Performance Evaluation of FANET Routing Protocols in Disaster Scenarios

Salma Badawi Mohammed Ahmed
Razak Faculty of Technology and Informatics, Universiti Teknologi Malaysia
Kuala Lumpur, 54100, Malaysia
b.mohammed-1983@graduate.utm.my

Syed Aamer Hussain
Razak Faculty of Technology and Informatics, Universiti Teknologi Malaysia
Kuala Lumpur, 54100, Malaysia
aamerhussain1987@graduate.utm.my

Liza Abdul Latiff
Razak Faculty of Technology and Informatics, Universiti Teknologi Malaysia
Kuala Lumpur, 54100, Malaysia
liza.kl@utm.my

Norulhusna Ahmad
Razak Faculty of Technology and Informatics, Universiti Teknologi Malaysia
Kuala Lumpur, 54100, Malaysia
norulhusna.kl@utm.my

Suriani Mohd Sam
Razak Faculty of Technology and Informatics, Universiti Teknologi Malaysia
Kuala Lumpur, 54100, Malaysia
suriani.kl@utm.my

2021 IEEE Symposium On Future Telecommunication Technologies (SOFTT) | 978-1-6654-0570-6/21/$31.00 ©2021 IEEE | DOI: 10.1109/SOFTT54252.2021.9673152

***Abstract*—In the case of disaster, communication networks may be damaged partly or totally. In such a situation, rescue operations require a quickly deployable communication system to save lives. Unmanned Aerial Vehicles (UAVs) are considered adaptable and quick-to-deploy communication mesh in catastrophe situations. To amend the efficiency of the UAV mesh, which is also called Flying Ad-hoc Network(FANET), it is essential to deal with the problems that might contribute to poor performance. One of the most difficult challenges is data routing from the source to the destination. This paper analyze the efficiency of routing protocols namely, AODV, DSR, OLSR and ZRP in disaster scenarios to evaluate the performance of FANET. Using the Netsim simulator, simulation-based testing is carried out, and it is shown that AODV and OLSR work effectively in disaster scenarios in FANETs' dynamic environments.**

***Index Terms*—Flying Ad-hoc Network FANET, UAVs, AODV, DSR, OLSR, ZRP, Netsim, routing protocols, disaster scenarios.**

I. INTRODUCTION

When a disaster occurs, whether natural or artificial, an area of emerging requirements for basic needs, health, and recovery activities is created. In most cases, relying on already existing networks to overcome these challenges is impossible because of the partial/complete distortion of the communication network [1], [2]. It means that an emerging network with unique properties is required. Unmanned Aerial Vehicles (UAVs) are considered a possible emergency situation option for deploying an intelligent mobile and flexible network. The self-organizing and ad hoc connection between UAVs is a critical element in Flying Ad-hoc Network (FANET), that can expand the communication range in an infrastructure-less environment [3].

The fast development of communication schemes like economical Wi-Fi radio communication, various sensors, position locating systems, and micro computers enable UAVs as a potential new field for armed forces and civilian usage. In a variety of civilian applications, including as public safety, disaster area locating and recovery [4], post-tragedy operations including disaster aid [5], monitoring [6], agriculture and products delivery, UAV devices have been employed [7].

UAV networks can be of paramount assistance to responders and victims in disaster situations, particularly at the incident site. Team men who assist in rescue operations will supply victims and emergency responders with multiple forms of services. One possible task is to conduct locating and retrieval operations to gather knowledge about the position of the victims. UAVs fast mobility makes it a viable option in post-disaster scenarios for capturing images and recording data from the catastrophe region and transferring it to a ground station [7], In order to prepare the recovery operations and pick the functional tasks to execute this data is very relevant for the first responders. The deployment of operational links between rescue crew personals is a key support that UAVs can provide.

The UAVs play the role of a versatile and quickly distributed communication structure in this scenario, that becomes essential when the existing mobile network infrastructures may be destroyed due to the disaster and not functioning [8]. A dependable network channel among the drones and the ground station is required to carry out such missions. Moreover, a routing mechanism that is suited for a highly mobile environment is necessary. Because the transmission range is restricted and the mobility of the nodes is high, the routing paths between the

This work was supported by the Universiti Teknologi Malaysia under Research University Grant R.K 130000. 2656. 18J05 and the ASEAN IVO (http://www.nict.go.jp /en /asean_ivo /index.html) project: Prevention of 4 Disasters and Their Single Recovery Networks based on Inter net-of-Things with Airborne Capability (PATRIOT-41R-Net)-R.K130000.7356.4B638 and financially supported by NICT (http://www.nict.go.jp/en/index.html).

