.      Best solution = GB[i]
18.    end for
19.  end
```

B. Selection of forwarder node

After selection of best particles obtained from equation 1 and 2, we need to choose the best forwarded node under multihop. In order to select here we adopt the cost function based on distance, energy and position. The following equation is given as.

$$cf(n) = \alpha \frac{d_n}{E_n} \tag{3}$$

Where d represent distance and e represents energy and α is a tuning parameter and value ranges between 0 to 1 and selection is based on different application in WBANs.

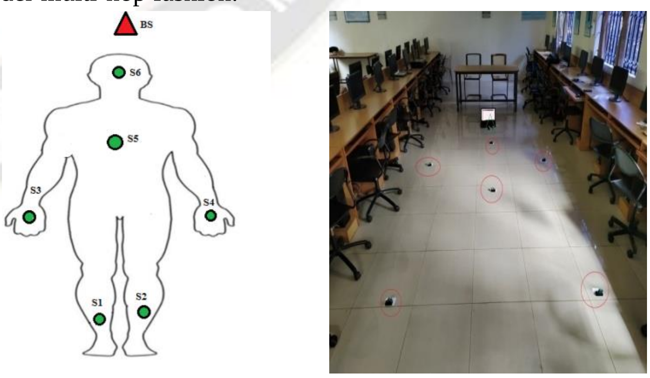
IV. SIMULATION AND TESTBED ENVIRONMENT

This subsection aims to compare the performance of existing WBAN routing protocols along with PSO optimization with several biomedical devices implant on human body under multi-hop fashion. Here we have considered two following scenarios to represent WBAN environments:

- Scenario I: WBAN along with different numbers of biomedical devices connected to asink node in a star topology under simulation.
- Scenario II: WBAN topology under real time testbed static sensors.

A. Testbed environment

In this section, we evaluated the performance of packet delivery ration and energy consumption achieved through real-time testbed environment for the WBAN topology. The testbed environment conducted on sensor motes (JN 5168) based on IEEE 802.15.4 Zigbee standard at 2.4GHz [14]. Here we deploy the sensor motes placed as like human body postures on the floor inside our Vinton Network Laboratory under multi-hop fashion.



(a) Representationof sensors and sink (b) Laboratory testbed environment

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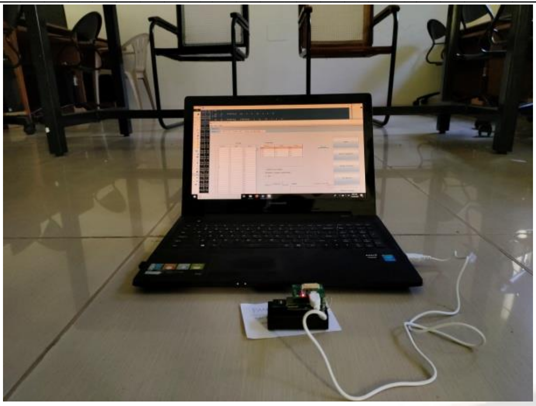
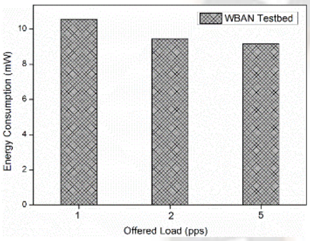
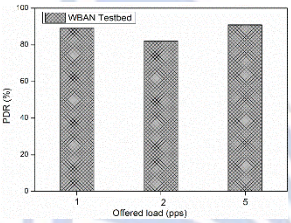


(c) Sink mote login window data collection
Figure4 Experimental WBAN sensor postures

In this experiment we considered 7 nodes (6 coordinators and 1 sink) as shown in Figure 4a. In figure 4b, the sensors nodes are placed in a respective manners assuming human body posture. In figure 4c, the data from the sensor nodes are collected and sent to the base station



(a) Offered load vs PDR



(b) Offered load vs Energy Consumption

Figure 5 Testbed environment results

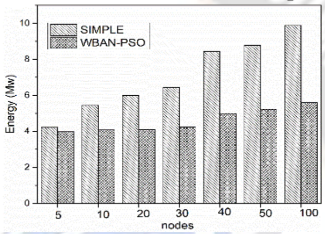
The realize testbed results as shown in Figure 5. When a traffic load is also there is a better performance at 1 packet per second (pps) and it attain 89% packet reception and at long traffic load it attain 91% PDR. Here there is a decrease in medium traffic with unstable fluctuation due to abrupt traffic leads to drop in packets. On other hand sensor node power consumption depends on radio modules such as transmitted power, Receiver power, CPU and it is calculated based on the following equation

$$\text{Re}\,sidualenergy = \frac{Initialenergy}{currentenergy} \quad (4)$$

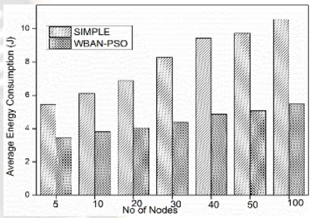
Where initial and current energy value is the actual energy of the mote and the obtained results demonstrate the packets are transmitted to Base station with a variable traffic load of 1, 2, 5 packets/seconds (pps). Figure 5 shows the energy consumption in WBAN testbed posture and it is found that energy consumption was 10.54 mW, 9.44 mW and 9.21 mW for 1pps, 2pps and 5pps traffic load. Alternatively, main basic objective of WBAN network is packet reception from pan coordinator (sender) to coordinator (receiver). Figure 5 shows the PDR in WBAN testbed and it found that 2.12%, 10.84% increase against 1pps and 2pps. The reason is proper choosing of forwarded leads to balanced packet reception at high traffic load.

