Simulation based performance evaluation of MANET routing protocols in UAV.

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Abstract

Mini-drones, officially called unmanned aerial vehicles, are widely used in many military and civilian fields. Compared to traditional ad hoc networks, the mobile ad hoc net-works established by UAVs are more efficient in completing complex tasks in harsh environments existing protocols or algorithms cannot be directly used for UAVs. In this project a Mobile Ad hoc Network (MANET) there is no fixed infrastructure by which routing is performed. The mobile nodes work both as routers and hosts. The absence of fixed centralized infrastructure and unpredictably varying topology in MANETs make routing and the design of routing protocols complex and challenging issues are focused. The performance characteristics existing routing algorithm helps to find out and deploy appropriate protocol for a particular network scenario. There are no adequate and comprehensive researches on the effect of each control variable on the protocols. In this project the performance analysis and comparison of popular protocols (AODV, DSR, OLSR, GRP) have been conducted using OPNET Modeler. The effect of FTP traffic load, network size and mobility variations on each of the protocols considered were analyzed. Average delay and throughput were used as performance measurement metrics. Simulation results show that the throughput performance increases and the delay performance decreases when traffic load and network size increase in all the protocols.

The Keywords—Unmanned Aerial Vehicle(UAV), Mobile Ad hoc Network(MANET),File Transfer Protocol(FTP), Optimized Network Engineering Tools(OPNET).

1.Introduction

The recent advances and the convergence of micro electro-mechanical systems technology, microprocessor hardware and Nano technology, integrated circuit technologies, wireless communications, distributed signal processing, Ad-hoc networking routing protocols and embedded systems have made the concept of Wireless Networks popular. Ad-hoc networks are a new paradigm of wireless communication for mobile hosts. Fixed base station is no more a requirement of the wireless network as a base station in mobile switching network. Each user communicate directly via wireless links between them and transfer messages to next user spaced at far distance. Node mobility causes frequent changes in topology.

Mobile ad-hoc networks hold the promise of the future, with the ability to establish networks at anytime, anywhere. These networks do not rely on inessential hardware which makes them an ideal candidate for rescue and emergency operations. As these networks are devoid of any single traffic concentration point, each node in the network plays the role of a router on the run.

This technology is rapidly experiencing the real world implementation and one of the leading research are as although it has its challenges of device heterogeneity, mobility, random traffic profiles and power conservation. As it is shown in the Figure 1, different mobile (unfixed) nodes are connected through a wireless link.

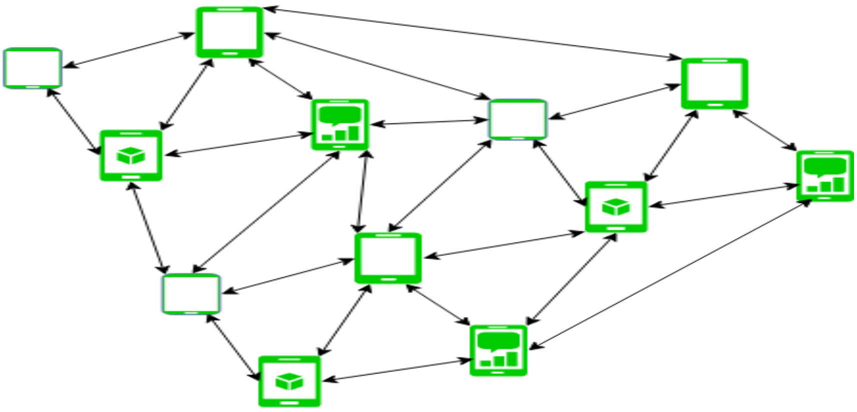

Figure 1.An example of MANET

Unmanned Aerial Vehicles (UAV) is equipped with radio communication devices and rely on unmanned autonomous flight control programs, which have been actively developed around the world. Given their low cost, flexible maneuvering capability and unmanned operation, UAVs have been widely used in both civilian operations and military missions, including aerial mapping, disaster rescue, agricultural irrigation, military surveillance and attack.

