



Research on OLSR Routing Protocol for High-Dynamic and Low-Density UAV Ad-Hoc Network

Shuo Shi^{1,2}(✉), Cong Zhou¹, and Zhong Zheng³

¹ School of Electronic and Information Engineering, Harbin Institute of Technology, Harbin 150001, Heilongjiang, China

crss@hit.edu.cn

² Peng Cheng Laboratory, Network Communication Research Centre, Shenzhen 518052, Guangdong, China

³ International Innovation Institute of HIT, Huizhou 516000, Guangdong, China

Abstract. The main content of this paper is to use NS2 simulation to evaluate the performance of the OLSR routing protocol and its performance comparison with routing protocols such as AODV in a motion scenario based on the PPRZM (Paparazzi Mobility) mobile model, and complete a running OLSR The actual measurement of the performance of the UAV self-organizing network of the routing protocol. Based on the above, some suggestions for optimizing the OLSR routing protocol are put forward. This article first analyzes the research status of the UAV self-organizing network, and then explains the main research content of this subject, including the working principle of the OLSR routing protocol, the optimization and implementation of the paparazzi movement model, and the NS2 simulation evaluation of the OLSR routing protocol in the above motion The performance evaluation under the scene and its performance comparison with other routing protocols, and the performance test of an actual UAV self-organizing network OLSR routing protocol. Through the research of the UAV self-organizing network motion scene, the working principle and performance simulation of OLSR, this paper gives the performance comparison of the current mainstream Ad Hoc routing protocol under the UAV self-organizing network, and finally shows the actual UAV Demonstration of running the OLSR routing protocol in a self-organizing network.

Keywords: PPRZM · OLSR · FANETs · High-dynamic

1 Introduction

With the development of technology and society, hardware technology and wireless communication technology have made great progress, which makes the performance of UAV stand-alone improved significantly, such as flight speed, battery capacity and obstacle avoidance. However, its price is declining, which makes it more and more widely used in many fields, such as real-time fire monitoring and management, crop

pest prevention, target recognition and tracking in complex environment, and temporary communication in earthquake relief, Fig. 1 below shows the schematic diagram of T30 UAV applied in plant protection of DJI.



Fig. 1. DJI T30 plant protection UAV

FANETs (Flying Ad Hoc Networks) are composed of the ground control part and multiple UAV nodes, which together form a wireless self-organizing network. Like the Ad Hoc network, each node is highly equal and has a high degree of autonomy. However, due to the extremely fast moving speed of the UAV node, the topology of the node changes highly, so the requirements for routing are higher. The OLSR routing protocol is classified as a kind of proactive routing in terms of routing search. It has a routing protocol with low delay and good self-adapting performance, and is a routing suitable for mobile ad hoc networks. Although FANETs are also a category of MANET, FANETs have their particular application in sports scenes [1].

The centralized communication structure has a central node, that is, the ground control center of the drone cluster. All nodes communicate and move under the control of the control center, but the drones cannot communicate with each other. All instructions all are issued by the ground control center. This architecture is similar to a wireless network with a central node AP, and all communications between nodes are regulated by the AP. Strictly speaking, this structure is not an ad hoc network in the strict sense, and communication between nodes is not possible. As a result, the application is limited to the movement and communication range of a single UAV, and the types of tasks that can be performed are very narrow. However, this communication structure also has its advantages. Its communication link is stable, the communication between a single UAV and the control center is interrupted, and the communication link will not affect or interfere with the communication between other UAV nodes and ground stations.

The distributed communication structure is based on the centralized communication structure with a communication structure that can also communicate with each other between drones. Under this architecture, the UAV will not be restricted by the fixed restriction of the central control station, and the UAV can communicate with each other and expand the UAV's search range through multi-hop node communication. The information coverage of the UAV self-organizing network is greatly extended. Therefore, the distributed structure of FANETs has the characteristics of wide coverage and flexible coverage search area. It is currently the most suitable communication structure for multi-UAV cluster tasks [2].

