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Improving Performance of Data Routing Protocol in Flying Ad-Hoc Networks

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Abstract - *Flying Ad-Hoc Networks (FANETs) have become very popular nowadays and have been widely used in various applications. However, due to the high mobility of Unmanned Aerial Vehicles (UAVs) and frequent topological changes, there are many challenges in FANETs such as routing path failure, packet loss, and frequent interruption of the link between UAVs. The unique characteristics of FANETs make designing routing protocols a difficult task. In this paper, we propose a routing protocol named Intelligence-OLSR (INT-OLSR) for FANETs. This protocol improves the routing performance of the Optimized Link State Routing protocol (OLSR) based on the Ant Colony Optimization algorithm (ACO) for efficient communication and obtain the most stable routes and the self-adaptation of the network in case of any topological changes. Our simulation was performed using NS2 simulator. The evaluation results show that the proposed protocol (INT-OLSR) performs better than the OLSR protocol in terms of packet delivery ratio, average time delay and throughput.*

Key Words*: *Flying Ad-Hoc Networks (FANETs), Optimized Link State Routing protocol (OLSR), Ant Colony Optimization Algorithm (ACO),Optimal Routing, Unmanned Aerial Vehicles (UAVs).

1.INTRODUCTION

Recently, Flying Ad-Hoc Networks (FANETs) have become widespread as they have been used in a wide range of applications by organizing a group of Unmanned Aerial Vehicles (UAVs) to cooperate with each other in order to accomplish many complex tasks with high efficiency [4] [1]. FANET is a distributed wireless network that allows UAVs to communicate with each other without a fixed infrastructure. It is an extension of Mobile Ad-Hoc Networks (MANETs) and Vehicle Ad-Hoc Networks (VANETs) [2].

Due to their versatility and flexibility, UAVs have been used in many military and civil applications, such as remote sensing operations, border control, fire management, disaster , and search operations [3]. However, there are a lot of peculiarities in the behavior of UAVs, such as unpredictable movement, high speed, irregular distribution across the network, and frequent changes in the network topology, thus, makes the design of FANET routing protocols a very complex task [4].

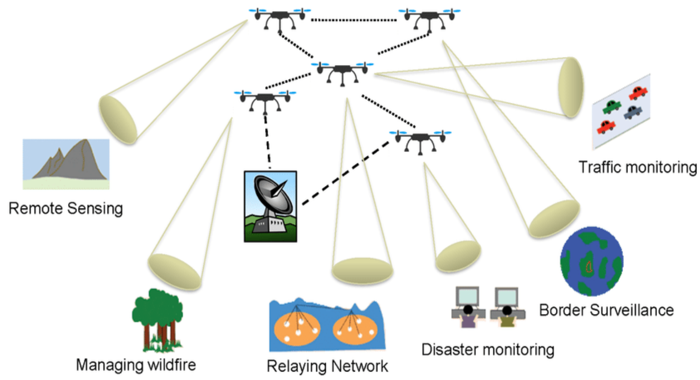


Fig -1: *Flying Ad-Hoc Networks applications.*

2. FANET ROUTING PROTOCOLS

There are several topology-based routing protocols that have been developed to suit the unique characteristics of FANET networks.

These protocols are based on information about links between nodes which rely on IP addresses for packet exchange between connected nodes. Topology-based routing protocols in FANET can be classified into three main categories [4]:

2.1 Proactive Routing Protocols

These protocols are also known as table-driven routing protocols, because they pre-select routes before they are used even when there is no data flow over those routes, and maintain routing tables for the entire network by routing private information in the network from node to node. The most widely used proactive routing protocols are as follows[5]:

Optimized Link State Routing Protocol (OLSR).
Destination Sequence Distance Vector Protocol (DSDV).

2.2 Reactive Routing Protocols

This class of protocol creates routes only on demand and does not maintain the entire network structure. Thus a

routing path is created when any node within the network wants to send data to another node.
The most widely used reactive routing protocols are as follows [5]:
Dynamic Source Routing Protocol (DSR).
Ad-Hoc On-Demand Distance Vector Routing Protocol (AODV).

2.3 Hybrid Routing Protocols

Hybrid routing protocols have the advantages and characteristics of reactive and proactive routing protocols. The most commonly used hybrid routing protocols is [5]:
Zone Routing Protocol (ZRP).

