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# A Fuzzy Approach for Congestion Avoidance in FANET and IoT

**Mahendra Sahare[1,*], Priti Maheshwary[1], Vinay Kumar Dwivedi[2]**

[1]Department of Computer Science and Engineering, Rabindranath Tagore University, Bhopal (MP), India
[2]Department of Computer Science & Engineering, AKS University Satna (M.P), India

Emails: mahendrasahare1110@gmail.com; pritimaheshwary@gmail.com; Vinaykumardwivedi14@gmail.com

**Abstract**

In the recent era of communication technology, flying ad hoc networks are gaining popularity because of their flexibility and broad area of application to gather data from environmental sources with limited infrastructure. FANET nodes, or unmanned aerial vehicles (UAVs), are heterogeneous devices, and coordination between the UAVs is an important part of communication with limited battery power sources. In ad hoc networks, devices have limited battery power, so proper battery utilization is critical to maintaining network connectivity. In order to establish a network without congestion, it is vital to have inter-UAV and IoT wireless communication for cooperation and collaboration among many UAVs. UAV connections may experience frequent disconnections. Another obstacle is the limited distance allowed between the stations. The routing algorithm selects only the nodes that are specifically requested by the source node based on its requirements and maintains the source node no longer needs the route until it. IoT devices have limited processing capability and memory. A single mobile device controls the IoT devices, or users can use the concept of automation to control the functioning of smart IoT devices. This research proposes a fuzzy-based congestion control scheme (MCPFB) to control the congestion between UAVs and IoT devices. UAVs are faster, and IoT devices can collect information from UAVs and forward it to other devices. The UAV's can store limited and sufficient types of information, but during routing, only a single path is available, which causes congestion in the FANET-IoT network. The fuzzy based load prediction and balancing routing is able to handle the problem of congestion in FANET-IoT. In order to overcome the problem of congestion with improper energy utilisation, this paper presents fuzzy rule-based congestion control techniques for a flying ad hoc network. We focus on the efforts to reduce congestion in the FANET-IoT network. Routing is a critical issue in FANET-IoT and hence the focus of this research is on the performance improvement of routing in FANET-IoT. Packets dropping on the nodes show congestion occurrence in the network, and the possibility of lost connectivity with other nodes is high. Unlike the aforementioned works, the proposed MCPFB routing shows better performance compared to the conventional BARS scheme in FANET-IoT.

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**Keywords:** Congestion; Fuzzy; FANET; IoT; Routing; UAV

## 1. Introduction

A flying ad hoc network is a collection of unmanned aerial vehicles (UAVs) used as sensor devices that collect environmental data such as temperature, humidity, and wind speed and send that data to ground-based stations (GBs) [1, 2]. The benefits of a single-UAV system include versatility and the ability to be utilized for decades [3]. Nonetheless, single-UAV systems limited coverage and simple functionalities limit their potential uses. As a result, multi-UAV systems are designed to improve operational performance by allowing UAVs to work together. However, multi-hop UAV systems have a limited network radius, which allows for communication from the UAV

to the GB. Disconnection may occur, necessitating immediate and effective resolution. Establishing ad hoc communication in a flying ad hoc network with the help of peer-to-peer UAV communication, their application covers broad areas of utilization such as weather forecasting, military services, and emergency rescue operations [4] in recent years to provide instant communication in a hostile and noisy environment. Although FANETs can be utilized in a wide range of applications, the high mobility of UAVs causes unreliable connectivity and makes distributed optimization challenging. In the previous, research numerous works done to improvising the flying ad-hoc communication and IoT enabled devices to solve various upcoming challenges before they apply to the real implementation. Some of them resolve the routing, resource utilization, unmanned aerial vehicle (UAV) node mobility prediction, network topology decision, security aspects and quality of service issues. Before moving on the proposal researcher study all those relative problems and different solving methods and design the research statement namely A fuzzy Approach for Congestion Avoidance in FANET and IoT [5] [6] [7] [8], this problem is solved in step by step process initially, it measures the network node capability in all relative parameters i.e. energy, processing capability, memory acquire for data buffering, channel bandwidth between link etc. All those above parameters are used to rank all the nodes (higher to lower order) at the routing decision time while communication is established and started. In real time, measure the utilization of each given matrix. At that time, watch each node's critical threshold value based on node resource utilization. If it is found that any one of the linked nodes is equal to the threshold limit, an alarm signal is sent to the source node and alternative routes so that a new route decision can take place and improve the network quality of service with respect to network parameters. This proposal meets the need for flying ad-hoc networks and helps point the new roadmap of broad research proposals in the right direction for the future.
For this article preparation number of research paper studies in the field of path selection, capability identification, fuzzy rules and efficient resource utilization but they can’t associate all those parameter in single research, in this article we incorporate in one complete efficient path selection with all aspect of network. The topic is also novel approach and cover in-depth of flying ad hoc network structure. So some new rules are defined in the article work [34] [35] [36].

