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Forward Node Selection by Evaluating Link Quality Using Fuzzy Logic in WBAN

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ABSTRACT- WBAN technology plays a vital role in human life monitoring and maintaining health remotely without being hospitalized, particularly during pandemic situations. The miniature-sized and heterogeneous sensors involved in WBAN with limited resources face reliability as a key challenge that limits the growth of WBAN technology. Designing an efficient routing protocol helps to achieve reliable data transmission between sensor nodes in WBAN. The proposed Fuzzy logic-based Forward Node Selection chooses the best node to transmit the data by introducing fuzzy logic on routing parameters such as link quality, data rate, node's residual energy and node-to-node distance. The key advantages of our proposed system are to extend the network lifetime and boost the packet delivery ratio. The efficiency of our proposed method is estimated by comparing the parameters of network lifetime and packet delivery ratio with DTS and EARP protocols.

Keywords: WBAN, Fuzzy Logic, Forward node selection, RSSI, LQI, Link quality, data rate.

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1. INTRODUCTION

WSN is a self-configured, intelligent, infrastructure-less wireless network that contains several miniaturized sensors for monitoring the characteristics of the environment and transmitting the information to the target node. In recent times, WSN has had several applications such as agriculture, smart home, military, medical field, etc., The Wireless Body Area Network was introduced by Van Dam to utilize the benefits of WSN. WBAN has the majority of its applications in the medical field. Body Area Network (BAN) contains numerous miniaturised sensors that may be embedded inside the body referred to as implants and some may be wearable devices that can be carried by humans such as in clothes, in hand, etc., used to monitor and collect various information about the patient through the sensor and transmit it to the end user (doctor). WBAN allows the patient to move due to its portable, compact device and to stay in any location due to its monitoring capability. WBAN technology plays a vital role in the human busy life in monitoring and maintaining their health from remote without being hospitalized. Recently we have gone through a pandemic situation, it is not safe and also not possible for all to get hospitalized and also for the aged or sick people who need assistance in such cases this technology is being used. Each sensor in WBAN has special characteristics so these features have both advantages and disadvantages based on the application it is used.

1.1. Architecture of WBAN

The WBAN is the integration of intelligent, particularly limited-powered miniature-sized sensors that are either placed or implanted on the human body and linked with other electronic devices to screen the biological factors of the human body. WBAN is linked with wireless network technology. The architecture of WBAN has three distinct Tiers as given in *figure. 1.*

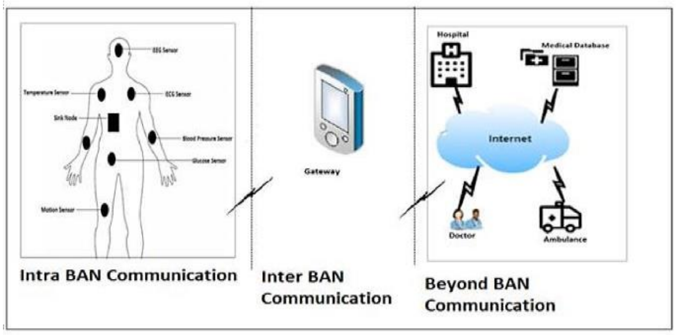

Figure 1. Architecture of WBAN

In Tier 1 - Several resource-constrained body sensors are placed in the human body. They are responsible for continuously monitoring and collecting the biological data of the humans such as temperature, pulse rate, oxygen level, BP, etc., and transmitting to the sink node which is not a resource-constrained node. Tier 2 Inter BAN communication is a gateway which uses a smartphone, laptop or any smart device to transmit the collected information between Tier 1 and Tier 3. The communication technologies used in this section are WLAN, Bluetooth, WiFi, ZigBee, 4G or any other wireless communication. Tier 3 Beyond BAN communication contains a database, doctor and ambulance service. The gateway in Tier 2 sends the information to the doctor or ambulance service in case of an emergency.

Major limitations of WBAN are Limited resources, reliability, mobility of nodes, and heterogeneous nodes. The research area in the physical layer of the network emphasises mainly optimizing the wireless channel to minimize data loss. The research area in the network layer focuses on determining a topology that will be suited for the moving human body and also to achieve data reliability. As WBAN carries critical medical data, it should rapidly and efficiently transmit the data to medical services to save the lives of humans. Miniature-sized sensors in WBAN have been implanted inside the body and hence cannot be replaced often if the battery capacity has been drained, so the energy of the nodes should be effectually utilised. Due to the heterogeneous nature of the sensor, all nodes are not able to transfer their data directly to the sink node, so it leads to the choice of multi-hop transmission. Efficient routing can help energy-efficient nodes to forward the data quickly and efficiently. There are several multi-hop routing protocols that mainly concentrate on the temperature of the nodes and energy of the nodes as the important factors in choosing the forwarded nodes to transmit the data. Link quality is a critical parameter in achieving the reliability of the data transmitted and also saves the energy of the nodes by avoiding retransmission. Fuzzy logic uses mathematical set theory ideologies which would impersonate human thinking while making decisions and give effective solutions to all complicated problems with limited computation.