The cluster communication structure of FANETs is a communication structure formed by introducing the mutual communication between drones and adding the concept of clustering. All small clusters are composed of drone nodes that are close together, and the entire drone network is a collection of clusters. And each small cluster will generate a central node called the cluster head, and the communication between nodes within the small cluster is carried out through the cluster head. The communication between the small cluster and the small cluster is forwarded through the small cluster. The disadvantage of the cluster communication structure is that in the case of high dynamics, the change rate of small clusters is very high, causing the communication between the cluster head and small cluster members to frequently lose the communication link and continuously create new clusters. The problem of dynamic network and cluster communication structure in the above-mentioned situation has not been solved yet. Therefore, the communication structure of the unmanned aerial vehicle ad hoc network of this subject does not adopt a clustered communication structure.

In summary of the discussion of FANETs communication structure, the communication structure selected in this article is a distributed communication structure. Compared with the ordinary Ad Hoc network, this communication structure has many particularities, which will be discussed below [3].

A single UAV node itself moves fast and can ignore the characteristics of the terrain and all the obstacles that can be surpassed, so it will cause frequent changes in the topology of each UAV network node, and the communication between UAVs must frequently search for routes. Therefore, FANETs The adaptive routing requirements are relatively high. The real-time search task needs to continuously return information to the ground control station, so the end-to-end time delay of the average node of the network is relatively high, so it also puts forward the low delay requirements for the routing of FANETs. Therefore, when communicating between FANETs nodes, the accuracy of the route search and the average end-to-end delay will directly affect the communication quality between the UAV network nodes, which in turn will affect the efficiency of the UAV swarm. And quality has a major adverse effect.

The OLSR routing protocol is a proactive and self-adaptive routing protocol, which is well applied in mobile ad hoc networks, but the application in FANETs is rarely mentioned, so the application performance of OLSR in FANETs is tested. Analysis has certain practical value and reference significance. Based on the search task of the UAV ad hoc network, this paper studies the performance analysis of the application of OLSR in FANETs, and establishes the NS2 simulation scenario PPRZM mobile model. In this motion scenario, the performance of OLSR under various conditions is simulated and evaluated. Finally, based on the simulation results, the applicability and limitations of OLSR in FANETs are discussed, which provides data and theoretical support for the better application of OLSR routing in FANETs [4].

2 Model Establishment

This paper studies the PPRZM mobile model and optimizes the PPRZM model and its implementation in NS2. The PPRZM mobile model, the paparazzi model, is a mobile model proposed by Bouachir O, Abrassart A, and Garcia F at the 2014 International Drone Driving Conference. They demonstrated the PPRZM mobile through experimental simulations in the article report. When the model is used in the UAV cluster

self-organizing network, it will be closer to the movement of the UAV cluster network and the communication link. They divided the movement of the drone into five types, namely circling movement, linear movement, scanning movement, elliptical movement and figure-of-eight movement, and gave them different occurrence probabilities. Based on their research, this paper takes into account the task requirements of the area search. In the simulation, the concept of area is introduced. The entire plane is divided into 9 areas, and each area is divided into a random number to represent the area of the task search. The size of the task volume and the distribution of drones between regions are evenly distributed by the size of random numbers. The realization of the motion scene relies on the setdest tool of NS2, and the scene model is introduced by modifying the source code of the setdest tool [4].

2.1 PPRZM Mobile Model

PPRZM is a mobile model based on the movement path of the mobile ad hoc network node. Compared with other mobile ad hoc network models, it simplifies the movement of the drone node into five movement modes. The author in the literature proved through simulation that, compared with the RWP model, when the PPRZM mobile model is used for the simulation of the UAV cluster self-organizing network, the PPRZM model is closer to the real movement trajectory of the mobile node and the communication link. It can also be well reflected. The five nodal trajectories of the PPRZM motion model are given below:

