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A New AODV Routing Protocol in Mobile Adhoc Networks

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Abstract: Many routing protocols in mobile ad-hoc networks have been developed by many researchers. One of ad-hoc routing protocol types is the on-demand routing that establishes a route to a destination node only when required. However, most of on-demand routing protocols reestablish a new route after a route break. In this paper, we propose a new route maintenance algorithm to avoid route breaks because each intermediate node on an active route detects a danger of a link break to an upstream node and reestablishes a new route before a route break. We propose this algorithm based on AODV (Ad-hoc On-demand Distance Vector routing protocol).

Key words: Ad-hoc networks · Routing · AODV · link break · AODV-BA

INTRODUCTION

In recent years, wireless networks with flexibility and simplicity such as the wireless LAN, are used in various places. However, most of these wireless networks have depended on infrastructures such as an access point and a router. For this reason, ad-hoc networks without the dependence to infrastructures are needed and are understudied by many researchers. Ad-hoc networks consist of mobile nodes with router functions and a wireless media. The routing algorithm is one of the important subjects of ad-hoc networks, because the network topology is changed dynamically by the movement of each node. In order to solve this subject, many routing protocols in ad-hoc networks have been proposed by present.

Routing protocols in ad-hoc networks are classified into the table drive type (the proactive type) and the on-demand type (the reactive type) largely. The table drive type is the protocol that a routing table in each node is updated by exchanging routing information between nodes periodically. But there is the problem that the routing overhead due to periodical exchanges is high. There are OLSR [1] and TBRPF [2] in typical protocols. The on-demand type is the protocol that establishes a route to a destination node only when required by a source node. Its overhead is low in comparison with the table drive type, but it is necessary to re-establish a new route when its route breaks down. There are DSR [3] and AODV in this type.

In order to realize the low overhead in ad-hoc networks, we focus on the on-demand type. Many routing protocols of the on-demand type reestablish a new route after a route break. So when its route breaks down, transmitted packets are lost and the communication is stopped until its new route is reestablished. In order to solve this problem, the establishments of a long-lived route (for example ABR [4]) and the multi-path routing (for example AOMDV [5]) have been proposed. But these are not efficient protocols because the route established at a certain time T is not always valid at time T + t in ad-hoc networks.

Then, we propose a new route maintenance algorithm to avoid route breaks. Thus, we propose this route maintenance algorithm based on AODV to avoid route breaks and we term our proposal as AODV-BA (AODV with Break Avoidance). To evaluate the AODV-BA, we present the computer simulation and make a comparison between the performance of AODV-BA and AODV.

AODV Routing Protocol: AODV is one of the routing protocols under study by MANET and the typical protocol of on-demand types. In AODV, each node has the routing table and the freshness of routes is ensured with the sequence number of each the routing information. When each node receives a control packet that occurred in on-demand, the routing table is updated based on the sequence number or the number of hops.

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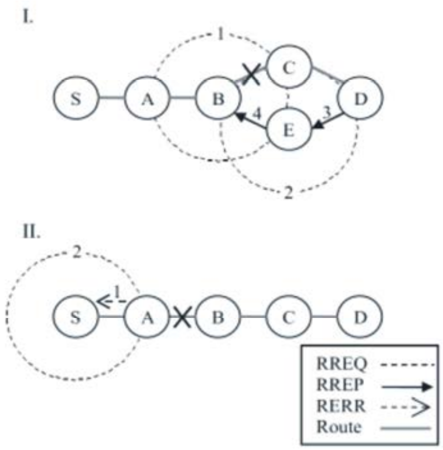

Fig. 1: The processes of route discovery

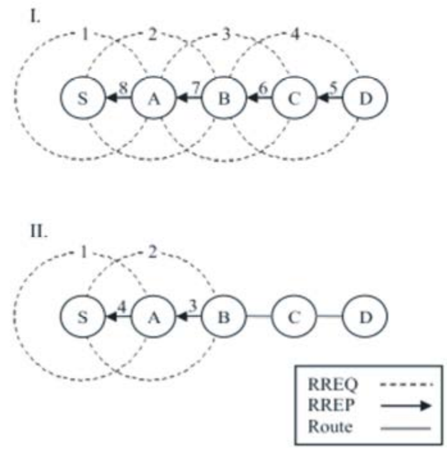

Fig. 2: The processes of route maintenance

If a route to a destination is needed, it is established at the route discovery phase and is maintained at the route maintenance phase.