Therefore, we propose an energy-efficient with the usages of fuzzy logic method that involves parameters like distance, link quality, data rate and residual energy as a main factor to choose the best-forwarded node at minimum computation to revise the energy utilization and reliability in WBAN.

1.2. Contribution of our paper

The key objective of our proposed method is to attain energy-efficient and reliable WBAN by proposing fuzzy logic-based routing.

The main contribution of this paper,

- Several existing works are analysed to select the parameters used to select the best routing path.

- Fuzzy logic control is established on the routing parameters like residual energy, link quality, node-node distance and sensor's data rate to determine the best-forwarded node to send the data to the destination node through a reliable and energy-conserved routing path.

The flow of the journal elaborates on the existing system related to this paper in Roman II, Roman III discussing the Proposed system, Roman IV discussing the Result and Discussion and Roman V presents conclusions and future enhancement.

2. RELATED WORKS

2.1. Routing protocols used in WBAN

A routing protocol is vital in designing an energy-efficient, low-cost reliable WBAN. Routing protocols are classified based on important parameters such as temperature, position of nodes, quality of service and clustering of nodes. Cluster-based protocol clusters the nodes into several groups and associates a cluster head to each group and different techniques are considered to determine a cluster head. This method reduces direct transmission between the nodes which ultimately saves the power of that particular sensor. Every sensor in the group communicates with the cluster head which forwards data that it receives from its members to the target node. Some existing cluster-based protocols are ANYBODY[1], DSCB [2], and CRPBA [3]. The main disadvantage of this method is delay and overhead during clustering and selection of cluster heads.

Wireless communication is carried out through radio signals which produce an electric and magnetic field around the sensor on the human body that is absorbed by the tissues and converted into heat leading to an increase in the temperature in the body so this criterion has to be considered when designing a WBAN. Generally, the body has a thermoregulation mechanism which means the body preserves a stable internal temperature that is suitable for survival. Specific Absorption Rate (SAR) is the amount of power absorbed by the body when the body is open to a radio frequency electromagnetic field.

$$SAR = (\sigma * E2)/md \qquad (1)$$

σ = conductivity of tissues E2 = electric and magnetic field md = mass density of tissues.

When the sensor in the body is working in limit or inactive does not increase the temperature. If the sensor is continuously working it will raise the temperature and when the temperature crosses the thermoregulation threshold value it will cause damage to the body. Some protocols designed to overcome these heat issues are TARA [4], LTR [5], LTRT [6], HPR [7], TSHR [8], TTRP[9] and DAC[10].

The mobility of nodes in WBAN is a critical parameter that should be considered while creating a routing protocol in a WBAN network because the sensors are positioned on the human body so that they move along with body part movement. Due to the dynamic node's position, the distance between nodes is also dynamic which makes it very difficult to select the route. Some protocols designed to adapt to the dynamic posture of sensor nodes are MHRP [11], NCMD[12] and PA-DDD[13]. As WBAN has been involved in the medical field which deals with real-time data but is constrained to the resources, QoS is an important parameter that should be considered when developing a WBAN. Quality of Services in WBAN includes parameters such as energy efficiency, data priority, reliability, low delay, etc., Some existing protocols to achieve QoS are LRPD [14] and HDRP[15].

2.2. Optimization and Fuzzy Logic used in WBAN

FLGR protocol[16], the nodes within the fuzzy location region are only accounted for choosing the next best forward node based on fuzzification process which avoids void nodes and reduces the number of hops. The parameters are the distance between the nodes, density and degree of distribution of nodes in CNR.

In HAOA[17], it applies fuzzy logic based on the temperature of the node, quantity of similar neighbour nodes, residual energy and path loss to create thermal aware clustering and also another fuzzy logic to select coordination node by considering parameters such as packet delivery ratio and distance between nodes. These parameters are tuned by a metaheuristic optimization hybrid of Aquila optimization and Arithmetic optimization algorithm.

In DTS[18], Fog assisted network is set up to decrease transmission errors and reply time. Minimum cost parent selection algorithm with an objective function that includes, the number of hops, cost function of link and distance between nodes to select the routing path to transmit the data that reduces response time and transmission error. Uses fuzzy logic for dynamic time slot allocation to reduce the delay.

SOPR[19], uses one-time password and shift operation to identify the malicious nodes that are avoided for routing nodes and provide secure transmission of data. ENS[20], uses fuzzy logic control on parameters link reliability, latency and link utilization function to decide the next forward node to send the data. In[21], to improve the lifetime of a device the selection of cluster head is programmed dynamically with a support vector machine and Gaussian regression model.