Nine sections make up the article. Section I describes the introduction of FANET-IoT and congestion control using fuzzy rules. Section II provides a detailed explanation of the existing approach to congestion control in FANET-IoT. Section III describes the research problem. Section IV describes the proposed approach to the fuzzy logic technique for congestion control. Section V detail describe about proposed MCPBF algorithm, Section VI describes the MCPFB congestion avoidance technique; Section VII give the detail explanation of simulation parameters, Section VIII illustrates the results of the proposed work and compares it to existing congestion management systems; and Section IX describes the conclusion and future work of the research paper.

## 2. Literature Review

This section attempts to improve awareness of recent advances in congestion management, energy efficiency, and Q-learning approach for routing. The authors presented a number of ways to reduce FANET congestion using IoT. They take into account the author’s most recent work.

Mehdi Hosseinzadeh *et al.* [9] proposed this research, which proposes revolutionary FANETs employ a Q-learning-based routing technique that makes use of an intelligent filtering algorithm. This research proposes a Q-learning-based routing solution for flying ad hoc networks that use a filtering technique known as QRF. There are two components to QRF: finding neighbours and using Q learning to determine routes.

Lansky et al. [10] the propose system intelligently monitors air quality using a Q-learning-based routing system for FANETs, known as QFAN. The system details methods for locating and controlling routing paths. First, the authors demonstrate how to use Q learning to determine routes of communication. QFAN designed a filtration scale for drones to manage and limit the learning environment.

Arafat and Moh [11] introduce QTAR, a FANET Q-learning routing method. So that better routing decisions may be made, QTAR aims to include information from two-hop surrounding nodes to acquire a more comprehensive local perspective of the learning environment. For each source-destination pair, several criteria, including location, latency, speed, and energy, are considered by QTAR while determining the optimal pathways for the communication link between 2-hop nearby UAVs.

Jung et al. [12] the authors propose QGeo for FANET, a location-based routing system that utilizes Q learning. The writers presented QGeo to reduce the financial burden of routing in ever-changing environments. QGeo is not dependent on global data and functions in a decentralized manner. On top of that, even in the most unpredictable networks, QGeo's Q-learning algorithm keeps packet delivery rates high.

Qiu *et al.* [13] presented here is QLGR, a FANET location-based routing approach that makes use of MAL. This method controls routing overhead and decreases the amount of packets that are missed. As a learning agent, each UAV in QLGR uses its own local knowledge to calculate the value of all neighbouring UAVs. In the QLGR, they calculate the cost function using the current energy value, connection quality, and current queue length, which helps minimize route disconnection.

Alam and Moh [14] they implemented QRIFC, using adaptive flocking control in a Q-learning-based routing system. To regulate the density of unmanned aerial vehicle (UAV) operations, QRIFC details the optimal drone movement using adaptive flocking control, taking into account the distance flown by each drone.

Rahmani *et al.* [15] they propose a FANET optimum link state routing method (OLSR+) that relies on fuzzy logic. A novel method is employed by OLSR+ to determine the length of each link by taking into account the direction of travel, the quality of the connection, relative speed, and distance. Next, it uses a fuzzy method to choose multi-point relays (MPRs) by giving more priority to one-hop nearby UAVs according to connection time, energy, and neighbour degree. The topology control (TC) message is also updated by OLSR+ to include two more fields: route energy and route lifetime.

Lansky *et al.* [16] they present a FANET link state routing system that is both efficient and mindful of energy consumption. This new routing method takes into account the ratio of welcome messages delivered to those received, as well as the length of the link, to arrive at an innovative conclusion about the quality of the network connection. To find the best MPR, this approach also uses a firefly algorithm (FA). FA selects high-powered UAVs with superior connection quality and degree from the surrounding network to serve as MPRs.

Jan Lansky *et al.* [17] the authors proposed a method for routing air quality sensors that use Q learning and operate with flying ad hoc networks. This paper describes an energy-aware Q-learning-based routine method (QFAN) for a smart air quality monitoring system based on FANET. The two primary components of QFAN are route discovery and route updates. The first section of QFAN employs a Q-learning-based path-finding strategy to determine the optimal route between the source and destination nodes. Every node in the network uses this technique to identify the local UAVs and their respective filtering parameters.

Arafat and Moh [18] they presented the QTAR method for FANETs, which is based on Q-learning and features topology-aware routing. In order to provide trustworthy paths, the QTAR algorithm takes into account data from both one-hop and two-hop neighbors. According to the authors, this method increases next-hop node selection, reduces route computation time, and boosts path discovery.

Jung *et al.* [19] presented QGeo, a geographic routing method based on Q-learning. In order to determine the best routes, this distributed method makes use of local knowledge. This approach's goal is to reduce or eliminate routing delays and overhead. During this process, QGeo neglected metrics like latency and energy in favor of geographical data and network node performance. Because of this issue, paths may end up with little energy, instability, and significant delay. This method uses the proximity and movement patterns of nearby nodes to calculate the discount factor for Q-learning.