3. OPTIMIZED LINK STATE ROUTING PROTOCOL

Optimized Link State Routing Protocol is a proactive routing protocol for ad-hoc networks because the paths are always available when a node wants to transmit on it. This is because information about the network topology is regularly exchanged between nodes. Where each node within the network is responsible for sending control packets to all other nodes. This method can generate an overhead on the network due to the continuous transmission of packets [6].
OLSR protocol is mainly based on Multi Point Relay (MPR) which improves communication between nodes by providing the shortest path. MPR works by selecting a number of neighboring nodes that will then retransmit control packets to all nodes within the network, reducing the amount of information exchanged on the network. OLSR provides two main functions: neighbor discovery and topology propagation. Through them, each node calculates the paths to all destinations. There are two types of important messages in the OLSR protocol which are HELLO and TC (Topology Control) messages:

1. HELLO message: Each node periodically broadcasts HELLO messages to all neighboring nodes, to support link sensing, neighbor discovery and MPR group selection.

2. TC messages: With the information obtained from the HELLO messages, topology control (TC) messages are generated and transmitted throughout the network by each MPR node [5].

4. RELATED WORK

Routing is one of the most essential aspects while conducting wireless communications between nodes in FANETs. It is very challenging due to the frequent moving and high speed of the UAVs which leads to changes in the network topology permanently.

Many routing protocols that specify how to route data across the network have been developed to reduce the impact of the high traffic and unbalanced load of FANETs. These routing protocols have a significant impact on improving the communication performance of UAVs networks.

In [7], a routing protocol called Predictive-OLSR (P-OLSR) was proposed, in P-OLSR the authors presented an extension to OLSR, which provides reliable communication even in case of very dynamic UAV networks. The basic idea is to make use of GPS information. They weight the expected transmission count (ETX) metric by a factor that takes into account the relative speed between the nodes. In [8], a routing protocol called Mobility and Load aware OLSR (ML- OLSR) was proposed, in ML-OLSR the authors presented mobility-aware algorithm and load-aware algorithm to the traditional OLSR protocol. MPR selection mechanism, topology discovery and routing are conducted with corresponding improvements.

In [9], a routing protocol called Unmanned Aerial Vehicles OLSR (UAV-OLSR) was proposed, in UAV-OLSR the authors presented the lifetime of communication link between two UAVs, then propose a measure metric called link live time (LLT) for the lifetime of the communication link, where a UAVs node with the maximum LLT is selected as the MPR.

In [10], a routing protocol called OLSR Expected Transmission Count (OLSR-ETX) was proposed, in OLSR-ETX the authors presented a new form of OLSR protocol, which takes into account the improved metric ETX using GPS information and residual energy of nodes. In [11], a routing protocol called Airborne-OLSR (AOLSR) was proposed, the proposed protocol AOLSR provides more optimization of Multi-point Relay (MPR) selection criteria used in OLSR protocol. This will reduce the load on the network by setting the MPR set to either the left side of the source node or the right side which depends on the location of the node to which the data will be sent.

In [12], a routing protocol called Trajectory-OLSR (T-OLSR) was proposed, in T-OLSR the authors presented a novel multi-hop protocol based on OLSR to handle the short link lifetime caused by the UAV's high-speed movement. This protocol is based on the UAV's trajectory information and adopts Q-learning deep learning tool to improve its performance. In [13], a routing protocol called Whale Optimization Algorithm OLSR (WOA-OLSR) was proposed, in which WOA-OLSR is applied to multi objective function combining the several parameters such as neighbor- hood benefaction, energy, stability time and key utilization of UAVs to provide optimal routing for energy efficient and secure FANET.

In this paper, we will propose to improve the olsr protocol based on the ant colony optimization algorithm, because it is suitable for dynamic optimization applications and routing problems, adapts greatly to changes in the environment, works in a distributed manner, and provides multi-path routing with load balancing [14].

5. MOTIVATION

Routing in a Flying Ad-Hoc Networks (FANETs) is a challenging problem Due to the high speed mobility, frequent topological changes, uncertain movement direction, and complicated communication environment of the UAV. The OLSR protocol will encounter loss of control messages, unstable routing, and the communication link between two UAVs may break suddenly when applied in the Flying Ad-Hoc Networks because the OLSR protocol based on the hop count metric in route selection and does not consider the impact of UAV speed and communication distance on communication when calculating routes[15]. So we propose the Intelligence-OLSR (INT-OLSR) protocol by improving the performance of data routing using the ant colony algorithm by adding parameters of node speed and the distance between the nodes.

6. PROPOSED PROTOCOL

Routing is one of the most important issues in FANETs. In this paper we present an improvement in the routing performance of the OLSR protocol for FANETs. The proposed protocol goes through several stages:

6.1 Neighbor sensing stage

Each node in the network sends Hello Packets to all one-hop nodes in order to detect the neighbor nodes. The proposed protocol works by sending these packets periodically, after making modifications to them by adding speed information and location information of the node to them. Figure (2) shows the Hello packet after modifying it by adding the three-dimensional location information fields to it, which are latitude, longitude, and altitude. The information about the speed of the node has also been added in the field (speed).

