

**CLUSTER BASED FUZZY DECISION-MAKING TRAFFIC FREE DATA
TRANSMISSION IN WIRELESS SENSOR NETWORK****P.Bharathi**

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ABSTRACT:

In Wireless Sensor Networks (WSNs), efficient and reliable data transmission is essential for improving network longevity and efficiency. This paper proposes a *Cluster Based Fuzzy Decision-Making approach for traffic-free(FDM-FT)* data transmission in WSNs. The system employs intelligent clustering to organize nodes into energy-efficient groups and utilizes fuzzy logic to dynamically evaluate factors like remaining energy and proximity to the base station and node congestion level. Based on these inputs, optimal cluster heads and routing paths are selected to minimize traffic congestion and energy consumption. Simulation results demonstrate improved packet delivery ratio, reduced latency, and enhanced network longevity compared to traditional routing protocols. This model *Cluster Based Fuzzy Decision-Making* approach for traffic-free(FDM-FT) offers a scalable and adaptive solution for congestion-aware and energy-efficient communication in resource-constrained sensor networks. The FDM-FT mechanism aims to reduce data loss, energy loss, and increase throughput. It is primarily focused on avoiding network traffic interruptions and ensuring continuous data flow source from the node (cluster head), to the base station. The performance of this mechanism is evaluated using the Network Simulator (NS2) and demonstrates impressive levels for the indices, indicating its suitability for real-world applications.

KEYWORDS: Sensor Node, Fuzzy Decision-Making, cluster, traffic-free

INTRODUCTION:

WSNs play an essential role in real-time data collection and transmission across diverse applications such as Human movements monitoring in forest area, Medical care, and smart office. However, the dynamic nature of sensor networks often leads to traffic congestion, reduced data accuracy, and energy inefficiency. To address these challenges, Cluster Based **Fuzzy Decision-Making** approaches electing cluster heads based on residual energy and node position. Demonstrates how fuzzy clustering can reduce congestion and energy consumption by optimizing intra-cluster distances [1] are increasingly being employed. This method groups sensor nodes into clusters and uses fuzzy logic to intelligently manage data transmission paths considering multiple parameters like node energy and distance, and traffic load . for cluster-head selection, incorporating node energy, degree, and neighbour residual energy to balance load and prevent hot-spot congestion.[2]

By enabling adaptive and intelligent decision-making, this approach minimizes congestion, improves energy efficiency while ensuring reliable, congestion-free data transmission. within the WSN.[2] Congestion in WSNs can result in packet loss and increased delay, energy wastage, and reduced network lifetime. To maintain efficient and reliable data transmission, it is important to adopt strategies that prevent or reduce congestion. The following are some effective methods used to avoid congestion in WSNs:

Fuzzy Logic-Based Congestion Control Fuzzy logic systems consider multiple factors such as node energy, queue length, and link quality to make smart routing decisions.[3] This prevents routing through congested nodes and balances the network load. **Load Balancing** Distributing data traffic evenly across the network avoids overloading specific nodes. Multi-path routing protocols can be used to send data via multiple routes instead of a single path.

