AN ORGAN CRITICALITY AND SESSION PRESERVED iM-SIMPLE PROTOCOL TO OPTIMIZE WBAN FOR DIFFERENT APPLICATION AREAS

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Abstract— The scope of WBAN is wide enough to monitor the health information, work performance, and perform activity classification of the individuals. Each of the operational and behavioral requirements has scope for different application areas. The mobility based iM-SIMPLE protocol already exists to identify the effective forwarder based on distance, energy and provides energy and packet size evaluation. In this paper, an improvement over the existing iM-SIMPLE protocol is provided by including the direction, organ criticality, and session preservation concepts. A more effective routing method is defined to observe each node and network level aspect to fulfill the communication requirements of each of the application areas considered in the present work. The algorithmic formulation is also provided to offer controlled communication in a single WBAN. The paper also provided the analytical study of each of the operational areas respective to the body sensor placement and effectiveness. The comparative results of the proposed improved iM-SIMPLE protocol are computed against the existing iM-SIMPLE protocol for six different application areas. The observations are taken against residual energy parameter. The node level evaluation verified that the proposed routing protocol has improved the node strength and network life for different application areas.

Keywords— WBAN; Patient Monitoring; Athletes; Routing; Energy Efficient

1. INTRODUCTION

Wireless Body Area Network (WBAN) [1, 2] is not only restricted to monitor the patients or to acquire the organ criticality status. Instead, it provides a proactive support to wider application areas. Various aspects are present to explore the significance of WBAN network [3-5]. The critical aspect covers the acquisition of organ criticality status, health status information, individual performance information, *etc.* This kind of information capturing is limited to various application areas including the patient monitoring system, athlete performance analysis, soldier efforts evaluation, *etc.* Each of the application requires dedicated placement of body sensors to acquire different kinds of health information. The common aspects associated with body area network are listed in Table I.

The operational areas [7-9] is the main broader aspect based on which the number of sensors, type of sensor, type of information required can be decided. The operational areas can be different in different application areas and for different individuals. Such as for health care applications, the operational behavior can be different for different patients. The sensing requirement for a cardiac patient is

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different from diabetic patients. The requirement factors include the temporal vector, the number of sensors, placement of sensors, type of information communication, types of sensing devices. The body sensors are costly and based on the integrated capabilities the cost increases. The work of the body sensor can only be limited to capture the information and pass it to the controller or it can act as a temporal and decision assisted sensor device. In such body sensors, the time interval can be set up to capture the organ-specific health information. The body sensor can also take the decision about the criticality of the captured information. The information transition or selective communication can also be regulated by these body sensors. The captured information can be different based on the requirement and the sensor type.

Table I. Various Aspects of WBAN

Aspect	Features
Operational Area	Patient Monitoring, Exercise Impact Monitoring, Activity Monitoring, Performance Monitoring
Associated Individuals	Athletes, Soldiers, Athletes, Sports persons
Type of Information Communication	Statistical Information, Chemical Information, Physiomechanical Information, Electronic Information
Data Forms	Discrete, Images, Videos, ECG Signal, EEG Signal
Placement	Inside Body, Outside Body
Type of Body Sensors	Electro-Mechanical
Number of Sensors	Application and Requirement Dependent
Sensor Capability	Information Capturing, Storage, Communication, Transformation, Decision Making, Temporal Setup

Table II depicts the type of information captured from body sensors and its scope for WBAN network is provided. The information can be discrete, visual, chemical or continuous. The requirement assisted role and responsibilities are decided and relatively the sensors are placed.

Table II. Captured Information and Body Sensor Types for Patient Monitoring

Captured Information Type	Body Sensors	e.g.
Discrete	Captures the Numerical Information	Temperature, Blood Pressure, Heart Rate
Continuous	The signal specific information to monitor the critical organ	EEG, ECG
Visual Information [In Body]	Inner organ images and videos can be captured for critical organs	MRI Images, Tumor Images
Visual Information [On Body]	Captures the Body and Face Skin Variation	Sweat Rate, Activity Monitoring
Chemical Information	The Featured Containment based information capturing can be done	Blood Test, Sweat Test

Each of the application area or the individual has specific featured responsibilities. In this paper, a comparative analysis of WBANs for different application areas is provided.

This paper has identified various application areas based on the functional requirements of individuals. Each of the application areas can have different WBAN scenarios with different roles and responsibilities of individual body sensors. The analytical observations are provided to evaluate the scope of each real-time functional network. In this section, various aspects of body area network are explored with the specification of data type, application area, and the individual to be observed. In Section 2, the work provided by earlier researchers is discussed. In Section 3, the generic communication architecture for different application areas is provided in the wider form. In Section 4, the analytical results for each application area are provided. In Section 5, the conclusion of the work is presented.