978-1-6654-0570-6/21/$31.00 ©2021 IEEE

drones and the ground node must be reestablished regularly.

In this paper, we investigated the performance of well-known FANET routing protocols AODV, DSR, OLSR and ZRP in disaster scenarios based on simulation to determine the most suitable routing protocol for these scenarios to perform disaster relief missions. The main contribution of this work in disaster relief and emergency response applications is to help researchers and disaster responders choose and develop the appropriate routing protocol for different disaster scenarios.

The rest of the paper is organised as follows: section 2 is an overview of routing protocols, including proactive, reactive, and hybrid routing protocols. Section 3 presents simulation setup, scenarios, parameters and performance metrics. Section 4 discussed the simulation result and evaluated the performance of the routing protocols in disaster scenarios. Finally, section 5 conclude the work and discuss possible research direction in the future.

II. OVERVIEW OF FANET ROUTING PROTOCOLS

This section discuss four routing schemes namely: Ad-hoc on Demand Distance Vector (AODV), Dynamic Source Routing (DSR), Optimized Link State Routing (OLSR) and Zone Routing protocol (ZRP). Researchers may use this description to gain a broad concept of networking schemes in FANETs and differentiate between proactive, hybrid and reactive routing protocols.

A. Ad-hoc on Demand Distance Vector Routing protocol (AODV)

AODV is a reactive communication scheme that deals with scenario where no routing path exist between the nodes, reactive scheme is used to discover a path between them. With minimal execution and storage requirements, minimal network activity, and the ability to describe unicast schemes from a transmitting node to a receiver node with communication loop prevention, this protocol adapts well to changing connection situations [9] dynamically. In order to send data across the network, the AODV scheme has multiple steps: discovery, transmission, and routing maintenance. In the case of data transmission, the node discovery process is first instantiated, allowing the route from the source to the destination node; after that packet transmission is performed, followed by routine maintenance, which involves repairing any errors or updating the routing tables if a problem occurs.

AODV sends the following control messages: 1) The Route Request RREQ message broadcasts the receiving address and chronological succession number to neighboring nodes to avoid the forwarding of early messages. 2) RREP-Route Reply Message: When a request comes in, the receiving node transmits an RREP request as a feedback confirmation that it is still listening for it. An RRER error message is created and broadcast to the other nodes when a link between nodes fails. The main drawback of AODV is that route discovery processes in FANET high topology change networks cause significant latency. Furthermore, every data transport consumes bandwidth by exchanging control messages frequently.

B. Dynamic Source Routing (DSR)

it is a reactive routing scheme designed explicitly for Multi-Hop networks, which is also utilised in FANETs for data transmissions between the UAVs. To minimize congestion, drones delivers packets with request ID using this protocol. Every transmitting node in DSR logs the path from the origin position to the receiver end in the header. In the case of a network issue, like a link failure, a maintenance procedure is run to discover new routes [10]. Because the topology of the FANETs network changes often and some UAV failures might cause route interruptions, DSR is not an appropriate protocol for use with the FANETs network.

1) Optimized Link State Routing (OLSR): It is a proactive routing scheme where path details are logged and exchanged in the network at fixed intervals to ensure that routing pathways are available across nodes in the network. In the OLSR scheme, there are two kinds of exchange requests: hello requests and topology control requests (TC) [11]. The goal of hello messages is to find adjacent users/clients in the straight link. Details of familiar adjacent nodes is included in these messages. The topology control requests are used to collect information on the topology of networks. These requests are sent out on a regular basis throughout the network to alert the other nodes that they need in order to refresh the routing log and remove outdated information.

The selection of Multi-point Relays nodes (MPRs) is the basic idea taken into consideration by OLSR. Their primary objective is to distribute controlled traffic all across the mesh. To do this, MPRs nodes employ an appropriate technique for traffic control dispersion. This strategy seeks to reduce communication requests. The TC requests mentioned are delivered by MPR nodes; which carry MPRs selectors (the nodes that picked it as a node MPR), as it communicate to all mesh that the particular node is accessible through mentioned selectors. Furthermore, exclusively MPR nodes contain knowledge regarding the condition of links; it can decide to only cover links among itself and its nodes selectors. As a result, unlike traditional link state technique, biased link details is spread throughout the mesh and used for route calculation.

