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MEMORY, CHANNEL AND PROCESS UTILIZATION FOR FUZZY BASED CONGESTION DETECTION AND AVOIDANCE SCHEME IN FLYING AD HOC AND IOT NETWORK

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Abstract. UAVs are flying in the air at different speeds and continuously forwarding the collected information to other UAVs or IoT devices in FANET. UAVs are playing an important role in data collection from places where humans can't reach them easily. The UAVs are intelligent devices, and these devices have sufficient bandwidth and memory for data forwarding and storing. The role of UAVs is specific, and they have the reflexibility to change the battery and control the data interval to control the congestion in network. The IoT devices with FANET can transfer the valuable data to other IoT devices for verification and matching. The proper utilization of bandwidth, memory, energy and processing capability are able to increase the Quality of Service (QoS) in FANET. In this paper, proposed the Memory, channel and Process utilization for Fuzzy based (MCPFB) for congestion detection and avoidance scheme to improve bandwidth utilization, energy consumption in FANET with the IoT network. primarily aims to identify and prevent network congestion, which is crucial for maintaining the QoS requirements and ensuring reliable communication. Congestion is a phenomenon that arises when the volume of data transmitted across a network exceeds its capacity. These factors can lead to disruptions, reduced efficiency, and potential data loss in communication networks such as Flying Ad Hoc Networks (FANETs). To effectively handle congestion in FANET and provide reliable communication in challenging and dynamic environments, it is crucial to employ efficient resource management, intelligent algorithms, and adaptable protocols. The process of designing fuzzy rules for Flying Ad Hoc Networks (FANET) entails developing a set of guidelines that utilize fuzzy logic to make decisions pertaining to different parts of the network. The MCPFB is better than the previous BARS approach in terms of different performance metrics.

Key words: Bandwidth, Congestion, Energy, MCPFB, IoT, FANET

1. Introduction.

In any network communication between devices play an important role in exchanging data from one place to another, but it depends on various factors i.e. communication medium, channel availability, intermediate devices, queue capacity, processing capacity of network devices, etc [1] [2]. In the new era of communication technology wireless communication plays a vital role in providing communication anywhere at any time which is further categorized in three ways FANET, MANET, and VANET. This paper works under FANET, Flying Ad Hoc Network (FANET) is a specialized kind of mobile ad hoc network (MANET) that facilitates communication between unmanned aerial vehicles (UAVs) or drones [1] [2]. Flying ad hoc network completely depends on intermediate nodes which help to provide a route from one device to another using FANET routing protocol, but the data exchange from device to device is not an easy task it requires sufficient channel bandwidth, processing power, node energy, node mobility, topology monitoring, etc. due to all this requirement, it a chance to challenge of network congestion. In this paper, our main focus is to detect and avoid network congestion which is further useful to maintain the network quality of service requirement and provide reliable communication.

In the given figure 1.1 number if UAVs are five and only two IoT devices are collecting the information from UAVs. UAVs are also connected to Base station. When the amount of data sent via a network surpasses its capacity, a phenomenon known as congestion occurs [3]. This can cause delays, decreased performance, and even packet loss in communication networks like Flying Ad Hoc Networks (FANETs). Efficient resource management, smart algorithms, and adaptable protocols are needed to manage FANET congestion and guarantee dependable communication in difficult and ever-changing conditions. In this paper detect and avoid congestion using fuzzy rules, designing fuzzy rules for Flying Ad Hoc Networks (FANET) involves creating a set of guidelines based on

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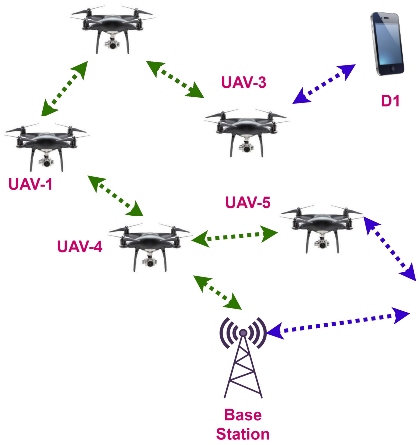