In[22] uses a genetic algorithm to select eligible nodes to be a cluster head and from the selected nodes one best node is selected with the help of modified particle swarm optimization. EARP[23] uses fuzzy logic control on parameters like quality of link, remaining battery level and hop count and calculates path benefit calculation to select the best-forwarded node. OFSR[24] uses fuzzy logic which takes link quality, delay and residual energy as input parameters to determine the next forwarded node and based on it the best route is discovered using Ant colony optimization.

MHR[25], uses residual energy as the modelled parameter in the Mamdani fuzzy inference system that prolongs the sensor's lifetime in WBAN. In EMRP[26] the appropriate forwarded node selection is based cost function constructed using residual energy, distance between the nodes, estimated path loss and energy consumption. The cost function is optimized using a genetic algorithm. In [27], a novel trust factor-based fuzzy logic is proposed in view of residual energy as the primary parameter and node with maximum bandwidth and neighbour nodes as the secondary parameters for choosing the best routing path. If two nodes have the same residual energy then the bandwidth of both nodes is taken into consideration as deciding parameter. When the two nodes with the same bandwidth, then the nodes with the maximum neighbour node are taken as the best choice for path construction to transfer the data.

In[28] finding the best relay node for WBAN has been proposed. For relay node selection, residual energy, node density, distance, SNR ratio, traffic and node criticality are considered as deciding parameters. The data transmission is based on AHP – TOPSIS which uses several parameters to decide the relay node. In [29], uses fuzzy logic with parameters such as RSSI, PER and SNR to calculate the link quality index. Utilizing the determined link quantity, residual energy and traffic load use the TOPSIS method for estimating the relay node for efficient data transmission. H2FIS [30] uses a hybrid fuzzy logic combination of the Mamdani and Takagi Sugeno fuzzy inference system with modelled parameters like residual energy and node–to–node distances and alive nodes to choose exact relay nodes in multi-hop networks.

3. PROPOSED SYSTEM

3.1. Proposed system parameters

3.1.1 Residual Energy

Sensors are randomly distributed in human body to amass biological facts to examine the body's condition. The calculation of energy requirement for a bit to be transmitted from one node to another node includes energy consumption by the transceiver in the sensor to send or receive a bit is denoted by E_{TC}, and energy consumption by the amplifier in the sensor is denoted by E_{AM}. The energy consumption at the transmitter and receiver side of the sensor node is given by the equations below,

On the transmitter side of the sensor, the energy consumption E_{TS},

$$E_{TS} = m * E_{TC} + m * E_{AM} \quad (2)$$

m- Number of bits transmitted.

On the receiver side of the sensor, the energy consumption E_{RS}

$$E_{RS} = n * E_{TC} \quad (3)$$

n- Number of bits received

Node's residual energy E_{RS},

$$E_{RE} = E_{IN} - (E_{TS} + E_{RS}) \quad (4)$$

E_{IN} – Initial energy of the node.

The residual energy is one of the important parameters in deciding on forwarded node selection to extend the node's life. When the nodes' residual energy grasps its threshold limit then it is permitted to perform its basic function and will not be involved in the routing path for transmission which helps the node to stay alive for some more rounds.

3.1.2 Link Quality

Link quality between sensors plays a vital role in achieving reliable data transfer. The link quality estimation is done by using physical layer metrics Received Signal Strength Indicator (RSSI) and Packet Received Ratio.

Received Signal Strength Indicator (RSSI) is the ratio of received signal power to transmitted signal power.

$$RSSI = 10\ log\frac{Received\ signal\ power}{Transmitted\ signal\ power} \quad (5)$$

Normalised Link Quality Estimation[31] is done by combining the Packet Received Ratio and Received Signal Strength indicator. PRR be determined by the strength of the signal received, interference level and decoding capability of the receiver.

$$\mathrm{LQI} = \mathrm{PRR} * (\mathrm{mean}\frac{\mathrm{RSSI}}{60} + \frac{100}{60}) \quad (6)$$

To make LQI values to be sturdy, several parameters representing the link quality are required. Basically, PRR is the most reliable parameter to represent the quality of the link but in the case of resource-constrained sensors where the links between those sensors would have the same PRR and different RSSI. Moreover, when PRR values are used in grading the link quality, they will vary frequently so it consumes more energy. In order to streamline sturdy LQI value, RSSI which can be computed quickly is also taken into account along with PRR.

PRR and normalized RSSI are combined to achieve a reliable transmission link with less computation.

