Optimization of OLSR Protocol in UAV Network

Kunqi Hong[1], Shuo Shi[1,2(✉)], Xuemai Gu[1,3], and Ziheng Li[1]

[1] School of Electronic and Information Engineering, Harbin Institute of Technology, Harbin 150001, Heilongjiang, China
thiebluesky@163.com, crcss@hit.edu.cn

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

[3] International Innovation Institute of HIT in Huizhou, Huizhou 516000, Guangdong, China

Abstract. In order to make the OLSR routing protocol more suitable for the self-organizing network of UAVs, this article optimizes the transmission method of HELLO messages and TC packets based on the change of the MPR selection method of the OLSR protocol. In order to adapt to the high dynamics and low density of UAV self-organizing network, the relative moving speed and link transmission quality are taken as the selection criteria of MPRs, so that the stability of MPRs can be improved. At the same time, in order to alleviate the routing overhead and energy problems caused by the increase of HELLO data packets, this article monitors the changes in the network and changes the sending frequency of HELLO messages and TC packets to reduce routing without affecting network updates. The problem of overhead and energy consumption. The network simulation is performed under the PPRZM motion model, and the protocol optimization effect is judged by the comparison of the packet delivery rate, the average end-to-end delay and the routing control overhead.

Keywords: OLSR · HELLO · UAV network · MPRS · End-to-end delay · Routing control overhead

1 Introduction

With the continuous development of hardware processors and wireless communication technology, the performance of UAVs has been significantly improved in all aspects, the price is continuously reduced, and the application fields have become more and more extensive. From the previous full-time military field to the civilian field, the company has excellent performance in fire supervision, emergency response, pesticide spraying, information collection, and target tracking. We can foresee that with the improvement of drone communication level and hardware capabilities, drones will gradually develop towards clustering, miniaturization, and intelligence. Compared with a single UAV, the UAV cluster network has a high degree of flexibility, a great

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information coverage, and a very high capacity limit that the UAV cannot compare. It can complete tasks that a single drone cannot.

Compared with the ordinary cellular mobile wireless network, the UAV ad hoc network does not require a base station, and has an incomparable high degree of flexibility and adaptability. It plays an incomparable role in earthquake relief, field exploration, battlefield information confrontation, etc. UAV self-organizing network has the characteristics of ordinary mobile self-organizing network without center, self-organizing network, multiple communications, etc., but also the high mobility of nodes, the sparseness of node density, and the energy autonomy of nodes. These characteristics bring about the extremely high dynamics of the topology of the UAV self-organizing network. Through these characteristics of the UAV self-organizing network, we choose the OLSR active routing protocol as the basis for our optimization. The OLSR protocol uses MPR to forward information and update routing in real time, which is in line with highly dynamic and large-scale UAV networks.

In order to make the OLSR protocol more suitable for the self-organizing network of drones, the OLSR protocol is optimized as follows. First, the selection criteria of MPRs are changed, and the MPR is selected based on mobile similarity and link transmission quality, so that MPRs have stronger stability Performance, reducing the number of updates. At the same time, in order to reduce the routing control overhead caused by the increase of HELLO data packets, we change the transmission frequency of control information by tracking the update status of the network, so as to reduce the routing control overhead while ensuring the timely update of network information.

The rest of paper is organized as follows: Sect. 2 introduces changes to the selection criteria for MPRs, Sect. 3 introduces the tracking of network status and changes in the frequency of control information is given in Sect. 3, Sect. 4 compares the optimized agreement with the original agreement through packet delivery rate, routing control overhead and end-to-end delay. The paper is briefly summarized in Sect. 5.

2 MPRs Selection Algorithm

The original OLSR routing protocol used the connection degree of one-hop nodes as the standard to select MPRs. The purpose is to achieve full coverage of two-hop neighbor nodes by selecting the fewest MPR nodes. However, due to the high dynamics of FANETs, the network topology changes frequently. MPRs need to be updated frequently, which increases the routing control overhead and network response time. Therefore, in order to meet the characteristics of the UAV self-organizing network, We use mobile similarity and transmission stability as the criteria for selecting MPRs to keep the stability of the network link as far as possible, reduce the update frequency of MPRs, and improve link quality. The selection process will be described in detail below.