Routing protocols for such environments must, therefore, be able to keep up with the high degree of node mobility that often changes the network topology dynamically and unpredictably. Therefore, different types of mobile ad hoc network routing protocols with different performance characteristics and efficiencies have been developed. Studying the performance characteristics against their performance metrics and identifying their weaknesses and strengths is crucial in order to find out the suitable routing protocol to make an efficient routing for a particular network operation scenario and make further optimizations.

The performance analysis and comparison of the popular MANET routing protocols (AODV, DSR, OLSR and GRP) based on a broad range of control variables on which the protocols are mainly optimized such as varying FTP traffic loads, network size scaling and mobility in the literature, there is still a need to widen the spectrum on the performance analysis of the protocols. Thus, in this project the performances of AODV, DSR , OLSR and GRP have been investigated in simulated networks to compare the impact of their technology designs on end-to-end behaviors such as end-to-end delay and throughput under different network scenarios using an OPNET modeler which is appropriate for network modeling and R&D operations and performance analysis of routing protocols.

The objective is to study, analyze and compare the performances of AODV, DSR, OLSR and GRP MANET routing protocols for Unmanned Aerial Vehicles (UAVs) using OPNET Modeler with FTP traffic under different network situations. To analyze the impacts of FTP traffic load, network size and mobility speed variations on the performances of the protocols in terms of delay and throughput.

In this Paper section I, the general introduction of the topic and the objectives section II presents the literature review. section III presents the methodology used in this Paper. The performance parameters and simulation environments are briefly discussed. In section IV, the results and analysis of the Project output are presented. Section v presents the conclusions drawn from the overall Project and a direction for future Work.

2.Related works

Abdel Ilah Alshabtat et.al [1] authors proposed a new routing protocol for Unmanned Aerial Vehicles (UAVs) that equipped with directional antenna. We named this protocol Directional Optimized Link State Routing Protocol (DOLSR). This protocol is based on the well known protocol that is called Optimized Link

State Routing Protocol (OLSR). We focused in our protocol on the multipoint relay (MPR) concept which is the most important feature of this protocol. We developed a heuristic that allows DOLSR protocol to minimize the number of the multipoint relays. With this new protocol the number of overhead packets will be reduced and the End-to-End delay of the network will also be minimized. We showed through simulation that our protocol outperformed Optimized Link State Routing Protocol, Dynamic Source Routing (DSR) protocol and Ad-Hoc On demand Distance Vector (AODV) routing protocol in reducing the End-to-End delay and enhancing the overall throughput. Our evaluation of the previous protocols was based on the OPNET network simulation tool.

Chen-Mou Cheng et.al [2] authors consider the task of using one or more Unmanned Aerial Vehicles (UAVs) to relay messages between two distant ground nodes. For delay-tolerant applications like latency-insensitive bulk data transfer, we seek to maximize throughput by having a UAV load from a source ground node, carry the data while flying to the destination, and finally deliver the data to a destination ground node. We term this the "load-carry-and-deliver" (LCAD) paradigm and compare it against the conventional multi-hop, store-and-forward paradigm. We identify and analyze several of the most important factors in constructing a throughput-maximizing framework subject to constraints on both application allowable delay and UAV maneuverability. We report performance measurement results for IEEE 802.11g devices in three flight tests, based on which we derive a statistical model for predicting throughput performance for LCAD.

Vineet R.Khare, et.al [3] authors explains the Ad-hoc network of unmanned aerial vehicles (UAVs) is modeled as a swarm of birds. Flock formation observed among birds in nature inspires the control of these UAVs, which perform a search and destroy task involving multiple, moving targets. The proposed control model is decentralized, adaptive and self-organizing to deal with the dynamic and distributed nature of the problem and relies only on local sensing and minimal communications to account for potential limitations in terms of global communications and lack of global information related to the task. The proposed model is tested for its self-organization capabilities in various simulation environments involving various number of UAVs and targets. These simulation show that the nature inspired control model is effective, robust and scalable in the context of the search and destroy tasks. Further simulations show that, because of the physical proximity of the UAVs within a swarm, a very good and robust routing performance can be achieved for these local, intra-swarm communications.

