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UNVEILING THE PERFORMANCE OF AODV AND OLSR IN FLYING AD-HOC NETWORKS

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Abstract: With the increasing reliance on unmanned aerial vehicles (UAVs) for critical tasks, Flying Ad hoc Networks (FANETs) have emerged as a vital communication framework. FANETs facilitate autonomous coordination among UAVs, offering promising applications in military operations, disaster response, and healthcare. This paper focuses on the delves of Flying Ad hoc Networks (FANETs), exploring its simulation tools and two prominent routing protocols: Ad hoc On-Demand Distance Vector (AODV) and Optimised Link State Routing (OLSR). The routing protocols were compared based on three performance metrics: throughput, end-to-end (E2E) delay, and packet delivery ratio (PDR). The methodology of each protocol was discussed, shedding light on their strengths and weaknesses. Furthermore, the paper examines real-world case studies to highlight the implementation of FANETs in military, disaster management, and healthcare scenarios. The findings of this paper provide valuable insights for researchers and practitioners in optimising FANETS performance and enabling its successful deployment across diverse domains.

Keywords: Flying Ad hoc Networks, Routing Protocols, Performance Metrics, Unmanned Aerial Vehicles, Simulation Tools

1. INTRODUCTION

The rapid advancements in Unmanned Aerial Vehicles (UAVs) have revolutionised various domains, including surveillance, disaster management, and communication systems. As the demand for efficient and reliable aerial communication increases, FANETs have emerged as a promising solution. FANETs refer to the ad-hoc networks formed by the UAVs, enabling them to communicate and collaborate dynamically and self-organising.

FANETs bring about a paradigm shift in the traditional wireless communication infrastructure by leveraging the unique capabilities of UAVs. These networks introduce a new dimension to ad-hoc networking, allowing UAVs to establish temporary networks on the fly without relying on any pre-existing infrastructure or centralised control. UAVs in FANETs act as network nodes and routers, forming a dynamic network topology that adapts to the changing operational environment. Such flexibility makes FANETs particularly suitable for scenarios where traditional communication infrastructure is absent, unreliable, or inadequate.

One of the challenges in FANETs is the development of efficient ad-hoc routing protocols that can cope with the dynamic nature of UAVs and their network topology. Ad-hoc routing protocols are crucial in establishing and maintaining communication paths between UAVs in a FANETs, enabling data exchange, coordination, and cooperation among the network nodes. These protocols should handle node mobility, intermittent connectivity, and limited energy resources inherent to UAVs. Moreover, they must consider factors such as route stability, PDR, and E2E delay ensuring reliable and timely communication.

In this paper, we delve into the characteristics, advantages, and challenges of FANETs, focusing on the role of ad-hoc routing protocols. We explore existing routing protocols explicitly designed for FANETs and discuss their strengths and limitations. Additionally, we highlight ongoing research efforts and emerging trends in the field to shed light on the prospects of FANETs. By understanding the intricacies of FANETs and their routing protocols, researchers and practitioners can make informed decisions and contribute towards the development of robust and efficient UAV communication systems

2. RELATED WORKS

A. Ad hoc On-Demand Distance Vector (AODV)

AODV is a reactive routing protocol used in FANETs. It is designed to establish a route between nodes when no routing path exists between them. The protocol involves multiple steps, including discovery, transmission, and routing maintenance, and sends control messages such as Route Request (RREQ), Route Reply (RREP), and Route Error (RRER).

One of the main advantages of AODV is that it adapts well to changing connection situations and has minimal execution and storage requirements. However, one of the main drawbacks of AODV is that the route discovery process in high topology change networks can cause significant latency. This is because the RREQ message needs to be broadcast to all nodes in the network, which can be time-consuming in large networks with high topology changes.

Researchers have proposed various modifications to AODV, such as AODV with Backup Routes (AODV-BR), which uses backup routes to reduce the latency of route discovery, and AODV with Unicast RREQ (AODV-UC), which uses unicast RREQ messages to reduce the routing overhead. These modifications aim to improve the performance of AODV in different scenarios and environments [1].

B. Optimised Link State Routing (OLSR)

OLSR is a proactive routing protocol that establishes and maintains routes between nodes before they are needed. In OLSR, each node maintains a routing table that contains information about the network topology, including the addresses of neighbouring nodes and the cost of the links between them. The routing table is periodically updated to reflect changes in the network topology.

