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Analysing the Effect of Posture Mobility and Sink Node Placement on the Performance of Routing Protocols in WBAN

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Abstract

Objective: Wireless Body area network is a combination of sensor nodes which communicate with each other through wireless link. Sensor nodes sense the data and sent to sink node. Sink node process the data received by the sensor nodes and send to the medical official. It aims at finding an optimal position of the sink in human body to place that gives better network lifetime, stability period and throughout. **Methods/Analysis**: Various routing protocols are developed for *Wireless Body Area Network* (WBAN). In these networks routing protocols plays an important role together with position of sink node. In this paper two routing protocols Adaptive Threshold-based Thermal-aware Energy-efficient Multi-hop *ProTocol* (ATTEMPT) and SIMPLE routing protocols are analyzed with different body posture mobility (arm, head, and leg) and different sink position. ATTEMPT protocol considers the body posture mobility factor when designing but SIMPLE protocol is not mobility aware. **Findings:** The protocol performs better when the sink node is placed at the center of the human body with no body posture mobility but the packet drop is high. When the sink node is placed at different body part which has the posture mobility and when position of the sink node is fixed at the center of the human body, there is more effect on the performance of SIMPLE protocol than ATTEMPT protocol. But overall the network lifetime and stability period is high in case of SIMPLE protocol than ATTEMPT protocol. Order of variation in body parts movement is ARM>Leg>Head. **Applications/Improvements:** This paper shows that the variation in the placement of a sink node within a WBAN with body posture movement could significantly vary the overall performance of the routing protocols. This motivated the researchers to work on an effective node placement strategy for a sink node, within a WBAN with the consideration for body posture mobility.

Keywords: Posture Mobility, Sink Node Placement Algorithms, Wireless Body Area Network (WBAN)

1. Introduction

A wireless body area network is a network of small and intelligent devices which are implanted on or in the human body[1]. These devices can set up a wireless communication link. These devices can provide continuous health monitoring. Two types of devices are mainly used sensors and actuators. The main function of the sensors is to measure vital signs of the human body internally or externally. Examples are body temperature, ECG, EEG etc. the actuators receive the signals from the sensors and interact with the user[2]. Energy consumption is a major issue in wireless body area network. Mainly energy consumption is divided into three sections: Sensing, Communication and Data processing. Most of the power is consumed during communication. Because the energy source of the sensor nodes is the battery, power available to the nodes is restricted.

Sensor nodes have limited energy and to recharge them is a very difficult task. In that situation main objec-

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tive of the routing protocols is the energy efficiency and increased network lifetime[3,4]. The number of sensor nodes is smaller in *Wireless Body Area Network* (WBAN). Communication range used in WBAN is also shorter than the other applications of sensor networks. In WBAN electromagnetic waves are attenuated and experienced a high path loss due to very loss medium in human body. Tissue heating is also an important issue in WBAN. Temperature is increased in the human body due to the transmission of power[5,6]

In[7] author checks the performance of position-predicated routing protocols under different mobility models. In this paper, two mobility models are considered Abysmal Mobility Model and Arbitrary Waypoint mobility model. Simulation is done utilizing network simulator, Ns2. In[8] author proposed a Cluster Predicated SPIN routing which is a modified version of the SPIN routing protocol. This protocol used the clustering technique to compose a network. MATLAB is utilized for simulation work. Cluster Predicated SPIN routing protocol performs better than SPIN protocol in terms of energy. In[9] authors analyze the variants of MANET routing protocols under the different weather conditions. Further, it compares the AODV, RIP, ZRP and STAR MANET routing protocol with and without considering weather conditions. In[10] author proposed a multipath load sharing algorithm. This load sharing algorithm utilizing node level analysis malevolent node detection, and channel sensing technique. It main objectives to propose an efficient load sharing technique which give less delay security and better throughput.

Mobility-supporting Adaptive Threshold-based Thermal-aware Energy-efficient Multi-hop *ProTocol* M-ATTEMPT[11] is a Mobility-supporting Adaptive Threshold-based thermal-aware Energy-efficient Multi-hop ProTocol employing heterogeneous sensors on human body. Two types of communication model is used in this protocol. Direct and Multi-hop communication. Emergency data is transmitted using direct communication means data from sensors directly sent to sink and normal data used Multi-hop Communication means sensors transmit the data to the sink using relay nodes. This protocol is thermal-aware routing protocol which is used to sense the link Hot-spot and routes the data away from these links.

In SIMPLE[12] protocol 8 sensor nodes are placed on the human body at fine-tune position to quantify the vital denotement of the human body. There are withal two types of communication models are utilized direct and multi-hop communication. Consequential data is transmitted directly to the sink on the other hand mundane data is transmitted to the sink through forwarder node. Forwarder node is culled utilizing a cost function. Cost function depends on two parameters distance and residual energy of the sink. If the residual energy of the sensor node is less than the threshold level sensor nodes uses direct communication to send data to sink.

This paper tries to find the best position to place the sink node in the human body. Sink node is placed at a different position in the human body and checks where the best results are obtained by comparing the network lifetime, dead node etc. parameters. Further in this paper Adaptive Threshold-based Thermal-aware Energy-efficient Multi-hop *ProTocol* (ATTEMPT) protocol is compared with SIMPLE protocol in different body postures (head, arm, leg movement) Rest of the paper is organized as follows: In section 2 related works is discussed. In section 3 system model is given. In section 4,5 and 6 results and discussion of experiment 1,experiment 2 and experiment 3 is given. Section 7 concludes the paper.