3.1.3. *Data rate*

WBAN is equipped with heterogeneous sensors so the data rate varies from sensor to sensor. ECG sensor needs a high data rate compared to temperature sensors. A sensor that requires a high data rate is chosen because it transmits data faster and reduces the transmission time. The high data rate sensor will probably reduce the collision due to the shortest transmission time and the decreased collision will automatically reduce the retransmission. Hence the percentage of accurate data received is higher than the quantity of energy utilised [32] which helps to save more power in the whole network. Here data rate parameter is the final decision-making parameter if the other two parameters of the two links are the same.

The data rate of a few sensors is mentioned in *Table 1*.

Table 1. Sensor and its data rate

Sensor	Data Rate
Temperature Sensor	2.4 bps
Pulse rate sensor	48 bps
ECG sensor	18 Kbps
EEG sensor	10 Kbps
Blood pressure sensor	1.2Kbps
Glucose sensor	480bps
Motion sensor	4.8Kbps

3.2. Fuzzy inference system

A fuzzy Logic System has its primary work of making decisions more accurately by using a fuzzy inference system. It uses conditional rules “IF-THEN” along with logical operators “OR” or “AND” to make decision rules. Mandami Fuzzy inference system is used which takes in several inputs and produces one decision output by using fuzzy rules. The fuzzy inference system is segmented into three processes as given in *figure 2*.

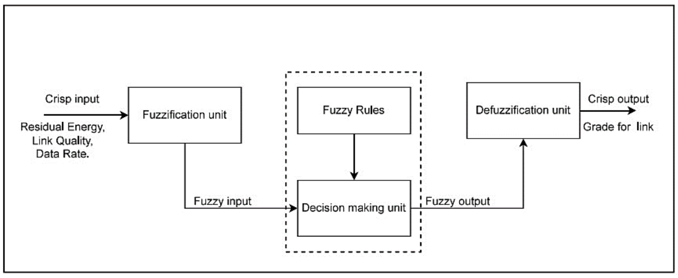

Figure 2. Fuzzy inference system

3.2.1. Fuzzification unit

Crisp inputs here including residual energy, link quality, and data rate are given to the fuzzification unit, which applies the membership function to map the crisp input to fuzzy input that lies between 0 and 1. Here range of the residual energy of the sensor is the crisp input that is considered to extend the sensor's lifetime. Link quality is considered to decide the path which leads to achieving reliable data transfer. In WBAN, the sensors involved are heterogeneous and have different processing capacities, data rates, and storage. When choosing a sensor that has a high data rate to transfer data its energy will be drained away very soon though it transmits data faster without delay. The mapping of crisp input to the fuzzy input is in *table 2*.

Table 2. Fuzzy input for routing parameters

Crisp input	Fuzzy input
Residual energy	Low, Medium, High
Link Quality	Poor, Satisfactory, Good
Data rate	Low, Medium, High

3.2.2. Decision-making unit

The decision-making unit in FIS makes use of rules that are predefined in the rule unit to decide on the input to generate a fuzzy output.

The proposed fuzzy logic for the selection of the best-forwarded node uses fuzzy logic that nonlinearly links the input to the scalar output. The fuzzy logic rulebooks are constructed using the residual energy of a node, node-to-node link quality and data rate of a node to select the best-forwarded node. The neighbour nodes are shortlisted based on the distances between the nodes. The prime conditions to select the best-forwarded node are,

- If the three parameters are high then the probability of that node being the best forwarded node is very high.
- If the residual energy and link quality of a node is high then probability of the node being the best forwarded node is very high.
- If the link quality and residual energy between two nodes are equal then the data rate of the node is taken as the deciding parameter to select the best one.

- If the node's residual energy is low then a node with a low data rate is the best choice.
- The high data rate node can be used when its residual energy is high.

The fuzzy rules based on which the decisions are taken are given in *table 3*.

Table 3. Fuzzy rule set for decision

Residual Energy	Link Quality	Data Rate	The grade for the link
Low	Poor	Low	Very low
Low	Satisfactory	Medium	Very low
Low	Good	High	Very low
Medium	Poor	Low	Low
Medium	Satisfactory	Medium	Good
Medium	Good	High	Good
High	Poor	Low	Low
High	Satisfactory	Medium	Very Good
High	Good	High	Very Good
High	Good	Low	Very Good

3.2.3. Defuzzification unit
The obtained fuzzy output is converted into crisp output. The obtained crisp output is the grade for each link and this grade decides the best link for transmission. *Table 4* represent the possibility of defuzzification output.

3.3. Proposed system
The proposed system consists of four phases 1. Initialisation phase, 2. Table updation phase, 3. Best Forward node selection phase, 4. Transmission phase.

3.3.1. Initialization phase
Individual node transfers a HELLO message to all neighbouring nodes at regular intervals. The packet contains node ID, residual energy$E_{RE,}$ data rate, and link quality. On receiving the packet, the neighbour node updates or creates its own Neighbour Node table. Each node periodically broadcasts its current status information and updates its path node table to guarantee an established connection between nodes. The initialization phase algorithm is below in *Algorithm 1*.