- (1) Circling and waiting: The UAV will continue to make a uniform circular motion with the target position as the center of the circle. This is a simulation of the UAV's backhaul after the target is found. Once the UAV finds the target, the UAV will hover in place and wait to return captured information and transmit related videos or pictures.
- (2) Waypoint flying in a straight line: The UAV will move straight towards the target position at a constant speed until it reaches the target position. This is a simulation task tracking situation. After the drone captures the target and returns it, it needs to keep track of the target and keep the target's information returning.
- (3) Scanning movement: The UAV scans the rectangular area with the starting point and the target point as the diagonal point. This is to simulate the motion state of the UAV when searching for the target. Before the UAV does not capture the target, it needs to perform a relatively comprehensive scan and retrieval of the area in which it is responsible.
- (4) "8"-shaped movement: The UAV will use the starting point and the target point as the center points of the two areas to perform a figure-eight cyclic movement. This is the case of simulating the coverage and search of the central area of the UAV. Same as above, the area search of the UAV can also be in the shape of "8".
- (5) Ellipse movement: The UAV will take the starting point and the target point as the focus, and perform elliptical trajectory movement. This is the case of a full-area rough search in the simulation task search. When scanning and precise key area search, the drone needs to perform rough detection to find the key detection area [5].

In the PPRZM model, the occurrence probabilities of these five trajectories are different. According to actual experiments, the literature found that the three trajectories of hovering waiting, elliptical motion and scanning motion have the highest probability of occurrence during the movement of the drone. The default probabilities of the five trajectories in the team movement model are circling waiting, elliptical movement, and scanning movement set to 30%, while figure-eight movement and waypoint straight-line flight are set to 5%. However, the probabilities of these five trajectories are not immutable. We can adjust the probabilities of UAV trajectories according to the different characteristics of different services to adapt to the needs of different simulation scenarios.

2.2 Optimization and Realization of PPRZM Mobile Model

When drawing on some other mobile models, in order to better simulate the search task of the drone cluster, we divided the entire plane area into 9 areas, each area is a subset of the search task, and a random number is given to each area. An integer represents the task intensity of the area. The initial area allocation of the UAV will be evenly distributed according to the size of the random number, and the probability of the movement trajectory of the PPRZM model will be realized [6].

The implementation of the PPRZM mobile model is to modify the setdest tool of NS2. Since the setdest tool can only generate nodes with linear random motion, the five trajectories of PPRZM are linearized, and the motion trajectory diagram shown in Fig. 2 is obtained:

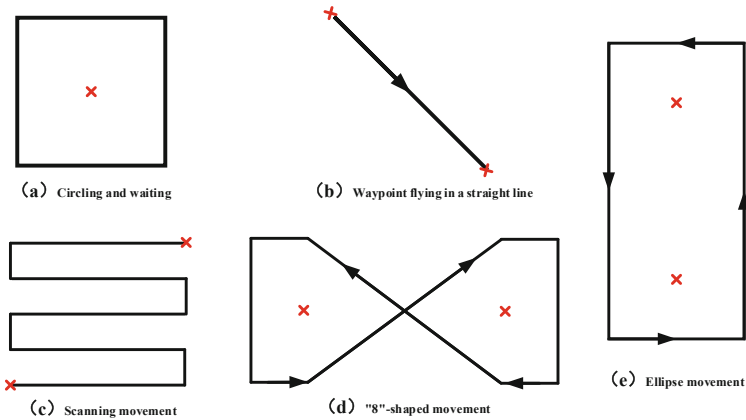


Fig. 2. PPRZM linearized motion trajectory diagram

The realization of this mobile model in this article is achieved by modifying the setdest.h and setdest.cc files of NS2, mainly by adding the realization of several drone flight trajectories (except straight trajectories), and this article reloads the file The RandomDestination() function allows it to move according to the destination position we specify and can evenly distribute the initial position of the drone according to the random number of the divided cell according to the assumption [7].

3 Simulation Test of OLSR in PPRZM Scenario

3.1 Optimization and Realization of PPRZM Mobile Model

The full name of NS2 is the second generation of network simulation simulator, which is an object-oriented, and its driver is realized and carried out using discrete time. NS2 started from the Real Network Simulator project. After years of development and absorbing the achievements of many scientific research institutions and scholars in the world, NS2 has become an excellent network simulation tool.