In FANETs, we can characterize the existence time and stability of the link between the two drones through the relative speed between the two drones, and can obtain the corresponding data through the drone's GPS system, so that each node can know Real-time position and speed information of oneself, in order to calculate the movement similarity between nodes. The mobility similarity of a node refers to the degree of similarity between a UAV node and another adjacent UAV node in the moving speed. Generally speaking, the greater the degree of similarity in the movement behavior between nodes, the link between the two nodes The longer the existence time, the two nodes are considered to be able to maintain a better connection status, otherwise the link between the two nodes is considered to be easily broken. Because in practical applications, the UAV does not change significantly in altitude and is not frequent, so our mobile scene only considers the two-dimensional situation. The speeds of the two drones are v_j and v_i. Then the movement similarity characterizing the relative movement of the two drones is:

$$\theta_{ij} = 1 - \frac{|v_i - v_j|}{|v_i| + |v_j|} \tag{1}$$

For the link transmission quality mentioned above, we characterize the link's evaluation index Expected Transmission Count (ETX) in reference [1], ETX calculates the expected number of retransmissions that are required for a packet to travel to and from a destination. The link quality, LQ, is the fraction of successful packets that were received by us from a neighbor within a window period. The neighbor link quality, NLQ, is the fraction of successful packets that were received by a neighbor node from us within a window period. So the ETX is calculated as follow:

$$ETX = \frac{1}{LQ \times NLQ} \tag{2}$$

In order to calculate and collect data more conveniently and quickly, we divide *ETX* into *MLQ* and *MLQ_L.MLQ* is the ratio of the HELLO message sent by the node from the neighbor node to the HELLO message sent by the node to the neighbor node. *MLQ_L* is the ratio of the HELLO message sent by the neighbor node to the HELLO message sent to the node by the neighbor node. And because the value range of the mobile similarity we defined is [0,1], in order to facilitate the calculation, we define a new value *R_ETX* that characterizes the link quality. The calculation formula is as follows:

$$R\_ETX = MLQ\_L \times MLQ \tag{3}$$

Therefore, we consider the selection criteria of MPRs based on the above two characteristics, and because the MPR node is a relay node that transmits information to a two-hop node, we also need to consider the transitivity of the selection indicator and the amplification during the transmission process. Based on the above considerations, we define a comprehensive link evaluation index L to replace the original link connectivity as the selection criterion for MPR nodes. The formula for calculating L is as follows:

$$L(y_i) = \alpha[\theta_{Ay_i} \text{ average } (\theta_{y_is_j})] + \beta[R\_ETX_{Ay_i} \text{ average } (R\_ETX_{y_is_j})] \quad (4)$$

Among them, A is the node performing MPR set calculation, yi is the 1-hop neighbor node of node A, and sj is the strictly symmetric 2-hop node reachable via yi in the 2-hop neighbor set of node A; represents node A and node yi performing calculation The link stability measure between represents the link transmission quality measure between node A and node yi; average() represents the link index between node yi and all strictly symmetrical 2-hop neighbor nodes sj reachable through this node The arithmetic mean value of; α and β are weight coefficients, and satisfy α + β = 1, and the weight can be adjusted for different network focus directions.

Because of the change in the selection criteria of MPRs, we need to change the format of the HELLO packet. Fill in the moving speed of the node in the X and Y directions, the R_ETX between the selected node and the MLQ of the critical point of the selected node. At the same time, we also need to modify the format of the node's local link information database, the one-hop neighbor table and the two-hop neighbor table. The results of the changes are as follows (Figs. 1, 2, 3, 4):

<table>
<tr><td colspan="2">Reserved(16bits)</td><td>Htime(8bits)</td><td>Willingness(bits)</td></tr>
<tr><td colspan="2">X-direction speed (16bits)</td><td colspan="2">Y-direction speed (16bits)</td></tr>
<tr><td>Link Code(8bits)</td><td>Reserved(8bits)</td><td colspan="2">Link Message Size(16bits)</td></tr>
<tr><td colspan="4">Neighbor Interface Address(32bits)</td></tr>
<tr><td colspan="4">Mobile Similarity θ (32bits)</td></tr>
<tr><td colspan="4">MLQ(32bits)</td></tr>
<tr><td colspan="4">R_ETX(32bits)</td></tr>
<tr><td colspan="4">Neighbor Interface Address(32bits)</td></tr>
<tr><td colspan="4">……</td></tr>
<tr><td>Link Code(8bits)</td><td>Reserved(8bits)</td><td colspan="2">Link Message Size(16bits)</td></tr>
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<tr><td colspan="4">Neighbor Interface Address(32bits)</td></tr>
<tr><td colspan="4">……</td></tr>
</table>

