AODV-Deleting Path with Bad Broken Index

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Abstract – In recent years, the development of mobile equipment makes the topology of the network to change rapidly. So that its routing problem becomes an important research subject accordingly. In all the proposed protocols, the Ad Hoc On-demand Distance Vector Routing Protocol (AODV) is applied to most wireless environments. With it, the shortest path from the source to destination node is chosen by the metric of hop counts. However, the chosen path with this metric may not be a stable one. With the research of predecessors, the Link Available Time (LAT) can be calculated by the strength of received signal and may be regarded as another usable routing metric. Based on that, the authors develop a protocol named AODV-Deleting Path with Bad Broken Index (AODV-DPWBB) and discuss all the logicality of it. The simulation is done for two contention modes in several node speeds with discussion followed. The simulation result shows better throughput, and end-to-end delay can be obtained comparing the original AODV with metric of hop-count.

Key words – *MANET*; *AODV*; *routing protocol*; *signal strength*; *simulation*

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1 Introduction

Mobile Ad Hoc Network (MAHN), all nodes may move at any instant. Since the received signal may be interrupted any time, the topology of this network may change from time to time. Thus, the routing table of nodes may need to change before the starting of transmission. In other word, all the routing work before the transmission may be a waste. These include the waste of network resource and the precious battery power of the nodes. Therefore, Ad Hoc On-demand Distance Vector Routing Protocol (AODV) becomes to be the most popular routing protocol for MANET. With this protocol, the routing is started by the source node only when it needs a path to the destination or some node detects the broken of being used path. In this protocol, an RREQ packet is flooded from the source node. All the other nodes will receive this packet through all possible paths and the path with the smallest number of hops will be chosen as the best path to the source node. Therefore, all nodes can find the best path to the source node passively through the receiving of RREQ packet. When the destination node receives the RREQ packet, the RREP packet will be sent back to the source node through the best path to the source node. Any node receiving this packet can know the next hop to the destination node for the best path. In this way, all nodes along the path of RREP packet will know the best path to the destination node[1].

Until now, the path with the smallest number of hops will be chosen as the best path in AODV. However, the best path may become broken promptly and the transmission may be interrupted and a search of new path may become needed. This means the throughput and end-to-end delay will be affected and more network resource and battery power will be wasted.

With this problem, some researchers try to replace the metric of hop number with Link Available Time (LAT) in AODV[2]. The LATs of all links along a path are combined to predict the live time of this path. The path with the longest live time will be chosen as the best path in this new AODV. However, the path with the longest live time may also contain the largest number of hop count. In other word, the best path in this protocol may have the largest end to end delay. For this, we propose a new protocol in this paper which will combine the LAT and hop count as a metric of AODV. In our proposal, the path of the first returned RREP packets will be taken as the first choice of the best path. With high probability, this path has the smallest end to end delay. This path will only be replaced by those with larger live time and smaller hop count.

The remainder of the paper is organized as follow. In the section 2, we will present some background for the AODV with LAT metric. The AODV with combined metric of hop count and LAT will be described in section 3. In section 4, the simulation result and performance analysis will be presented and discussed. Finally, some remark about conclusion and future work are shown in section 5.

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2 Background about AODV with metric of LAT

2.1 MANET

As shown in Fig. 1, the mobile nodes can move arbitrarily and the network has dynamic topology. Mobile nodes can communicate directly if they can receive the signal of each other. In this case, we say they are neighboring nodes or there is a link between them. If the nodes are not neighboring, the source has to route the data to the destination with the help of other nodes. In other word, the mobile nodes can be a host or router whenever it is necessary. The neighboring nodes use IEEE802.11 to communicate on the MAC layer. For the network layer, AODV is the most popular routing protocol for this kind of network. With AODV, the nodes can build their routing tables. When a data packet arrives, the destination address will be checked and the next hop will be found from the routing table. Then, the packet will be forwarded until it reaches the destination node.

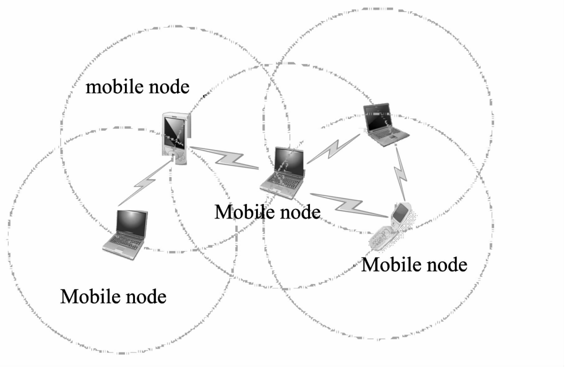

Fig. 1 MANET

2.2 AODV

As shown in Fig. 2, the unicast routing protocols for MANET can be divided into topology-based and geographical-based routing protocols. The topology-based protocols can be divided into table driven, on demand and mixed protocols. For table driven protocols, the routing packets are exchanged periodically. Unless special event occurred, the routing tables are also updated periodically[3-6]. For on demand protocols, an entry in the routing table will be cleared if its live time is up. If the source node has data to send and has no path to the destination, it will start an algorithm to search a path to the destination. This is why these protocols are called on-demand protocols[7-9]. The mixed protocols have the characteristic of both table driven and on demand protocols[10]. Geographical-based routing protocols need to use GPSs to detect the positions of mobiles nodes and an algorithm is needed to exchange them[11-12].

