Optimization of AODV Routing Protocol in UAV Ad Hoc Network

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Abstract. According to high-speed mobile nodes in unmanned aerial vehicles (UAV) Ad Hoc network to bring the network topology changes frequently, link time is short, and node energy is limited, this paper puts forward an optimized AODV protocol (EV-AODV) based on residual energy and relative movement speed of nodes. Simulation results show that EV-AODV routing protocol proposed improves the packet delivery ration and network life time compared with traditional AODV protocols. It is better suitable for the networks environment with UAV Ad Hoc network.

Keywords: UAV · AODV · High-speed mobile nodes · Link stability · EV-AODV

1 Introduction

The UAV ad hoc network developed by the vehicle self-organizing net-work completes the communication between the drones through dynamic networking, and has the characteristics of high dynamic topology, self-organization, no center and multi-hop, but the link is easy to break and it is difficult to meet the network performance requirements of military drones [1–4]. In the process of establishing a link in the AODV routing protocol, the established link between the two nodes is easily broken due to the mobility and energy consumption of the nodes in the network, and the link survival time is short.

There have been many improvements to the problem of unmanned self-organizing network routing. The energy-improved AODV-E routing protocol [5] selects links with few hops and high node energy for data transmission to avoid the fracture problem, but does not fundamentally reduce the node energy consumption. The cognitive-based AODV routing protocol [6] selects links with a large average number of neighbor nodes to transmit data to improve the success rate of link repair, but in-creases the storage space. The AODV routing protocol based on local route repair [7] uses a two-hop local repair mechanism to save resources and reduce end-to-end delay, but the link repair mode is limited by the location of the break, and the repair speed is slow. These improvements are mainly for networks with low node movement speeds, not for fast moving speeds.

In this paper, an improved AODV (EV-AODV) routing protocol is proposed for the problems of high node mobility, fast network topology change and unstable link

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connection. EV-AODV considers the energy and relative moving speed factors, and makes some improvements to the routing process to achieve efficient energy utilization, improve the quality of the selected link, and achieve the purpose of prolonging the network lifetime.

2 Optimization of AODV Routing Protocol

2.1 Link Stability

The stability of the link in the UAV ad hoc network is affected by many factors. UAV nodes move faster, and each node has different load and power consumption conditions, and the stability of links between nodes is different. Therefore, it is difficult to establish a stable and long-lasting link, and the broken chain the probability of road reconstruction is not high. The traditional AODV routing protocol uses the hop count as the metric to select the transmission path. It does not consider the link state. It is easy to select the path with unstable links. Especially in an environment where the network topology changes rapidly, the route is frequently interrupted, affecting the network performance. For the scenario where the node moves faster and the network topology changes drastically, the traditional AODV protocol is obviously not applicable. For this reason, we propose an improved AODV protocol (EV-AODV). It defines routing stability in the UAV ad hoc network and selects in the routing process with the routing stability as the metric.

We define E_0 as the initial energy of the node, generally a fixed value, and E_i is the residual energy of the node i, so the energy residual ratio η_i of the node i can be expressed as:

$$\eta_i = \frac{E_i}{E_o} \tag{1}$$

To measure the relative mobility of the two nodes, we define V_{ij} as the relative velocity between node i and node j, which can be expressed as:

$$V_{ij} = \sqrt{(v_{ix} - v_{jx})^2 + (v_{iy} - v_{jy})^2} \tag{2}$$

In Eq. (2), v_{ix} and v_{jx} represent the velocity components in the horizontal direction representing node i and node j, v_{iy} and v_{jy} represent the velocity components in the vertical direction representing node i and node j. Normalize the relative movement speed between nodes, we define σ_{ij} as the relative movement rate between node i and node j:

$$\sigma_{ij} = \frac{V_{ij}}{V_{ij\max}} = \frac{\sqrt{(v_{ix} - v_{jx})^2 + (v_{iy} - v_{jy})^2}}{|v_i| + |v_j|} \tag{3}$$