2. RELATED WORK

WBAN enables the intelligent, continuous and eventual monitoring of human disease, injuries, and their performance. The monitoring is possible for individual organ, activity or behavior. Type of body sensor, monitoring schedule, and the sensor position can vary based on involved application. In real time scenarios, the patient, athlete and soldier health monitoring are quite common. In this section, the contribution of earlier researchers on optimization of communication in different application areas is discussed. The study is provided on different sensor types, application frameworks and the algorithmic method suggested by the researchers to optimize the WBAN communication. In this section, the contribution of earlier researchers in different application areas is provided and also listed in Table III.

An athlete has to face heavy competition in the field. The difference between the defeat and victory can be of milliseconds. More advanced training requires to evaluate the performance of athlete scientifically. The body sensors provide the growing support to this field to evaluate the performance of an athlete as well as his organs. These kinds of measures help to determine the chances of expected injuries and reduce the degree of deficiencies. Chakraborty *et. al.*, [1] has provided a method to measure the foot pressure at different segments of foot. A design model was provided to evaluate the force based on the training routines and to determine the impact of postural balance on the athlete. The continuous observation and follow up to the suggested precautions ensure the non-occurrence of expected injuries to the patient. A wider architecture for connecting the athletes of a sports organization via WBAN integrated cloud environment was provided by Rakovic *et. al.*, [2]. The continuous and unobtrusive monitoring under various health parameters was provided for professional athletes and the information was maintained in the global cloud repository. Boano *et. al.*, [5] has designed continuous monitoring of skin to measure the variation in body temperature of an athlete. Lap wise analysis was applied on the Marathon runner to identify the effect of environmental parameters. A customized test was applied by the author to recognize the physiological changes.

Activity monitoring or movement classification is another application of body sensors. The recognition of work efforts, actions, and activities of individuals can be identified and classified using these body sensors. In more intelligent form, body sensors can also evaluate the effect of these activities and actions. Hosein *et. al.*, [3] used three body sensors called accelerometer, magnetometer, and gyroscope for classification of exercise and its impact. A comparative analytical study was provided by the author using different classifiers. The cost and efforts of individuals are evaluated by the author based on the classification results. The performance and energy consumption of individuals can be measured in terms of sweat rate. Matzeu *et. al.*, [4] setup the video and image-based body sensors to capture the sweat rate. The parametric composition is analyzed by the author in terms of fitness level,

environmental conditions, exercise intensity, *etc.* A real-time sweat trail was provided by the author for a specific session and the efforts of individuals was identified. The chemical and statistical observations are composed in hybrid form to identify the degree of hydration.

The evolution of WBAN is done to provide proactive support from fatal and chronic diseases. The diseases such as Heart Disease, Depression, *etc.*, that requires continuous monitoring can be trailed using body sensors. Saha *et. al.*, [6] has presented a framework to monitor the posture, behavioral and physical activities. The collaborative observations are taken by the author to verify that the patient is depressed or not. Ivanov *et. al.*, [7] have set up an architecture to monitor similar patients in a group. The policies and metrics are set up to observe the comparative health status of patients. The physiological data-dependent condition observation was provided for sharing the information between patient and physician. Rasyid *et. al.*, [8] developed a glucometer monitoring system to control the patient's glucose level. The developed model also connects the system to the web to transfer the collected information to the doctors. Arboleda *et. al.*, [9] has designed a service process model to monitor chronic heart diseases. A conceptual prototype was designed by the author to characterize heart diseases. The composite model captured the temperature, ECG, Oximetry information through body sensors and transfers the information to the doctors for instant heart solution.

WBAN is application based real-time network which includes multiple integrated stages including the body sensor selection, node placement, capturing process specification, temporal feature inclusion, data collection, information sharing, *etc.* Even though, the network suffers from various challenges in terms of limited energy, coverage range, type of sensor, *etc.* Each of the associated capturing or communication stage requires the optimization and improvement to improve network life. Sarra *et. al.*, [10] has evaluated the WBAN network under different scenarios and characterization. A link quality estimation and network formation evaluation was provided by the author. Network computation is provided under mobility, node placement, and network size parameters.