Fig. 1.1: FANET with IoT Communication

fuzzy logic to make decisions related to various aspects of the network [4]. To offer immediate communication in a challenging and distracting setting, FANET applications have been extended to other networks in the past several years. While FANETs have many potential uses, distributed optimization becomes more difficult due to the unreliability of connectivity caused by the increased mobility of UAVs [5]. Prior studies have focused on improving flying ad hoc communication and Internet of Things (IoT) equipped devices to address future difficulties before using them in the real world. A few of them fix problems with routing, resource utilization, predicting the movement of unmanned aerial vehicle (UAV) nodes, deciding on the topology of the network, security, and quality of service. Researchers gather all relevant issues and potential solutions, as well as write the research statement, before proceeding with the project. Fuzzy Methods for FANET and Internet of Things Congestion Avoidance in a methodical approach, this issue is resolved [6] [7] [8]. At first, it assesses the capacity of each node in the network in terms of all related metrics, such as energy consumption, processing speed, memory acquired for data buffering, channel bandwidth across links, and so on. At the moment of routing decision, when communication is being formed and initiated, all of the nodes are ranked from highest to lowest based on the aforementioned factors.

The article is divided into six sections. section 1 describes about introduction of FANET, and congestion control using fuzzy rule, section 2 gives a detailed explanation of existing work of congestion control in FANET, section 3 describes the proposed fuzzy logic technique for congestion control. Section 4 describes the proposed algorithm for congestion control, and section 5 shows the outcome of the proposed work and compares it with the existing system of congestion control in the last section 6 describes the conclusion and future work of the research article.

2. Issues in FANET and IOT. FANET and the Internet of Things (IoT) are two fast emerging technologies that, when coupled, offer a plethora of possibilities and applications. However, its integration poses many obstacles and issues [1][4][9]. Here are some of the major difficulties raised by integrating FANET and IoT.

Reliability of communication. FANET is based on wireless communication between aerial nodes or drones. Interference, signal attenuation, and limited bandwidth can all have an impact on communication reliability. A dependable communication link is critical in IoT applications, particularly those demanding real-time data delivery.

Scalability of a network. The network must scale as the number of IoT devices and aerial nodes grows. Managing a large-scale FANET with numerous networked IoT devices involves network architecture, addressing, and efficient routing problems.

Constraints on Energy. Drones in FANET and IoT devices frequently have low battery power. Energy-efficient communication protocols and solutions for regulating the energy consumption of aerial nodes and IoT devices are crucial for network operations to continue [10].

Privacy and security. Security is a major issue in both FANET and IoT. Combining the two creates new issues in terms of safeguarding communication channels, protecting data integrity, and ensuring the privacy of data collected by IoT devices.

Topology of a Dynamic Network. Because of the mobility of drones, FANETs have dynamic and unpredictable network topologies. Integrating IoT devices in such a dynamic environment necessitates adaptive routing algorithms and protocols capable of dealing with frequent topology changes [11].

Coordination and synchronization. Maintaining synchronization and coordination across drones and IoT devices is critical for data collecting, processing, and decision-making efficiency. Synchronization issues exist in a dynamic and decentralized FANET, and they must be solved.

Regulatory and Legal Considerations. FANET and IoT integration may generate regulatory and legal problems about airspace control, data ownership, and privacy. Following existing regulations and ensuring compliance with new ones becomes critical.

Fusion and processing of data. FANET generates massive amounts of data, which IoT devices contribute to. To extract relevant information from the merged data sources in real time, efficient methods for data fusion, processing, and analytics are required.

Autonomous mode of operation. FANET and IoT systems frequently operate autonomously or semi-autonomously. It is vital to ensure the reliability and safety of autonomous systems, especially in dynamic and unpredictable contexts.

Environmental Implications. The environmental impact of FANET, including drone energy consumption and electronic trash disposal from IoT devices, should be considered. The design and operation of these systems must incorporate sustainable practices and technologies.

To address these difficulties, professionals in communication systems, control theory, cybersecurity, and regulatory compliance must work together. Furthermore, continual research and development are required to establish solid solutions for FANET and IoT integration.

3. Literature Survey. This section aims to enhance understanding of current advancements in the areas of congestion, energy efficiency, and load balancing. The authors proposed numerous strategies for mitigating congestion in FANET with IoT. The recent work of authors considered.

Nousheen Akhtar et al. [12], proposed a bandwidth ware routing scheme (BARS) that is sensitive to bandwidth. It caches information in a queue to dynamically modify communication rates and alleviate congestion. The technique enables the source to modify its transmission rate whenever the network is close to experiencing congestion. We adapt the existing AODV protocol based on the available bandwidth in the network and the remaining queue sizes of each node in the path. The suggested routing strategy alters the RREQ and RREP messages of AODV by incorporating information about path bandwidth and queue size. Furthermore, the RERR message is also adapted to address path disconnection. To ensure high-quality routing, we have employed bandwidth and queue size as criteria for selecting routes. The limitation of this research is PDR decreases when mobility increases and packet loss % is more than 16%.

