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An Improvement of AODV Protocol Based on Reliable Delivery in Mobile Ad hoc Networks

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***Abstract*—AODV protocol is a comparatively mature on-demand routing protocol in mobile ad hoc networks. However, the traditional AODV protocol seems less than satisfactory in terms of delivery reliability. This paper presents an AODV with reliable delivery (AODV-RD), a link failure fore-warning mechanism, metric of alternate node in order to better select, and also repairing action after primary route breaks basis of AODV-BR. Performance comparison of AODV-RD with AODV-BR and traditional AODV using ns-2 simulations shows that AODV-RD significantly increases packet delivery ratio(PDR). AODV-RD has a much shorter end-to-end delay than AODV-BR. It both optimizes the network performance and guarantees the communication quality.**

Keywords-mobile ad hoc networks; AODV; delivery reliability; network simulation

I. INTRODUCTION

A mobile ad hoc network (MANET) consists of a set of mobile wireless nodes that can communicate with each other without requiring the existence of fixed networking infrastructure. Therefore, it can set up the network fast and relatively inexpensive. For these characteristics, MANETs have been widely used in military field, disaster relief, the organization of conferences and so on.

Since MANETs are characterized by self-organized, dynamic changes of network topology, limited bandwidth, and instability of link capacity, etc, the reliability of data transmission in the network can not be guaranteed. In some special application conditions with harsh requirements on PDR and link quality, higher criteria for routing protocol will have been laid out.

The routing protocols of MANETs mainly include: DSDV (Destination-Sequenced Distance Vector), OLSR (Optimized Link State Routing), DSR (Dynamic Source Routing), AODV (Ad-hoc On-Demand Distance Vector) [1], ZRP (Zone Routing protocol), etc. The AODV routing protocol is the most widely used on-demand protocol. Many problems in AODV remain to be discovered and resolved. Today, there are some partial improvement programs, such as AODV-BR [5], which set up the alternate routing in order to increase the reliability of transmission without any extra control message. However, this algorithm has no repairing action when primary route breaks. It simply rebuilds route according to the information of alternate routing table, so it isn't fit for the networks whose topology changes frequently. Several performance studies [6, 7] propose a link availability prediction algorithm, which can measure the availability of link in a next period of time by forecasting the life time of link. But the prediction algorithm cannot well adapt to frequent topology changes.

In view of the insufficiency of above research study, we proposed AODV-RD based on link failure prediction mechanism with due consideration given to link status and improved AODV-BR combination to achieve the full purpose of improving PDR. The simulation results show that this algorithm greatly improves PDR, speeds up the re-convergence rate, and has a better performance in MANETs.

II. AODV-BR PROTOCOL

AODV-BR establishes the mesh and multi-paths to destination. The primary route and alternate routes together establish a mesh structure that looks similar to a fish bone. When primary route breaks, alternate routes can be initiated to carry out data transmission. Compared with AODV, AODV-BR increases PDR, but has longer end-to-end delay since AODV-BR delivers more packets, and those packets are delivered in AODV-BR but not in AODV, taking alternate and possibly longer hop routes.

Before sending packets, source node will search routing table to see if there are arrival destination routing. If there is routing information, date packets begin to transmit. Otherwise, it will start route discovery process.

Route discovery process: Source node searches a route by flooding a route request (RREQ) to neighbor node, after receiving RREQ, node will search their routing table. It then broadcasts the packet or sends back a route reply (RREP) packet to the source if it has a route to the destination. If it has not, they will flood RREQ to their neighbor node. And so on, until arrival destination node or one node that knows routing to the destination. When a node out of primary route receives RREP from a neighbor, this neighbor node will be recorded in the alternate routing table as "next hop" to the

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destination. When the RREP packet reaches the source of the route, the primary route between the source and the destination is established and ready for use.

Route maintenance process: When a node detects a link break, it performs a one hop data broadcast to its immediate neighbors. The node specifies in the data header that the link is disconnected and thus the packet is candidate for “alternate routing”. At the same time, the node sends route error (RRER) to the source node.

III. AODV-RD PROTOCOL

To reduce the time and control message after link breaks, above-mentioned AODV-BR is able to play a more visible role. However, when the primary route breaks, there still exist some problems to be discussed in the following: (1) There will be a time interval used to select the alternate routes, it must lead to data packet loss and delay increase, etc. (2) If there is more than one alternate node, then it must be considered which node is to be selected. (3) AODV-BR has no action to repair link, but simply uses information of alternate routing table, and it cannot well adapt to MANETs.

For these above-mentioned problems, in some real-time applications, we propose a link failure prediction mechanism in order to reduce, even cancel the required time interval after primary route breaks; set up an effective metric of alternate nodes based on improved AODV-BR, select alternate node whose communicating power is stronger by comparing metric to participate in forwarding.