C. Zone Routing Protocol

ZRP routing protocol is ranked in the hybrid routing offered as a solution to the routing overhead limitation of proactive schemes and increase latency issue in the reactive schemes. Each node in this protocol has its zone; thus, the zones of nearby nodes intersect. Proactive protocols are used to preserve routes in intra-zone routing; as a result, if the transmitting and receiving nodes are in the identical region, packets are sent immediately. Reactive protocols are used in inter-zone routing to identify and maintain routes [12].

III. PERFORMANCE EVALUATION

Simulations can be used to assess FANET networks' disaster response capabilities. A total of four different routing protocols were employed to simulate different transmission types to accurately assess these network types: AODV, DSR OLSR,

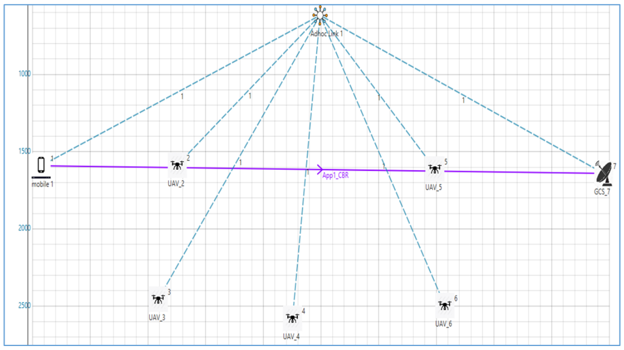

Fig. 1. Simulation window of scenario-1.

TABLE I
SIMULATION PARAMETERS OF SCENARIO-1.

Simulation Parameters	**Type**
Network simulator	Netsim
Channel Type	Wireless
Simulation area	5000*5000 m sqre
Simulation time	100s
No of UAV nodes	5
No of ground mobile nodes	1
UAVs speed	0-50 m/s
ground mobile nodes speed	0-2 m/s
Mobility model	Group mobility
Routing protocols	AODV, DSR, OLSR, ZRP
Transport protocol	UDP
MAC protocol	802.11b
Data type	CBR
Packet size	512 bytes

and ZRP. The Netsim simulator was used to create two simulation scenarios in disaster relief. Each scenario has specific parameters that illustrate different situations for disaster and emergency response environments. The parameters of each scenario were defined in table 1 and 2.

Table I presents the variables of the first scenario where UAVs are deployed to generate a temporary communication mesh to connect mobile ground nodes to help the disaster victims and rescue teams effectively communicate. This scenario evaluates the performance of the flow of data packets between the ground mobile node and ground Control Station (GCS) using a swarm of UAVs. In this scenario, we assume that the GCS directly links with the infrastructure network to communicate between mobile devices. The mobile ground nodes move at a maximal speed of 2 m/s and drones fly at 50 m/s. Figure 1 shows the simulation environment of this scenario in the Netsim simulator.

Table II present the second scenario where UAVs employed in post-disaster scenarios gather visual imagery from the catastrophe region and send the collection to a central station. This scenario evaluates the performance of video transmission between UAV and GCS, where UAVs fly at a maximum speed of 50 m/s. Figure 2 shows the simulation environment of this scenario in the Netsim simulator.

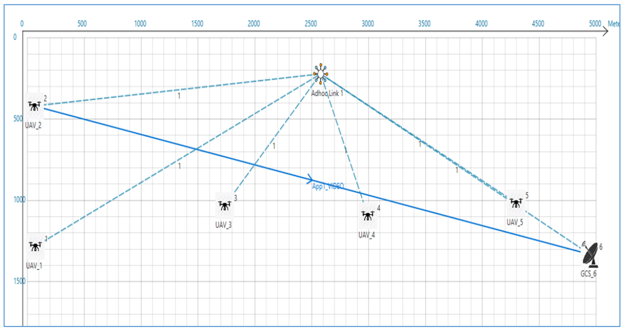

Fig. 2. Simulation window of scenario-2.

TABLE II
SIMULATION PARAMETERS OF SCENARIO-2.

