Performance Analysis of MANET Routing Protocols for UAV Communications

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Abstract — **Unmanned Aerial Vehicles (UAVs or commonly known as drones) have the potential benefits in improving communications in wireless network environment. Besides their utilization in military operations, the potential use and applicability of UAVs in civilian applications is becoming a fast growing phenomenon. Routing is one of the vital aspects while conducting wireless communication among UAVs. It is extremely challenging because of dynamic topology changes resulted from frequent mobility of UAVs. In this paper, we analyse the performance of different Mobile Ad-hoc Network (MANET) routing protocols for the communication of UAVs. Using Riverbed (OPNET) Modeler, we evaluate the performance of four MANET routing protocols (AODV, DSR, GRP and OLSR) for UAV communications based on scenarios of various data rates supported by IEEE 802.11p (WAVE) standard.**

Keywords — **Routing protocol; Unmanned Aerial Vehicle; UAV; Drone; Mobile Ad-hoc Network; MANET; Flying Ad-hoc Network; FANET**

I. Introduction

Unmanned Aerial Vehicles (UAVs or commonly knowns as drones) have the potential benefits in wireless communication while delivering data from the air to one or more ground stations as well as directly among the drones themselves. In the past decades, the UAVs have been utilized only for military operations. Recently, the potential uses and applicability of UAVs in civilian application domains such as package delivery, healthcare delivery [1], air pollution monitoring [2], disaster management [3-6], surveillance [7], crop and soil condition inspection [8], search and rescue missions [9, 10], forest fire monitoring and detection [11-13], traffic monitoring [14, 15], tourism (guiding tourists in video recording from different view and photograph taking), is becoming a fast growing phenomenon. In addition to this, during emergencies, UAVs in Flying Ad hoc Networks (FANETs) [16], for instance, can be utilized in improving the wireless ad hoc communication network. Such missions can be accomplished by a groups of UAVs that are armoured with various kind of cameras, sensors, data storage, GPS units and other embedded devices like wireless communication transceivers, flight controller and on-board processing units.

Routing is one of the vital aspects while conducting wireless communication among UAVs. It is extremely challenging due to the dynamic topology changes resulted from frequent mobility of UAVs. In this paper, we present the performance analysis of four MANET routing protocols (Ad-hoc On-Demand Distance Vector (AODV), Dynamic Source Routing (DSR), Geographic Routing Protocols (GRP) and Optimized Link State Routing (OLSR)) for UAV communications based on scenarios with various data rates. Performance evaluation of these protocols is made using the Riverbed (OPNET) Modeler 18.6 [17].

The remainder of this paper is organized as follows. Section II presents performance evaluation of the routing protocols. Conclusion is made in Section III.

II. Performance Analysis

In our simulation environment, we employed Riverbed (OPNET) Modeler 18.6 [17] with 1 Ground Control Station (GCS) node and 50 mobile nodes randomly deployed in an 8000m X 8000m deployment region (see Fig. 1). We configured the wireless LAN (WLAN) parameters as per the specification of the IEEE 802.11p standard for wireless access in vehicular environment (WAVE). After setting the values of simulation parameters as per indicated in Table I, we divide the simulation into scenarios with data rates of 4.5, 9, 18 and 27 Mbps. Then, for each scenario and a routing protocol, we run the simulation for 3600 seconds using http application traffic.

We evaluate the performance of AODV, DSR, GRP and OLSR routing protocols for the UAV communications in relation to the effect of changing data rate. The assessment is made based on the following performance metrics.

(i) Routing traffic sent/ received: the amount of routing traffic sent and received (in bits/sec) in the whole network.

(ii) Delay: the end-to-end delay (in second) of all the packets that are received by the WLAN MAC layer of all the deployed nodes in the network and then forwarded to the higher layer.

(iii) Load: the total load (in bits/sec) submitted to all WLAN layers by all higher layers in all deployed nodes of the network.

