Middle East Technical University
Informatics Institute

IMPACT OF MOBILITY ON GPSR AND AODV ROUTING PERFORMANCE IN FANETS

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January 2026

TECHNICAL REPORT
METU/II-TR-2026-

Orta Doğu Teknik Üniversitesi
Enformatik Enstitüsü

UÇAN GEÇİCİ AĞLARDA HAREKETLİLİĞİN GPSR VE AODV YÖNLENDİRME PERFORMANSINA ETKİSİ

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Ocak 2026

TEKNİK RAPOR
ODTÜ/II-TR-2026-

REPORT DOCUMENTATION PAGE

1. AGENCY USE ONLY (Internal Use)

2. REPORT DATE
16.01.2026

3. TITLE AND SUBTITLE

IMPACT OF MOBILITY ON GPSR AND AODV ROUTING PERFORMANCE IN FANETS

4. AUTHOR (S)

Salih Deniz Ünal

5. REPORT NUMBER (Internal Use)

METU/II-TR-2026-

6. SPONSORING/ MONITORING AGENCY NAME(S) AND SIGNATURE(S)
Informatics Master's Programme, Department of Information Systems, Informatics Institute, METU

Advisor: Prof. Dr. Altan Koçyiğit Signature:

7. SUPPLEMENTARY NOTES

8. ABSTRACT (MAXIMUM 200 WORDS)

Flying Ad Hoc Networks (FANETs) enable communication between Unmanned Aerial Vehicles (UAVs); however, their high speed and mobility create significant routing challenges. This study compares the performance of Greedy Perimeter Stateless Routing (GPSR) and Ad Hoc On-Demand Distance Vector (AODV) protocols under different mobility models in FANET architectures. Simulations are conducted using OMNeT++ with the INET framework. 36 drones are placed in a 1000m x 1000m area with Stationary, Random Waypoint (RWP), Gauss Markov (GM), Linear, and Circle mobility models at speed ranges of (5-10) m/s and (10-15) m/s. Packet Delivery Ratio (PDR), Mean End to End Delay (E2E Delay), and Mean Throughput are used as performance metrics. The results show that AODV provides higher PDR and Mean Throughput, while GPSR achieves lower Mean E2E Delay. These findings indicate that AODV is more suitable for reliable data delivery, whereas GPSR is preferable for low-latency applications in FANETs.

9. SUBJECT TERMS

FANET, GPSR, AODV, Routing Protocols, Mobility Models, OMNeT++, UAV

10. NUMBER OF PAGES

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LIST OF SYMBOLS / ABBREVIATIONS

3D	Three Dimensional
ACK	Acknowledgment
AODV	Ad Hoc On-Demand Distance Vector
AOMDV	Ad-hoc Ondemand Multipath Distance Vector
dBm	decibel-milliwatts
DSDV	Destination-Sequenced Distance Vector
DSR	Dynamic Source Routing
DYMO	Dynamic MANET On-demand
E2E Delay	Mean End to End Delay
FANET	Flying Ad Hoc Network
GM	Gauss Markov
GPSR	Greedy Perimeter Stateless Routing
GPSR-CB	Greedy Perimeter Stateless Routing - Cross-layer Backbone
HWMP	Hybrid Wireless Mesh Protocol
J	Joule
m	meter
m/s	meters per second
MANET	Mobile Ad Hoc Network
Mbps	Megabits per second
NS-3	Network Simulator version 3
OLSR	Optimized Link State Routing
PDR	Packet Delivery Ratio
RWP	Random Waypoint
s	second
UAV	Unmanned Aerial Vehicle
UDP	User Datagram Protocol
UF-GPSR	Utility Function based Greedy Perimeter Stateless Routing

CHAPTER 1

INTRODUCTION

Due to the availability of the new technological advancements in recent years, Unmanned Aerial Vehicles (UAVs), most generally named as drones, have become cheaper and more accessible. These changes draw attention to the usage of the drones, hence, increase their utilization in civil, academic, industrial and military applications [1]. Drones can easily access dangerous and hard to reach areas for surveillance and monitoring purposes. This capability makes them highly beneficial in tough conditions across various sectors such as healthcare, agriculture, and defense [2]. Under these challenging conditions, using a single drone would not be enough to complete the mission. Therefore, Flying Ad hoc Networks (FANETs) are formed as communication networks of drones which allow wireless communication between them.

Although the wireless communication is the main advantage of the drones, it has some drawbacks. Since the drones are highly mobile, maintaining reliable communication has become a significant problem. There are several routing protocols which address this problem, Greedy Perimeter Stateless Routing (GPSR) is one of them. GPSR is an effective location-based routing protocol which only holds information about the destination and the locations of the network nodes to make the decisions on forwarding the packets [3].

Since the mobility of the networks has a direct effect on the location of the network nodes, GPSR routing is highly influenced by the mobility models of the drones. This study aims to simulate the performance of GPSR under different mobility models on a basic FANET architecture. The performance of GPSR protocol on basic FANET architecture is compared with Ad Hoc On-Demand Distance Vector (AODV) routing protocol across Random Waypoint (RWP) mobility, Gauss Markov (GM) mobility, Linear mobility, and Circle Mobility. During this study, OMNeT++ is used as a network simulator by utilizing INET framework. Performance metrics such as Packet Delivery Ratio (PDR), Mean End to End Delay (E2E Delay), and Mean Throughput used for evaluation.

The rest of the report is organized as follows: In Chapter 2, background information about Ad hoc networks, routing protocols, mobility models, OMNeT++ and INET framework is provided. Chapter 3 reviews the related work in the literature. Chapter 4 explains the methodology used in this study including simulation environment, FANET architecture, routing protocols, mobility models and performance metrics. In Chapter 5, the simulation results are presented and discussed in detail. Finally, Chapter 6 concludes the report and suggests future work.

CHAPTER 2

BACKGROUND INFORMATION

In this chapter, background information about Ad hoc networks, routing protocols, mobility models, OMNeT++ and INET framework are provided.