Route Discovery: When a source node needs a route to a destination node and there is not the valid route in the routing table, the source node broadcasts a route request packet (RREQ) to the destination node. When each node receives the RREQ, it creates or updates a reverse route to the source node in the routing table. If it does not have a valid route to the destination node in the routing table, it rebroadcasts the RREQ. When the RREQ flooding from the source node arrives at the destination node, the destination node creates or updates the reverse route. And it unicasts a route reply packet (RREP) which has an incremented the sequence number to the reverse route.

When each node receives the RREP, it creates or updates a forward route to the destination node and it forwards the RREP to the reverse route. When the RREP arrives at the source node along with the reverse route, it creates or updates the forward route and starts communications.

For example, Figure 1-I shows the process of the route discovery, which the source node S broadcasts the RREQ and the destination node D unicasts the RREP. If each node has the valid route to the destination node in the routing table when it receives the RREQ, it unicasts the RREP to the source node instead of the destination node. For example, Figure 1-II shows such a process, which the node B unicasts the RREP instead of the node D. During the route discovery, when each node receives the RREQ that it has already processed, it discards the RREQ, so the loop is avoided and the overhead becomes low.

Route Maintenance: Each node broadcasts a Hello packet periodically for local connectivity. It broadcasts the RREP with TTL=1 as the Hello packet. When the node does not receive any packets from a neighbor during a few seconds, it assumes a link break to the neighbor. In addition, when the node has the link break to the neighbor based on an acknowledgment of MAC layer, it detects a route break to the destination node that the next hop of the route is the neighbor. When the node that detects the link break is close to the destination node (that is to say the number of hops to the destination node is smaller than the number of hops to the source node), it requires a new route to the destination node, which is known as Local

Repair: The local repair is the route discovery which is similar to the description above. During the local repair, arrival data packets received are buffered. When the RREP is received and the local repair is successful, the node starts sending data packets in the buffer.

For example, Figure 2-I shows the process of the local repair after the link break between the node B and the node C. On the other hand, when the node that detects the link break is far from the destination node, or when the local repair is unsuccessful, the node propagates a route error packet (RERR), which contains the addresses of the unreachable destination, toward the source node. When each intermediate node receives the RERR, the routes which have the unreachable destination node and have the next hop which is the propagation node of the RERR are made invalid and it propagates the RERR again. When the source node receives the RERR, the route to the destination node is made invalid similarly and it rediscovers the route again. For example, Figure 2-II shows the process of the route maintenance after the link break between the node A and the node B.

Related Work: In this section we describe several protocols proposed in papers that try to improve performance of original AODV routing protocol. These protocols try to decrease the number of loss packets and end-to-end delay. Many of these improvements are in building backup routes around the active route or in building multiple paths between source and destination nodes.

In the protocol that proposed by TANG and ZHANG [6] the route is built on-demand and maintained by locally updating route information. Multiple backup routes are built around the active route and the highest priority backup route will be switched to become the new active route when the current active route breaks or is less preferred. Routes adapt to fast topology variations and reach local optimum quickly.

Protocol tries to enhance AODV with multiple paths. It generates multiple routes without propagating more control messages than AODV. In this protocol, the RREQ process is the same as in AODV. When the RREP is sent back to the source node, each intermediate node builds the forwarding route and the nodes, which neighbor the route and overhear the RREP, build backup routes. When a link in the active route breaks, the upstream node of the broken link broadcast the data packet and sends an RERR to the source at the same time. If neighboring nodes have backup paths, the packet will be forwarded.

In the protocol that proposed by Sakurai and Katto [7] by applying a newly developed route update procedure with combined metrics of delay, hop count and disjointness, each intermediate node deliberately selects multi-path candidates while contributing to suppression of unnecessary routing packets. Extension of RREQ/RREP packets with a source route list is also incorporated, not only to alleviate limitation of the hop count based approaches but rather to provide more efficient multiple routes. Protocol extends the route discovery process by letting each intermediate node select reverse routes and forward routes in a distributed manner according to a specified metric.

