



# MPR Selection Based on Link Transmission Quality and Motion Similarity in OLSR for FANETs

Ziheng Li, Shuo Shi<sup>(✉)</sup>, and Xuemai Gu

Harbin Institute of Technology, Harbin, China

liziheng@stu.hit.edu.cn, {crcss, guxuemail}@hit.edu.cn

**Abstract.** With the development and popularization of 5G networks and unmanned aerial vehicle (UAV) applications, UAV networks have received more and more attention. Routing protocols have always been a key technology in mobile ad hoc networks (MANETs), especially in Flying Ad-hoc Networks (FANETs). The rapid changes in network topology brought about by the high-speed mobility of UAV nodes make the network performance more susceptible, which poses a greater challenge to FANETs routing technology. This paper mainly focuses on the optimization problem of OLSR protocol in FANETs under planar topology, considering the link transmission quality and link stability between nodes, uses a weighted index to replace the node connection degree as the MPR set selection criterion, an MPR set selection algorithm based on motion similarity and link transmission quality is proposed. Then in the NS2 emulator, a comparative analysis of packet delivery ratio, average end-to-end delay, and routing overheads are performed to verify the performance improvement of the proposed algorithm.

**Keywords:** FANETs · OLSR · Multi point relay · Mobility

## 1 Instruction

FANETs is an extended application of MANETs in the field of drones, usually consisting of a ground control station (GCS) and multiple UAV nodes. FANETs can be seen as a special kind of MANETs, has the commonalities of traditional MANETs, such as no center, multi hop, self-organization, and self-healing, but it also has its own application form, network structure and network characteristics. UAV nodes are aerial nodes, and their movement is not easily affected by terrain factors. Compared with MANETs, UAV nodes have faster speed and higher freedom of movement. The distance between UAV nodes is mostly far, and the density of UAV nodes in a certain airspace is relatively low. These problems have caused the link stability and link quality between nodes to be more easily affected, and the network topology changes more frequently.

As we all know, the fast and accurate data transmission mechanism between UAV nodes is an important part of FANETs. The quality of the communication protocol directly determines the network transmission performance of FANETs, which in turn

affects the application effect of FANETs. However, due to the characteristics of fast movement of UAV nodes, low node density and limited energy, the routing protocols used in traditional MANETs and VANETs are usually not able to directly adapt to the highly changing scenarios of topology and routing information in FANETs. In turn, it affects the communication performance of the entire network. Therefore, a core research point in FANETs is the study of routing protocols. How to overcome the adverse effects of FANETs' high mobility, frequent topology changes, and overall energy constraints, and design an excellent one suitable routing protocols for FANETs is especially critical.

## 2 Related Works

### 2.1 OLSR Protocol

The optimized link state routing protocol, OLSR protocol [1], is a proactive routing protocol with a flat topology. Compared with the LSR protocol, it mainly has the following two characteristics: Using multi-point relay technology (MPR), only those nodes selected as MPR in the network can forward TC messages, which reduces the number of forwarding control packets and overhead. OLSR can distinguish the old and new routing messages through the sequence number ANSN field in the TC messages, and use this to maintain and update the topology of the entire self-organizing network.

Many researchers have conducted detailed research and improvement on the OLSR protocol. K. Singh [2] provides ideas for the evaluation method of FANETs routing protocol and optimizes for the OLSR protocol under different mobile models. Pardeep Kumar [3] proposed an AOLSR routing protocol that optimizes the MPR selection criterion based on the location of the destination node of the data to be sent. Yi Zheng [4] proposed an OLSR protocol based on mobility and load awareness, that is, the ML-OLSR protocol, and introduced a mobile sensing algorithm and a load sensing algorithm. De-gan Zhang [5] proposed an artificial neural network OLSR protocol QG-OLSR based on quantum genetics to optimize the selection of MPR sets.

