2012 Second International Conference on Business Computing and Global Informatization

A Bidirectional Backup Routing Protocol for Mobile Ad Hoc Networks

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***Abstract*—In mobile ad hoc networks (MANET), due to rapidly changing network topology, routing break occurs frequently. Ad hoc on-demand distance vector adaptive backup with local repair routing (AODV-ABL) protocol creates and maintains backup routes to the destination node by overhearing data packets to increase the success rate of repairing invalid routes. However, AODV-ABL may lose some backup routes with one hop distance to the destination node, and cannot adjust the primary routes in time to adapt to the dynamic topology. In this paper, based on AODV-ABL, an AODV bidirectional fast adaptive backup local repair (AODV-BFABL) routing protocol for bidirectional traffic load scenarios is proposed, which can maintain the bidirectional routes to the destination and source nodes to reduce route failures. In order to improve the adaptability of AODV-BFABL, the primary routes are merged with the backup routes and the routes are updated when transmitting the data packets. Simulation results show that AODV-BFABL has better packet delivery ratio, end-to-end delay and control overhead than AODV-ABL.**

Keywords-mobile ad hoc networks; overhearing; bidirectional backup route; bidirectional traffic load

I. INTRODUCTION

Mobile ad hoc networks (MANET) can be deployed in any location in an ad hoc manner, without the need of an existing wired infrastructure [1]. It can be widely applied in many fields, such as the Internet of Things (IOT), mobile commerce, military communications, mobile conferencing and disaster relief. In particular, when it is applied to mobile commerce field, the effective data transfer among nodes is an important issue to guarantee the future large-scale commercial IOT.

MANET is a peer-to-peer multi-hop wireless network, in which each node is both a host and a router. The nodes in MANET move randomly, resulting in a dynamic network topology. Therefore, routing protocols for MANET should be adaptive and efficient.

Ad hoc on-demand distance vector (AODV) protocol [2] [3] is a classic on-demand routing protocol designed for MANET. AODV tries to repair the link failure without informing the source node or interrupting the data delivery to improve the transmission performance. Only if the attempt of local route repair is unsuccessful, a route error (RERR) message is sent to the source node to re-initiate a route discovery process. Several methods have been proposed to improve the success rate of AODV local route repair.

AODV adaptive backup with local repair routing (AODV-ABL) establishes backup routes by overhearing route reply (RREP) messages and data packets [4]. Alternative nodes in the backup routes can improve the success rate of local route repair. The drawbacks of AODV-ABL are that the routing information cannot be updated in time, and the backup routes near to the destination node may be lost. Implicit backup routing-AODV (IBR-AODV) [5] employs local recovery of routes for reliability and reduces the number of control messages for efficiency. Improved AODV (I_AODV) [6] creates backup node for next hop during the route discovery process and prolongs the network's lifetime by using backup nodes. In AODV-backup routing with least hop count first (AODV-BRL) [7] the alternate routes are created by the Extended Hello Message that is similar to RREP packets, to reduce the distance between the repaired node and the destination. However, the Extended Hello Messages increase the network overhead.

Because the MANET topology changes quickly and the link bandwidth is limited and unstable, it is necessary to design routing protocol with adaptability and less network overhead. Bidirectional traffic load is common in many application scenarios, such as instant messaging, FTP, TELNET, and so on. Sessions in these scenarios are bidirectional. In each session, the source node of one direction is the destination of the other direction, and vice versa.

Considering the bidirectional traffic load scenarios, we propose an AODV bidirectional fast adaptive backup local repair (AODV-BFABL) routing protocol based on AODV-ABL, which has the characteristics of rapid self-adaptability and lower network overhead.

The rest of this paper is organized as follows. In Section II, the related works are presented. Our scheme AODV-BFABL is proposed in Section III. Performance comparison is shown in Section IV. Finally, our work is concluded in Section V.

II. AODV PROTOCOL AND AODV-ABL PROTOCOL

AODV is an on-demand routing protocol. Different from the proactive routing protocols, it does not need to periodically exchange routing information to maintain the routing table, thereby reducing the network overhead. In

978-0-7695-4854-8/12 $26.00 © 2012 IEEE
DOI 10.1109/BCGIN.2012.162

the route discovery process, the source node broadcasts a route request (RREQ) packet to probe routes. When intermediate nodes receive the RREQ packet, they can establish a reverse route to the source node. These nodes broadcast RREQ packet further to their neighbors until the RREQ packet reaches either an intermediate node with a route to the destination node or the destination node itself. Subsequently, RREP unicast packets are created by these nodes and are forwarded along the established reverse path. When an RREP packet arrives at an intermediate node, the node forwards it and stores the forwarding route in its routing table.