Protocol specifies two methods with different metric definitions. The first one is based on a hop count minimization principle. Both the reverse routes and the forward routes are updated when delayed RREQ/RREP packets shows less hop counts. In this case, re-unicast or re-bicast applies to inform the update to a source node. The second method is based on a delay minimization principle. Since the metric is delay, RREQ/RREP packets are accepted in their arrival order and no re-unicasting or re-bicasting is performed. Protocol slightly modifies the principle that, when a delayed packet shows a hop count difference larger than m, the packet is not accepted even if the packet arrives fast.

Many routing protocols have been done to improve the performance of routing protocols. However, they can not overcome the problems of edge effect and route break at same time without incurring heavy control overhead. In the protocol that proposed by Feng and Cheng [8], based on the analysis of routing problem, a self-healing routing scheme based on AODV is proposed that routes can be constructed with long lifetime and unstable route can be self-heal to stable one before being broken absolutely.

AODV-BA Routing Protocol: In this algorithm each intermediate node on an active route detects the danger of the link break to the upstream node and route breaks are avoided by reestablishing a new route before route breaks.

Detection of a Danger of a Link Break: Each intermediate node on an active route detects a danger of a link break to an upstream node based on four elements which are the received radio, the overlap of routes, the battery and the density. When it detects the danger of the link break, it notifies the danger to the upstream node.

Received Radio: The danger of the link break due to the distance between nodes being farther than the communication range is detected based on the received radio. The received power P_r at the time of receiving packets as shown with the following equation depends on the distance d between nodes.

$$P_r = \frac{P_t . G_t . G_r , h_t^2 . h_r^2}{d^A . L}$$

Two-Ray Ground Reflection model [9] used as the radio propagation model. P_t,G_t and h_t are the transmitted power, the antenna gain and the height of the antenna on the transmitted side. G_r and h_r are ones on the received side. L is the loss factor of the system. In advance, each intermediate node transmits information of the transmitting side to the next hop of the destination route. The threshold of the received power which corresponds to the distance between nodes detecting the danger of the link break is defined from the above information. When the received power at the time of receiving data packets is less than the threshold and has decreased as compared with the previous received power, the node notifies the upstream node the danger of the link break. After that, the received RREQ which is transmitted from the upstream node is discarded and not processed for a while.

Overlap of Routes: When there is a certain intermediate node on several active routes, the transmission delay increases by the traffic loads and also the battery of the node is quickly consumed. In addition, several routes are broken at the same time by the node being downed. Because of this, when the node receives date packets from several source nodes and the number of received data packets per a second is more than the average of number of received data packets from the start of communication, it detects the danger of the link break.

The node selects the route which it is possible to perform the local repair from among routes, or the route which has the smaller number of hops to the source node if it is not. And the node notifies the danger of the link break to the upstream node. After that, the received RREQ is discarded and not processed for a while. However, in the case of one hop from each intermediate node to the source node or the destination node, it does not notify the upstream node after detecting the danger of the link break.

Battery: When the battery of each intermediate node is empty, it is impossible to communicate and the link break is occurred. When the battery is less than the threshold, the node notifies the upstream node the danger of the link break. After that, until the battery recovers, the received RREQ is discarded and not processed[10].

Density: On an access control in a radio media, each node transmitting a packet acquires a wireless channel shared with neighbor nodes. When the number of neighbor nodes around each intermediate node increases and the density rises, the transmission delay increases by competing of acquiring the wireless channel.

In AODV, each node periodically transmits a Hello packet and then the number of Hello packets received during a fixed time approximates to the number of neighbor nodes. When each node transmits the Hello packet, it contains its number of Hello packets received during the fixed time (as HELLO-COUNT). And each node calculates the average of HELLO-COUNT in each Hello packet received during the fixed time. When its number of Hello packets received during the fixed time is more than this average and the threshold, the node notifies the danger of the link break to the upstream node. After that, until the number of neighbor nodes is normally, the received RREQ is discarded and not processed. However, in the case of one hop from each intermediate node to the source node or the destination node, it does not notify the upstream node after detecting the danger of the link break.