One of the features of OLSR is its ability to reduce the number of control messages sent in the network. This is achieved using Multipoint Relaying (MPR), which allows each node to select a set of MPR nodes that can reach all its neighbours with the minimum number of hops. When a node wants to send data to another node, it sends the data to its MPR nodes, which then forwards the data to their MPR nodes, and so on, until the data reaches the destination node. This reduces the number of control messages sent in the network and improves the efficiency of the routing protocol.

OLSR protocol is known for its low overhead and fast convergence time. It is particularly well-suited for large, dense networks with high mobility, where the topology changes frequently. However, one of the main drawbacks of OLSR is that it requires a significant amount of memory and processing power to maintain the routing tables, which can be a challenge in resource-constrained environments [1].

C. Summary of existing works in FANETs

Table 1 provides a concise overview of existing routing protocols designed for FANETs. Furthermore, Table 2 presents the specific simulation parameters utilized in these studies.

Table 1: Existing works of routing protocols in FANETs

Related Work	Approach	Limitation	Performance metric
[1]	Evaluates the efficiency of AODV, DSR, OLSR, and ZRP routing protocols.	Does not include additional performance metrics beyond	PDR. Throughput. E2E Delay.

Related Work	Approach	Limitation	Performance metric
		PDR, throughput, E2E delay, and jitter.	Jitter. Overhead.
[2]	Focuses on performance metrics and considers random movement mobility models.	Ignores other realistic mobility models.	Packet loss ratio. E2E delay. Throughput. Routing overhead. Number of hops.
[3]	Analyses strengths, weaknesses, applications, methodology, scalability, and potential improvements of CBRPs.	Only considers CBRPs, neglecting other routing protocols.	PDR. Throughput. Packet loss rate. Delay.
[4]	Considers unique characteristics of FANETs and outperforms existing benchmark protocols.	Does not explore existing routing protocols for MANETs or VANETs in the context of FANETs.	PDR. Average throughput. Overhead. E2E Delay.
[5]	Requires predefined source-destination pairs and long distances to prevent data loss.	Limited to specific scenarios with predefined source and destination.	PDR. Packet loss ratio. Throughput. Delay.
[6]	Considers performance evaluation and the importance of security aspects.	Does not provide specific performance metrics.	PDR. Overhead.
[7]	Customizes the routing algorithm based on different scenarios.	The same algorithm may not work optimally in all situations.	Packet success rate. Throughput. E2E delay. Packet drops ratio.
[8]	High mobility is considered a limiting factor for certain algorithms.	Time constraints may limit the effectiveness of the algorithms in optimizing routing.	E2E Delay. Throughput. Overhead.
[9]	Highlights the need for actual experiments, security considerations, and routing algorithm certification.	Does not explore other performance metrics in detail.	PDR. E2E delay. Normalized Routing Load (NRL). Routing overhead. Hop count. Average throughput. Jitter. Dropped packets.
[10]	Focuses on the performance evaluation of six routing protocols.	Does not consider other potential protocols.	PDR. E2E delay. Throughput.

Related Work	Approach	Limitation	Performance metric
[11]	Acknowledges the need to refine the model for better representation.	Limited to a static mobility model and two routing protocols.	PDR. Average Throughput. E2E Delay. Jitter. NRL. Hop Count.
[12,13]	Considers AODV and OLSR routing protocols to study a static mobility model in FANETs with UAVs.	The static mobility model may not accurately represent real-world scenarios, and simulations do not cover all possible routing protocols.	Average PDR. Packet drop.
[14]	Focuses on application scenarios, propagation model, MAC/PHY specifications, simulation parameters, and performance metrics.	Primarily discusses application scenarios without extensive performance metric analysis.	Average PDR. Average E2E delay. NRL. Routing overhead. Average hop count. Average throughput. Jitter. Dropped packets.
[15]	Uses a simulation environment, specific scenarios, and assumptions about node capabilities.	The limited scope of comparison to AODV and OLSR lacks comparison with other protocols and communication architectures.	Average PDR. Average E2E delay. NRL. Average hop count. Average throughput. Jitter. Dropped packets.
[16]	Identifies suitable protocols for specific scenarios without providing extensive network conditions or constraints considered.	Lacks detailed information on network conditions and constraints.	E2E delay. Throughput. Data Dropped Ratio. Hop count.