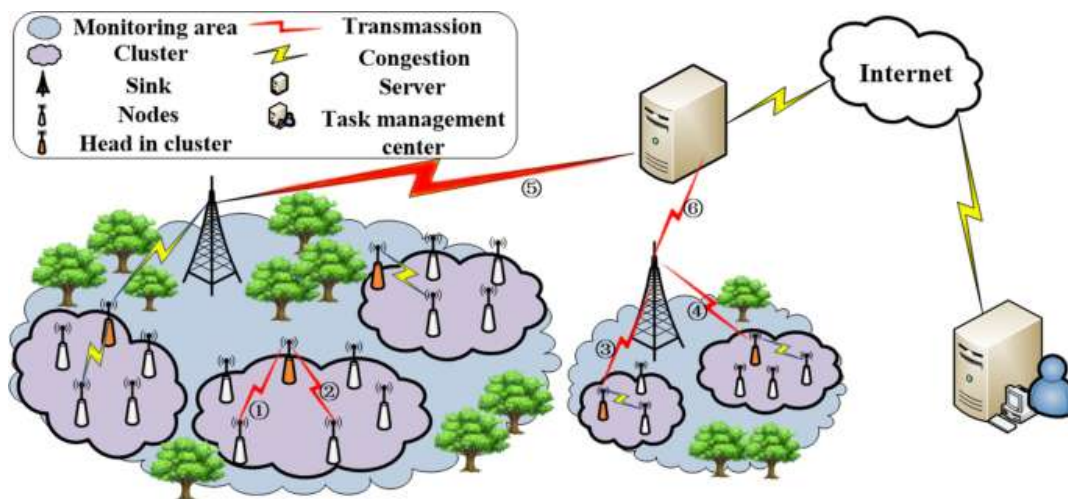


Fig .1 Cluster Based Data Transmission in WSNs

Congestion Detection and Notification Nodes can monitor their buffer or queue status. If congestion is detected, they notify upstream nodes to reduce the sending rate or re-route traffic. Example: Congestion Detection and Avoidance (CODA) protocol. **Traffic Prioritization** Assigning priority to different types of data ensures that critical information (such as emergency alerts) is transmitted first. This reduces the chances of vital data being dropped during congestion. Example: live data from fire sensors can be given higher priority than routine temperature readings.

II.Related Work

1. Realisation of a Cluster-based Protocol Using Fuzzy C-means Algorithm for Wireless Sensor Networks. Hoang (2023, IET WSNs). Suggests a centralized cluster based on Fuzzy C means (FCM) where the Cluster leaders will be selected In accordance with residual energy & node location. Shows that fuzzy clustering can minimize intra-cluster distances to maximize and minimize congestion and energy usage on clusters

2. Fuzzy-Logic Based Distributed Energy-Efficient Clustering Algorithm for WSNs (MDPI Sensors, 2020) Describes a distributed algorithm (EEDCF) using fuzzy logic (TSK model) for cluster-head selection, incorporating node energy, degree, and neighbour residual energy to balance load and prevent hot-spot congestion.

3. Optimized Cluster-Based Routing Using a Fuzzy Logic–Particle Swarm Hybrid Model

Yenugula Swapna et al. (2024, *Journal of Computational Analysis and Applications*). A hybrid FL-PSO model integrating fuzzy logic with Particle Swarm Optimization for energy-efficient and congestion-minimizing routing in clustered WSN.

4. Fuzzy-Based Congestion Detection and Control Algorithm for Energy-Efficient WSN

F.--E. FBCDCA (Journal of the National Science Foundation of Sri Lanka, 2022). Introduces a fuzzy inference system for detecting congestion, notification and rate-adjustment control mechanisms, improving QoS and network lifetime .

5. FFMCP: Feed-Forward Multi-Clustering Protocol Using Fuzzy Logic for WSNs

(MDPI Energies, 2021). Multi-hop clustering with unequal cluster size; fuzzy logic selects cluster heads and relay nodes based on residual energy, distances, and delay to reduce congestion and energy use .

6. Fuzzy-Based Congestion Control for Wireless Multimedia Sensor Networks

Maps buffer occupancy, network network load, and the count of contenders into a congestion index based on fuzzy logic; applicable to bursty data situations .

III. Proposed work

In this proposed work *Cluster Based Fuzzy Decision-Making approach for traffic-free (FDM-FT)* correspond to data transmission in WSNs. are distributed sensor nodes located in space and whose role is to collect and relay data to a base station. Such networks have many applications that include environmental surveillance, military surveillance, and smart cities. But traffic congestion, energy constraints and unstable data-transmission in WSNs are key challenges since the sensor nodes are dynamic and have limited resources. To overcome these challenges, Cluster-Based Fuzzy Decision-Making approaches have emerged as an efficient traffic free data Transmission.

