OLSR-Based Multipath Routing Strategy for UAV Ad Hoc Networks (Postprint)

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Abstract

In recent years, the application of unmanned aerial vehicles (UAVs) has become increasingly widespread, and the coordination of multiple UAVs to accomplish tasks has substantially improved operational efficiency. Motivated by this phenomenon, numerous scholars have devoted themselves to research on communication methods for UAV swarms, with routing protocols consistently representing a key focus of network research. To address the problem in existing literature where routing metrics selected for routing protocol studies fail to incorporate the current performance level of UAV ad hoc networks, thereby leading to unreasonable routing decisions, this paper proposes an Optimized Link State Routing Protocol based on Multi-indicator and Multi-Path (MIMP-OLSR) with load-aware and network topology change-aware capabilities. The protocol first considers node mobility characteristics in UAV scenarios and network lifetime, and defines three metrics for routing selection: node MAC-layer blocking degree, node neighbor change rate, and the number of MPR_S (Multi-Point Relay Selector) neighbors. Second, it proposes a metric advertisement mechanism that combines HELLO and TC control messages to flood metric information to all nodes in the network. Finally, based on the metric information, a multipath routing scheme is proposed. Simulation results demonstrate that, compared with OLSR, SETT_{MPOLSR}, and UAV-OLSR protocols, the proposed MIMP-OLSR protocol achieves significant improvements in success rate, end-to-end delay, and throughput performance, thereby proving the rationality of the proposed multipath routing scheme.

Full Text

Multi-path Routing Strategy for UAV Ad-hoc Networks Based on OLSR Protocol

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Abstract

In recent years, drone applications have become increasingly prevalent, with multiple drones collaborating to complete tasks, thereby significantly improving work efficiency. Motivated by this phenomenon, numerous scholars have devoted themselves to researching communication methods for UAV swarms, where routing protocols remain a central focus of network research. Existing literature on routing protocols often selects routing metrics that fail to incorporate the real-time performance characteristics of UAV self-organizing networks, leading to suboptimal routing decisions. To address this issue, we propose a Multi-indicator and Multi-Path Optimized Link State Routing Protocol (MIMP-OLSR) with load awareness and network topology change awareness. The protocol first considers node mobility characteristics and network lifetime in UAV scenarios, defining three metrics for routing selection: MAC layer blocking degree, neighbor change rate, and MPR_S (Multi-Point Relay Selector) neighbor count. Second, it introduces a metric advertisement mechanism that leverages HELLO and TC control messages to flood metric information throughout the network. Finally, based on this metric information, a multi-path routing scheme is proposed. Simulation results demonstrate that compared with OLSR, SETT_{MPOLSR}, and UAV-OLSR protocols, the proposed MIMP-OLSR protocol achieves significant improvements in success rate, end-to-end delay, and throughput performance, thereby validating the rationality of the proposed multi-path routing scheme.

Keywords: UAV Ad-hoc network; OLSR; multi-indicator and multi-path routing; HELLO message; TC message

0 Introduction

UAV Ad-hoc Networks (UANETs), as a special type of Mobile Ad-hoc Network (MANET) [?], not only inherit the decentralized and self-organizing characteristics of MANETs [?], but also exhibit unique properties such as low regional coverage, high node mobility, and stringent communication delay requirements. Due to the high flexibility and convenience of drones, UANETs have attracted widespread attention in recent years.

Routing protocols, as the core technology of ad-hoc networks, have always been a hot research topic in this field. Based on whether routes are established before data arrival, existing routing protocols can be classified into three categories: proactive routing protocols, reactive routing protocols, and hybrid routing protocols [?]. OLSR [?, ?, ?], a proactive routing protocol, has been widely adopted in UAV ad-hoc networks due to its excellent low-latency characteristics.

Current research on OLSR protocols for UAV ad-hoc networks can be broadly divided into two categories: single-path routing and multi-path routing. Multi-path routing protocols maintain multiple routes for data transmission, enabling traffic splitting, which significantly increases network throughput while reducing end-to-end delay [?], thereby substantially improving network performance. Consequently, research on multi-path OLSR protocols is essential, and numerous scholars both domestically and internationally have shown interest in this area.

Literature [?] proposes an energy and queue-aware multi-path OLSR routing protocol (MBQA-OLSR). This protocol defines three node metrics related to energy and Quality of Service (QoS): residual energy, idle time, and queue length, and constructs a new link cost function based on these metrics to measure link quality between nodes. The most effective and reliable path to the destination is calculated, and simulation results demonstrate significant improvements in packet delivery success rate and end-to-end delay performance. However, this protocol does not consider dynamic changes in network topology.