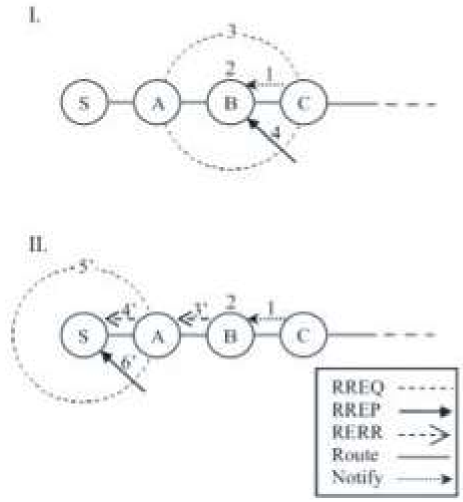

Fig. 3: The processes of avoiding a route break

Algorithm of Avoiding Route Breaks: The following sequence of steps is the detailed description of the proposed algorithm. Figure 3 shows the process that the route break is avoided by detecting the danger of the link break.

Step 1: The node C detects the danger of the link break to the upstream node B and notifies the danger of the link break to the node B. (refer to Figure 3-I and II)

Step 2: The notified node B sets the weak state to the routing flag of the route entry that the next hop is the node C. After that, the received RREQ that the node C has transmitted, is discarded and not processed for a while. (refer to Figure 3-I and II)

Step 3: When the node B is close to the destination node, it performs the local repair. (refer to Figure 3-I)

Step 4: After that, when the node B receives the RREP, it alternates to a new route instead of the route that the routing flag is on the weak state. (refer to Figure 3-I)

Step 3': When the node B is far from the destination node, it transmits the RERR with setting the W flag, which the route is not made invalid when each node receives this RERR. (refer to Figure 3-II)

Step 4': The node A which received this RERR sets the weak state to the routing flag of the route entry that the next hop is the node B and it transmits this RERR again. (refer to Figure 3-II)

Step 5': The source node S which received this RERR sets the weak state to the routing flag similarly and it broadcasts the RREQ to reestablish a new destination route. (refer to Figure 3-II)

Step 6': After that, when the node S receives the RREP, it alternates to a new route instead of the route that the routing flag is on the weak state. (refer to Figure 3-II)

If the routing flag of the route entry is on the weak state, it is possible to transmit data packets to the next hop. But when the node receives the RREQ to the destination node of the entry, it does not transmit the RREP even if it has the valid route. And when the link to the next hop breaks, it does not transmit the RERR. In addition, this entry is made invalid after a fixed time. In this way, the route break is avoided by the above process and the communication is not stopped during this time.

Simulation Experiments: This section evaluates the performance of AODV-BA composed with AODV by the computer simulation using ns-2 [11].

Simulation Environment: The source node S and the destination node D are not moved and are set on the field of 1000×1000m. The node S transmits data packets to the node D during 60 seconds. Other nodes are set to the random position at first and move with the random way point movement model. It is the movement model which moves at a certain fixed speed below maximum speed from a certain position to a certain destination one and stops during a pause time after arriving at the destination one and starts moving again after the pause time.

And there are several sources other than the node S, which transmit data packets to a certain destination. The buffer size of each node is 64 packets and each node drops buffered packets after 30 seconds. The battery of each node is consumed at the time of sending and receiving packets and at the time of idle state and it is impossible to communicate when the battery is empty. In this simulation, an RREP-ACK and a Gratuitous-RREP are not used. And for each parameter of AODV, the default value of ns-2 is used. Other detailed simulation environments are shown below.

Simulator	:	ns-2.27
Position of Node S	:	(50,50)
Position of Node D	:	(950,950)
Number of Nodes	:	100,150,200
Number of Sources	:	0,5,10
Maximum Speed	:	5,10,20 m/sec
Pause Time	:	1 sec
Packet Size		: 512 bytes
Sending Rate	:	4 packets/sec (CBR)
Transport Layer	:	UDP
Mac Layer	:	IEEE 802.11 DCF
Antenna Type	:	Omni antenna
Communication Range	:	250 m
Bandwidth	:	2 Mbps
Initial Battery	:	10 W
Consumed Send Power	:	0.28 W/sec
Consumed Receive Power	:	0.28 W/sec

Each threshold of four elements which detect the danger of the link break is defined below. The received power which corresponds to the distance 240m between nodes is defined by the transmitted power, the antenna gain, the height of antenna, the loss factor and the equation of 4.1.1.

