



OLSR Protocol Optimization Based on Node and Link Stability

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Abstract. As UAV (unmanned aerial vehicle) formation is more and more widely applied in the real environment, how to effectively organize a communication network between UAVs is the main research hotspot and difficulty at present. The characteristics of UAVs, such as flexible movement, limited load and limited communication distance, pose great challenges to the design of communication protocols. After years of development, unmanned aerial vehicle Ad hoc network has gradually become the key technology in this field. This paper focuses on the classical routing protocol in the UAV Ad hoc network, optimizes the Link State routing protocol (OLSR), and further optimizes and tests the advantages and disadvantages of it. The optimized routing protocol is more suitable for the complex environment of UAV, and further improves the network transmission performance.

Keywords: UAV · FANETs · OLSR · MPR

1 Introduction

With the rapid development of electronic devices, sensors and communication technology, more and more unmanned aerial vehicles (UAVs) are coming into people's sight. These systems are capable of flying autonomously and can carry out special missions without any intervention from external operations. Because of their versatility, flexibility, ease of installation, and minimal operational costs for redeployment, the use of UAVs offers a new approach for several military and commercial applications. For example, map exploration, target search, network relay [1], disaster monitoring, remote sensing and traffic management [2]. While the systems for single UAVs are fairly mature and have been developed for decades, the development and deployment of a fleet of small UAVs is just beginning. There are many advantages to operating a large unmanned aerial vehicle. However, with the broader application, there are challenges unique to multi-UAV systems. Prominent among the challenges is the design of communication networks between multiple UAVs.

In this paper, Flying Ad-hoc Networks (FANETs), a proprietary network architecture of UAVs is adopted. This Ad hoc network between UAVs is considered as a new form

of networks. The unique structure and characteristics of UAVs Ad hoc network have aroused close attention to its solutions and a series of open research. FANETs is able to use the wireless device on the drone as a mobile terminal, but also let the terminal function as a router, without the help of infrastructure such as base stations for network communication. Each node on the network is automatically configured to connect to each other, enabling dynamic networking and rapid deployment. This complex distributed network provides a new solution for designing a flexible and powerful data transmission network.

Because FANETs is restricted by UAV cluster carriers and functions, the routing protocols used in traditional MANETs and VANETs usually cannot directly adapt to the scenarios where FANETs topology and routing information change strongly, thus affecting the communication performance of the whole network. Therefore, it is necessary to design a routing protocol suitable for FANETs scenario to support the communication function of UAV formation. At present, a series of drafts on Ad-hoc routing published officially provide developers and researchers with reference to design the best routing protocol suitable for different application scenarios [3].

This paper focuses on the Optimized Link State Routing (OLSR) protocol for mobile Ad-hoc networks and its implementation and improvement in the context of UAV networks. By optimizing the classical link algorithm and combining with the actual demand of mobile Ad hoc network, the expert group designed the OLSR routing protocol. It inherits the stability of the original link-state algorithm and uses table-driven management scheme. OLSR is an active routing protocol. In the process of transmission, the nodes of the network will exchange the network information in their information base with the surrounding nodes at a fixed frequency. The routing overhead of OLSR protocol is large but relatively fixed, but its overhead is related to the size of the network. Using active routing to establish routing table and maintain it in real time, the end-to-end delay performance in the network is better. Therefore, it is more suitable for the QoS requirements of communication networks in FANETs scenarios.

2 Related Work

As the root of FANETs, MANETs technology has gone through a long process of research. DAERA was the first to design and research mobile Ad hoc networks on behalf of the U.S. government. In June 1997, the Internet Engineering Task Force (IETF) established the MANET Working Group. The establishment of the MANET enabled the commercial process to move forward quickly.

With the deepening of MANET research, its combination with unmanned aerial vehicle network has gradually emerged in the sight of researchers. S. Temel and Bekmezci designed the architecture for the combination of High-Altitude Platform (HAP) and FANETs to become one of the most promising technologies for military and civilian near space wireless networks in [4]. The HAP system resides in the stratosphere and solves the challenging problem of identifying the location of neighboring UAVs in FANETs. It plays an important role in reliability, security and conflict avoidance, and then proposes a media access control (MAC) protocol.