At present, the mainstream network simulation software includes NS2, NS3, OPNET, etc. Among them, OPNET is a relatively mature commercial simulator, which can build and simulate the network according to different styles of switches and routers, but its expensive charges are comparable to NS2. Compared with open source and free of charge, NS2 is more favored by academia.

NS2 uses two programming languages, C++ and OTcl. Among them, C++ is used to implement specific protocol simulation, because C++ can process various information efficiently. Because the OTcl language runs fast and is convenient to repair errors in the program, the network environment parameter settings and specific simulation scenarios are written in the OTcl language. The mutual communication between C++ and OTcl requires a third-party “translation”. TclCL is a bridge between these two languages, and it is an encapsulation based on OTcl.

The tree diagrams on the left and right sides represent the hierarchical relationship of objects in C++ and OTcl, respectively, and the dotted line represents that the two can access each other. It can be seen from the figure that the objects in the same level of the two can access each other, and then the information is circulated in the structure through the tree hierarchy [7].

3.2 Simulation Parameter Setting

FANETs are different from other wireless self-organizing networks. Their movement area is the sky. The general flying height is tens of meters, and there is a high vertical height from the ground. Therefore, they are generally not affected by obstructions and belong to line-of-sight propagation. The transmission model we simulated is the Rice fading model, so the channel model in the simulation selects Two Ray Ground.

At present, the mainstream UAV is a rotary-wing UAV. Take the model DJI MATRICE 600 PRO as an example. Its flying altitude is up to 120 m, and its maximum flying speed is 65 km/h under no wind, so we set the node’s movement speed range It is 5 m/s–20 m/s. Taking into account the actual situation, in order to accurately model the FANETs task search scene, the motion trajectory of the FANETs node in this paper uses an improved PPRZM model, and the probability of the motion trajectory in the PPRZM model is fine-tuned, and it is assumed that all UAV nodes are in On a unified height. The parameter list is in Table 1 below:

Table 1. NS2 simulation parameter setting

Parameter name	Parameter setting
Simulation software	NS2
Simulation duration	300 s
Mobile model	PPRZM
Propagation model	Two Ray Ground
MAC type IEEE	IEEE 802.11
Topological range	2000 m–2000 m
Number of nodes	20–60
Maximum moving speed	10 m/s–35 m/s
Communication distance	500 m
Packet size	512 Bytes

The simulated motion scene is generated by the Setdest tool of NS2. The Setdest file of NS2 has been modified above to make it a tool file for generating an improved PPRZM motion model. On this basis, you only need to type in the command line: “ns -n 50 -p 0-s 30 -t 300 -x 3000 -y 3000> scene” to generate 50 random nodes in the scene file, the maximum The moving speed is 10 m/s, and it does not stay at the destination, and the range of random movement is $3000 \text{ m} \times 3000 \text{ m}$.

The simulated traffic generator is generated by the Cbrgen tool that comes with NS2. It is a transmission generator that can generate cbr data stream and tcp data stream. Since the UAV self-organizing network is connected in a connectionless manner, it is selected for this topic It is the cbr data stream. Go to the cbrgen.tcl directory, open the terminal, and type the following command on the command line: “ns cbrgen.tcl -type cbr -nn 50 -seed 0 -mc 15> cbr”, the cbr file will generate 50 for nodes up to 15 The random cbr data stream of a business link, the specific data stream rate and packet size can be modified twice in the file [7].

4 Simulation Results

The simulation simulates the impact of three parameters on the performance of the routing protocol. They are the number of UAVs, that is, the number of nodes in the network, and the service data volume of UAVs is the cbr rate of the network and the moving speed of the UAV. In order to illustrate the applicability of the OLSR routing protocol to FANETs, a comparative test with the AODV routing protocol was made.