Literature [?] proposes a network coding-based multi-path routing scheme (NC-OLSR) for FANETs (Flying Ad-hoc Networks) based on the principle that network coding can exploit the broadcast nature of wireless channels. This scheme establishes a hybrid multi-path selection model based on neighbor node link quality and designs a network coding-based data transmission scheme for each end-to-end transmission task. However, this protocol does not consider node energy consumption issues.

Literature [?] considers energy and node mobility speed when calculating routes and proposes a multi-path energy and mobility-aware routing scheme based on MP-OLSRv2 by ranking link stability according to these two factors. However, this protocol does not consider node load issues.

Literature [?] employs a Q-learning algorithm to select optimal energy-efficient intermediate nodes and obtain optimal routing based on three state parameters: energy level, mobility, and link quality parameters, ensuring network stability, reliability, and performance over time.

Literature [?] proposes a high-QoS, low-energy multi-path OLSR routing protocol (MEQSA-OLSRv2) using node lifetime, residual energy, idle time, node mobility speed, and queue length as routing metrics.

Literature [?] calculates the expected transmission count and bandwidth values between nodes and proposes a multi-path OLSR routing protocol based on expected transmission time (SETT_{MPOLSR}). However, this protocol does not consider node load and energy issues.

Literature [?] proposes a routing protocol suitable for UAV ad-hoc networks (UAV-OLSR) that addresses the dynamic nature and energy constraints of such networks. The protocol first adjusts the transmission periods of HELLO and TC control messages by sensing network changes based on neighbor variations within HELLO message intervals and topology changes within TC message intervals. Second, it optimizes the MPR mechanism based on link quality and energy. Finally, it proposes a multi-path routing mechanism based on these metrics. However, this protocol sacrifices significant control overhead and lacks description of how network-wide nodes obtain routing metric information.

Building upon the aforementioned research and considering the specific characteristics of UAV scenarios, this paper proposes an improved multi-path routing protocol for UAV ad-hoc networks with load and network topology awareness. The main contributions include: (1) defining multiple metrics that reflect current network performance; (2) proposing a metric advertisement mechanism for network-wide metric information dissemination; and (3) defining an objective function based on the obtained metric information and proposing a multi-path routing scheme.

1 Research on OLSR Protocol in UAV Ad-hoc Networks

As a typical routing protocol in mobile ad-hoc networks, OLSR achieves its goal of enabling nodes to promptly find appropriate routes when data arrives, thereby reducing end-to-end delay, by completing two communication processes: the node joining and discovery process, and the network-wide route generation process based on topology flooding using the shortest path algorithm. These two processes rely on HELLO and TC control messages, respectively.

1.1 HELLO Message Transmission and Processing

In a distributed network using the OLSR protocol, each node broadcasts HELLO messages every 2 seconds within its communication range to update and advertise its currently discovered neighbors and their status information. HELLO messages include three types of neighbor information: asymmetric neighbors, symmetric neighbors, and MPR (Multi-Point Relay) neighbors. A node is set as an asymmetric neighbor if the node can receive HELLO messages from it. If the node and another node complete a three-way handshake of HELLO messages within a valid time, they become symmetric neighbors. Nodes selected by the local node using the MPR selection algorithm based on one-hop and two-hop information are recorded as MPR neighbors.

1.2 TC Message Transmission and Processing

MPR nodes in the network broadcast TC messages every 5 seconds to inform surrounding nodes about the MPR_S (nodes that have selected this node as their MPR) information. MPR and MPR_S nodes are symmetric neighbors of each other. These TC messages are further flooded by the node' s MPR nodes, enabling all nodes in the network to obtain the complete network topology and execute Dijkstra' s algorithm locally using hop count as the routing metric to obtain the shortest route to other nodes.

1.3 Problem Description

For any routing protocol, the routes obtained after completing the full communication process should be rational and reliable. Regarding the route generation process of OLSR, two main problems exist:

a) **Single routing metric.** OLSR uses Dijkstra' s algorithm with hop count as the routing criterion. However, end-to-end delay in data exchange is not solely constrained by hop count; it is also affected by factors such as the current load condition and network change magnitude of the UAV ad-hoc network. Therefore, from a rationality perspective, using only hop count as a single routing metric is insufficient.

b) **Single reachable route.** Most existing literature on OLSR protocols maintains only one reachable route between nodes. Considering that UAV nodes in UANETs may need to exchange substantial data, when the only route experiences interruption due to network congestion or insufficient node energy, data cannot be delivered promptly and will eventually be discarded, significantly degrading network performance. Therefore, from a reliability perspective, establishing only one reachable route when multiple routes exist between source and destination nodes is inadequate.