Simulation Parameters	**Type**
Network simulator	Netsim
Channel Type	Wireless
Simulation area	$5000 \times 5000\ m^2$
Simulation time	100 s
No of UAV nodes	5
UAVs speed	0-50 m/s
No of GCS	1
Mobility model	ergodic way point
Network delivery protocols	AODV, DSR, OLSR, ZRP
Transport protocol	TCP
MAC protocol	802.11b
Data type	Video
Frame/s	10 frames
Pixel/frame	10000

The following efficiency evaluation metrics were deployed to analyse the four dynamic communication schemes in two disaster scenarios:

1) Packet Delivery Ratio(PDR): The parameter is calculated using the ratio of number of packets arrived at source node to the total number of data packets.

$$PDR = \frac{\sum(Deliverydata)}{\sum(Transmitteddata)} \qquad (1)$$

2) Throughput : The parameter is characterised as the count of the successful packets arrived at the destination node over a specific period. The routing protocol's performance is better as the throughput increases.

3) End-to-End Delay: The parameter evaluates the period when a message is transmitted to the intended destination by the source node—the total end-to-end time lag required for the transmitted packets to be forwarded to their receiving nodes. In reality, this delay combines sending and propagation delay, route building delays, buffer, waiting, and intermediate node evaluation delay.

$$EndtoEnddealy = \frac{\sum(arrivaltime - sendtime)}{\sum(numberofconnections)} \qquad (2)$$

4) Jitter : Jitter is defined as a change in delay over time. It is the variation in communication delay from end to end among selected packets in the similar packet stream, excluding any packets that may have been lost.

5) Routing overhead: The parameter deals with the amount of routing traffic sent and received in bytes in the whole network.

IV. RESULTS AND ANALYSIS

Experimental analysis of the AODV, DSR, OLSR and ZRP schemes was done in this simulation in two scenarios, and the results are presented in Figure (3,4,5,6 and 7). In the scenario-1, where is UAVs used to Create temporary communication network to connect ground mobile nodes, and as observed from Figure (3,4,5) the AODV routing protocol exceed other schemes in term of PDR, throughput and time lag that because this protocol adapts well to dynamically changing connection situations [13]. While DSR routing protocol present the least routing overhead and jitter.

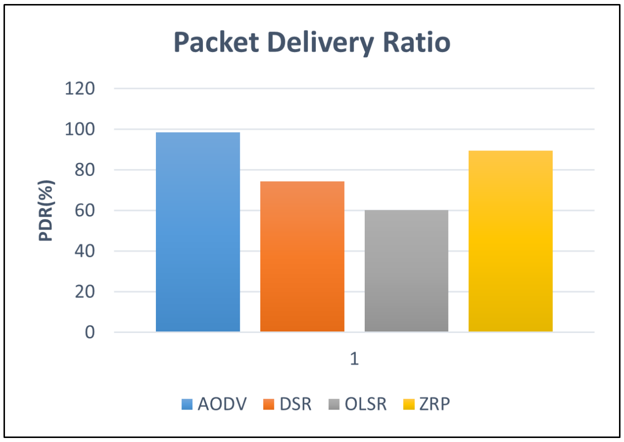

Fig. 3. Packet Delivery Ratio of scenario-1.

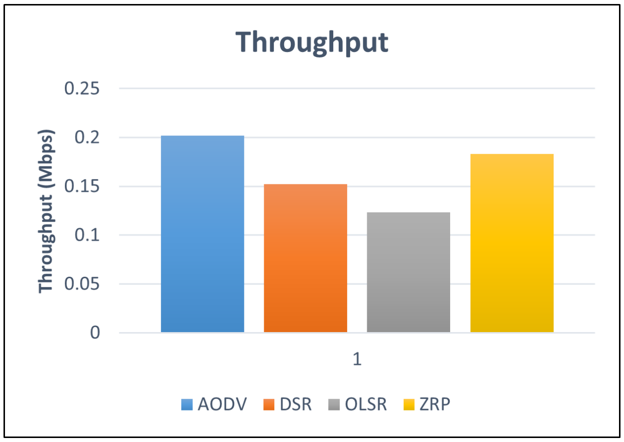

Fig. 4. Throughput of scenario-1.

