Quadcopter Video Surveillance over FANET

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DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

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Quadcopter Video Surveillance over FANET

Major Project

Submitted in partial fulfillment of the requirements

for the degree of

Master of Technology in Computer Science and Engineering

Submitted By

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(14MCEN11)

Guided By

Dr. Priyanka Sharma

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Certificate

This is to certify that the major project entitled **"Quadcopter Video Surveillance over FANET"** submitted by **Karan Palan (Roll No: 14MCEN11)**, towards the partial fulfillment of the requirements for the award of degree of Master of Technology in Computer Science and Engineering of Nirma University, Ahmedabad, is the record of work carried out by him under my supervision and guidance. In my opinion, the submitted work has reached a level required for being accepted for examination. The results embodied in this major project , to the best of my knowledge, haven't been submitted to any other university or institution for an award of any degree or diploma.

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Statement of Originality

I, **Karan Palan (14MCEN11)**, give undertaking that the Major Project entitled "**Quadcopter Video Surveillance over FANET**" submitted by me, towards the partial fulfillment of the requirements for the degree of Master of Technology in **Computer Science & Engineering** of Institute of Technology, Nirma University, Ahmedabad, contains no material that has been awarded for any degree or diploma in any university or school in any territory to the best of my knowledge. It is the original work carried out by me and I give assurance that no attempt of plagiarism has been made.It contains no material that is previously published or written, except where reference has been made. I understand that in the event of any similarity found subsequently with any published work or any dissertation work elsewhere; it will result in severe disciplinary action.

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Abstract

Due to many characteristics of UAVs, they can be used in a number of fields and they have a large number of applications and one of the latest trends is using multiple UAVs in place of single UAV. Mostly UAVs are remotely piloted which reduces there range of performance as the range of communication is limited Their range of application can be increased by establishing an ad-hoc network between them, such an ad-hoc network of UAV is known as Flying Adhoc Network (FANET). Also it overcome some of the problems of infrastructure-based networks. FANET differs from other ad-hoc networks in many ways hence it should be handled differently. The main problem with FANET or other multi-UAV systems is communication between UAVs. With improved communication FANET will find many new applications and help to improve other multi UAV applications.

Abbreviations

FANET	Flying Adhoc Network.
UAV	Unmanned Aerial Vehicle.
MAV	Manned Aerial Vehicle.
ESC	Electronic Speed Controller.
MANET	Mobile Adhoc Network.
VANET	Vehicular Adhoc Network.
GPS	Global Positional System.
AGPS	Assisted GPS.
DGPS	Differential GPS.
OLSR	Optimized Link State Routing Protocol.
MPR	MultiPoint Relay.
GPMOR	Geographic Position Mobility Oriented Routing.
OR	Opportunistic Routing.
LODMAC	Location Oriented Directional MAC.
AODV	Ad Hoc On-Demand Distance Vector Routing.

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Introduction

1.1 Introduction

Quad-copter : A multirotor system that is lifted and propelled by four rotors that provide the necessary aerodynamic force. Utilizes two arrangements of indistinguishable altered pitched propellers. Movement is Controlled by changing turn rate of one or more propellers.
Quadcopter can be classified as Unmanned Aerial Vehicle (UAV) and Manned Aerial Vehicle (MAV). Autonomous flying capacities of quad-copters have discovered many new application.
A quadcopter has following components

- Frame.
- Propeller
- Motors.
- Electronic Speed Controllers (ESC).
- Fight Controller.
- Radio Transmitter and Receiver.
- Sensors.
- Battery

Frame: A frame is used to accommodate all the necessary parts needed to build the quad-copter. While choosing a frame its weight, size and materials should be considered.
Propeller: A Propeller is used to provide thrust to Quadcopter using rotation provided by Motors. While choosing a Propeller its type, material, pitch and length should be considered.
Motors: Motors are used to rotate the Propellers and control their speed and direction.While choosing a motor its power, thrust and rpm should be considered.
Electronic Speed Controllers (ESC): ESC's are used to inform Motors to control their Speed and Rotation. One ESC is required for each Motor. While choosing ESC the type, current / voltage rating and programmability should be considered.
Flight Controller: It is the important part of Quad-copter. It includes sensors like gyroscopes and accelerometers that helps in controlling and determining the speed of Quad-copter. While choosing a flight controller the features it provides should be considered.
Radio Transmitter and Receiver: Radio Transmitter and Receiver are used to control the Quad-copter remotely. No of channels required are important for this purpose.
Sensors: There are many sensors available that can be used with Quadcopter like Camera, gyroscopes, accelerometers , GPS ,etc.
Battery: Battery is used to provide necessary power to various components of Quad-copter.
A simple block diagram of Quad-copter is shown below.

1.2 Applications of Quadcopter :

Some areas where Quadcopter can be used extensively are:

- Traffic Surveillance
- Crop Monitoring
- Border Patrolling
- Wildfire Monitoring
- Disaster Management
- Commercial Drones

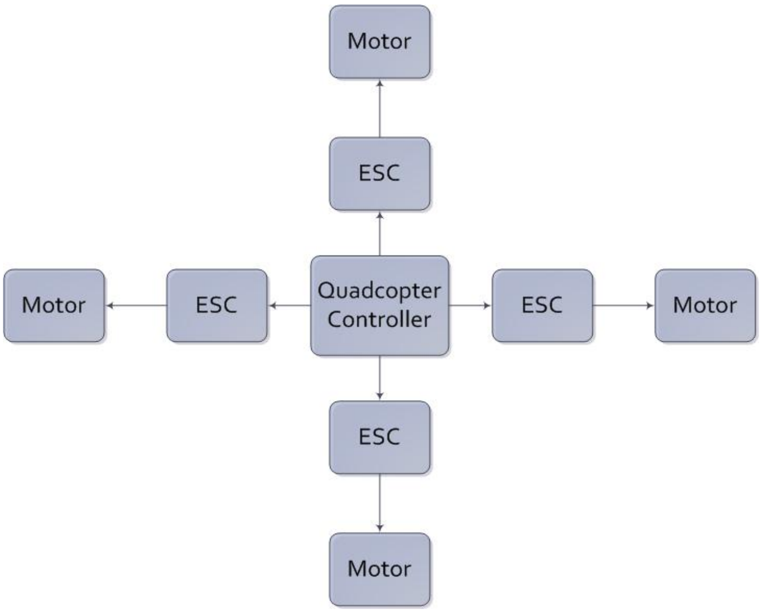

Figure 1.1: Simple Block Diagram of Quadcopter

Traffic Surveillance: The use of UAV's have increased for Traffic Surveillance in the USA as stated by the US Department of Transportation.[1]The bird's eye view, traffic conditions and details about emergency situations can be provided by UAV's to the control station as shown in Fig 1.2. In [2], a good survey on the use of UAV's for Traffic Surveillance is provided by the authors.

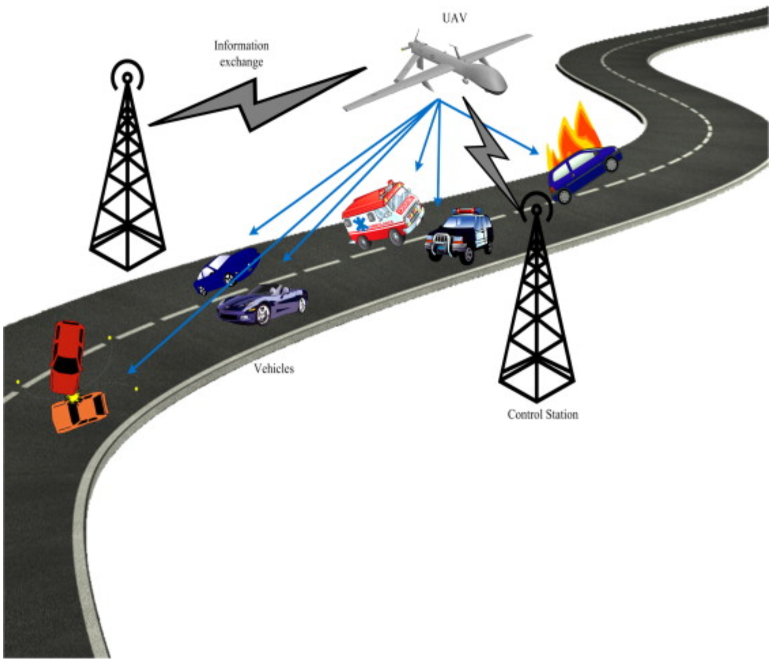

Figure 1.2: Traffic Monitoring [1]

Crop Monitoring: In [3],a system is proposed which uses of UAV's along with wireless sensor network in order to provide improved situation awareness of the crops to the farmers[1]. As shown in Fig.1.3, crops information is collected by sensor nodes which is sent to UAV's when is visits the sensor nodes and base station processes this information when it receives through UAV's. The person at the base station can take appropriate actions for crops.[1]

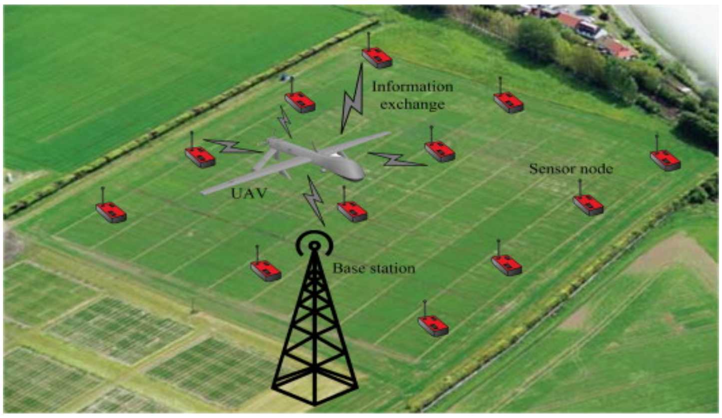

Figure 1.3: Crop Monitoring [1]

Border Patrolling: In most of the nations the is an increased need for national security which requires good border patrolling systems.There are a number of proposed Border Patrolling Systems which provides real time border patrolling with minimal human involvement and high accuracy. In [4] , a new system called BorderSense is proposed which is composed of the hybrid wireless sensor network and UAVs. For the detection of intruders or illegal border crossing, sensor nodes are used.UAVs are used for tracking the intruder.[1].As shown in Fig. 1.4, ground sensors, UAV's and Surveillance Towers are used for Border Patrolling and tracking Intruder.