### 2.2 Paparazzi Mobility Model (PPRZM)

This paper investigates the existing FANETs mobility models and finds that there are two main types: one is the modification and adjustment of the traditional MANETs, making it suitable for FANETs, such as Random Walk (RW) model [6], Random Way Point (RWP) model [7], Gauss-Markov (GM) model [8], etc. RWP model is used in most UAV ad hoc network simulation scenarios.

Although the above mobile models can largely reflect the mobility of drones, FANETs are mostly application-oriented, the mobility of flight nodes is often more diverse, and traditional models often cannot accurately reproduce their behavior. Therefore, the second type is specially designed for FANETs, with its unique constraints, such as Semi-random Circular Movement (SRCM) model [9], Paparazzi Mobility (PPRZM) model [10].

Paparazzi mobility model is designed based on the Paparazzi UAS. Similar to the RWP model, PPRZM is also a path-based random mobility model, but PPRZM has

more node movement behaviors that are closer to FANETs. The distribution uniformity of UAV nodes, regional communication frequency, number of link connections and other parameters are more in line with the actual situation.

### 3 Optimization Algorithm of MPR Set

The MPR set selection method of the traditional OLSR protocol is based on the node degree. However, due to the high mobility of UAV nodes, the stability of the links between the nodes decreases and the nodes with high connectivity may quickly leave the communication range of other nodes, and the larger coverage of the FANETs also makes the link quality different. As a result, it is inappropriate to adopt a single node connection degree as the selection criterion of the MPR set.

#### 3.1 The Central Idea of the Optimization Algorithm

In FANETs, the relative movement between each node can usually represent the link survival time and stability between the nodes, and it is easy to be obtained and calculated. According to the link evaluation index in article [11], the link transmission quality between nodes can be characterized by the Expected Transmission Count (*ETX*). Therefore, this paper will introduce the node motion similarity and the transmission quality of nodes links as the criterion for measuring the link performance between nodes and selecting MPR sets.

This paper assumes that each node can know its real-time position and speed information, in order to calculate the motion similarity between nodes. Motion similarity refers to how similar a UAV node is to another neighboring UAV node in moving speed. Generally speaking, the greater the degree of similarity in the movement behavior between nodes, these two nodes are considered to be better able to maintain the connection state. Because this paper mainly focuses on planar topology, the vertical velocity of the UAV is not considered.

Now suppose that there are two UAV nodes  $i$  and  $j$ , with speed  $\mathbf{v}_i$  and  $\mathbf{v}_j$  respectively, then referring to the mobility measure of Euclidean distance, the calculation of the motion similarity of these two nodes as shown:

$$\theta_{ij} = 1 - \frac{|\mathbf{v}_i - \mathbf{v}_j|}{|\mathbf{v}_i| + |\mathbf{v}_j|} \quad (1)$$

The link transmission quality between nodes is calculated by *ETX*. The smaller the value of *ETX*, the higher the link quality of network communication. *ETX* is obtained by calculating the values of link quality (*LQ*) and neighbor link quality (*NLQ*) according to the proportion of two nodes receiving HELLO messages sent by its neighbors within a certain period. Then the calculation method of *ETX* of a node is as follows:

$$ETX = \frac{1}{LQ \times NLQ} \quad (2)$$

However, after analysis, it is found that *LQ* and *NLQ* cannot be directly calculated, and furthermore, *ETX* cannot be calculated. Therefore, this paper defines Mutual Link

Quality ( $MLQ$ ) as an intermediate quantity to calculate the  $ETX$  of two nodes. For local nodes, the  $ETX$  calculation method is as follows:

$$MLQ_L = \frac{i \text{ received the number of HELLO sent by } j}{\text{Number of HELLO } i \text{ sent to } j}$$

$$MLQ = \frac{j \text{ received the number of HELLO sent by } i}{\text{Number of HELLO } j \text{ sent to } i} \quad (3)$$

$$ETX = \frac{1}{MLQ_L \times MLQ} \quad (4)$$

Through further analysis, it is found that the range of node motion similarity is  $[0, 1]$ , and the larger the value, the better the link stability, while the value range of  $ETX$  is  $[1, +\infty]$ , but the smaller value means that the link transmission quality is higher. This leads to the inconvenience of normalizing the two indexes and the weighted average, which affects the calculation of the optimal link performance index. Therefore, this paper defines a new link transmission quality index  $R\_ETX$ , with value range  $[0, 1]$ .