The specific parameters of the set simulation experiment are as follows:

- (1) Change the number of nodes in the network: set the number of nodes to 10, 20, 40, 60 and 100 respectively, their cbr speeds are all 1 M/s, and the maximum moving speed of the UAV is 30 m/s.

- (2) Change the traffic of the network: set the cbr data stream of the network to 0.5, 2, 5, 10, 15 and 20 M/s respectively, the number of their nodes are all 30, and the maximum moving speed of the drone is 30 m/s.
- (3) Change the maximum moving speed of UAV: set the maximum moving speed of nodes to 10, 15, 20, 2, 30 and 35 m/s, cbr speeds are all 2 M/s, and the number of UAV nodes is 30.

The experimental results of changing the number of nodes are shown in Fig. 3, Fig. 4, Fig. 5 and Fig. 6. The comparison diagrams of the packet delivery rate, end-to-end average delay and routing overhead of OLSR and AODV under this condition are respectively given.

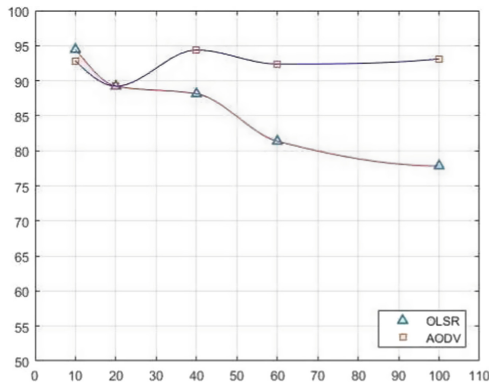


Fig. 3. Comparison of packet delivery rates between OLSR and AODV when the number of nodes increases

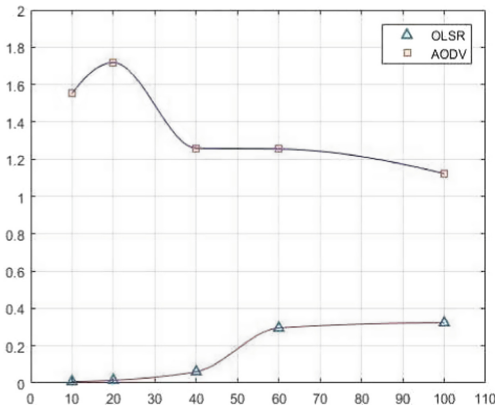


Fig. 4. Comparison of the average delay between OLSR and AODV when the number of nodes increases

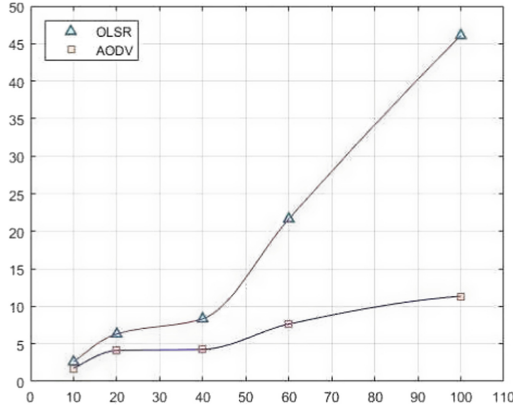


Fig. 5. Comparison of the average delay between OLSR and AODV when the number of nodes increases

From the perspective of packet delivery rate, the efficiency of OLSR gradually decreases with the increase in the number of nodes, and finally stabilizes at about 80%, and the performance of the AODV routing protocol has a larger number of nodes in terms of packet delivery rate, which is in a medium-scale. The packet delivery rate under the network is significantly higher than OLSR by about 10%, which is significantly better than the OLSR routing protocol. And in the case of low density, at the beginning of a small network with 10 nodes, the routing cost of OLSR and AODV is similar, but as the number of nodes increases, the routing cost is much higher than that of the AODV protocol. This is because the increase in the number of nodes will cause the control packets sent by the OLSR routing protocol such as HELLO. The number of messages and TC packets increased sharply, while the cbr packets remained unchanged, resulting in a sharp increase in routing overhead. From the perspective of average end-to-end delay, the OLSR protocol is far superior to the AODV routing protocol in either low-density scenarios or medium-to-high node density scenarios. This is because OLSR is a proactive routing, and there is no need to find a route during the sending process. AODV is an on-demand routing, so routing needs to be found during the process of sending data, so the performance of OLSR in terms of end-to-end average delay is far better than AODV. The search task of the UAV ad hoc network requires a service with low latency, especially the real-time video transmission service. In the actual UAV test in Chapter 5, the real-time video transmission experiment of the UAV formation will be tested. Because this is a scenario for UAV ad hoc network applications [7] (Fig. 6, Fig. 7, Fig. 8 and Fig. 9).