Manjit Kaur et al. [13], proposed a highly effective load balancing algorithm in FANET. This work is based on the traffic congestion control algorithm as a problem of optimizing network utility, while considering several network characteristics. The suggested method distributes the computing load among airborne nodes while determining the location of unfamiliar nodes. Furthermore, the method has been enhanced by integrating the Firefly algorithm and the traffic congestion control algorithm into a FANET. The limitations of the research include a simulation time of only 12 milliseconds and a recommended technique with a PDR value above 100, which is not feasible. The analysis of packet dropping resulting from congestion is absent.

Shaojie Wen et al. [14], proposed an Optimization of distributed systems with time constraints in Flying Ad-Hoc Networks (FANETs) using both primal and dual decompositions." The objective of this title is to enhance several network characteristics in a decentralized manner for delay-constrained flying ad hoc networks (FANETs) without having access to global network topology information. For this purpose, every Unmanned Aerial Vehicle (UAV) calculates the mean amount of disturbance over a specific duration to ascertain the status of the channels. The distributed optimization problem is thus expressed as a utility maximization problem that simultaneously optimizes power control, rate allocation, and routing with constraints on delay. A method is shown to eliminate the restriction on connection capacity, employing a dual approach. The primary limitation of the research is to analyze the varying speeds of UAVs, which are influenced by communication factors and the results lack an overhead analysis.

Lingli Yang et al. [15], proposed a RES-TDMA, which is a decentralized scheduling system based on time-division multiple access (TDMA), specifically designed for FANET. This protocol can allocate time slots dynamically by monitoring packets that request time slot reservations. By managing the traffic table, network nodes can obtain time slot allocation information within a maximum of two hops, as well as promptly recognize and free up time slots. Furthermore, the integration of an intent-driven network into FANET, the proposed RES-TDMA, provides the ability to perform self-analysis and self-configuration functions depending on the traffic intent. Our proposed technique effectively reduces the influence of node mobility and enhances the utilization of time slots. The primary limitation of the research is the absence of an investigation of the specific number of operational UAVs within a given time window. The impact of time slots on packet reception is not assessed and the time slot method for long-term users is not specified.

G. Soni et al. [16], proposed a novel privacy-preserving under dense traffic management (PPDM) routing method to safeguard the 6G-VANET from malicious black hole attacks in VANET. Black hole cars disregard essential information from traffic status packets transmitted by leading vehicles to trailing vehicles. A security system is capable of detecting and effectively preventing the loss of data packets within a network node. The existing SAODV security system is compared to the innovative PPDM system. By implementing a ban on aggressive cars within the network, the PPDM effectively safeguards and improves the performance of the VANET. An evaluation is conducted to compare the effectiveness of the proposed PPDM system with the existing SAODV. The PPDM demonstrates superior performance and less data loss as compared to the SAODV. The primary limitation of the research is its exclusive focus on detecting a single node, rather than several nodes. The drop in performance is solely attributed to the attacker not being assessed and the role of RSU in assault detection is not elucidated. Torkzadeh et al. [17], proposed a distinctive and efficient evolutionary method to tackle this problem. The researchers introduced an innovative QoS routing algorithm that incorporates evolutionary approaches (EAs). This algorithm is efficient and generates feasible solutions within a brief timeframe. The goal of the EAs is to ascertain the best appropriate and feasible solution for the given circumstance. In order to accomplish this, we initially assess the criteria of our problem, specifically the task of determining a viable route from a designated starting point to a specified endpoint inside an extensive network. The main goal of routing algorithms is to choose a path in a flexible, intelligent, and adjustable fashion. The primary limitation of the research is the minimal disparity in the success rate between the suggested strategy and earlier approaches and what is the benefit of this extremely low success rate? It is not specified. Assessment of routing performance with respect to data packets is lacking.