$$R\_ETX = MLQ_L \times MLQ \quad (5)$$

Therefore, the two indicators of link stability between nodes and link transmission quality between nodes are comprehensively considered, and since MPR nodes are used as relay nodes to cover 2-hop neighbors, their transitivity and relay amplification must be considered. In this paper, the comprehensive link evaluation index  $L$  is used to replace the node degree in the standard MPR selection algorithm as the decision basis to optimize the MPR set selection method. The calculation formula of  $L$  is as follows:

$$L(y_i) = \alpha[\theta_{A y_i} \text{ average}(\theta_{y_i s_j})] + \beta[R\_ETX_{A y_i} \text{ average}(R\_ETX_{y_i s_j})] \quad (6)$$

Among them,  $A$  is the node that performs the MPR set calculation,  $y_i$  is the 1-hop neighbor node of node  $A$ , and  $s_j$  is the strictly symmetric 2-hop node reachable by  $y_i$  in node 2-hop neighbor set;  $\text{average}()$  represents the arithmetic average of the link indicators between node  $y_i$  and all strictly symmetric 2-hop neighbor nodes  $s_j$  reachable through this node;  $\alpha$  and  $\beta$  are weighting coefficients, and satisfying  $\alpha + \beta = 1$ , which can be adjusted for different network emphasis directions.

### 3.2 Algorithm Implementation Process

In order to obtain the numerical values described in the formula and add them to the OLSR protocol, it is necessary to modify the frame format of the HELLO and the format of the local link set and neighbor set to add some new parameters.

Because this paper assumes that all UAV nodes are on the same horizontal plane, the node only needs to know the horizontal speed of its neighbor nodes to calculate the motion similarity between the nodes. The node also needs to know the  $MLQ$  of its neighbor node to calculate the  $R\_ETX$  between the two nodes, thereby updating the node's local link set and neighbor set. In addition, the node needs to know the motion similarity and  $R\_ETX$  between a certain neighbor node and the 2-hop neighbor node

Reserved(16bits)		Htime(8bits)	Willingness(bits)
X-direction speed (16bits)		Y-direction speed (16bits)	
Link Code(8bits)	Reserved(8bits)	Link Message Size(16bits)	
Neighbor Interface Address(32bits)			
Mobile Similarity <sup>0</sup> (32bits)			
MLQ(32bits)			
R_ETX(32bits)			
Neighbor Interface Address(32bits)			
.....			
Link Code(8bits)	Reserved(8bits)	Link Message Size(16bits)	
Neighbor Interface Address(32bits)			
Mobile Similarity <sup>0</sup> (32bits)			
MLQ(32bits)			
R_ETX(32bits)			
Neighbor Interface Address(32bits)			
.....			

**Fig. 1.** Modified HELLO message format, which is added parameters such as node speed, movement similarity and *R\_ETX*.

reachable via the HELLO to establish a 2-hop neighbor set. In summary, the frame format modification of the HELLO is shown in Fig. 1. Similarly, these parameters will also be added to the node local link set, neighbor set, and 2-hop neighbor set.

Based on the optimized packet format of the HELLO message and the table format of the neighbor information base, the improvement of the MPR set selection algorithm is implemented. Now suppose that the MPR set calculation is node A, and its MPR set is described by *M*; the set of 1-hop neighbor nodes of node A is *N*, and the set of 1-hop neighbor nodes is *y*; the set of 2-hop neighbor nodes *s* is *N2*, which not includes the 2-hop neighbor nodes that are reachable only through the nodes in set *N* whose forwarding intention is WILL\_NEVER, the node A itself that performs MPR set calculation, and all 1-hop symmetric neighbor nodes of node A.