2.1 Ad hoc Networks

Ad hoc literally means 'for this purpose' in Latin. Ad hoc networks are formed temporarily for a purpose and do not need a preset infrastructure [4]. These types of networks do not include a centralized base station or an access point. The communication is established by the nodes in the network through the packet forwarding and routing protocols.

Mobile Ad hoc Networks (MANETs) are one type of Ad hoc Networks in which the nodes have mobility [4]. In these types of networks, since the nodes are not stationary but mobile, the topology constantly changes. Route maintenance and discovery become more challenging due to the dynamic nature of the topology. FANETs on the other hand, are MANETs that have flying nodes [5]. Nodes can fly in 3D space with high speeds which causes more frequent changes in the topology.

FANETs are cooperative networks composed of multiple drones allowing wireless communication between them. There are different types of FANET architectures proposed for the communication. There are UAV Ad hoc Networks, Multi-Group UAV Ad hoc Networks and Multi-Layer UAV Ad hoc Networks [5].

In UAV Ad hoc networks, shown in Figure 1, a backbone UAV is responsible for the communication between the ground station and the other nodes in the network [5]. In these types of networks, the backbone UAV is capable of both short and long-range communication in order to maintain a connection between the network and the ground station. In Multi-Group UAV Ad hoc Networks, shown in Figure 2, there are multiple groups and each group has a different backbone UAV which connects with the ground station. In these types of networks, the intergroup communications are established by the ground station while intragroup communications are not. Last but not least, the Multi-Layer UAV Ad hoc networks, shown in Figure 3, consist of multiple groups, whose backbone UAVs are connected to each other. Only one of the backbone UAVs is connected with the ground station.

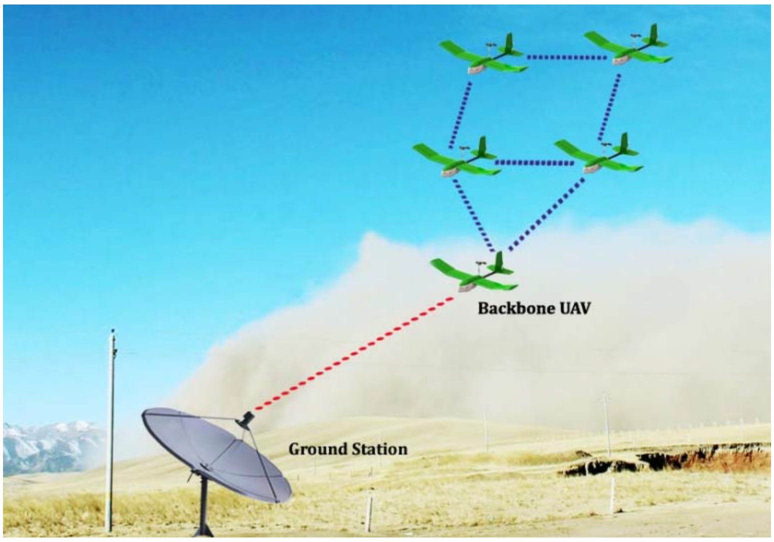


Figure 1: UAV Ad hoc Network [5]

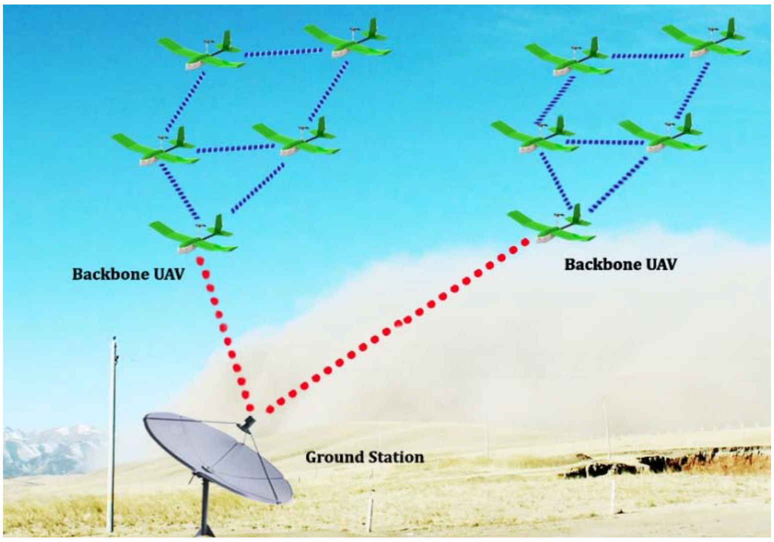


Figure 2: Multi-group UAV Ad hoc Network [5]

2.2 Routing Protocols

Since drones can achieve high speeds and dynamically change the network topology, an efficient routing must be applied to maintain reliable communication within the network. Routing

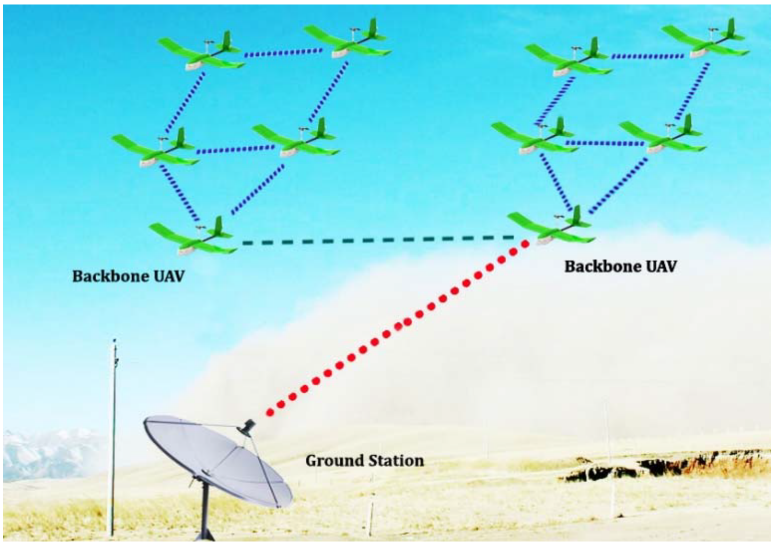


Figure 3: Multi-layer UAV Ad hoc Network [5]

protocols of FANETs are divided into two types: topology-based and location-based protocols [6]. In topology-based protocols, the topology of the network has been used to forward packets and there must be a predetermined routing path from the source node to the destination node. On the other hand, in location-based protocols, the geographical positions of the network nodes are used. Packet forwarding is applied based on the location of the neighboring nodes.