## 3. Problem Identification

Flying ad hoc communication form the network to connect critical geographical region where wired and static wireless communication not possible and it is well known that existing protocols for flying ad hoc networks (FANETs) have certain weaknesses like delay, overhead, packet lose, energy issues etc, As we have discussed above, without congestion awareness and control, following problems occurs [20-23]:

- Increases the network overhead and congestion, which affected the output of network performance such as a packet delivery ratio, data drop rate etc.
- It may utilize higher network resources of nodes and gives an unstable path, which damages the route in higher rates.
- Network route search time is higher and some time we cannot re-establish communication with receiver node.
- It may not provide fair service, due to network load, which is not properly distributed based on its capability.

To resolve these issues, various kind of research have been proposed by many researchers previously, but all the works are done separately to address the above issues but still has many gaps to consider, that are discussed in chapter two in literature survey.

The proposed work collectively resolves the energy, congestion and overhead minimization in real time i.e. when a route is created as well as data is in transmit. Therefore, this study is trying to solve this issue, by proposing A Fuzzy Approach for Congestion Avoidance in FANET-IoT.

## 4. Proposed Approach

Flying ad hoc network is a resource constraint device, but recent trends of communication it is a very useful for the hot spot communication between devices and internet of thing technology. FANET device is capable to form route, provide service to other flying device and cost less communication. In previous research various flying ad hoc routing are designed and emulate in limited range but dynamic network topology hurdle for adaption of these types of technology. Through the previous research studies encourages toward the flying ad hoc communication and design some objective to contribute the proposed research work.

To solve the problem of research topic is fuzzy rule based congestion avoidance and path selection for efficient utilization of resource in FANET-IoT, through the sub module based methodology.

Flying network communication depends on unmanned aerial vehicles (UAVs) nodes and channel between devices. So that the route discovery phase device and channel utilization capability are measured [24]. UAV device contains the battery, processor and memory that information retrieved at the time of the route discovery state where all the neighbor nodes or route packet receiver nodes give the information of (power, processing, memory) utilization in per packet based by the following formula.

**a) Processor utilization**

$$P_{cu} = P_{c+t} - P_c \text{ ..................(1)}$$

$$P_u\% = \left(\frac{P_{cu}}{P_i}\right) * 100 \text{ ...............(2)}$$

$$P_{tu}\% = P_u\% + P_{u\_old}\% \text{ .........(3)}$$

Where $P_{cu}$: Processor clock utilization per data packets

$P_{c+t}$: Processor clock change after t time

$P_c$ : Processor clock before t time

$P_u$%: Percentage of processor utilization

$P_i$: Processor clock at ideal case

$P_{tu}$% : Percentage of total processor clock utilized

$P_{u\_old}$%: Percentage of processor clock utilized at time t

**b) Memory Utilization**

$$M_u\% = 100 - \left(\frac{((M_d - (M_t + M_{t+1}))}{M_d}\right) * 100 \text{.........(4)}$$

$$M_{tu}\% = M_u\% + M_{u\_old}\% \text{ .......................(5)}$$

Where $M_u$% : Percentage of memory utilization at new data arrival

$M_{tu}$% : Percentage of total memory utilization

$M_{u\_old}$% : Percentage of memory utilization at time t

$M_d$ : Default memory size in bytes

$M_t$ : memory utilization at time t

$M_{t+1}$ : memory utilization at after arrival of new packets at t +1 time

**c) Energy Utilization**

$$E_u\% = 100 - \left(\frac{(I_e - (T_x * T_{xt}) - (R_x * R_{xt}))}{I_e}\right) * 100 \text{.........(6)}$$

$$E_{tu}\% = E_u\% + E_{u\_old}\% \text{ ....................(7)}$$

Where $I_e$ : initial energy in joule

$T_x$ : transmission power requirement

$R_x$ : Receiving power requirement

$T_{xt}$ : Transmission time

$R_{xt}$ : receiving power requirement

$E_{u\_old}$% : energy utilization percentage at time t

$E_u$% : energy utilization percentage at time t+1

$E_{tu}$% : percentage of total energy utilization

Through all those formulas measure the node capability in real time after the node capability and utilization identification, external parameter is also measured such as bandwidth utilization, signal strength and frequency [25].

**d) Bandwidth Utilization**

Bandwidth unit measures through a mega bit per second handle by the channel or to allocate to the link in the communication, similarly signal strength-measuring unit is decibel and frequency is measured through hz, these are formulated as follow.

$B_u\% = 100 - \left(\frac{B_a - B_{ut}}{B_a}\right) * 100$……………(8)

Where

$B_u\%$ = percentage of utilization bandwidth in Mbps

$B_a$: Available bandwidth ideal case

$B_{ut}$ : bandwidth utilized at current time

Signal strength depends on the distance between two devices and atmospheric condition device is nearer than signal strength is higher and far condition signal strength is lower it gives the real time signal strength in decibel units. Frequency information is useful for collision free data transmission between devices, its control by the connected device because its allocation through the communicator nodes and do not assign same frequency band to other nearby devices [26].

After that entire measurement, comparative table is deployed for assigning the rank of communication line and devices that contain following values

The concept of ranking is low utilization of processing power, memory, energy and bandwidth and higher signal strength set as a higher ranker nodes or path and rest of device rank assign in a similar manner. After the rank assignment, categorize the level of classes based on fuzzy rule. Top 33% rank node as normal class (A), middle 34% to 66% rank set as medium class (B) and rest of rank node set as higher class (C) (high utilization), that class useful for the efficient path selection, load sharing as well as trust deployment. If the route discovery phases all class, nodes detected than the out of those table rank based nodes and paths are selected for the further communication [27].