Reserved		HTime	Willingness
Link Code	Reserved	Link Message size	
Longitude		Latitude	
Speed		Altitude	
Neighbor Interface Address			
Neighbor Interface Address			
.....			

Fig -2: Hello Message structure of INT-OLSR

6.2 Path detection and selection stage

OLSR protocol mainly depends on the number of hops only in finding the path to the destination node and does not take the distance of the node nor the speed of the node into consideration.

At this stage, the ants algorithm will be relied upon to detect paths and choose the optimal path, after modifying its probability rule, which depends on distance only, and therefore we will add the node speed factor to the probability rule as well.

The algorithm initializes the parameters (number of ants, number of iterations) and starts with a new iteration. An ant is selected in order to find a path from the source node to the destination node.

The ant moves on the nodes until it reaches the destination node according to the modified probability rule, depending on the distance of the node and the speed of the node.

The equation for the distance between two nodes (i, j) is given in the following form:

$$d(i,j) = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2 + (z_i - z_j)^2}$$

Where$(x_{i,}y_{i,}z_i)$are the location coordinates of node (i).
where $(x_{j,}y_{j,}z_j)$ are the location coordinates of node (j).
The equation for the relative velocity of node (j) to node (i) is given by the following equation:

$$V_{ij} = |V_i - V_j|$$

Thus, the probabilistic rule for calculating the path cost from node (i) to node (j) becomes as follows:

$$p_{ij} = \frac{[\tau_{ij}]^{\alpha}[\eta_{ij}]^{\beta}[\sigma_{ij}]^{\omega}}{\sum_{h \in s}[\tau_{ij}]^{\alpha}[\eta_{ij}]^{\beta}[\sigma_{ij}]^{\omega}}$$

where:
τ_{ij} is the amount of pheromone on the path between the two nodes (i, j).
η_{ij} is the inverse of the distance between the two nodes (i, j).
σ_{ij} is the inverse of the relative velocity between the two nodes (i, j).
ω,β,α are constants.
The pheromone value is updated on the path that was found according to the following equation:

$$\tau_{ij}(t) = (1-\rho).\tau_{ij}(t-1) + \sum_{K=1}^{m} \Delta\tau_{ij}^{k}$$

where:
ρ is the evaporation constant.
m is the number of ants.
$\Delta\tau_{ij}^{k}$ is the amount of pheromone placed on path (i, j) by ant K and can be calculated as follows:

$$\Delta\tau_{ij}^{k} = \left(\frac{Q}{L_K}\right)$$

where:
Q is a constant number.
L_K is the path length of ant K.

6.3 Data passing stage

Each routing decision is made using a probability formula that gives preference to the next hops associated with higher pheromone values and better in terms of distance and speed. With this information, a decision can be made and data packets can be sent on the best path obtained from the source node to the destination node.
probability routing sends data with automatic load balancing. When the path becomes non-optimal it will be avoided and the load on it will be reduced.
Figure 3 shows the flow chart of the proposed protocol (INT-OLSR):