Sharma et al. [18] proposed a Distributed priority tree-based routing algorithm for FANETs. Their study focused on network partitioning between aerial and ground ad hoc networks and aimed to build a routing protocol that can effectively handle transmission in a coordinated system. The system relies on a combination of three primary criteria: link quality, traffic load, and spatial distance. Pu et al. [19], proposed a multipath routing protocol specifically designed for flying ad hoc networks (FANETs) to mitigate intentional jamming, disruption, isolated failures, and localized failures. The aim is to prevent these issues from negatively impacting the overall network performance of FANETs. Fang et al. [20] proposed a hybrid media access control mechanism for aeronautical ad hoc networks that ensures quality of service (QoS). The protocol is based on pre-allocating transmission time slots and providing rapid access. The aforementioned routing algorithms exclusively consider transmission dependability and disregard the constraint of packet latency.

M. Ploumidis et al. [21], proposed a method for allocating flows in random-access wireless multi-hop networks. The goal of their approach is to maximize throughput and limit latency by allocating different flows across numerous discontinuous pathways. This is particularly relevant for networks with multi-packet reception capabilities. In order to enhance the overall flow throughput and minimize packet latency, the issue is formulated as a non-convex optimization problem, and a distributed flow allocation method is suggested.

4. Proposed Approach.

A flying ad hoc network is a collection of highly movable nodes to interconnect by wireless medium, which has a low capability of processing power, memory, and energy retention. Due to their limitations, it faces the congestion problem because it has a low bandwidth capacity. In the section of the existing survey, we study various congestion resolution algorithms that deal with overcoming the problem of congestion and improving the service quality of the network. In this article, our objective is to implement a fuzzy rule-based congestion control technique for flying ad hoc networks (MCPBF), which detects and further avoids congestion from the network as compared to the existing approach. The section describes how the fuzzy rules work, what parameters are taken to control and avoid congestion in the network, and the type of output impact after the avoidance rule is applied.

Assuming we want to determine the level of congestion in the FANET based on factors such as channel utilization, data interval, energy and memory utilization. Flying ad hoc networks form the route decision in a dynamic way, which takes time complexity O(n2), and after the route establishment process, the source device sends data to the base station or receiver node, which requires time complexity O(n) for data transmission. Analyzing Memory, Data interval, Channel, and Process Utilization for Fuzzy-Based Congestion Detection and Avoidance in Flying Ad Hoc and IoT Networks (MCPFB) entails assessing how the proposed system manages and uses these resources. Here's how may go about approaching this analysis:

4.1. Data Interval.

In data transmission between nodes, the data interval often refers to the time period between data packets. The channel bandwidth, data size, and data type all affect the amount of time between data packets. In network communication, when the data interval is lower than the average interval, congestion occurs; on the other hand, when the interval is higher than the average data interval, bandwidth utilization is low, necessitating the use of a technique that keeps the data interval consistent. To preserve the consistency of data intervals, MCPBF first identifies the data interval and obtains a fuzzy inference such as low, medium, or high, and then applies the congestion avoidance approach when the data interval becomes low and leads to congestion.

4.2. Energy Utilization.

Flying devices have a low capability of energy devices because they only work under limited battery power, which has the chance to increase the sudden communication loss. To improve communication, it's more important to utilize energy resources in an efficient way which is possible to increase the communication time using low energy utilization. Energy parameters are involved in calculating the congestion level when a node has low energy and sudden loss of network which changes the route from one to another and increases the load of other paths, so in the proposed MCPBF approach more emphasis on detecting every node energy to be aware of congestion level. Congestion is detected using a fuzzy-based technique which uses the linguistic variable as (Low, Medium, High) their rules if defined in below section.

4.3. Memory Utilization.

Flying ad hoc devices having low capable memory units, which handle the incoming and outgoing data flows of devices. While the incoming data flow of any intermediate device is higher than the outgoing then it increases the utilization of memory of the device and any instance of time node memory is fully utilized which raises the problem of congestion. The memory of the device is indirectly dependent on congestion which is monitored by a fuzzy rule-based technique their linguistic variables are (Low, Medium, and High).

4.4. Channel Utilization.

Congestion occurs in a flying ad hoc network when each node delivers data to its destination at the same time, exceeding the capacity of the channel. At the moment, just the data link layer is active, allowing the source nodes to perceive the medium all the way to the next linked node. However, when the capacity of that shared connection is depleted due to severe demand, congestion in the network becomes an issue. The rules of the suggested (MCPBF) method, which uses a fuzzy-based approach to identify and avoid network congestion, are defined in the section below. By systematically analyzing these aspects, you can gain insights into how the MCPFB system performs in terms of memory, channel, and process utilization for fuzzy-based congestion detection and avoidance in a Flying Ad Hoc and IoT Network.

