Research and Equilibrium Optimization of AODV Routing Protocol in Ad Hoc Network

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Abstract. In the Ad Hoc network of AODV protocol, local node failure will occur when a node dies due to high cost or the network energy consumption is too large and the problem is serious. In this paper, based on the routing cost design, an optimized design scheme of AODV protocol (E-AODV) is proposed through the establishment and maintenance method. Simulation results show that this method improves the performance of AODV network, reduces the death process of nodes and reduces the energy consumption.

Keywords: AODV · Energy consumption · Route maintenance · E-AODV

1 Introduction

Ad Hoc network is a multi-hop self-organizing and self-managing network composed of a group of mobile terminals with wireless transceiver devices. Ad Hoc network does not require a fixed base station, and has the characteristics of strong survivability, and extremely convenient creation and movement. It makes up for the shortcomings of cellular systems and wired networks. It can be easily and flexibly networked and used in public services, emergency search and rescue, and intelligent Transportation and other fields have broad application prospects.

The nodes of the Ad Hoc network are both communication terminals and routers, which can move freely. In the Ad Hoc network, the network topology will often change due to the irregularity of the wireless channel changes, the movement of nodes, joining, and exiting, and due to the limitations of the wireless coverage of the nodes, two nodes that cannot be directly connected It needs to rely on the message forwarding of other nodes to communicate [1–4]. The role of the routing protocol is to monitor changes in the network topology in this network environment, exchange routing information, locate the location of the destination node, generate, maintain and select routes, and forward data according to the selected route. Ensuring network [5] connectivity is the basis for mobile nodes to communicate with each other, and is an important and core issue in Ad Hoc networks.

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At present, dozens of Ad Hoc network single-path routing protocols have been proposed to solve the routing problem in Ad Hoc networks. According to different ways of establishing routes, routing protocols [6] can be divided into a priori routing protocols and reactive routing protocols. DSDV is a more typical a priori routing protocol, and DSR, AODV and TORA are more typical reactive routing protocols. Research shows that in the case of node movement, the reactive routing protocol has lower routing overhead, and its performance is better than the a priori routing protocol; among the reactive routing protocols, the AODV protocol has [7] moderate routing overhead and fast convergence. The advantages are obvious. It is one of the promising routing protocols in the Ad Hoc network and has become the basis for the expansion of multipath protocols.

Compared with other routing protocols, the AODV routing protocol starts routing search only when needed, thereby improving the utilization of network resources and reducing delay. The AODV routing protocol can quickly respond to network topology changes and will not form a loop. Due to the continuous improvement of people's requirements for network performance, many scholars have optimized the AODV routing protocol in different aspects in recent years.

Lu Wei et al. [8] proposed a new improvement mechanism for energy loss and constructed a mathematical model, which included the signal attributes of the nodes. Choose the path according to the link quality and energy consumption. This protocol can not only ensure the minimum energy consumption but also select the optimal path in communication.

Literature [9] proposed a power estimation strategy, which uses the composite expected number of transmissions and the remaining energy of the node as the routing metric. The improved algorithm effectively reduces energy loss and prolongs the network lifetime. This new mechanism is superior to traditional AODV in terms of routing performance.

Due to the limited energy availability of each wireless node in the Ad Hoc network, the energy of the node will continue to decrease until it is exhausted during the communication process, so it is very necessary to consider energy in the data forwarding process. To ensure stable transmission of the link, congestion must be considered. The consequences of congestion can lead to data loss and even network breakdown. Therefore, the choice of routing metric is critical to communication quality.