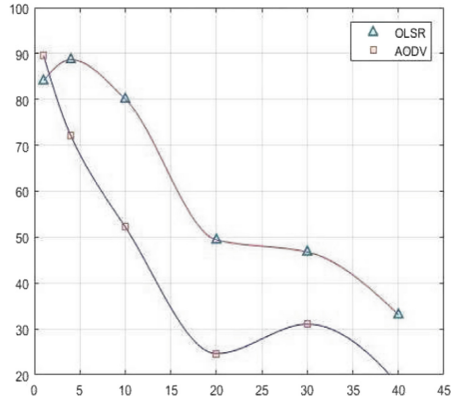


Fig. 6. Comparison of packet delivery rates between OLSR and AODV when the volume of business data increases

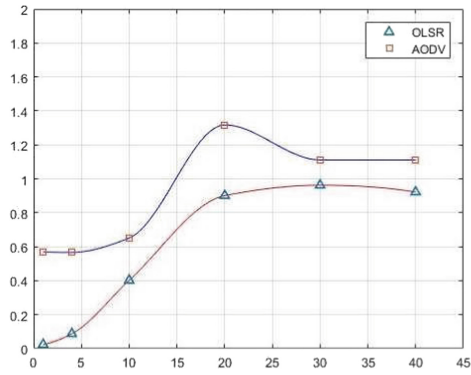


Fig. 7. Comparison of the average delay between OLSR and AODV when the volume of service data increases

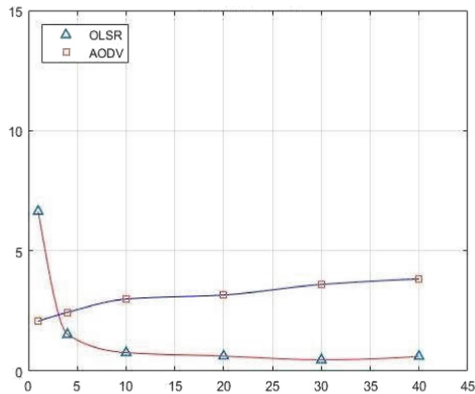


Fig. 8. Comparison of the average delay between OLSR and AODV when the volume of service data increases

The rise in business data has increased the delivery rates of OLSR and AODV, and AODV is slightly higher than the data of OLSR. This is because the rise in business data has increased the possibility of business data collisions, so the correct delivery rate of corresponding data packets has decreased. The increase in business data leads to an increase in the average end-to-end delay of AODV and OLSR. This is because the message packet of the node is transmitted by UDP. The more data, the longer the sending time, and the receiving node must wait for all data to be sent. The sequence numbers of the data packets can be sorted after completion, which leads to the end-to-end average delay side length. For routing overhead, OLSR decreases with the growth of cbr data services. This is because the growth of service data is the original definition of routing overhead compared to the size of control packets. The frequency of OLSR sending control packets is fixed, so the number of control packets Relatively fixed, and the cbr data at this time is increasing, so relatively speaking, the routing overhead of OLSR shows a rapid decline and tends to zero. As for the AODV routing protocol, it is routing on demand, so every time you send data, you need to search for routing and send control packets, so when the business data increases. Its routing overhead is almost unchanged.

