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RESEARCH ARTICLE

A Novel Agent-Based Multipath Routing Protocol to Extend Lifetime and Enhancing Reliability of Clustered Wireless Sensor Networks

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Abstract – Over the clustered wireless network systems, development in wireless technology has had a more substantial influence. Entities need to communicate with one another in order to create a sustainable ecosystem. Clustering methods help connect and organise the sensor nodes by load balancing and extending the network lifetime. Only now, various techniques have been developed for solving routing problems but have yet to focus on routing reliability with avoidance of data collision in real scenarios. This research is carried out for the reliability of routing by multi-objective optimization in static and dynamic environments through agent-based analysis with avoidance of data collision and depletion of energy. This study introduces a fuzzy-based multipath clustering technique that exhibits both static and dynamic clustering formation properties. The designated region starts the clustering process once the sensor nodes are ready to begin the data transmission procedure. The proposed technique works in two steps: a) fuzzy cluster head selection; and b) multi-objective agent-based multipath routing protocols for shortest route path discovery. The enhancement made in cluster creation and selection is the critical feature. A well-organized sensor ecosystem has lessened the negative impacts of network collision and energy exhaustion. The packet delivery ratio, communication overhead, and energy consumption are the performance metrics examined when simulating the specified protocol using the computer language NS2. The devised fuzzy-based multi-path routing (FC-MRP) clustering technique outperforms the AODV (Ad-hoc on-demand distance vector routing) protocol, according to the results. The average percentage of improvement concerning PDR, Throughput, end-to-end latency, Overhead, Energy utilised, Energy efficiency, Network lifetime, and PLR is found to be +2.53, +2.23, -18.58, -22.46, -17.95, +23.00, +4.11, -18.09 respectively.

Index Terms – Clustering Approach, Multi-Objective Optimization, Fuzzy Logic System, Routing Protocols and Multipath Agents, FC-MRP, AODV.

1. INTRODUCTION

Many real-time applications, including the military, the air force, etc., have been impressed by current research in Wireless Sensor Networks (WSNs) technology. A wireless sensor network generally transmits and receives data using radio frequency [1]. It significantly decreased the requirement for wired connectivity. Hop radio relays function without an infrastructure. Contrarily, in the case of dispersed mode, the sink will assist in coordinating for the sake of data transfer. Despite the availability of a variety of information services, WSNs guarantee accurate data exchange by localising in time and place in response to user demand. A typical WSN [2] functions well under specific resource limitations. Energy efficiency is not managed since the sensor nodes are dispersed. Based on its capabilities for computing and communication, each sensor node in the sensing field makes a judgment. The node gathers and transmits the data to its other node in the network with the aid of a base station. As a result, the designated area network becomes overcrowded [3]. Clustering techniques are used in WSNs to address concerns

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with availability, network scalability, and, most importantly, network congestion avoidance [4]. Clustering methods in WSNs provide a number of benefits that guarantee decreased installation costs, support for distant communication, simple usage of new data sources, and improved accuracy. Instead of being time-driven, most wireless networks are event-driven [5]. Event-driven models can occasionally perform monitoring services inefficiently. Information-transmitting services benefit from the use of localization techniques.

1.1. Problem Statement

Development and implementation of an agent-based approach with fuzzy min-max clustering with optimal multipath routing through multi- objective optimization to improve the reliability and sensor network lifetime.

1.2. Contributions of the Proposed Work

The important contributions of this study are:

- To explore the scope of the clustering approach in Wireless Sensor Networks (WSNs).
- The fundamental plan is to lessen the workload of nodes by employing a clustering approach and multipath routing protocols.
- The process involved in selecting cluster heads looks for optimal routes with unlimited resources at the base station.
- The routing protocols' design is resilient toward frequent paths, and thus, the reliability of the routing protocol is ensured by the multi-objective optimization models.

The organization of the present research is as follows: Section 1 briefly discusses introduction to the research with the objective and contributions of the study. Section 2 represents related work that discusses the results of the existing method and research gap with motivation and organization of the study. Section 3 provides the research of this model. Section 4 depicts the implementation output and Discussion, describing the achieved performance using the proposed techniques. Section 5 concludes the research, discusses the present study's analysis, and shows the comparative results.

2. RELATED WORK

An overview of the current methodologies used in this research study is presented in this section. The two primary performance metrics that govern clustering wireless sensor networks are reliability and network longevity [6]. During communication the data size, sink nodes use more energy. In the observation, it is seen that, the AODV and DSR protocols outperformed the TORA in terms of throughput, overheads, and latency. Adding more sensor nodes to the architecture has decreased performance while extending the network lifespan. In large coverage [7] networks, getting to the base station has become reasonably challenging. Under energy metrics, the link aspect between the nodes was effectively managed. The recommended method has a 75% greater network lifespan than SPT and DCT. In [8] explored an energy-efficient LEACH approach to increase the residual energy. Every sensor node that has been installed was projected into a clustering procedure. Resources are optimized according to cluster chiefs' instructions. Although the energy used rate has reduced, the clustering method does not investigate the traffic flow between the sensors.

