Flying Ad-Hoc Network Routing Protocol Based on Backward Algorithm

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Abstract. To cope with the challenge of nodes moving at high speed, we propose a flying ad hoc routing protocol based on backward algorithm (FANET-BA). When selecting a relay node, the neighboring node who has the maximum path value will be selected as relay node based on the backward algorithm. When a node encounters a routing void, we categorize this problem into two cases namely the half routing void and the whole routing void, then propose solutions for them respectively. Simulation results show that compared with greedy perimeter stateless routing protocol (GPSR), FANET-BA improves throughput by about 89.0% and successful packet delivery rate by about 55.9%.

Keywords: Flying Ad Hoc Network · Backward Algorithm · The Half Routing Void · The Whole Routing Void

1 Introduction

With the rapid growth of ad hoc, the application of flying ad hoc network (FANET) becomes more and more widespread. Traditional mobile ad hoc routing protocols including greedy perimeter stateless routing (GPSR), ad hoc on-demand distance vector routing (AODV), etc. perform well in low dynamic networks and hence they become a hot topic for researchers. However, their performance decreases drastically when the speed of nodes increases.

For the last few years, researchers conducted many researches around traditional routing protocols for ad hoc networks. In [1] and [2], the authors improved the AODV protocol to make it perform better in dynamic ad hoc. The authors of [3, 4] and [5] have studied the optimized link state routing (OLSR) protocol and made some improvements to its performance. However, it has been shown that GPSR has better performance in dynamic ad hoc networks compared with other traditional routing protocols [6][7].

Therefore, more and more researchers are focusing on GPSR protocol. The authors of [8] proposed an improved GPSR based on ant colony algorithm and improved the performance of the protocol by integrating parameters including energy, speed and deflection angle. In [9], the authors proposed a scheme designed specifically for flying ad hoc network and improved the relay node selection in the FANET environments. To obtain better

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latency performance, the authors of [10] proposed an improved GPSR (TD-GPSR) based on consideration of cross-layer factors, in which the suitable relay node was selected by considering time and space distance. In [11], the authors proposed a hybrid relay node selection strategy, in which the node would select two relay nodes. In addition, there are studies that combine GPSR and AODV routing protocol [12], the authors divided FANETs' routing process into two stages, which are the greedy routing stage and the flooding path-finding stage.

In summary, although there have been many studies on GPSR, they focused on the link quality from source node to its neighboring nodes and did not focus on the link quality after the neighboring nodes.

Therefore, we propose a flying ad hoc network routing protocol based on backward algorithm (FANET-BA). Compared with traditional ad hoc routing protocols, FANET-BA is more suitable than them for flying ad hoc networks such as UAV ad hoc and so on. Of course, it also has some limitations such as that UAV nodes must be able to know their position and speed at all times and they want more overhead to ensure that the nodes get information about their two-hop neighboring nodes. In this paper, we have two main contributions. First, when selecting a relay node, according to the backward algorithm, we consider the sum of link qualities from one-hop neighboring nodes to the two-hop neighboring nodes. Second, when encountering the routing void, we categorize this problem into two cases namely the half routing void and the whole routing void, then propose solutions for them respectively.

2 Relay Node Selection Based on Backward Algorithm

2.1 Backward Algorithm and Hello Package Format

First, in order to apply the backward algorithm to relay node selection, we need to add not only the node's own position and speed to the hello package, but also the corresponding information of one-hop neighboring nodes. Therefore, the new hello package is formatted as Table 1.

Table 1. Hello Package Format

ID	Position	Speed
I_o	P_o	V_o
I_n	P_n	V_n

As shown in Table 1, I_o, P_o and V_o are the node's own ID, location, and speed. I_n, P_n and V_n are those of one-hop neighboring nodes. Nodes periodically broadcast and receive hello packets. Based on this information, nodes can predict the location of their one-hop as well as two-hop neighboring nodes.

As shown in Fig. 1, D, E and F are the next states of A, B and C. The numbers are the weights of the paths. According to the backward algorithm, the total weights of A, B,

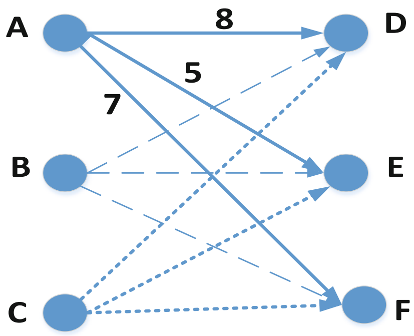

Fig. 1. The example of backward algorithm

C are the sum of weights of their paths to the next states. Then the state with the largest total weight is the optimal state. The weights of the paths are composed of state transfer probabilities and observation probabilities.