Jean-Daniel Medjo Me Biomo, et.al [4] designing Routing protocols for the Unmanned Aeronautical Ad Hoc Networks (UAANETs) are a type of Mobile Ad Hoc Networks (MANETs) which are infrastructure less and self -organizing networks. The specificity of UAANETs is that they are formed by small and medium sized Unmanned Aerial Vehicles (UAVs) also known as drones. In UAANETs as well as in MANETs, geographic routing is widely used. Geographic routing relies on Greedy Forwarding (GF), also called Greedy Geographic Forwarding (GGF). GGF fails when a packet arrives at a node that has no neighbor closer to the destination than it is. The node in this situation is referred to as a void node. Simulations in OPNET show an increase in packet delivery ratio of about 2% at virtually no additional cost. Designing routing protocols for Unmanned Aeronautical Ad Hoc Networks (UAANETs) is very challenging due to the high mobility and the transmission range limitations of the UAVs. Broadly speaking in Mobile Ad Hoc Networks (MANETs) topology-based protocols, we further distinguish proactive (e.g. OLSR, etc.), reactive (e.g. AODV, DSR, etc.) and hybrid (e.g. GRP) protocols. In the group of position-based protocols, we have protocols that do not rely on link states. Instead, only the nodes' physical location information is essential. Those protocols are also called geographic protocols, and the main one is Greedy Geographic Forwarding (GGF). The idea is to forward the data packet to the neighbor whose location is closer to the destination than that of the forwarding node. If there is no such neighbor, GGF is said to have failed and the packet is dropped.

3. Methodology

The Project was basically conducted based on two approaches in a bid to meet the objectives. In the first approach, the working principles of the selected routing protocols, which are the foundations for further analysis, were thoroughly studied through literature review. In the second approach network simulation software called Optimized Network Engineering Tool (OPNET) Modeler was used to make a detailed performance analysis and comparisons of the MANET routing protocols in different scenarios by varying the traffic loads, network sizes and mobility speeds. It is usually difficult to model and formalize routing algorithms in mathematical models. They are, therefore, studied, analyzed, evaluated and tested through simulations using simulation platforms.

There are various performance evaluation metrics of routing protocols which represent different behaviors of the overall performance of the protocols such as packet delivery ratio, routing overhead, delay and throughput. In this project, the performance evaluations and comparisons of the protocols were done with respect of delay and throughput which greatly determine the performance characteristics of the MANET routing protocols.

The complete modeling procedure in OPNET basically has four sections-design of network model, selection of individual statistics, collection of simulation results and analysis of the results obtained, as it can be seen in Figure 2.

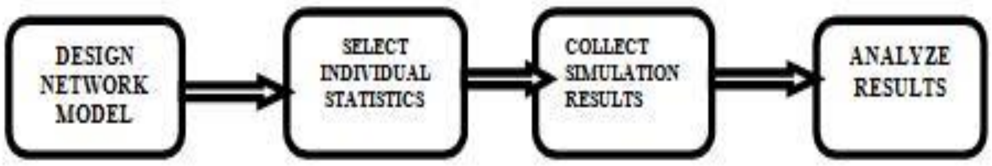

Figure 2 Complete overview of designing a project in OPNET Modeler

The simulation set up was carried out on OPNET 17.5 Modeler where multiple scenarios of MANETs were designed, simulated and analyzed. The simulations were conducted on different scenarios by varying different key design and simulation parameters where each scenario was particularly designed to study and analyze the impact of a specific network operation condition on the end-to-end performance behavior of MANET routing protocols. Control variables on which the MANET routing protocols are normally optimized such as Traffic load, network size and Mobility speed were considered. The simulation setups for the multiple scenarios, therefore, were categorized as follows:

3.1.Impact of Application Traffic load variation: The application traffic generator used was File Transfer Protocol (FTP) whose traffic load was varied in order to see and analyze the effect of traffic load scaling on the end-to-end performance behaviors of the routing protocols. Therefore three different FTP traffic loads were used. They are FTP light load with data size of 1000 bytes, FTP medium load with data size of 5,000 bytes and FTP heavy load with data size of 50,000 bytes.