2. System Model

In this paper 8 sensor nodes are placed in the human body to monitor the physiological signals. Location of these sensors is shown in Figure 1.

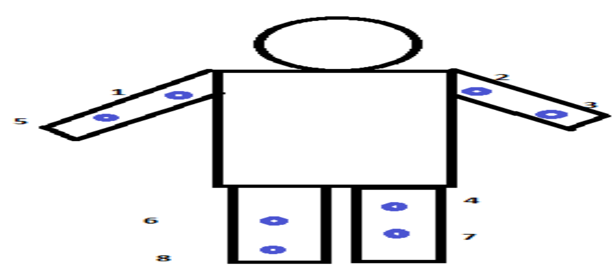

Figure1. Placement of sensor node on human body

This paper is divided into three parts

Part 1: In Part 1 sink node is placed at different position of human body (waist, head, chest, arm.leg). There are 5 cases to place the sink node in the human body.

Case 1. Sink node is placed at waist of the human body

Case 2. Sink node is placed at the head of the human body

Case 3. Sink node is placed at chest

Case 4.Sink node is placed at right arm

Case 5. Sink is placed at right leg

Simulation is done in MATLAB. For reference ATTEMPT protocol is used. In this simulation best position is found to place the sink node in the human body. Results are compared using network lifetime, stability period, and packet drop and throughput parameters.

Part 2:

Performance analysis of ATTEMPT and SIMPLE protocol in different body postures with different sink node position.

In this part different body part movement is considered (head, arm and leg).Sink is also placed at that moving part of the body (sensors and sink mobility). With this experiment effect of mobility on the two protocols is compared.

Part 3:

Performance analysis of ATTEMPT and SIMPLE protocol in different body postures with fixed sink position**.**

In part 3 sink positions are fixed i.e. at the waist of the human body. In this also two routing protocols ATTEMPT and SIMPLE are compared in different body positions (head movement, arm movement, leg movement)

Following parameters are considered for comparison

Stability Period: The time duration before the first node of the network dies is called stability period. Time duration after the first node dead is called unstable period.

Network Lifetime: Network Lifetime is the time period at which the last node of the network dies.

Throughput: Total no of packets received by the sink is called throughput.

3. Analysis of Attempt Protocol with Different Sink Node Position

There are 5 cases to place the sink node in the human body

Case 1. Sink node is placed at the waist of the human body
Case 2. Sink node is placed at the head of the human body
Case 3. Sink node is placed at chest
Case 4.Sink node is placed at right wrist
Case 5. Sink is placed at right leg

Placement of sensor nodes and sink is shown in Figure 2. Blue color dot is used to represent sensor nodes and red color dot is used to represent sink node.

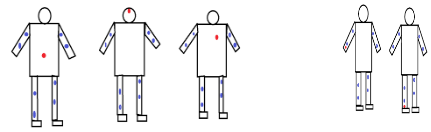

Figure 2. Placement of sensor nodes and sink on human body in Part1

Table 2. Distance of sensor nodes from sink node in part1

	waist	chest	Leg	head	wrist
Nodes	**Dista -nce**	**Dist -ance**	**Dist-ance**	**Dist-ance**	**Dist-ance**
1	0.3606	0.3162	1.0050	0.4472	0.5701
2	0.2828	0.2236	0.9487	0.5385	0.7106
3	0.3162	0.5385	0.7211	0.8544	0.6671
4	0.3162	0.7000	0.4472	1.0050	0.4528
5	0.3162	0.6403	0.6325	0.8544	0.1528
6	0.4031	0.8139	0.3041	1.1011	0.3354
7	0.6083	1.000	0.2236	1.3038	0.5701
8	0.8016	1.2093	0.1118	1.5008	0.6265
Sink placed at	X=0.4 Y=0.9	X=0.5 Y=1.3	X=0.3 Y=0.2	X=0.4 Y=1.6	X=0.05 Y=0.65

From the results Figure 3. it is clear that the Stability Period is almost same in case 1 and case 4 and it is greater than the which was obtained in case 2 and case 3. In case 5 stability period is slightly less than the case 1 and case 4.

Order of Network Lifetime in all 5 cases are Center>wrist>Leg>Chest>Head.

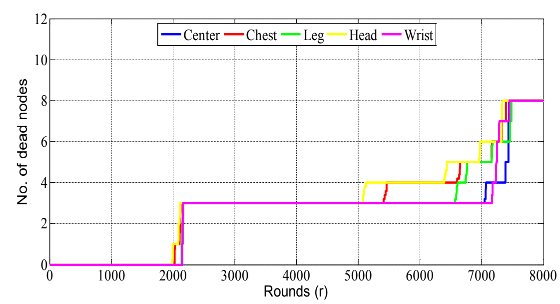

Figure 3. Analysis of stability period and network lifetime

In this paper, to calculate the packet drop random uniformed model is used (packet drop probability is assumed 0.3). According to this model a minimum level is set for successful reception. If the status of the link is below this level packets are dropped. This is because is this case the node which is selected as forwarder node does not has the sufficient energy to send the data to the sink. Order of Packet Drop in all 5 cases are Waist>Leg>Wrist>Chest>Head.