2 Principle and Implementation of the Improved MIMP-OLSR Protocol

To address the two problems identified in Section 1.3 regarding the route calculation process of OLSR in UAV scenarios, this paper proposes a Multi-indicator and Multi-Path Optimized Link State Routing (MIMP-OLSR) algorithm. The algorithm first adds three routing metrics considering UAV node mobility characteristics, optimizing the rationality of obtained routes. Second, based on these metrics, it proposes a multi-path routing scheme to improve route reliability.

2.1 Multiple Routing Metrics

To address the problem of single routing metric in OLSR for UAV ad-hoc networks, this paper considers three metrics from the perspectives of node load capacity, network topology change magnitude, and network lifetime performance: MAC layer blocking degree, one-hop neighbor change rate, and MPR_S node count. These metrics are defined as follows:

1) **Node MAC Layer Blocking Degree**
In this paper, the complete communication process of OLSR is implemented at the network layer. To achieve reliable transmission, a buffer is established at the MAC layer with an acknowledgment and retransmission mechanism, primarily for retransmitting data packets when the source does not receive the corresponding ACK from the destination within a set time interval. To quantitatively analyze node MAC layer blocking degree,

the buffer usage rate at the MAC layer is considered. At any given moment, there are seven types of packets in the buffer: data packets to be sent (s_d), data packets to be forwarded (f_d), HELLO packets to be sent (s_H), TC packets to be sent (s_T), TC packets to be forwarded (f_T), retransmitted data packets (ret_d), and ACK packets (ack_num), with counts denoted as num_{s_d}, num_{f_d}, num_{s_H}, num_{s_T}, num_{f_T}, num_{ret_d}, and num_{ack}, respectively, as shown in Equation (1). Assuming the buffer size is L, the node MAC layer blocking degree C is defined as:

$$C = \frac{num_{s\_d} + num_{f\_d} + num_{s\_H} + num_{s\_T} + num_{f\_T} + num_{ret\_d} + num_{ack}}{L}$$

When calculating routes, nodes with smaller MAC layer blocking degree are preferred to reduce node load and consequently decrease end-to-end delay in data exchange.

2) **Node One-hop Neighbor Change Rate**
The one-hop neighbor change rate represents the ratio of changed neighbor count to original neighbor count between two HELLO message transmission moments, quantitatively estimating the magnitude of network topology changes around a node. In OLSR, nodes update their topology tables upon receiving TC messages and set the validity time of topology entries, typically three TC message transmission intervals. Therefore, to prevent topology information from becoming invalid, selecting nodes with smaller topology change magnitude as intermediate nodes in complete routes from source to destination is more appropriate. The one-hop neighbor change rate $neighR$ is defined as shown in Equation (2):

$$neighR = \frac{num_{incr} + num_{decr}}{num_{orig}}$$

where num_{incr} represents the number of newly added neighbors between two HELLO message transmission moments, num_{decr} represents the number of reduced neighbors, and num_{orig} represents the original neighbor count before changes.

3) **Node MPR_S Node Count**
MPR_S nodes are those that have selected this node as their MPR. The number of a node' s MPR_S nodes can be obtained from TC message entries and is recorded as num_{MPR_S}. When a node is selected as a relay by multiple MPR_S nodes, it must forward TC messages for these MPR_S nodes. Therefore, a larger num_{MPR_S} results in more residual energy consumption and shorter network lifetime.

2.2 Metric Advertisement Mechanism

To notify all other nodes in the network of each node' s metric information for subsequent route selection, HELLO and TC messages must be utilized. Different processing methods for sending and receiving HELLO and TC messages are adopted based on whether a node is selected as an MPR node (determined by whether the MPR_S set is empty). The specific procedures are as follows:

1) **Sending HELLO Messages**
   In the improved protocol, the HELLO message format of OLSR is modified as shown in Fig. 1. The Reserved field value is either 0 or 1. If the node is an MPR node, Reserved=0; otherwise, Reserved=1. If Reserved=1, node A needs to inform its MPR node of its metric information through HELLO messages (which will then be advertised network-wide by the MPR node through TC messages). Therefore, two additional fields are added to represent the metric information. Reserved=1 indicates that the node selects a node from its MPR set as a forwarding agent for metric information; if Reserved=0, the HELLO message does not contain C and $neighR$ fields. All other processing remains the same as in OLSR.