(iv) Throughput: the total number of bits (bits/sec) forwarded from WLAN layers of all the deployed nodes in the network to the higher layers.

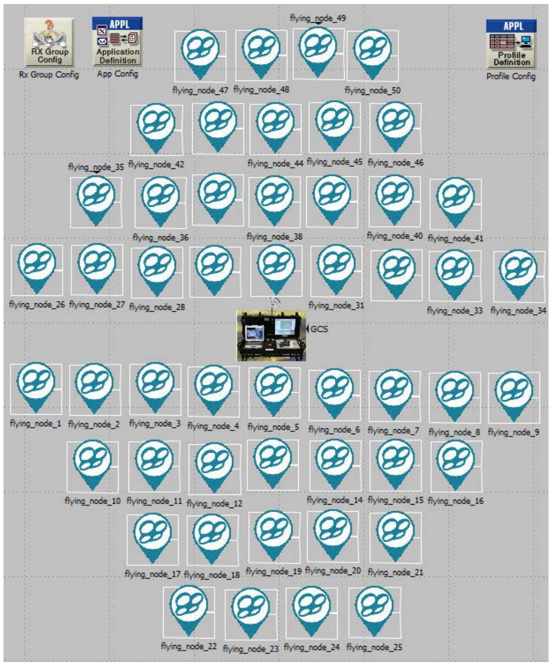

Fig. 1. Snapshot of deployed mobile nodes and a GCS

TABLE I. SIMULATION PARAMETERS AND VALUE

Parameter	Value
Deployment region size	8000m X 8000m
Number of mobile nodes	50
GCS node	1
Routing protocols	AODV, DSR, GRP, OLSR
MAC/PHY layer	IEEE 802.11p (WAVE)
Nodes mobility	Trajectory-based
Transmit power	1.995W (33dBm)
Packet reception-power threshold	-95dBm (3.1623e-13W)
Transmission range	1000 meter
Channel frequency and type	5GHz SCH 172
Channel bandwidth	10MHz
Traffic type	http traffic
Data rate	4.5, 9, 18 and 27Mbps
Speed	20m/s
Packet inter-arrival time	1 second
Packet size	1024bits (128bytes)
Simulation time	3600 seconds

For each metrics, the performance of each routing protocol is evaluated while changing the data rate (the speed of travel of a given data) from 4.5 to 9, 18 and 27Mbps. Detail statistical information regarding the performance result of each routing protocol with respect to different data rates is presented in Table II.

As seen from Table II, for 50 mobile nodes and a GCS node, in all data rate scenarios, the routing traffic sent and received by OLSR is the highest as compared to AODV, DSR and GRP (an instance graph of the experimental result for the routing traffic sent is shown in Fig. 2). This implies that for large number of mobile nodes the OLSR incurs highest control message overhead while maintaining the routing table periodically for every possible paths within the network. The OLSR has also exhibited the highest load followed by GRP and AODV. At the expense of such overheads, however, in all data rate scenarios, the OLSR has shown the least delay and the highest throughput performance as compared to other protocols. In this case, in all data rate scenarios, the OLSR could be a potential routing protocol candidate for delay sensitive application. An increase in data rate has resulted in a decrease in delay values of all the protocols.