Table 2: Simulation parameters used in the existing works

Related Work	Simulation tools	Mobility model	Routing protocol	Number of nodes
[1]	Netsim	Group mobility, Ergodic way point	AODV, DSR, OLSR, ZRP	5
[2]	OPNET	Pursue Mobility Model (PRS), Semi-Circular Random Movement (SCRM), Manhattan Grid Mobility Model (MGM), and Random Waypoint (RWP).	AODV, DSR, Temporally Ordered Routing Algorithm (TORA), Geographic Routing Protocol (GRP), and OLSR.	15

[3]	MATLAB, OMNeT++, C++, NS3, NS2	Paparazzi and RWP.	CBRPs	N/A
[4]	NS3	Gauss-Markov, RWP.	OLSR	10,20,30,4 0,50
[5]	NS3	Constant Velocity Model.	OLSR	30,60,90
[6]	NS3	N/A	AODV	50
[7]	NS2	RWP.	AODV	30-180
[8]	NS2	Random Walk (Levy Flight)	AODV, OLSR, DSDV, DSR, ZRP, TORA, USMP, LAR	10, 40, 60, 80, 100
[9]	NS2	RWP.	AODV, OLSR	50
[10]	NS2	RWP, Gauss-Markov, Pheromone repel, Semi-Random Circular, Paparazzi	AODV, DSDV, DSR, OLSR, AOMDV, and HWMP.	20
[11]	NS2	Static mobility model.	AODV, OLSR	50
[12]	NS2	Static mobility model.	AODV, OLSR	10, 30, 50, 80, 100
[14]	NS2	RWP.	OLSR, AODV	50
[16]	NS2	RWP.	AODV, OLSR	50
[17]	Network Modeler, OPNET	MGM, RWPM, SCRM, PRS	AODV, DSR, TORA, GRP, OLSR	15

3. METHODOLOGY

A. General Architecture of FANETs

FANETs are a specialised ad hoc network designed for communication among unmanned aerial vehicles (UAVs), or drones, as shown in Figure 1. UAVs can create a self-configuring network using FANETS without relying on a centralised or existing communication infrastructure on the ground. Each UAV in a FANETS serves as both a node and a router, enabling the construction of a dynamic network as UAVs move and alter their positions. FANETS's main goal is to make it easier for UAVs to communicate, coordinate, and work together so they may share information, work together to complete tasks, and have better situational awareness. Multi-hop routing is a common feature in FANETS topologies, in which UAVs pass data packets back and forth until they reach their final destinations. Depending on the complexity of the mission and the quantity of UAVs participating, the network. FANETs are distinguished by their self-organisation, multi-hop routing, scalability, considerations for quality of service (QoS), security, and privacy safeguards. They are used in several contexts, such as aerial surveillance, disaster management, search and rescue operations, environmental monitoring, and support for UAV swarm communication. FANETs allow UAVs to collaborate to make decisions, share data, and coordinate actions, greatly boosting their capabilities and mission performance.