A routing void is a very common issue in location-based routing protocols. It occurs when there is no neighboring node which is closer to the destination node than the current node and the destination is not in the communication range of the current node. GPSR is a location-based protocol introduced to address the routing voids [6]. The network nodes forward packets to their neighbors which is called as greedy forwarding. If the intersection of source node's range and the destination node's range does not contain any neighbors, greedy forwarding fails. In such cases, perimeter forwarding is used to forward the packet around the perimeter of the void by traversing the network nodes using right hand rule [3]. Figure 4 shows an example of how GPSR avoids routing voids. In this figure, source node is labeled as S and destination node is labeled as G. GPSR starts forwarding the packets with greedy forwarding. When the packet reaches to node B, there is no closer nodes to the destination G than node B. Hence, GPSR initiates perimeter forwarding to forward the packet around the void. When the packet reaches to node E, which is closer to the destination G than node B, GPSR switches back to greedy forwarding [6].

In GPSR, beaconing is utilized. A beacon is sent periodically to let other nodes know the identity and position of the beaconing node. This beacon is sent periodically and has a timeout to be able to determine the network nodes that are not in the range and delete them from neighbor list. In GPSR, the forwarded packets also contain information about the node's

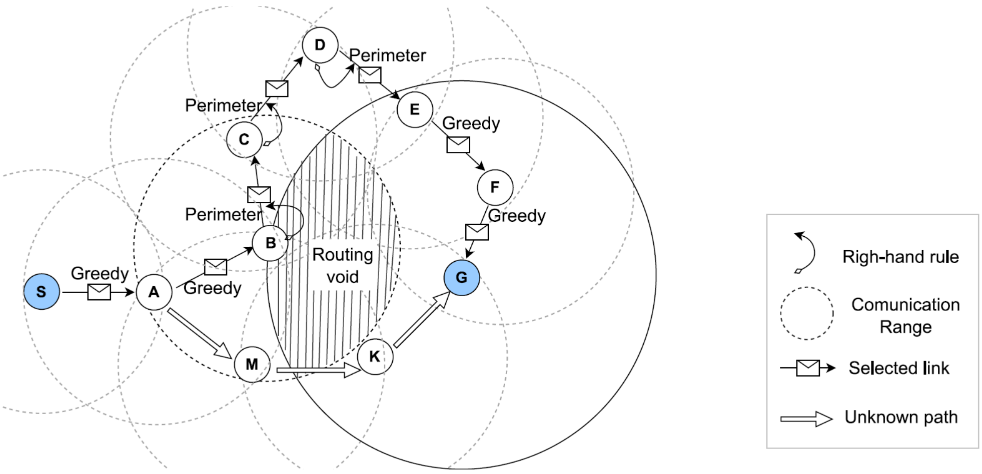


Figure 4: GPSR Greedy and Perimeter Forwarding [6]

positions, hence can be used to reset beacon timer. Using packets as beacons decreases the beacon traffic in the areas that forwarding packets are intense.

2.3 Mobility Models

To simulate the movement of the mobile nodes of the networks, several models have been developed. Random Walk Mobility Model [7] is a model that nodes can move in any direction without a restriction. RWP Mobility Model [8], on the other hand, is very similar to Random Walk Mobility, but there is a destination and when the destination is reached, nodes stop there for some time then moves to the next destination. The Random Direction Mobility Model [9], also known as Random Mobility Model, is very similar to the RWP Mobility Model, but in this model destinations are on the edge of the fixed space while in RWP Mobility Model, they can be also inside the fixed space. Manhattan Grid Mobility Model [10] can simulate the movement in a layout such as a road layout. The nodes in this mobility model move in any directions and can take turns in case of intersections. For multi vehicle scenarios, collisions might happen in the random models. To overcome this problem, Semi-random Circular Movement Model [11] is suggested. In this model, a predetermined circular or curved route is followed by the node to reach the destination, then as it is in the RWP Mobility Model, node stops for a while then moves to the next destination [7].

2.4 OMNeT++ and INET

OMNeT++ [12] is an open-source discrete event simulation environment that has been released in 1997. Since then, it has been used in various domains such as network simulations and business process simulations [13]. It has been designed as an extensible, modular, component based C++ simulation library and framework. Instead of providing simulation components, it provides a framework that can be used to create the simulation components. There are several simulation models and tools such as INET, Simu5G, and SimuLTE developed for OMNeT++. In this study, INET framework is used for the simulations.

The INET is open-source framework developed in OMNeT++ simulation environment for wired, wireless and mobile networks. In the INET framework, there are several models, protocols and components for Internet stack, wired and wireless networks, and mobility support [14].

CHAPTER 3

RELATED WORK

Musaddiq et al. [15] simulated a multi hop wireless network in 1500m x 1500m area using OMNeT++ and INET frameworks. They have utilized MANET routing protocol and used six stationary network nodes. They have observed that number of hops affects the average packet delay and round trip time.

Bezziane and his colleagues [16] have compared the performance of GPSR routing protocol under different mobility models on FANETs using OMNeT++, INET and AVENS frameworks. In this study, RWP, Mass Mobility and GM Mobility have been used in a simulation area of 1000m x 1000m x 1000m. They have compared the performance of the GPSR using Packet Delivery Ratio, Energy Consumption, Loss Rate and End-to-End delay performance metrics. Their results have shown that while energy consumption increases in the Mass Mobility and GM Mobility models as the number of drones increases, the RWP mobility model has higher energy consumption compared to the other mobility models.