Wildlife Monitoring: Most of the countries are facing an important issue to Forest fires which cause a large economic cost. In long term, they result in wildlife ecological damage and can also affect the climate and in some situations it may also cost human lives.[1] In [5], the authors described the use of UAVs for wildfire monitoring and proposed an application.

Disaster Management: In Disaster situation Internet / Telecom facilities might be damaged. In such situations, inconsistent and incomplete information may be available to the Rescue Team which may be harmful. Quadcopter equipped with Cameras and other Appropriate sensors can be helpful un such cases.[1]

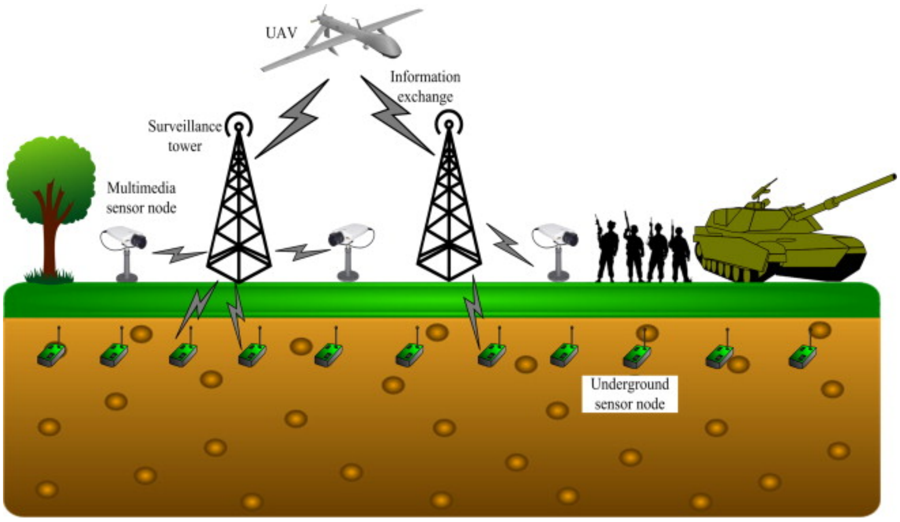

Figure 1.4: Border Patrolling [1])

Commercial Drones: In past many companies demonstrated or presented an idea to use UAV's for different purpose like amazon demonstrated the use of quadcopter to deliver goods from warehouse to customer premises, Domino's presented the use of Qctacopter to deliver Pizzas. These types of commercial applications open new doors to different applications for UAVs in the urban scenario.[1]

1.3 Working Principle

Quadcpoter's movement is controlled using following operations.

- Hovering / Altitude Control
- Roll
- Pitch
- Yaw

Hovering / Altitude Control: A Quadrotor floats or modifies its height by applying equivalent push to each of the four rotors.

Roll / Pitch : Working Principle : Pitch / Roll A Quadrotor alters its pitch or roll by applying more push to one rotor what's more, less push to its oppositely inverse rotor.

Yaw: A Quadrotor changes its yaw by applying more push to rotors turning in one heading.

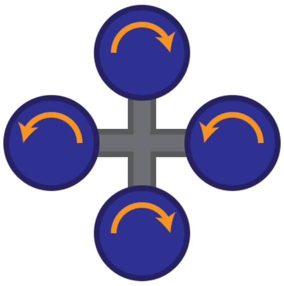

Figure 1.5: Hovering

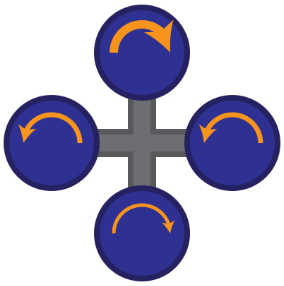

Figure 1.6: Roll

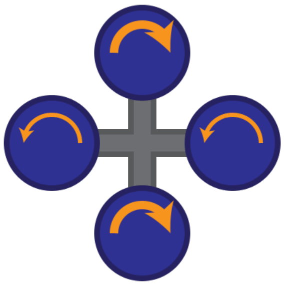

Figure 1.7: Yaw

1.4 Issues With Quadcopter:

The following are the major issues with Quadcopter.

- Collision Avoidance
- Equipment Failure
- Tradeoff between UAV and MAV.
- Security
- Navigation
- Fast Dynamics
- Limited onboard computation.

1.5 Wireless Networks Introduction

The wireless connection can be used in scenarios to extend the network to different places as it removes the need to establish the point to point wired links. Wireless Networks can be either infrastructure based networks or ad-hoc networks. Infrastructure Based Networks have a central coordinator which manages every node while ad-hoc network does not have a central coordination or fixed topology which increases complexity in sending or receiving packets between nodes.

1.6 FANET Introduction

MANET & VANET are much popular parts of ad-hoc networks. MANET is an ad-hoc network of mobile nodes while VANET is an ad-hoc network of Vehicular nodes. In 2012, Ilker Bekmezci introduced the concept of FANET, an ad-hoc network of flying nodes and provided a detailed survey on FANET in [6]. UAV's are used in many applications such as Traffic Monitoring, Crop Monitoring, Search and Rescue etc.because of their low cost, easy installation, better flying capabilities etc.

Although there are many single UAV application but using multiple UAV systems co-operating with each other can be helpful in many ways. But different issues and challenges are needed to be addressed in the case of multi-UAV system. Co-operation between UAV's is essential in multi-UAV system which requires better communication and that is one of the major problems in FANET[6]. A typical FANET scenario is shown in Fig 1.8

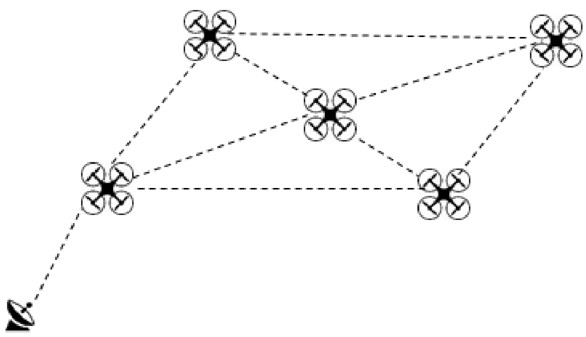

Figure 1.8: FANET Scenario

Chapter 2

Literature Survey

2.1 FANET

Rather than creating and working one substantial UAV, utilizing a gathering of little UAVs has numerous preferences. Multi-UAV frameworks have additionally one of a kind difficulties and a standout amongst the most conspicuous configuration issues is correspondence For the most part All UAVs are specifically associated with a foundation, for example, a ground base or a satellite.This foundation based correspondence building design limits the abilities of the multi-UAV frameworks Ad-hoc networking between UAV's can solve this problems.[6]

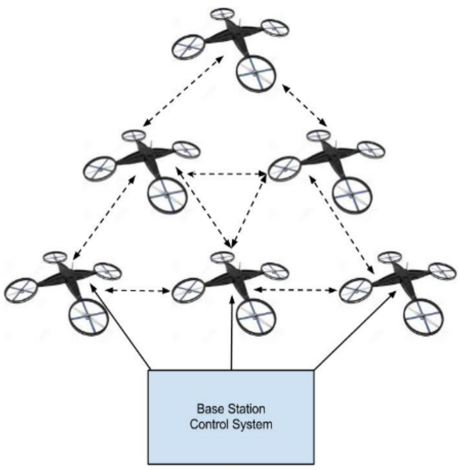

Figure 2.1: FANET

The existing protocols for MANET can be adopted for UAVs communication by considering the following aspects related to FANET.

- **UAV mobility:** The performance of routing protocols depends on the mobility of the nodes. to achieve better performance the a high mobile network, there has to be a large control overhead which is because dynamic networks needs to exchange a lot of information

- **Number of UAVs in the network:** Scalability is another issue that has to be taken care off. there are some routing protocols which has better performance on small-sized networks while there are others which shows better performance in large- scale networks.

- **Memory and storage capacity:** to promote better performance, some protocols need additional storage and memory capacities.

- **Power consumption:** To perform well in FANET, protocols require more power and energy, hence energy consumption must be kept in mind and energy aware protocols must be used.

- **Transmission robustness and security:** There should be minimum delay in the reaction of UAV when a task is alloted and also security is another important factor. As the security increases, control overhead and delay also increases which affects robustness.

- **Connection to infrastructure:** Certain applications which requires centralized storage systems or internet access needs continuous connection to infrastructure.

- **Throughput:** Different applications needs to support different data traffic rates which can be supported by UAVs networks hence, Throughput is an important factor.

- **Handoff and roaming:** Appropriate handoff and roaming strategies must be used to support continuous switching between base stations as UAVs keeps on moving in and out of communication range. Processing capability: Some applications require protocols to support real time traffic which may require large computations and processing power.

2.2 Advantages of multi-UAV system

- **Cost** - FANET can reduce cost as compared to single quadcopter system performing a similar task as the cost of maintaining and acquisition of many small quadcopter will be less than one large quadcopter.