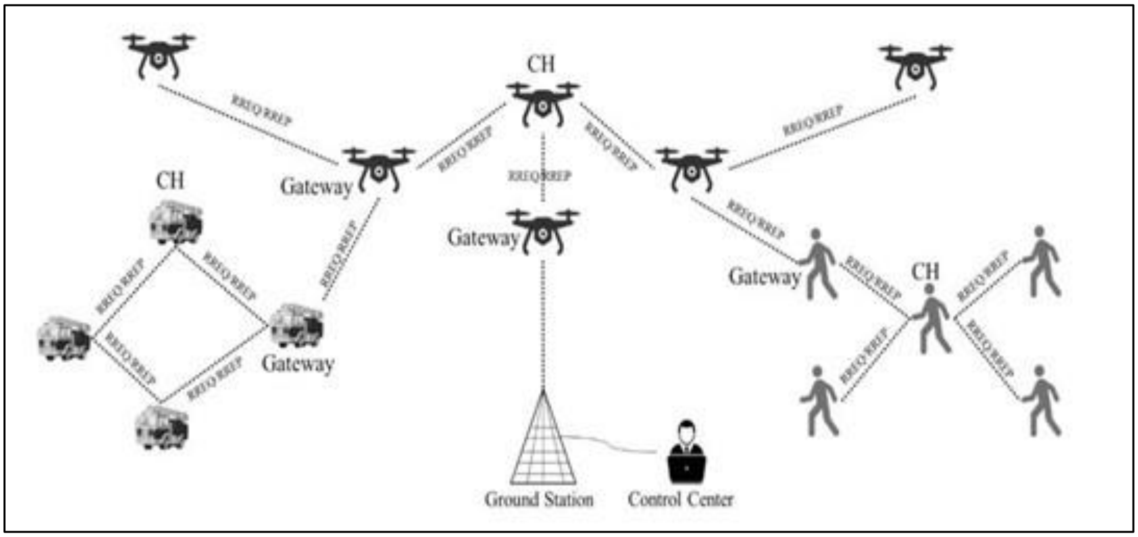

Figure 1: FANETs Architecture

B. Ad hoc On-Demand Distance Vector (AODV) protocol method in FANETs

Flying Ad-hoc Networks (FANETs) use the Ad-hoc On-Demand Distance Vector (AODV) protocol to create routes on demand. A source node starts the route discovery process by broadcasting a Route Request (RREQ) packet. Intermediate nodes then rebroadcast the packet until it reaches the destination or a node having a route. The destination or intermediate node sends a Route Reply (RREP) packet in response to receiving the RREQ to establish the route. While adaptive beaconing and energy-efficient routing optimise network performance, AODV in FANETs considers UAV features like mobility and limited battery life. It improves FANETS capabilities by enabling effective data transport and communication amongst UAVs in a decentralised, dynamic way.

Based on Figure 2, Node S is trying to communicate with Node D. So, Node S initiates a route discovery process to reach Node D. Node S creates a Route Request (RREQ) packet and broadcasts it to all the nodes in the network. Nodes A and B, which are neighbours of Node S, receive the RREQ packet and evaluate it for packet replication. If they determine that the replication is new, they register Node S in their routing information table as a backward pass to Node S. All the nodes in the network search their routing information tables to check for valid path entries for the destination node (Node D). If they don't find any valid path, they rebroadcast the RREQ packet to propagate the route discovery further. Intermediate nodes that have a valid route entry in their routing table will send a Route REPly (RREP) packet back to the source node (Node S) in the backward direction. Finally, once the message from Node S reaches the destination node (Node D), it will construct RREP packets and send them to the source node (Node S) through the shortest backward direction. In the figure above, the destination node uses the minimum distance among the three possible paths (D-J-F-B-S) to send the RREP packets [6].

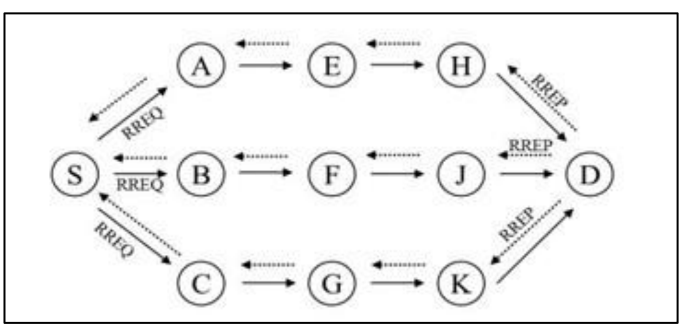

Figure 2: AODV Routing Protocol

C. Modified (Optimised Link State Routing) OLSR protocol for FANETs

OLSR stands for Optimised Link State Routing, a routing protocol used in wireless ad hoc networks. OLSR is an extension of the classic link state routing protocol, which optimises the protocol by compressing the quantity of information conveyed in messages and reducing the frequency of retransmissions for flooding these messages within the network. OLSR is designed to quickly make available the best routes in terms of hop count, and it effectively and inexpensively floods its control messages by declaring only a portion of the links (i.e., for multipoint relays (MPRs)) with the neighbours rather than the complete set of links.

The proposed modified OLSR routing protocol builds upon the traditional OLSR protocol by considering the unique characteristics of Flying Ad Hoc Networks, such as frequent topological changes and energy efficiency. Figure 3 presents a detailed flowchart of the modified OLSR routing protocol. The process begins with the crucial step of network initialization, which involves configuring the network nodes and establishing the necessary communication links between them. Once the network is initialised, the protocol selects MPRs for each node. The MPR selection process involves identifying the two-hop neighbours of each node and selecting a subset of these neighbours as MPRs. The MPRs are selected based on their ability to cover the maximum number of nodes in the network with the minimum number of MPRs. This helps to reduce the overhead associated with maintaining the routing tables and forwarding packets.

Once the MPRs are selected, the protocol uses them to forward packets to their destination. The packets are forwarded along the shortest path to the destination, considering the network's energy efficiency and frequent topological changes. The protocol also uses a multi-metric routing strategy that considers the residual energy of nodes, as well as the link stability and lifetime [1].