3.2.Impact of Network size variation: In this case the network size was varied by varying the number of mobile nodes deployed in the simulation area of 1500mx1500m in order to assess its impact on the overall performance of the protocols in terms of delay and throughput. Three different sets of networks with network size of 5, 20 and 30 mobile nodes were modeled and deployed in the simulation area. The choice of the network sizes was random. Other network size can also be chosen. But the same values were used in all the scenarios for consistency.

3.3.Impact of Mobility speed variation: In this simulation scenario the effect of mobility on the performance of the MANET protocols in terms of delay and throughput was studied and analyzed by varying the mobility speed of the nodes within the simulation area 1500mx1500m. Two different mobility speeds (10 m/s and 20 m/s) were used to investigate the performance effects of mobility speed on the MANET routing protocols. The summary of the main simulation parameters used in this project are given in the table 1.

Environment Area (mxm)	1500x1500
Mobility Model	Random waypoint
Routing Protocol	AODV, DSR, OLSR,GRP
Data rate	11 Mbps
Traffic source	FTP [Low load, Medium load, High load]
Number of nodes (m/s)	5, 20, 30
Mobility speed	10, 20
Simulation time (seconds)	1800
MAC protocol	802.11b
Transmission power (W)	0.005
Node placement	Random
Pause time	150
Stations	Wlan_wkstn
Server	Wlan_server
Transceiver Antenna	Omnidirectional

Table 1. MANET Model Design and Simulation parameters

FTP traffic load variation on the performances characteristics of the protocols are analyzed in terms of average end-to-end delay and throughput. The impact of network size and mobility speed variations on the delay and throughput performances of the protocols are then analyzed. Finally, the comparison analyses of the performances of the protocols in all the scenarios are made in terms of the delay and throughput. The results for all protocols and scenarios were collected through global statistics.

4. Impact on the delay performances

In the Figures 3, 4, 5, and 6 the effect of the FTP traffic load levels on the delay of each protocol are indicated. The graphs show how each protocol behaves when the application traffic generator (FTP) traffic load varies from Low to Medium load and then to High load. A MANET model consisting of 30 nodes each moving at a speed of 10 m/s was designed and used.

4.1.DSR

As it is indicated in the graphs in Figure 3 average delay of DSR increases as the FTP traffic load level is increased. That is the FTP high load has the highest delay followed by FTP medium load and FTP low load. It is observed that DSR has a higher delay from 6 minutes up to 12 minutes of the simulation and starts to decrease as the simulation time progresses in all the FTP traffic load levels.

Note that in all the graphs, the horizontal line is the simulation time in minutes on which the statistics of the end-to-end performance behavior was collected.

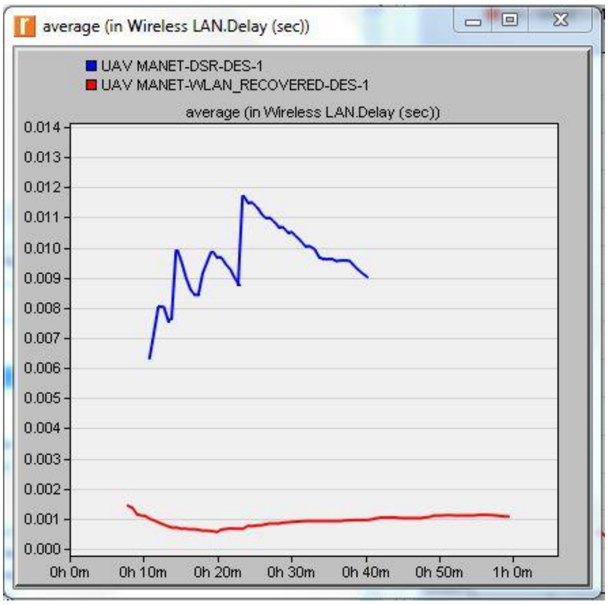

Figure 3. Average Delay of DSR

4.1.1.AODV

The performance of AODV in terms of delay was observed to be better when the FTP traffic load level is low. The delay is also observed to be highest in the FTP high traffic load. Delay in general increases from the beginning of the simulation for small portion of the simulation above which it starts to slightly decrease. This is mainly associated with the initial route discovery delay and inconsistent routes caused by stale entries when the intermediate nodes have a higher but not the latest destination sequence number and very old source sequence number. The average delay variation as the FTP traffic load varies is indicated in the graphs in Figure 4.