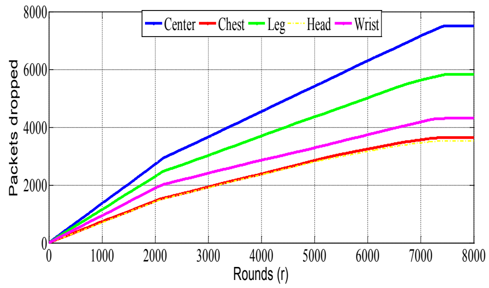

Figure 4. Analysis of packet dropped

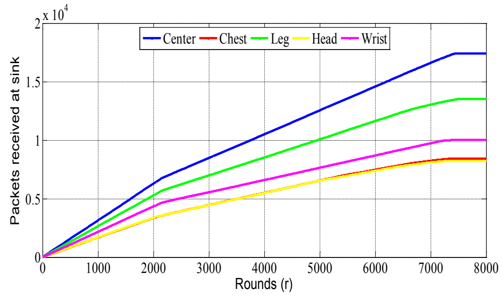

Figure 5. Analysis of throughput

Figure 5 shows the throughput analysis. Total no of packets received by the sink node is called throughput. No of alive node is inversely proportional to dead nodes. As shown in Figure 4. Network life time is more in center position. It means no of alive nodes are more in that position. Throughput depends upon the no of live nodes. When the no of alive nodes are more, more packets are sending to the sink which increases the throughput of the network. In terms of throughput, the performance order of the selected cases is: Center>Leg>Wrist>Chest>Head.

From these results it is concluded that the best position to place the sink is center of the human body. At this position high stability period, network lifetime and throughput is obtained but packet drop is high at this position.

4.Comparison of Performance Analysis of ATTEMPT and SIMPLE Protocol with Sink Node Mobility

WBANs are small scale networks in which nodes move due to the movement of human body which causes the network topology to reorganize. The mobility pattern of human body is difficult to predict. Nodes' positions change as the body moves. To route data effectively, nodes create wireless link with their nearest neighbor. The sensed data is lost, when a mobile node fails to find its neighbors. To handle such situation, routing protocol must support mobility. To study the impact of mobility on Attempt and Simple Protocol, we consider arms, head leg mobility.

Case 1. Head Movement
Case 2. Arm movement
Case 3. Leg movement

4.1 Head Movement

In this experiment sink is placed at the head of the human body. Figure 6 shows three different positions of head movement. As the head moves in right side sink distance decreases with the sensors those are placed at right arm and right leg. On the other hand when the head is moved left side distance between sink which is placed at head and sensor nodes those are placed at left arm and left leg dencreases. Table 3 shows the distance of the sensor nodes from the sink in experiement 2. Figure 6 shows the mobility patterns of human head.

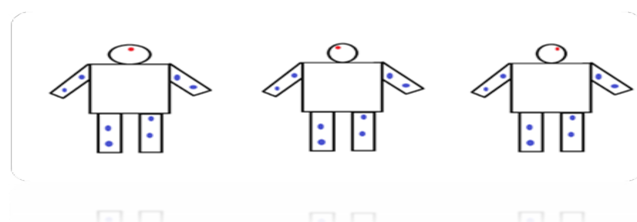

Figure 6. Head movement in experiment 2.

Table 3. Distance of sensor nodes from sink in part 2 (head movement)

Nodes	Center Distance	Right Distance	Left Distance
1	0.4472	1.4278	0.4717
2	0.5385	0.5590	0.5220
3	0.8544	0.8732	0.8382
4	1.0050	1.0112	1.0012
5	0.8544	0.8382	0.8732
6	1.1011	1.1000	1.1045
7	1.3038	1.3086	1.3010
8	1.5008	1.5000	1.5033
Sink placed at	0.4 1.6	0.35 1.6	0.45 1.6

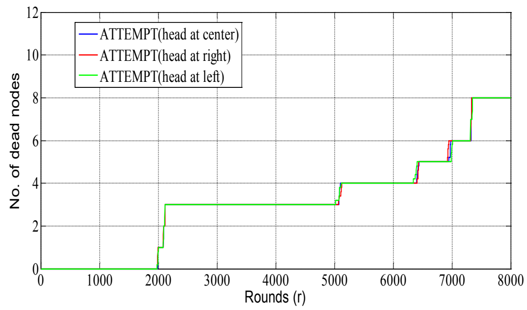

Figure 7. Analysis of stability period and network lifetime in attempt protocol

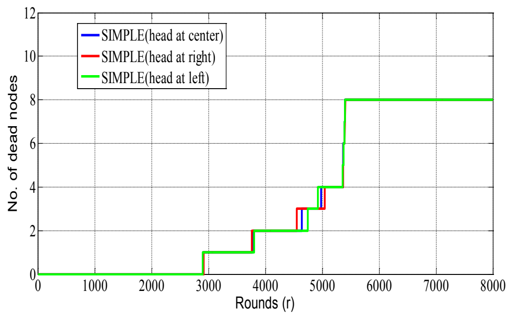

Figure 8. Analysis of stability period and network lifetime in simple protocol

Figure 7 shows the comparison of average network lifetime of three different positions of head in Attempt protocol. Figure 8 shows the comparison of average network lifetime of three different positions of head in Simple protocol. In ATTEMPT, as the number of forwarder nodes is more than that of SIMPLE, thus the ATTEMPT protocol consumes more energy as compared to the SIMPLE protocol. Hence, nodes die early in ATTEMPT.

Results also show that there are very small variations in the graph with head mobility as compared to SIMPLE protocol. Order of Network Lifetime in all 3 cases is head at right <head at left < head at center.