2.2 Relay Node Selection

In FANET, the next states correspond to the next hop nodes. A, B and C are one-hop neighboring nodes of source node, D, E and F are two-hop neighboring nodes. Then the state transfer probability P_{ist}, observation probability P_{iob} and the weight of path η_i are shown in (1).

$$\begin{cases} P_{ist} = \dfrac{1}{d_i} \\ P_{iob} = \dfrac{1}{\left|\overrightarrow{V_o} - \overrightarrow{V_t}\right|} \\ \eta_i = P_{ist} * P_{iob} \end{cases} \tag{1}$$

where d_i is distance from two-hop neighboring nodes to the destination node, $\overrightarrow{V_o}$ and $\overrightarrow{V_t}$ are the speeds of one-hop neighboring nodes and two-hop neighboring nodes.

According to (1), we can get the total weight η of A, B or C, which is shown in (2).

$$\eta = \sum_{i=1}^{m} \eta_i \tag{2}$$

where m is the number of two-hop neighboring nodes.

The node carrying data packets called source node will select the one-hop neighboring node with $\max\{\eta\}$ as its relay node.

3 Solutions for Routing Voids

When a source node does not have any one-hop neighboring node who is closer to the destination node, it encounters a routing void. To solve the problem of routing voids, we subdivide it into two cases and propose corresponding solutions for them.

3.1 The Half Routing Void

When the source node has some two-hop neighboring nodes who are closer than source node to destination node, it encounters the half routing void.

In this case, we only need to calculate the path weights from the source node to these two-hop neighboring nodes. η_i of path from one-hop neighboring nodes to two-hop neighboring nodes is calculated in the same way as (1). So we can get η_{new}.

$$\eta_{new} = \sum_{i=1}^{k} \eta_i \tag{3}$$

where k is the number of these two-hop neighboring nodes who are closer than source node to destination node.

Then we need to calculate a new parameter ω_{new},which is shown in (4).

$$\omega_{new} = \eta_{new} * \frac{\left|\overrightarrow{V_s}\right|}{\left|\overrightarrow{V_s} - \overrightarrow{V_o}\right|} \tag{4}$$

where $\overrightarrow{V_s}$ and $\overrightarrow{V_o}$ are the speeds of source node and one-hop neighboring nodes.

The source node carrying data packets will select the one-hop neighboring node with $\max\{\omega_{new}\}$ as its relay node.

3.2 The Whole Routing Void

When the source node has no two-hop neighboring node who is closer to destination node, it encounters a whole routing void. In this case, the source node will combine the number of two-hop neighboring nodes m and the relative speed of one-hop neighboring nodes to get a new parameter τ, which is shown in (5).

$$\tau = \frac{\left|\overrightarrow{V_s}\right|}{\left|\overrightarrow{V_s} - \overrightarrow{V_o}\right|} * m \tag{5}$$

Then the source node will select the one-hop neighboring node with $\max\{\tau\}$ as its relay node.

4 Simulation Tests

To verify the performance of FANET-BA, we compared it with GPSR protocol in terms of network throughput (THP) and packet loss rate (PLR).

4.1 Simulation Parameters

In our simulation, we randomly placed 50 and 100 UAV nodes. The range of network is 100 km * 100 km, the communication distance of nodes is 10 km and the broadcast period of Hello message is 60 s. The speed of nodes is 25 to 125 m/s. The parameters are shown in Table 2.

Table 2. The simulation parameters.

Parameters	Value
Number of nodes	50 and 100
Range of network	100 km*100 km
Communication distance	10 km
The speed of nodes	25–125 m/s
Broadcast period	60 s

4.2 Simulation Results

First, we randomly placed 50 nodes and their speeds are 25–125 m/s. The performance of two routing protocols is shown in Figs. 2 and 3.

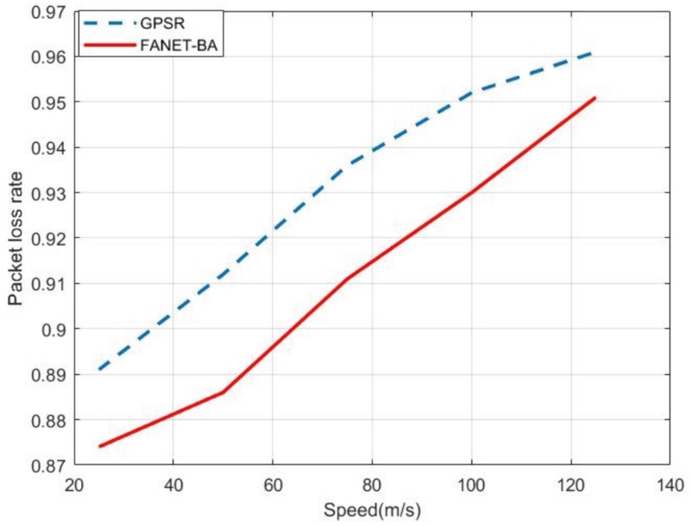

Fig. 2. The PLR of the two routing protocols

As shown in Fig. 2, the PLR of both routing protocols increases with increasing speed, but the PLR of FANET-BA is always lower than that of GPSR. In other words, compared with GPSR, the successful packet delivery rate (PDR) of FANET-BA increases by about 28.6%.