In scenario-2, the UAVs are used to transmit video from affected areas to the ground station. The results of this scenario obtained in the Figure (8, 9, 10, 11 and 12). As observed, the OLSR protocol gives the best performance in terms of all performance metrics except routing overhead due to the proactive

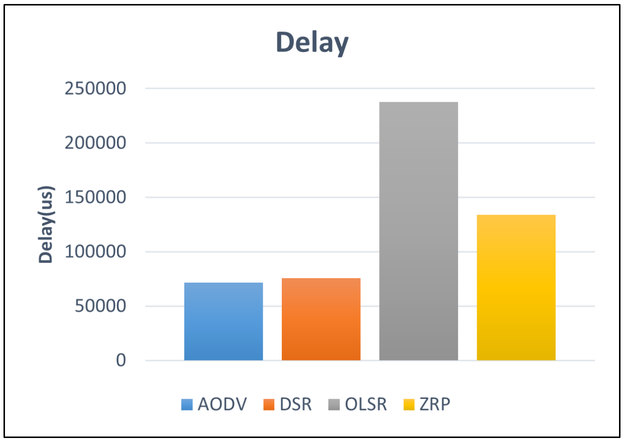

Fig. 5. Network Delay for routing schemes in scenario-1.

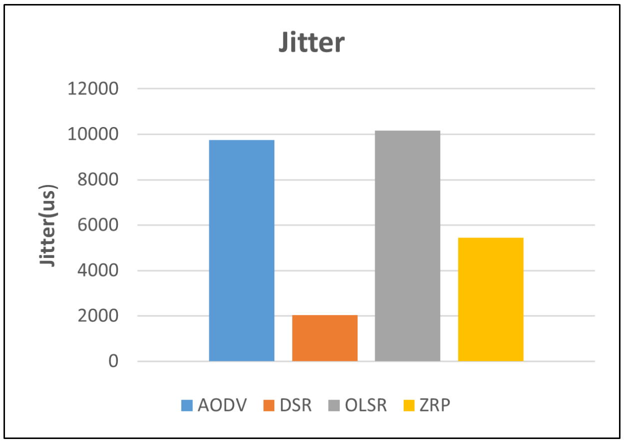

Fig. 6. Jitter in scenario-1.

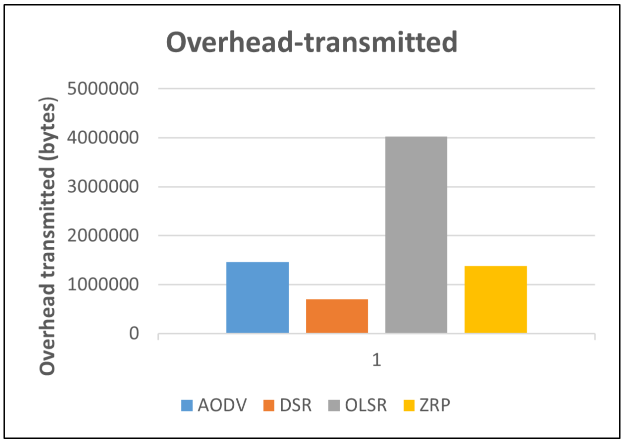

Fig. 7. Routing overhead in scenario-1.

protocol that updates routing tables regularly. Although DSR shows the highest delay and jitter, it demonstrates the least routing overhead. ZRP also shows a good performance in this scenario in terms of all simulation metrics and AODV has less PDR and throughput and higher delay than OLSR and ZRP that AODV discovers path as required and no log of the destination routes is maintained. In this scenario, the DSR routing protocol has shown the least performance and higher delay. Because the topology of the FANETS network changes often and some UAV failures might cause route interruptions, DSR is not a very appropriate protocol for use with high dynamic FANETS network [14].