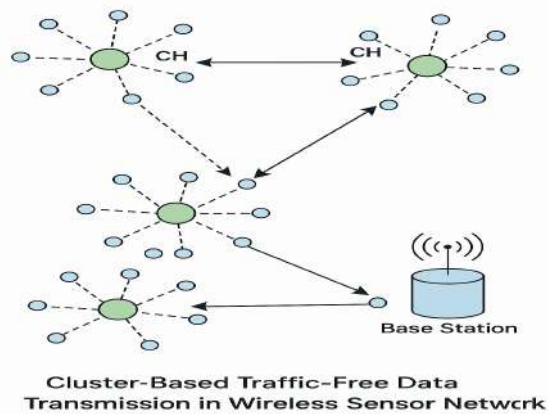


Fig 2. Advanced energy efficient cluster-based Technique data transmission

Role of Fuzzy Decision-Making

Fuzzy logic is used to create intelligent choices in uncertain or imprecise environments. In WSNs, it helps select the most suitable nodes as cluster heads or forwarding nodes based on multiple dynamic parameters such as:

- Residual Energy
- Proximity to the Base Station
- Traffic Load or Queue Length
- Link Quality
- Node Degree (Number of Neighbours)

Instead of rigid threshold-based decisions, fuzzy logic allows multi-criteria evaluation and adaptive decision-making, improving reliability and load distribution.

How It Works

Process Flow

Clustering Phase: Nodes share their parameters (e.g., energy level, position). A fuzzy inference system evaluates each node using fuzzy rules (e.g., "If energy is high and load is low, then CH suitability is high"). The optimum nodes are chosen Cluster Heads (CHs).

Phase Data Aggregation: The CH is presented with data turned by members of a cluster. The CH collects the information to reduce redundancy.

Fuzzy-Based Routing Phase: A fuzzy decision-making unit assesses routing paths based on congestion level, energy, and distance. The path with the lowest risk of congestion and highest efficiency is selected. If a CH is overloaded, the system reroutes data through alternative, less congested CHs or relay nodes.

Traffic-Free Transmission: By considering real-time conditions and using fuzzy logic, data is transmitted via the most efficient and least congested route. This prevents node buffer overflow, reduces packet drops, and enhances Quality of Service (QoS).

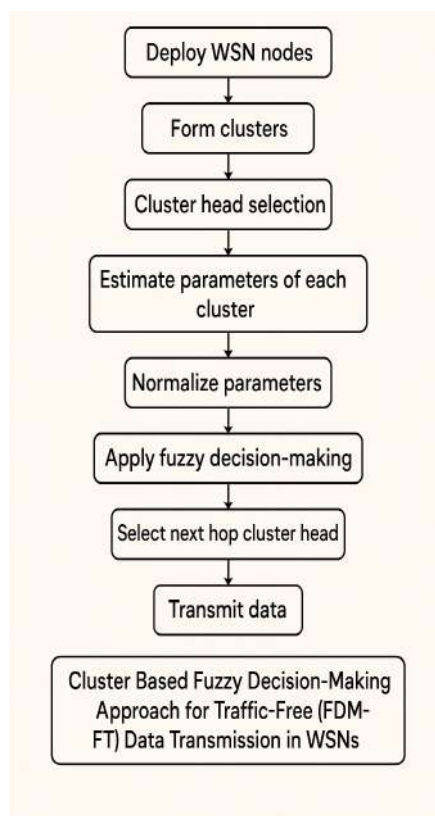


Fig 3. Flowchart for Cluster Based Fuzzy Decision-Making approach for traffic-free (FDM-FT) Protocol in WSN.

Flowchart explanation

The flowchart for the Cluster Based Fuzzy Decision-Making Traffic-Free (FDM-FT) Protocol begins with the initialization of the WSNs, where sensor nodes are randomly placed in the target area and initialized. with parameters such as residual energy, buffer size, and position. Once the network is initialized, nodes begin the process of cluster formation based on their proximity and communication range. To ensure efficient clustering, fuzzy logic is applied to select optimal Cluster Heads (CHs). Each node evaluates itself and nearby nodes using input elements such as remaining energy and proximity to the base station, node density, and current buffer occupancy. These values are processed through a fuzzy inference system to generate a score for CH candidacy. The node with the highest fuzzy score in each region is elected as the CH.