- **Scalability** - FANET provides a large amount of usage as coverage area increases.The size of the operation area can be increased by adding new UAVs. The system dynamically rearranged its network structure according to new locations of UAVs.

- **Survivability** - The task or Mission can survive for a longer duration because of FANET.Fault tolerance of Multi-UAV systems is more as the operation can still continue even when one of the UAV is down or fails.

- **Speed up** - FANET helps to speed up the task because of multiple UAV's.The number of UAVs affects missions, such as reconnaissance, surveillance, search and rescue.More number of UAV's means faster the mission will be completed.

- **Small radar cross-section** - In Military, cross-section, infrared signature, and acoustic signature are used to detect the items for which Radar is used. The cross section, acoustic signature and infrared signature of small UAV is less which makes it hard to detect as compared to large UAVs hence, it can be used for military applications.[6]Radar the cross-section is crucial for military applications.

2.3 Difference between FANET, MANET and VANET

- **Node mobility** - The performance of FANET and other adhoc networks is dependent on node mobility. In MANET node mobility is low as compared to VANET. In FANET, the nodes mobility is much higher as compared to VANET and MANET[6].

- **Mobility model** - Special Mobility Model is needed for FANET. FANET nodes have different speeds and different characteristics than MANET and VANET, hence, special Mobility models are needed for FANET. [6]

- **Node density** - The average number of nodes in a unit area is defined as Node Density. In FANET the node density is much lower as compared to MANET and

VANEt as the nodes are distributed in the sky and generally the distance between them can be several kilometers even in case of small UAV system.[6]

- **Topology changes** - Because of high mobility, FANET topology changes more rapidly as compared to MANET and VANET.Also UAV platform failure may affect the topology of FANET. Topology update is required when a UAV fails.similarly UAV addition will also result in new link formation which also requires topology update. Link outages will occur because of Node mobility and variation in node distances which will also result in topology changes.[6]

- **Radio propagation model** - Radio propogation Models of FANET are different as compared to MANET and VANET as in MANET and VANET the nodes are relatively close to round and the might be no line of sight available between sender and receiver. In MANET and VANET the radio signals are mostly affected by the geographic structure of the terrain.Therefore, radio signals are mostly affected by the geographical structure of the terrain while in FANET the nodes are mostly away from ground and also line of sight is also available.

- **Power consumption and network lifetime** - Network lifetime is an important factor while designing any adhoc network which consist of battery powered components. Developing energy efficient communication protocols is the goal of efforts to increase the network lifetime. In MANET and VANET we have to consider energy efficient protocols for such scenarios while in FANET there is no restriction on power usage.In mini UAVs application energy utilization can still be design issue.

- **Computational power** - In ad hoc network concept, in order to process incoming packets nodes need additional processing capabilities.In MANET because of small size and energy restrictions . the nodes have a limited computational power while in VANET and FANET the nodes can be equipped with high computational capabilities also FANET have necessary space and energy to support such equipments. But if such equipments are added to UAVs its weight might become a issue as UAVs have limited payload capacity.

- **Localization** - Location is at the center point of mobile and coopratative ad hoc networks. In MANET, GPS is mostly used to get location details of nodes but in some cases when GPS cannot be used then beacon nodes or proximity-based techniques can also be used. In VANET, GPS can provide location within accuracy of 10-15m which is enough for route guidance but for cooperative safety applications, such as collision warnings for cars it is not enough. Assisted GPS (AGPS) or differential GPS (DGPS) are used to increase accuracy. Because of the high speed and different mobility models of multi-UAV systems, FANET needs highly accurate localization data with smaller time intervals which is provided by GPS but it may not be sufficient for certain FANET protocols so in such case an inertial measurement unit (IMU) can be used to provide location details ata a quicker rate.

Because of the above-mentioned differences between FANET, MANET and VANET; FANET is considered as a different adhoc network family.[6]

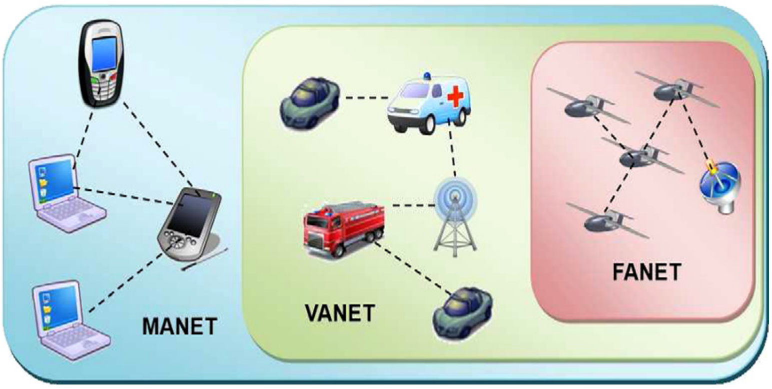

Figure 2.2: Difference between various adhoc networks

Comparioson of different adhoc family is shown in table below

	MANET	VANET	FANET
Node Mobility	Low	High	Very High
Mobility Model	Random	Regular	Regular for predetermined Paths but special mobility models for autonomous multi UAV systems
Node Density	Low	High	Very Low
Topology Change	Slow	Fast	Fast
Propagation Model	Close to Ground LOS is not available for all cases	Close to Ground LOS is not available for all cases	High above Ground LOS is available for the most of Cases
Power consumption and Network Lifetime	Energy Efficient protocols	Not Needed	Energy Eficiency for mini UAV's but not needed for small UAV's
Computational Power	Limited	High	High
Localization	GPS	GPS, AGPS, DGPS	GPS, AGPS, DGPS, IMU

Table 2.1: Comparison of MANET, VANET and FANET

2.4 FANET Layered Approaches and their Open Research Issues

At the following layers, some work has been done to improve communication in FANET.

- Physical
- MAC
- Network
- Transport

Physical Layer:

Radio Propagation Models :Two ray ground Propagation and UAV - UAV propagation are similar[6].

Antenna Structures : Directional Antenna And their Advantages over Omnidirectional antenna are compared.[6]

Open Research Issues:

- Existing FANET studies 2D FANET topology.[6]
- Antenna behavior in 3D can be different than 2D.
- Analyze existing Protocols and develop new protocols[6]
- physical layer designs are not much explored for 3D topology[6]

MAC Layer:

Directional Antenna based FANET MAC-layer : Because of large distance between nodes Directional Antenna can be helpful in case of FANET[6]

Full duplex MAC Layer and multi-packet reception multi-packet reception-possible to realize full-duplex wireless communication on the same channel[6]

Open Research Issues:

- Directional antenna based mac assumes location service is handled by upper layers.[6]
- , Unlike MANET, FANET may include advanced hardware for efficient
- FANET MAC design which is not much explored.[6]

Network Layer:

DOLSR : OLSR is used along with Directional Antenna to increase Packet Delivery Ratio and decrease Latency[6]

Time-slotted on demand routing : To Decrease Collisions , AODV is used along with TDMA[6]

GPMOR : Next Hop is decided using Gauss-Markov Mobility Model prediction and UAV node movement [6]

Mobility prediction clustering UAV networking and clustering : Clusters of UAV are created on the ground, and then updates on the clusters during the operation of the multi-UAV system.[6]

Open Research Issues:

- Routing algorithms supporting peer to peer communication and converge cast traffic is not much explored[6]
- Data-centric FANET routing is also another topic that is yet to be explored.[6]

Transport Layer:

JAUS emerging standard for messing between UAV [6]

STANAG 4586 - common transport for network-centric operations between multiple UAV networks.[6]

Open Research Issues:

- Reliable and efficient data transfer protocols specifically for FANET are not much explored[6]

2.5 FANET Cross Layered Approaches

Cross Layered Architecture:

IMAC UAV with DOLSR - A new Mac layer IMAC UAV is used along with DOLSR at the network layer.[6]

Meshed Tree algorithm - MAC and Network Layer are combined and TDMA is used.[6]

Open Research Issues:

- The entire area is not much explored.[6]
- Very few studies are only available.[6]
- Scope for new cross layered FANET protocols[6]

2.6 Communication Protocols for FANET

Much work has been done at different layers to improve the communication between UAVs. Some of the protocols, related to the same are discussed in this section.

2.6.1 Adaptive MAC protocol

The link quality fluctuates in FANET because of high mobility of nodes and continuously changing the distance between nodes. MAC design for FANET faces new challenges because of such link quality fluctuations and failures. Latency can also be another challenge. A directional antenna can be helpful in scenarios to increase the range of communication, spatial reuse, enhancing security. In [7], an adaptive MAC protocol has been proposed which uses an omnidirectional antenna for control packets transfer and directional antenna for data packets transfer. End to End Delay, Throughput and Bit Error Rate were improved with the use of this approach.

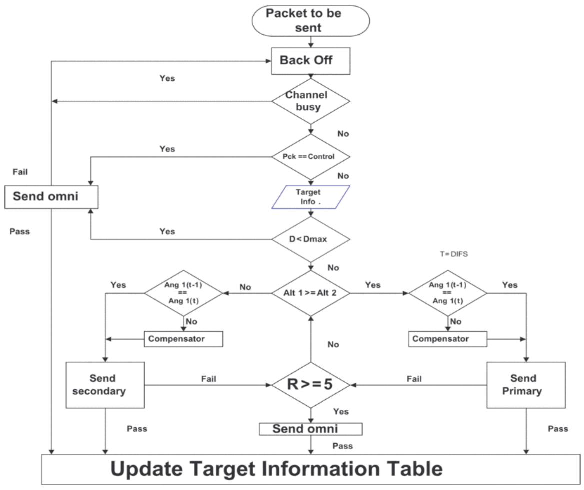

Figure 2.3: MAC scheme flows chart for UAV

2.6.2 Token MAC

A Token based approach was proposed in [8] to update target information, to overcome the problem in traditional contention based protocols and link failures due to high mobility. Full Duplex Radios and Multi-Packet Reception (MPR) were used to improve the MAC performance in multi-UAV network environment. The delay is reduced with Full Duplex Systems as each node can transmit and receive at the same time and Multi-packet reception capabilities improve the throughput in multi-UAV systems.