Routing strategy for the communication is an important part of the network, in past decades of research number of dynamic routing algorithm proposed for route selection between sources to receiver. Proposed path or route selection methodology check the capability of node and link quality and based on rank of node path are selected for the communication. Path selection is crucial, but provide more reliable and congestion free communication between nodes [28].

Through the above-proposed methodology justified that proposed approach gives efficient and congestion free route for flying ad hoc IoT communication.

**Table 1:** Estimated Percentage of Utilization

| Estimated Percentage of Utilization | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Device No | Processing Power % | Priority | Memory % | Priority | Energy | Priority | Bandwidth | Priority | Signal Strength | Priority | Rank |
| -- | -- | 1 | -- | 2 | -- | 3 | -- | 4 | -- | 5 | 1 to n |

## 5. Proposed MCPFB Algorithm

This section outlines the formal definition of memory, channel, and process utilization. We use a fuzzy rule-based technique that divides congestion into three levels: low, medium, and high. Reducing the amount of memory and channel used, along with lengthening the data interval, can resolve excessive congestion and allow the flying ad hoc network to flow through it [29].

The input, method, and output are the three sections that make up the algorithm. Declare variables in the input section, such as source and receiver devices, fuzzy variables, data intervals, protocol types, data types, and so on. NS-2.31 configures each of these variables by invoking the function with the stated variable. In the procedure section, use the data interval, channel usage, and memory usage of each intermediate flying device to guide the routing procedure. Next, employ a fuzzy rule to distinguish the optimal path—a route free of congestion—from those that fall into the heavy or medium congestion status categories, thereby obstructing the selection of nodes for communication. Finally, among other strategies, address congestion by minimizing data rates. Use the suggested method to identify and prevent congestion in the IoT-flying ad hoc network [30]. In the output section, obtain the MCPFB algorithm's findings in terms of throughput, packet delivery ratio, routing load, congestion status, energy, memory, channel utilization status, etc.

**Algorithm:** MCPFB

**Input:**

$N_t$: Network type IoT-FANET

$f_d$: flying device

$D_s$: Data source device ∈$f_d$
$R_d$/BTS: Data receiver device or base receiver ∈$f_d$
$I_f$: Intermediate flying device ∈$f_d$
$F_{zv}$: (L, M, H) fuzzy value
$Ch_u$: Channel utilization
$M_{uti}$: Memory utilization
$D_{inter}$: Data Interval
$E_{uti}$: Energy utilization
$Cong_s$: Congestion Status
$R_{pt}$: routing protocol MCPFB
$D_{type}$: Data type TCP, UDP
Ψ: radio range $550m^2$

**Output:** Throughput, Packet Delivery Ratio, Routing Overhead, Congestion Status, Data interval, Energy, Memory utilization.

**Procedure:**

```
Form Nt with active fd
Ds want to sent data to Rd
Ds call Rpt & Create packet (Ds, Rd, Rpt)
While visited!= fd || If != Rd
        If If in Ψ & If != Rd then
                Calculate (Dinter, Euti, Chu, Muti) of If
                Apply MCPBF for fuzzy inference
If (Dinter is Low) AND (Chu is High) AND (Muti is High) then
                        If (Congs) ← High
                        If← node not selected
        Stop forwarding
Else if (Dinter is medium) AND (Chu is medium) AND (Muti is medium) then
                        If (Congs) ← Medium
If ← Selected in route & If stop receiving new route packet
If← forward route packet to next-hop
                Else
                        If (Congs) ← Low
If ← Selected in route & If stop receiving new route packet
If← forward route packet to next-hop
                        If++
                End if
Else if If in Ψ & If == Rd then
                Rd←If
                Rd receiver route packet
                If path > 1 then
                Calculate Euti of each node in ∀paths
                        If pathi(Euti) < pathj(Euti) then
                        pathi select for communication
                        Else
                        Pathj select for communication
                        End if
                Else
                        Only Single path available
                         Select for communication
                End if
        Else
                Rd not found or not reachable
                Recall route method
        End if
                Rd Send acknowledgement to  Ds
                Ds call Data_pkt(Ds, Rd, Dtype)
Data_pkt(Ds, Rd, Dtype)
        Ds start data sending to Rd
        Check Congs of each If node in path
If (Dinter is Low | medium) AND (Chu is High | medium) AND (Muti is High | medium) then
```

If (Cong$_s$) ← *High* | medium
Increase $D_{inter}$ | min($P_{size}$)

**Else**

If (Cong$_s$) ← *Low*
$D_s$ send $D_{type}$ without changing $P_{size}$ & $D_{inter}$

**End if**

**End Procedure**

## 6. Fuzzy Approach for Congestion Avoidance

Fuzzy analysis represents a method for solving problems, which are related to uncertainty and vagueness, in the research apply the fuzzy approach to avoid congestion from flying ad hoc internet of things network. The proposed approach divided into three sub module is as follows

- Design and develop the simulation network and analyze the impact of processing, energy and buffer utilization, which helps to identify the device capability of the network.
- The define parameter of processing, energy and buffer utilization is useful to developing the fuzzy rule for classification of the congestion status of the network.