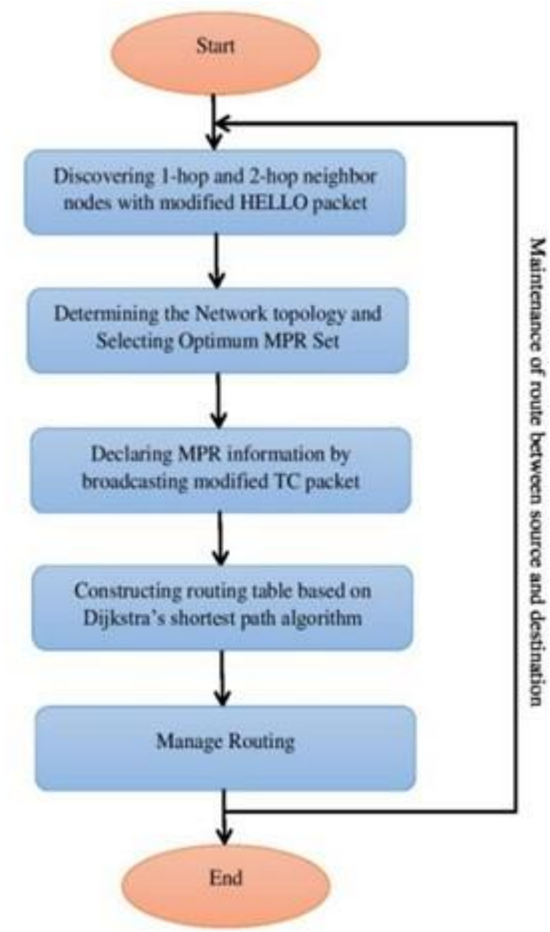

Figure 3: OLSR Routing Protocol

4. RESULT AND DISCUSSION

This section examines the performance of AODV and OLSR routing protocols in the context of FANETs. The evaluation is based on three essential performance metrics: throughput, end-to-end (E2E) delay, and packet delivery ratio (PDR). By analyzing these metrics, the strengths and limitations of each protocol are identified. The findings are then related to practical applications, offering actionable insights for the optimization and deployment of FANETs.

A. THROUGHPUT

Throughput in a FANET refers to the amount of data that can be transmitted successfully over the network within a given time frame. It represents the network's capacity to transfer data and is typically measured in bits per second (bps), kilobits per second (Kbps), or megabits per second (Mbps). The throughput may vary depending on several factors, including the network topology, the number of nodes in the network, the available bandwidth, and the protocols and algorithms used for data transmission [15]. To achieve high throughput in FANETs, several techniques can be employed:

- Adaptive Routing: FANETs can utilise adaptive routing protocols that dynamically select the best paths for data transmission based on the current network conditions, such as link quality and node mobility. These protocols aim to maximise throughput by avoiding congested or unreliable links.
- Multi-Channel Communication: FANETs can use multiple frequency channels for communication. By leveraging multiple channels, the network can increase its overall capacity and reduce interference, thereby improving throughput.
- Quality of Service (QoS): FANETs can implement QoS mechanisms to prioritise certain types of traffic or specific applications that require higher throughput mechanisms to ensure that critical data, such as control signals or video stream, are given priority over less time-sensitive traffic.
- Efficient Medium Access Control (MAC) Protocols: MAC protocols are crucial in managing access to the shared communication medium in FANETs. The network can achieve higher throughput by employing efficient MAC protocols that minimise collisions and maximise channel utilisation.

Higher throughput allows for quicker data transmission and improved network performance. High throughput can be difficult to achieve, especially in networks with heavy traffic or constrained bandwidth. An important consideration in FANETS applications where real-time data transfer, video streaming, or large-scale data exchange is required.

i. Throughput in AODV Routing Protocol

AODV utilises route discovery to find a path between a source and a destination. The delay in route discovery can affect the throughput, as it introduces additional time before data transmission can begin. Longer route discovery delays can decrease the effective throughput of the network. For route maintenance, AODV periodically checks the validity of routes and performs maintenance operations to update or repair broken paths. The overhead incurred during route maintenance can impact the overall throughput by consuming bandwidth and increasing packet delivery latency. FANETs are highly dynamic networks. The movement of drones can lead to frequent link disruptions and changes in network topology. it can affect the overall throughput performance. If AODV is slow to react to network changes, the throughput can be negatively impacted. This can be beneficial in scenarios with low mobility and limited network changes. AODV can be efficient for smaller networks with infrequent route changes.