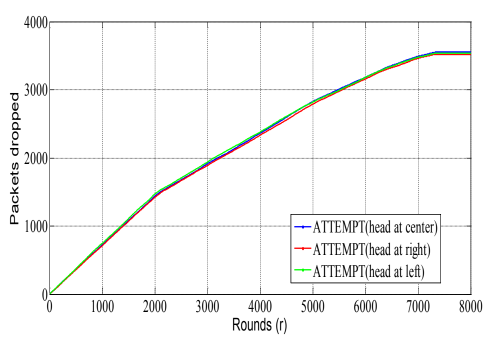

Figure 9. Analysis of packet drop in ATTEMPT protocol

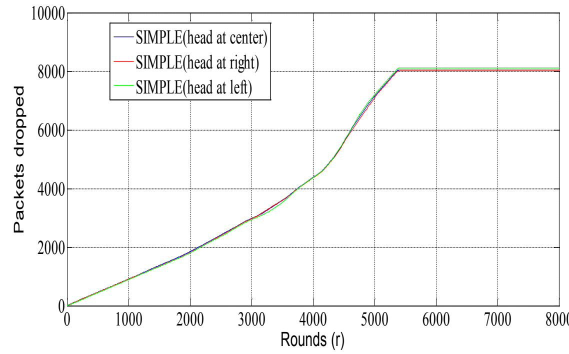

Figure 10. Analysis of packet drop in SIMPLE protocol

Figure 9 and 10 shows the comparison of packet drops of three different positions of head in ATTEMPT and SIMPLE Protocol. In this paper random arbitrary uniformed model is utilized form the calculation of packet drop rate. According to this model packets are dropped when the status of the link is below the threshold required for prosperous packet reception. Figure 4 shows that among the 5 cases, case 1 has the highest packet drop rate. As in this case the culled forwarder node may not have congruous energy for data transmission too the cessation station. Order of Packet Drop in all 5 cases are Canter>Leg>Wrist>Chest>Head.

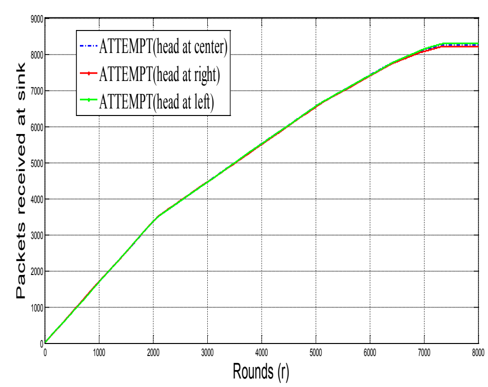

Figure 11. Analysis of throughput in ATTEMPT protocol

SIMPLE protocol achieves high throughput as compared to ATTEMPT protocols, as shown in Figure 11 and 12. Number of packets sent to sink depends on the number of alive nodes. More alive nodes send more packets towards sink which increases throughput of the network. Thus, shorter stability period of ATTEMPT (as compared to SIMPLE) is the major cause of its decreased throughput. It is also clear that very small variations in packets received with head movements in both protocols.

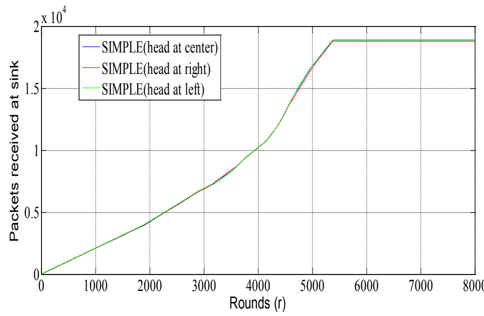

Figure12. Analysis of throughput in SIMPLE protocol

4.2 Arm Movement

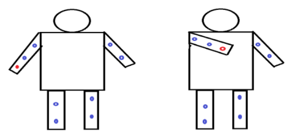

Figure 13. Arm movement in experiment 2

Table 3. Ddistance of sensor nodes from sink in arm movement

	Position1	Position 2
Nodes	**Distance**	**Distance**
1	0.5701	0.4272
2	0.7106	0.3606
3	0.6671	0.3000
4	0.4528	0.2236
5	0.1528	0.1414
6	0.3354	0.3041
7	0.5701	0.5099
8	0.6265	0.7018
Sink placed at	0.05 0.65	0.4 0.8

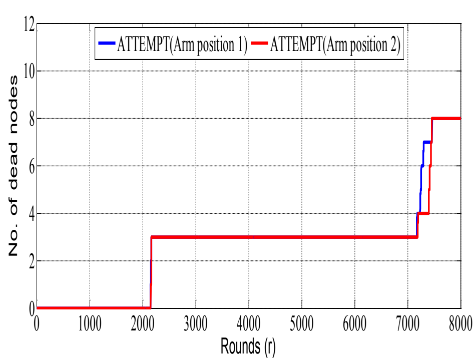

Figure 14. Analysis of stability period and network lifetime in ATTEMPT

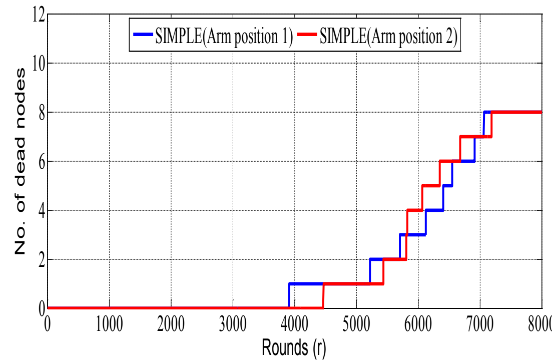

Figure 15. Analysis of stability period and network lifetime in SIMPLE

Arm posture are shown in Figure 13 sink is placed at the wrist of the human body.In first position distaance of sensor nodes placed on right arm from the sink remains same in both the postures but in second posture of arm distance between the sensors placed on left arm and legs sensor decreases this difference in distance increases the stability period and Network lifetime in second posture of arm which is shown in Figure 14. and 15.