2.6.3 Directional Optimized Link State Routing Protocol

In [9], a protocol is proposed which uses modified OLSR(Optimized Link State Routing Protocol) and uses a directional antenna. In OLSR, the key step is selecting multi point relay(MPR). Reducing the number of MPR will result in reduced control packets transferred. In [9], as proposed by authors to transfer the packets, information about the destination is used and if the distance to the destination from source is less than half of maximum capacity of the directional antenna than DOLSR is used otherwise OLSR is used for routing. They have also proposed a new approach which reduces the number of MPR which results in reduced control overhead. The proposed approach reduces delay and enhances the overall throughput.

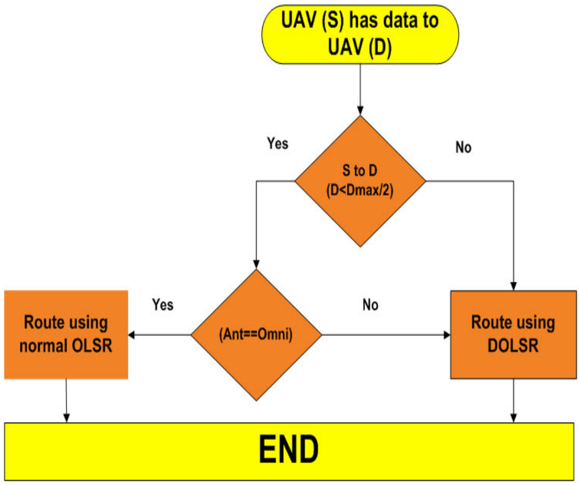

Figure 2.4: DOLSR routing protocol block diagram

2.6.4 Time Slotted Adhoc on Demand Distance Vector routing

To reduce collisions, time slotted reservation scheme is used along with AODV. In [10] the authors proposed a hybrid approach to minimize the intermediate node communication. Time reservation mechanism used in this approach is similar to that of Slotted ALOHA. Each node is assigned a time slot to send data to the master node or cluster head and has communication privilege over other nodes in this particular time slot. The proposed approach reduces collisions and also improves packet delivery ratio.

2.6.5 Geographic Position Mobility Oriented Routing

In[11], a geographic-based routing protocol GPMOR is proposed which can find the best available next hop to effectively decrease the impact of intermittent connectivity caused by the highly dynamic mobility. Firstly, they used Gauss-Markov mobility model for predicting the node position to decrease routing failure. Secondly, they used the mobility relationship to select next-hop for routing more accurately[11]. The proposed approach improves the stability of cluster and cluster heads.

2.6.6 Mobility prediction clustering

In UAV networking, the existing clustering algorithms were not suitable because of high mobility and frequent cluster updates. To overcome such problems , in [12] a new mobility prediction which uses cluster weighted model is proposed which uses UAV attributes. It predicts the network topology using the Trie data structure dictionary prediction and link expiration time mobility model. It helps in constructing more stable cluster structure and improved network performance because of the reasonable cluster head electing algorithm and on-demand cluster maintenance mechanism.

2.6.7 Clustering algorithm of UAV networking

Before the operation, the clusters are created and UAV's are grouped together and then during the operation process the updates are sent at regular intervals of time.[13]. UAV communication can be efficiently realized by utilizing near-space communication system. It helps overcome issues of a poor capability of networking and over horizon communication among UAVs. The proposed approach raises stability and flexibility in near space clustering and also reduces system cost and complexity in dynamic routing of UAV nodes.

2.6.8 IMAC UAV with DOLSR

A hybrid approach that works at MAC and network layer. It uses proposed intelligent MAC (IMAC) as the MAC layer and OLSR as the network layer protocol and uses a directional antenna. A shared data set sharing attributes like antenna type, bit error rate, multipoint relay (MPR) locations, aircraft altitude and locations is used to facilitate communication between the first three layers. The proposed techniques give better end-to-end delay than the IEEE 802.11 standard [14] and reduces the number of MPR selected which results in reduces the control overhead.

2.6.9 Meshed Tree algorithm

A hybrid approach that works at MAC and network layer to eliminate limitations of the layered protocol stack. Clusters of UAV's are formed and data is routed from UAV's to cluster heads. To schedule Time slots at MAC layer TDMA is used.[6]. It allows the formation of multihop overlapped cluster to support data aggregation and scalability. It improves packet delivery ratio and end-to-end delay which are important for surveillance purposes. [15]

2.6.10 Adaptive Forwarding Protocol

In [16], a new forwarding mechanism is proposed for FANET which is adaptive. In FANET, forwarding a packet may not always reach the destination. AFP uses adaptive forwarding scheme which uses forwarding probability and forwarding zone creation. To reduce redundant broadcast forwarding probability is used. Forwarding zone helps in controlling range of forwarding and reduce unnecessary broadcast and collision. [16]. The proposed approach improves End to End Delay, Packet Delivery Ratio and Energy Consumption per Packet Received.

2.6.11 A Beaconless Opportunistic Routing

Beaconless Opportunistic Routing (OR) allows increasing the robustness of systems for supporting routing decisions in a completely distributed manner. In [17], LinGO is proposed which is a Geographical Beaconless OR protocol. The addition of a cross-layer scheme enhances the benefits of a beaconless OR, and also enables multimedia dissemination with Quality of Experience (QoE) support. This protocol delivers live video flows with QoE support and robustness in mobile and dynamic topologies[17].

2.6.12 Location Oriented Directional MAC protocol for FANETs

In [18], a novel MAC protocol, LODMAC is proposed. The proposed approach uses Directional Antennas and estimated the location of neighbour nodes within MAC layer. Along with Traditional Control Packets Request to Send (RTS) and Clear to Send (CTS) packets, a new Busy to Send (BTS) packet is used. Directional Antennas have a major problem of Directional Deafness which is better addressed by LODMAC. LODMAC improves throughput, Delay, network utilization. LODMAC performs better than DMAC (Directional MAC), LODMAC protocol outperforms the well-known DMAC (Directional MAC) which can be helpful for upcoming FANET MAC Protocols.[18]

Protocol	Layer	Improves	Reduces
Adaptive MAC	MAC Layer	Throughput	End to End Delay, Bit Error Rate
Token MAC	MAC Layer	Throughput	End to End Delay
DOLSR	Network Layer	Throughput	End to End Delay, Control Packets Overhead
TAODV	Network Layer	Packet Delivery Ratio	Collisions
GPMOR	Network Layer	Packet Delivery Ratio	End to End Delay, No of Hopes
Mobility prediction clustering	Network Layer	Stability of cluster and cluster heads	-
Clustering algorithm of UAV networking	Network Layer	Stability of cluster, Dynamic Networking	-
IMAC UAV with DOLSR	MAC and Network Layer		End to End Delay, Control Overhead
Meshed Tree algorithm	MAC and Network Layer	Packet Delivery Ratio	End to End Delay
AFP	Network Layer	Packet Delivery Ratio	End to End Delay, Energy Consumption
LinGO	MAC and Network Layer	Reliability, Robustness	Control Overhead
LODMAC	MAC Layer	Throughput,Goodput	End to End Delay

Table 2.2: Comparison of Protocols

2.7 Mobility Model

The performance of an ad hoc protocol may be largely affected by the mobility model used. The mobility model depends on the node characteristics like speed and randomness also the application for which it is to be used.The Mobility Model used should be related to the intended purpose for better and accurate results

Well known Mobility Models for UAV:

- Random Walk Model - In the Random Walk model, a node initially chooses a random direction and speed and travels for a fixed amount of time. After that it chooses a new set of direction and speed .Next set of speed and direction is chosen in a fixed amount of time or after a fixed distance is travelled.This model is a stateless model.[19]

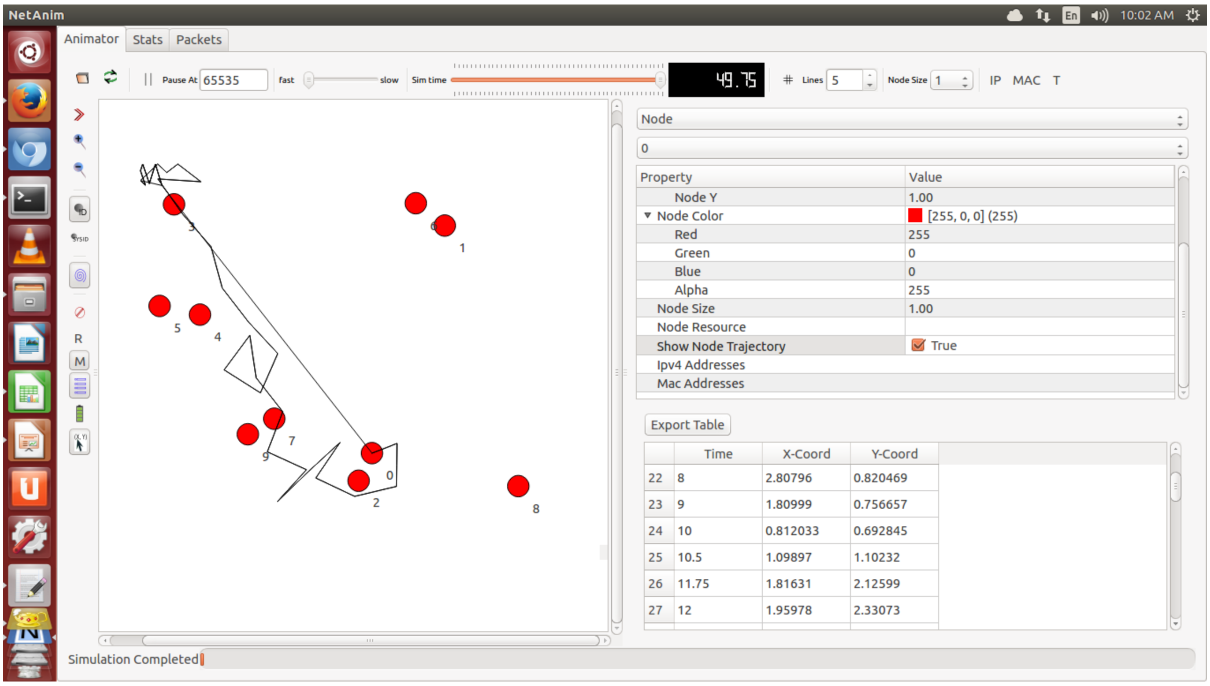

Figure 2.5: Node Trajectory in Random Walk Mobility Model

- Random Way Point Mobility Model - In Random Way Point Model a node chooses a random region and moves towards this choosen region with rabdomly choosen speed. After reaching the destination it pauses for some time and after that it again chooses a new destination.[19] compared to random walk model this model provides more realistic results.