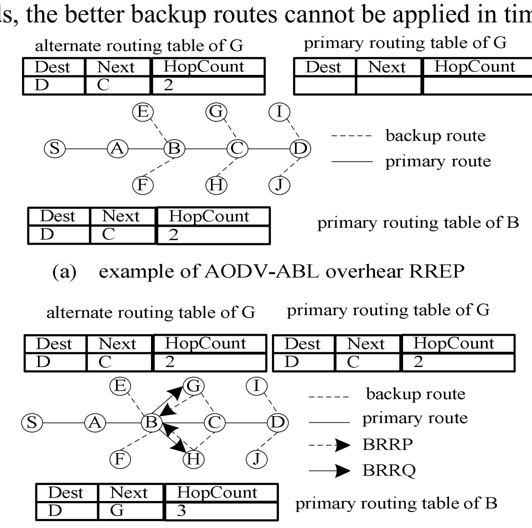
The network control overhead of AODV is mainly generated in route discovery process due to flooding RREQ packets. In order to improve the transmission efficiency and reduce network overhead, when the link failure occurs, AODV tries to locally repair the error. Only when the local repair process fails, the upstream node of the invalid link sends a route error (RRER) packet to the source node and then re-initiates the route discovery process. The upstream node broadcasts a special RREQ packet in local repair process. The time to live (TTL) value of this RREQ packet is relatively small. If the local repair process is successful, then the network overhead caused by flooding RREQ packets from source node can be avoided. However, if the local repair process fails, the source node must be re-initiate the route discovery process, then the network overhead will increase. Therefore, the key to improve the performance of AODV is to improve the success rate of the local repair process.

Alternate node can be either an intermediate node with a route to the destination or the destination node itself. With the increase of the number of the alternate nodes that around the upstream node of the invalid link, the local repair success rate of AODV is getting higher. AODV-ABL tries to overhear data packets and RREP packets to create the backup routes, which can increase the number of alternate nodes. In AODV-ABL protocol, nodes work in promiscuous mode. It means that those nodes not only can receive the broadcast packets or unicast packets to itself, but also can overhear the unicast packets that forwarded to other nodes by its neighbor. Each node has a primary routing table and an alternate routing table. AODV-ABL forwards data packets according to the routes in the primary routing table, and stores the backup routes in the alternate routing table. In local repair process, the upstream node of the invalid link broadcasts a 1-hop backup route request (BRRQ) packet. When neighbor nodes receive the BRRQ packet, they look for the backup routes from their alternate routing table. If the backup routes exist, those backup routes will be copied to primary routing table, and a backup route reply (BRRP) unicast packet will be replied to the upstream node.

Fig. 1 is an example showing how the AODV-ABL overhearing process and the local repair process are accomplished. In route discovery process (Fig. 1(a)), node C sends a unicast RREP packet to node B. Node B receives the RREP packet and creates a primary route in its primary routing table. Node G overhears the RREP packet too and creates a backup route in its alternate routing table. When the link breakdown occurs between node B and node C during forwarding data packets process (Fig. 1(b)), the upstream node B will broadcast a 1-hop BRRQ packet. Then node G and node C will reply a 1-hop BRRP to node B. Node B will choose node G as the next hop to destination node D.

In AODV-ABL protocol, the backup route with 1-hop distance to the destination node is lost occasionally due to the maintenance of backup routes by overhearing data packets. For example, for node I and node J (Fig. 1(a)), backup routes with 1-hop distance to node D may be lost, because node D never send data packet to itself.

Another drawback of the AODV-ABL protocol is that routes in backup routing table are not updated in time to the primary routing table. Fig. 2 is an example to show how AODV-ABL exchanges the routes information between primary routing table and alternate routing table. There are two sessions in Fig. 2. Node S is the source node of one session, and node C is the source node of the other session. Node D is the destination node of the two sessions. When node C moves into the communication range of node A, node A creates a backup route with 2-hops distance to node D via overhearing the data packets that forwarded by node C. But node A cannot update the primary routing table immediately, because the link between node A to node B does not break, even if the backup route is superior to the primary route. In other words, the better backup routes cannot be applied in time.