ii. Throughput in OLSR Routing Protocol

OLSR maintains a network topology database to store information about the network's nodes and links. The stability of the network topology is crucial for efficient routing and throughput performance. Network density and scalability with different numbers of drones deployed in the airspace. OLSR's throughput performance can be influenced by network density and scalability. Higher network density may increase control message exchanges, leading to higher overhead and negatively impacting throughput. Route calculation is a proactive approach that precomputes routes to all reachable destinations in the network. The efficiency and accuracy of route calculation impact the overall throughput. If the route calculation process is time-consuming, it can introduce delays and affect the network's throughput. OLSR is a routing protocol where routes are precomputed before they are needed. It provides quicker route availability. OLSR is often suitable for networks with high mobility and frequent topology changes, allowing for faster adaptation to network dynamics.

B. End to End Delay

In FANETs, the End to End (E2E) delay refers to the time it takes for a packet or data to travel from the source node to the destination node in the network. E2E Delay consists of 4 types of delays in FANETs which are:

- Propagation Delay: It is the time taken for a signal to propagate from the source node to the destination node (influenced by factors such as the distance between nodes, altitude, and environmental conditions).
- Transmission Delay: The time required to transmit the entire packet from the source node to the first-hop node or between intermediate nodes (delay depends on the data rate, packet size, and available bandwidth).
- Queuing Delay: It is the time a packet spends in a node's buffer waiting for transmission.
- Processing Delay: It is the time required for a node to process the packet, which includes tasks such as packet forwarding, routing decision-making, and packet header processing.

The total E2E delay in FANETs is the sum of all these individual delays along the path. To achieve low E2E delay in FANETs, it is essential to employ efficient routing protocols, adaptive transmission schemes, optimised channel allocation, and congestion control mechanisms. These strategies help ensure timely and reliable data delivery, supporting the requirements of real-time applications in FANETS environments.

i. E2E Delay in AODV Routing Protocol

Route discovery in AODV, when a source node wants to send a packet to a destination node, it initiates a route discovery process. This route discovery process introduces additional delay. Route maintenance in AODV uses a combination of sequence numbers and periodic route maintenance messages (RERR) to maintain and update routes. If a link or node fails, AODV triggers a route discovery process to find an alternative path. This route maintenance process introduces additional delays for updating routes. The network size of AODV is well-suited for small to medium-sized networks. As the network size increases, the route discovery process becomes more complex and may result in higher E2E delays. AODV establishes routes on-demand, adapting to dynamic changes in the network topology caused by node movements. This adaptability helps reduce E2E delays as routes are discovered or updated based on real-time connectivity.

ii. E2E Delay in OLSR Protocol

Route establishment in OLSR, unlike reactive protocols like AODV, OLSR maintains pre-established routes in the routing table, enabling faster route selection when a packet needs to be forwarded. Control Message Overhead in OLSR periodically exchanges control messages These messages contain information about node connectivity, link quality, and other metrics. While these control messages help maintain accurate routing information, they also consume network bandwidth and can add to the E2E delay. It organises nodes into multiple levels based on their proximity and selects a few "Multipoint Relay" (MPR) nodes in each level to relay control messages. This hierarchical structure reduces the control message overhead and improves the efficiency of the protocol. In larger FANETs, OLSR's periodic control messages and topology maintenance overhead may result in increased E2E delays.

C. PDR

PDR is a performance metric used in FANETs networks to measure the percentage of successfully delivered packets from the source node to the destination node. It indicates the reliability of packet transmission in the network. PDR can vary depending on various factors, including the network topology, mobility patterns of the drones, radio interference, and network congestion. Exact PDR for FANETs as it can differ based on the specific deployment scenario and the performance of the underlying communication protocols. Efforts have been made to improve the PDR in FANETs through the development of efficient routing protocols, adaptive modulation and coding schemes, and interference management techniques, but they are still subject to many dynamic and unpredictable factors, such as weather conditions, link quality, and the presence of obstacles. In FANETs, where nodes are flying and highly mobile, maintaining a high PDR is challenging due to the dynamic nature of the network and various factors that can affect packet delivery. PDR is calculated by dividing the number of successfully delivered packets by the total number of packets sent, expressed as a percentage. A higher PDR indicates a more reliable and robust network, while a lower PDR implies a higher packet loss rate or delivery failures. Monitoring and improving PDR in FANETs is essential for maintaining reliable communication. Techniques to enhance PDR include:

- Effective Routing Protocols: Utilising routing protocols designed for FANETs that can adapt to node mobility, select reliable routes, and dynamically adjust to changing network conditions.
- Quality-of-Service Mechanisms: Implementing prioritisation, traffic shaping, and admission control to manage network congestion and prioritise important packets, thereby improving the PDR.
- Link Quality Estimation: Developing methods to estimate link quality and select more reliable links for packet transmission, improving the overall PDR.

i. PDR in AODV Routing Protocol

Network size in AODV may perform well in small to medium-sized networks. As the network size increases, the overhead and latency associated with route establishment and maintenance may impact the PDR. AODV reasonably handles node mobility by initiating route repairs when links or nodes fail. However, frequent topology changes due to high mobility can increase route discovery overhead and potentially affect the PDR. Network load in AODV may face challenges in high-load scenarios where the available bandwidth is saturated. Congestion may occur as more nodes compete for limited network resources, affecting the PDR.AODV might be more suitable for FANETs with limited bandwidth or resource-constrained environments due to its on-demand route discovery mechanism and ability to handle node mobility.

ii. PDR in OLSR Protocol

Network size in OLSR is known to perform well in large networks with many nodes due to its proactive nature. OLSR reduces the latency for establishing routes and can help achieve a high PDR even in large-scale deployments. OLSR is designed to handle node mobility efficiently. The periodic exchange of control messages helps nodes adapt to changes in the network topology and maintain up-to-date routing information. This adaptability enhances the PDR in scenarios where nodes frequently move. The use of MPR Flooding reduces redundant transmissions and optimises the utilisation of network resources. In situations of high network congestion, the PDR may be affected due to limited available bandwidth. OLSR might be more suitable for FANETs with a larger number of UAVs or dense networks due to its proactive nature.

D. Case study

FANETS-based Emergency Healthcare Data Dissemination [4] is a case study that simulates FANETs implementation in a healthcare firm. It explains using a flying Unmanned Aerial Vehicle (UAV) ad-hoc network to improve communication and data dissemination in emergency healthcare situations. In this case study, it consists of several criteria which are:

- Routing Protocol
  The routing protocol that is used in this case study is OSLR. OLSR is a proactive routing protocol that establishes and maintains routing paths in advance. In healthcare scenarios where timely communication is critical, proactive routing helps minimise route setup delays and enables quick packet transmission. This is particularly advantageous for emergency situations where immediate data exchange is essential
- Number of Nodes

The number of nodes chosen in this case study 30,60,90 may reflect the desired network size or the scale of the healthcare application. For instance, if the healthcare FANETs need to cover a large area or involve a significant number of medical sensors or drones, a higher number of nodes (e.g., 60 or 90) may be selected to ensure adequate coverage and data collection. A smaller number of nodes (e.g., 30) might be selected to simplify network management, reduce computational complexity, or ease the monitoring and control of healthcare FANETs. This could be particularly relevant in scenarios where limited resources or manpower are available for network maintenance and operation.

- Mobility Model
  Mobility model that is used in this case study is the constant velocity model. In healthcare FANETs, the movement of nodes may not always be completely random or unpredictable. Nodes such as drones or medical sensors may follow predefined flight paths or move at relatively stable velocities to perform their intended tasks, such as patient monitoring, data collection, or emergency response. The Constant Velocity Model, despite its simplifications, can capture this general trend of relatively stable and continuous movement.
- Internet Protocol (IP)
  The IP that is used in this case study is IPV4. IPv4 is the most widely deployed IP version, and it is supported by a vast majority of networking devices, operating systems, and applications. In healthcare settings, where various devices and systems need to communicate with each other seamlessly, the compatibility offered by IPv4 ensures interoperability and ease of integration. IPv4 has been in use for several decades, and as a result, extensive tools and resources are available for network administrators and engineers that are easy to configure and troubleshoot.
- Transport Layer Protocol
  The transport layer protocol chosen in this case study is User Datagram Protocol (UDP). UDP is well-known for real-time data transmission. Healthcare applications often transmit real-time data, such as patient monitoring data, video streams, or voice communication. UDP is well-suited for real-time applications because it delivers data packets in the order they are received without requiring reassembly or reordering. This characteristic is particularly advantageous when timely data delivery is more important than guaranteed delivery.

E. FANETS Implementation in Military, Disaster and Healthcare

FANETs are an important wireless communication network in a lot of professional fields. Based on the research on 15 articles about the FANETs, it’s proven that FANETs implementation in Healthcare, Disaster and Military plays a crucial role.