Multi-objective functions established Quality of Service (QoS) [9]. Here, geographic-based routing models were used to develop heuristic-based neighbour selection models. It used the metrics for distance, delay, and path to find the best routing path. Even though it has dramatically decreased network usage, network congestion has worsened. [10] Presented several offloading computational techniques to make the most of route-discovery processes for topology construction. While determining the routes, cluster head selection takes more time. Over time, it acquires a protocol overhead. As a result, various non-deterministic clustering-based routing protocols were created [11]. The PSO protocol was created to increase network scalability and CH lifespan. The system has decreased the cluster head, making it impossible to study the connection quality of networks.

More number of sink deployment technique.[12] was recommended for encoding the particles and assessing fitness with the PSO as a baseline. Depending on the hop count, the multiple hop count was used for energy-efficient systems. Heuristics models were employed to determine the minor sink consumption because the sink's position has drastically reduced energy availability. Then, a technique called Enhanced PSO-Based Clustering Energy Optimization (EPSO-CEO) was proposed for enhancement of existing local searching algorithms for CH selection [13]. Multi-hop routing systems increase the sensor lifetime and reduce energy utilisation.The mechanisms for gathering and aggregating data need to be improved. Multi-hop routing methods based on delay were developed by [14]. Here, probability-blocking techniques were used to improvise an end-to-end delay. Relay nodes were given different numerical models to use, which decreased the end-to-end delay. The likelihood of the hop count increases in small-scale networks despite enhanced QoS models.

Different scholars looked at various optimization approaches. An alternative numerical solution was recommended since the transmission/consumption of energy [15] is still a complex problem. The clustering speed, hop-count, and transmission nodes were used to choose the cluster head. Mechanisms for cluster communication were devised for cluster-based aggregation. To lessen the congestion close to cluster nodes,

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network overloads [16] were reformulated. However, there needs to be a clear definition of removing the cluster head nodes—the location of the sink nodes allowed for the modification of the energy consumption rate. The ring routing protocols' introduction helped lower the mobile sinks' overhead.

On small-scale networks, the system has boosted the packet delivery rate. Genetic algorithms [17] were researched for network lifespan augmentation and cost minimization along with similar goals. A system known as Genetic Algorithm based energy efficient Clustering Hierarchy (GAECH) was developed taking into account three factors: First Node Die (FND), Half Node Die (HND), and Last Node Die (LND). The node's life and stability were increased since the anticipated fitness function made sure a balanced cluster formed. The degree of a node may also have an unintended effect on how well the network lasts over time. In virtual networks, wireless connectivity is essential for cluster head creation. The correct use of the cluster head selection has been investigated by deploying a Weakly Connected Dominating Set (WCDS) [18].

In this study, load balancing and the network edge were enhanced. Regardless of node size, the technology has improved cluster head usage. Similar strategies were investigated in game theory technique [19]. In order to solve the issues of throughput rate, latency, and energy consumption, the majority of routing protocols were developed. Game theory was applied in conjunction with this to increase the packet delivery rate. They are using hierarchical routing technologies to optimize the route construction time continuously. The multi-objective-oriented decision-making process is not focused even if packet delivery has enhanced. IoT applications that use wireless networks are very prevalent. The clustering technique has once again been encouraged by the Internet of Things. It was investigated using LEACH protocol [20] and showed a 60% improvement in throughput, overhead, network time, and remaining energy. In a similar vein, the Energy Efficient Clustering routing protocol (GEEC), which is based on game theory [21], was created for energy efficiency and longevity without sacrificing wireless networks' QoS. With improved cluster forming, topology formation has overcome the energy replenishment problem. Evolutionary game models have produced better control messages due to the nodes' behaviour being considerably identified.

Cluster member nodes having smaller size control frames, a Data Aggregation technique for energy efficient Clustered Wireless Sensor Networks (EEDAC-WSN) was created [22]. The member nodes of the network are effectively communicated with by keeping track of the node's stability. The recommended methods have reduced the delay rate even for network of small and large compared to the LEACH protocol. Induction trees in hierarchically based clustering have been studied in order to overcome the inference problems during induced tree construction. [23]. The Induced Tree of the Crossed Cube was constructed using the degree of the network nodes as a base (ITCC).It was acknowledged that the Voronoi cell had kept track of the node's actions. Despite its promise of a lower latency rate, more relay nodes are being used. A clustering approach is used to convert the information because the WSNs are decentralized. The WEMER protocol addressed the sensor node's increased energy consumption during the clustering-based communication process [24, 25]. Although the focus was on improving the gateway nodes, there was not much congestion between those nodes. The approach described in [26, 27] employs a fuzzy method that is particularly effective in real-time application, can handle dynamic scenarios, and models intrinsically inaccurate conditions.