Rule 1: IF (Data interval is Low) AND (Channel Uses is High) AND (Memory Uses is High) **THEN** (Congestion is High)
Rule 2: IF (Data interval is Medium |High) AND (Channel Uses is Medium) AND (Memory Uses is Medium) **THEN**

Table 5.1: Parameters for simulation

Parameters	Configuration Value
Simulation Tool	NS-2.31
Routing Protocol	BARS, MCPBF, WRA, DRA
Simulation Area	1650m∗1065m
Network Type	FANET
Number of Nodes	69
Physical Medium	Wireless, 802.11
Simulation Time (Sec)	300Sec
MAC Layer	802.11
Antenna Model	Omni Antenna
Traffic Type	CBR, FTP
Propagation radio model	Two ray ground
Energy (Initial)/J	Random

(Congestion is Medium)
Rule 3: IF (Data interval is Medium |High) AND (Channel Uses is Low) AND (Memory Uses is Low) **THEN** (Congestion is Low)

4.5. Proposed MCPFB Algorithm. This section describes the formal description of memory, channel, and process utilization to detect congestion using a fuzzy rule-based method which is classified into three levels i.e. low, medium, and high. We get high congestion that is resolved by minimizing channel utilization and memory utilization methods and increasing data interval to overcome the congestion in the flying ad hoc network. The algorithm will be divided into three parts: input, procedure, and output. In the input section, declare the variables such as source device, receiver device, fuzzy variables, data interval, protocol type, data type, etc. All these variables are configured with NS-2.31 by calling the function using the declared variable. In the procedure section, perform the routing procedure using data interval, channel utilization, and memory utilization of each intermediate flying device, and apply a fuzzy rule to select the best path, which is a congestion-free route; the other path is under the category of heavy or medium congestion status, so that the nodes are not selected for communication, and resolve the issue of congestion by data rate minimization, etc. In the output section, retrieve the results of the MCPFB algorithm in terms of throughput, packet delivery ratio, routing load, congestion status, energy, memory, channel utilization status, etc. with the help of the proposed algorithm to detect and avoid congestion in the IoT-flying ad hoc network.

5. Simulation Parameters. Simulation parameters depend on the specific context and goals of your simulation. However, for a general simulation involving Free-floating Aerial Networks (FANET) with Internet of Things (IoT) devices. The simulation parameters considered for simulation are simulation time that should be sufficient to capture relevant events and behaviors, the number of nodes, the communication range, and the rest of the parameters mentioned in Table 5.1.

6. Result Description. This section mentions the result analysis of previous BARS and the proposed MCPFB approach. The performance of both the protocols evaluated by performance metrics and the performance of MCPFB is better.

6.1. Throughput Analysis. Throughput is the amount of data sent from one end to the other in a certain amount of time. If the received packets are of higher quality, there will be a longer delay in data retransmission. This implies that the throughput parameter is good for measuring packet receiving at the destination end because there is no room for data retransmission and the network is congested, it is desirable to have a significant delay in successful transmission. In this graph, we have taken the analysis of DRA, WRA, BARS, and MCPFB protocols, where MCPFB has a maximum throughput performance of 550 kbps, BARS has a maximum throughput performance of 400 kbps, WRA has 400 kbps, and DRA's maximum throughput is nearly 340 kbps. With the comparative analysis of throughput, we conclude that the proposed MCPFB