In the study conducted by Sommer et al. [17] a comprehensive simulation of Ad Hoc routing protocols using OMNeT++ is demonstrated. They have explained simulation approaches, performance analysis techniques, validation and simulation control that can be used in further performance analysis studies of Ad Hoc routing protocols as a baseline. They have used Dynamic MANET On-demand (DYMO) routing protocol on MANET scenarios. Although the focus is on MANET, their findings and guidelines can be used in different Ad Hoc routing scenarios including FANETs.

Kumar et al. [18] have implemented Utility Function based Greedy Perimeter Stateless Routing (UF-GPSR) for FANETs by modifying the GPSR protocol by adding a Utility Function which uses residual energy ratio, distance degree, movement direction, link risk degree and speed to enhance the next hop decision while forwarding the packets. They have used NS-3 simulator for simulations and have shown that their proposed routing protocol has better performance metrics on packet delivery ratio, throughput, packet drop ratio an delay compared to GPSR protocol. They have used RWP mobility model and in a simulation area of 1000m x 1000m x 1000m.

Tho et al. [6] have suggested a novel routing algorithm, Greedy Perimeter Stateless Routing - Cross-layer Backbone (GPSR-CB) for FANETs with multi-level backbone UAVs. They have implemented a cross-layer design which uses transmission power control, link quality monitoring and ACK-based feedback mechanism. These enhancements allow selecting reliable links, adapting to changes in the topology and overcome noise and interference issues. Their results have shown that GPSR-CB have strong performance on packet delivery ratio, throughput and power consumption compared to UF-GPSR [18] and GPSR protocols. For the comparison, the simulations has conducted using OMNeT++ and INET frameworks. A simulation area of 1000m x 1000m x 1000m is used with RWP mobility model.

Yang et al. [19] have used an algorithm, named hybrid ant colony algorithm, to find the best relay node while routing in large scale FANETs. They have named their proposed protocol inter-cluster routing protocol (ICRP). They have conducted simulations for comparison of the performance of ICRP with AODV, fuzzy logic assisted AODV and Enhanced Any AODV protocols using OMNeT++. The GM Mobility model has been utilized in 1500m x 1500m area. Performance metrics such as end to end delay, packet delivery ratio, energy consumption, routing establishment time has been used.

Rodriguez et al [20] have conducted an analysis research on routing protocols in FANETs. They have used NS-3 network simulator and compared Optimized Link State Routing (OLSR), Destination-Sequenced Distance Vector (DSDV), AODV, Dynamic Source Routing (DSR), Adhoc Ondemand Multipath Distance Vector (AOMDV), and Hybrid Wireless Mesh Protocol (HWMP) routing algorithms. GM Mobility model is used in a 500m x 500m simulation area with varying altitude from 10m to 50m. The simulation results have evaluated based on throughput, packet delivery ratio, and end to end delay.

In the literature, most of the studies focus on the performance of a single routing protocol under different mobility models, or performance of different routing protocols under single mobility model. Moreover, some studies focus on proposing new routing protocols or improving the existing ones. There is a lack of studies that compare the routing performance of GPSR routing under different mobility models with AODV routing performance. In this study, the performance of GPSR and AODV routing protocols is compared under different mobility models on a basic FANET architecture. The aim is to fill the gap in the literature by providing a detailed comparison of these two routing protocols under different mobility models.

CHAPTER 4

METHODOLOGY

In this chapter, the simulation environment, FANET architecture, routing protocols, mobility models and performance metrics used in this study are explained in detail.

4.1 Simulation Environment

In this study, OMNeT++ version 6.0 is utilized along with INET framework version 4.2.10 as the simulation environment. OMNeT++ is widely used network simulator and INET framework provides models and protocols for network simulations. These tools have been selected because of their usage in similar studies in the literature [6] [15] [16]. The simulation parameters are summarized in Table 1. The main purpose of selecting these parameters is to create a realistic FANET scenario while ensuring sufficient network density for communication. IEEE 802.11g communication standard has been selected since it is widely used in wireless communication applications. The simulation time is set to 600 seconds to allow sufficient time for communication. However, since drones have limited battery capacities, an energy model is included in the simulations. Their energy is depleted during the simulations before the time limit is reached. Number of drones is selected as 36 to ensure sufficient network density. UDP traffic is used with 1 second intervals and the packet size selected as 10000 bytes to simulate high data rate applications.

Each simulation scenario is repeated 5 times with different random seeds for the random locations of the drones in order to obtain statisically accurate results. The average of these 5 runs are presented in the Chapter 5 and used while evaluating the performance.

Table 1: Simulation Parameters

Parameter	**Value**
Simulation Area	1000m x 1000m
Number of Drones	36
Mobility Models	Stationary, GM, Linear, RWP, Circle
Speed of Drones	[(5-10), (10-15)] m/s
Routing Protocols	GPSR, AODV
Simulation Time	600 seconds
Traffic Type	UDP
Packet Size	10000 bytes
Channel Data Rate	54 Mbps
MAC Protocol	IEEE 802.11g
Noise Model	Isotropic Scalar Background Noise
Noise Level	-110 dBm
Initial Energy of Drones	1 J
Shutdown Energy Threshold	0 J
Propagation Model	Constant Speed Propagation
Path Loss Model	Free Space Path Loss

4.2 FANET Architecture

In this study, 36 drones are used to form a FANET. First drone in the drone list is selected as receiver and the last drone is selected as sender. The remaining drones are used as relay nodes for forwarding packets from sender to receiver. At the beginning, random locations are assigned to each drone in the simulation area. The movement of the drones are determined by the mobility model in the scenario. The FANET architecture used in this study is shown in Figure 5, including the communication range of sender and receiver drones.

4.3 Routing Protocols

The aim of this study is to compare the performance of GPSR routing in different mobility models with different speed ranges. Since the reactive routing protocols such as AODV is more suitable then the proactive routing protocols [21] such as GPSR, AODV routing protocol is selected as the comparison protocol.