In the QoS-limited scenario, in order to provide the best possible paths for data transfer [28], the author has introduced an efficient QoS-aware cluster protocol called QoS-CR. The suggested paradigm runs through three key phases. After the nodes have been deployed and started, the FBC process is run to cluster the nodes and choose the CH. Then, the FF-L method is used to identify the best routes from sources to destinations. Then, in order to evenly balance the network's load and energy consumption, the maintenance stage is initiated. This study has not included fault tolerance and security. In [29], this research suggests and implements the FAJIT algorithm for single-sink networks. When a packet is sent out, a different parent should be chosen. Depending on the kind of packet, the parent is chosen. In comparison to DICA and its extension. In [30], the author suggested a distributed clustering routing protocol named DAPFL that considers energy efficiency and energy balance to increase network lifetime. The findings demonstrate that DAPFL displays excellent output in case of energy consumption, residual energy, throughput, and longevity. Here fault-tolerant and security has not been considered. In [31] the network management architecture is designed using a cluster tree, and this research effort proposed a fuzzy-GWO technique and opportunistic routing algorithm. This study focuses mainly on PDR, throughput and low energy consume by using buffer. It consumes some extra energy consumption by using buffer.

Reviewing the aforementioned recent research has led to the conclusion that energy efficiency has been the main emphasis of most investigations. However, approaches are still required for traffic analysis in static and dynamic scenarios with avoidance of data collision and energy loss. So, this research is carried out to overcome the issues of over-energy utilization by nodes while obtaining the neighbour information. Significant improvements are observed concerning evaluation parameters.

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3. RESEARCH METHODOLOGY

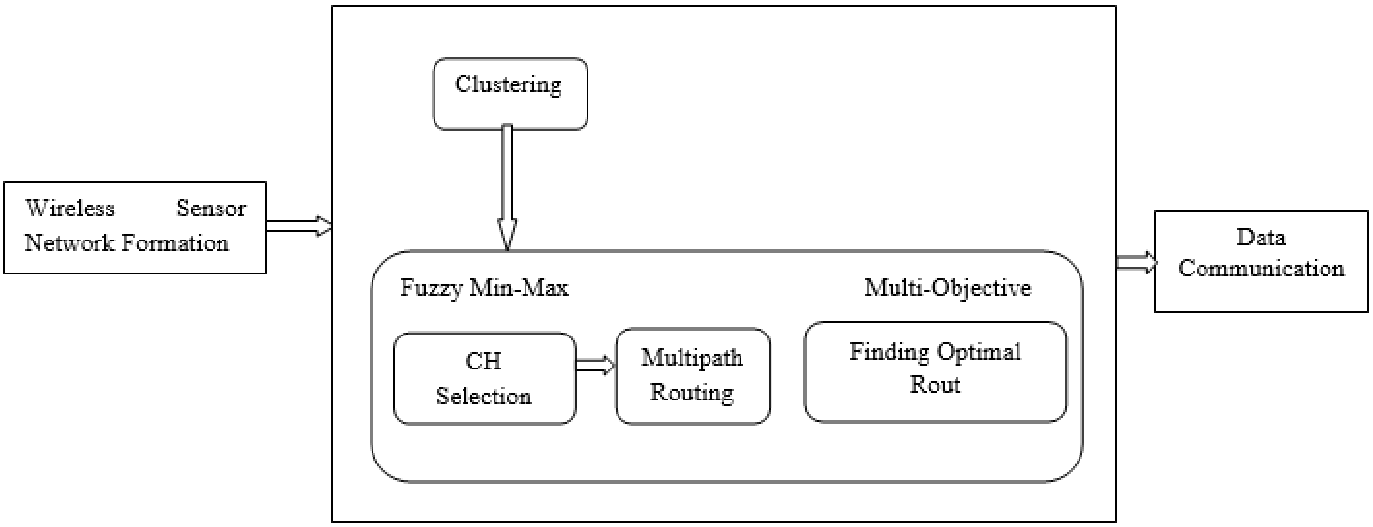

Figure 1 Architecture Diagram of the Proposed System

This study introduces a novel agent-based multipath routing protocol for the clustered wireless environment. In order to enhance the reliability of the wireless networks, the clustering approach is designed. Simultaneously, it reduces the energy utilization and enhance network's lifetime. The incremental steps followed in developing and performing the research are given below:

Step 1: Initially, Network formation will be done with the node size, position and number of nodes to be considered.

Step 2: Once the nodes are created, the transmission path has to be formulated by considering shortest path between the sender and receiver.

Step 3: For the above process, we incorporated advanced fuzzy based clustering approach to cluster the nodes into various groups. Here we employ agent based approach in order to overcome the issues of over energy utilization by nodes in finding out the neighbour information's.

Step 4: Each cluster will be assigned with a cluster head (CH) for which the agent nodes are assigned. Here two agents will be created for the whole network. One is node selection agent and other is path selection agent.

Step 5: By employing the agent based clustering approach; the data collision and energy losses can be avoided to greater extend thereby improving the network/node lifetime.

Step 6: We employ energy efficient routing protocol in proposed scheme for proper utilization of resources. Path selection agent is responsible for finding out or suggesting new optimal paths through which the data transmission will be carried out.

Step 7: In this proposed approach, we design an enhanced optimal routing protocol wherein we integrate optimization algorithm for effective routing process. Path finding usually requires various parameters like energy, channel usage has to be enhanced and distance, energy utilization, number of hop has to be reduced. For this we consider multi-objective optimization algorithms which select the nodes and path based on the objective functionality.

Step 8: Finally performance metrics are estimated to show the performance improvement of proposed approach over existing methods.