The EV-AODV routing protocol proposed in this paper comprehensively considers the node energy residual rate and the relative mobility of the nodes. On the basis of the normalization process, the energy consumption rate and the relative mobility rate are weighted, and the route cost of node i is defined as:

$$EV_i = \alpha(1 - \eta_i) + \beta\sigma_{ij} = \alpha\frac{E_0 - E_i}{E_0} + \beta\frac{V_{ij}}{V_{\max}} \tag{4}$$

In formula (4), EV_i is the route cost of node i, $1 - \eta_i$ represents the energy consumption rate of node i, α and β are the weighted parameters, and they satisfy $\alpha + \beta = 1$. We choose the appropriate weighting coefficient for different network. The more residual energy of a node, the smaller the relative mobility, the higher the stability of the node. Therefore, the smaller the value of EV_i, the higher the stability of node i.

$$EV = \sum_{i=0}^{N} EV_i = \sum_{i=0}^{N} \left[\alpha(1 - \eta_i) + \beta\sigma_{ij}\right]\ j \in [i+1, N] \tag{5}$$

EV is the stability of the entire path, N is the number of nodes on the path. According to Eq. (5), we define the function of selecting the best route for the EV-AODV protocol as

$$PathSelect\langle source, dest\rangle = \min[EV(k)]\ k \in [1, M] \tag{6}$$

In formula (6), M is the number of available paths. We choose the path with the smallest EV value as the best transmission path.

2.2 Improvements in Route Discovery

The traditional AODV protocol finds routes based on hop count and network delay. The intermediate node and the destination node only forward and respond to RREQ packets with short delay and few hops. However, the route constructed according to this standard has a big problem in a highly dynamic network, and a route interruption or destruction may occur in a short time in the future. Therefore, the improved AODV protocol takes into account the stability factor of the link. For the received RREQ, the power of the received signal of the node, the hop count of the link, the remaining energy of the node, and the stability of the forwarding link are considered. Construct a stable path based on it.

When the source node wants to send a packet to the destination node, if there is no valid route to the destination node, the source node will initiate the route discovery process. In the route discovery process, the source node obtains its own horizontal split speed, vertical split speed, and remaining energy into the new data field of the RREQ message, and makes the initial value of the *EV* in the message 0, and then the message The broadcast is sent to the neighboring node; each node that receives the RREQ message first obtains its own horizontal and vertical speeds, and after calculating the previous route stability coefficient by the formula (1) to formula (4), Then use formula (5) to accumulate it in the new data field *EV*. After the RREQ packet arrives at the destination node, the destination node sends back a RREP packet along the original route, and the packet records the final *EV* value of the link. The source node receives multiple RREP packets within a specified time. After discovering multiple routes, according to formula (6), the path with the smallest *EV* is selected as the transmission route.

3 Simulation Analysis

3.1 Simulation Environment

The experiment uses network simulation software NS to simulate and compare the traditional AODV and the EV-AODV routing protocol. The topology environment of the network is composed of 100 mobile nodes according to the random waypoint model. The nodes are randomly distributed in the simulation area of $1500\,\mathrm{m} \times 1500\,\mathrm{m}$. The moving speed of the nodes is between 5 and 30 m/s, and the dwell time is 0, the attenuation law of the wireless signal conforms to the dual-ray ground reflection model, the wireless bandwidth is 2Mbps, the effective wireless transmission range is 250 m, and the link layer protocol uses IEEE 802.11 DCF (Distributed Coordination Function). The initial energy of the node is 10 J, the transmission power is 0.6 W, the receiving power is 0.3 W, the simulation time is 600 s, and the average value of 10 simulation results is taken.

3.2 Simulation Results and Performance Analysis

We evaluate the impact of EV-AODV on reliability and effectiveness by comparing the difference in average packet arrival rate between AODV and EV-AODV protocols, and evaluate the improvement of EV-AODV by simulating average node lifetime. In this simulation, we take the weight coefficient of *EV* as $\alpha = \beta = 0.5$.