Algorithm 1 MCPFB

```
Input:
$N_t$: Network type IoT-FANET
$f_d$: flying device
$D_s$: Data source device $\epsilon$ $f_d$
$R_d$/BTS: Data receiver device or base receiver $\epsilon$ $f_d$
$I_f$: Intermediate flying device $\epsilon$ $f_d$
$F_zv$: (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 MCPBF
$D_{type}$: Data type TCP, UDP
$\Psi$: radio range $550m^2$

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

Procedure:
Form $N_t$ with active $f_d$
$D_s$ want to sent data to $R_d$
$D_s$ call $R_{pt}$ and Create packet ($D_s$, $R_d$, $R_{pt}$)
  while (visited $\neq f_d$ OR $I_f \neq R_d$) do
    if ($I_f$ in $\Psi$ and $I_f \neq R_d$) then
      Calculate ($D_{inter}$, $E_{uti}$, $Ch_u$, $M_uti$) of $I_f$
      Apply MCPBF for fuzzy inference
      if (($D_{inter}$ is Low) AND ($Ch_u$ is High) AND ($M_uti$ is High) then
        $I_f$ ($Cong_s$ ) $\leftarrow$ High
        $I_f$ $\leftarrow$ node not selected
        $I_f - 1$ forward route packet to other next-hop
        $I_f = I_f + 1$
      else if ($D_{inter}$ is medium) AND ($Ch_u$ is medium) AND ($M_{uti}$ is medium) then
        $I_f$ ($Cong_s$ ) $\leftarrow$ Medium
        $I_f$ $\leftarrow$ Selected in route and $I_f$ stop receiving new route packet
        $I_f$ $\leftarrow$ forward route packet to next-hop
      else
        $I_f$ ($Cong_s$ ) $\leftarrow$ low
        $I_f$ $\leftarrow$ Selected in route and $I_f$ stop receiving new route packet
        $I_f$ $\leftarrow$ forward route packet to next-hop
        $I_f = I_f + 1$
      end if
    else if ($I_f$ in $\Psi$) and ($I_f == R_d$ ) then
      $I_f \leftarrow l_f$
      $R_d$ receiver route packet
      if (Path > 1) then
        Calculate $E_{uti}$ of each node in $\forall$ paths‘

        if $path_i(E_{uti}) < path_j(E_{uti})$ then
          $Path_i$ select for communication
        else
          $Path_j$ select for communication
        end if
      end if
      $R_d$ Send acknowledgement to $D_s$
      $D_s$ call $Data_{pkt}$ $(D_s, R_d, D_{type})$
    end if
    $Data_{pkt}$ $(D_s, R_d, D_{type})$
    $D_s$ start data sending to $R_d$
    Check $Cong_s$ of each $I_f$ node in path
    if ($D_{inter}$ is Low) AND ($Ch_u$ is High) AND ($M_{uti}$ is high or medium) then
      $I_f$ ($Cong_s$ ) $\leftarrow$ High or Medium
      Increase $D_{inter}$ or min($P_{size}$)
    else
      $I_f$ ($Cong_s$ ) $\leftarrow$ Low
      $D_s$ send $D_{type}$ without changing $P_{size}$ and $D_{inter}$
    end if
  end while
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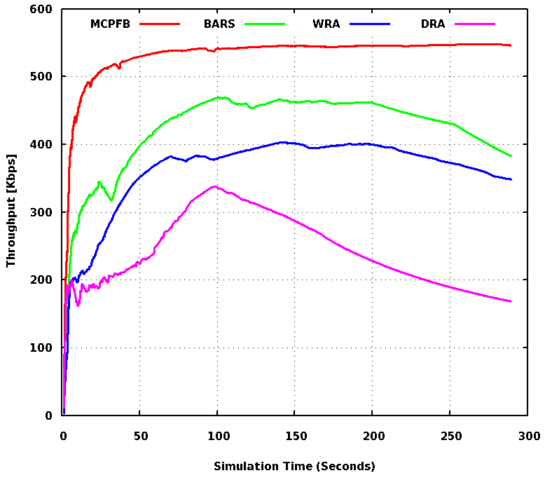

Fig. 6.1: Throughput Analysis

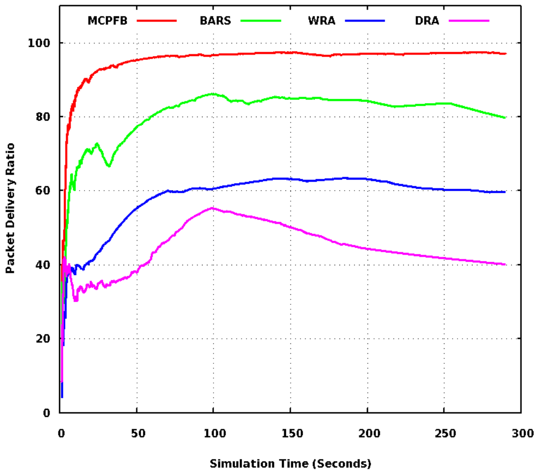

Fig. 6.2: PDR Analysis

technique gives efficient performance with a congestion-free network.

6.2. Packet Delivery Ratio Analysis. The data-receiving percentage performance indicates how much data was successfully received and delivered to the destination. The available bandwidth capacity is the most crucial feature of any wireless connection, and having adequate bandwidth means minimal data loss. Initially, the MCPFB technique in the network establishes paths through nodes that get a high signal strength. The MCPFB has received 92%, when the BARS have received 80% and two other existing techniques WRA and DRA packet delivery ratio less than 60%. At the destination end, MCPFB ensures that maximum number of packets is successfully received. The MCPFB technique allows for effective channel utilization as well as optimal bandwidth utilization and energy utilization. When network congestion is addressed appropriately using the provided technique, data loss is reduced and performance is improved.