The proposed objectives, reliability, and network lifetime are achieved, and the phases are explained as follows:

3.1. System Network Formulation

The larger sensor network associated with the transmission link within the specified coverage is collectively known as 'Wireless Sensor Networks (WSNs).' To begin the node exploration process, it is randomly distributed over the wireless network environment. The modeled network is projected in the graphical structure G (V, E) where sensor nodes$V = \{v_1, v_2, \ldots, v_n\}$. The deployed sensor nodes are enabled with the maximum transmission covrage of R; thus, E is the edge (link) that connects the sensor nodes. Since we have utilized a bidirectional link between the sensor nodes, the distance value plays a vital role. The network system consists of sensor nodes and the base station with available memory, computation, and energy rate. Initially, all energy levels of the sensor nodes are predefined and maintained adequately. The threshold value is defined as 35% of the initial energy.

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3.2. Fuzzy-Based Clustered Multipath Routing Protocols (FC-MRP)

Here, Fuzzy-based Clustered Multipath Routing Protocols is designed for an efficient transmission process. It is achieved by finding the shortest paths via a clustering approach. The steps involved in the proposed FC-MRP are presented as follows:

3.2.1. Discovery of Neighbouring Nodes and the Topology

In order to ease the transmission process, the sender node, receiver node, and their neighbouring nodes are discovered. The node is randomly selected for transmission purposes. Initially, the packets are broadcasted to a group of sensor nodes. The scattered nodes are formed in accordance with the set of nodes that acknowledge the broadcasted packets. The multicasting techniques are followed to collect the neighbouring data. The less energy spent on computation, the lifetime of the nodes is increased. Each sensor node shares the energy with its selected neighbouring nodes. The energy limit of the deployed nodes is measured and expressed in equation (1).

$$E_{energy} = \frac{\sum_{j=1}^{n} S_j E_r}{\text{nb}} \tag{1}$$

Where,

S_j = current sensor node.

E_r = energy of the remaining nodes.

Nb= the count of neighbours.

The cluster size is determined from the communication distance and remaining energy of the network. The nearer nodes are selected for the transmission system.

3.2.2. Formation of Clusters

Within the time frame and the distance, values are encountered to cluster the deployed sensor nodes. The deployed sensor nodes select the Cluster Head (CH) according to the energy parameter. It aids data aggregation, agglomeration, and communication to the sink nodes. This uses the sensor nodes' hierarchical structure. Additionally, it diversifies the cluster chiefs and member nodes. The cluster size and number, algorithm complexity, overlapping, relay overhead between clusters, and routing regulations are other clustering characteristics.

3.2.3. Cluster Head Selection

The cluster head is elected by incorporating a fuzzy clustering technique. Clusters selection is determined by two approaches as explained below.

i) Measures of validity: Most data in the partitioning space is represented as scalar indices. In order to achieve appropriate clusters, the clustering algorithm searches for the goodness of fit. It is a rule that the clustering number and the data group must be equal to eliminate the misclassification rate. If the error rate i.e., misclassification, is high, then the cluster number is rearranged. It defines the linear separation of the data and the handling procedures of those data in a hyper plane.

ii) Merging (or) insertion of clusters: The objective is that when the merging of clusters brings several changes to the defined criteria on accurate data, it is further adopted for the consecutive steps of the data grouping process. Likewise, if the insertion of a cluster brings changes to the already defined criteria for accurate data, it is also adopted for enhancing the lowest data points.

3.2.3.1. Component of Fuzziness

The component of fuzziness m in the partitioning space is essential. When the data points of a component approach infinity, the data points are entirely fuzzy, i.e., all the mean values of the clusters belong to the total mean value of all data points in the database.

3.2.3.2. Stopping Criterion

When the same cluster is determined, the stopping criterion will stop the database operation. Here, the normalization between two clusters has reached successive steps before the stopping criterion. It has reduced computational time.

3.2.3.3. Constructing the Partitioning Space into a Matrix

Distance analysis among the data points will ensure the shape of the clusters. It assists us in finding outliers data points.

Algorithm 1 shows the algorithm for initialization of sensor nodes

---

Void time_synchronization ();

int nodes =0;

If (receive (h1)) {flag=1}

Else if (receive (h2))

{

/∗estimate the distance between the sink and itself.

The boundary between the two ray ground and free space models is at d0.

The received signal intensity at the sink node and this node is represented by RSSI (Cluster head) and RSSI (Cluster member).

$$E_{energy} = \frac{\sum_{j=1}^{n} S_j E_r}{\text{nb}}$$

If (flag!=1) broadcast(grads);

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```
}
/*X and Y are the boundaries of the deployment area*/
```

Algorithm 1 Initialization of the Sensor Nodes

3.3. Multi-Objective Optimization Strategy

Here, the clustered wireless network environment is further devised to derive an optimal routing path. Multi-objective optimization models develop a set of non-dominated solutions, and the quality measurement is tedious. Several communication factors have been introduced to measure the quality of the results. Algorithm 2 depicts the algorithm for fuzzy cluster based multipath routing protocol.