It can be seen from Fig. 1 that as the node moves faster, the packet delivery rate decreases. At the same rate, the EV-AODV packet delivery rate is higher than that of AODV, because EV-AODV considers the relative mobility of nodes and the relative mobility between nodes, increasing the probability of participation of high-energy nodes and relatively stable nodes, and routing requests. The response is not blindly performed, effectively reducing the probability of link disconnection and improving the packet delivery rate.

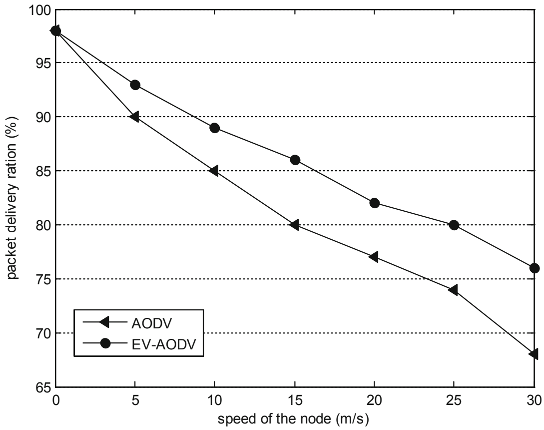

Fig. 1. Packet delivery ration

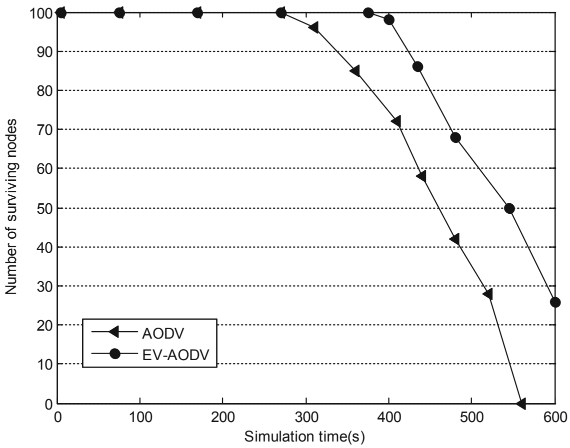

Fig. 2. Number of surviving nodes

As can be seen from Fig. 2, the classic AODV routing protocol begins to have the first node failure around 280 s, while the EV-AODV routing protocol takes about 380 s to appear the first failed node. At the simulation time of 600 s, the EV-AODV routing protocol has 25 surviving nodes, while the classic AODV routing protocol has no remaining nodes.

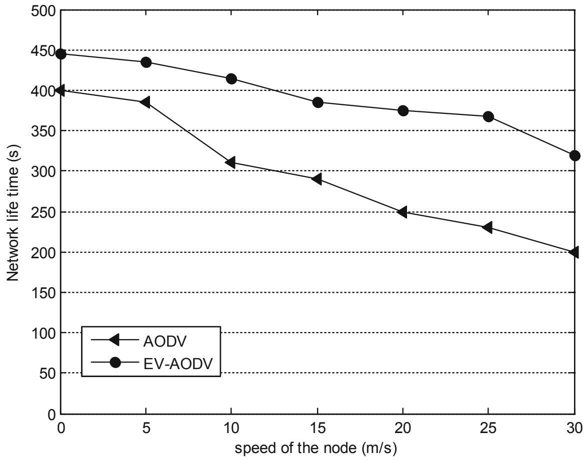

Fig. 3. Network life time

It can be seen from Fig. 3 that the network lifetime decreases with the increase of the node rate, but the EV-AODV route improvement scheme adopts the energy threshold and the route request forwarding rule to avoid the probability of participation of lower energy nodes, so that the established route is established. The probability of link breakage is reduced, which effectively prolongs network lifetime.

4 Conclusions

Aiming at the instability of UAV ad hoc network, a new EV-AODV protocol algorithm is proposed. In the process of link establishment, we comprehensively consider the residual energy of the node and the relative mobility between the nodes, and define the parameter *EV* that measures the stability of the route, by selecting the link with the lowest *EV* value and the link is stable. The simulation results show that EV-AODV has higher packet delivery rate when the node has higher mobility, which improves the link life and significantly prolongs the network lifetime. In addition, EV-AODV can flexibly adjust the weighting factors to meet more network environments.

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