The AODV is an on demand protocol. If the source node has data to send and has no path to the destination node, it will flood an RREQ packet into the network. In other word, this packet will be forwarded to all output ports when it is received. To prevent the packet is flooded repeatedly at the same node, the receiver will keep records for all received RREQ packets. This record includes a sequence number, address of source node and address of destination node. The hop count in the RREQ packet will be increased with one by the receiver. When a node receives an RREQ packet, it will know the hop number from the source node. When a node receives the first arrived RREQ packet, it will record this as the best path from it to the source node. In the routing table, the input port of this packet will be recorded as the output port of this path to the source node. The hop count in the received RREQ packet will be the hop number of the best path in the table. Later, if another packet from the source node with smaller hop count will change this entry of the table. From the input port and hop count of this packet, the node can know the next hop and hop counts of the best path to the source node. In other word, all nodes can find the best path to the source node from the flooding of RREQ packets.

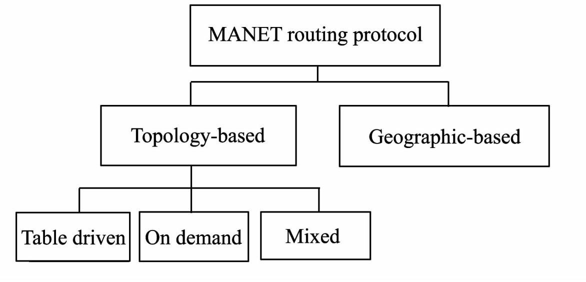

Fig. 2 Classification of routing protocol for MANET

When the RREQ packet is received by the destination, it will be compared with the path to the source node in its routing table. If this path has smaller hop count, it will send an RREP packet through this best path to the source node. All nodes receiving this RREP packet will compare the hop count in it with the best path to destination node in its routing table. If it has smaller hop count, it will be recorded in the routing table and the RREP packet will be forwarded through the best path to the source. When the RREP is received by the source node, all nodes in its path will know the next hop to the destination. At this time, a path is built and the data can be sent from the source to the destination. Since the topology of MANET is dynamic, the newer path is more important than the older ones. The AODV mentioned should be adjusted as follow. The RREQ packet and RREP packet can afford possible best path to the node generating them. Later generated packet affords newer path. Therefore, there is a counter in each node which will be increased by one whenever a new RREQ or RREP packet is generated.

The sequence number in this counter will be included into the generated RREQ and RREP packet. Larger number in RREQ or RREP packet affords newer path. When a node takes the path afforded by these packets, this sequence number will be included into the routing table. If this sequence number in the RREQ or RREP packet is larger than that in the entry of the routing table, this packet carry newer path and its path will replace the older one in the table. If the packet carry older path, it will be discarded. Otherwise, the sequence number is the same and the hop count will be used to choose better path.

2.3 Related works for LAT

In Ref.[2], the LAT has been used as the metric deciding the best path for AODV. Let $\mathrm{RSS}_{i,j}(t)$ be the strength of received signal from node i to node j . Let's assume the link is symmetric. In other word, $\mathrm{RSS}_{i,j}(t) = \mathrm{RSS}_{j,i}(t)$. Let $\Delta\mathrm{RSS}_{i,j}(t)$ be the rate of change for RSS. Then, it can be calculated by

$$\Delta\mathrm{RSS}_{i,j} = \frac{\mathrm{RSS}_{i,j}(t_2) - \mathrm{RSS}_{i,j}(t_1)}{t_2 - t_1}, \text{ for } t_2 > t_1. \quad (1)$$

By assumption, $\mathrm{RSS}_{i,j}(t) = \mathrm{RSS}_{j,i}(t)$. Thus, $\Delta\mathrm{RSS}_{i,j}(t) = \Delta\mathrm{RSS}_{j,i}(t)$. Since RSS is inversely proportional to the square of distance between nodes in general. Smaller distance has larger RSS and larger distance has smaller RSS. Therefore, we can conclude the following results.

When mobile node i and j move toward each other, $\Delta\mathrm{RSS}_{i,j}(t) > 0$; When mobile node i and j move away from each other, $\Delta\mathrm{RSS}_{i,j}(t) < 0$.