Based on the working process of AODV, an improved AODV routing protocol (E-AODV) was proposed to solve routing cost, low node survival rate and unstable link connection problems. Establish multiple routing nodes to destination nodes based on cost path. Use this method to improve energy utilization rate and link quality to extend the life of the network. Figure 1 shows the classification block diagram of Ad Hoc network routing protocols:

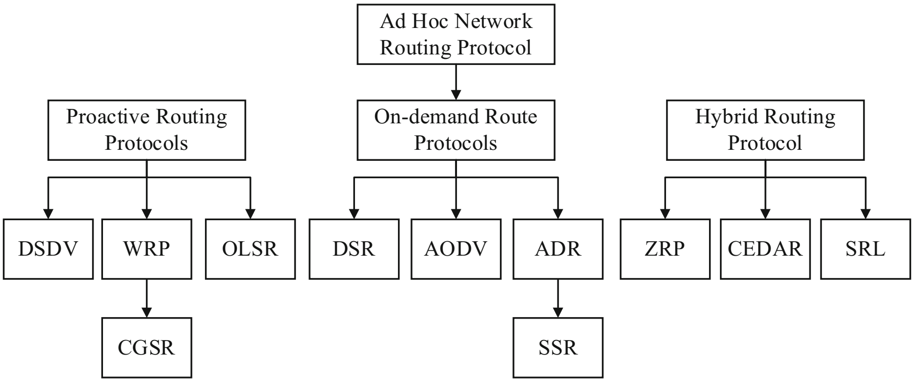

Fig. 1. Classification block diagram of Ad Hoc network routing protocol

2 AODV Protocol and Working Principle

2.1 The Advantages and Inadequate of AODV Protocol

The AODV routing protocol is designed for nodes in the Ad Hoc network to perform mutual data transmission. It is an on-demand routing protocol. On-demand means that the node does not store the routing information of all nodes in the network. When the destination node transmits data, it will check the routing table. If there is no route, it will broadcast the routing request to the network. Route request (RREQ), route reply (RREP), route error (RERR) and active route detection (HELLO) are the four types of information defined by the AODV routing protocol. The RREQ, RREP, and RERR information messages all contain a sequence number field. The use of the serial number allows the node to distinguish between the old and new information messages, so that the node can update the routing information generated by the old information messages in the routing table with the new information messages. HELLO information is a special case of RREP information. By broadcasting HELLO information, the connection between a node and its directly connected node can be detected. This information is transmitted by UDP, so the IP protocol address can be used.

The AODV routing protocol supports operation in a small-scale network, with the number of nodes ranging from tens to thousands, and complete trust between nodes that require mutual communication, because the data may need other intermediate nodes in the process of transmitting to the destination node Analyze data and forward. In general, the AODV routing protocol has the following advantages:

(1) There is no need to maintain the routing table in real time, and only seek routing and update the routing table when needed.
(2) The intermediate node can replace the destination node to reply, reducing the delay of the route discovery process and improving the convergence speed.
(3) All nodes and information messages have sequence numbers, which avoids the problem of routing loops and counting to infinity.
(4) Support multicast, good scalability.

(5) Widely studied at home and abroad, there are many improved protocols based on AODV routing protocol.

The AODV protocol is essentially a combination of DSDV and DSR. It is based on the DSDV protocol and combined with the improvement of the on-demand routing mechanism of DSR. The difference is that AODV uses a hop-by-hop method instead of DSR. Source routing method to improve bandwidth utilization.

2.2 The Working Process of AODV Protocol

AODV is a pure on-demand route acquisition mechanism. Only two nodes that need to communicate with each other can perform route search and maintenance, and the intermediate node can provide forwarding services. The AODV protocol assumes that the wireless link is bidirectional, and its routing protocol mechanism can be summarized as two processes, route discovery and route maintenance.

Generally speaking, when the source node needs to establish a communication link with the destination node, it must first broadcast RREQ (routing request) within the communication range. The intermediate node will decide whether to forward according to whether the RREQ is received for the first time, and the destination node receives After arriving at RREQ, it needs to reply RREP (routing reply) to the source node. The message RREP will pass through the intermediate node and return to the source node. At this time, the routing path is established. When the link is interrupted during the communication process, AODV will initiate local route repair for maintenance. The following describes each process in detail.