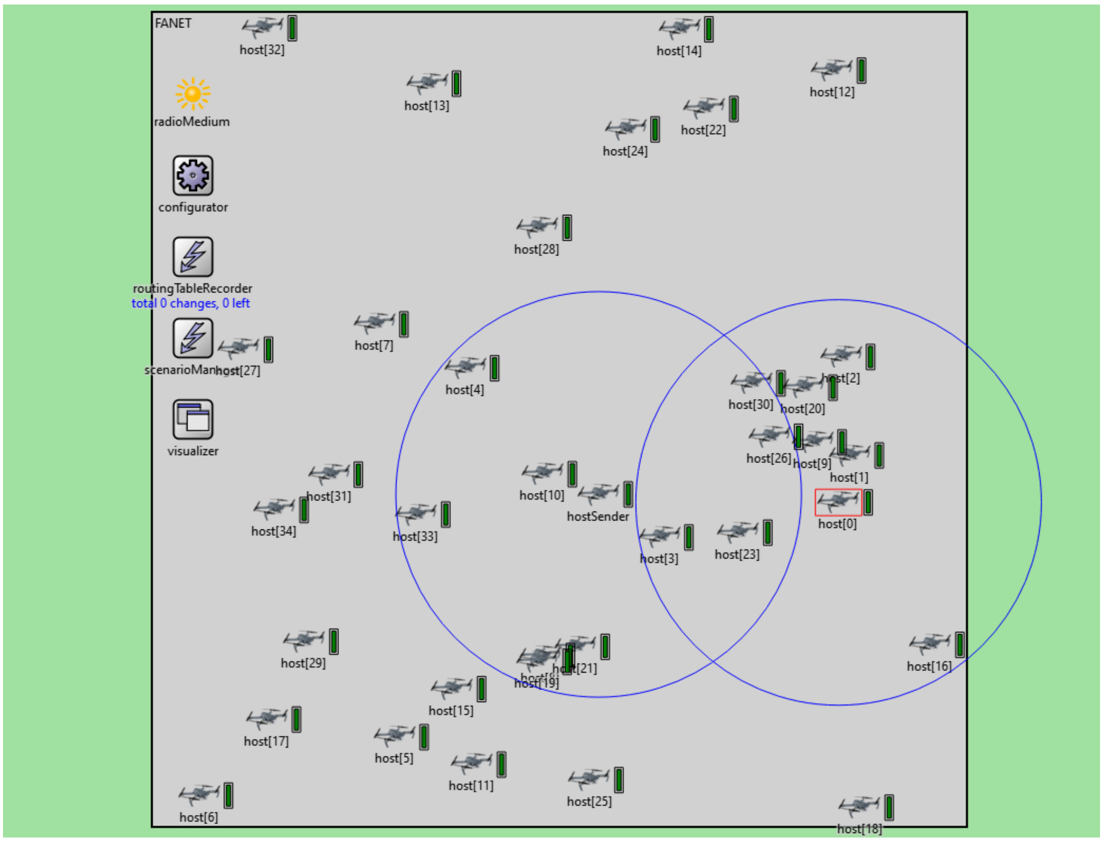


Figure 5: FANET Architecture

4.4 Mobility Models

In this study, there are four different mobility models are utilized to simulate the movement of the drones in the FANET. The used mobility models are RWP, GM, Linear, and Circle Mobility models. Each mobility model is simulated with two different speed ranges, (5-10) m/s and (10-15) m/s to observe the effect of speed on the routing performance. In order to have a baseline for comparison, initially the drones are placed in a stationary grid topology with 200m spacing, as shown in Figure 6. The mobility model assigned to these nodes in OMNeT++ is named Stationary Mobility Model.

4.5 Performance Metrics

In OMNeT++, each node can have an application to run. While creating the FANET, UDP Basic App is used in the sender and UDP Sink App is used in the receiver node. These applications record the statistics such as number of packets sent, number of packets received (Figure 7), end to end delay (Figure 8) and throughput (Figure 9). The performance metrics used in this study are PDR, E2E Delay, and Mean Throughput.