```
Thresh ← Current round's threshold
StateNode == Random (Plain node)
Cluster = 0
 For every node
      temporary_random= random (0,1)
       If temporary_random < Thresh then
              StateNode is CH
              Cluster = cluster +1
              Broadcast CH  data packet (ID)
          Endif
End for
  Receive ( )
     All CH data packet
For each sensor  node(p)
       If State Node=Plain node then
              Channel fuzzy (distance(S), 1)=0
          For each cluster head CH(q)
     Receive energy, sink, and CH distances, respectively.
    Utilize fuzzy IF-THEN mapping rules to evaluate the fuzzy value.
 Fuzzy membership (q,1)= Fuzzy value
          End for
    buffer= max(fuzzy value)
    id1= search (fuzzy value== buffer)
    node(p). CH_ID= id1;
  End if
End for
 For each  sensor node(p)
   For each cluster head CH(q)
              If CH_ID= node(p). CH_ID
          Transmit  CH link packet(ID)
          Add node_ID to the CH list
Endif
End for
End for
```

Algorithm 2 Fuzzy-cluster-based Multipath Routing Protocols

4. RESULTS AND DISCUSSION

The experimental examination of the suggested approach is presented in this part. The Network Simulator (NS2) tool simulates the suggested technique. The simulation study of multi-agent-based routing protocols in a WSN context is shown in Table 1.

Table 1 Implementation Parameters

Parameters	Ranges
Medium Used	Wireless Sensor
Communication Model	Bidirectional
Network Layer	Physical & Data link layer
Sensing coverage Area (M)	500 * 500
Data Size	5000 ifq
NetworkRouting protocol	AODV,Agent-based optimal routing protocols
Total sensor nodes	100
Simulation time	15 sec

The figure 2 presents the initialization of the sensor nodes. Here, the sensor environment is formed up of 100 nodes, which is identified as S1, S2 ...Sn. The sensor nodes are randomly placed; thus, a random location data is collected.

Figure 3 presents the message dissemination process. Once the sensor network formed, the Euclidean distance between the sensor nodes are calculated. The similar distance values are grouped together and then the cluster head is elected using fuzzy logic approach. According to the energy properties, the optimal route paths are collected.

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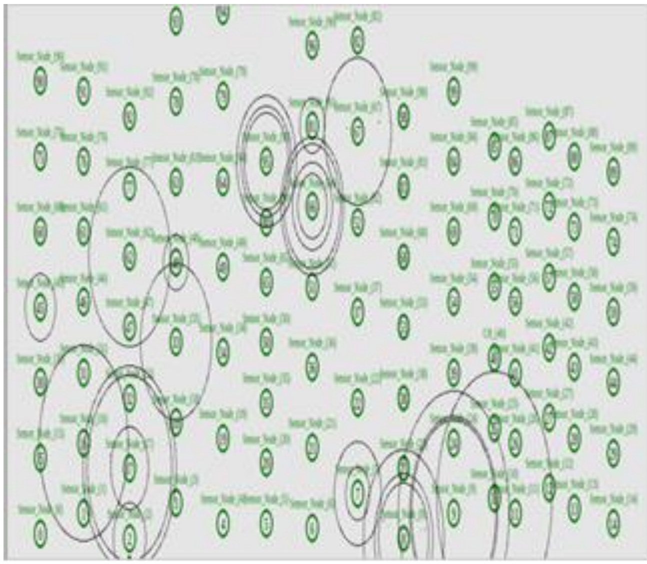

Figure 2 Initializing the Sensor Nodes

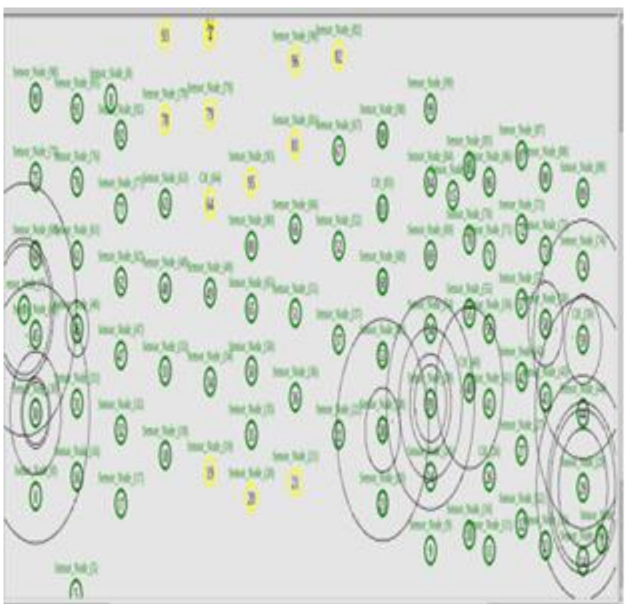

Figure 3 Request Message Forward to the Neighbors

4.1. Packet Delivery Ratio (PDR)

Packet Delivery Ratio is termed as the proportion of the aggregate rate of delivery of the packets ($PDR_{successful}$) from the source node to the target sensor node to the aggregate rate of packets (PDR_{total}). It is measured in kbps. It is given in equation (2).

$$PDR = \frac{PDR_{successful}}{PDR_{total}} \quad (2)$$

The figure 4 and table 2 presents the results of packet delivery ratio analysis between existing and proposed techniques. The results show that the average percentage improvement of +2.53 is found compared with the existing method. Compared to the existing method, the proposed approach outperforms better by better data dissemination via fuzzy logic.