It is also there is more varioation in SIMPLE protocol than ATTEMT protocol.

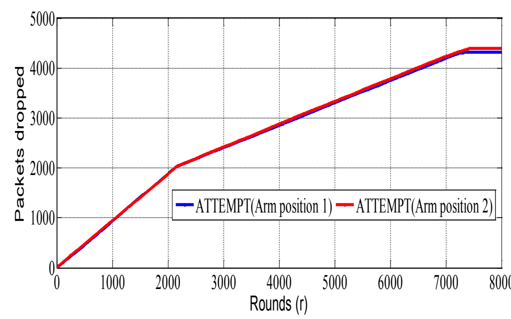

Figure 16. Analysis of packet drop in ATTEMPT protocol

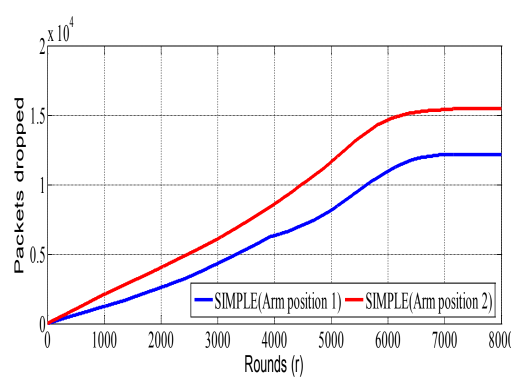

Figure 17. Analysis of packet drop in SIMPLE protocol

From Figure 16 and 17 it is clear that in arm position 2 packet drop rate is more than the arm position 1 in both protocols.It is also shown than there is more variation in SIMPLE protocol than ATTEMPT protocol.

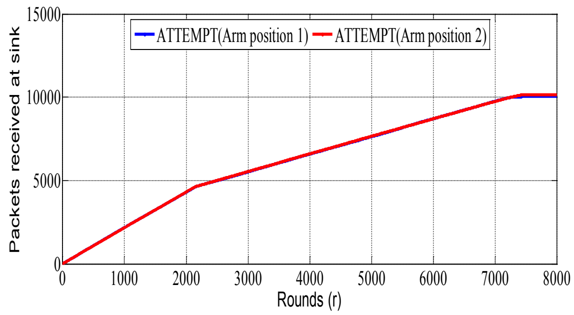

Figure 18. Throughput analysis in ATTEMPT protocol

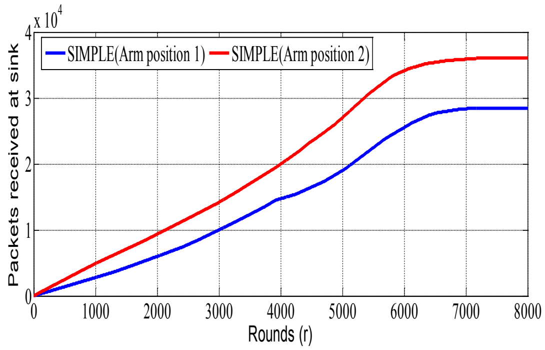

Figure 19. Analysis of throughput in SIMPLE protocol

In Figure 18 it is observed that there is small variation in throughput in both arm position but in Figure 19. It is seen that there is more difference in the throughput obtained in both positions of arm.

Results obtained from the ARM postures shows that ATTEMPT protocol is better that the SIMLE Protocol.

4.3 Leg Movement

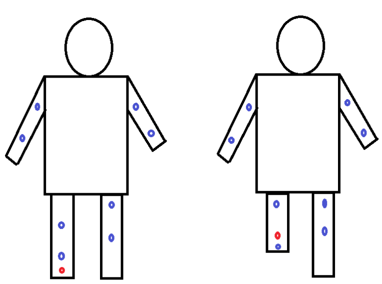

Figure 20. Leg movement in experiment 2

Table 4. Distance of sensor nodes from sink in leg movement

	Position1	Position 2
Nodes	Distance	
1	1.0050	0.6576
2	0.9487	0.6265
3	0.7211	0.4717
4	0.4472	0.2062
5	0.6325	0.3202
6	0.3041	0.0707
7	0.2236	0.3202
8	0.1118	0.4528
Sink placed at	0.3 0.2	0.3 0.55

Leg posture are shown in Figure 20 sink is placed at the right leg of the human body.In second posture of the leg the distance of all sensor from the sink is decreased except sensor 7 and 8.