To optimize the WBAN communication, one requirement is to optimize the routing algorithm. The routing is more complex when mobility exists in the network. Birgani *et. al.*, [11] has optimized the route discovery and route maintenance methods in mobile WBAN network. The demand-driven multihop routing algorithm was provided by the author which is strengthened by avoiding the loops and considering node power as an effective parameter. An improved energy effective data transfer protocol was suggested by Sethi *et. al.*, [12]. The cluster head selection-based communication model is provided by the author to utilize the network resources effectively. Rajagopalan *et. al.*, [13] has defined a new multi-hop routing algorithm based on multiple objectives. The delay and energy adaptive method was defined by the author to select the intermediate node. The domination rank evaluation and effective route generation are provided using Genetic-based approach. Tauqir *et. al.*, [14] has analyzed the body sensors under energy, distance, and communication relay parameters. The body sensor analysis was provided based on communicating data type and line-of-sight parameters.

Table III. Body Sensor Responsibilities Worked by Earlier Researchers

Author	Individual	Monitoring Organ	Application behavior
Chakraborty et. al. [1]	Athlete	Foot Segments	Kinematic Behavior Based Movement and Injuries Observation
Rakovic et. al. [2]	Athletes in an Organization	Complete Body	A cloud system architecture is provided to connect WBAN captured information of Athletes belonging to particular Sports or Sports organization
Hosein et. al. [3]	Exercise	Accelerometer, Gyroscope and Magnetometer	The motion recognition and classification are provided using different classifiers to evaluate the efforts of individuals.
Matzeu et. al. [4]	Arm and Back Video Sensors	Sweat Analysis	A composition of video and chemical sensors is applied to identify the sweat rate and its contents. The Effort evaluation is provided against the exercise.
Boano et. al. [5]	Athlete	Ear and Skin	Skin Feature analysis is done on various laps of Marathon to evaluate the impact of environmental and physiological factors.
Saha et. al. [6]	Depression Patient	Accelerometers, Barometric Pressure	A Situational driven model was provided to monitor the depression patient against physical activities, posture, and behavioral activities
Ivanov et. al. [7]	Patient Group	ECG	A composite model was proposed to generate comparative group health status information and sharing it with patients and doctors.
Rasyid et. al. [8]	Diabetic Patient	Glucometer	A Desktop central application was designed to capture the Glucose information and transfer to the physician
Arboleda et. al. [9]	Heart Patient	Temperature, ECG and Oximetry	A system prototype is defined to capture the composite chronic features including ECG, Temperature, etc.

3. WBAN HORIZONS FOR DIFFERENT APPLICATION AREAS

WBAN has scope in different application areas having different functional specifications. The configuration, constraints and the requirement of each of functional structure are different at each stage. In this section, the generic model is defined to provide effective communication in any application area. The section also explored each of the work stages relative to the real-time configuration.

Fig. 1 Generic WBAN Communication Architecture

The generalized architecture of WBAN communication is shown in Fig. 1. Communication in the global scenario can be accomplished using three main process stages. At the first stage, the selection of body sensors is done based on the functional requirement. The organ supported body sensors are selected with capabilities and cost constraint analysis. In the second stage, the topological placement of body sensors and controller is done. The placement should be specific to the organ, application area, and the individual activity. The coverage and the distance from the controller are also considered while localizing the WBAN nodes. Once the architectural constraints are set up, the final task is to activate the body sensors. The body sensors will acquire the physical status or information and pass it to the controller through a routing path. The route formation can be single hop or multihop based on the node level constraint adaptation. Each of the work stages in this generic architecture is defined below.

3.1. SENSOR SELECTION

The primary requirement of WBAN communication is the selection of body sensors that can map the functional requirements of a specific application area. Application areas in present work include individuals or patients suffering from different diseases such as Heart, Coma, Blood Pressure, Diabetes, and Brain Injury considered for monitoring. To perform the sensor selection, the first requirement is to recognize the critical, essential and basic monitoring requirements. Such as for heart patient, the ECG signal capturing is the critical requirement and along with this blood pressure, heartbeat analysis is among the essential information elements. Body sensor sets up for feet or hand activity are considered as a secondary requirement. The functional requirement specific essential body sensor requirements are listed in Table IV.

Table IV. Essential Body Sensors based on Functional and Application Area Requirement

Application Area	Functional Aspect	Essential Body Sensors
Athlete	Exercise	Feet, Hand, Knees, Temperature, Heart Rate, Blood Pressure
Patient	Coma Patient	ECG, EEG, Heart Rate, Blood Pressure, EMG, Temperature
Patient	Heart Patient	Heart Rate, Blood Pressure, ECG, Temperature, Sugar, EMG
Patient	Blood Pressure	Heart Rate, Blood Pressure, EMG, Temperature, Hand, Feet, Sugar, ECG
Patient	Sugar	Heart Rate, Blood Pressure, Temperature, Sugar
Patient	Brain Injury	EEG, ECG, Temperature, EMG, Head Movement, Blood Pressure, Heart Rate

The sensor criticality and requirement-based responsibilities of body sensors are decided. These responsibilities include the type of information captured, transformed and the storage. The capabilities of body sensors decide the cost of WBAN setup. The capturing information also identified in different data forms that will be communicated over the network. The storage and data transformation capabilities are also integrated into these sensor nodes.