2) **Receiving HELLO Messages**
   The Reserved field value is extracted. If Reserved=0, HELLO message processing is the same as in OLSR. Otherwise, after receiving the HELLO message, the metric information is recorded in the node' s memory (assuming an exploration table is used for storage, with structure shown in Table 1).

Table 1. Structure of Exploration Table

Forwarding Node P	P' s C Value	P' s neighR Value	Flag_{forward}	Delete_{time}

The exploration table contains five entries: the node P whose information is to be forwarded, P's C value, P's neighR value, a flag indicating whether forwarding is needed, and the entry expiration deletion time. All other processing remains the same as in OLSR.

3) **Sending TC Messages**
   The improved protocol achieves network-wide metric advertisement by adding C and $neighR$ information to TC messages and flooding them. The modified TC message packet format is shown in Fig. 2, where C and $neighR$ form a pair of metric information for a node. The Reserved field value indicates the number of metric pairs, i.e., the number of nodes requiring metric information forwarding, with Reserved ≥ 1. After processing HELLO messages, the exploration table is traversed, and the following judgments are made:

- If the exploration table is empty, only the node' s own C and $neighR$ information is added to the TC message, with Reserved=1.
- If the exploration table is not empty, the node' s own metric pair and the metric pair of nodes requiring information forwarding (which are also MPR_S nodes) are added to the TC message, with Reserved > 1. To map metric information to MPR_S nodes, the sequence of MPR_S nodes in the TC message corresponds to the sequence of metric pairs. When Reserved > 1, the first MPR_S node corresponds to the first metric pair, with the node' s own metric pair added at the end.

All other processing remains the same as in OLSR.

4) **Receiving TC Messages**
The C and $neighR$ information from TC messages is mapped to corresponding nodes, the number of MPR_S nodes for each TC message sender is counted, and these three metrics are recorded in local memory for subsequent route calculation. All other processing remains the same as in OLSR.

2.3 Multi-path Routing Mechanism

To address the problem of single reachable route in OLSR for UAV ad-hoc networks and incorporate the aforementioned routing metrics, a multi-path routing mechanism is proposed to maintain multiple reachable routes between nodes. Considering the high delay requirements of UAV ad-hoc networks and the positive correlation between hop count and delay, hop count remains the primary metric for multi-path routing. Since maintaining multiple routes increases computational overhead, the improved MIMP-OLSR protocol maintains only two routes between source and destination nodes (if they exist).

Based on metrics 1 and 2, an objective function F for route selection is defined as shown in Equation (3):

$$F = \alpha \cdot \bar{C} + \beta \cdot \overline{neighR}$$

where $\bar{C}$ represents the average MAC layer congestion degree of nodes on the path, $\overline{neighR}$ represents the average one-hop neighbor change rate, and α and β are weighting coefficients. This objective function possesses load discovery and topology awareness capabilities, with the positive/negative impact and correlation of different metrics on route selection aligning with theoretical analysis.

Using hop count as the primary metric, the process for calculating the top two shortest-hop routes is as follows:

1) Establish network-wide topology based on TC messages and generate an undirected graph G. Each node executes Dijkstra' s algorithm once to find the shortest path from source to destination, denoted as P_1. Initialize variable $k = 1$ and three empty sets at each node: route repetition set M,

candidate route set NR, and final candidate route set ZR, all initialized to empty, with P_1 added to M, NR, and ZR.

2) Check if $k < 2$. If not, the algorithm terminates. Otherwise, treat the current shortest path P_k as the research object. Sequentially select each node in P_k (except the destination) as a branching point V_x (each node records its out-degree, and an out-degree of 1 indicates only one routing direction when this node serves as the source).

3) For each branching point, use Dijkstra' s algorithm to find the shortest path from the branching point to the destination, add the path from source S to branching point V_x in P_k to obtain the complete route $Path$. Check if $Path$ already exists in route repetition set M. If not, add it to candidate route set NR; otherwise, take no additional action. After traversing all V_x, select the route with the shortest hop count from NR, denote it as P_{k+1}, add it to final candidate route set ZR as an alternative data transmission route, remove P_k from NR, set $k = k + 1$, and proceed to step 5.