As shown in Fig. 3, the THP of both routing protocols decreases with increasing speed, but the THP of FANET-BA is higher than that of GPSR. Compared with GPSR, THP of FANET-BA increases by about 17.3%.

Then we randomly placed 100 nodes. Their speeds are also 25–125 m/s. The performance of two routing protocols is shown in Figs. 4 and 5.

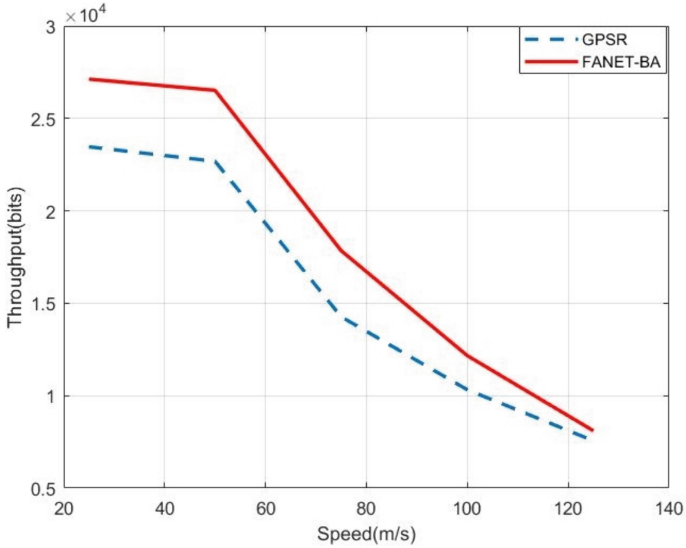

Fig. 3. The THP of the two routing protocols

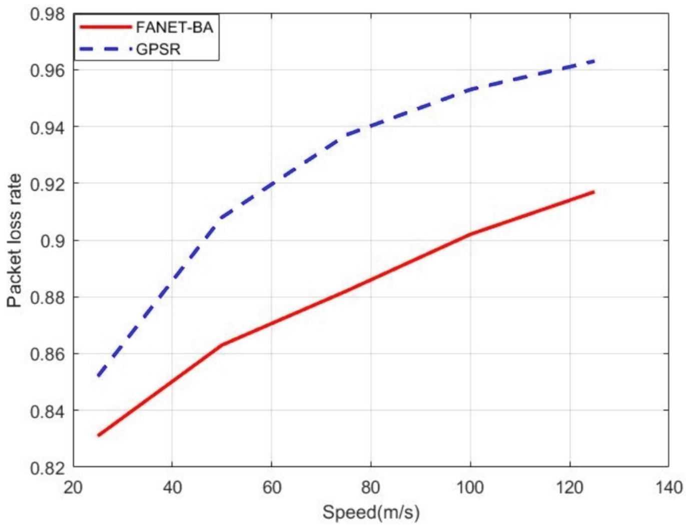

Fig. 4. The PLR of the two routing protocols

As shown in Fig. 4, the trend of PLR is similar to Fig. 2. Compared with GPSR, the PDR of FANET-BA increases by about 55.9%.

As shown in Fig. 5, the trend of THP is similar to Fig. 3. Compared with GPSR, the THP of FANET-BA increases by about 89.0%.

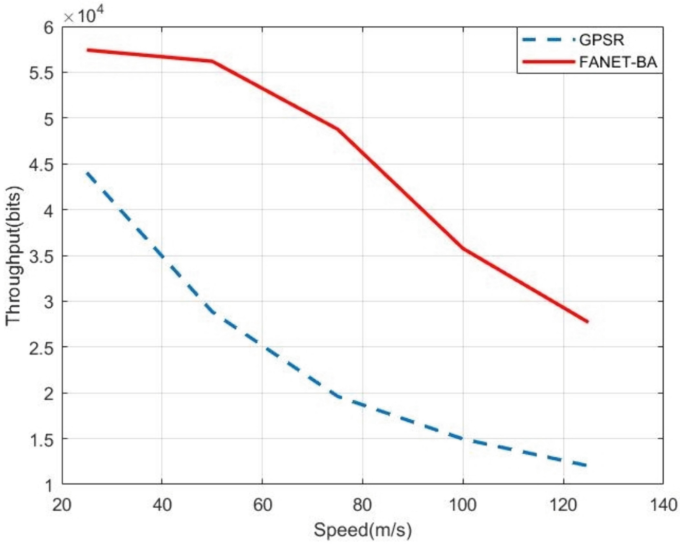

Fig. 5. The THP of the two routing protocols

5 Conclusion

Our simulation shows that compared with GPSR protocol, FANET-BA has lower packet loss rate and higher throughput in flying ad hoc networks. This shows that FANET-BA has better adaptability as well as development prospects in flying ad hoc networks.

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