3.2. ARCHITECTURAL FORMULATION

After identification of body sensor requirements, the next stage is to connect them in the form of body area network on the human body. The organ-specific sensor placement and the organ criticality-based monitoring is the main requirement of this architectural setup. The functional features of the architectural setup for different WBANs configurations or patients are listed in Table V. The node requirement, critical nodes,

observation frequency, and the temporal vector are also defined in this table for different application scenarios.

Table V. Architectural Setup for Monitoring Different Functional WBANs

	Athlete	Coma Patient	Heart Patient	Blood Pressure	Sugar	Brain Injury
No. of Sensors	9	6	6	10	4	7
Observation Frequency	Continuous for Hand Feet Movement and heart rate	Continuous for Heart Rate, EMG, Temperature	Continuous for Heart Rate, Blood Pressure ECG	Continuous Blood Pressure, Heart Rate, ECG	Continuous Sugar, Blood Pressure	Continuous EEG EMG Heart Rate Blood Pressure
Rest Frequency	5 Min	4 Min	15 Min	15 Min	4 Min	5 Min
Signal Form	No one	ECG EMG and EEG	ECG	No One	No One	EEG EMG ECG
Highly Critical	No	No	Heart Rate, Blood Pressure	Blood Pressure	Sugar	Heart Rate, EMG EEG

The architectural setup basically represents the individual sensors in the form of network and provides the integration between real-time capturing and communication. The mapping of capturing aspects to the communication aspects is done in this stage which involves the optimum identification of node locality, its responsibility, and the coverage. The energy consumption features are also monitored while setting up the network. The activity of the individuals, comfort, impact, and accuracy of health information acquisition and communication is defined at this stage.

3.3. SIMPLE (STABLE INCREASED-THROUGHPUT MULTI-HOP PROTOCOL FOR LINK EFFICIENCY)

WBAN is defined with restricted nodes and in smaller network region. The lesser constraint requires to gain the equalized utilization of constraints and to keep the network stable. SIMPLE is one such routing protocol which can provide effective output for such an adaptive network with restricted capabilities and features. In the earlier WBAN model, each node is defined with equal power consumption for each kind of sensor node. No data or node specific rules are defined for the energy consumption of nodes. The major features of the existing SIMPLE protocol are listed hereunder:

- No communication sessions are considered by the protocol. Each communication is performed at the same interval.
- The intermediate node selection is not affected based on node criticality or communicating data type.
- The energy consumption for each node is similar independent to communicating data or node criticality.

In this SIMPLE protocol, the sink node broadcasts the control message with location information to spread the information about the sink and other nodes. After this initiation, each node has position information of neighbor and that of the sink nodes. SIMPLE protocol is able to generate the multihop path for improving the communication throughput and to reduce the overall network energy consumption. The next hop selection is done based on distance and residual energy analysis. In each round a new next hop selection is done. Next hop rotation is useful in spreading the energy consumption evenly in the network. The cost computation for selection of next hop is done by the sink node using the equation (1)

$$\text{Cost}(i) = \frac{d(i)}{\text{ResEnergy}(i)} \quad (1)$$

where, Cost is the node cost function
i is any communicating node
d is the distance vector
ResEnergy is the residual energy of node

After estimating the cost of nodes, the eligible neighbor with minimum cost is selected as next forwarder. The forwarder node is the neighbor with maximum residual energy and minimum distance to the sink node. The time slots are also assigned to perform scheduled communication. Each node is assigned with the equal time slot and the communication is performed only in the assigned time slot.

3.4. IM-SIMPLE PROTOCOL

iM-SIMPLE is the modified form of the existing SIMPLE protocol described in Section 3.3. The SIMPLE protocol has not considered mobility and has not proved much effective in improving the communication throughput. But in this protocol, the limitations of SIMPLE protocol are resolved and a more effective routing protocol is designed. The node position acquisition process is same as of the SIMPLE protocol. In this work, the balanced energy consumption scheme is taken while selecting the forwarder to reduce the node level energy consumption. The cost evaluation and forwarder selection method is here controlled using mathematical modeling to maximize the throughput and to minimize the energy consumption at the node level. The forwarder node is here defined to accept data from the other nodes, perform aggregation of data and to transmit it to the sink node. The energy consumption for each operation is defined with a different ratio.