6.3. Routing Overhead Analysis. The normal routing load is defined as the ratio of the number of data packets received to the number of packets utilized to establish connections. As the number of greeting or control packets increases, so does the amount of bandwidth consumed. This indicates that when the bandwidth

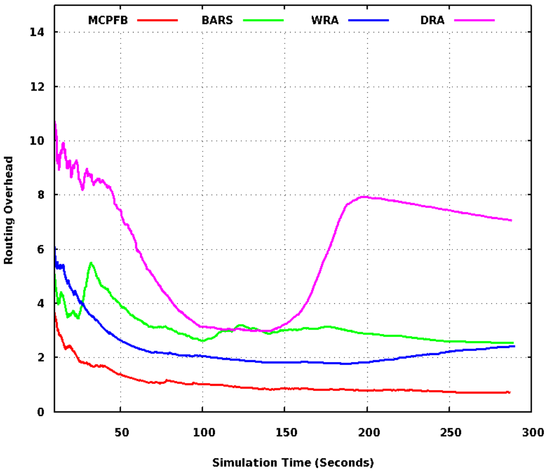

Fig. 6.3: Routing Overhead Analysis

Table 6.1: Data interval analysis

	BARS		MCPFB	
Connection Pair	Data Interval	Status	Data Interval	Status
0< − >60	0.16	Medium	0.32	Low
10< − >61	0.1	High	0.166666667	Medium
15< − >62	0.3	Low	0.333333333	Low
20< − >63	0.2	Medium	0.222222222	Low
35< − >3	High			
45< − >65	0.12	High	0.171428571	Medium
47< − >66	0.21	Low	0.35	Low
50< − >67	0.51	Low	0.566666667	Low
52< − >68	0.19	Medium	0.211111111	Low

utilized by hello packets is less than the bandwidth available for data packets. The NRL of previous technique WRA, DRA and BARS is higher than MCPFB approach in FANET-IoT network. The NRL of proposed MCPFB is less than 1, it is barely 2 in the beginning of simulation. The overhead of BARS is three times more which shows unnecessary bandwidth consumption. When there is less overhead, the link between the sender and the recipient becomes more reliable. The amount of data lost in the network is lowered as a result of the decreased possibility of packet retransmission. The only way to accomplish this extraordinary result is to use buffer management and multipath path routing in tandem with suitable channel allocation.

6.4. Data Interval Analysis. The data interval analysis uses the fuzzy linguistic (low, medium, and high) technique mentioned in Table 6.1, and the status of MCPFB congestion is low on some connection pairs as compared to the previous BARS scheme in the network. The connection pair 0 and 60, 45 and 65 or more congestion status has been approved. Less congestion means more fast packets receiving.

6.5. Channel Analysis. The channel analysis using the fuzzy linguistic (low, medium, and high) technique is mentioned in table 6.2 and the status of MCPFB channel utilization is showing medium status but that was high in the previous. The connection pairs 0 and 60, 20 and 63 utilize channel efficiently. Proper channel utilization gives better as compared to MCPFB.

6.6. Queue Analysis . The queue analysis is mentioned in Table 6.3 and the status of MCPFB congestion is medium to low for connection 45 to 65. The queue utilization shows balanced data forwarding in the network.

Table 6.2: Channel Analysis

	BARS		MCPFB	
Connection Pair	Channel Utilization	Status	Channel Utilization	Status
0< − >60	100	High	50	Medium
10< − >61	100	High	66	High
15< − >62	40	Medium	35	Medium
20< − >63	75	High	35	Medium
35< − >64	100	High	100	High
45< − >65	42	Medium	34	Medium
47< − >66	42	Medium	40	Medium
50< − >67	3	Low	3	Low
52< − >68	15	Low	13	Low

Table 6.3: Queue Analysis

	BARS		MCPFB	
Connection Pair	Queue Uses	Status	Queue Uses	Status
0< − >60	16	Medium	14	Medium
10< − >61	20	Medium	18	Medium
15< − >62	24	Medium	22	Medium
20< − >63	3	Low	3	Low
35< − >64	4	Low	4	Low
45< − >65	10	Medium	9	Low
47< − >66	18	Medium	16	Medium
50< − >67	4	Low	4	Low
52< − >68	6	Low	5	Low

Table 6.4: Energy Utilization Analysis

	BARS		MCPFB	
Node Pair	Percentage of Utilization(E)	Status	Percentage of Utilization(E)	Status
0< − >60	38.46	Medium	30.59	Medium
10< − >61	50	High	45.44	High
15< − >62	42.1	High	33.93	Medium
20< − >63	42.34	High	32.13	Medium
35< − >64	39.72	Medium	28.69	Medium
45< − >65	50	High	45.22	High
47< − >66	47.11	High	33.15	Medium
50< − >67	37.04	Medium	29.81	Medium
52< − >68	35.1	Medium	25.36	Medium

The normal queue utilization means faster packet receiving.