Fig. 1. Modified HELLO packet format

L_local_iface_addr	L_neighbor_iface_addr	L_SYM_time	L_ASYM_time	L_time	Mobile Similarity	MLQ_L	R_ETX

Fig. 2. Modified local link information database format

N_neighbor_main_addr	N_status	N_willingness	Mobile Similarity	R_ETX

Fig. 3. Modified one-hop neighbor table format

N_neighbor_main_addr	N_2hop_addr	N_time	Mobile Similarity	R_ETX

Fig. 4. Modified two-hop neighbor table format

The entire selection process of MPRs is shown in the Fig. 5.

3 Optimization of HELLO Message and TC Packet Transmission

After changing the selection criteria of MPRs in Sect. 2, we have increased the stability of MPRs and reduced the update frequency. But because of the changes to the HELLO packet, the routing overhead for sending HELLO messages has increased. In order to solve the problem of increased routing overhead and energy consumption, we changed the sending interval of HELLO and TC packets, and changed their sending frequency by tracking the real-time status of the network. The fixed transmission interval of the OLSR protocol leads to the following two situations: when the network structure changes rapidly, the OLSR protocol cannot update the network status in time, which greatly reduces the network performance; when the network topology is relatively static, routing control packets It is still being sent relatively frequently, causing the entire network to be flooded with a large number of redundant messages, resulting in a great waste of network resources. However, the number of nodes in the UAV network is usually large and has high mobility. It is very possible that the local topology of the network changes too quickly or the local topology remains stable. Therefore, we learn the changes of the network topology by monitoring the changes of the node link and the MPR selection set, and adjust the sending frequency of HELLO and TC packets in real time and adaptively. In this way, we can reduce routing control overhead while ensuring communication performance.

3.1 Optimization of HELLO Message Sending Interval

The HELLO message is the most basic and most important message structure of the OLSR protocol. It contains the neighbor type, primary address, and link status information of all neighbor nodes of the sending node. It is mainly used in the link awareness and neighbor discovery phases. Local link information base, 1-hop and 2-hop neighbor set establishment and node MPR set calculation. So we can adjust the sending interval of the HELLO message according to the change of the link status.