3.5. PROPOSED PROTOCOL

The final associated work stages for different application-based scenarios are to transfer this captured health information to the controller using a single or multiple hop path. The communication constraint setup and its adaptation to the route formation is defined at this stage. The communication constraints are divided as the essential required constraints based on which the node can be selected as the intermediate nodes. Constraints are also defined to avoid a node to get selected as the intermediate communication node. The first level check and second level node parameter analysis is shown in Figure 2.

Fig. 2 Features of Communication Setup

Figure 2 has divided the communication parameter considered as two-level checks. At the first level, high-level parameters are applied to shortlist the nodes and to identify the effective neighbors. The coverage range and the direction identify the neighbors and the energy check identifies the most effective neighbors from the list. Once the neighbors are shortlisted, the low-level check is performed to select the body sensor as an intermediate node. The node criticality, organ criticality, type of data and load vector prevented the

nodes from being set as the intermediate node. A highly critical node or the node with higher load cannot be considered as an intermediate node. The algorithmic formulation of route generation between the body sensors and the controller node is shown in Table VI.

In this proposed protocol, an improvement to the iM-SIMPLE protocol is provided in which the route selection is based on the network parameters.

Table VI. Proposed Algorithm

<p>Algorithm (BSensors, Controller) /*BSensors is the list of application specific body sensors and Controller is the centralized receiver node*/</p> <pre> { 1. Setup the communication limits based on body sensor and network capabilities • Sensing Range • Energy Threshold • Load Limit [The constraints are defined to limit the node selection in routing path] 2. For each source in BSensors [Process all body sensors and set as source node] { 3. Set Dst=Controller Set Cur=source [Set the controller as destination node and source as current node] 4. While Cur<>Dst [Repeat Process 5 to 15] { 5. Neighbors=GetNeighbors(Cur, SensingRange) [Identify the neighbors within the sensing limit of current node] 6. Neighbors=Limit(Neighbors,Energy, Load) [Identify the neighbors with effective energy and lesser load] 7. For i=1 to Neighbors.Length [Process all neighbors] { 8. If (Neighbors(i).Type<>Critical And Neighbor(i).Energy>Max And Distance(Neighbor(i), Cur)>MDistance) [Identify the non-critical node with maximum energy limit and maximum distance within coverage] { 9. Nxt=i [Identify Next possible Neighbor] } 10. Else If (Neighbors(i).Type<>Critical And Neighbor(i).Energy>Max) [Identify the non-critical node with maximum energy limit] { 11. Nxt=i } 12. Else If (And Neighbor(i).Energy>Max) [Identify the node with maximum energy limit] { 13. Nxt=i } } 14. Cur=Nxt 15. Path.Add(Cur) [Set Next Effective Neighbor as intermediate Node] } } } </pre>

The effective forwarder selection is here done based on energy, node criticality, communicating data type and distance parameters. The route formation at the node level is defined in this work to improve the communication and to improve the validation. At the earlier stage, the sensing range and energy level evaluation is performed to shortlist

the neighbor nodes. In the second level, direction, failure probability, packet size, and organ criticality parameters are analyzed to identify the effective forwarder node. The multi-hop route is generated between each body sensor node and the controller node for effective route formation. The algorithmic formulation of this proposed work is shown in Table VI. Table VI presents the algorithmic formulation for route generation between each body sensor and the controller node. The algorithmic process shows that the high-level parameters are considered as the primary criteria to shortlist the neighbor nodes and later on the low-level parameters are applied for effective intermediate node selection. The multi-hop route is formed between each body sensor and the controller node. After forming the route, the communication is performed over the WBAN network.

In this section, the generic process model with specialized constraints and configuration setup is defined. The constraint consideration is provided based on the functional requirement of a WBAN. The simulation setup and the analytical results associated with each functional scenario are provided in the next section.

4. RESULTS AND DISCUSSION

In this paper, the WBAN network is implied for various real-time application architectures. These application networks also have a sub domain based on the internal functional specification. Architectural composition, role, and responsibilities are already explored in Table IV and Table V. The simulation of these architectures is done in Matlab environment. The characterization of the simulation scenario is provided in Table VII. The simulation scenario defines that the multiple networks are composed of a different number of nodes and with random energy and specialized constraint specification. In this chapter, the comparative results are evaluated to prove the significance of the provided work model.