S. Temel and Iens. Bekmezci argue in [5] that interference brought by simultaneous transmission in FANETs limits the maximum amount of concurrent communication, so

the deployment of traditional omnidirectional antennas cannot effectively improve the spatial reuse rate. In this regard, they put forward a scheme to set up directional antennas to increase the space reuse rate and network capacity of FANETs. An analysis model is proposed to analyze the influence of different UAV flight types and different flight scenarios on the transmission information between communication nodes. K. Singh and A. K. Verma proposed the application of OLSR routing protocol in FANETs scenario in [6], and also focused on the network performance of OLSR under different mobility models of UAVs, and put forward guidance on how to continue to optimize. Y. Mostafaei and S. Pashazadeh analyzed the problems caused by the direct application of OLSR routing protocol in FANETs, and pointed out that the OLSR routing protocol did not fully consider the mobility of nodes in the process of MPR selection, leading to link disruption in [7].

In this paper, a new selection method is proposed, in which as many as possible nodes that are prevented from moving violently are selected as relay nodes. According to the simulation results, this method increases the network lifetime. Alamsyah et al. established the wireless network model of health monitoring system in [8]. The performance of AODV, DSDV and OLSR routing protocols is compared by simulation, and the performance of the three protocols in different scenarios is evaluated by delay, throughput and packet delivery rate. Through research, it is found that OLSR has better performance in the mobile terminal, especially when the node of the mobile terminal is above 50. Therefore, OLSR routing protocol is more suitable in FANETs scenario.

3 Problem Description

The problems related to flooding are collectively called Broadcast Storm Problem. In the OLSR routing protocol, three schemes are adopted to avoid broadcast bursts in AD hoc networks [9]:

- 1) The protocol selection adopts the multi-point relay technology, that is, only the MPR relay node selection algorithm is used to select the nodes with high connectivity to forward the control packets sent by the source nodes, avoiding the waste of network resources caused by unrestricted replay in the flooding mechanism.

- 2) According to the protocol, only selected MPR nodes are allowed to generate link-state information to participate in the calculation and generation of routing tables, which can effectively reduce the number of control packets transmitted in the network and reduce the control overhead of network protocols.

- 3) MPR nodes selected by the algorithm can choose to broadcast only the link information between themselves and their MPR selectors, so as to further reduce the control overhead.

By analyzing the MPR set selection algorithm in RFC3626 specification of OLSR routing protocol, it is not difficult to see that OLSR protocol, as a link-state based first response routing, can effectively reduce the network control overhead because of the MPR set generation and selection process [10]. The nodes in the network will select multiple appropriate relay nodes in their one-hop neighbor table by the algorithm, and each node is independent of each other in this process. Whether the relay node selection is optimal is whether all the two-hop neighbors under this selection can be covered by

nodes in the MPR node set. The MPR selection scheme in the original OLSR protocol uses a greedy selection algorithm. The greedy algorithm has a fast convergence rate and requires fewer computing resources. However, in the greedy strategy adopted by MPR algorithm in OLSR routing protocol, the generation of MPR sets depends on the connection degree of nodes in the one-hop neighbor table. In this way, an appropriate MPR relay node can be quickly selected, which greatly reduces the transmission of control packets in the network, reduces the flooding of link information when routing information is broadcast, and gives full play to the advantages of OLSR protocol.

However, for the existing operational network architecture of unmanned aerial vehicles, the movement speed of the UAV itself is an important factor that cannot be ignored. The current UAV speed is up to hundreds of km/h. If the multi-point relay MPR set selection algorithm in the original protocol is still adopted, the update frequency of network topology information may not catch up with the change frequency of network topology structure. Under the influence of the drastic change of network topology, the UAV is likely to move out of the communication range before completing the transmission task, resulting in the unreachable network.

Therefore, an optimized MPR set selection algorithm should be designed. The consideration of this algorithm is not only based on the connectivity of one-hop neighbor nodes and the willingness of nodes, but also the moving speed of current nodes, link change rate and other factors affecting network transmission. In the MPR selection algorithm, the emphasis of the original OLSR on node willingness is changed to the emphasis on node quality. Nodes can get indicators to describe whether they are suitable as relay nodes by sensing the changes in the surrounding topology. Based on the size of this metric, the source node will decide whether to add it to the MPR node or participate in the comparison consideration with other nodes. In this way, a comprehensive selection algorithm is implemented, which makes FANETs more capable of resisting the impact of drastic changes in network topology and link breaks on transmission.

4 Proposed Algorithm

From the above analysis, we can know that OLSR limits the scale of message flooding in the network through its unique MPR mechanism. Therefore, when selecting which nodes can be used as MPR relay nodes, relatively stable nodes and links can be selected in advance, which plays a key role in improving the transmission performance of the network. In this paper, it is defined as a measure of FANETs node mobility, which includes node stability and link stability.