4) Transition to step 3.

The above steps for finding the top two shortest routes are illustrated in the flowchart in Fig. 3.

The complete multi-path routing scheme is as follows:

1) Select the top two shortest-hop routes (if they exist).

2) Compare the hop counts of the two routes. If they are equal, proceed to step 3; otherwise, select the route with fewer hops as the primary route and the other as the alternative route, then terminate the algorithm.

3) Calculate the average MAC layer congestion degree $\bar{C}$ and average one-hop neighbor change rate $\overline{neighR}$ for all nodes on each path, compute the F values (F_1 and F_2) using Equation (3). If Equation (4) is satisfied, proceed to step 4; otherwise, select the route with the smaller F value as the primary route and the other as the alternative route, then terminate the algorithm.

$$\max(F_1, F_2) - \min(F_1, F_2) < \delta$$

where δ is a threshold parameter.

4) Count the number of MPR_S nodes for each node in both routes and calculate the sum Sum. If the Sum values differ, select the route with the smaller Sum as the primary route and the other as the alternative route, then terminate the algorithm. Otherwise, select the first route in ZR as the primary route and the other as the alternative route, then terminate the algorithm.

This process is illustrated in the flowchart in Fig. 4.

3 Simulation Verification and Analysis

In the simulation, UAV-OLSR, SETT_{MPOLSR}, and standard OLSR protocols are used as benchmarks to analyze the performance of MIMP-OLSR in terms of success rate, control overhead, end-to-end delay, and throughput.

3.1 Simulation Parameter Settings

Five simulation scenarios were built using OPNET simulation software with a size of $1200m \times 1200m$. Detailed simulation parameters are shown in Table 2.

Table 2. Simulation Parameter Settings

Simulation Parameter Name	Parameter Value
Number of nodes	50
Number of business flows	10
Packet size	1024 Bytes
Simulation time	300 s
Node' s moving speed	10~30 m/s
Scene size	$1200m \times 1200m$

3.2 Feasibility Analysis of Routing Scheme

Regarding whether the proposed routing scheme increases route flapping risk: Route flapping arises from two aspects: frequent routing table updates and unreasonable routing scheme design. In the proposed routing scheme, routing tables are actually updated periodically, with each route having a certain validity time. Given a node communication radius of 150m and mobility speed less than 30m/s, the possibility of significant network topology changes in a short time is small, so routing tables will not be updated frequently. According to the complete multi-path routing scheme described above, when hop count, objective function F value, and MPR_S node count sum Sum are all identical, the first route recorded in ZR is selected as the primary route and the other as the alternative route, thus resolving the issue of route selection with equal values caused by unreasonable routing schemes.

Regarding whether the proposed routing scheme increases network deployment complexity: The metric advertisement mechanism proposed in Section 2.2 enables network-wide dissemination of metric information required by the routing scheme without additional manual network deployment. Moreover, the network is distributed, and the proposed routing scheme demonstrates adaptability to different environments based on its communication process, thus not increasing network deployment complexity.

3.3 Simulation Results Analysis

The simulation results for the proposed MIMP-OLSR protocol are analyzed below in terms of success rate, control overhead, end-to-end delay, throughput, and network lifetime.

1) **Success Rate Analysis**
   The success rate $P_{success}$ is calculated as shown in Equation (5):

$$P_{success} = \frac{Num_{recv}}{Num_{send}}$$

where Num_{send} represents the number of sent packets and Num_{recv} represents the number of successfully received packets.

Fig. 5 shows the success rate curves for the four protocols. The results indicate that success rate performance decreases with increasing node mobility speed because higher mobility causes more frequent topology changes, potentially rendering routes invalid during data transmission and reducing Num_{recv}. The MIMP-OLSR protocol achieves the highest success rate among the four protocols. SETT_{MPOLSR} improves over OLSR by considering not only hop count but also link differences through the Expected Transmission Time (ETT) concept and maintaining multiple available routes for backup when the primary route fails. UAV-OLSR further improves over SETT_{MPOLSR} by proposing an improved MPR mechanism and multi-path routing with smaller overhead and larger bandwidth for data transmission. MIMP-OLSR outperforms UAV-OLSR by comprehensively considering node load capacity, network topology change magnitude, and network lifetime while maintaining multiple routes and achieving even smaller overhead, resulting in more bandwidth for data transmission.