The process of optimizing the MPR set selection algorithm is as follows:

- (1) First, add all nodes in node A's 1-hop neighbor set *N* whose forwarding intention is WILL\_ALWAYS, that is, the value of N\_willingness is 7 to MPR set *M*;
- (2) If there is a node in the set *N2* that is not covered by at least one node in the set *M*, then calculate the integrated link index  $L(y_i)$  of each node  $y_i$  in the set *N*.
- (3) Compare the link index  $L(y_i)$  of each node in set *N*, and add the node with the largest  $L(y_i)$  value to set *M*. If the value of  $L(y_i)$  is the same, the node with the

largest  $N\_willingness$  is selected to join the set  $M$ . Then, the nodes in the  $N2$  set that are covered by the nodes in the existing  $M$  set are removed.

- (4) If the  $N2$  set is not empty, go back to step (2); if the  $N2$  set is empty, then set  $M$  is the final MPR set of node  $A$ .

## 4 Simulation and Performance Analysis

### 4.1 Simulation Setup and Metrics

In this paper we analyze OLSR, OLSR with L routing protocol using NS2 (Network Simulator 2) version 2.35 and the performance analysis is done using AWK script. In order to accurately simulate the movement scenes of FANETs, after analyzing the actual situation, the mobility model of UAV nodes uses PPRZM. For the simulated wireless propagation model, the two-path propagation model, the Rice fading model, can be used to more realistically simulate the actual fading of FANETs communication, corresponding to the Two Ray Ground model in NS2. The parameters of the simulation scenario are shown in the following Table 1.

**Table 1.** Simulation parameters

Parameters	Values
Simulation tools	NS2 (version 2.35)
Simulation duration	200 s
Mobility model	PPRZM
Propagation model	Two Ray Ground
MAC protocol	IEEE 802.11
Simulation area	3000 m × 3000 m
Number of nodes	50
Speed	0–30 m/s
Transmission range	400 m
Data type	CBR
Number of connections	10
Data packet size	512 Bytes

This paper focuses on three performance parameters: Average End-to-end Delay, Packet Delivery Ratio (PDR), and Routing Overheads. PDR is the ratio of the number of successfully received packets to the total number of packets sent during network data transmission. Average End-to-end Delay is the average time taken by the entire message to travel from source to destination. Routing Overheads is the ratio of the number of routing control messages sent through the network over the data messages received. However, since the main research object of this paper is OLSR protocol, the size of

data packet in OLSR is uncertain. In addition, the packet format of Hello message is modified, which further leads to the change of routing control packet size. Therefore, in order to accurately measure the cost of routing control, this paper uses the ratio of the number of packets received by the destination node to the number of bits contained in the routing control packet as the routing overheads measurement standard, that is, the number of routing control packets required for successful transmission of one bit data packet.

## 4.2 Performance Analysis

According to the NS2 simulation parameters described above, the simulation scene is built, and the experimental results are obtained as follows. Figure 2 shows a comparison of PDR. Compared with the original OLSR protocol, OLSR after MPR set selection optimization has a certain degree of improvement in PDR. With the increase of the maximum speed of the nodes, the change of the network topology is further accelerated, the overall PDR shows a downward trend. However, the OLSR that uses node link stability and link transmission quality instead of node degree as the new MPR set selection criterion can better adapt to the rapid topology change scenario. Its performance is better and more stable at high node speed. The main reason is that the movement of the nodes is considered when selecting the MPR node, so that the relative mobility of the link is smaller and the link survival time is longer.