- Gauss-Markov Mobility Model - In this model, the velocity of mobile node is assumed to be correlated over time and modeled as a Gauss-Markov stochastic process

- Pheromone-based mode- each node marks the area that it scans on the map called Pheromone Map , and shares this map to other nodes in order to maximize the coverage[19]UAVs prefer the movement through the area with low pheromone smell.the pheromone base model has very reliable scanning properties

- Semi-random circular movement - The Semi-Random Circular Movement (SRCM) mobility model restricts UAVs to circle around a fixed center with variable radii[19]it is applicable for simulating UAVs turning around a specific position in order to gather some information.

- Mission Plan-Based Mobility Model: In MPB model, the nodes are made aware of the entire scenario information. The nodes then travel towards the predetermined path.In MPB mobility model, the mobility files are created and updated frequently after some period of time is over.

Chapter 3

Proposed Approach

3.1 AODV overview

Ad Hoc On-Demand Distance Vector Routing (AODV) is a proactive protocol. AODV was an improvement over DSDV by reducing broadcast packets as it creates routes on demand. Sequence Number (SN) is used to avoid loops and ensures freshness of routes. AODV has 2 main phases.

- Route Discovery - finding the route to destination using RREQ packet
- Route Maintenance - Identifying Link failure using HELLO packet and inform other nodes about this link failure using RERR packet.And if necessary it may again initiate Route Discovery phase.

Its message set consists of 4 types of packets

- RREQ - Route Request
- RREP - Route Reply
- RERR - Route Error
- Hello - for link status monitoring.

RREQ When any node needs route to destination RREQ packet is is broadcasted by source.RREQ packet include ip addresses of source and destination it also includes Boead-cast id (BrID) to uniquely identify each request and sequqnce number is used to determine timeline of packets. The nodes receiving RREQ packet update their Routing table which

helps intermediate nodes to find the reverse paths. RREQ contains a Sequence Number (SN) which is used to avoid stale routes to destination.
RREP When destination receives RREQ packet it unicasts route information back to source. Intermediate nodes can also generate the RREP packet if it has a fresh route to the destination.The nodes receiving RREP packets also updates their routing tables.
RERR This packet is used to inform other nodes about link failure. End nodes of link sends this packet and intermediate nodes reciving this packet passes on to other nodes.
HELLO This packet is used for sharing connectivity information. If a node does not receive HELLO packet for certain amount of time it assumes that link to its neighbour has been damaged.HELLO packets can provide better knowledge of the network and also improve the route discovery process.

Latency of the network is increased by the on demand discovery of route in case of reactive protocols as the request is flooded and it also increases the control overhead and congestion. In AODV, Broadcasting is used for route discovery, although it is simple but inefficient. It also over utilizes the limited resources like energy of the nodes, bandwidth. Traditional flooding scheme causes more retransmissions which may increase congestion and collisions that affects the network performance.

3.2 Location assisted AODV

AODV is a reactive protocol in which if a sender wants to send data but the path does not exist only then route discovery mechanism takes place. In AODV the main phases are Route Discovery and Route Maintenance.
In Route Discovery phase the request packet is flooded (broadcasted) to all the neighbouring nodes. The main idea in this work is to take help from GPS coordinates of intermediate nodes and to reduce the control overhead by reducing the request messages forwarded.
In original Route Request and Route Reply packets additional information about the GPS coordinates of nodes was added. A node receiving either of this packet adds this information of sender nodes in a new routing table which maintains details of nodes and their GPS locations along with that some other information is maintained like sequence number and timer.Now with the help of the GPS coordinates the scope of Route request packet is reduced, details about which are explained later.

A sequence number is used to identify when a new packet is received containing GPS information of a particular node.If the sequence number is greater then the GPS information is latest and updates the details in the table else discards the details.The timer is used to keep the fresh details of the nodes if after certain amount of time the information is not updated then the existing information in table is considered stale and removed.
A GPS provides mainly longitude and latitude , it can also provide altitude but it can be erronous so to find the altitude of a UAV's barometer is used. Due to the above limitations of GPS, we will assume with 2D coordinate system only while modifying the protocol. The latitude and longitude provided by GPS are assumed to be X and Y coordinate of node's position.
To take advantage of GPS coordinates we modified the original AODV protocol to support the following features:

- Keep track of the known node coordinates,
- Distribute the node coordinates in the network, and
- Use destination coordinates to limit the scope of the route discovery mechanism.

The angle between sender-Receiver and sender- destination is calculate and if it is more than 90 then only the route request is forwarded as shown in Fig. 3.1
Angle is calculated as

$$\theta = \cos^{-}1(\frac{S\vec{N}.S\vec{D}}{|S\vec{N}|.|S\vec{D}|})$$

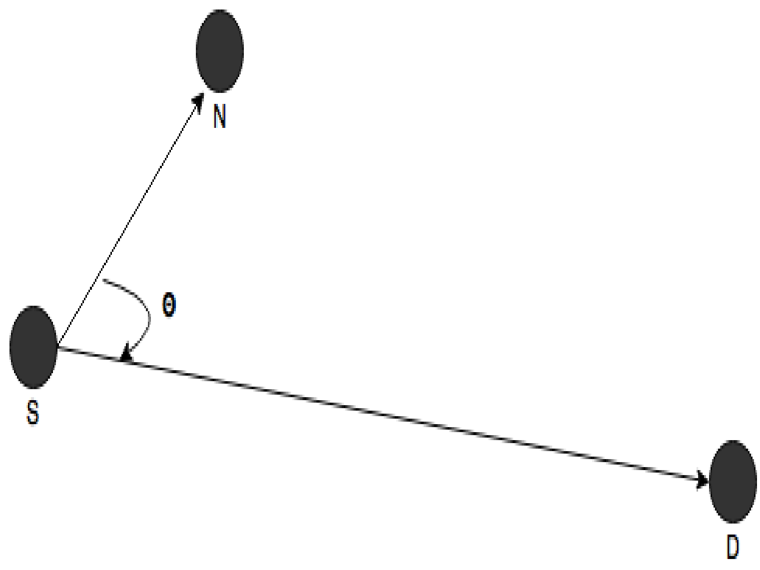

Figure 3.1: Calculating Angle

Another table is used to keep the track of nodes and their respective positions.It includes Node ID, Location Information, Sequence Number and Time Details. If after certain time the information of node is not update then it is removed from the table. Sequence Number is used to identify freshness of node information.

Chapter 4

Implementation

4.1 Simulation Tool

NS3 simulator is used for the simulation purpose.It is a discrete event based simulator.NS-3 is a discrete-event network simulator, targeted primarily for research and educational use. NS-3 is free software, licensed under the GNU GPLv2 license and is publicly available for research, development and use. The goal of the NS-3 project is to develop a preferred, open simulation environment for networking research: it should be aligned with the simulation needs of modern networking research and should encourage community contribution, peer review and valida- tion of the software . NS-3 is available for Linux, Mac OS and MS Windows using cygwin.

In comparison with other discrete-event network simulators, NS-3 is distin- guished by the high level design goals. Many simulators use a domain-specific modelling language to describe models and program flow. NS-3 uses C++ or Python, allowing users to take advantage of the full support of each language. Simulation events in NS-3 are simply function calls that are scheduled to exe- cute at a prescribed simulation time. Any function can be made into an event and scheduled, by use of a callback function. This is in contrast to specialized handler functions that centralize the processing of events in each simulation object. Call- backs are also heavily used in the simulator to reduce compile-time dependencies between simulation objects.

4.2 Implementation Details

The already existing AODV module is modified to support the desired features. For thie purpose the following files are modified or added.