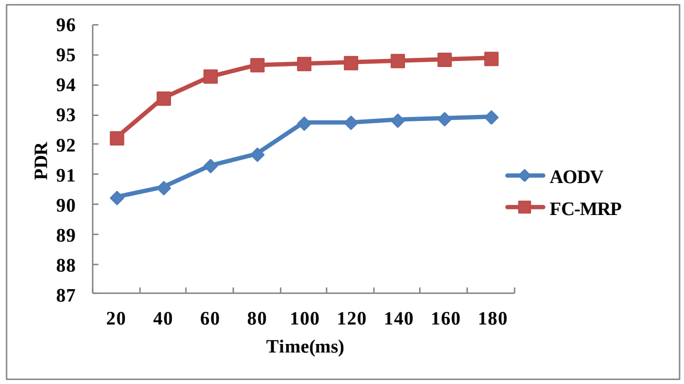

Figure 4 Packet Delivery Ratio (PDR) Analysis between AODV and FC-MRP

Table 2 Packet Delivery Ratio

Simulation time (s)	Existing (%)	Proposed (%)
20	90.23	92.23
40	90.56	93.56
60	91.3	94.3
80	91.68	94.68
100	92.72	94.72
120	92.75	94.75
140	92.82	94.82
160	92.87	94.86
180	92.93	94.89

4.2. Throughput

Throughput is the proportion of data that successfully reaches the intended nodes from the source nodes. It is estimated in equation (3).

$$T_p = \frac{N_{Rp} * P_l * 8}{c_t * 1000} \quad (3)$$

Where,

T_p is the throughput

N_{Rp} is the received packets aggregate value.

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P_l is the packets length.

c_t is the communication time.

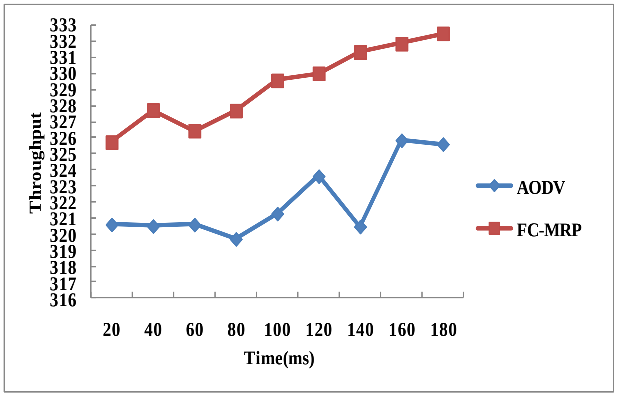

Figure 5 Throughput Analysis

Table 3 Throughput Results

Simulation time (ms)	Existing (%)	Proposed (%)
20	320.60	325.73
40	320.50	327.73
60	320.59	326.45
80	319.70	327.70
100	321.28	329.58
120	323.61	330.02
140	320.47	331.35
160	325.85	331.87
180	325.61	332.51

The figure 5 and table 3 presents the results of throughput analysis between existing and proposed techniques. The results show that the average percentage improvement of +2.23 is found compared with the existing method. As the time increases, the flow of nodes also increases, which enhances throughput rate. It proves that the proposed method overcomes the stability in the clustering model.

4.3. Latency (End-to-End Delay)

End-to-end latency is the successful transmission of the packet arriving at the head of the queue to the sender without any delays. It shows the average amount of time required for packet transfer. It is evaluated in equations (4) and (5).

$$E_{2T} = T_D + P_D + Q_D + R_D \quad (4)$$

$$E_{2T} = N*(T_D + P_D) + (M-1)*(R_D + Q_D) + (N-1)*(T_D) \quad (5)$$

Where,

E_{2T} = end-to-end delay

T_D = Transmission delay

P_D = Propagation delay

R_D = Processing delay

N= Communication links.

M = No of propagation models.

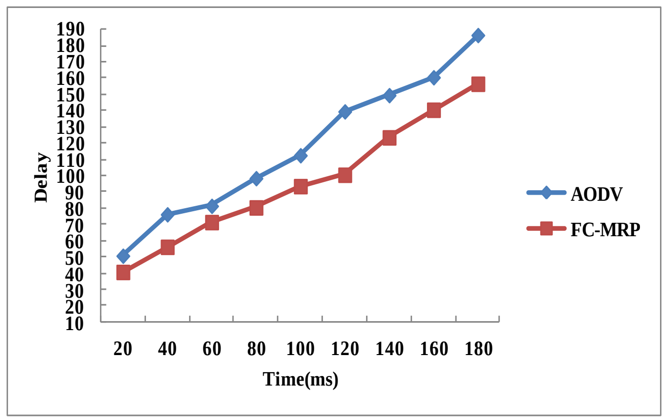

Figure 6 End-to-End Delay Analysis

Table 4 End-to-End Delay

Simulation time (ms)	Existing (%)	Proposed (%)
20	50.727	40.727
40	76.211	56.211
60	81.430	71.430
80	98.466	80.466
100	112.575	93.575
120	139.58	100.58
140	149.592	123.59
160	160.59	140.59
180	186.60	156.60

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The figure 6 and the table 4 represent the End-to-End delay analysis between existing and proposed techniques. The results show that the average percentage improvement of -18.58 is found compared with the existing method. The achieved results prove that the proposed technique has significantly reduced delayed transmissions.

4.4. Communication Overhead

Communication overhead is stated as the overlapping of packets between similar zones. It develops an irrelevant time consumption that leads to higher communication costs.