(a) example of AODV-ABL overhear RREP

(b) example of AODV-ABL local repair

Figure 1. example of AODV-ABL

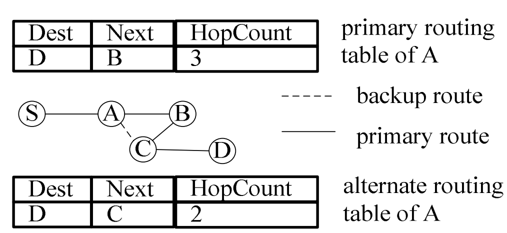


Figure 2. AODV-ABL exchanges routing table information

III. AODV-BFABL PROTOCOL

In scenarios with bidirectional traffic load, when the source node transmits data to the destination node, the destination node transfers data to the source node also. AODV-BFABL protocol is proposed for such scenarios based on AODV-ABL. AODV-BFABL has two major improvements. Firstly, AODV-BFABL merges primary routing table and alternate routing table into one routing table, which means there is only one entry in the routing table to each destination node. When overhearing the better backup routes, AODV-BFABL will replace the corresponding entries in the routing table by those backup routes as soon as possible, and then will improve the adaptability to the changes in network topology. Secondly, AODV-BFABL overhears the data packets forwarded from source node to destination node, and vice versa, to avoid the loss of routes with one-hop distance to the destination node.

In order to maintain the routes to the source node, AODV-BFABL add two fields in the AODV-ABL packet head to store the hops from current node to the source node and the routing sequence number of source node.

In Fig. 3, there is a session with bidirectional traffic load between node S and node D. In the route discovery process, node C establishes the route with 1-hop distance to node D by overhearing the RREP packets from D. Then node C maintains this 1-hop route by overhearing the data packets from D. In Fig. 4, when node E moves into the communication range of node A, by overhearing the data packet forwarded by node E, node A chooses node E as the next hop node to node D. Therefore, the route of node A to node D is optimized in time.

Because AODV-BFABL has only one routing table, the operation needed to maintain the routing table is simplified. AODV-BFABL adds operations to maintain the routes to source node in the overhearing and forwarding data packets process. Fig. 5 shows the pseudocode of overhearing data packs process. Other processes are similar. In Fig. 5, function *TapData* is designed to overhear the data packet *p* which is sent from source node S and forwarded from current node M to destination node D.

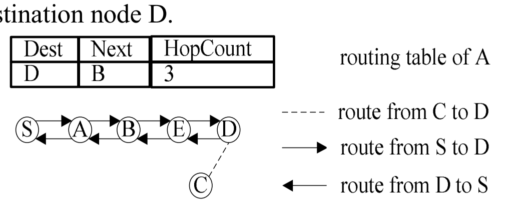


Figure 3. AODV-BFABL overhears two-way data packets

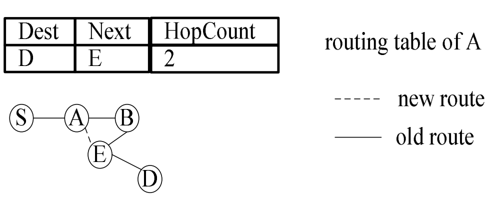


Figure 4. AODV-BFABL updates routing table

```
TapData ( Packet p){
   if(routing entry to D is not exist || routing entry to S is not exist){
      creates routing entry to D  or(and) S;
      update those newly created routing  entry;
      return;
   }
else{
      analyses packet head of p, look for
         (1)get hops count to D and S;
         (2)sequence number of  D and S;
       then calculates the new route to S and the new route to D;
       finds out corresponding routing entry to D and S;
       compares  the new route to the route in routing table.
       if (the sequence number in new route is less than that in routing
table entry || (the sequence number in new route is equal to that in routing
table entry && the hops is no more than that in table entry))
         {
           updates the corresponding routing entry with new route;
         }
      }
}
```

Figure 5. AODV-BFABL pseudocode of overhearing data packets

IV. SIMULATION AND ANALYSIS

A. *Simulation Environment and Parameters*

In this section we simulate an ad-hoc network via network simulation tool NS2 (version 2.34) to compare the performance of AODV, AODV-ABL and AODV-BFABL. Packet successful delivery ratio, average end-to-end delay and normalized network overhead are used as the performance metrics. Totally, 10 different scenarios with pause time from 0 to 300 seconds are created by tool SETDEST, and each scenario contains 25 bidirectional CBR sessions. Other parameters are shown in Table I.