Table VII. Network Scenario

Parameters	Values
Number of Body Sensors	4 to 10
Initial Energy	Random
Packet Size	4K
Communication Type	Discrete or Continuous
Number of Communication Rounds	1000
Topology	Functional Requirement Dependent
Controller	Fixed

To evaluate the significance of presented WBAN communication architecture, the comparative evaluation of each network scenario is done for each of the functional architectures. The existing method is defined with consideration of the same sensing nodes and architectural specification. The routing method implied in the existing method is based on energy and distance parameter. The continuous observation of nodes is provided for each node in each network form. The analysis of the work is provided in terms of remaining energy for each body sensor.

The first level comparative analysis of the proposed intra-routing model is provided against iM-SIMPLE Protocol. The node level analytical comparison is provided to verify the strength of the proposed routing method on different application areas. The node level comparative evaluation under remaining-energy parameter for each application area is done. The network configuration for different application areas is already described in the previous section. In this section, the graphical analytical results at node level are presented. The communication in different application environments is performed for 1000 rounds. Each node has performed the single or multi-hop communication to the controller node. Figure 3

shows the placement of sensor nodes to measure various physiological parameters for patients suffering from various diseases. Figure 3(a) shows the placement of sensor nodes to monitor the performance of an athlete as described in Table V.

Table VIII shows the remaining energy of various nodes in the network at different number of rounds. Here, Ex represents the existing iM-SIMPLE protocol and Pr represents the proposed protocol.

Table VIII. Residual Energy (J) for nodes on an Athlete

Rounds	1000		3000		5000	
Protocol	Ex	Pr	Ex	Pr	Ex	Pr
Temp*	0.3968	0.4932	0.1731	0.4797	0.0233	0.4662
LHM*	0.43	0.4329	0.2907	0.2987	0.1508	0.1644
BP*	0.348	0.4933	0.1517	0.4798	0.0114	0.4663
Left Knee	0.4324	0.4697	0.2448	0.409	0.0518	0.3483
LFM*	0.4287	0.4228	0.2861	0.2685	0.1434	0.1141
RFM*	0.4287	0.4228	0.2861	0.2685	0.1434	0.1141
Right Knee	0.4322	0.4697	0.2448	0.409	0.0518	0.3483
HR*	0.4326	0.4327	0.2981	0.298	0.1634	0.1633
RHM*	0.4325	0.4329	0.2977	0.2987	0.1628	0.1644

*Temp=Temperature, LHM=Left Hand Movement, BP=Blood Pressure, LFM=Left Foot Movement, RFM=Right Foot Movement, HR=Heart Rate, RHM=Right Hand Movement.

The first node in iM-SIMPLE for athlete dies at round 5170 and all nodes die at round 7429 whereas in our work they die at 6480 and 74251 rounds respectively.

Fig. 4 Remaining Energy analysis for Athlete

Figure 4 shows the node level comparison of the remaining energy parameter for an athlete. Here, the x-axis shows the individual nodes and the y-axis shows the remaining energy in each node. The figure shows the observations collected for the athlete who is doing some exercise with hand movement. The observations are conducted after the exercise of 5 minutes. The observations verified that for most of the nodes in the network higher energy is remaining. Only for nodes 5 and 6 *i.e.*, LFM and RFM, the remaining energy is lesser but for rest of nodes, the remaining energy for the proposed routing method is having the edge over the iM-SIMPLE protocol. The results verify that the proposed routing model is effective to optimize the communication for athlete information evaluation.

Fig. 3(a) Athlete

Fig. 3(b) Blood Pressure Patient

Fig. 3(c) Brain Injured Patient

Fig. 3(d) Heart Patient

Fig. 3(e) Sugar Patient

Fig. 3(f) Coma Patient

Fig. 3 Sensor Node Placement for Patients suffering from different diseases

Fig. 3(b) shows the placement of sensor nodes for a patient suffering from Blood Pressure problem. The nodes sense and transmit data as described in Table V. Table IX shows the remaining energy of various nodes in the network at a different number of rounds for a patient suffering from Blood Pressure fluctuations.

Table IX. Residual Energy (J) for nodes on a patient Blood Pressure patient

Rounds	1000		3000		5000	
Protocol	Ex	Pr	Ex	Pr	Ex	Pr
Temp	0.4327	0.4978	0.2982	0.4932	0.1009	0.4888
ECG*	0.4327	0.4329	0.2981	0.2988	0.1634	0.1647
LHM	0.43	0.4978	0.291	0.4933	0.0891	0.4889
BP	0.4324	0.4327	0.2972	0.298	0.1621	0.1633
LFM	0.4287	0.4975	0.2864	0.4923	0.1454	0.4872
RFM	0.4287	0.4975	0.2864	0.4923	0.1456	0.4872
Sugar	0.4324	0.4978	0.2842	0.4933	0.0885	0.4888
HR	0.4326	0.4327	0.2981	0.298	0.1634	0.1633
RHM	0.4329	0.4978	0.21	0.4933	0.0443	0.4889
EMG*	0.3315	0.4978	0.0893	0.4933	0	0.4889

*ECG=Electrocardiogram, EMG=Electromyogram.