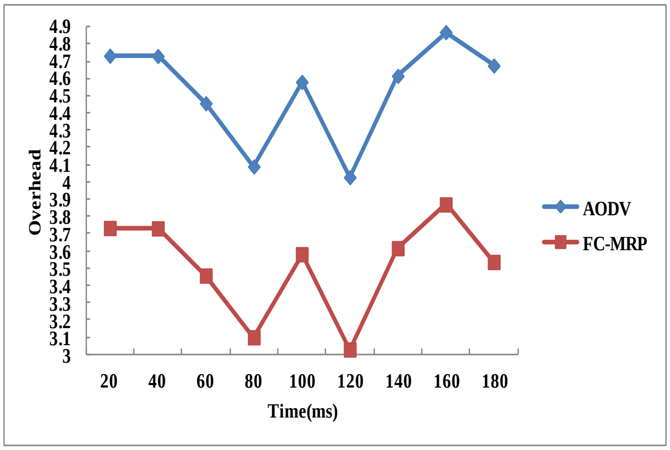

Figure 7 Communication Overhead Analysis

Table 5 Communication Overhead Analysis

Simulation time (ms)	Existing (%)	Proposed (%)
20	4.733	3.733
40	4.731	3.731
60	4.457	4.457
80	4.090	3.099
100	4.581	3.581
120	4.028	3.028
140	4.616	3.616
160	4.870	3.870
180	4.676	3.536

The figure 7 and table 5 presents the results of communication overhead analysis between existing and proposed techniques. The results show that the average percentage improvement of -22.46 is found compared with the existing method. The achieved results prove that the proposed technique has significantly less overhead as compare to existing technique.

4.5. Energy Consumption

Average energy consumption is the measure of the average variation between the consumed and the remaining energy in each cluster node. It is expressed in Joules (J) as shown in equation (6).

$$Avg_{Energy} = \frac{Energy_{initial} - Energy_{consumed}}{Total no. of sensor nodes(N)} \quad (6)$$

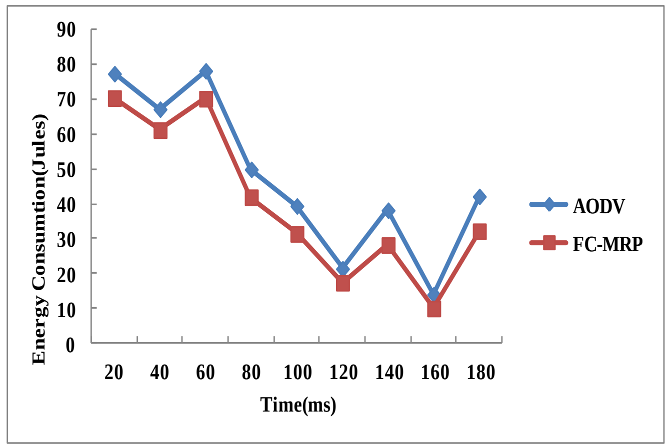

Figure 8 Energy Consumption Analysis

Table 6 Energy Consumption Analysis

Simulation time (ms)	Existing (%)	Proposed (%)
20	77.41	70.41
40	67.22	61.22
60	78.23	70.23
80	49.94	41.94
100	39.44	31.44
120	21.42	17.42
140	38.21	28.21
160	14.02	10.02
180	42.18	32.18

The figure 8 and table 6 presents the results of energy consumption analysis between existing and proposed techniques. The results show that the average percentage

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improvement of -17.95 is found compared with the existing method. The consumed energy is comparatively less in the proposed method.

4.6. Energy Efficiency

One of the crucial characteristics that need to be sharply targeted in order to avoid intrusion. Let the starting energy (i_e); receiving energy (R_p);, communication energy (T_p); idle state energy (I_p)and the sleep state energy (s_p). The energy model (η) is calculated as expressed in equation (7).

$$\eta = p * t \quad (7)$$

Where

p is the ratio between initial to receiving energy.

t is the total time duration.

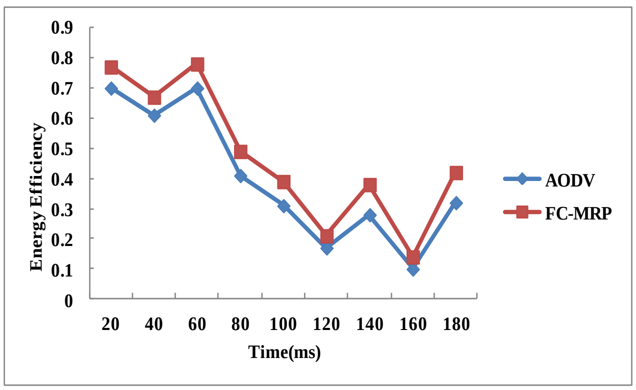

Figure 9 Energy Efficiency Analysis

Table 7 Energy Efficiency Analysis

Simulation time (ms)	**Existing (%)**	**Proposed (%)**
20	0.70	0.77
40	0.61	0.67
60	0.70	0.78
80	0.41	0.49
100	0.31	0.39
120	0.17	0.21
140	0.28	0.38
160	0.10	0.14
180	0.32	0.42

The figure 9 and table 7 represents the outcome of energy efficiency analysis between existing and proposed techniques. The results show that the average percentage improvement of +23.00 is found compared with the existing approach. From the above output, it concludes that the projected Fuzzy logic multipath technique achieves high energy efficiency compared to previous methods.

4.7. Network Lifetime

Network lifetime is derived from the efficient use of energy consumption.

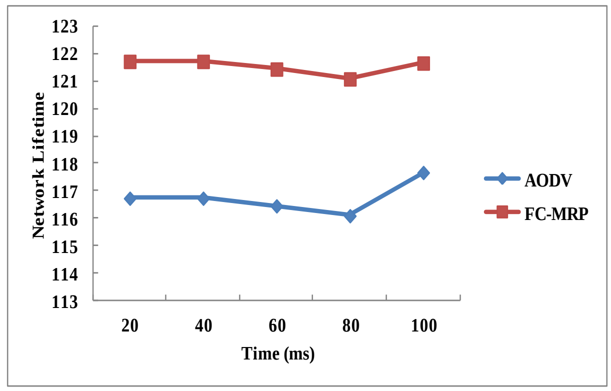

Figure 10 Network Lifetime Analysis

Table 8 Network Lifetime Analysis