(1) Route discovery. When the source node has data to send and needs to communicate with the destination node but the route to the destination node is not found, the source node broadcasts a route request RREQ message in order to find a route to the destination node, and the neighboring node receives the RREQ message Firstly, judge whether the same RREQ packet has been received before sending, if yes, discard it, if not, use the information in the RREQ packet to establish a reverse route. If the intermediate node contains a route to the destination node, it sends a route response RREP message to the source node, otherwise it broadcasts the RREQ message to surrounding nodes in turn. When the destination node of the RREQ receives the RREQ packet, it also establishes a reverse route, and then sends the RREP packet in unicast form to the source node of the RREQ packet. Figure 2 shows the establishment process of the reverse route:

(2) Route maintenance. The node periodically broadcasts the hello message through the MAC layer to determine the link status. If the node does not receive the hello response message for three consecutive times, the link is considered to be disconnected, the routing information containing the link is deleted, and routing is initiated The wrong RRER message informs the neighboring node and the corresponding upstream node to delete routing information that causes the destination node to be unreachable due to link disconnection.

Figure 3 shows the establishment process of the forward route:

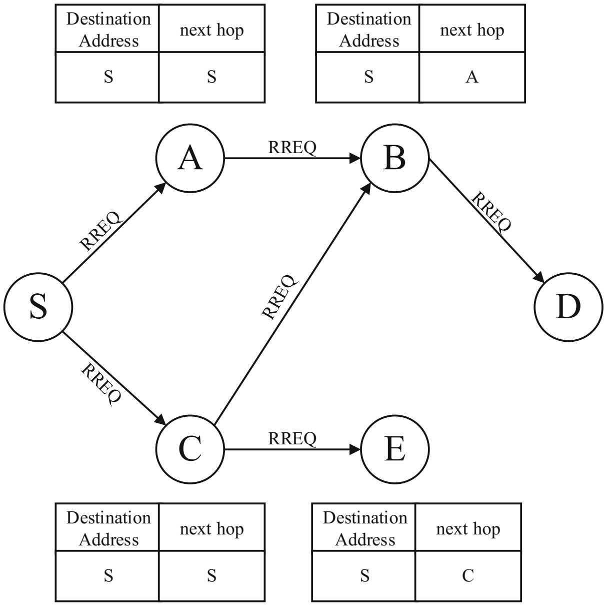

Fig. 2. Reverse route establishment

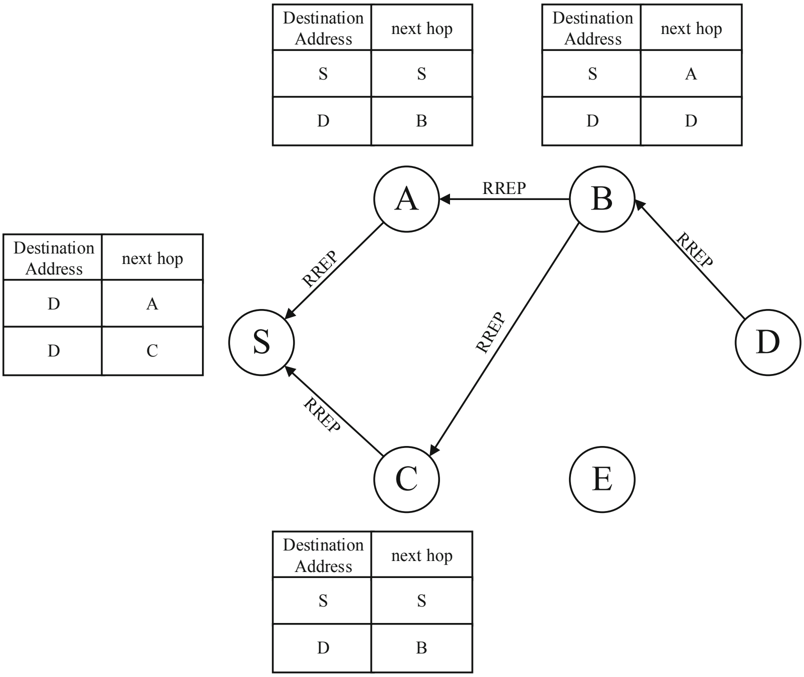

Fig. 3. Forward routing establishment

3 Optimization of AODV Routing Protocol

3.1 Optimization of Routing Discovery Process

Define the initial energy of the i-th node as E_{i0}, and E_i is the residual energy of the node. We can use the ratio of the initial energy and the residual energy of the node to represent the energy state of the node. Therefore, the residual energy percentage can be expressed as:

$$E = \frac{E_i}{E_{i0}} \tag{1}$$

It can be seen from formula (1) that the larger the E, the more the relative residual energy, the less energy consumption, So we can use this ratio to calculation the energy expenditure of the node's life cycle.

In order to measure the load of the i-th node, we define N_{i0} as the original maximum volume of the data buffer queue of node i, and N_i as the data length in the remaining data buffer of node i. So N as the ratio of the two can be written as:

$$N = \frac{N_i}{N_{i0}} \tag{2}$$

It can be seen from formula (2) that the N become larger, the bigger of data length in the remaining buffer of the node, the smaller the load on the link layer, and the smaller the probability of blocking, so we can compare the chain by this ratio The load of the road layer is estimated.