Develop the fuzzy classification rule and inbuilt with ad hoc on demand routing protocol to select the efficient path where congestion probability is low.

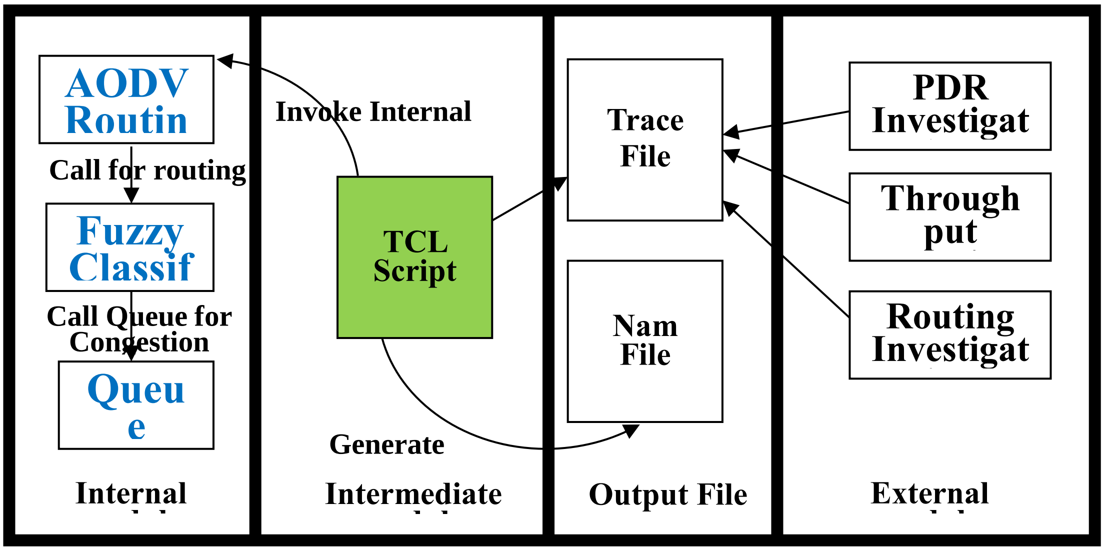


**Figure 1.** Proposed Architecture

## 7. Simulation Parameters

Here we go over the basics of running the simulation, how the MCPFB algorithm works, and the run's outcomes. We evaluated the effectiveness of the MCPFB scheme using the network simulator NS2.31. Transmission range is set to 500m$^2$ radio propagation model is Two Ray Ground. Different simulation scenarios of different data rate considered for performance measurement. In the rate, density scenarios random deployment of nodes considered where number of nodes are 69 with equal number of senders and receivers. Transmit a regular traffic of CBR using UDP and FTP using TCP. Taking the connection less and connection oriented both type of connections. We have taken the random energy of UAVs and IoT devices for communication. Parameters of proposed MCPFB are shown in Table 2. The same parameters are also considered for previous BARS scheme.

**Table 2:** Parameters for Simulation

| Parameters | Configuration Value |
|---|---|
| Network Simulator Version | NS-2.31 |
| Routing Strategy | BARS, MCPFB |
| Area of Simulation (m$^2$) | 1650m*1065m |
| Network Type | FANET |
| Number of Nodes | 69 |
| Physical Medium | Wireless, 802.11 |
| Data Rate (bit/seconds) | 2000, 4000, 6000, 8000, 10000 |

| | |
|---|---|
| Simulation Time (Sec) | 300Sec |
| MAC Protocol | 802.11 |
| Antenna Uses | Omni Antenna |
| Traffic Uses | CBR, FTP |
| Radio Propagation Type | Two ray ground |
| Initial Energy (J) | Random |

## 8. Result Description

This section discusses the results of the previous BARS and the proposed MCPFB approach. Based on performance metrics, the performance of both protocols and MCPFB is superior.

### 8.1 Packet Receives Analysis

The packet receiving in the network improves the performance of the network. In FANET, this graph shows the packet analysis of previous BARS and proposed MCPFB approaches. The performance of both protocols is measured at different data rates, and it is evident that retransmission incurs extra overhead.