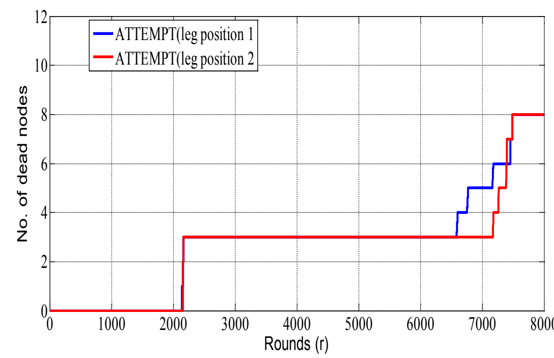

Figure 21. Analysis of stability period and network lifetime in ATTEMPT protocol

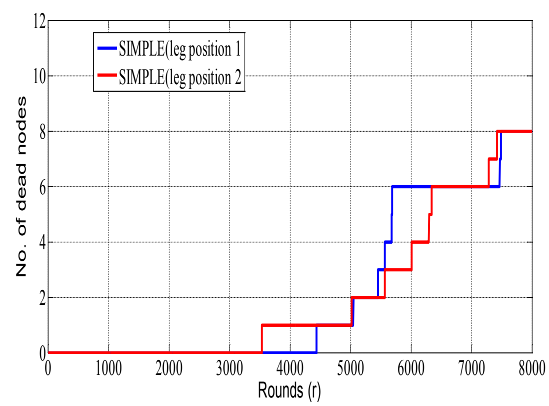

Figure 22. Analysis of stability period and network lifetime in SIMPLE protocol

Figure 21 Shows that the stability period in both position is almost same but the network lifetime is more in position 2 than position 1.

Figure 22 Shows that there is difference in stability period and in network lifetime in SIMPLE protocol. Stability period is more in position 1 whereas network lifetime is more in position 2.

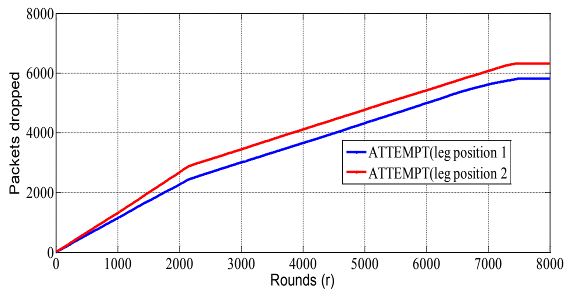

Figure 23. Analysis of packet drop rate in ATTEMPT protocol

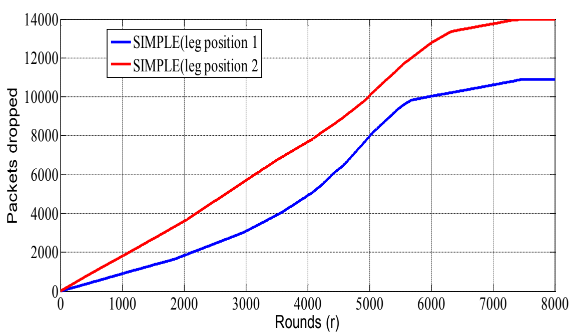

Figure 24. Analysis of packet drop rate in SIMPLE protocol

From Figure 23 and 24 it is clear that in Leg position 2 packet drop rate is more than the Leg position 1 in both protocols.It is also shown than there is more variation in SIMPLE protocol than ATTEMPT protocol.

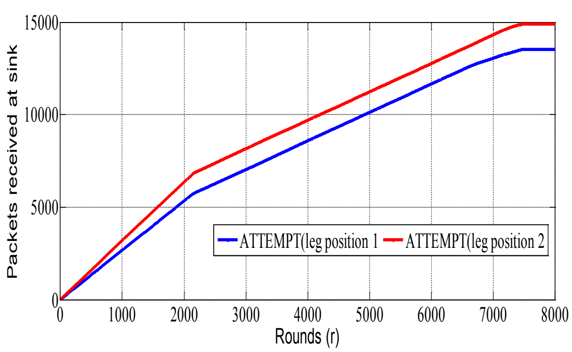

Figure 25. Throughput analysis in ATTEMPT protocol

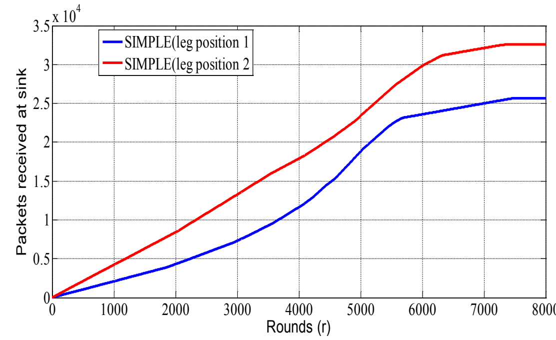

Figure 26. Throughput analysis in SIMPLE protocol

In Figure 25 it is observed that there is small variation in throughput in both leg position but in Figure 26. It is seen that there is more difference in the throughput obtained in both positions of leg. Conclusion of Experiment 2

Results shows that there are more variations in SIMPLE protocol than ATTEMPT protocol with different body part movement But the network lifetime and stability period is high in case of SIMPLE protocol than ATTEMPT protocol. Order of variation in body parts movement is ARM>Leg>Head

5. Comparison of Performance Analysis of ATTEMPT and SIMPLE Protocol with Fix Sink Node Position

5.1 Body Movement When Sink Placed at Center

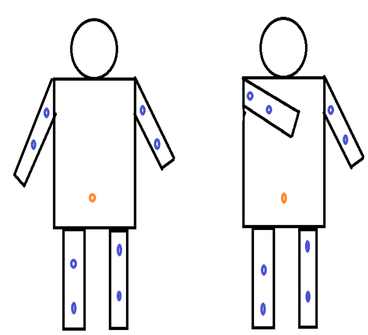

Figure 27. Arm movement in experiment 3

Table 5. Distance of sensor nodes from sink in arm movement

	Position1	Position 2
Nodes	Distance	Distance
1	0.3606	0.3354
2	0.2828	0.2828
3	0.3162	0.3162
4	0.3162	0.3162
5	0.3162	0.1000
6	0.4123	0.4031
7	0.6083	0.6083
8	0.8062	0.8016
Sink placed at	0.4 0.9	0.4 0.9

Figure 27 shows the two arm Position when the sink in placed at center. In position 2 distance of sensor node 1,5,8 is decreased from the sink.