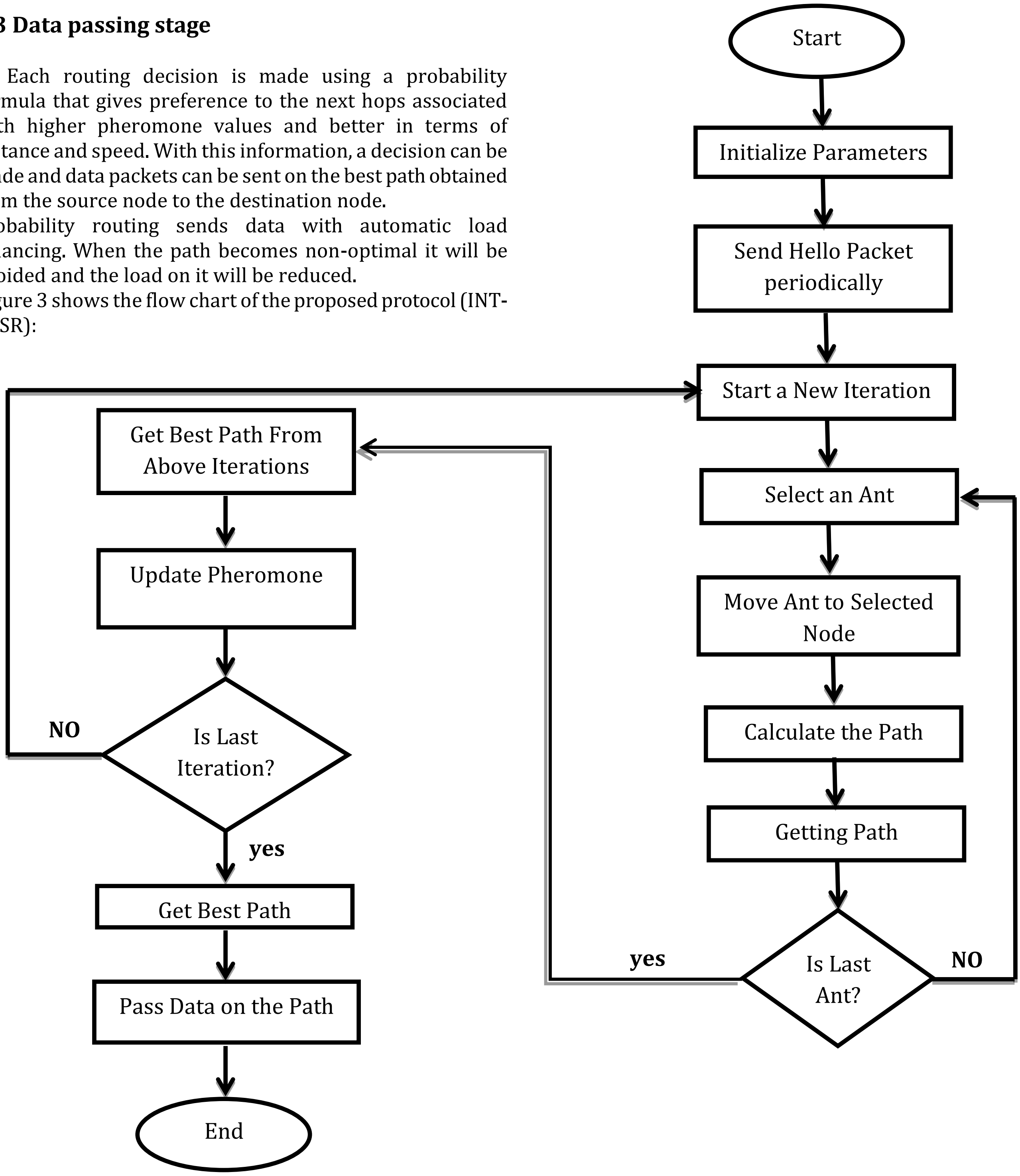


Fig -3: The flow chart of the proposed protocol (INT-OLSR).

7. PERFORMANCE EVALUATION

In this section, we compare the performance of the proposed routing protocol INT-OLSR, with that of the OLSR routing protocol.

7.1 Simulation Settings

The simulation was performed using the NS2 network simulator. This simulator is specially designed for simulating protocols and network research and is the most popular and widely used simulator for research work. Allows simulation of protocols for wired and wireless networks.

The simulation process was conducted within a three-dimensional network of 1500m x 1500m x 1500m with different number of nodes (10,20,30,40,50) nodes. These nodes move at a speed ranging from 10 to 50 m/s, the size of the packet is 512 bytes, The transmission range of each node is 200m. Table (1) shows the parameters that were used in the simulation.

Table -1: Simulation Parameters

Simulation parameter	Value
Simulator	NS-2 version 2.35
Deployment topology	1500 m x 1500 m x 1500 m
Number of nodes	10-50 nodes
Transmission range	200 m
Mobility Model	Random Way Point
Node Speed	10-50 m/s
MAC	IEEE 802.11
Data packet size	512 byte
Simulation time	1000 s

7.2 Performance Metric

There are several performance evaluation criteria used to evaluate the performance of the proposed protocol and compare it to the OLSR protocol. Each of these criteria is described as follows:

1- Packet delivery ratio: It is the ratio of the number of packets received at the destination node to the total number of packets sent by the source node.

2- End-to-end delay: It is the time it takes for a packet to pass through the network from the source node to the destination node.

3- Throughput: It is the amount of data that has been successfully received by the destination node during one unit of time.

7.3 Simulation Results

7.3.1 Packet Delivery Ratio:

Figure (4) shows the effect of node density on the data delivery rate, where we note that the data delivery rate in the proposed protocol is better than the OLSR protocol with the increase in the number of nodes, due to the selection of more stable paths and the decrease in the number of broken links and the avoidance of choosing high-speed nodes in the proposed protocol. Unlike the OLSR protocol which relies on the number of hops in selecting the node's MPR group.