B. *Average End-to-end Delay*

In Fig. 6, we notice that end-to-end delay of AODV is approximately 50% of AODV-ABL's when pause time is less than 100s, which is consistent with the conclusions in [4]. The reason lies in that AODV will re-establish the primary route in the presence of route breakdowns and the routes for packet deliveries are almost the optimal paths from the source to the destination during the transmission. Therefore, the end-to-end delay of AODV is shorter than

TABLE I. SIMULATION PARAMETERS

Parameter name	Parameter value
Simulation time	300 s
Simulation area	1500m × 300m
Number of nodes	50
Motion Model	Random waypoint
Nodes motion speed	0～35 m/s
Bandwidth	2 Mbps
MAC protocol	802.11
Propagation Model	Two-ray
Transmission Range	250m
CBR data rate at each direction	2 packets /s
Bidirectional CBR data sessions	25
Packet size	512 bytes

AODV-ABL's. However, the end-to-end delay of AODV-BFABL is approximately 70% of AODV's when pause time is less than 100s. It shows that adaptive mechanism of AODV-BFABL can quickly use the optimum routing and reduce the delay.

C. Normalized Network Overhead

The normalized network overhead is the ratio of routing control packets received by all nodes to the data packets received by all destination nodes. The more frequently a protocol finds and repairs the route, the higher normalized network overhead becomes. Fig. 7 shows that that AODV-BFABL has better network overhead than AODV and AODV-ABL when the pause time is less than 100s. It means that AODV-BFABL gets higher success rate of local repair when the network topology varies frequently.

D. Packet Successful Delivery Ratio

Fig. 8 shows that AODV-BFABL has the best packet successful delivery ratio in the three protocols. Delivery ratio of AODV-BFABL is 10% higher than AODV-ABL's and 5% higher than AODV's when the pause time is less than 100s. It means that AODV-BFABL has higher reliability.

V. CONCLUSIONS AND FUTURE WORK

Based on the overhearing mechanism, AODV-BFABL combines the primary routing table with alternate routing table to improve the adaptability to the dynamic network topology. Simulation results show that AODV-BFABL achieves the best performance compared with AODV and AODV-ABL. In the future, the improvement of the protocol under the scenarios with non-symmetrical and non-constant rate traffic load will be studied.

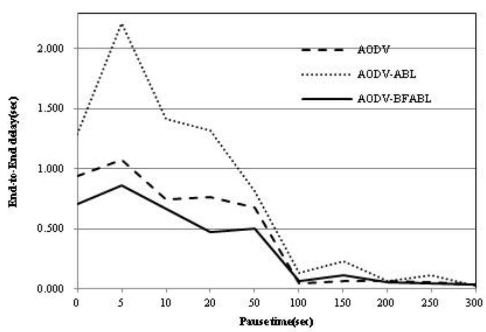


Figure 6. Average end-to-end delay

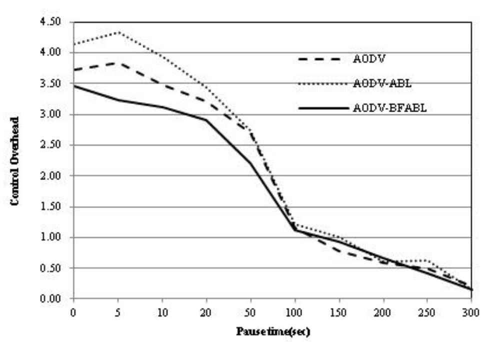


Figure 7. Normalized network overhead

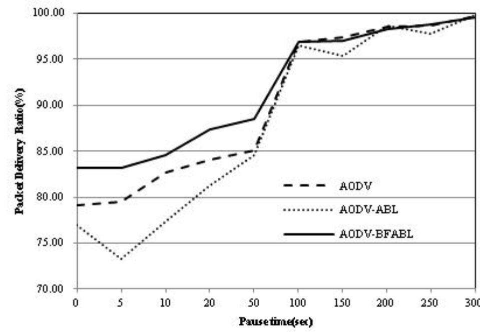


Figure 8. Packet successful delivery ratio

ACKNOWLEDGMENT

Our research is supported by Science and Technology Program of Hubei Provincial Department of Education (No. 20111803), Excellent Mid-youth Innovative Team Program of Hubei Provincial Department of Education (No. T200903), Hubei Key Laboratory of Automotive Power Train and Electronic Control (Hubei Automotive Industries Institute (No. ZDK201002)) and Scientific Research Foundation for Doctors of Hubei Automotive Industries Institute (No. BK200906).

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