#Algorithm 1. Initialization phase

```
Input: Exchange of Hello message between      nodes
Output: Neighbour Node list for each node Start
      For i =1 (nodes)
           For j =1 (nodes)
     Calculate the distance (dij) between node i and all
       other nodes j;
                 If  dij < transmission range
                    L[]= node j ;
                  Else Reject the node ;
                 End If
      Create Neighbour Node List NLi for      each node
         in L[] ;
           End For
     EndFor
     End
 Start.
```

3.3.2. Table updation phase
When the node has to transfer the data before finding the best forward node, it has to update its Neighbour Node Table which helps in finding the next best forward node. All the neighbour nodes that are in the Neighbour Node table have to send their current residual energy, link quality and data rate. The table updation phase is given below in *Algorithm 2*.

#Algorithm 2. Neighbour node table updation

```
Input: Node i (has data to transfer) and its neighbour nodes in NLi
Output: Updation of Neighbour Node Table NLi of   Node i.
     Start
       For j=1 to len(L[])
         Calculate the residual energy of the nodes;
         Calculate link quality among node i & j
                Node j sends HELLO message HM j (node
          ID, Residual Energy, Link Quality, data rate) to node
          i;
               If(HMj(ID,RE,LQ,DR)==NNi(ID,
          RE,LQ,DR))
             discard HM j;
                Else   update   NNi(ID,   RE,LQ,DR)=
          HMj(ID,RE,LQ,DR) ;
            End If
     End For
     End Start.
```

3.3.3. Best forward node selection
The fuzzy Inference system is involved in the determination of the best-forwarded node by finding the cost for each node based on parameters like link quality, data rate, and residual energy. The selection of the best forward node is given below in *Algorithm 3*.

 # Algorithm 3. Selection of best forward node

```
Input: Residual energy, Link quality, data rate, distance dij of all
 nodes
Output: grade of the link
Start
   fuzzification maps crisp input to fuzzy input;
   decision-making unit makes decisions based on rules;
   defuzzification unit converts fuzzy output to crisp output;
End Start.
```

3.3.4. Transmission phase
After choosing the forward node, data are transmitted through it. The node transmits its data to the best forward node and the next subsequent forward nodes are discovered until it reaches the sink node. The transmission phase is given below in *Algorithm 4*.

#Algorithm 4. Data transmission

```
Input: Best forward node
Output: data transmission
Start
    The best forward node is obtained;
    Node i transmits the data;
  If the best forward node is not a Sink node, then
        Go to the Table updation phase;
  Else end transmission;
  End If
  End Start
```

4. RESULT AND DISCUSSION

We used an NS3 stimulator to make a WBAN environment to evaluate the efficiency. It explores the efficiency of the proposed system and results are compared with the existing two fuzzy logic-based forwarded node selections which use different parameters as the modelled parameter. *Table 4* below discusses/compares the existing and proposed system with their methodology, contribution and limitations.

Table 4. Fuzzy input for routing parameters

Protocols	Objective	Modelled Parameters	Contribution	Limitation
FLGR [16]	To design geographic routing protocol using fuzzy logic.	Distance between the nodes, density and degree of distribution of the nodes.	Fewer hops, higher packet delivery rate and reduced rate of routing failure.	Additional routing overhead.
OFSR [24]	An optimized fuzzy-logic swarm routing.	Energy consumption, average delay and link quality.	Enhances the network lifetime, minimises link and node failure.	Computation overhead.
EARP [23]	To design fuzzy logic-based energy-aware protocol.	Link quality, hop count and residual energy.	Expands life time of the network and increases reliability.	Green energy technology for energy efficiency.
DTS [18]	To design Minimum cost parent selection, link cost function for routing and dynamic time slot allocation using fuzzy logic.	Packet interval, available buffer size, and remaining energy of sensors.	Reduces response time and transmission error, and reduces waiting time of the packet.	Additional network delay due to network dependability and channel utilization
ENS [20]	To design a link cost function for the selection of the best forwarded.	Link utilization, link reliability, residual energy and latency.	Improves power efficiency and packet delivery ratio.	Link quality estimation is unstable
MHR [25]	To design an energy-efficient multi-hop routing protocol using fuzzy logic.	Residual energy of the node.	Prolongs the lifetime of sensors in WBAN.	Implementing to handle real-time data is limited.
Proposed	To design forward node selection by evaluating link quality using fuzzy logic.	Residual energy, link quality, data rate, node-to-node distance.	Enhances the network lifetime, increases the packet delivery ratio, no computation overhead.	Network stability enhancement.