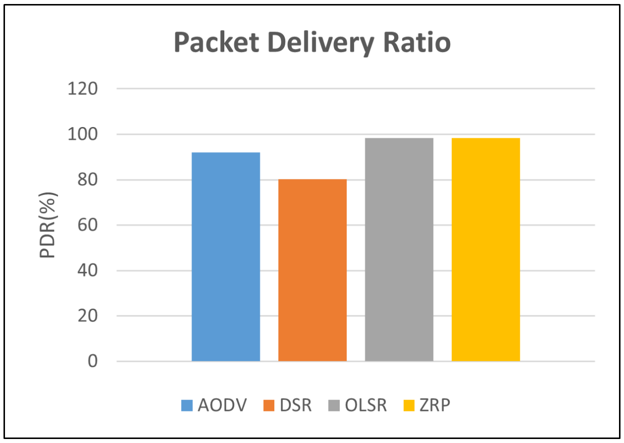

Fig. 8. Packet Delivery Ratio of scenario-2

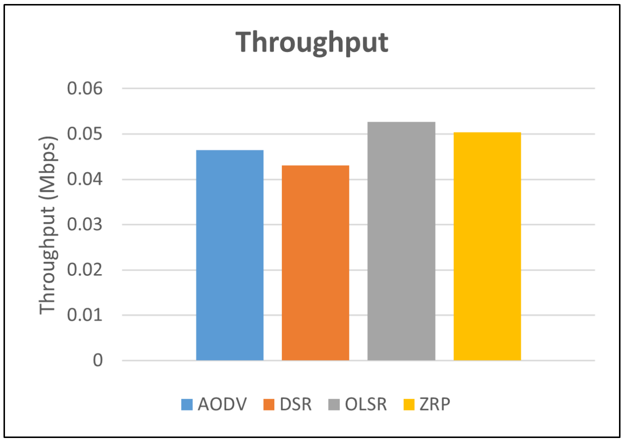

Fig. 9. Throughput of scenario-2.

V. Conclusion

For various uses, including disaster assistance, the FANET, an ad hoc network that links multiple UAVs, is emerging as an effective solution. This paper evaluated the efficiency of different schemes from different categories: proactive, reactive and hybrid routing in two disaster scenarios. In the first scenario, UAVs connect mobile ground nodes when the infrastructure network is likely to be damaged. In this case, the AODV routing protocol gives the best performance in

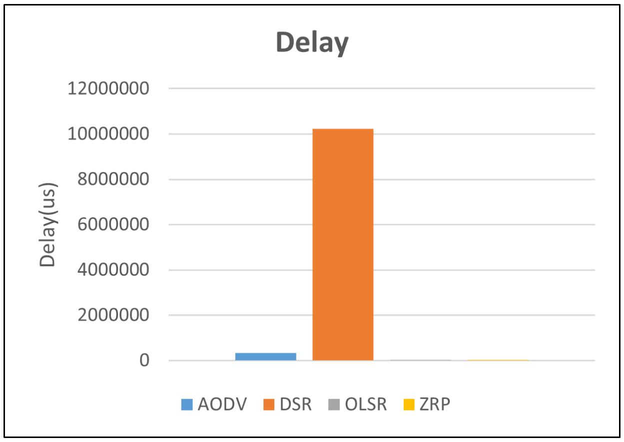

Fig. 10. Delay in scenario-2.

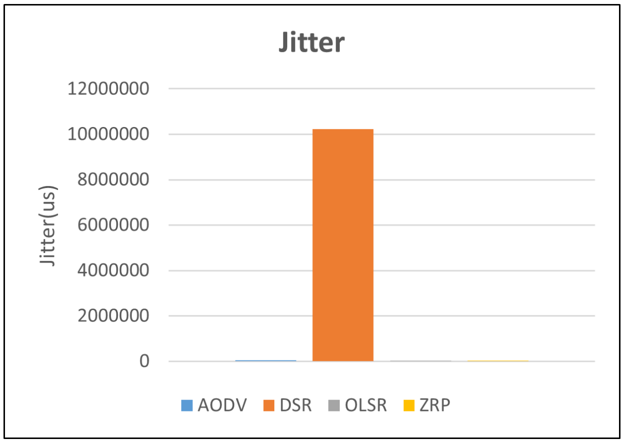

Fig. 11. Jitter in scenario-2.

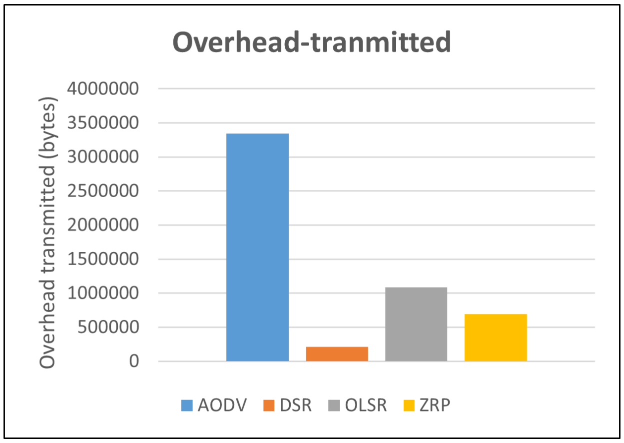

Fig. 12. Transmitted overhead due to routing in scenario-2.