After the CHs are selected, they broadcast their status, and the remaining nodes (Cluster Members or CMs) associate themselves with the CH offering the best signal strength or lowest transmission cost. Once the clusters are formed, the data transmission phase begins. Member nodes gather sensing data and transmit it to their respective CHs, which then aggregate the data to eliminate redundancy. To forward the aggregated data destined for the base station, CHs use another fuzzy logic-based decision process that selects the most efficient, congestion-free route. This path selection considers metrics such as queue length, link reliability, number of hops, and energy level of potential forwarder nodes. If congestion is detected on a selected route—indicated by a high buffer queue or packet delay—the fuzzy system dynamically recalculates the best alternate path to avoid traffic and packet loss.

Throughout the process, nodes update their energy levels after each transmission, and dead nodes are excluded from the next round. When energy levels fall below a threshold, or when CHs become inactive, the network enters a new round, triggering replastering and fresh CH selection. This cycle continues until the network meets the termination condition such as a majority of node failures or energy depletion. The FDM-FT protocol thus ensures efficient, energy-aware, and congestion-free communication in WSNs through adaptive and intelligent decision-making based on fuzzy logic.

Algorithm for Cluster Based Fuzzy Decision-Making approach for traffic-free (FDM-FT) Protocol in WSN.

Input: n_round , deployment area, p , sink p , initial e , c_range , n_nodes , t_node

Output: $R_VALUE = \{CHs, alive_n\}$

1:

n_{pnt} —Sensed data from cluster members

 Output—Gathered data to Sink

CH_i CH of cluster $C_i, J = 1, 2, \dots, N$

CM_{ij} Cluster member of C_j

V_t Vector with data packets sensed at time t

$Sim(V_t, V_{t-\Delta})$ Similarity between vectors at time t and $(t-\Delta)$

$Sim(V_t, V_k)$ Similarity between vectors of $C_{i,j}$ and $C_{k,j}$

$D_i, i = 1, 2, \dots$ Incoming data packets at $C_{i,j}$

$Dist(CH_i, BS)$ Distance between CH_j and BS

 For each cluster C_j

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If CHj receives Dj,
  CHj estimates Sim (Vt, Vt - □)
If Sim (Vt, Vt - □) or Sim (Vt, Vk) exists
  Data is considered redundant and dropped
Else
  Data is considered as non-redundant
End If
End If
CHi transmits gathered data to BS
If dist (CHj, BS) > dmax then
  Re-clustering phase initiated
End If

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4. RESULTS AND ANALYSIS

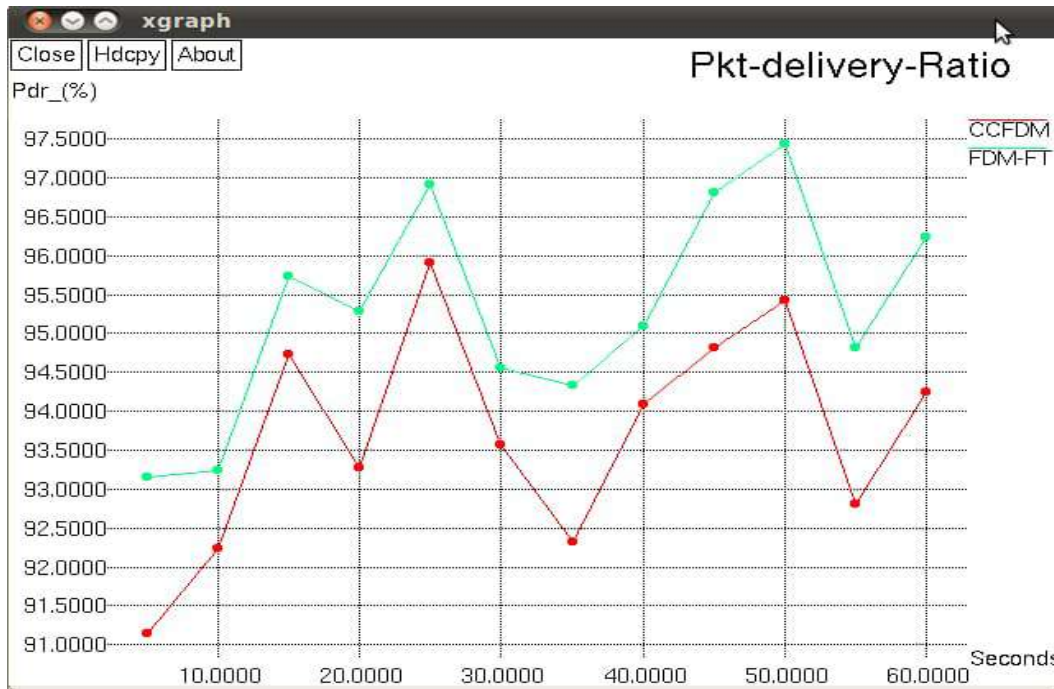
The effectiveness of the suggested **FDM-FT protocol** was evaluated through simulation using standard Wireless Sensor Network (WSN) scenarios. The goal was to assess how effectively the protocol reduces congestion, improves data delivery, and prolongs network lifetime when compared with traditional protocols.