Node stability is defined as the degree of change of the neighbor set between a node and all its neighbors. The higher the stability is, the lower the relative mobility of its neighbors, the smaller the change of the surrounding topology of the node, the smaller the impact on routing performance, and the shorter the time of routing recovery after route breakage. Link stability is defined as the remaining lifetime of a link. The higher the stability is, the longer the link can guarantee the transmission link, which plays a key role in the stability of the path. When establishing a complete stability evaluation mechanism, node stability and link stability should complement each other. Node stability can only estimate the topological changes of neighboring nodes quantitatively, while link stability

can obtain the moving direction and speed of nodes by GPS devices, and estimate the remaining life time of links accordingly, so that nodes can select stable links in advance.

4.1 Stability Evaluation Mechanism Based on Node

In order to measure the neighbor changes of each node in FANETs, the concept of node stability is introduced. The basic idea of the algorithm is to measure the rate of change of the neighboring nodes through the stability of the node, so as to obtain the description of the stability degree of the node. The basic idea is to evaluate the stability by the HELLO packets passed between nodes and the rate of change of neighbor table entries of nodes. The neighbor stability of node i is defined in Eq. (1).

$$NS_i = \frac{|S_{i_t} \cap S_{i_{t+\Delta t}}|}{|S_{i_t} \cup S_{i_{t+\Delta t}}|} \quad (1)$$

where S_{i_t} is the neighbor set of node i at time t , after time Δt , that is, the neighbor set of node i at time $t + \Delta t$ is $S_{i_{t+\Delta t}}$. The value of NS_i is between 0 and 1, that is, the stability of node i is between 0 and 1.

Based on the evaluation method of node stability, the first optimization scheme of OLSR protocol is proposed. In this optimization protocol, a weight model of node stability is proposed, which takes both node stability and connectivity as greedy strategies to participate in the MPR node screening algorithm, and to participate in the mechanism of evaluating whether the node is suitable for MPR node. The comprehensive link evaluation index L is calculated by formula (2).

$$L(y_i) = NS_i * D(y_i), i \in [nb] \quad (2)$$

The comprehensive link evaluation index L is used as the standard to evaluate whether the adjacent node is suitable to join the MPR node.

4.2 Stability Evaluation Mechanism Based on Link Mobility Prediction

To properly assess the lifetime of a communication link between two nodes, we need to make additional assumptions about how each node is configured. It is assumed that any two UAV nodes can communicate bidirectionally in FANETs, and the radius of communication transmission range of each node is R . Moreover, each network node is equipped with GPS, and the node can perceive the position, speed and time information and periodically send its coordinates, speed and other information to the neighbor node. At this time, each node receives the message sent by the neighbor node and extracts the geographical location information according to the received information to predict the remaining lifetime of each link, so as to obtain the link stability of the node. The survival time of the two nodes is calculated as follows.

The initial distance of two nodes M and N is d , and the link life cycle is estimated as shown in Fig. 1. Calculating the remaining time of link MN is to estimate the time of node N within the transmission radius R of node M . The relative motion of two nodes

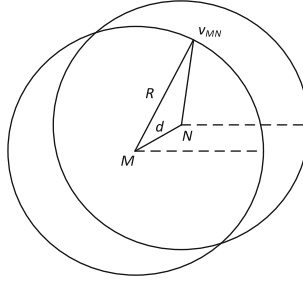


Fig. 1. Link lifetime estimation between two nodes

can be regarded as one node being stationary and the other node moving. In this way, the position of node M relative to node N can be calculated as the following Eq. (3).

$$(x_{MN}, y_{MN}) = (x_N - x_M, y_N - y_M) \quad (3)$$

In this case, the distance between M and N is shown in Eq. (4).

$$d = \sqrt{x_{MN}^2 + y_{MN}^2} \quad (4)$$

Since the two nodes are in relative motion, after time t , the position of node M relative to node N is

$$\begin{aligned} x'_{MN} &= x_{MN} + |v_{MN}|t \cos \theta_{MN} \\ y'_{MN} &= y_{MN} + |v_{MN}|t \sin \theta_{MN} \end{aligned} \quad (5)$$

In Eq. (5), θ_{MN} is the velocity angle between node M and node N , and v_{MN} is the velocity between node M and node N . When the distance between them is R , the link is broken.