- aodv-packet.h - to add position details in header files
- aodv-packet.cc - to modify RREQ and RREP packets to add Position Details of Nodes.
- aodv-rtable.h - to add new table details in header files
- aodv-rtable.cc - to add details in Position Table and to modify it as per requirement.
- aodv-routing-protocol.cc - to support reduced broadcast of RREQ packet

Simulation Parameters

- No. of Nodes - 10, 15, 20
- Mobility Model - Gauss Markov Mobility Model.
- Node Speed - 25 to 30 m
- Transmission Range - 250 m
- Protocols - AODV, OLSR and Modified AODV
- Area (m X m) - 250 to 750 m.
- Wifi Standard - 802.11n
- Bandwidth - 54Mbps
- Propogation Model - Friss Signal Propogation Loss Model

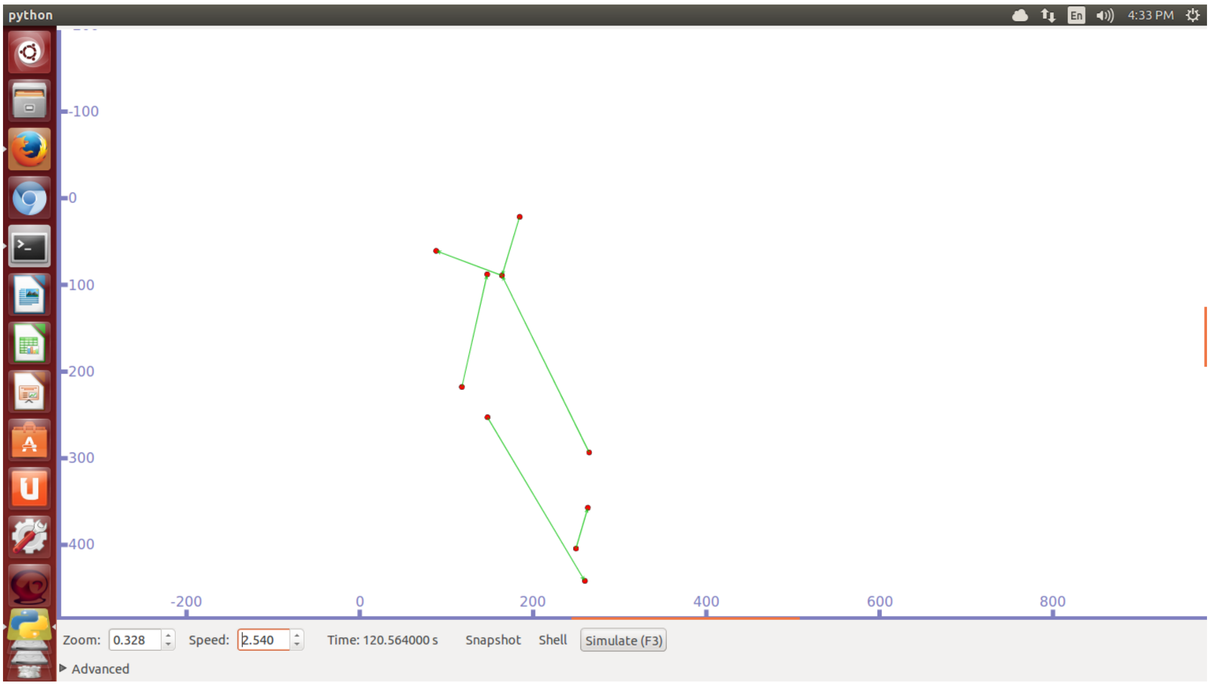

Figure 4.1: Simulation animation in Python Visualizer

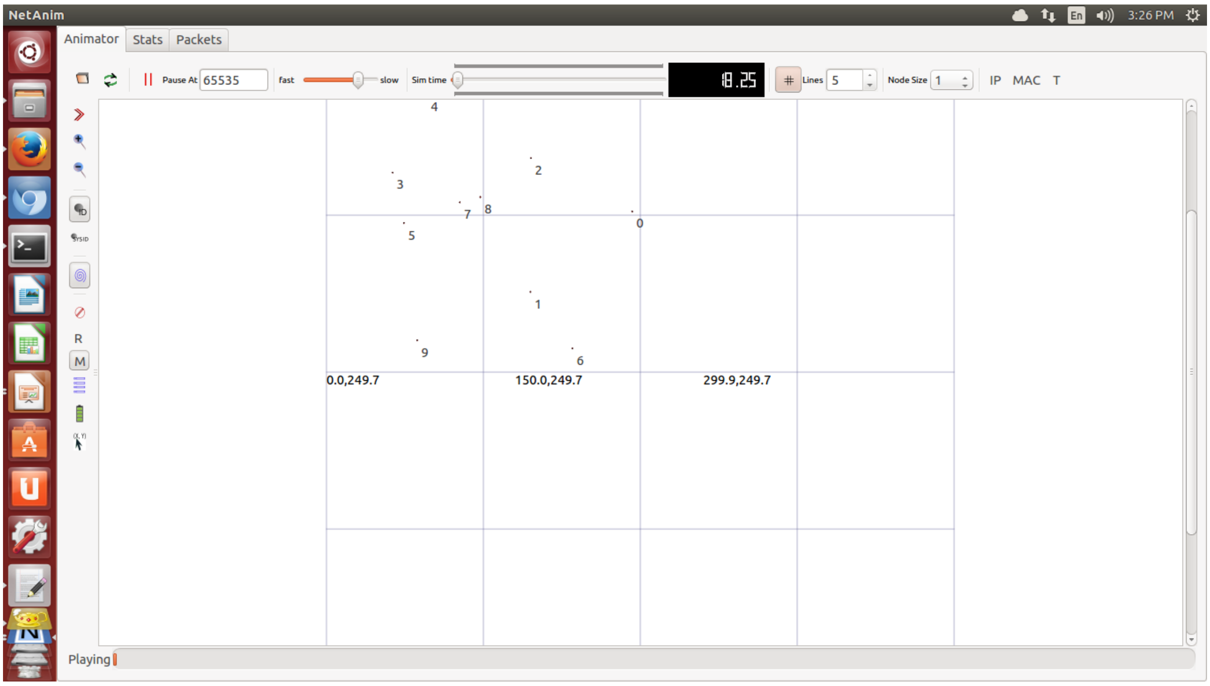

Figure 4.2: Simulation animation in NetAnim

The following performance metrices were used to compare various routing protocols.

- PDR - a ratio between the number of datagrams received by the destination and the number of datagrams transmitted by the source.

- Overhead - were measured as all control messages of each routing protocol in bytes divided by the simulation time