4.1 Packet delivery ratio

It is a metric to measure reliability and it is the total amount of packets reached at the receiver side divided by the total amount of packets transmitted from the transmitter side. Selecting the best forward node will improve the packet delivery ratio. In the proposed system, link quality, data rate and residual energy are used as modelled parameters in fuzzy logic with minimum computation to estimate the best-forwarded node. The link quality is estimated by combining RSSI and PRR which guarantee the estimation of link quality accurately. Compared to existing DTS and EARP, the proposed system has a high packet delivery ratio even after dead of some nodes, because the link quality will be estimated accurately with the available nodes and the data rate of a node also has a critical role in choosing the best forwarded node. In EARP, link quality is calculated using RSSI value alone which does not guarantee the quality of the link in all situations [33] whereas in DTS the link quality cost function calculates the quality of the link using the number of successful transmissions using that link. This factor would not guarantee the accuracy of the quality of the link between the heterogeneous nodes in all situations. After many rounds the energy of the sensors will deplete so there will be a decrease in the quantity of alive nodes. A comparison of the packet delivery ratio of the existing algorithm DTS and EARP with proposed system using parameters as the number of dead nodes and packet delivery ratio is shown in *figure 3*.

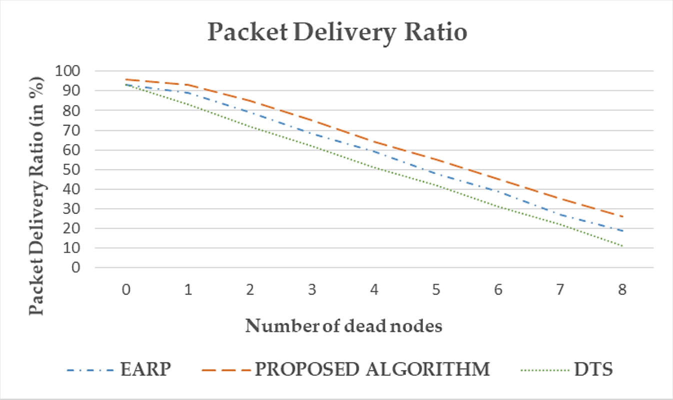

Figure 3. Packet Delivery Ratio

4.2 Network Lifetime

It is another important metric of reliability and it is a measure of the amount of duration all the nodes are alive. By selecting the best route for data transmission with less computation, the network lifetime can be increased. The node's residual energy is considered in determining the forwarded node for data transmission. After some rounds, the energy of the node will deplete and lead to an increase in dead nodes. In the proposed system after completion of 5300 rounds, only the first dead node appears while in DTS and EARP it occurs after 5200 and 5030 rounds respectively. *Figure 4* Network Lifetime represent the comparison of existing algorithms DTS, EARP and the proposed system by using parameter number of rounds and number of dead nodes.

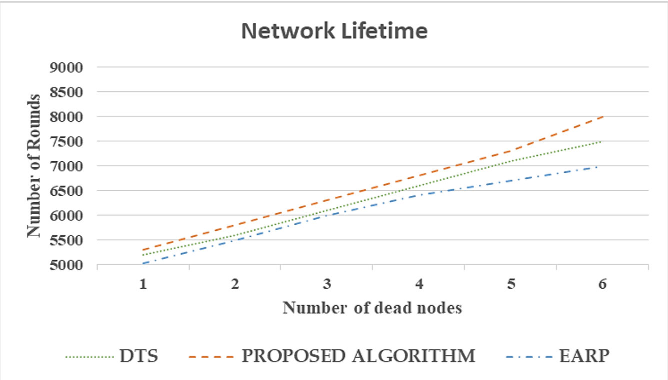

Figure 4. Network Lifetime

5. CONCLUSION AND FUTURE ENHANCEMENT

The proposed system helps in selecting the best-forward node by establishing fuzzy logic on link quality, data rate, residual energy of nodes and node-node distance. Parameter data rate ensures a decrease in delay, link quality and node-node distance ensure reliability and residual energy ensures the network lifetime. The performance is evaluated by comparing the proposed system with existing DTS and EARP protocols. It provides an energy-efficient reliable WBAN by increasing packet delivery ratio and network lifetime. The future enhancement will be parameter optimization to further enhance the stability of the network.

REFERENCES

[1] T. Watteyne, I. Augé-Blum, M. Dohler, and D. Barthel, "AnyBody: A self-organization protocol for Body Area Networks," BODYNETS 2007 - 2nd Int. ICST Conf. Body Area Networks, 2007, doi: 10.4108/bodynets.2007.186.

[2] Z. Ullah, I. Ahmed, K. Razzaq, M. K. Naseer, and N. Ahmed, "DSCB: Dual sink approach using clustering in body area network," Peer-to-Peer Netw. Appl., vol. 12, no. 2, pp. 357–370, 2019, doi: 10.1007/s12083-017-0587-z.

[3] B. Abidi, A. Jilbab, and E. H. Mohamed, "An energy efficiency routing protocol for wireless body area networks," J. Med. Eng. Technol., vol. 42, no. 4, pp. 290–297, 2018, doi: 10.1080/03091902.2018.1483440.