Transmitted Power	:	0.28183815 W
Antenna Gain	:	1.0
Height of Antenna	:	1.5 m
Loss Factor	:	1.0
Threshold of Radio	:	4.3e-10 W (240 m)
Threshold of Battery	:	1%
Threshold of Density	:	50 nodes

With the above simulation environment, it is simulated by changing three parameters of the number of nodes, the number of sources other than the node S and the max speed of nodes. When it changes a certain parameter, other two parameters is fixed as the number of nodes is 150, as the number of sources is 5 and as the max speed is 10 (m/s).

Results and Analysis: The average of 10 times simulations with each parameter is shown in following graphs. Figure 4 shows separately the number of detections of the danger of the link break according to four elements between nodes S-D in AODV-BA. It is shown that the number of detections of the received radio is the most of total. The number of detections of the density increases due to the increase of the number of nodes. The number of detections of the overlap of routes increases due to the increase of the number of sources and the number of detections of the battery also increases because the battery of each node is consumed much by the increase of the traffic. The number of detections of the received radio increases because the max speed of node becomes more quickly.

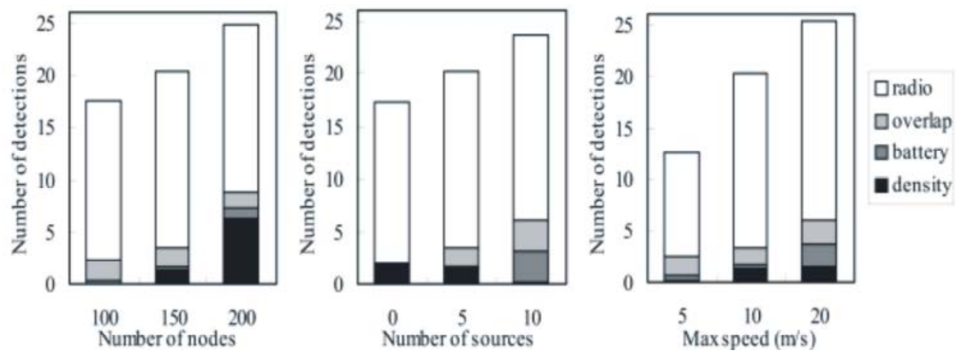

Fig. 4: Number of detections

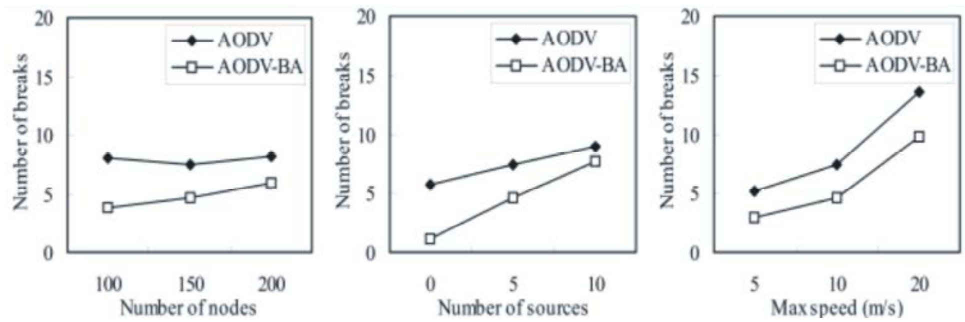

Fig. 5: Number of route breaks

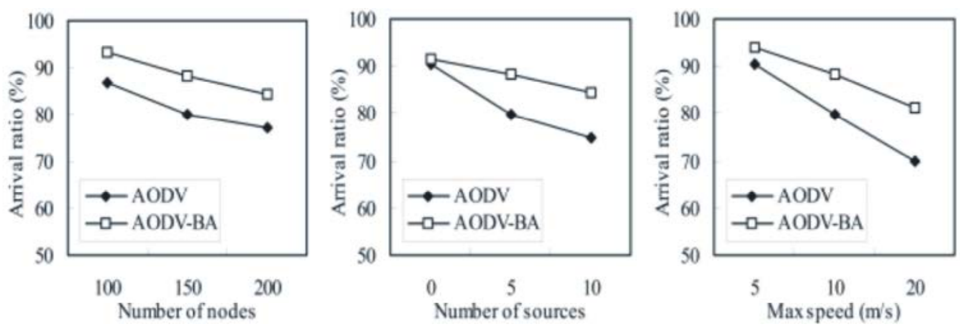

Fig. 6: Packet arrival ratio

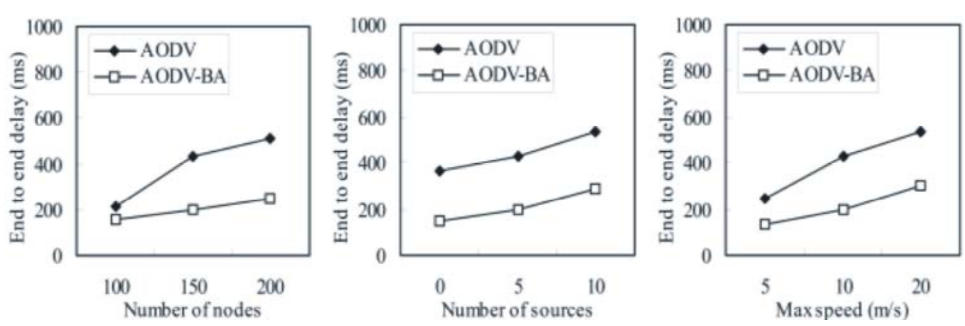

Fig. 7: End to end delay

Figure 5 shows the number of route breaks between nodes S-D. Avoiding route breaks by detecting the danger of the link break exactly is effected by decreasing the number of route breaks in AODV-BA. Figure 6 shows the packet arrival ratio, which is the ratio of the number of data packets that the node D received in the number of data packets that the node S required to transmit. Because the number of loss data packets due to route breaks decreases, the packet arrival ratio of AODV-BA rises in comparison with AODV.