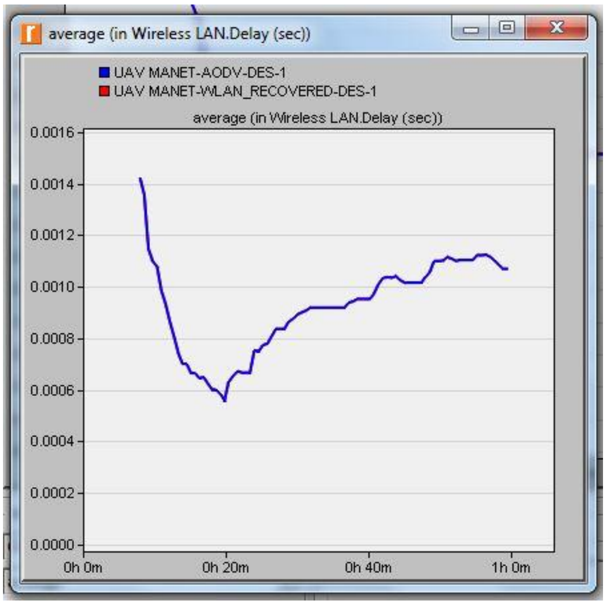

Figure 4 .Average Delay of AODV

4.1.2.OLSR

The delay of OLSR, shown in the graphs in Figure 6, is higher when the FTP traffic load level is high. But the delays in the medium and low FTP traffic load levels are overlapped. That is, OLSR performs equally well when the FTP traffic load is medium and low. It was also observed that unlike AODV and DSR, there is no increment on the delay at the beginning of the simulation in OLSR. This is because of the proactive nature of OLSR. As OLSR is a proactive (table-driven) routing protocol, there are predefined routes to all the destinations. Therefore network nodes can use the available routes to send their messages or packets to the destination without any route discovery process. This helps OLSR to avoid the delay associated with the route discovery. But the delay slightly increases as the traffic load increment and periodic updates of routes increase the overhead and congestion.

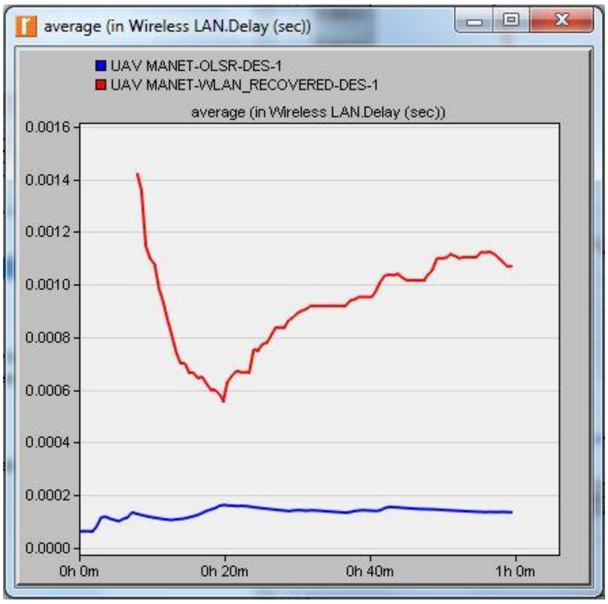

Figure 5. Average Delay of OLSR

4.1.3.GRP

The performance of GRP in terms of delay was observed to be better when the FTP traffic load level is low. The delay is also observed to be highest in the FTP high traffic load. Delay in general increases from the beginning of the simulation for small portion of the simulation above which it starts to slightly decrease.

This is mainly associated with the initial route discovery delay and inconsistent routes caused by stale entries when the intermediate nodes have a higher but not the latest destination sequence number and very old source sequence number. The average delay variation as the FTP traffic load varies is indicated in the graphs in Figure 6.