[4] Q. Tang, N. Tummala, S. K. S. Gupta, and L. Schwiebert, "TARA: Thermal-Aware Routing Algorithm for implanted sensor networks," Lect. Notes Comput. Sci., vol. 3560, pp. 206–217, 2005, doi: 10.1007/11502593_17.

[5] A. Bag and M. A. Bassiouni, "Energy efficient thermal aware routing algorithms for embedded biomedical sensor networks," 2006 IEEE Int. Conf. Mob. Ad Hoc Sens. Syst. MASS, vol. 1, pp. 604–609, 2006, doi: 10.1109/MOBHOC.2006.278619.

[6] D. Takahashi, Y. Xiao, and F. Hu, "LTRT: Least total-route temperature routing for embedded biomedical sensor networks," GLOBECOM - IEEE Glob. Telecommun. Conf., pp. 641–645, 2007, doi: 10.1109/GLOCOM.2007.125.

[7] A. Bag and M. A. Bassiouni, "Hotspot Preventing Routing algorithm for delay-sensitive applications of in vivo biomedical sensor networks," Inf. Fusion, vol. 9, no. 3, pp. 389–398, 2008, doi: 10.1016/j.inffus.2007.02.001.

[8] M. Tabandeh, M. Jahed, F. Ahourai, and S. Moradi, "A thermal-aware shortest hop routing algorithm for in vivo biomedical sensor networks," ITNG 2009 - 6th Int. Conf. Inf. Technol. New Gener., pp. 1612–1613, 2009, doi: 10.1109/ITNG.2009.274.

[9] A. R. Bhangwar, P. Kumar, A. Ahmed, and M. I. Channa, "Trust and Thermal Aware Routing Protocol (TTRP) for Wireless Body Area Networks," Wirel. Pers. Commun., vol. 97, no. 1, pp. 349–364, 2017, doi: 10.1007/s11277-017-4508-5.

[10] M. M. Monowar and F. Bajaber, "Towards Differentiated Rate Control for Congestion and Hotspot Avoidance in Implantable Wireless Body Area Networks," IEEE Access, vol. 5, pp. 10209–10221, 2017, doi: 10.1109/ACCESS.2017.2708760.

[11] K. Karmakar, S. Biswas, and S. Neogy, "MHRP: A novel mobility handling routing protocol in Wireless Body Area Network," Proc. 2017 Int. Conf. Wirel. Commun. Signal Process. Networking, WiSPNET 2017, vol. 2018-Janua, pp. 1939–1945, 2017, doi: 10.1109/WiSPNET.2017.8300099.

[12] A. Samanta and S. Misra, "Energy-Efficient and Distributed Network Management Cost Minimization in Opportunistic Wireless Body Area Networks," IEEE Trans. Mob. Comput., vol. 17, no. 2, pp. 376–389, 2018, doi: 10.1109/TMC.2017.2708713.

[13] R. Goyal, R. B. Patel, H. S. Bhaduria, and D. Prasad, "An Efficient Data Delivery Scheme in WBAN to Deal with Shadow Effect due to Postural Mobility," Wirel. Pers. Commun., vol. 117, no. 1, pp. 129–149, 2021, doi: 10.1007/s11277-019-06997-5.

[14] M. Anand Kumar and C. Vidya Raj, "On designing lightweight QoS routing protocol for delay-sensitive wireless body area networks," 2017 Int. Conf. Adv. Comput. Commun. Informatics, ICACCI 2017, vol. 2017-Janua, pp. 740–744, 2017, doi: 10.1109/ICACCI.2017.8125930.

[15] S. Vetale and A. V. Vidhate, "Hybrid data-centric routing protocol of wireless body area network," Int. Conf. Adv. Comput. Commun. Control 2017, ICAC3 2017, vol. 2018-Janua, pp. 1–7, 2017, doi: 10.1109/ICAC3.2017.8318793.

[16] X. Hu, L. Ma, Y. Ding, J. Xu, Y. Li, and S. Ma, "Fuzzy logic-based geographic routing protocol for dynamic wireless sensor networks," Sensors (Switzerland), vol. 19, no. 1, 2019, doi: 10.3390/s19010196.