$$d' = \sqrt{x'^2_{MN} + y'^2_{MN}} = R \quad (6)$$

Substitute Eq. (5) into Eq. (6) to obtain the following Eq. (7).

$$|v_{NM}|^2 t^2 + 2|v_{NM}|(x_{NM} \cos \theta_{NM} + y_{NM} \sin \theta_{NM})t + d^2 - R^2 = 0 \quad (7)$$

$$\begin{aligned} v_M &= (|v_M| \cos \theta_M)i + (|v_M| \sin \theta_M)j \\ v_N &= (|v_N| \cos \theta_N)i + (|v_N| \sin \theta_N)j \end{aligned} \quad (8)$$

$$v_{NM} = v_N - v_M = (|v_N| \cos \theta_N - |v_M| \cos \theta_M)i + (|v_N| \sin \theta_N - |v_M| \sin \theta_M)j \quad (9)$$

$$|v_{NM}| = \sqrt{(|v_N| \cos \theta_N - |v_M| \cos \theta_M)^2 + (|v_N| \sin \theta_N - |v_M| \sin \theta_M)^2}$$

$$\theta_{NM} = \tan^{-1} \left(\frac{|v_N| \sin \theta_N - |v_M| \sin \theta_M}{|v_N| \cos \theta_N - |v_M| \cos \theta_M} \right) \quad (10)$$

In Eq. (10), θ_M is the moving direction of node M , θ_N is the moving direction of node N , v_M is the speed of node M , and v_N is the speed of node N . Since t cannot be negative, it can be evaluated as Eq. (11).

$$t = \frac{\sqrt{R^2 - (x_{MN} \sin \theta_{MN} - y_{MN} \cos \theta_{MN})^2} - (x_{MN} \cos \theta_{MN} + y_{MN} \sin \theta_{MN})}{|v_{MN}|} \quad (11)$$

The link stability is defined as Eq. (12).

$$LS_{MN} = \frac{t}{t_{max}} = \frac{t}{\frac{R}{|v_{MN}|}} \quad (12)$$

$$= \frac{\sqrt{R^2 - (x_{MN} \sin \theta_{MN} - y_{MN} \cos \theta_{MN})^2} - (x_{MN} \cos \theta_{MN} + y_{MN} \sin \theta_{MN})}{R}$$

In Eq. (12), x_{MN} is the difference of abscissa between node M and node N , y_{MN} is the difference of ordinate between node M and node N , the value of LS_{MN} is between 0 and 1 when the two nodes are gradually away from each other, and greater than 1 when the two nodes are gradually close to each other.

Based on the evaluation method of the link stability, a second OLSR protocol optimization scheme is proposed. In this optimization protocol, a weight model that can refer to the link stability between nodes is proposed, and a greedy strategy is taken into consideration of link stability and node connectivity to participate in the MPR node screening algorithm, which is involved in the mechanism of evaluating whether the node is suitable for MPR node. The comprehensive link evaluation index L can be calculated by the calculation formula, see Formula (13).

$$L(y_i) = \sum LS_{y_i s_j}, i \in [nb], j \in [nb2hop] \quad (13)$$

The comprehensive link evaluation index L is used as the standard to evaluate whether the adjacent node is suitable to join the MPR node.

4.3 Evaluation Mechanism of Integrated Node Stability and Link Stability

The comprehensive stability of nodes and links can be obtained by integrating the two mechanisms: the rate of change of nodes' neighbors and the prediction of the remaining lifetime of link MN, as shown in Eq. (14).

$$PS_{MN} = \lambda_1 NS_N + \lambda_2 LS_{MN} \quad (14)$$

In the formula, λ_1 and λ_2 are the change rate of node neighbors and the selection coefficient of link stability respectively, which are between 0 and 1, and their value is dynamically adjusted according to the network type and state. The value of PS_{MN} will directly affect whether the node is suitable as a relay node in MPR. The proposed algorithm can comprehensively consider node stability, link stability and node connectivity to obtain a comprehensive link evaluation index L . The calculation method is shown in Eq. (15).

$$L(y_i) = \lambda_1 \overline{LS_{y_i s_j}} + \lambda_2 NS_i, i \in [nb], j \in [nb2hop] \quad (15)$$

5 Simulation Results

We use NS2 to simulate the OLSR protocol and its optimization part. Both node stability and link stability are integrated to test the final impact of MPR node selection algorithm on the network performance of OLSR routing protocol after the design of weighted comprehensive link evaluation mechanism. By comparing the experiment with the original protocol, when the maximum moving speed of the node is between 5 m/s and 30 m/s, the simulation interval is 5 m/s, and the control overhead (Fig. 2), end-to-end delay (Fig. 3) and packet loss rate (Fig. 4) vary with the moving speed of the node:

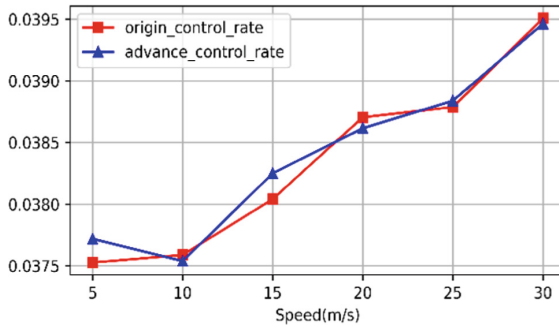


Fig. 2. Comparison of network control overhead between original and optimized protocols

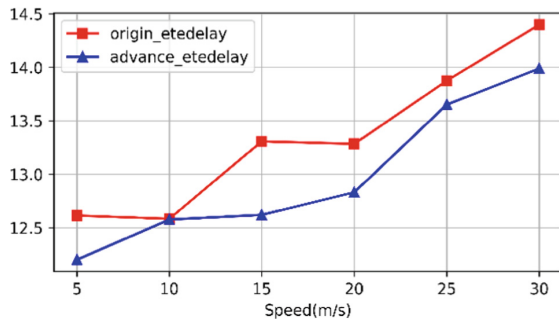


Fig. 3. Comparison of network end-to-end delay between original and optimized protocols

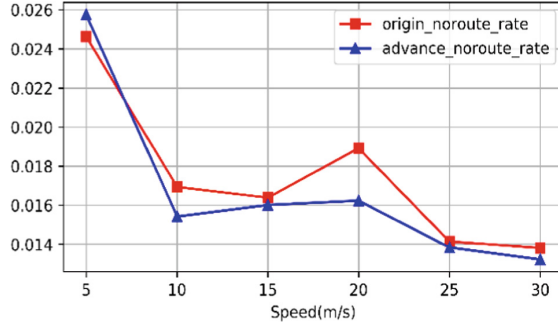


Fig. 4. Comparison of network packet loss rate between original and optimized protocols

At the same time, this paper also considers the influence of protocol optimization on network throughput. We focus on the network throughput changes over time when the number of network nodes is 20, the maximum moving speed of nodes is 20 m/s, and the moving range of nodes is 500 m*500 m. The link evaluation mechanism protocol, which integrates node stability and link stability, is compared with the original protocol, as shown in Fig. 5.

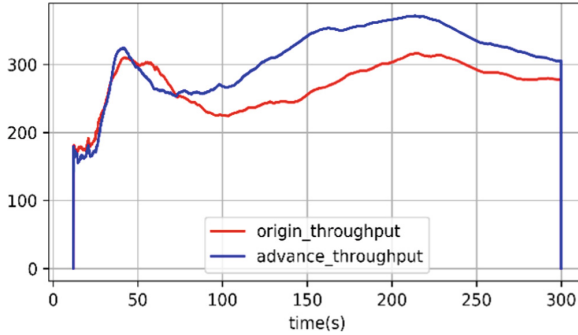


Fig. 5. Network throughput comparison between original and optimized protocols

According to the experimental results, we can see that the routing protocol that integrates two optimization schemes of node stability and link stability can improve the network performance in end-to-end delay and packet loss rate without increasing the network control overhead. In the experimental results of throughput change, we can see that when the network is just established and in the node exploration link exploration stage, there is basically no difference in throughput between the two protocols. After a period of time, when the network topology is basically established and data transmission service is the main work, the throughput performance of the optimized protocol is significantly better than that of the original protocol. Therefore, it can be confirmed that the scheme achieves the purpose of MPR node selection optimization algorithm.

6 Conclusion

This paper focuses on the MPR node selection algorithm of standard OLSR protocol, and points out that the greedy strategy adopted in the greedy algorithm is not completely suitable for FANETs mobile scenario. A link stability evaluation mechanism based on node stability and link prediction is proposed. The design principle of the evaluation mechanism is pointed out in detail. After the OLSR routing protocol using this mechanism is investigated, the network performance indexes of routing cost, end-to-end delay, packet delivery rate and throughput rate are investigated. Through comparison, it is found that the end-to-end delay, packet delivery rate and throughput rate are improved to a certain extent without significantly increasing the routing overhead.

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