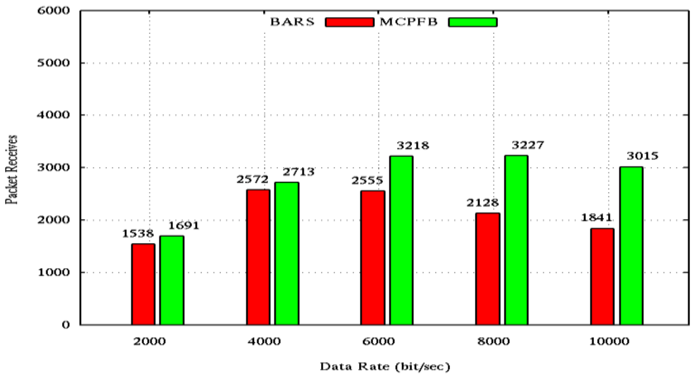


**Figure 2.** Packet Receive for Variation in Data Rate

The more data received showing a strong connection between UAVs and IoT devices, the higher the data rate, which is considered in bits per second. In lower data rates (2k and 4k), the receiving difference is not very much, but in higher data rates, due to properly managing the available bandwidth by fuzzy-based MCPFB, the receiving packet difference is more than 30% in 8k and 10k bits/sec data rates. The higher packets received mean that other metrics such as PDR and throughput will show good performance figures.

### 8.2 Packet Delivery Ratio Analysis

Increased data rates have a negative impact on packet delivery. When the data rate increases in the BARS scheme, improper bandwidth management leads to increased packet loss. While the proposed MCPFB data rate is efficiently manageable, in a rate of 8000 bits/sec, the packet delivery ratio is 72% in BARS and 96% in the proposed MCPFB. Each node in a mobile BARS system must keep data packets in queue for an extended period before sending them on. Consequently, data loss becomes more likely. This system adapts data rates; however, it breaks down at faster node speeds. In fact, the suggested method allows for immediate route re-establishment after disconnection of mobile nodes.

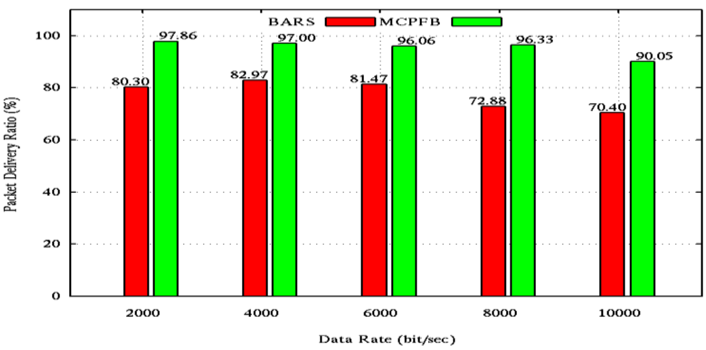


**Figure 3.** Packet Delivery Ratio for Variation in Data Rate

This study shows how the ratio of packet delivery to maximum node speed changes in a dynamic setting. Results show that our proposed scheme is better and efficiently utilizes the bandwidth in a highly dynamic environment.

### 8.3 Normal Routing Load Analysis

The routing load performance metric quantifies the inflow of routing packets into the network for the purpose of sending and receiving connection confirmation and setup. There is a noticeable improvement in performance for a small percentage of routing packets that reach the network. In this graph, the overhead NRL performance of BARS is very poor because it consumes a lot of bandwidth, which affects data packet reception and increases delay in the network, but MCPFB shows remarkable performance in a dynamic environment. More routing packets are using up the network's capacity, which in turn affects the time it takes to transmit data. With the proposed MCPFB lowering the routing load, congestion is also highly unlikely. The performance of both schemes was measured in different data rates with the same other parameters.

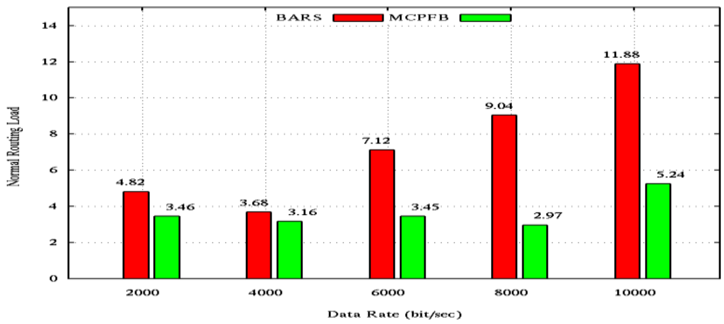


**Figure 4.** Normal Routing Load for Variation in Data Rate

### 8.4 Packets Dropping Analysis

Packet loss happens when the transmitting node is unable to successfully transfer a packet to the destination node. Packet loss is primarily caused by congestion.

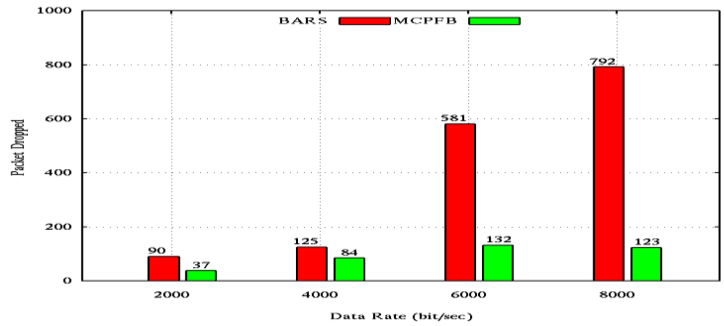


**Figure 5.** Analysis of Packet Drop for Variation in Data Rate

In this graph, illustrate the packet loss with four different data rate scenarios. Because nodes are unable to manage data rates, packet loss in the BARS scheme is severe, and node buffer capacity becomes overflowing. However, there is currently no way to handle congestion caused by poor bandwidth capacity, even when the data rate adaptation method has been adjusted. We found significantly lower packet loss with the proposed MCPFB method compared to BARS, even though it uses bandwidth as a parameter to prevent congestion. At an 8k bit/sec data rate, there is a 60% reduction in packet loss, and at a 6k rate, there is a roughly 40% reduction. This graph illustrates the findings for dynamic topology, demonstrating a lower packet loss ratio at random speeds. The results show that, compared to its competitors, the MCPFB approach has significantly lower packet loss.