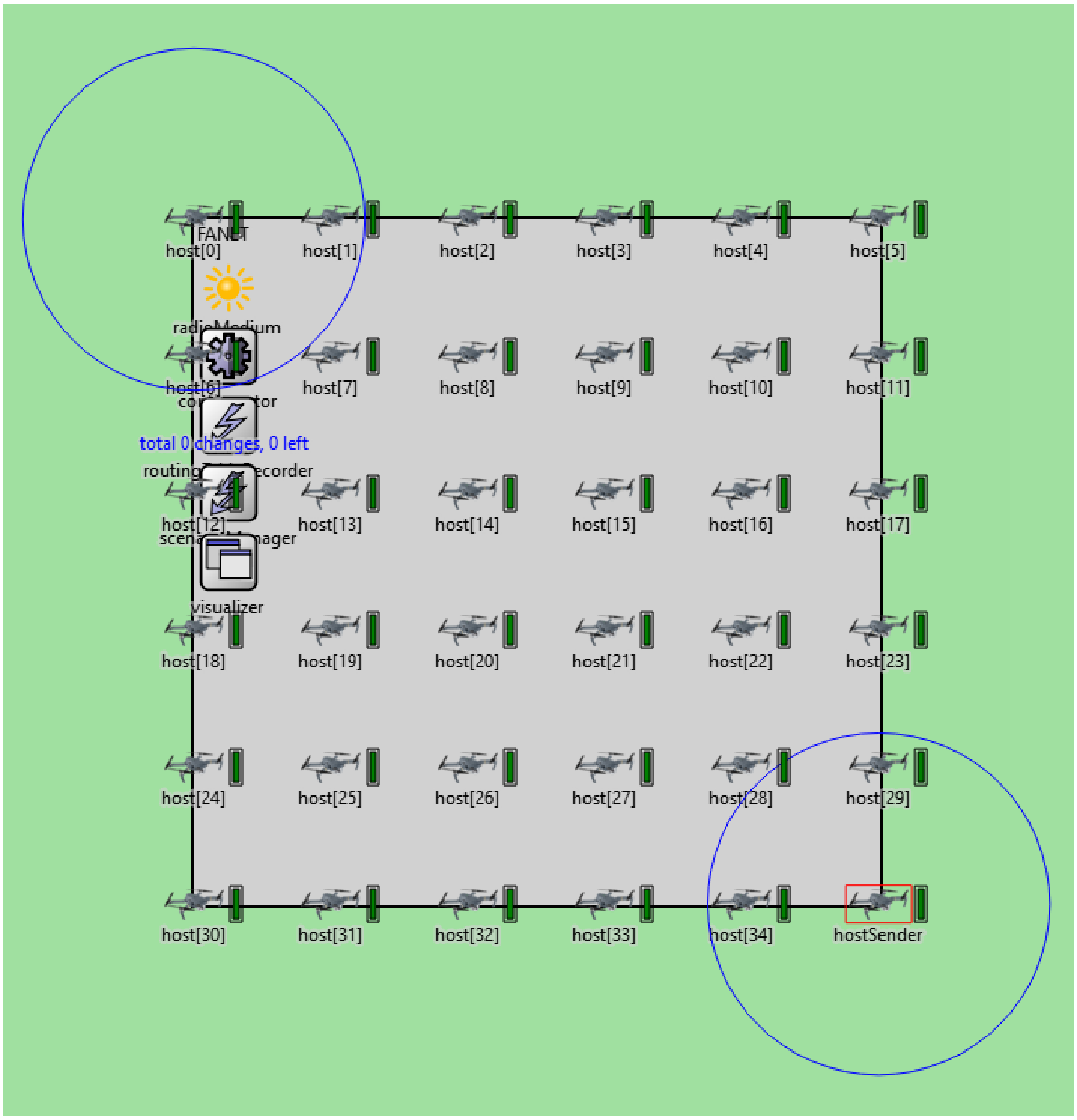
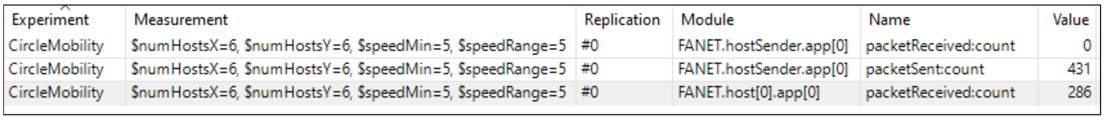
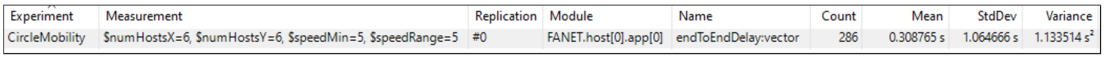


Figure 6: FANET Grid Layout for Stationary Topology



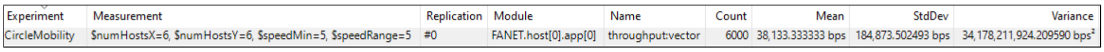
Experiment	Measurement	Replication	Module	Name	Value
CircleMobility	$numHostsX=6, $numHostsY=6, $speedMin=5, $speedRange=5	#0	FANET.hostSender.app[0]	packetReceived:count	0
CircleMobility	$numHostsX=6, $numHostsY=6, $speedMin=5, $speedRange=5	#0	FANET.hostSender.app[0]	packetSent:count	431
CircleMobility	$numHostsX=6, $numHostsY=6, $speedMin=5, $speedRange=5	#0	FANET.host[0].app[0]	packetReceived:count	286

Figure 7: Example Packet Sent and Received Statistics in OMNeT++



Experiment	Measurement	Replication	Module	Name	Count	Mean	StdDev	Variance
CircleMobility	$numHostsX=6, $numHostsY=6, $speedMin=5, $speedRange=5	#0	FANET.host[0].app[0]	endToEndDelay:vector	286	0.308765 s	1.064666 s	1.133514 s²

Figure 8: Example E2E Delay Statistics in OMNeT++



Experiment	Measurement	Replication	Module	Name	Count	Mean	StdDev	Variance
CircleMobility	$numHostsX=6, $numHostsY=6, $speedMin=5, $speedRange=5	#0	FANET.host[0].app[0]	throughput:vector	6000	38,133.333333 bps	184,873.502493 bps	34,178,211,924.209590 bps²

Figure 9: Example Throughput Statistics in OMNeT++

The PDR is calculated using the number of packets received by UDP Sink App at the receiver drone and the number of packets sent by UDP Basic APP at the sender drone. Calculation of the PDR is shown in Equation 4.1. UDP Sink App records the Mean E2E Delay and Mean throughput directly, the mean values are taken for all 5 simulation runs and the average is presented in the Chapter 5.

$$PDR(\%) = \left(\frac{\text{Number of Packets Received}}{\text{Number of Packets Sent}} \right) \times 100 \tag{4.1}$$

CHAPTER 5

RESULTS AND DISCUSSION

In this chapter, the simulation results of GPSR and AODV routing protocols under different mobility models are presented and discussed in detail. The performance metrics used for the comparison are PDR, Mean E2E Delay, and Mean Throughput.

5.1 Packet Delivery Ratio

Figure 10 and Figure 11 show the comparison of the PDR of GPSR and AODV with the mobility models mentioned in the Section 4.4. The Figure 10 shows the comparison with Stationary Mobility and the other mobility models for the speed range (5-10) m/s while the Figure 11 shows for the speed range (10-15) m/s. As it can be seen from these figures, GPSR and AODV routing have significant differences. The performance of these routing protocols are very similar for the stationary mobility model. When the mobility has been introduced, both protocols have performance degradation while AODV outperforms the GPSR in all of the mobility models. For example for lower speeds, AODV reaches up to 76.78% PDR with RWP mobility while GPSR reaches only to 41.57%. Increasing the speed range causes further decrease in the PDR. In the GM mobility, GPSR only reached 18.8% PDR while AODV only decreased to 68.15%.