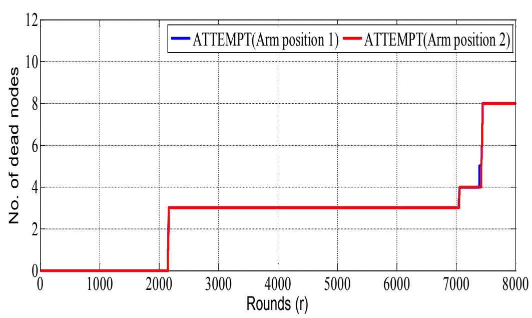

Figure 28. Stability period and network lifetime in ATTEMPT protocol

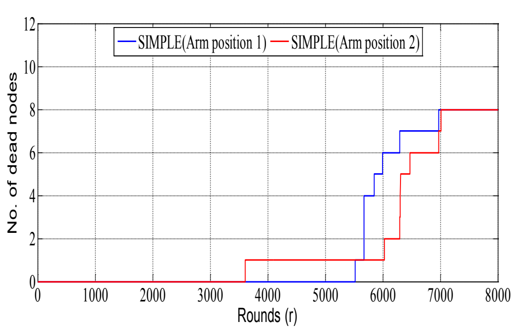

Figure 29. Analysis of stability period and network lifetime in SIMPLE protocol

From Figure 28 it is clear that stability and network lifetime is almost same from both arm position in ATTEMPT protocol. Figure 29 Shows that stability period from arm position 1 are more than the arm position 2 but network lifetime is almost same for both positions.

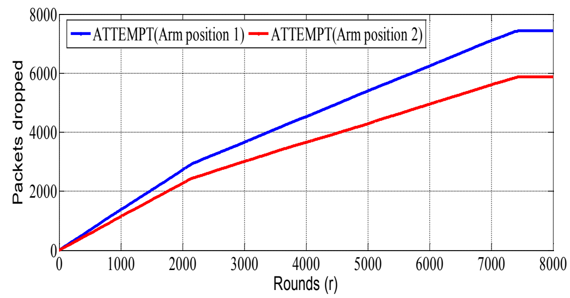

Figure 30. Analysis of packet drop rate in ATTEMPT protocol

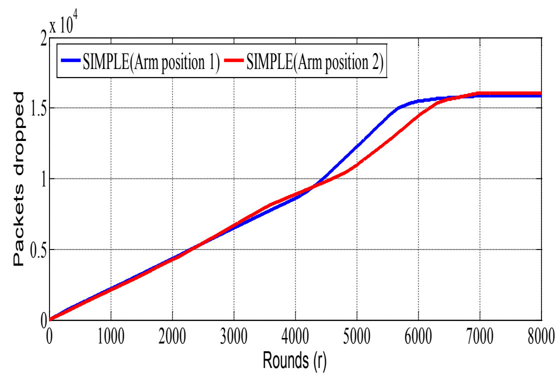

Figure 31. Analysis of packet drop rate in SIMPLE protocol

From Figure 30 and 31 shows that packet drop rate is more in ATTEMPT protocol than SIMPLE Protocol.

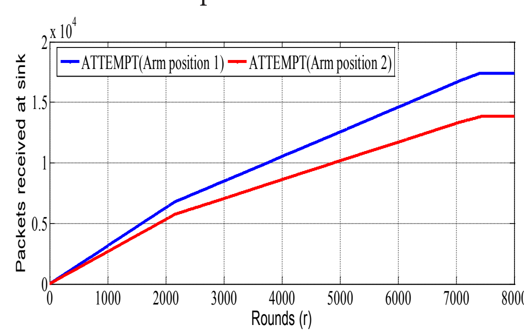

Figure 32. Analysis of throughput in ATTEMPT protocol

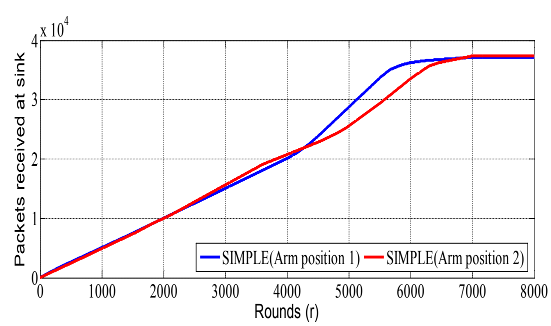

Figure 33. Analysis of throughput in SIMPLE protocol.

From Figure 32 and 33 it is clear that the throughput is more in arm position 1 in both protocols. ATTEMPT protocol has more variation in both arm position than SIMPLE Protocol.

5.2 Leg movement

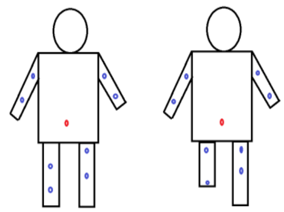

Figure 34. Leg movement in experiment 3

Table 6. Distance of sensor nodes from sink in leg movement

	Position1	Position 2
Nodes	Distance	
1	0.3606	0.3606
2	0.2828	0.2828
3	0.3162	0.3162
4	0.3162	0.3162
5	0.3162	0.3162
6	0.4123	0.4123
7	0.6083	0.6083
8	0.8062	0.6083
Sink placed at	0.4 0.9	0.4 0.9

Figure 34 shows the two leg postures and table shown the distance of sensor nodes from sink. From table it is clear that the distance of node is decreased from the sink in leg position 2.