### 8.5 Analysis Delay in [ms]

As packet loss rises, delay also increases. As packet loss grows, there will be more retransmissions and a longer end-to-end latency. The BARS system's high packet loss rate resulted in dropped data packets and significant overhead. Instead, the suggested MCPFB efficiently manages the load in a dynamic network by adjusting the data rate according to the available bandwidth, which leads to a decrease in packet losses. Controlling the data rate can prevent congestion, thereby lowering the network's latency.

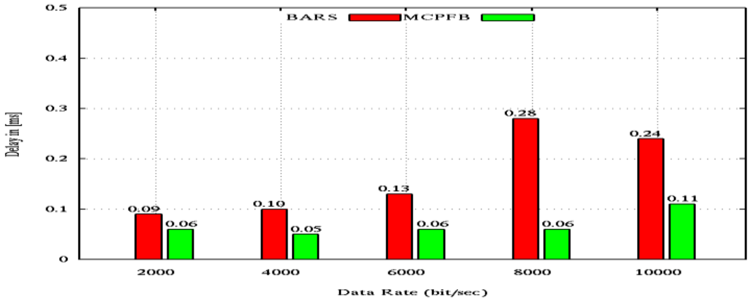


**Figure 6.** Delay in [ms] for Variation in Data Rate

It explains that for a data rate of 8 kbit/s, the average end-to-end delay is 50% less for MCPFB compared to BARS. Weak connections between wireless nodes cause mobile nodes in BARS to have a large end-to-end latency. A quick fix for route breakage and node reconnection is provided by the suggested MCPFB technique. As a result, the network's latency decreases as the number of dropped packets decreases. A dynamic topology reduces the end-to-end latency for node speeds of 2k, 4k, 6k, and 8k m/sec. When compared to its dynamic peers, MCPFB always comes out on top.

### 8.6 Analysis of Throughput [Kbps]

Congestion in a network has the opposite effect on throughput. In terms of throughput, the MCPFB scheme outperforms BARS because we have effectively dealt with congestion in the proposed scheme. This figure elucidates the throughput performance in different data rate scenarios. Results show that as the data rate increases, throughput also increases. The results indicate that the evaluation of throughput takes place in Kbps. MCPFB's performance is better than that of BARS. The locations of nodes in a dynamic network are constantly shifting. The sending nodes' inability to locate the receiving nodes reduced the throughput. We vary the data rate from 2,000 to 10,000 bits per second, and the graph displays the throughput in a dynamic setting. The results demonstrate that throughput is directly proportional to the data rate. According to the findings, BARS is the most popular choice for stationary nodes and mobile nodes, respectively.

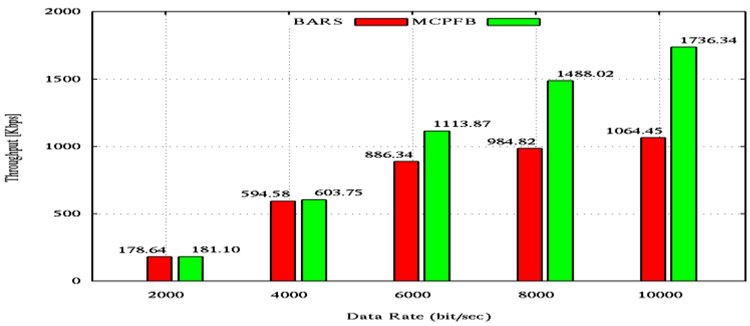


**Figure 7.** Analysis of Throughput [Kbps] for Variation in Data Rate

### 1.8.7 Analysis of Energy Consumption

UAVs and IoT devices are energy dependent devices. Each action-required energy for sensing, route request, route reply, data sending, and acknowledgement sending, and receiving.