Routing overhead is determined by load and node lifetime. We can estimate the routing cost of the node through the parameters derived from formula (1) and formula (2). Set the weight of life cycle and load to α, and the number of nodes to d, then The routing cost of a node can be expressed as:

$$Routing\_\text{Cost} = \alpha \times \sum_{i=1}^{d} \frac{E_i}{E_{i0}} + (1 - \alpha) \sum_{i=1}^{d} \frac{N_i}{N_{i0}} \tag{3}$$

It can be seen from formula (3) that the routing cost comprehensively considers the residual energy of the node and the congestion of the path. The difference of α determines that the ratio of the life cycle and load of the node in the routing cost measurement function is different. we can accroding to reality to select the appropriate path. The source node will limitedly select link with higher routing cost when the residual energy of nodes in the path is small or congestion occurs.

3.2 Optimization of Route Maintenance

In an Ad Hoc network, the constant movement of nodes will cause changes in the network topology, resulting in problems such as link failures. Therefore, maintaining the stability of routing lines is a necessary function of routing protocols. The maintenance of AODV routing table includes three parts: route repair, HELLO message, route buffer timer.

Due to the movement of nodes, the routing table of each node is constantly updated. If the update is stopped for a period of time, the route will fail and the line will be cleared. The AODV protocol detects the failure of the link by broadcasting the HELLO data packet message regularly. If it fails, the routing information will be cleared immediately.

Once the notification of the broken link is received, the source node restarts the route discovery process and establishes a new route. However, the establishment of a new route will also cause the increase of network energy consumption, which will interrupt the link. In order to avoid this phenomenon If it happens, we optimize the AODV protocol so that it can track and delete nodes that may be interrupted to establish a more stable route.

If the remaining energy of a node in the network is small (less than a certain percentage of the remaining energy of the maximum node) or the load is too large, this node will broadcast the RRER, and the upstream node will immediately delete the selected node as the RRER after receiving its broadcast RRER The routing link of the next hop. At this time, the data can be transmitted through the alternate route. If there is no alternate route (the node is unique), the RREQ is repaired from the last hop node to obtain new routing information. If a new route cannot be found, the route will eventually be rediscovered from the source node. This method can greatly reduce network delay and routing overhead.