In the military context, FANETS can be implemented to enhance the capabilities and effectiveness of military operations. FANETs utilised in military setting for [2]:

- Surveillance and Reconnaissance: Drones equipped with cameras and sensors can form FANETs to gather intelligence and provide real-time surveillance over a particular area. The drones can communicate with each other, share data, and provide a comprehensive situational picture to military personnel on the ground.
- Communication and Coordination: FANETS allows for seamless communication and coordination between multiple drones and ground-based units. It enables the sharing of tactical information, such as target locations, enemy movements, and friendly force positions. This enhances situational awareness and facilitates better decision-making for military commanders.

In the disaster context, FANETS can be implemented to enhance situational awareness, coordination and aid delivery. FANETs utilised in disaster scenarios for [7]:

- Search and Rescue Operations: FANETS-enabled drones can assist in search and rescue efforts by providing aerial views of disaster areas, detecting survivors, and transmitting their locations to rescue teams. Drones can communicate with each other, forming a network that coordinates search patterns, shares information, and facilitates efficient deployment of resources for rescue operations.
- Delivery of Aid and Supplies: Drones within FANETs can be employed to transport essential supplies, such as medical equipment, food, water, or communication devices, to affected areas. The drones can communicate with each other to optimise delivery routes, monitor cargo status, and ensure timely and efficient aid distribution to those in need.

FANETS can be leveraged in healthcare settings to enhance various aspects of patient care, medical logistics, and emergency response. FANETs utilised in healthcare scenario for [4]:

- Surveillance and Outbreak Management: Drones equipped with thermal cameras and sensors can form a FANETs to monitor public spaces, track disease outbreaks, and identify potential hotspots. They can provide real-time data on crowd density, body temperature, or other relevant parameters, aiding healthcare authorities in early detection, contact tracing, and implementing appropriate public health measures.
- Emergency Medical Services: Drones operating within a FANETs can be equipped with medical supplies, such as defibrillators, medications, or first-aid kits, and dispatched to provide immediate assistance in emergency situations. These drones can navigate through traffic or difficult terrains, reaching patients quickly and potentially saving lives.

From the case studies about FANETS wireless communication, it's clear that this network provides many key benefits in all scenarios. For the military, it enhances awareness, improves communication and coordination, better decision-making for military commanders, and optimises the use of military assets. The same way goes for disaster situations, where FANETS provides rapid response and aid delivery, efficient search and rescue operations, improved coordination between response teams, and enhanced situational awareness in disaster areas. Implementing FANETS in healthcare provides quick emergency medical assistance, timely delivery of medical supplies, improved access to healthcare services in remote areas, effective outbreak management, and streamlined logistical operations within healthcare facilities. While there are some similarities in the applications of FANETS across these contexts, such as surveillance and communication, each domain has unique requirements and considerations based on the specific needs and challenges they face. Implementing FANETs in each field aims to address specific objectives and leverage the capabilities of drones and wireless communication to enhance operations and improve outcomes.

5. CONCLUSION

The emergence of FANETs has revolutionized wireless communication systems by harnessing the advanced capabilities of UAVs. FANETs enable UAVs to establish dynamic, self-organizing networks without needing pre-existing infrastructure or centralized control, making them a critical solution for scenarios requiring flexible and efficient aerial communication. As the demand for reliable UAV networks grows, developing effective ad-hoc routing protocols becomes essential to address challenges such as dynamic topologies, high mobility, and intermittent connectivity.

This study evaluated two prominent FANET routing protocols—AODV and OLSR—focusing on their performance in terms of end-to-end (E2E) delay, throughput, and packet delivery ratio (PDR). AODV, an on-demand protocol, is particularly well-suited for smaller networks with minimal topology changes, as it reduces control overhead and provides low E2E delay and high PDR. OLSR, a proactive protocol, excels in dense and dynamic environments, delivering high throughput and PDR through its pre-established routing tables, although it generates significant overhead in larger networks.

The findings underscore the importance of selecting a routing protocol based on the specific requirements of the FANET application. AODV is ideal for scenarios where rapid route discovery and minimal control messages are critical. At the same time, OLSR is better suited for high-density networks requiring efficient data transmission and frequent updates. By understanding the strengths and limitations of these protocols, researchers and practitioners can design optimised FANET solutions tailored to diverse operational needs, ensuring reliable and efficient UAV communication systems.

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