These results are not surprising when we consider the basic GPSR mechanism. GPSR protocol is using location information of the network nodes with periodically sent beacons for routing. These periodic updates are not enough for the changing network topology due to mobility. Since the drones are highly mobile, the network topology changes significantly and GPSR protocol having trouble to maintain high PDR. On the other hand, in AODV protocol, the routing paths are discovered when necessary. Because of this, AODV protocol outperforms the GPSR since

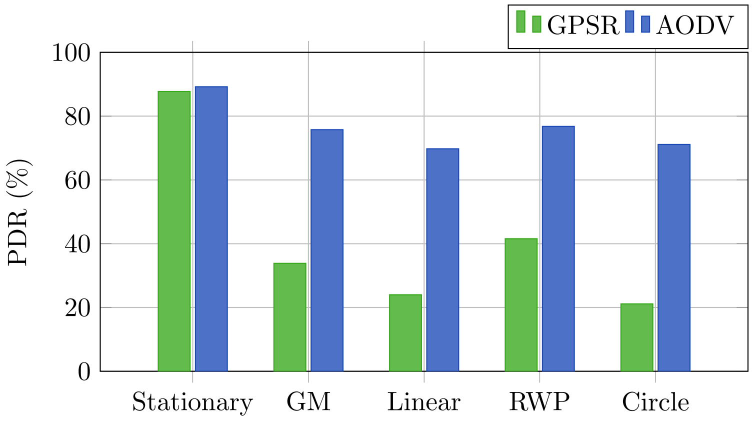


Figure 10: PDR Comparison of GPSR and AODV with Different Mobility Models for Speed Range (5-10) m/s

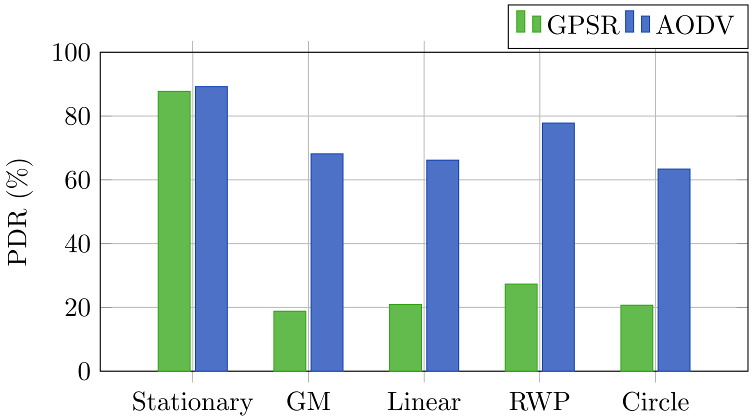


Figure 11: PDR Comparison of GPSR and AODV with Different Mobility Models for Speed Range (10-15) m/s

it can adapt to the changes in the network topology.

The RWP mobility model has the best performance for both lower and higher speeds among all of the mobility models for both routing protocols. In the lower speed range, AODV PDR is 76.78%. Higher PDR under the RWP mobility model can be explained by the characteristic of the RWP mobility model, which is the pause time. When drones reach to their destination points, they stop for 1 second. This makes the network topology stable for a while. On the other hand, Circle mobility has performed the worst in lower speed range for GPSR, while it doesn't change too much when speed increases. This result can be explained by the movement of the drones in Circle mobility model. The circular path of drones allows them to move away from each other. Hence, the topology changes more frequently causing less packets to be delivered.

5.2 Mean End to End Delay

Mean E2E Delay comparison of GPSR and AODV protocols under the aforementioned mobility models for speed ranges (5-10) m/s and (10-15) m/s are shown in Figure 12 and Figure 13 respectively. As it can be seen from these figures, the GPSR protocol has lower E2E Delay compared to AODV protocol among all of the mobility models. For example, for lower speed range, under GM mobility model, GPSR has 0.025s while the AODV has 0.204s, which is around 8 times compared to GPSR. When the speed range increased, the E2E Delay for GPSR under the same mobility model almost doubled to 0.048s and AODV increased to 0.294s.

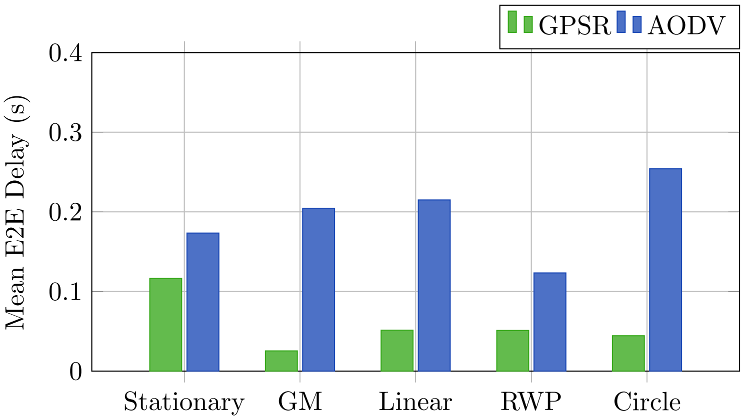


Figure 12: Mean E2E Delay Comparison of GPSR and AODV with Different Mobility Models for Speed Range (5-10) m/s