Simulation time (ms)	Existing (%)	Proposed (%)
20	116.73	121.73
40	116.73	121.73
60	116.45	121.45
80	116.09	121.09
100	117.67	121.67

The figure 10 and table 8 presents the results of Network lifetime analysis between existing and proposed techniques. The results show that the average percentage improvement of +4.11 is found compared with the existing method. From this simulation results, the proposed Fuzzy logic multipath techniques achieve long network lifetime compared to previous methods.

4.8. Packet Loss Ratio (PLR)

The packet drop rate is the frequency of data packets that fail to arrive at their destination within the allotted time. It is specified in equation (8).

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$$P_{LR} = 1 - \{\frac{N_{RP}/RS}{N_{PS}/SS}\} \quad (8)$$

Where

P_{LR} = Packet loss rate.

N_{RP}/RS=No of packets received.

N_{PS}/SS =No of packets sent.

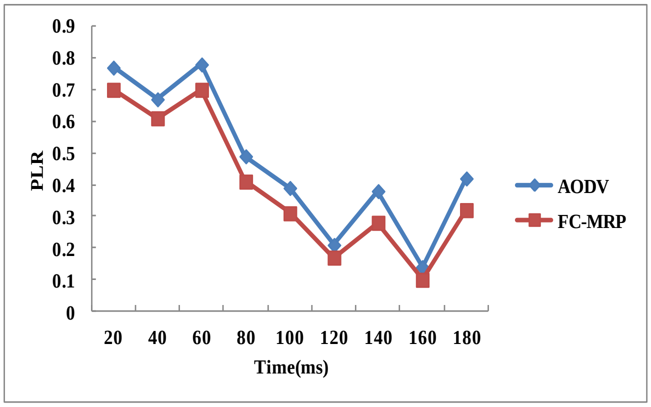

Figure 11 Packet Loss Ratio (PLR) Analysis

Table 9 Packet Loss Ratio Analysis

Simulation time (ms)	Existing (%)	Proposed (%)
20	0.70	0.77
40	0.61	0.67
60	0.70	0.78
80	0.41	0.49
100	0.31	0.39
120	0.17	0.21
140	0.28	0.38
160	0.10	0.14
180	0.32	0.42

The figure 11 and table 9 presents the results of packet loss ratio analysis between existing and proposed techniques. The results show that the average percentage improvement of -18.09 is found compared with the existing method. From this simulation results, the proposed Fuzzy logic multipath techniques achieve less packet loss compared to existing methods.

5. CONCLUSION

Researchers are delving further into the study of agent-based wireless routing protocols systems due to the tremendous advancements in wireless technology. The main objective of the study is to make sure that a noteworthy feature consists of reliability, enhanceing network lifespan, and decreased energy used rate. Due to problems like traffic congestion and shortened network lifespan scenarios, more than a comprehensive solution is needed. This work uses a novel agent-based multipath routing protocol to build an energy-efficient and ideal routing system. It is investigated in two stages, including selecting the cluster heads using the FCM technique and discovering the shortest path using multi-objective energy-aware optimization. Our key innovation is that the clustering process starts when a request is received. It removes the clustering traffic analysis. When the presented protocol is implemented using the NS2, the performance looked at includes packet delivery ratio, end-to-end latency, and energy usage. The performance of developed technique is compared with existing methodologies and significant improvements with respect to PDR, throughput, end to end delay, overhead, energy consumption, energy efficiency, network lifetime, PLR is observed. The suggested fuzzy based clustering based routing methods results better than the AODV protocol, according to the results.

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