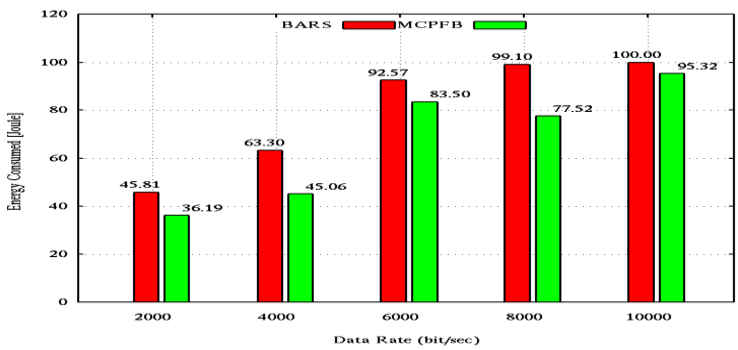


**Figure 8.** Energy Consumption for Variation in Data Rate

Different numbers of additional packets flood the network, providing information about other conditions such as congestion and collision. Fuzzy-based classification of congestion control minimizes congestion and makes routing reliable in the network. In sending data packets, energy consumption will be highest, and if, due to link breakage, packets are retransmitted in the network, then energy consumption will be higher and energy utilization will be poor. In this graph, the average energy consumption in different data rates is measured, but the consumption of the MCPFB protocol is less, which means it consumes less energy in communication. In all data rate scenarios, the performance of BARS was poor due to consuming more energy. The routing procedure of the proposed scheme uses energy efficiently and provides better routing performance.

### 8.8 Analysis of Residual Energy [joule]

The residual energy of nodes in dynamic connection among UAVs to UAVs and UAVs to IoT shows extra life or still, nodes can participate in routing procedures. The energy level of nodes is reducing in every data delivery or route by which data packets are sent. Energy consumption is utilized if a greater number of data packets are received at the destination with respect to the sending of data. In this graph, the residual energy analysis is measured between the MCPFB and BARS protocols. Higher data rates mean more energy is required for data sending and receiving, but strong connection establishments enhance the possibility of energy savings and successful data receiving. The fuzzy rules of the proposed scheme are able to enhance the life of nodes as compared to the previous BARS scheme.

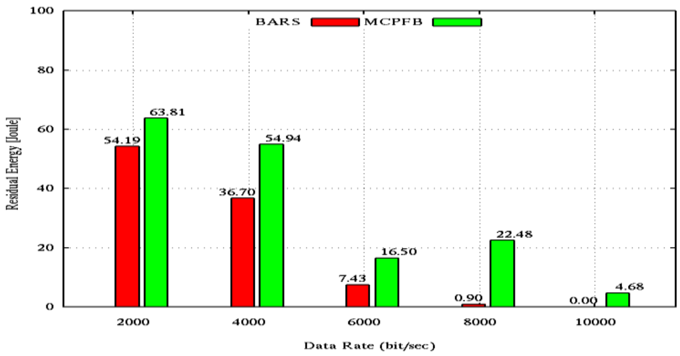


**Figure 9.** Residual Energy [Joule] for Variation in Data Rate

The node's energy consumption in the case of MCPFB is less in the network; that is why the remaining energy, or residual energy, is higher, and due to proper energy utilization, the residual energy of the nodes in the proposed routing remains more.

## 9. Conclusion and Future Work

Generally, UAVs are move with high mobility speed and deployed in low density, while IoT devices are deployed in low density with moderate or low mobility. The communication range of different types of UAVs is different, and some UAVs are able to connect with satellites or base stations to transfer information over long distances in FANET. However, for this, it required a symmetrical link between the mobile and stationary components in the network. The IoT network is reliable as compared to the hop-to-hop sort of distance network because all the devices in the IoT are connected to the internet for communication. Due to the frequent changes in the network topology and information gathering, the load on the UAVS is increased, which causes congestion problems in the network. Due to the high speed of UAVs, communication between the UAVs is frequently disconnected, and because of that, many data is dropped in the network. This research proposes a MCPFB scheme to control the congestion in FANET-IoT. The fuzzy rules are showing the congestion status, which is based on the load and data rate. The FANET-IoT network is reliable in terms of transferring information over long distances with the help of IoT devices. The probability of congestion is higher because UAVs can collect many data, and IoT devices need some time to collect and transfer data because of their limited bandwidth capacity. This disrupts the communication network, leading to a detrimental effect on both routing efficiency and performance. Disrupted connectivity in networks increases the complexity of routing in UAV networks compared to their current state. Hence, fluctuations in the network have an adverse impact on routing efficiency and result in packet dropouts. Routing is crucial in UAV networks for facilitating cooperative and collaborative network operations. MCPFB is an advanced and all-encompassing solution for optimizing the performance of congestion control routing algorithms in UAV networks. The performance of the MCPFB is being compared to that of the prior bandwidth-aware routing scheme, BARS. These comparative results can assist researchers and engineers in selecting the most suitable congestion management routing technique based on superior performance. The proposed MCPFB shows a 20% improvement in PDR performance, a 50% reduction in data dropping, 40% less overhead, and a

30% improvement in throughput compared to BARS. UAVs are fast and reliable devices for information collection in places where human presence is difficult and easily transfer the information to other places with the strong internet connectivity of IoT devices. This paper focuses on the research that enhanced routing performance increased the performance of the network and minimized energy consumption. The MCPFB is able to increase its performance by balancing the load on routes established by senders. The main advantage of reliable congestion control is to avoid the possibility of congestion, unnecessary energy consumption, and the retransmission of data packets in the network. The proposed MCPFB approach is responsible for providing a congestion-free path between communicator nodes and providing efficient communication with minimum overhead. Further MCPFB is simulated by the network simulator-2 and the network behavior during communication is analyzed. In the future, we will try to propose a method to secure the FANET network from dropping attacks.

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