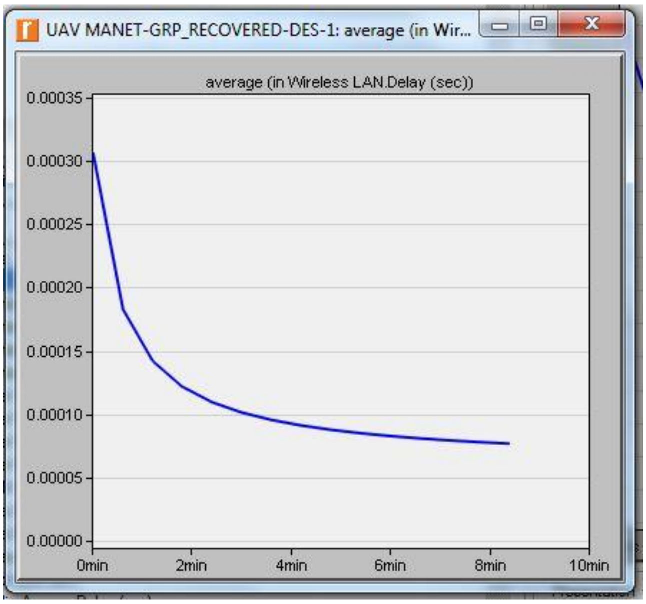

Figure 6 Average Delay of GRP

4.2. Impact on the throughput performances

In this subsection the effect of FTP traffic load variation on the throughput performance of the three protocols (DSR, AODV, OLSR and GRP) are discussed. The graphs in Figures 7,8,9 and 10 show how the FTP traffic load variations affect the throughput performance of each protocol.

4.2.1.DSR

The throughput performance of DSR increases as the FTP traffic load level increases according to the traffic load levels considered in this study. As shown in the graphs in Figure 7, the highest throughput performance is observed in the FTP high traffic load followed by the medium and low FTP traffic load levels.

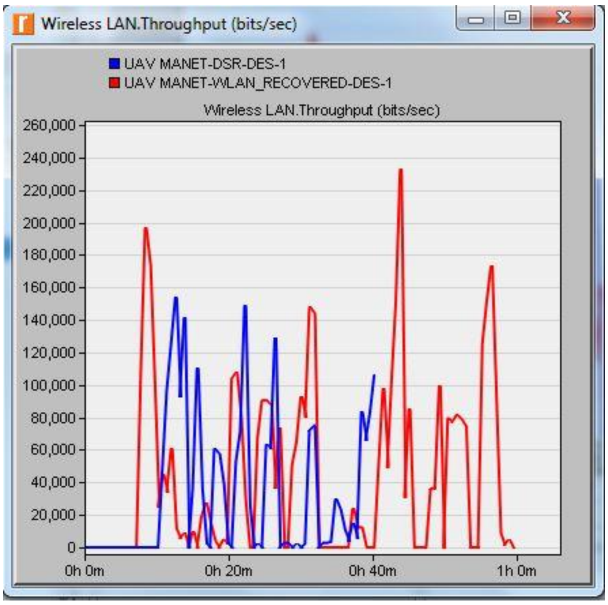

Figure 7.Throughput of DSR

4.2.2.OLSR

The throughput performance of OLSR like in AODV and DSR is better when the FTP traffic load is high. There is no significant throughput performance difference between the medium and low traffic load levels. The overall throughput performance of OLSR is the second best of the three protocols. Details of performances comparisons are discussed in the next sections in this chapter. Figure 8 shows how the throughput performance of OLSR behaves when the FTP traffic load varies.