4 Simulation Analysis

NS2 is a network simulation software widely used in academia at present. This experiment uses the NS2 simulation platform to simulate and analyze the AODV protocol of the Ad Hoc network. The configuration options include: routing protocol, protocol stack, channel, topology, transmission model, and whether to open the wired routing, whether to open the trace of each layer, etc.

The simulation scenario used in this article is to configure 50 nodes in a space of 800 m × 800 m, the node's moving speed is between 15 and 20 m/s, the effective wireless transmission range is 250 m, and the packet transmission rate is 1 packet/sec. The value of α is 0.5, the critical value of routing cost is 10%, and the simulation time is 600 s. These parameters are used to compare the performance of traditional AODV and E-AODV routing protocols.

We evaluate the impact of E-AODV on reliability and effectiveness by comparing the changes in energy consumption between AODV and E-AODV protocols as the nodes increase, and evaluate the improvement of E-AODV by simulating the average node life.

Figure 4 shows that the energy consumption of both protocols increases as the number of nodes increases, but the total energy consumption of AODV is always higher than that of E-AODV because E-AODV uses the multi-path routing mechanism optimizes the original route, reduces the flooding of the original route, and also reduces the route cost and total energy consumption.

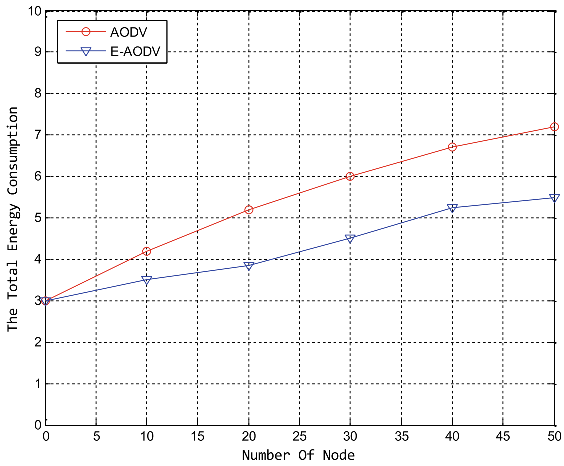

Fig. 4. Total energy consumption

It can be seen from Fig. 5 that the number of dead nodes increases as the simulation time increases. The number of dead nodes under the AODV protocol is significantly higher than that of the E-AODV protocol, and the gap between the number of dead nodes under the E-AODV and AODV protocols at different times is getting bigger and bigger. This is because the E-AODV protocol balances network overhead through node energy and load.

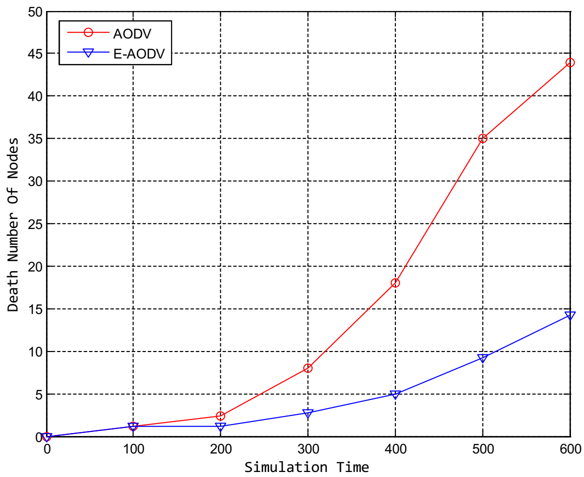

Fig. 5. Number of dead nodes

5 Conclusions

Due to the defects of the AODV protocol in Ad Hoc network, we finally proposed a new AODV optimization protocol E-AODV. We comprehensively consider the remaining energy of the node and the load of the node in the process of establishing the link. Maintain and optimize multi-protocol networks by deleting nodes with lower routing costs. The simulation results show that compared with the original AODV, the E-AODV protocol can reduce the total energy consumption, balance the network overhead. Moreover, the scale factor can be freely selected according to the situation to adapt to more network environment.

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