TABLE II. PERFORMANCE RESULT

		Routing Protocols			
		AODV	DSR	GRP	OLSR
Metrics	Rate(Mbps)	sample mean	sample mean	sample mean	sample mean
Routing traffic sent (bits/sec)	4.5	9,227.86	1,232.23	8,334.94	81,197.37
	9	7,834.58	806.53	8,605.97	81,541.60
	18	7,509.85	732.13	8,855.49	81,769.50
	27	7,518.35	680.71	8,970.96	81,762.41
Routing Traffic received (bits/sec)	4.5	27,147.16	1,310.84	20,965.17	295,669.24
	9	23,242.35	889.44	22,095.99	298,219.52
	18	22,688.89	818.34	23,380.06	299,605.99
	27	22,594.56	768.36	23,863.66	299,780.76
Delay (sec)	4.5	0.00104	0.00692	0.00176	0.00031
	9	0.00072	0.00528	0.00092	0.00019
	18	0.00051	0.00335	0.00080	0.00012
	27	0.00042	0.00266	0.00067	0.00010
Load (bits/sec)	4.5	104,673.07	113,143.63	109,600.29	234,820.66
	9	97,671.84	94,179.33	101,957.28	235,267.55
	18	97,866.09	99,089.16	100,745.46	234,949.74
	27	97,772.63	98,139.06	106,943.86	234,849.68
Throughput (bits/sec)	4.5	121,775.61	112,350.62	121,616.15	623,285.60
	9	112,691.89	93,836.88	115,320.85	628,237.56
	18	112,866.55	98,905.78	115,303.68	630,257.27
	27	112,767.13	98,120.99	121,856.41	630,532.47

In all data rate scenarios, the DSR has shown the least routing traffic overhead as compared to other protocols (see Table II). When the data rate has increased from 4.5 to 9, 18 and 27Mbps, the routing control message overhead of DSR has decreased. The decrease in overhead could be resulted from the unique behaviour of DSR such as absence of periodic control message broadcast and absence of keeping a routing table by the network nodes. However, in all the scenarios, the throughput performance of DSR is the lowest and delay is the highest. The delay in DSR is due to the fact that to get routing information, every node in the network spends a lot of time while processing control messages received from the network nodes. This, in turn, results in higher routing path establishment delay of DSR as compared to other protocols.

As depicted from Table II, in all data rate scenarios, GRP has experienced higher load than the two reactive routing protocols – AODV and DSR. For data rates of 9, 18 and 27Mbps scenarios, GRP has shown better throughput performance than AODV and DSR. However, the routing control message overhead incurred by GRP is higher than DSR and AODV. In all data rate scenarios, AODV has experienced the least load as compared to other protocols. In addition to this, it has shown lower delay than GRP and DSR protocols.

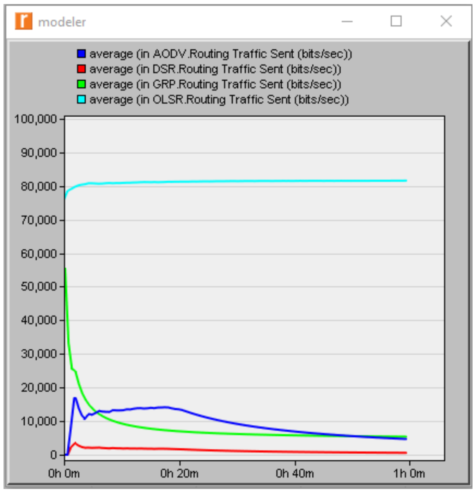

Fig. 2. Routing traffic sent for 50 mobile nodes and 4.5Mbps data rate

III. Conclusion

Unmanned Aerial Vehicles (UAVs or commonly known as drones) have the potential benefits in improving communications in wireless network environment. In this paper, we have presented the performance analysis of four MANET routing protocols (AODV, DSR, GRP and OLSR) for UAVs communications based on scenarios with varying data rates supported by IEEE 802.11p (WAVE) standard.

The evaluation result has revealed that (a) varying the data rate values has an impact in the delay performance of all protocols (b) AODV has experienced the least load followed by DSR and GRP (c) the DSR has exhibited the least routing traffic overhead, the lowest throughput and the highest delay as compared to other protocols (d) GRP has experienced higher load than AODV and DSR (e) the OLSR protocol has experienced the highest routing traffic overhead followed by GRP and AODV (f) the OLSR protocol has shown the highest throughput performance followed by GRP and AODV (g) the OLSR protocol has shown the lowest delay followed by AODV and GRP (h) the OLSR protocol has shown maximum load followed by GRP and AODV.

As an extension to this paper, we will investigate whether the performance of these protocols varies or not when applied to other supported data rates in WAVE and different application traffics such as ftp and video.

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