The first node in iM-SIMPLE for BP patient dies at round 4336 and all nodes die at round 7430 whereas in our work they die at 7426 and 224251 rounds respectively.

Fig. 5 Remaining Energy analysis for Blood Pressure Patient

Here Figure 5 shows the node level analytical observation for remaining energy evaluation for blood pressure patient. The blood pressure evaluation depends on heart rate, ECG and other heart-related information. The blood pressure information can be acquired by placing 10 nodes. In this figure, X-axis shows all the nodes and Y-axis shows the remaining energy. The results identified that for three sensor nodes *i.e.*, ECG, BP and HR, the energy consumption is nearly same in the case of the proposed protocol as compared to iM-SIMPLE. For remaining body sensors the proposed protocol proves to be better in terms of energy.

The placement of sensor nodes for a patient suffering from Brain Injury is shown in Figure 3(c). Table X shows the remaining energy of various nodes in the network at different number of rounds for a patient suffering from Brain Injury.

Table X. Residual Energy (J) for nodes on a Brain Injured person

Rounds	1000		3000		5000	
Protocol	Ex	Pr	Ex	Pr	Ex	Pr
Temp	0.4327	0.4932	0.1427	0.4797	0	0.4662
EEG*	0.4268	0.4145	0.2805	0.2436	0.1341	0.0727
HM*	0.4312	0.4923	0.2935	0.4769	0.0443	0.4615
ECG	0.319	0.4933	0.1009	0.4799	0	0.4665
BP	0.4324	0.4327	0.2972	0.298	0.1621	0.1633
HR	0.4325	0.4327	0.2978	0.298	0.1629	0.1633
EMG	0.4331	0.4332	0.2993	0.2996	0.1655	0.1659

*EEG=Electroencephalogram, HM=Hand Movement.

Fig. 6 Remaining Energy analysis for Patient with Brain Injury

Figure 6 shows the remaining-energy evaluation on each node for the brain-injury patient. Brain-Injury affects brain signals, heartbeat, and blood pressure. For this, seven sensors are placed to measure the EEG, EMG, Blood pressure and heart rate. In this figure, the evaluation is performed on a WBAN network with seven nodes. The x-axis represents the nodes and the y-axis shows the residual energy for each node. The observations show that only for node 2 *i.e.*, EEG, the remaining energy is lower in the case of the proposed approach. For 3 nodes *i.e.*, BP, HR and EMG, the remaining energy is at the same level. For other nodes, a slight edge is obtained in case of proposed approach while measuring the residual energy. The first node in iM-SIMPLE for Brain Injury patient dies at round 4494 and all nodes die at round 7476 whereas in our work they die at 5853 and 73921 rounds respectively. The results show that the lesser energy is consumed for most of the nodes in case of the proposed approach. The results verified that the proposed routing method can be applied effectively on energy consumption analysis for the Brain-Injury patient.

Heart patients also require the continuous monitoring for identification of chances of stroke occurrence. The heart rate and blood pressure analysis is required to be observed to identify the chances of heart disorder. A WBAN setup is simulated with six nodes to monitor the heart patient. The sensor nodes are applied to measure the heartbeat, ECG and blood pressure. For a Heart Patient, the node placement is shown in Figure 3(d). Table XI shows the remaining energy of various nodes in the network at different number of rounds for a patient suffering from Heart Patient.

Table XI. Residual Energy (J) for nodes on a Heart Patient

Rounds	1000		3000		5000	
	Ex	Pr	Ex	Pr	Ex	Pr
Temp	0.4327	0.4978	0.2681	0.4932	0.053	0.4888
ECG	0.4327	0.4329	0.2981	0.2988	0.1634	0.1647
BP	0.4324	0.4327	0.2972	0.298	0.1621	0.1633
Sugar	0.4324	0.4978	0.2352	0.4933	0.041	0.4888
HR	0.4325	0.4327	0.2978	0.298	0.1629	0.1633
EMG	0.3315	0.4978	0.0721	0.4933	0	0.4889

Fig. 7 Remaining Energy analysis for Heart Patient

In Figure 7, the analytical results on individual sensor life evaluation are provided. In this figure, X-axis represents the individual nodes and the y-axis shows the residual energy of nodes. The first node in iM-SIMPLE for heart patient dies at round 4079 and all nodes die at round 7430 whereas in our work they die at 7426 and 224521 rounds respectively. The results identified that for each node the proposed model has reduced the energy consumption and improved the life of the sensor node as well as the overall network life.