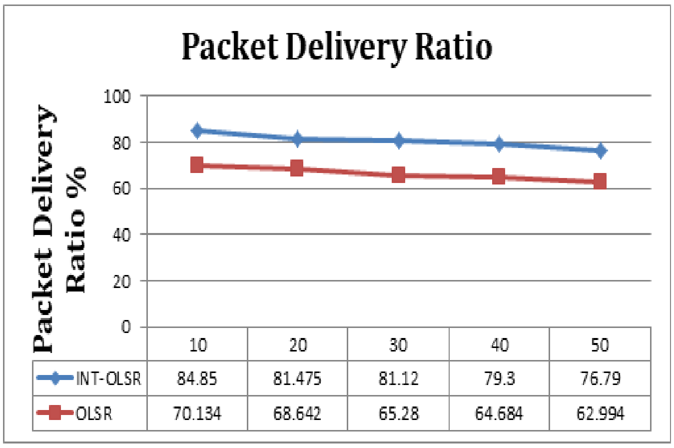


fig -4: Packet Delivery Ratio vs. Number of Nodes.

7.3.2 End-to-End Delay:

Figure (5) shows the effect of node density on the delay. We note that the delay increases with the increase in the number of nodes in both protocols. This is due to the increase in network traffic, but the delay remains higher in the OLSR protocol due to unstable routing and deviation from the shortest path.

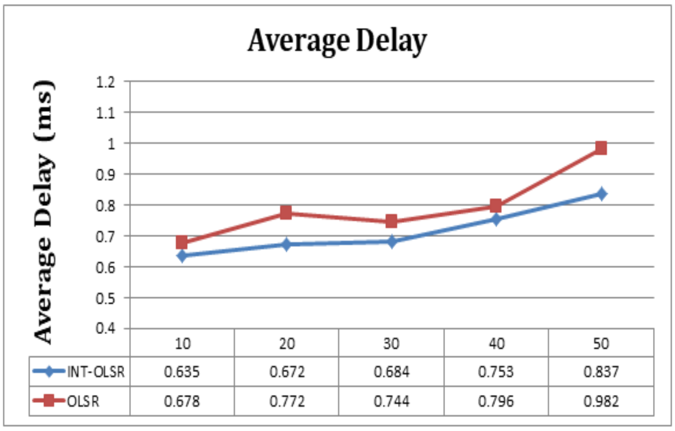
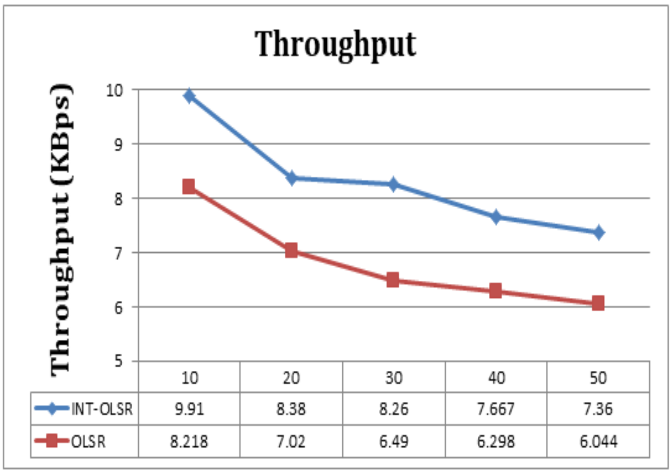


fig -5: End-to- End Delay vs. Number of Nodes.

7.3.3 Throughput:

Figure (6) shows the effect of node density on throughput. We notice that the throughput decreases with the increase in the number of nodes in both protocols. This is due to the decrease in network performance in general with the increase in the number of nodes, but the throughput remains higher in the proposed protocol due to the increase in the data delivery rate compared to the OLSR protocol.



	10	20	30	40	50
INT-OLSR	9.91	8.38	8.26	7.667	7.36
OLSR	8.218	7.02	6.49	6.298	6.044

fig -6: Throughput vs. Number of Nodes.

8. CONCLUSIONS

In this paper, we have proposed an INT-OLSR protocol that improves routing performance in Flying Ad-Hoc Networks based on the ant colony optimization algorithm. The INT-OLSR protocol selects the most stable paths and avoids high-speed nodes by taking into account the speed and distance of the node while discovering the path to the destination node.

The simulation and performance evaluation process was carried out using the NS2 network simulator. The simulation results show that the proposed protocol achieves better performance compared to the OLSR protocol in terms of data delivery ratio and throughput. While the end-to-end delay was similar to the OLSR protocol.

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