2) **Control Overhead Analysis**
   Control overhead is generated by HELLO and TC control messages. As shown in Fig. 6, the control overhead curves for all four protocols exhibit stable trends, fluctuating around their stable values S. Control overhead depends on control message frequency and message size. Increased node mobility may enlarge HELLO message entries and cause TC message loss, but overall control message size variation remains limited and stable, though the stable values S differ among protocols.

SETT_{MPOLSR} modifies OLSR message formats by adding three 32-bit fields to each neighbor in HELLO messages for ETT calculation and one 32-bit field to each neighbor in TC messages for ETT flooding, significantly increasing its stable value S compared to OLSR. UAV-OLSR adds 50-bit fields to HELLO and TC messages for routing metric information, placing its control overhead between OLSR and SETT_{MPOLSR}. Although MIMP-OLSR also modifies message formats, it only adds its own metric pair (32 bits) to HELLO messages when the node is not an MPR node, and only requires an MPR node to forward metric information for non-MPR nodes in TC messages. Consequently, MIMP-OLSR' s control overhead performance falls between OLSR and UAV-OLSR.

3) **Average End-to-End Delay Analysis**
The average end-to-end delay $eteD$ is calculated as shown in Equation (6):

$$eteD = \frac{\sum recvT}{Num_{recv}}$$

where $\sum recvT$ represents the total time experienced by all successfully delivered packets from transmission to reception.

Fig. 7 shows the end-to-end delay curves for the four protocols. The results demonstrate that average end-to-end delay performance degrades with increasing node mobility speed due to faster topology changes and higher probability of wireless link disconnection. Multi-path routing protocols exhibit much lower delay than single-path OLSR. When a link in one route becomes overloaded, alternative routes can be used to distribute traffic and reduce queuing delay. UAV-OLSR has smaller control overhead than SETT_{MPOLSR}, providing more bandwidth for data transmission and thus smaller delay. MIMP-OLSR achieves the best end-to-end delay performance by comprehensively considering MAC layer blocking degree, network topology change magnitude, and network lifetime, selecting the top two shortest routes where hop count significantly impacts delay, and further reducing control overhead.

4) **Throughput Analysis**
Throughput is calculated as shown in Equation (7):

$$Throughput = \frac{Num_{recv} \times pkS}{eteD}$$

where pkS represents packet size (1024 Bytes in the simulation).

Fig. 8 shows the throughput curves for the four protocols, indicating that network throughput is negatively correlated with node mobility speed. Higher mobility increases end-to-end delay $eteD$, thus reducing throughput. SETT_{MPOLSR} calculates more reasonable routes than OLSR by considering hop count and wireless link quality. As control overhead decreases from SETT_{MPOLSR} to UAV-OLSR to MIMP-OLSR, more bandwidth becomes available for effective data packet transmission, resulting in gradually improved throughput performance.

5) **Network Lifetime Analysis**
Network lifetime represents the maximum time a network can exist, typically limited by node residual energy in routing protocols. Fig. 9 shows the network lifetime curves for the four protocols, demonstrating that network lifetime performance decreases with increasing node mobility speed for all protocols. SETT_{MPOLSR}' s larger control messages cause

faster energy consumption, but its multi-path routing scheme based on link quality distributes network traffic and prevents excessive energy consumption differences among nodes, resulting in longer network lifetime than OLSR. UAV-OLSR adjusts control message transmission frequency and has smaller control messages than SETT_{MPOLSR}, yielding longer network lifetime. MIMP-OLSR considers the MPR_S node count (reflecting node energy level) and has smaller control messages than UAV-OLSR, further improving network lifetime performance.

4 Conclusion

Most existing literature on multi-path OLSR protocols typically considers routing metrics such as hop count and link quality, failing to fully incorporate various performance aspects of the network at that time. Therefore, this paper proposes an improved multi-path OLSR protocol (MIMP-OLSR) that comprehensively considers node load capacity, network change magnitude, and network lifetime, quantitatively calculating three routing metrics. The protocol introduces a metric advertisement mechanism using HELLO and TC control messages to disseminate metric information throughout the network. To meet the high delay requirements of UAV ad-hoc networks, a multi-path routing scheme is proposed based on shortest routes. Simulation results show that the improved MIMP-OLSR protocol demonstrates superior performance in success rate, end-to-end delay, and throughput. The metric advertisement mechanism modifies HELLO and TC message formats, incurring some additional overhead. Future work will focus on optimizing the multi-path routing scheme for UAV ad-hoc networks to address control overhead issues.

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Note: Figure translations are in progress. See original paper for figures.