Simulation of Parameters

Parameters	Value
Sensor Field	1000*1000
Probability of a node to CH	0.05
Initial energy	0.5j
BS Location	50*50m
Data packet size	500 bytes
Transmitter/Receiver Electronics	50nj/bit
Number of nodes	50

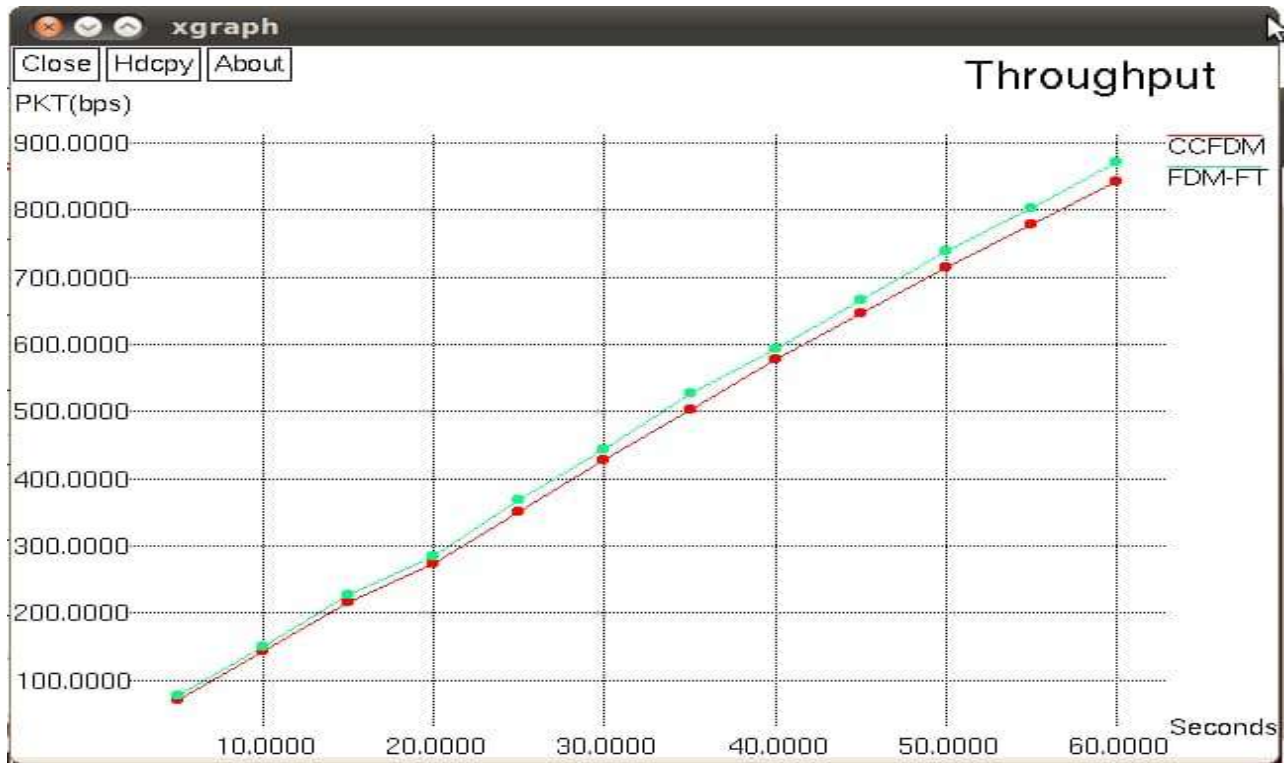
1. Packet Delivery Ratio

This Figure demonstrates Interests in Effect of Number of Packet Delivery where the model proposed is delivering Highs Number of Packet data Compare to CCFDM even at Highs Density *of Nodes*.