A. *Link Failure Prediction Mechanism*

In MANETs, the strength of the packet signal [2] which the node receives may be defined as formula (1).

$$P_r = \frac{P_t G_t G_r H_t^2 H_r^2}{d^4} \tag{1}$$

Among them, P_r is the strength of received signal, P_t is the strength of the transmitting signal, G_r , G_t is the antenna gain of the receiver and transmitter, respectively. H_r , H_t is the antenna altitude of the receiver and transmitter respectively, d is the distance between the sending node and the received node. d can be defined as formula (2).

$$d = \sqrt[4]{\frac{P_t G_t G_r H_t^2 H_r^2}{P_r}} \tag{2}$$

Supposing each node has the same transmit power, from formula (2), we know that the changing strength of the received packet node signal reflects the fluctuation of the distance among nodes. Therefore, we can define a receiving power warning threshold $P_{r\_critical}$. When P_r is lower than $P_{r\_critical}$, determines that the link in the warning stage and link state is unstable and possible interrupts at any time. So when the node in primary route detects $P_r \langle P_{r\_critical}$, immediate access to the alternate route selecting process. After selection, the primary route switches to alternate routes in order to eliminate the required time interval to rebuild route.

B. *Select Alternate Node*

For selecting a alternate node, we can refer to Signal Stability-Based Adaptive Routing (SSA) [8, 9]. SSA method is based on the strong or weak communication signals of the two adjacent nodes to identify the good or bad link between them. Communication signals, strong or weak, divide the neighbor's communication channel into "strong channel" and "weak channel". Choose "strong channel" corresponding to the node as a selected alternate node. Its communications ability can be set up by formula (3).

$$M = f(V, P_r, D) = A*V + B*P_r - C*D \tag{3}$$

Among them, V is transfer rate, unit is packets/s. D is transfer delay, unit is ms. A , B , C are constant. M retain one after the decimal point. To avoid the alternate nodes having the same metric, we add a random number of 0.001-0.099 to it. Finally put the calculated value of M stored in the alternate routing table. Set a criticality value $M_{critical}$, reflects stability of communication ability. When metric $M \langle M_{critical}$ in the alternate routing table, we determine that alternate node is unstable, and unfit for use. When $M \geq M_{critical}$, we will select a higher metric in the alternate node information to forwarding.

C. *Repair Action of AODV-RD*

With the problems arising from lack of repair action after primary route breaks arising in AODV-BR, in AODV-RD, when a node detects primary route break, that node broadcasts RREQ that TTL=1, asks if the neighbor node has an alternate route to be used. At the same time, send RRER to the direction of the source. When neighbor nodes contain a alternate route, they will reply back RREP that TTL = 1, and a metric reflects stability of communication ability in RREP. Node will compare with metric after receiving RREP that TTL=1, and it will select the alternate node which has a Maximum metric $M_{\max}$ ($M_{\max} \geq M_{critical}$). If $M_{\max} \langle M_{critical}$, it does not contain a stable alternate route, you need to wait for the source to receive RRER and rebuild route.

In Fig. 1(a), node a is date source, node e is destination. Date packets are delivered through primary route <a-b-c-d-e>. Node g, h, i, j, k are alternate nodes and each node maintains a alternate routing table (including destination, next hop, metric). As shown in Fig. 1(b), with the network topology changes, the primary route breaks between nodes b, c. Node b will broadcast RREQ that TTL=1, due to alternate nodes h, i has alternate routes to node c, they reply a RREP that TTL=1 which includes a metric value. Received by node b, it will select an alternate node which has higher metric value. Finally, the primary route changes to<a-b-h-c-d-e>.

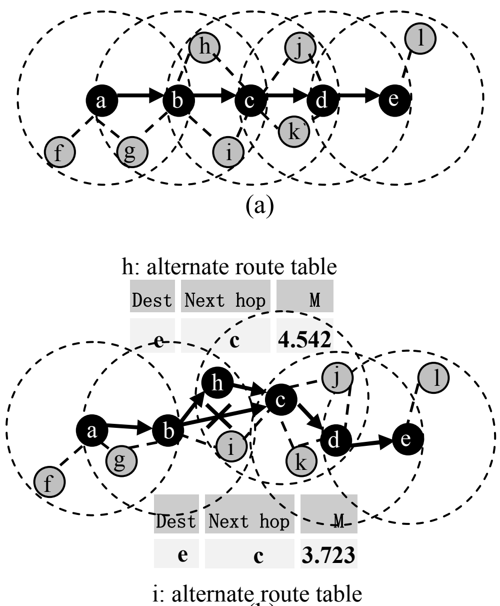

Figure 1. Repair action of AODV-RD

IV. SIMULATION EXPERIMENTS

The simulations are based on the ns-2 network simulator. There are 40 mobile nodes in the simulation environment, which move at the rate of 0-10m/s in a range of 1000m*1000m. The length of the data packet is 512byte. The simulation time is 300s. Nodes are set up at antenna height 2.0m, transmitting power to 0.281838 w. We assume distance between nodes to be more than 230m as into the warning stage. According to the formula (1), $P_{r\_critical} \approx 1.396 P_{r\_\min}$ =1.61155636e-9 w. ($P_{r\_\min}$ is strength of received signal at the edge of communication range of 250m). In the formula (3), A=1/4096(sec/packets), B =1e8(1/w), C =1000(1/ms).And We assume that $M_{critical}$=1.0.