International Journal of
Electrical and Electronics Research (IJEER)
Research Article | Volume 12, Issue 2 | Pages 512-519 | e-ISSN: 2347-470X

[17] D. Javaheri, P. Lalbakhsh, S. Gorgin, J. A. Lee, and M. Masdari, "A new energy-efficient and temperature-aware routing protocol based on fuzzy logic for multi-WBANs," Ad Hoc Networks, vol. 139, no. December 2023, pp. 0–27, 2023, doi: 10.1016/j.adhoc.2022.103042.
[18] S. Pushpan and B. Velusamy, "Fuzzy-based dynamic time slot allocation for wireless body area networks," Sensors (Switzerland), vol. 19, no. 9, 2019, doi: 10.3390/s19092112.
[19] R. Dass, M. Narayanan, G. Ananthakrishnan, and T. K. Murugan, "A Cluster- Based Energy- Efficient Secure Optimal Path-Routing Protocol for Wireless Body-Area Sensor Networks," Sensors, vol. 23, no. 14, 2023.
[20] M. Saini and G. Pandove, "A Research Article on Efficient Next-Node Selection Algorithm for WBAN by Using Fuzzy Logic," Int. J. Comput. Intell. Res., vol. 13, no. 8, pp. 1977–1990, 2017.
[21] R. Praveenkumar, Kirthika, D. Arumugam, and Dinesh, "Hybridization of Machine Learning Techniques for WSN Optimal Cluster Head Selection," Int. J. Electr. Electron. Res., vol. 11, no. 2, pp. 426–433, 2023, doi: 10.37391/IJEER.110224.
[22] R. Praveen Kumar, J. S. Raj, and S. Smys, "Performance Analysis of Hybrid Optimization Algorithm for Virtual Head Selection in Wireless Sensor Networks," Wirel. Pers. Commun., vol. 123, no. 2, pp. 1925–1940, 2022, doi: 10.1007/s11277-021-09222-4.
[23] X. Wang, G. Zheng, H. Ma, W. Bai, H. Wu, and B. Ji, "Fuzzy Control-Based Energy-Aware Routing Protocol for Wireless Body Area Networks," J. Sensors, vol. 2021, 2021, doi: 10.1155/2021/8830153.
[24] C. Gomathi and N. Santhiyakumari, "OFSR: An Optimized Fuzzy Based Swarm Routing for Wireless Body Area Networks," 3rd Int. Conf. Signal Process. Integr. Networks, SPIN 2016, pp. 507–512, 2016, doi: 10.1109/SPIN.2016.7566748.
[25] S. R. Chavva and R. S. Sangam, "An energy-efficient multi-hop routing protocol for health monitoring in wireless body area networks," Netw. Model. Anal. Heal. Informatics Bioinforma., vol. 8, no. 1, 2019, doi: 10.1007/s13721-019-0201-9.
[26] H. Esmaeili and B. Minaei Bidgoli, "EMRP: Evolutionary-based multi-hop routing protocol for wireless body area networks," AEU - Int. J. Electron. Commun., vol. 93, pp. 63–74, 2018, doi: 10.1016/j.aeue.2018.06.003.
[27] J. D. Rao and K. Sridevi, "Novel security system for wireless body area networks based on fuzzy logic and trust factor considering residual energy," Mater. Today Proc., vol. 45, no. xxxx, pp. 1498–1501, 2021, doi: 10.1016/j.matpr.2020.07.632.
[28] N. Bilandi, H. K. Verma, and R. Dhir, "Energy-efficient relay node selection scheme for sustainable wireless body area networks," Sustain. Comput. Informatics Syst., vol. 30, no. January, p. 100516, 2021, doi: 10.1016/j.suscom.2021.100516.
[29] K. Das, R. Ray, and S. Moulik, "Optimal relaying nodes selection for IEEE 802.15.6-based two-hop star topology WBAN," Internet of Things (Netherlands), vol. 22, no. October 2022, p. 100740, 2023, doi: 10.1016/j.iot.2023.100740.
[30] S. R. Chavva, A. Vijayaraj, E. Venkata Pavan Kumar, R. Ganesh Kumar, and S. Teja, "Hybrid Hierarchical Fuzzy Inference System to Improve Network Lifetime of WBANs for Health Monitoring," 2023 Int. Conf. Comput. Commun. Informatics, ICCCI 2023, pp. 1–6, 2023, doi: 10.1109/ICCCI56745.2023.10128507.
[31] M. Rondinone, J. Ansari, J. Riihijärvi, and P. Mähönen, "Designing a reliable and stable link quality metric for wireless sensor networks," REALWSN 2008 - Proc. 2008 Work. Real-World Wirel. Sens. Networks, pp. 6–10, 2008, doi: 10.1145/1435473.1435476.
[32] A. H. Sodhro, L. Chen, A. Sekhari, Y. Ouzrout, and W. Wu, "Energy efficiency comparison between data rate control and transmission power control algorithms for wireless body sensor networks," Int. J. Distrib. Sens. Networks, vol. 14, no. 1, 2018, doi: 10.1177/1550147717750030.
[33] K. Srinivasan and P. Levis, "RSSI is Under Appreciated," Proc. Third Work. Embed. Networked Sensors, vol. 3031, p. 239242, 2006, [Online]. Available: http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:RSSI+is+Under+Appreciated#0