6.7. Energy Utilization Analysis. The energy utilization of low-capacity devices is impacted by more parameters because if device energy utilization is higher, it means devices frequently change the route from a dead path to an alive path. In this section, describe in Table 6.4 the simulated analysis of energy utilization in the existing BARS and the proposed MCPBF technique using fuzzy linguistic variables (low, medium, and high) and conclude that the proposed MCPFB is efficient because it minimizes energy utilization as compared to the BARS technique. It means MCPFB minimizes energy consumption while increasing network stability.

Table 6.5: Summarized Performance Analysis

Parameters	BARS	MCPFB	WRA	DRA
Number of Packets Sends	14529	15866	15026	12966
Number of Packets Receives	11584	15388	8977	5208
Percentage of Data Receives	79.73	96.99	59.74	40.16
Normal Routing Load	5.07	1.43	2.41	7.06
Average e-e delay(ms)	149.29	66.53	73.36	190.12
Average Energy Consume	83.2	63.26	80.25	90.85
Average Residual Energy	16.46	36.1	19.28	8.88

6.8. Summarized Performance Analysis. In this section, we describe the summarized results of FANET-IoT application protocols. Table 6.5 compares the performance of the existing technique DRA, WRA, and BARS with the proposed MCPFB and gets the outcome in terms of the number of packets sent, received, percentage of data received, routing overhead, delay, and energy consumption. All collective parameters perform more efficiently and are more adoptable while applying the proposed MCPFB technique, which is useful for futuristic FANET-IoT.

7. Conclusion and Future Work. In the Flying Ad-hoc Network (FANET), UAVs build a temporary network with IoT devices to send information from one location to another or to other devices, such as IoT. The UAVS has the ability to collect and record current state data and transfer it to distant IoT devices. The data interval, bandwidth, and memory space all play key roles in the proper communication of hybrid devices in networks. In this study, IoT devices were able to send direct instructions to any other IoT device via regular connectivity. In order to identify and avoid network congestion more effectively than the current approach, this study proposes a fuzzy rule-based congestion control technique known as MCPFB. The MCPFB explains how fuzzy rules work, the parameters used to manage and prevent network congestion, and the consequent impact on output after applying the avoidance rule. To determine the amount of congestion in the FANET, we will look at channel use, data interval, energy utilization, and memory utilization. Finding out how well the proposed system manages and makes use of these resources is part of studying Memory, Data Interval, Channel, and Process Utilization for Fuzzy-Based Congestion Detection and Avoidance in Flying Ad Hoc and IoT Networks (MCPFB). The UAVs cannot examine the data to decide if it is valid or erroneous. The bandwidth and processing capabilities of UAVs are always difficult for researchers to manage and send across FANET. The congestion control approaches mentioned in this study are trustworthy and capable of improving network performance. MCPFB aims to enhance accuracy and produce better outcomes than earlier approaches. The MCPFB throughput performance is more than 100 kbps greater than BARS, WRA, and DRA, and the PDR is more than 15%, indicating higher data packet reception. The better data receiving means lower overhead, which is why the overhead of MCPFB is 1.4, resulting in a less congested network than other existing techniques, and BARS is 5.1 (four times) higher than the other two existing WRA and DRA, which also have higher overhead, increasing network congestion. In the future, try to propose a fuzzy-based security approach in FANET against flooding. The role of the fuzzy rule is to detect the attacker's presence and the prevention scheme's role is to disable the exitance of an attacker to control the malicious actions in the network.

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