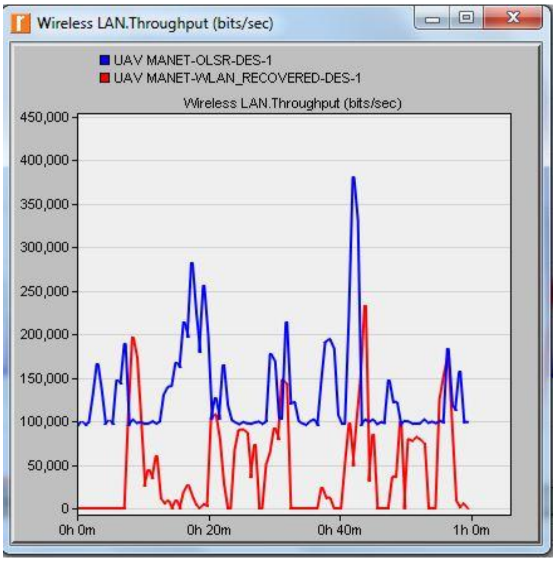

Figure 8.Throughput of OLSR

4.2.3.AODV

The throughput performance of AODV increases as the FTP traffic load level increases according to the traffic load levels considered in this study. As shown in the graphs in Figure 9, the highest throughput performance is observed in the FTP high traffic load followed by the medium and low FTP traffic load levels.

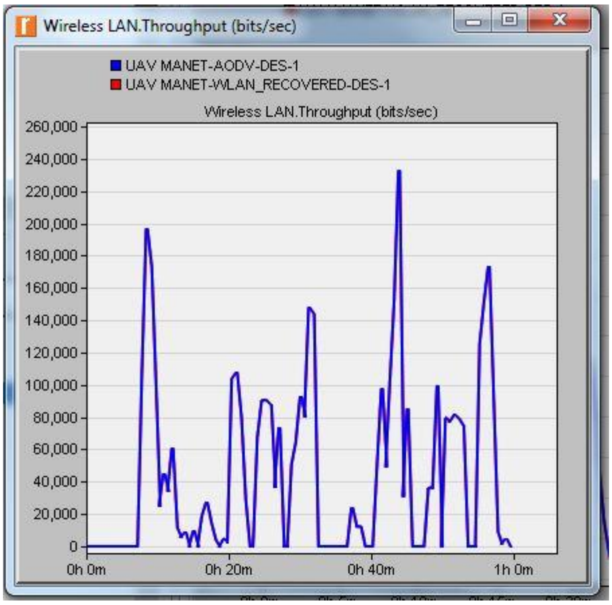

Figure 9. Throughput of AODV

4.2.4.GRP

The throughput performance of DSR like in AODV and DSR is better when the FTP traffic load is high. There is no significant throughput performance difference between the medium and low traffic load levels. The overall throughput performance of OLSR is the second best of the three protocols. Details of performances comparisons are discussed in the next sections in this chapter. Figure 10 shows how the throughput performance of GRP behaves when the FTP traffic load varies.

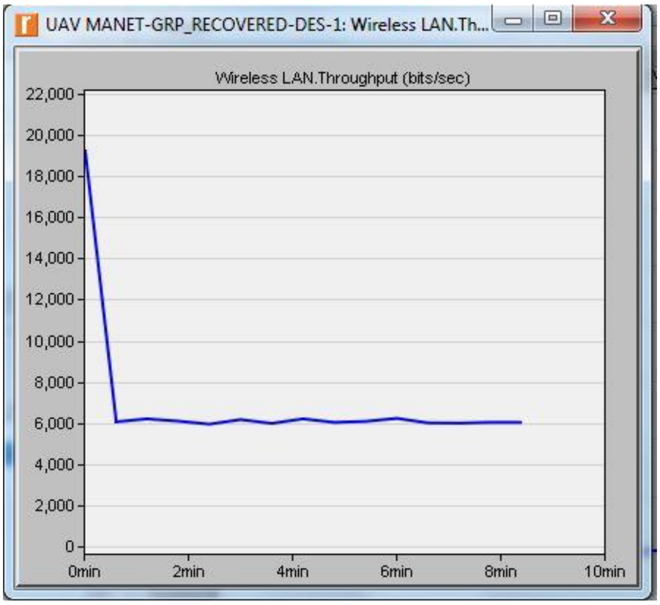

Figure 10 Throughput of GRP

4.3.Performance Comparisons of Delay And Throughput

Figure 11 performance comparisons of Delay and Throughput for the Four protocols under different FTP application traffic generator traffic load levels. It was observed that DSR has the highest delay in all the traffic loads and hence poor performance. AODV has the second highest delay in all the FTP traffic loads except in the medium FTP traffic load whereas OLSR has the least delay and hence best performance.