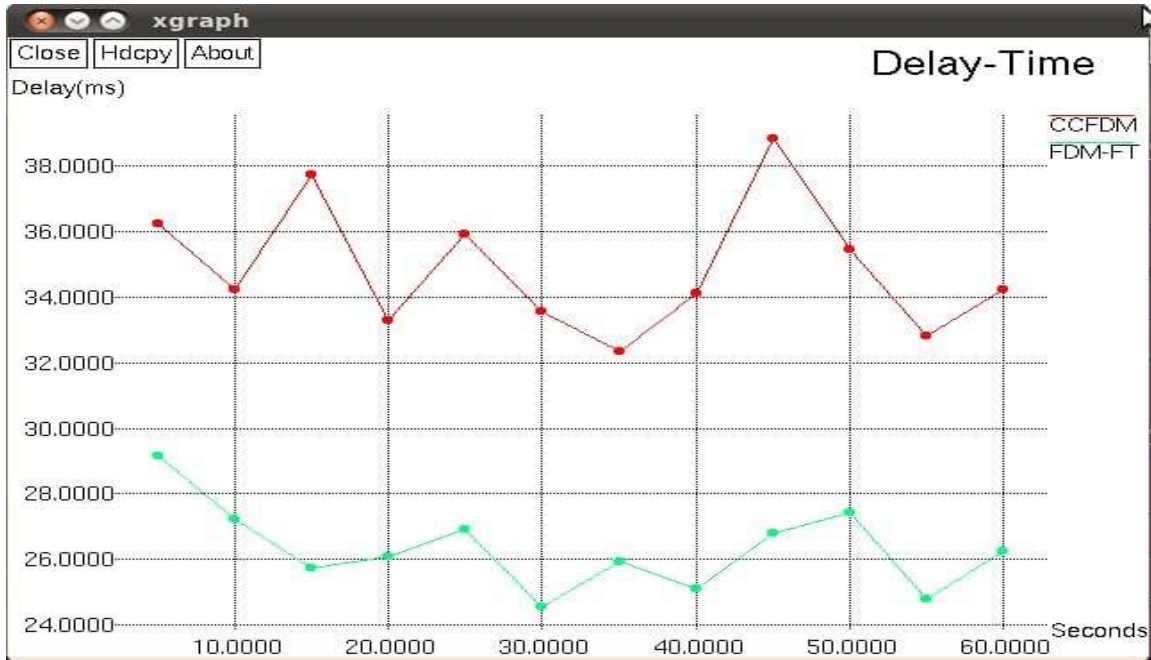
2. Throughput

Packet Data Received at a particular moment in time is defined as the count of packets received. This measurement demonstrates the result of throughput, attributed to multipath routing. A proposed Cluster Based Fuzzy Decision-Making approach for traffic-free (FDM-FT) aims to avoid congestion. This method achieves a high throughput value when compared to IEE-LEACH, respectively.