Diabetes is one of common disease from which large numbers of individuals are suffering. Sugar patients do not require continuous observation. The hourly monitoring and capturing of health information can be done to identify the health status of expected sugar patients. The blood pressure and sugar level analysis are done for this monitoring. A WBAN network is composed of four sensor nodes to monitor sugar patients. Figure 3(e) depicts the placement of sensor nodes on a patient suffering from Diabetes. Table XII shows the remaining energy of various nodes in the network at different number of rounds for a patient suffering from Diabetes.

Table XII. Residual Energy (J) for nodes on a Diabetic Patient

Rounds	1000		3000		5000	
	Ex	Pr	Ex	Pr	Ex	Pr
Temp	0.3744	0.4915	0.134	0.4746	0	0.4577
BP	0.4324	0.4327	0.2972	0.298	0.1621	0.1633
Sugar	0.4324	0.4327	0.2972	0.298	0.1621	0.1633
HR	0.3759	0.4916	0.1207	0.4747	0	0.4579

Fig. 8 Remaining Energy analysis for Sugar Patient

Here, in Figure 8, the representation of the evaluation of sensor capability is provided graphically. X-axis here represents the observing node and y-axis shows the residual energy of nodes. The analytical results show that the proposed routing method for intra-WBAN has reduced the energy consumption for each node. The first node in iM-SIMPLE for sugar patient dies at round 4685 and all nodes die at round 7399 whereas in our work they die at 7426 and 59401 rounds respectively the overall network life is improved by using the proposed routing method.

A coma patient is not able to respond verbally or through any gesture in case of any health issue. These patients can be in a critical stage so require the continuous monitoring for some organs and for a particular disease. Heart rate and blood pressure are the common issues that can affect the health of coma patient critically even in an unconscious state. This health information can be captured on a fixed interval to verify the health status of a coma patient. In this work, six sensor devices are placed to monitor the heart, ECG and EMG signal of a coma patient. The node placement for a Coma Patient is depicted by Figure 3(f). Table XIII shows the remaining energy of various nodes in the network at different number of rounds for a Coma Patient.

Table XIII. Residual Energy (J) for nodes on a Coma Patient

Rounds	1000		3000		5000	
Protocol	Ex	Pr	Ex	Pr	Ex	Pr
Temp	0.4322	0.4324	0.2965	0.2971	0.1609	0.1618
EEG	0.4294	0.4893	0.2855	0.468	0.0515	0.4466
ECG	0.3351	0.4916	0.1104	0.4749	0	0.4581
BP	0.4157	0.4916	0.1371	0.4747	0	0.4579
HR	0.4325	0.4327	0.2978	0.298	0.1629	0.1633
EMG	0.4331	0.4332	0.2993	0.2996	0.1655	0.1659

The first node in iM-SIMPLE for coma patient dies at round 4578 and all nodes die at round 7476 whereas in our work they die at 7426 and 59649 rounds respectively. The results show that proposed work has higher stability period and network lifetime than the iM-SIMPLE protocol.

Fig. 9 Remaining Energy analysis for Coma Patient

In Fig. 9, the validity of the proposed routing method is provided to measure the improvement in the sensor strength capability while monitoring the patient. In this figure, the x-axis shows the nodes and the y-axis represents the remaining energy. The results verified that the proposed routing method has reduced the node level energy consumption for each sensor device and improved the life of the overall network.

The overall results of each scenario signify that the proposed model has improved the network life in each scenario as the routing decision is done based on the node capabilities and the communication statistics. The model is able to improve the life of individual body sensors and body area network.

5. CONCLUSION

WBAN is the real-time network in which the network performance depends on sensing devices, architectural placement, the role, and the communication method. The existing iM-SIMPLE protocol has not considered the organ criticality or direction while identifying the next effective forwarder. In this paper, an improvement to existing iM-SIMPLE Protocol is provided to improve the network communication. In this protocol, the direction, session preserved energy balancing and organ criticality parameters are included to improve the strength of the existing protocol. A generalized routing method is provided that can be applied to various application areas of WBAN. The paper has divided the communication into three main stages called sensor selection, architectural specification, and communication. The characterization of each of the stage is done with integration to different applications. The comparative simulation results are provided for each body sensor of each application area. The simulation results show that the proposed model has improved the lives of individual nodes and the network. The comparative results are taken against the iM-SIMPLE protocol. The results verified that the proposed improved protocol has reduced the node level energy consumption and improved the node and network life.

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