AODV and OLSR have equal latency when the FTP traffic load is medium. AODV and DSR are reactive routing protocols whereas OLSR is a proactive routing protocol.GRP least delay at 10 minutes and Average Performance.

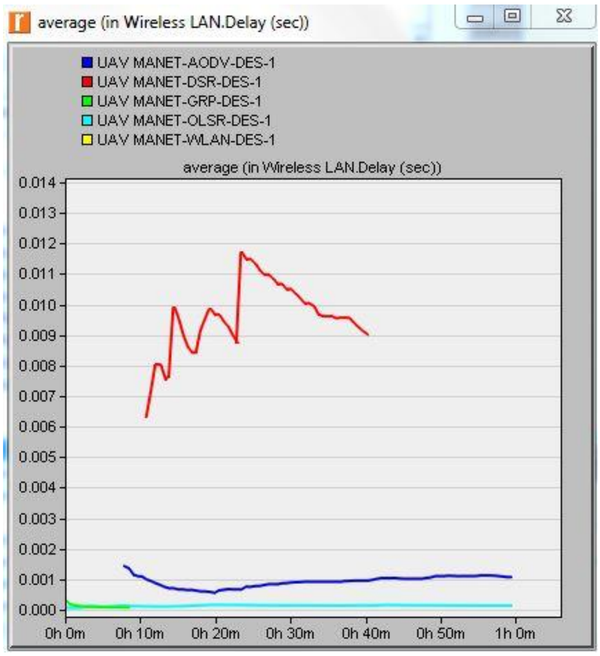

Figure 11.Comparison of Average Delay

In figure 12, X-axis denotes time in minutes and Y-axis is denotes data rate which is in Packets/sec. It shows that the average peak value of retransmission is almost 0.04199 packets for AODV, 0.03657 packets for DSR, 0.04199 packets for GRP and 0.03450 packets for OLSR. After 15 minutes, it gradually drops as time progress and reaches to almost 0.01851 packets for AODV, 0.02469 packets for DSR, 0.01851 packets for GRP and 0 packets for OLSR.

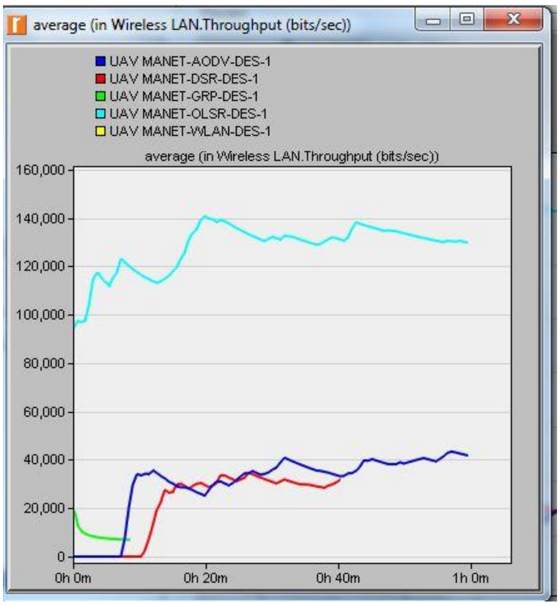

Figure 12. Comparisons of Throughput

5.Conclusion and future work

In this Paper the Simulation based Performance Evaluation of popular MANET routing protocols in UAV have been carried out with respect to the performance metrics of throughput and average delay. The performance evaluations and comparisons were analyzed in different network scenarios by varying the control variables along which MANET routing protocols are mainly optimized. The impact of each control variable on the performance behaviors of each protocol has been analyzed. Two well-known reactive routing protocols (AODV and DSR), one well-known proactive protocol (OLSR) and one well-known hybrid protocol (GRP) have been analyzed and compared through simulations using a simulation tool called OPNET Modeler 17.5.

In this paper, the weaknesses and strengths of popular reactive, proactive and hybrid protocols have been identified in different scenarios. Their performances in terms of delay and throughput in different network scenarios have been articulated. Future work is suggested in the optimization and enhancement of the performance of the protocols for reliable and efficient routing with a minimum possible delay using soft computing techniques such as artificial intelligence, neural networks and genetic algorithms.

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