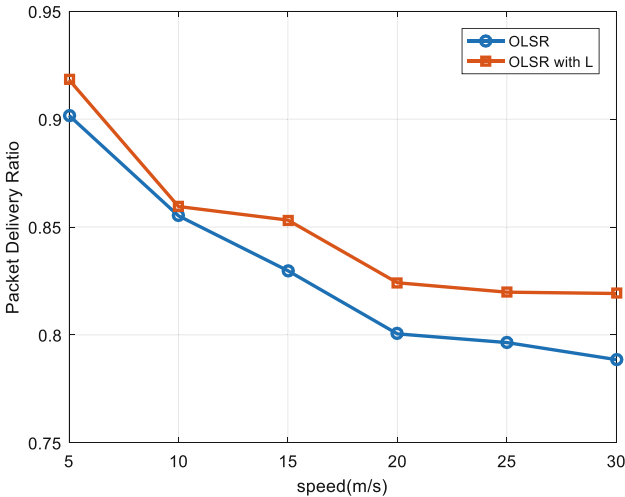
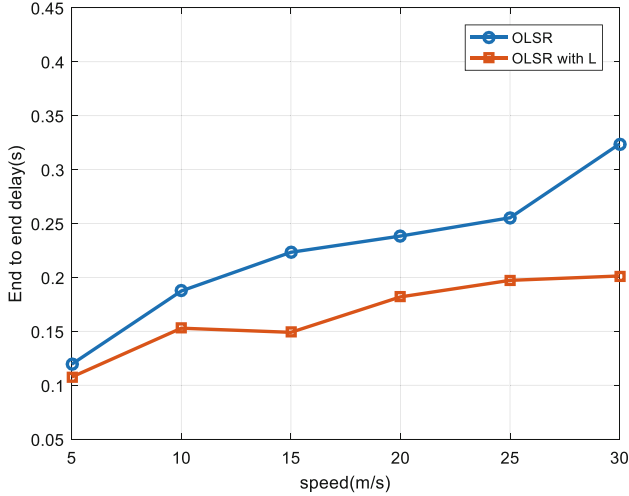


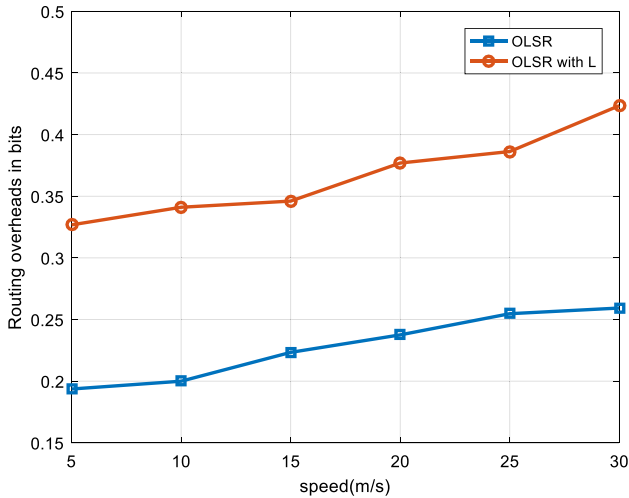
Fig. 2. PDR simulation results under the change of node movement speed

Figure 3 shows the average end-to-end delay simulation of the two routing protocols. From this figure, it can be seen that the average end-to-end delay of the optimized OLSR protocol is less than the original OLSR protocol. When the node speed is low, the algorithm proposed in this paper refers to the link transmission quality when selecting MPR nodes, so although the average delay performance of the two is not much different,

it still has improvement. When the node speed is high, the average end-to-end delay performance improvement is more obvious. The consideration is that the selection algorithm of MPR set in this paper is more stable, which making the communication link more stable, so as to reduce the delay.