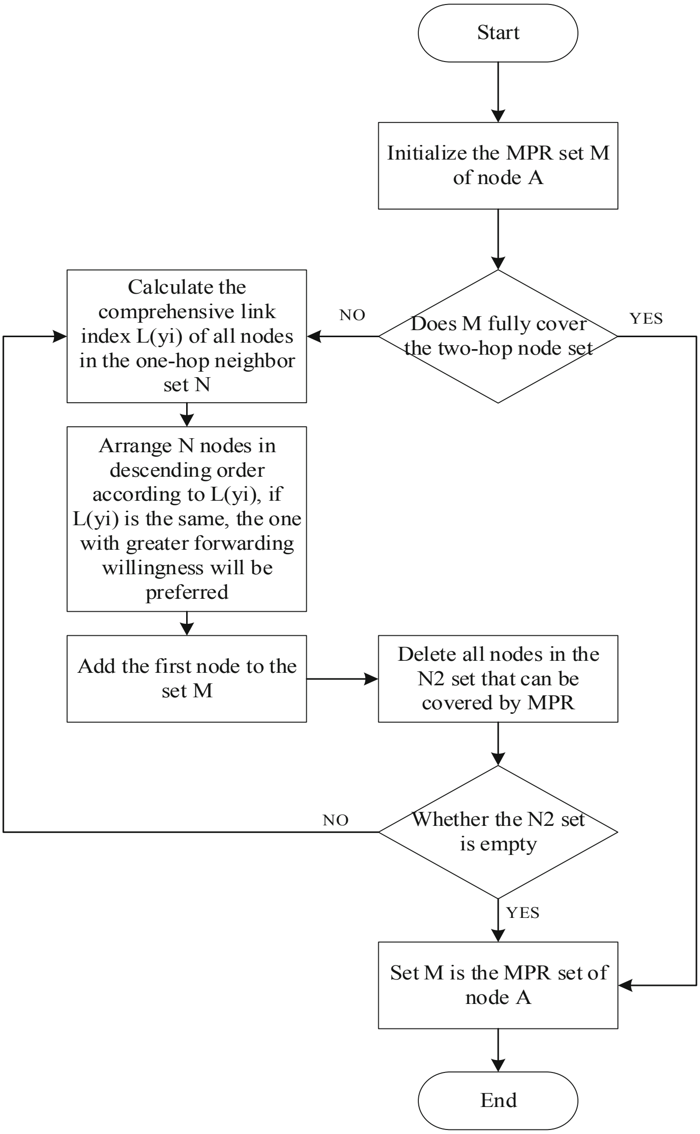

Fig. 5. MPRs selection algorithm process

We set the flag to indicate the three states of the link. SYM_LINK represents that the link is a two-way symmetric link, and both nodes can send and receive data packets to each other; ASYM_LINK represents that the link is an asymmetric link and can only receive each other The message sent by the node; LOST_LINK represents that this link has failed, and both nodes cannot send data packets. After that, we set a link change counter (LCC) inside the node to monitor the link status of the node. The LCC calculation formula is as follows, where New represents the number of new elements in the local link information database, ASYM is the number of times the link identifier changes to ASYM_LINK, SYM This is the number of times the link ID has changed to SYM_LINK.

$$LCC = 3 * New + 2 * ASYM + 1 * SYM \quad (5)$$

The HELLO message sending interval HELLO_INTERVAL set by the OLSR protocol is 2 s. This paper assumes that the lower limit of the HELLO message sending interval is HI_MIN = HELLO_INTERVAL − ΔHI, and the upper limit value is HI_MAX = HELLO_INTERVAL + ΔHI, and ALCC is the average value of LCC in a sending interval of a node. Then, the calculation formula of the adaptive HELLO message sending interval HI is as follows:

$$HI = \begin{cases} HELLO\_INTERVAL + \Delta HI, \ 0 \le x < 0.5 \\ -2 * \Delta HI * x + 2 * \Delta HI + HELLO\_INTERVAL, \ 0.5 \le x < 1.5 \\ HELLO\_INTERVAL \text{ - } \Delta HI, \ 1.5 \le x \end{cases} \quad (6)$$

x = LCC = ALCC.

3.2 Adaptive Optimization of TC Grouping

The TC packet (topology control packet) is used in the topology discovery phase of the OLSR protocol, broadcast to the entire network through the MPR mechanism, and provides topology connection information for subsequent node routing table calculations. In the network, only the nodes that are added to the MPR set can generate and send TC packets; and in addition to the preset TC packet update cycle, if the MPR selection set of the MPR node changes, the MPR node will send TC group for routing maintenance process. Based on the above two reasons, the adaptive transmission frequency of TC packets can be measured by the change of the node's MPR selection set.

An MPR selection change counter MSCC is set in the node, which is activated when the node is selected as the MPR node. It is used to monitor the change status of the node MPR selection set within a sending interval TC_INTERVAL to complete the adaptive adjustment of the TC packet sending interval. The counting rule of this counter is that when the MPR selection set of the node changes, the counter MSCC will increase by 1.

The default TC packet sending interval of the OLSR protocol is TC_INTERVAL, and its value is 5 s. Now suppose that the maximum sending interval TCI_MAX of TC packets is 8 s. Then the calculation method of the transmission interval TCI of the TC packet is as follows:

$$TCI = \begin{cases} TC\_INTERVAL, \ MSCC \neq 0 \\ TCI_{last} + 1, \ MSCC = 0 \end{cases} \quad (7)$$

TCI_{last} is the last TC packet transmission interval, and $TCI \in$[TC_INTERVAL, TCI_MAX].

4 Simulation and Conclusion

This paper mainly focuses on the simulation of three parameters. The end-to-end delay represents the time consumed by the data packet sent by the source node in the network from the moment it was sent to the destination node. The average end-to-end delay is the average of the time consumed by all successfully received data packets. The packet delivery rate represents the percentage of the total number of data packets successfully received by the destination node to the number of data packets sent by the source node during the network data transmission process. The routing control overhead index refers to the ratio of the number of bits of the data packet received by the destination node to the number of bits contained in the routing control packet, that is, the number of bits of the routing control packet required to successfully transmit 1 bit of data. OLSR is the original OLSR protocol, OLSR-M is the OLSR protocol optimized for the MPR selection standard, and OLSR-MI is the OLSR protocol optimized for the transmission frequency of OLSR-M.