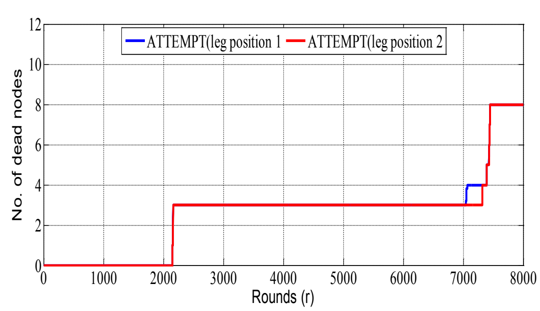

Figure 35. Analysis of stability period and network lifetime in ATTEMPT protocol

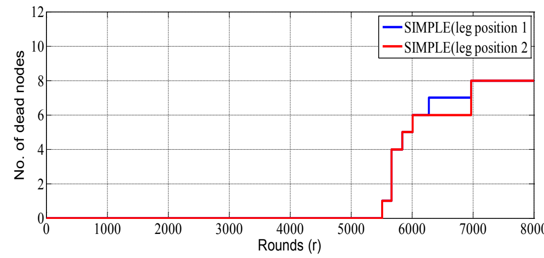

Figure 36. Analysis of stability period and network lifetime in SIMPLE protocol

Figure 35 and 36 shows that the stability period for two leg positions is almost same in both protocols but the network lifetime is more for leg position 2 than leg position 1 in both protocols. From the results it is also clear that there is more variation in SIMPLE protocol than ATTEMPT protocol.

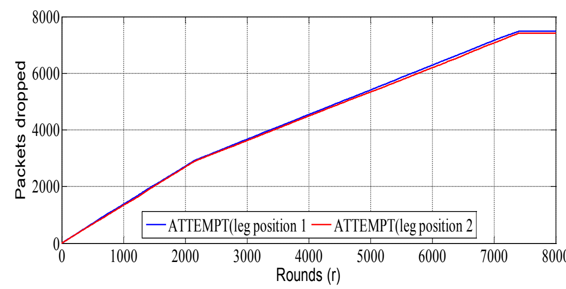

Figure 37. Analysis of packet drop rate in ATTEMPT protocol

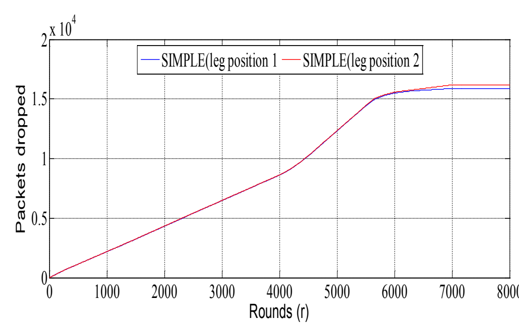

Figure 38. Analysis of packet drop rate in SIMPLE protocol

Figure 37 show that packet drop rate is more in leg position 1 than leg position 2. Figure 38 show that packet drop rate in leg position 2 is more than the leg position 1.

From Figure 39 it is clear that the throughput s almost same in both leg position. Figure 40 shows that tee throughput in more in leg position 2 than leg position 1.

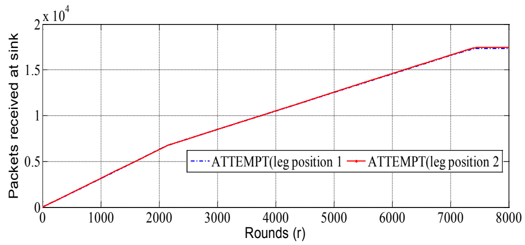

Figure 39. Analysis of throughput in ATTEMPT protocol

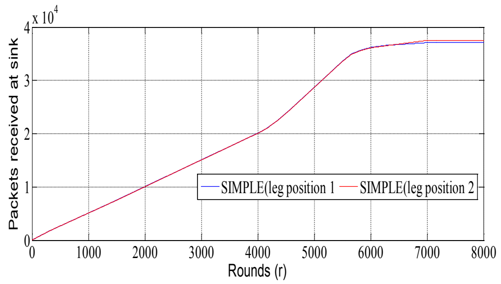

Figure 40. Analysis of throughput in SIMPLE protocol

5.3 Conclusion of Experiment 3

Results shows that there are more variations in SIMPLE protocol than ATTEMPT protocol in both body part movement (Arm and Leg).Order of variation is Arm>leg.

6. Conclusion

Attempt protocol performs better when the sink node is placed at the center (waist) of the human body with no body posture mobility but the packet drop is high. When the sink node is placed at different body part which has the posture mobility and when position of the sink node is fixed at the center of the human body, there is more effect on the performance of SIMPLE protocol than ATTEMPT protocol. But overall the network lifetime and stability period is high in case of SIMPLE protocol than ATTEMPT protocol. Order of variation in body parts movement is ARM>Leg>Head. This paper shows that the variation in the placement of a sink node within a WBAN with body posture movement could significantly vary the overall performance of the routing protocols. This motivated the researchers to work on an effective node placement strategy for a sink node, within a WBAN with the consideration for body posture mobility.

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