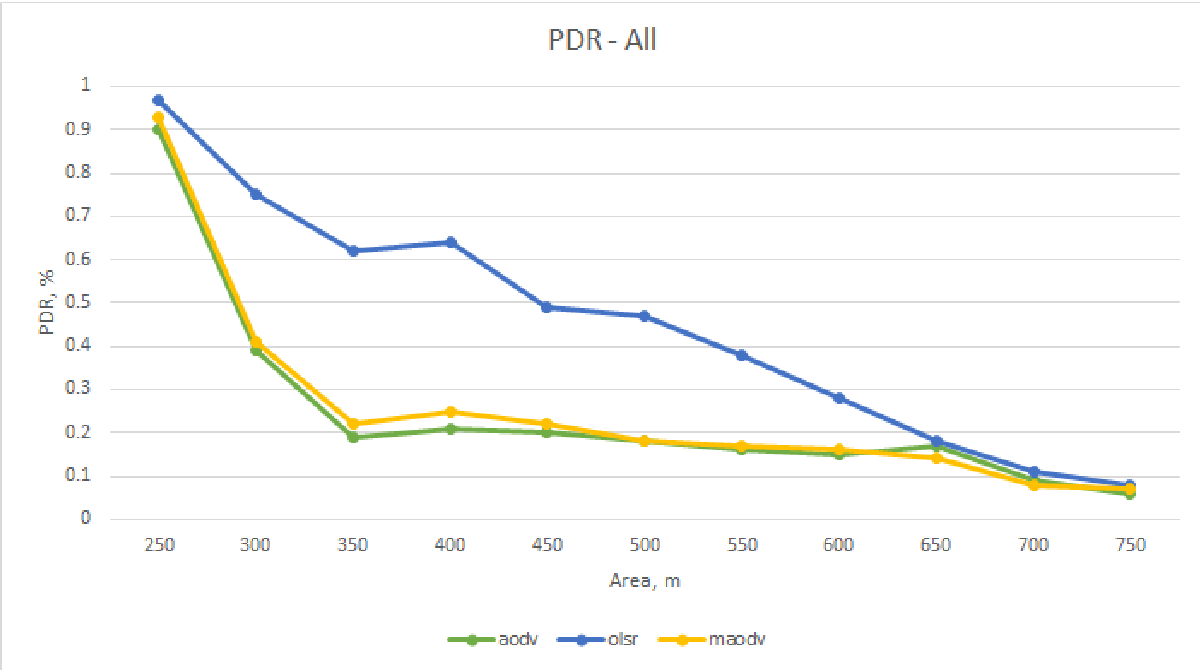

Figure 4.3: PDR for various protocols

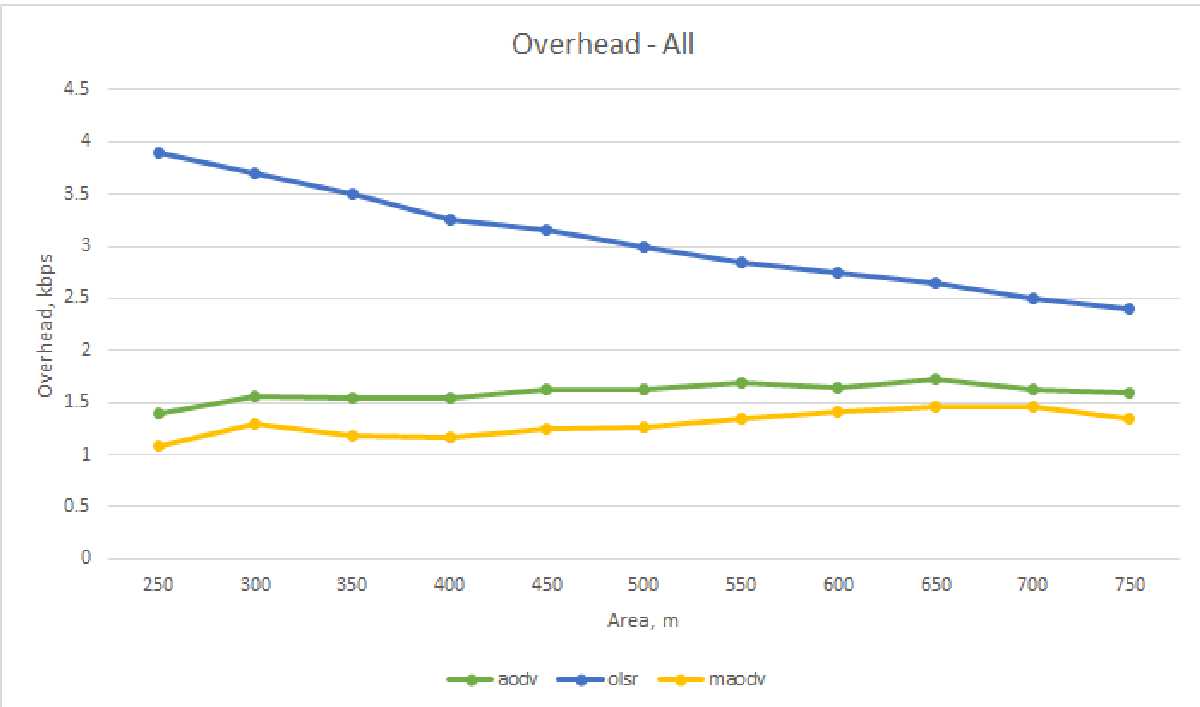

Figure 4.4: Control Overhead for various protocols

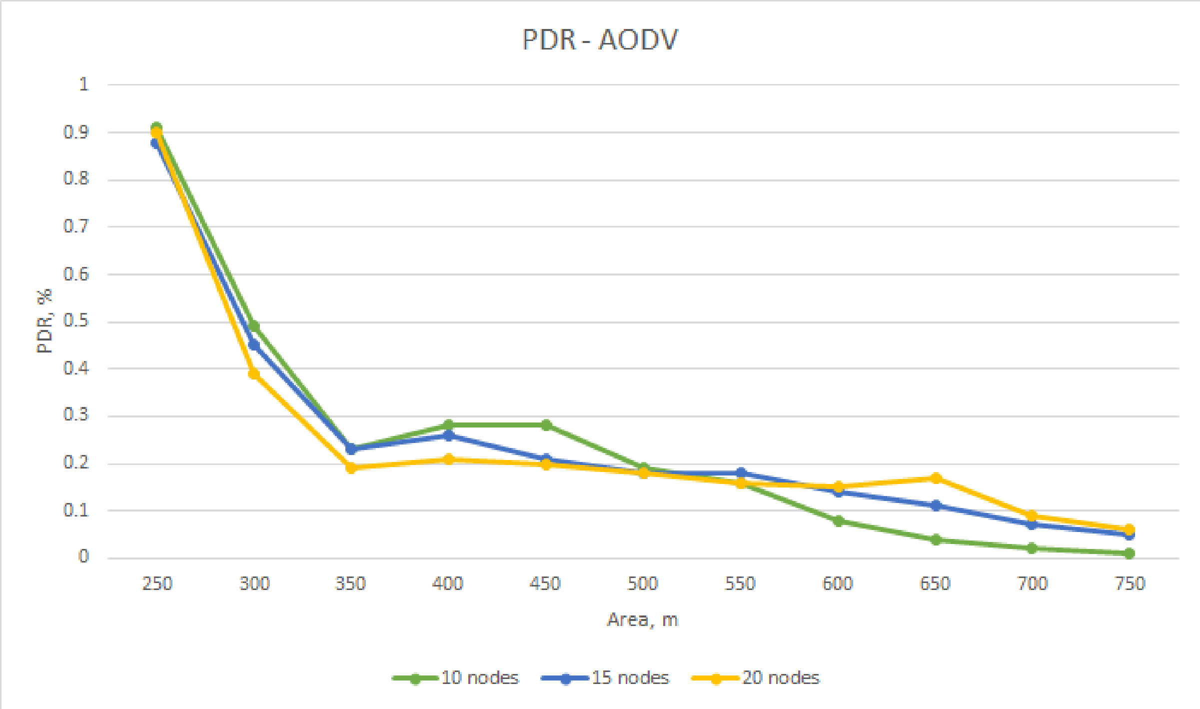

Figure 4.5: PDR for AODV

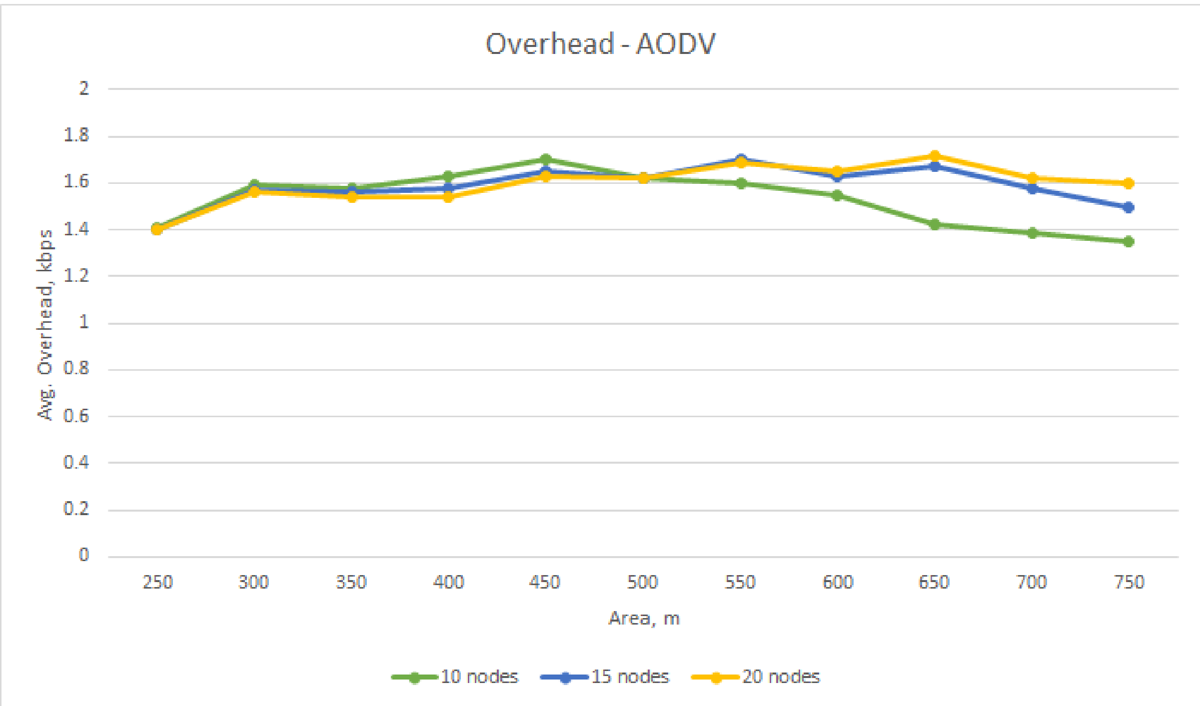

Figure 4.6: Control Overhead for AODV

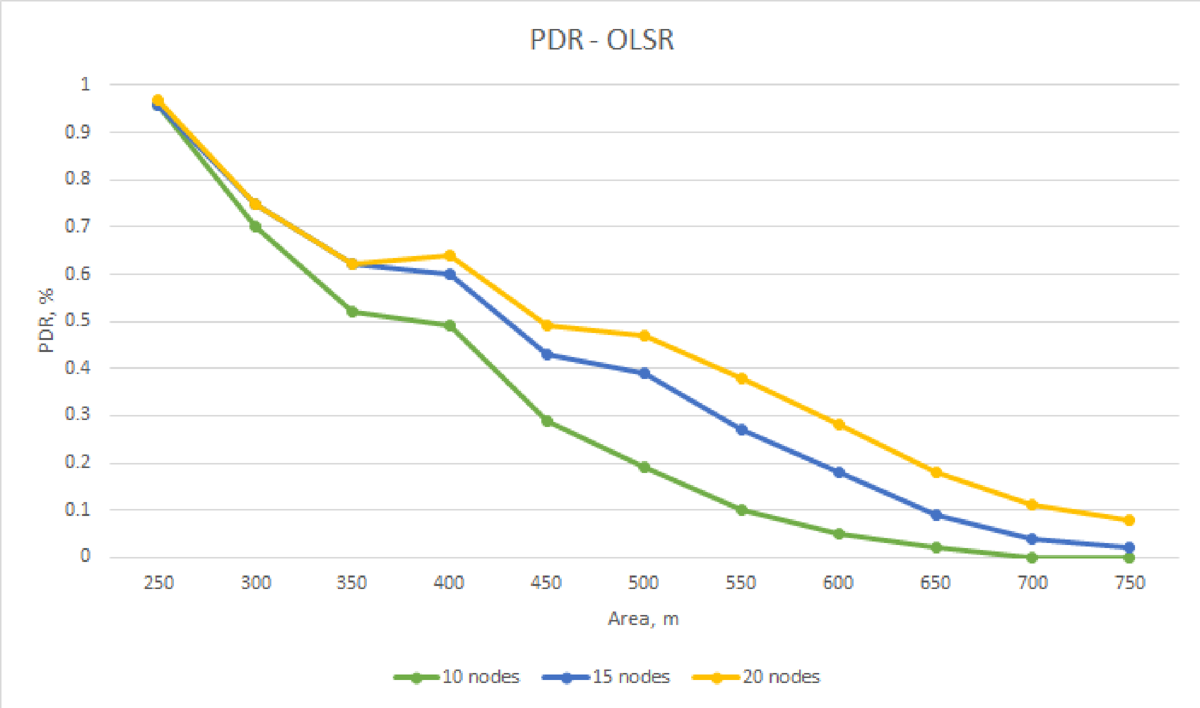

Figure 4.7: PDR for OLSR

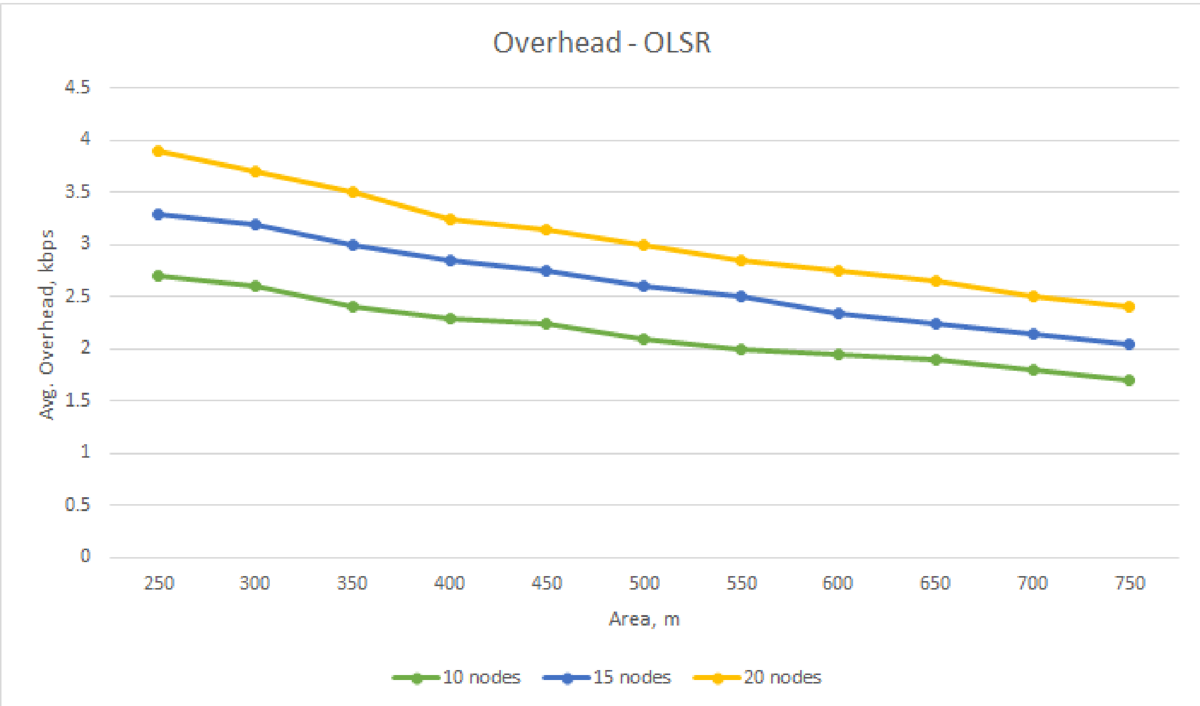

Figure 4.8: Control Overhead for OLSR

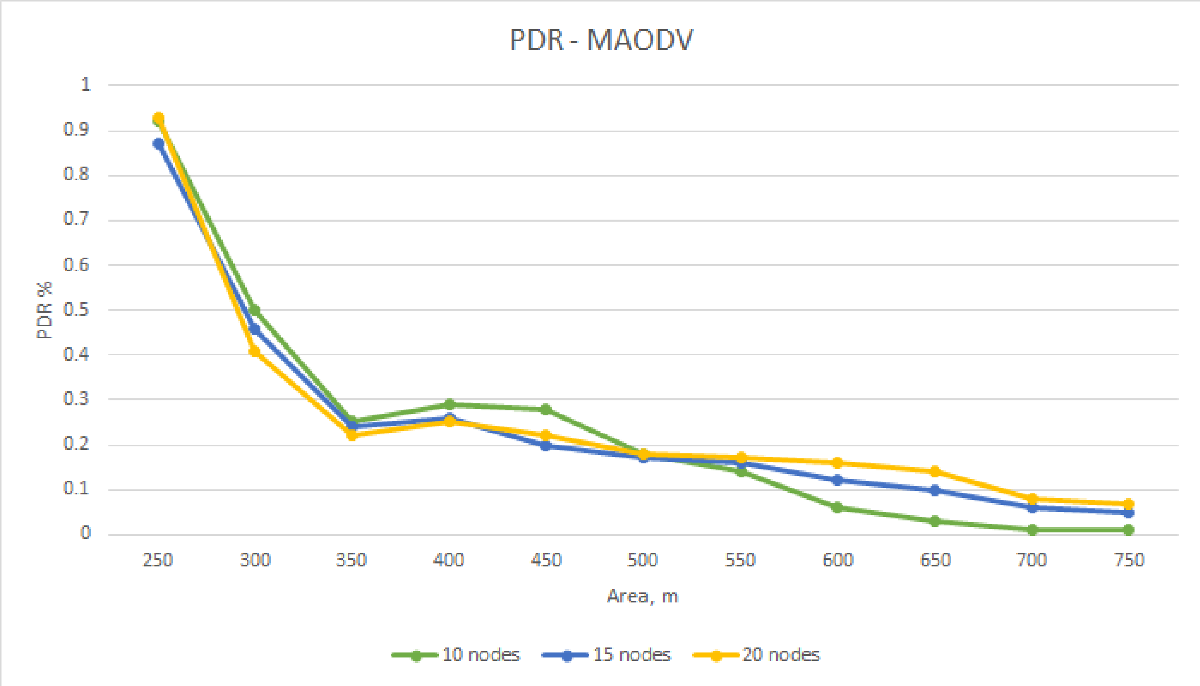

Figure 4.9: PDR for Modified AODV

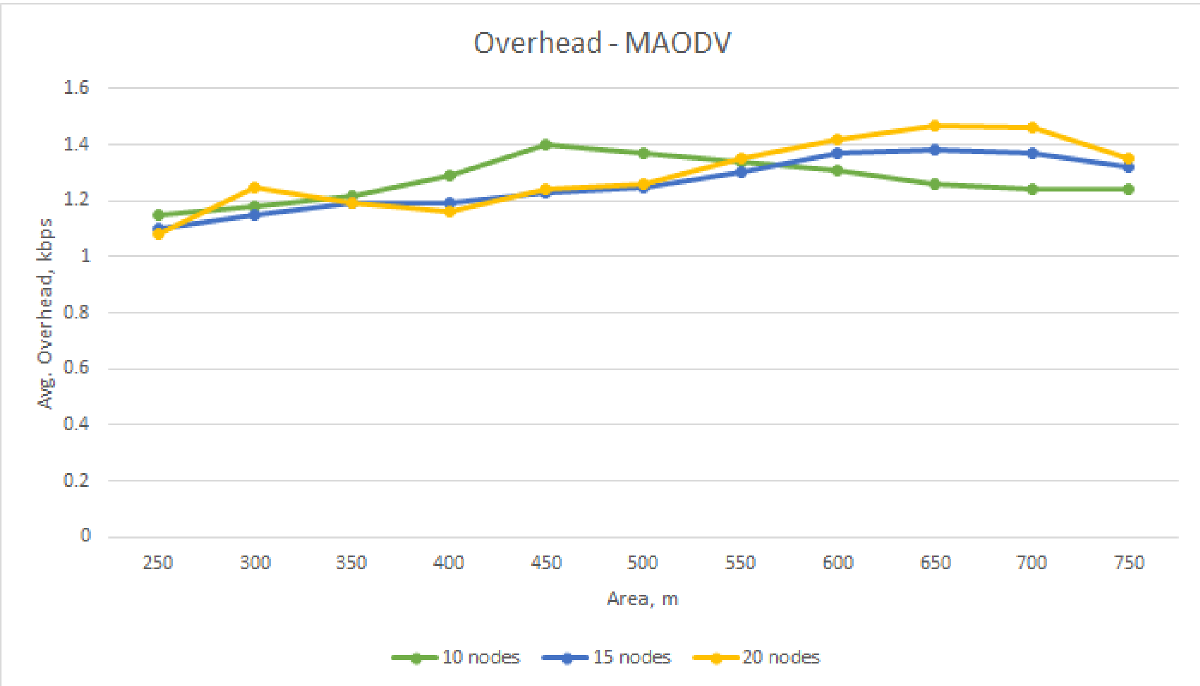

Figure 4.10: Control Overhead for Mofidied AODV

In Fig 4.3 and Fig 4.4, PDR and Overhead is compared for various routing protocols for 20 nodes.

In Fig 4.5 and Fig 4.6, PDR and Overhead is compared for AODV routing Protocol for different number of nodes.

In Fig 4.7 and Fig 4.8, PDR and Overhead is compared for OLSR routing Protocol for different number of nodes.

In Fig 4.9 and Fig 4.10, PDR and Overhead is compared for modified AODV routing Protocol for different number of nodes.

Chapter 5

Conclusion and Future Work

5.1 Conclucsion

- In this work, A slight modification is done for AODV and then it is compared with OLSR and AODV routing protocols using performance matrices like PDR and Overhead.
- Out of all the three protocols, PDR of OLSR was more as compared to others but it showed comparatively high overhead.
- The modification in AODV didn't affected much in terms of PDR, it was quite similar to that of AODV but it showed some reduction in overhead.

5.2 Scope for Future Work

- In this only Position of node was to considered to limit the scope of RREQ broadcast, velocity of node can also be used to further limit the broadcast area.
- Also Omnidirectionan Antenna was used for this work, results can further be improved by using direcitonal antenna as it reduces collisions.

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