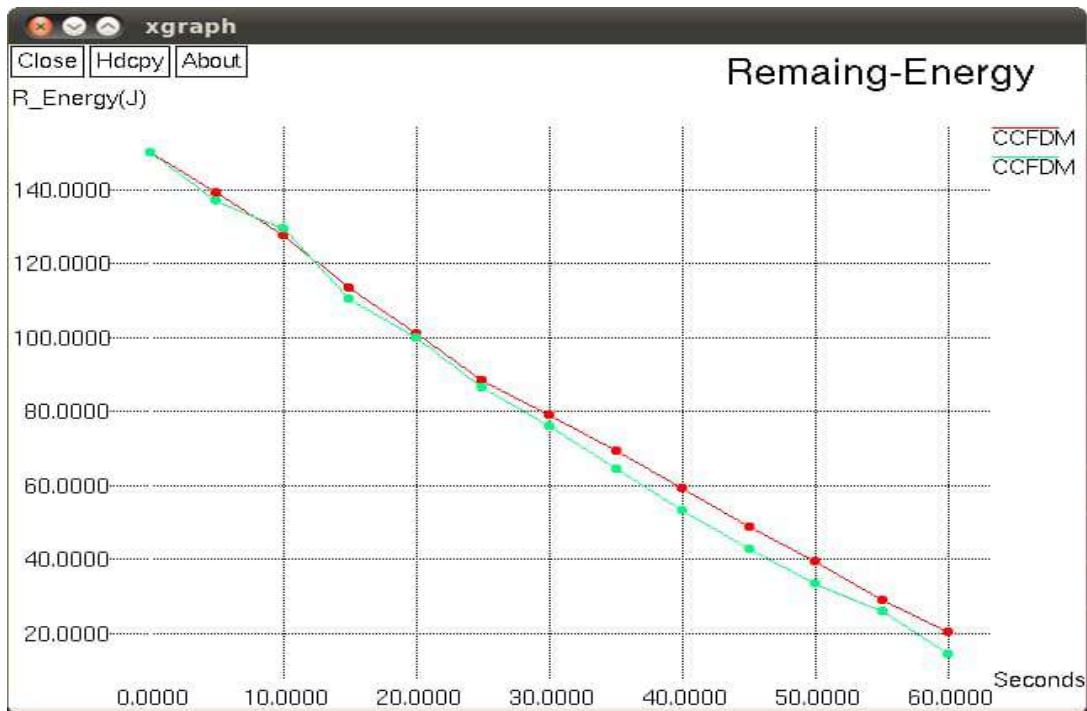


4.Delay Time

Time delay is the maximum value of the time portion in which a packet is transmitted through a network at the source to the sink. As illustrated in the figure, an attempt to prevent congestion, and reduce the end-to-end time delay is through a cluster-based fuzzy decision-making method known as traffic free (FDM-FT) technique. These simulation results evidently indicate that cluster-based fuzzy and decision-making (CCFDMM) technique is relatively efficient and proved to be very effective.



5. Remining Energy



The Remaining Energy Is Very High. A Proposed *Cluster Based Fuzzy Decision-Making approach for traffic-free(FDM-FT)* technique is avoid the congestion Method Achieves More Compare than IEE-LEACH Respectively

The main theory seeks to bring a mechanism to the continuous flow the data exchanged between source the node and the destination nodes. in the layered WSN. The methodology will consider the integration of a Cluster Based Fuzzy Decision-Making methodology in the paradigm of traffic-free (FDM-FT) to pursue an energy efficient approach and rich network life. It involves traffic distribution in nodes with substantial energy known as Cluster Head (CH) and offering the ability to redirect the packet flow in the event of traffic congestion in the layered network. The proposal has also assessed the measures of performance based on network simulator (NS2) to prove its viability over other patterns of routing and create a new thought wave in this form of communication.

Conclusion:

Cluster Based Fuzzy Decision-Making Traffic-Free (FDM-FT) Protocol proposes a strong and intelligent technique to real-life data relay in WSNs. The integration of fuzzy logic in the clustering and routing process has proved effective in this protocol in that it chooses the most optimal cluster heads and routes depending on various criteria and parameters of the nodes that include energy, the load of the node, and the proximity to the base station. This smart decision-making model also lowers a lot of data jams and controls the balanced utilization of energy throughout the network.