**Fig. 3.** Average end-to-end delay simulation results under the change of node movement speed



**Fig. 4.** Routing overheads simulation results under the change of node movement speed

As shown in Fig. 4, it shows the performance comparison of the two routing protocols in terms of routing control overhead. The MPR selection optimization algorithm based

on motion similarity and link transmission quality can effectively reduce the frequency of MPR selector set member changes and reduce the frequency of TC message transmission during route maintenance, so that the cost of route control has been reduced to a certain extent. However, due to the modification of the HELLO packet format in this paper, the size of the HELLO has more than doubled the original OLSR protocol, and OLSR uses a fixed HELLO and TC message transmission interval, this makes the overall routing cost of the optimization algorithm proposed in this paper increase, and the routing control cost increases more obviously when the node moves at a lower speed. This problem is obviously not what we want. In the future, we will listen to the topology changes, and further optimize the routing protocol performance by adjusting the sending interval adaptively.

## 5 Conclusion

This paper first introduces the problems caused by OLSR used in the FANETs scenario, and secondly studies the MPR selection algorithm of OLSR, and introduces an optimized MPR set selection algorithm based on the node link transmission quality and motion similarity. Then, this paper redesigns the MPR set selection criterion, and replaces the node degree with the weighted comprehensive link evaluation index  $L$  to calculate the MPR set. After introducing the design ideas of the optimization algorithm, the implementation process of the algorithm is described in detail. Finally, the simulation compares the three performances of the average end-to-end delay, PDR, and routing overheads of the OLSR and the optimized MPR selection algorithm proposed in this paper, and analyzes the simulation results. As shown in the figures, the optimized MPR set selection algorithm based on node link transmission quality and motion similarity proposed in this paper has improved PDR and average end-to-end delay performance, but it brings greater routing overheads. We will consider adjusting the transmission interval of routing control packets adaptively to reduce routing overheads in the future.

## References

1. OLSR [OL] (2003). <http://www.faqs.org/rfcs/rfc3626.html>
2. Singh, K., Verma, A.K.: Applying OLSR routing in FANETs. In: 2014 IEEE International Conference on Advanced Communications, Control and Computing Technologies (2014)
3. Kumar, P., Verma, S.: Implementation of modified OLSR protocol in AANETs for UDP and TCP environment. *J. King Saud Univ. Comput. Inf. Sci.* (2019)
4. Zheng, Y., Wang, Y., Li, Z., Dong, L., Jiang, Y., Zhang, H.: A mobility and load aware OLSR routing protocol for UAV mobile ad-hoc networks. In: 2014 International Conference on Information and Communications Technologies (ICT 2014) (2014)
5. Zhang, D., Cui, Y., Zhang, T.: New quantum-genetic based OLSR protocol (QG-OLSR) for mobile ad hoc network. *Appl. Soft Comput. J.* **80**, 285–296 (2019)
6. Manimegalai, T., Jayakumar, C.: A conceptual study on mobility models in MANET. *Int. J. Eng. Res. Technol. (IJERT)* **2**(11), 3593–3598 (2013)
7. Bettstetter, C., Hartenstein, H., Pérez-Costa, X.: Stochastic properties of the random waypoint mobility model. *Wirel. Netw.* **10**(5), 555–567 (2004)

8. Liang, B., Haas, Z.J.: Predictive distance-based mobility management for PCS networks. In: Proceedings of the Eighteenth Annual Joint Conference of the IEEE Computer and Communications Societies, INFOCOM 1999, vol. 3, pp. 1377–1384. IEEE (1999)
9. Wang, W., Guan, X., Wang, B., Wang, Y.: A novel mobility model based on semi-random circular movement in mobile ad hoc networks. *Inf. Sci.* **180**(3), 399–413 (2010)
10. Bouachir, O., Abrassart, A., Garcia, F., Larrieu, N.: A mobility model for UAV ad hoc network. In: 2014 International Conference on Unmanned Aircraft Systems (ICUAS), pp. 383–388. IEEE (2014)
11. Mohapatra, S., Tripathy, T.: MM-OLSR: Multi metric based optimized link state routing protocol for wireless ad-hoc network. In: Signal Processing, Communication, Power and Embedded System (SCOPEs), pp. 153–158. IEEE (2016)