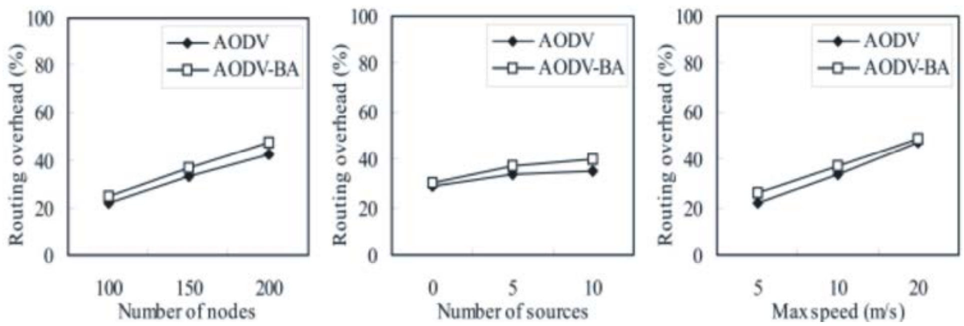

Fig. 8: Routing overhead

Figure 7 shows the end to end delay (T2-T1). T1 is time when the node S required transmitting the data packet and T2 is time when the node D received it. Because the time of reestablishing a new route due to route breaks is shortened in AODV-BA, the end to end delay of AODV-BA decreases in comparison with AODV.

Figure 8 shows the routing overhead between nodes S-D. The routing overhead is defined the following equation in this paper.

$$\text{Routing Over heed} = \frac{\sum_{i=1}^{M} a_i b_i}{\sum_{j=1}^{M} c_i d_j + \sum_{i=1}^{M} a_i b_i}$$

M is the number of control packets except HELLO packets between nodes S-D, α_i is the number of control packets transmitted and forwarded by generating nodes or intermediate nodes and b_i is size of each control packets. N is the number of arrival data packets at the node D, c_j is the hop count of each data packet to the node D and d_j is size of each data packets. It is shown that the routing overhead of AODV-BA increases a little in comparison with AODV, because in AODV-BA the number of control packets increases due to increase of the number of reestablishing.

From the above results of simulations, AODV-BA has the following characteristics and it is shown that AODV-BA is more effective than AODV:

- The number of route breaks decreases.
- The packet arrival ratio raises.
- The end to end delay decreases.
- The routing overhead increases a little in comparison with AODV.

CONCLUSION

In this paper, we proposed AODV-BA which avoids route breaks based on AODV in ad-hoc routing protocols. It is the algorithm which each intermediate node on an active route detects the danger of the link break to the upstream node based on four elements of the received radio, the overlap of routes, the battery and the density and route breaks are avoided by reestablishing a new route with our proposal algorithm before route breaks. From the results of computer simulations, it is shown that AODV-BA is more effective than AODV.

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