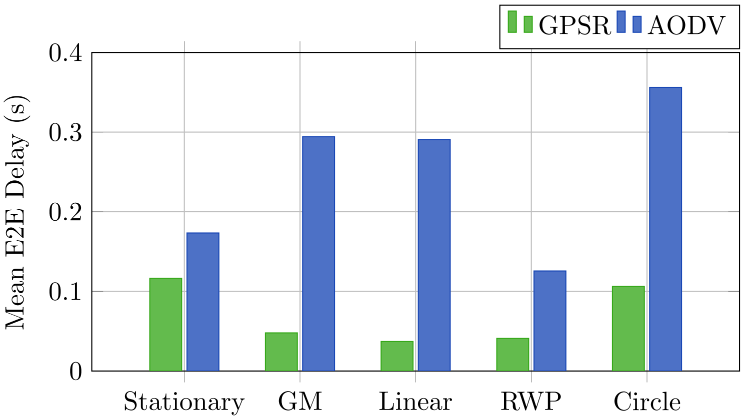


Figure 13: Mean E2E Delay Comparison of GPSR and AODV with Different Mobility Models for Speed Range (10-15) m/s

The reason behind the GPSR having lower E2E Delay compared to AODV can be explained by the beaconing mechanism of GPSR. Since GPSR updates the neighboring nodes with beaconing mechanism periodically, when a packet reached to a node, it knows the neighbors to forward the packet. However, in AODV, route discovery starts when it is required which takes time. For GPSR, there is a significant decrease in the E2E delay when nodes become mobile instead of stationary. This decrease can be explained by the PDR results discussed in the Section 5.1. Since the PDR decreases, there have been less packets delivered and since the topology constantly changing, the packets that are delivered might have shorter paths. On the other hand, AODV having more PDR, it also delivers packets that have longer paths, hence E2E Delay is higher. The PDR of GPSR and AODV in the stationary mobility model are almost equal. Comparing the E2E Delay performance of GPSR and AODV under the stationary mobility model with similar PDR values is more meaningful since one variable is fixed. Being the PDR almost equal for both protocols, the GPSR have less E2E Delay. This verifies our explanation about the beaconing mechanism makes the GPSR have less E2E Delay, and route discovery mechanism makes the AODV have higher E2E Delay.

5.3 Mean Throughput

Throughput results are shown in Figure 14 and Figure 15 for speed ranges (5-10) m/s and (10-15) m/s respectively. Since throughput is directly related with the size of the packets delivered per unit time, higher PDR results in higher throughput. As expected, these results are correlated with the PDR results shown and discussed in the Section 5.1.

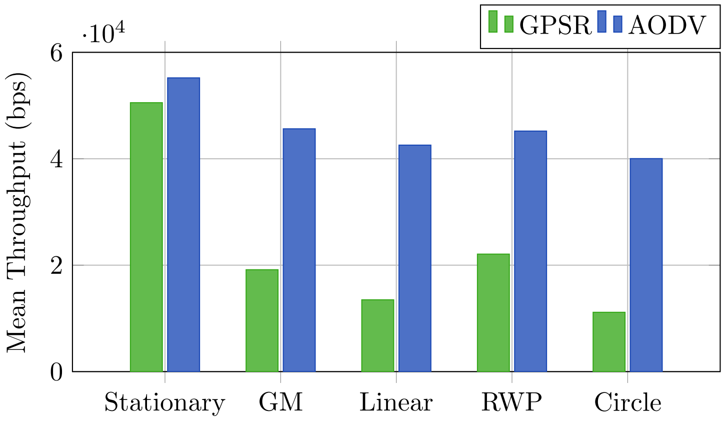


Figure 14: Mean Throughput Comparison of GPSR and AODV with Different Mobility Models for Speed Range (5-10) m/s

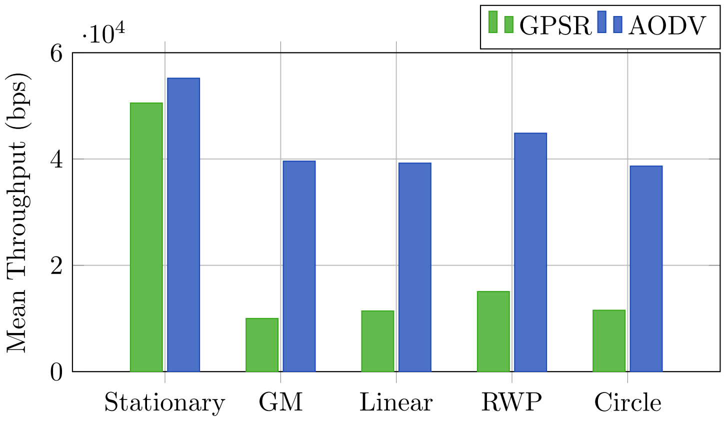


Figure 15: Mean Throughput Comparison of GPSR and AODV with Different Mobility Models for Speed Range (10-15) m/s

Although the throughput performance of AODV decreases by increasing the speed range, it is still higher than the performance of GPSR in all of the mobility models. Comparing with the stationary mobility model, the GPSR throughput decreases around 60-80% while the AODV having 15-30% decrease for lower speed range. Increasing the speed range casuses throughput of GPSR to decrease around 70-80% and AODV to decrease around 20-30% compared to stationary mobility model.

CHAPTER 6

CONCLUSION

This study compared the performance of GPSR and AODV routing protocols across different mobility models using PDR, E2E Delay, and Mean Throughput as performance metrics. The results reveal that AODV achieves higher PDR and Mean Throughput but suffers from increased delay, while GPSR delivers fewer packets with lower latency. GPSR is advantageous in terms of E2E Delay due to its beaconing mechanism, but struggles to adapt to changing topologies, resulting in lower PDR and throughput. Conversely, AODV's on-demand route discovery mechanism enables better adaptation to dynamic networks at the cost of higher delay. These findings provide valuable insights for selecting appropriate routing protocols in FANETs depending on application requirements: AODV is more suitable for applications prioritizing reliable packet delivery, while GPSR is preferable for delay-sensitive applications where some packet loss is acceptable.

There are several directions that this study can be extended and continued in the future. Some suggestions for future work are listed below.

- More routing protocols might be compared to provide a more comprehensive analysis.
- Different node densities can be used to observe the effect of the network density.
- Real time scenarios can be simulated for more realistic results such as search and rescue operations, agriculture monitoring etc.
- Adding other performance metrics such as energy consumption or security to observe different aspects.

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