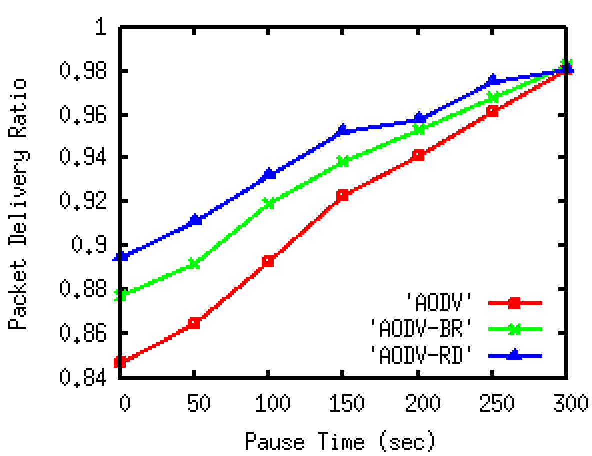

Figure 2. Packet Delivery Ratio

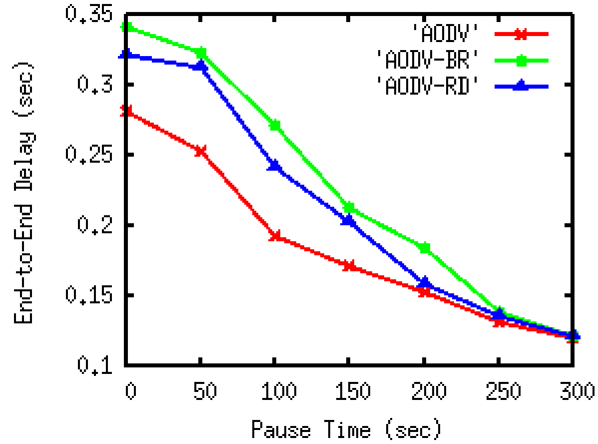

Figure 3. End-to-End Delay

PDR and end-to-end delay are presented in Fig.2 and Fig.3. Maximum speed of each node is 10m/s. As expected, three improvements significantly enhance the PDR and reduce the end-to-end delay compared with AODV-BR. AODV-RD is better adapted to frequent topology changes in MANETs, and ensure higher PDR. Although AODV-RD has longer end-to-end delay than AODV, it delivers more packets through alternate routes.

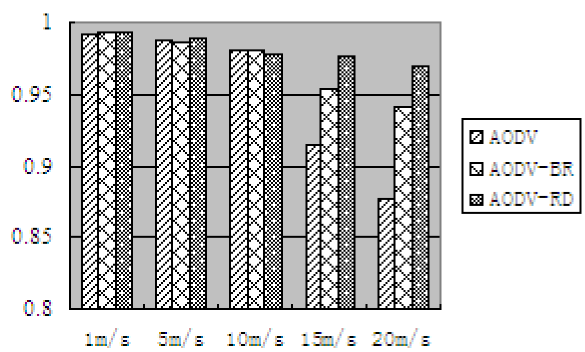

Figure 4. Maximum speed of node vs PDR

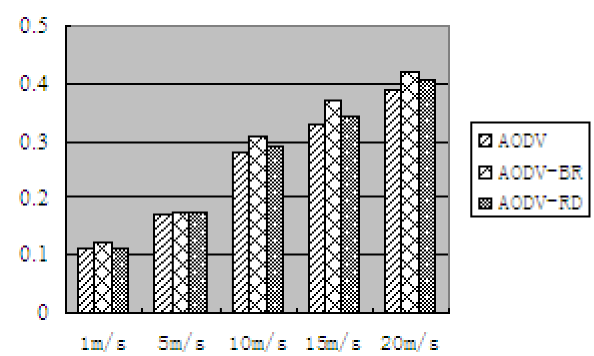

Figure 5. Maximum speed of node vs End-to-End Delay

PDR under different speeds of node are shown in Fig.4. In AODV-RD, because of link failure prediction mechanism proposed, can always guarantee to have a higher PDR under different speeds of node. End-to-end delays under different speeds of node are shown in Fig.5. That shows AODV-RD has a shorter delay than AODV-BR. End-to-end delay differences are not too great between them.

V. Conclusion

The AODV and AODV-BR routing protocol are analyzed in this paper, and some problems on reliable delivery are pointed out. We propose AODV-RD based on improved AODV-BR. The simulation results show that it provides a higher PDR, optimizes the network performance and also guarantees the communication quality. At present, routing protocol in MANETs seems complex, for the special nature of nodes, therefore the protocol awaits further optimization and promotion.

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