terms of performance metrics. When drones send the video to GCS in search and rescue missions in the second scenario, the OLSR gives the best performance. Although AODV and OLSR perform better in data delivering, DSR routing protocols have the most negligible routing overhead in both scenarios. To conclude, no single routing protocol is suitable for all disaster scenarios; instead, the choice of routing protocol is supported on various factors, including the network's overall size and density, UAV velocity, and disaster application. Future work will analyse other ad-hoc protocols for disaster scenarios, considering practical limitations and deployment strategies.

ACKNOWLEDGMENT

This work was supported by the Universiti Teknologi Malaysia under the Research University Grant R.K 130000. 2656. 18J05, and ASEAN IVO (http://www.nict.go.jp /en /asean_ivo /index.html) project: Prevention of 4 Disasters and Their Single Recovery Networks based on Internet-of-Things with Airborne Capability (PATRIOT-41R-Net)-R.K130000.7356.4B638 and financially supported by NICT (http://www.nict.go.jp/en/index.html).

REFERENCES

[1] Younis, Z. A., Abdulazeez, A. M., Zeebaree, S. R., Zebari, R. R., & Zeebaree, D. Q. (2021). Mobile Ad Hoc Network in Disaster Area Network Scenario: A Review on Routing Protocols. International Journal of Online & Biomedical Engineering, 17(3).

[2] Jahir, Y., Atiquzzaman, M., Refai, H., Paranjothi, A., & LoPresti, P. G. (2019). Routing protocols and architecture for disaster area network: A survey. Ad Hoc Networks, 82, 1-14.

[3] Khan, M. A., Qureshi, I. M., & Khanzada, F. (2019). A hybrid communication scheme for efficient and low-cost deployment of future flying ad-hoc network (FANET). Drones, 3(1), 16.

[4] Leonov, A. V., & Litvinov, G. A. (2018, November). Simulation-Based Performance Evaluation of AODV and OLSR Routing Protocols for Monitoring and SAR Operation Scenarios in FANET with Mini-Uavs. In 2018 Dynamics of Systems, Mechanisms and Machines (Dynamics) (pp. 1-6). IEEE.

[5] Micheletto, M., Petrucci, V., Santos, R., Orozco, J., Mosse, D., Ochoa, S. F., & Meseguer, R. (2018). Flying real-time network to coordinate disaster relief activities in urban areas. Sensors, 18(5), 1662.

[6] Srivastava, A., & Prakash, J. (2021). Future FANET with application and enabling techniques: Anatomization and sustainability issues. Computer Science Review, 39, 100359.

[7] Arafat, M. Y., & Moh, S. (2018). Location-aided delay tolerant routing protocol in UAV networks for post-disaster operation. IEEE Access, 6, 59891-59906.

[8] Sánchez-García, J., García-Campos, J. M., Toral, S. L., Reina, D. G., & Barrero, F. (2016). An intelligent strategy for tactical movements of UAVs in disaster scenarios. International journal of distributed sensor networks, 12(3), 8132812.

[9] Perkins, C., Belding-Royer, E., & Das, S. (2003). RFC3561: Ad hoc on-demand distance vector (AODV) routing.

[10] Johnson, D. B. (2001). The dynamic source routing protocol for multi-hop wireless ad hoc networks. Ad hoc networking, 139-172.

[11] Clausen T, Jacquet P, Adjih C, Laouiti A, Minet P, Muhlethaler P, Qayyum A, Viennot L. (2003). Optimized link state routing protocol (OLSR).

[12] Beijar, N. (2002). Zone routing protocol (ZRP). Networking Laboratory, Helsinki University of Technology, Finland, 9, 1-12.

[13] Nayyar, A. (2018, August). Flying adhoc network (FANETs): simulation based performance comparison of routing protocols: AODV, DSDV, DSR, OLSR, AOMDV and HWMP. In 2018 International Conference on Advances in Big Data, Computing and Data Communication Systems (icABCD) (pp. 1-9). IEEE.

[14] Khan, M. A., Khan, I. U., Safi, A., & Quershi, I. M. (2018). Dynamic routing in flying ad-hoc networks using topology-based routing protocols. Drones, 2(3), 27.