From the above simulation results, we can see that by changing the selection criteria of MPRs, we have improved the packet delivery rate of the OLSR protocol and reduced the end-to-end delay. But because we added speed and other information in the HELLO data packet, the control information overhead becomes larger. However, by optimizing the sending interval of the TC group and the HELLO message, the control overhead has been significantly reduced, while maintaining an excellent end-to-end delay and packet delivery rate. Through the above analysis, we can see that our optimization of OLSR is successful (Figs. 6, 7, 8).

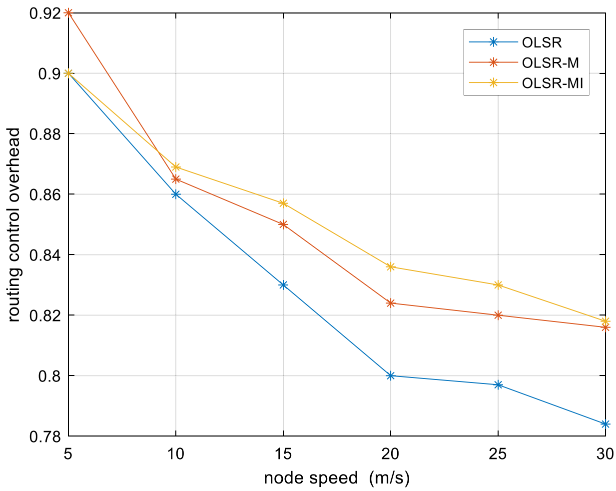

Fig. 6. Packet delivery rate

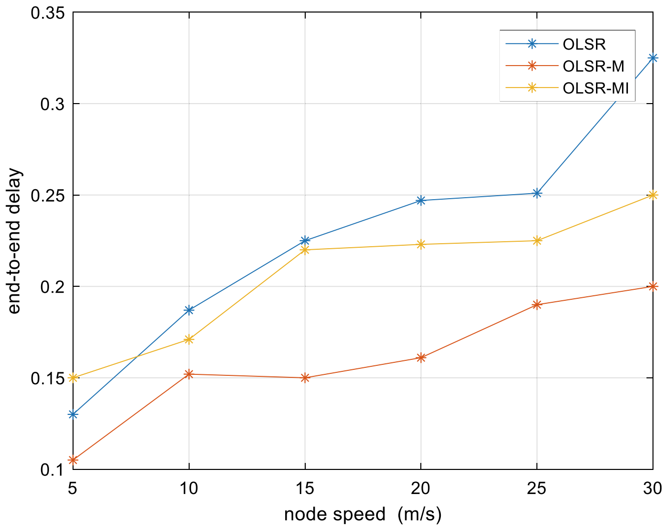

Fig. 7. End-to-end delay

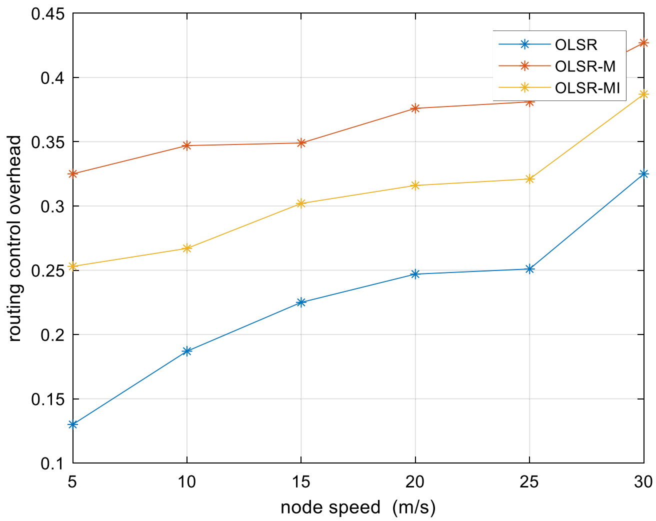

Fig. 8. Routing control overhead

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