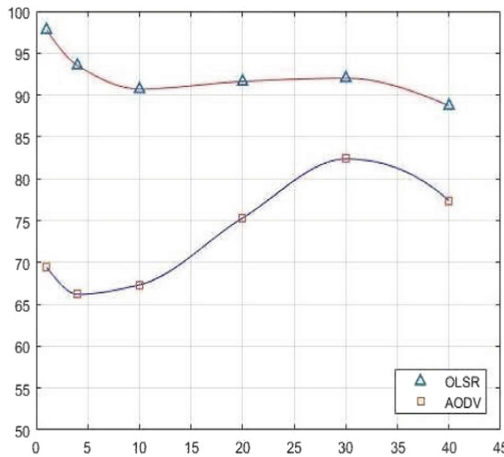


Fig. 9. Comparison of packet delivery rate between OLSR and AODV when the speed increases

It can be seen from Fig. 10 that under a medium-speed and small-scale network structure, a highly dynamic network, when the node’s mobile speed is 5 m/s and 30 m/s, the packet delivery rate of OLSR is much higher than that of AODV; From the data reflected in Fig. 11, as expected, the delay of the proactive routing protocol OLSR is much lower than AODV regardless of whether the node is highly dynamic. The average end-to-end delay performance is good, and it is suitable for The routing protocol for the search task of the man-machine ad hoc network; Fig. 12, it can be seen that in terms of routing overhead, the highly dynamic UAV node causes the routing overhead of AODV and OLSR to be almost the same. So on the whole, in the scene of high-speed movement of nodes, the performance of the OLSR routing protocol is better than AODV in terms of routing overhead, packet delivery rate and average end-to-end delay.

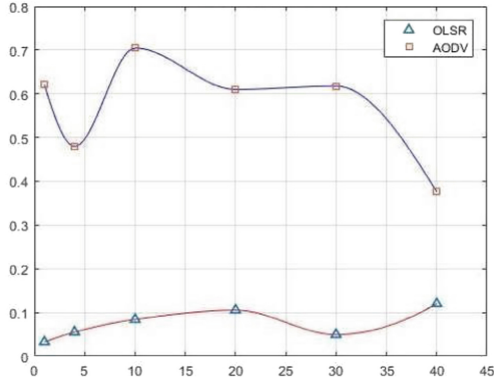


Fig. 10. Comparison of the average delay between OLSR and AODV when the speed increases

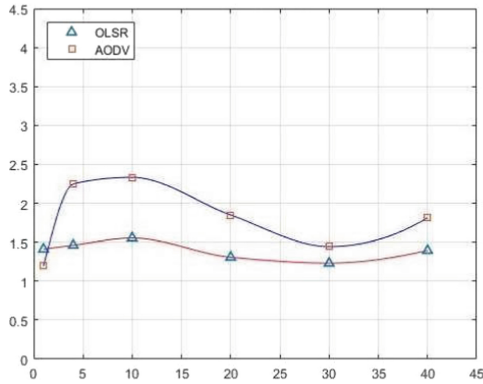


Fig. 11. Comparison of routing overhead between OLSR and AODV when the speed increases

After completing the simulation experiment and data analysis, we come to the following conclusions:

- (1) In the PPRZM scenario, the OLSR routing protocol has excellent performance in a low-density, high-dynamic network, that is, a small-scale high-dynamic network, which is significantly better than the AODV protocol, so it can be used in a drone with a small number of nodes. The networking has better applications, and can have better packet delivery rates and delay guarantees in various business data transmission rates, including video transmission and other services.
- (2) AODV can be applied to the UAV self-organizing network under the premise of high node density and high network topology change rate, and when the delay requirement is not high, its performance is obviously better than OLSR, but this article The background of the research is the search task of FANETs, so it is generally a small network, and the network delay requirements are high, so in the search task of FANETs, AODV is not well applicable, and the OLSR routing protocol should

be used at this time. Therefore, in the context of this subject, the OLSR routing protocol has good applicability, but it also has its limitations, such as not being suitable for medium and large-scale UAV networks.

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