B. Simulation environment

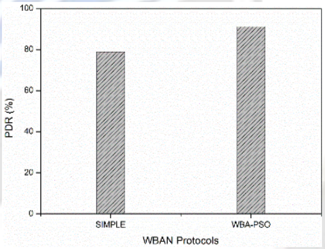
In this section, we compare WBAN-PSO optimization with existing SIMPLE WBAN routing protocol in-terms of selected routing metrics such as network lifetime, PDR and energy consumption by using MatLab 2022b simulator. Here we have taken eight sensors position as (x_i, y_i) coordinates inside the human body, and destination or sink node kept centre of position in a network environment. Here we consider areas (500 x 500) m and (1000 x 1000) m, initial distance d◦ is 0.1 m, threshold energy (Eth) value is 0.4Junder simulation environment under multihop.



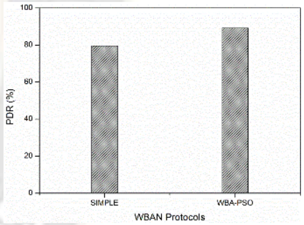
(a) No of nodes vs Average Energy Consumption(500x500)



(b) No of nodes vs Average Energy Consumption(1000x1000)



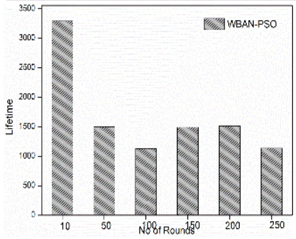
(c) Protocols Vs Throughput (500x500)



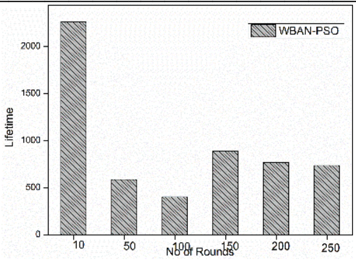
(d) Protocols Vs Throughput (1000x1000)

Figure 6 Simulation Results on WBAN

In figure 6, the average energy consumption of nodes with respect to number of nodes. It is noted from the graph that the protocol with an optimizer outperforms the other protocols without any optimizing techniques. The WBAN under PSO protocol reduces the energy consumption by 41.1% against SIMPLE protocoldue to effective selection of forwarding nodes due optimizing technique. Also, the throughputs of three different protocols are plotted and it shows the increase in throughput with the implementation of optimizing technique in both simulation areas. In different simulation area also, the protocol with optimizer outperforms the other protocols without any optimizer



(a)No of rounds Vs Lifetime (500 x 500)



(b)No of rounds Vs Lifetime (1000 x 1000)

Figure7 Variation of rounds Vs Lifetime

In Figure 7, the lifetime and Time taken of every nodes has been analysed with respect to number of rounds. The results proving that the lifetime of nodes are constantly increasing as numbers of rounds are increasing. Also, the time taken for nodes to reach the destination is reducing. This proves that PSO is a better optimizing technique when considering the lifetime of the nodes in various simulation areas

CONCLUSION

In this Paper, a WBAN protocol with an optimizing technique is analysed and has been compared with other WBAN protocols. The benefits of using an optimization is increase in efficiency in terms of energy as well as lifetime in addition to that proper selection of best forwards node selection leads to better performance under large WBAN network. Here we carried out the performance evaluation both in simulation and real-time testbed. The simulation results confirm that a protocol with an optimization has performed better in terms of throughput and average energy consumption. Furthermore the energy and packet reception is demonstrated under indoor environment with WBAN human posture.

However the proposed WBAN is considered only for static environment. Hence in future dynamic or mobility based environment place an important role as the patient's moves once place to other. Hence the design of routing protocol with proper selection forwarded node is challenging task under body movement. A novel design will be required in the future to address problems towards dynamic environment for indoor and outdoor under multi-hop for large scale WBANs.

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