The value of $\mathrm{RSS}_{i,j}(t)$ depends on the distance between node i and j at time t . Since the distance divided by time equal to velocity, the value of $\Delta\mathrm{RSS}_{i,j}(t)$ can be used as an index of the relative velocity between node i and j . In other word, larger $|\Delta\mathrm{RSS}_{i,j}(t)|$ means larger relative velocity and the nodes are move toward or move away from each other. Similarly, smaller $|\Delta\mathrm{RSS}_{i,j}(t)|$ means.

Now, let's use nodes move in the same direction. RSS and ΔRSS to derive the LAT between two nodes. This is the time interval from now to the link is broken. Here, the link broken means two nodes cannot receive the signal of each other. Let's define some useful parameters as follow: $D_{i,j}(t)$: the distance between node i and node j at time t ; $S_{i,j}(t)$: the relative velocity between node i and node j at time t ; TR : the maximum distance wireless signal can be received.

As shown in Fig.3, the time interval before the two nodes are closest to each other is $D_{i,j}(t)/S_{i,j}(t)$. Also, the time interval before they cannot communicate directly is $TR/S_{i,j}(t)$. Therefore, the LAT of two nodes is $[TR + D_{i,j}(t)]/S_{i,j}(t)$ if they are moving toward each other. Similarly, the LAT of two nodes is $TR - D_{i,j}(t)/|S_{i,j}(t)|$ if they are moving away from each other. When two nodes are moving toward each other, $\Delta\mathrm{RSS}_{i,j}(t)$. Therefore, we can have the following results:

$\Delta\mathrm{RSS}_{i,j}(t) > 0$: $\mathrm{LAT}_{i,j}(t) = [TR + D_{i,j}(t)]/S_{i,j}(t)$,

$\Delta\mathrm{RSS}_{i,j}(t) < 0$: $\mathrm{LAT}_{i,j}(t) = [TR - D_{i,j}(t)]/S_{i,j}(t)$.

Therefore, the value of LAT can be found with $D_{i,j}(t)$ and $S_{i,j}(t)$. The RSS is proportional to D^{-2} in general. From the definition of $\Delta\mathrm{RSS}$, we can hawe $\Delta\mathrm{RSS} = (\mathrm{dRSS})/(\mathrm{d}t) \propto (\mathrm{d}D^{-2})/(\mathrm{d}t) = -2D^{-3}(\mathrm{d}D/\mathrm{d}t) = -2D^{-3}S_{i,j}(t)$. Thus, $S_{i,j}(t) \propto D^3\Delta\mathrm{RSS}(\mathrm{RSS})^{-3/2}\Delta\mathrm{RSS}$. Therefore, For $\Delta\mathrm{RSS}_{i,j}(t) > 0$,

$$\mathrm{LAT}_{i,j}(t) = \frac{TR + (\mathrm{RSS}_{i,j}(t))^{-1/2}}{[\mathrm{RSS}_{i,j}(t)]^{-3/2} \cdot \Delta\mathrm{RSS}_{i,j}(t)}. \quad (2)$$

For $\Delta\mathrm{RSS}_{i,j}(t) < 0$,

$$\mathrm{LAT}_{i,j}(t) = \frac{TR - (\mathrm{RSS}_{i,j}(t))^{-1/2}}{[\mathrm{RSS}_{i,j}(t)]^{-3/2} \cdot \Delta\mathrm{RSS}_{i,j}(t)}. \quad (3)$$

The above equations are from Ref.[2]. However, it should be noted that we neglect all the proportional constants in the above equations. Therefore, the LAT derived is only an index of the real LAT. Only the relative values of real LAT are needed to compare the links. Therefore, the above equations will be used to calculate LAT in our proposal.

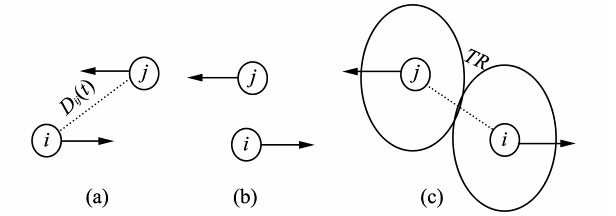

Fig.3 Two nodes move toward and away from each other

3 AODV-Deleting Path with Bad BI (AODV-DPWBB)

3.1 Problems of AODV and the direction of solution

In AODV, the nodes use hop count to choose the best path. With high probability, the path with minimum hop count has the least end to end delay. Also, the smallest network resources will be used to send data to the destination if we consider the number of physical layer transmission. However, the arguments here will not be true if this best path contains a link with small LAT. With small LAT, the link and the path will be broken. Then, the source needs to be notified and a new path needs to be found. This makes the foregoing search of path meaningless. In this case, why doesn't the protocol prevent to use the path with small LAT in the beginning? Maintaining the Integrity of the Specifications.

3.2 The broken index of a path

In equation (1),(2),(3), we have shown how to find the LAT of a link from the RSS and ΔRSS of the receiver. Since a path may contain several links and each link has its own RSS, we need a method to decide its link available time from that of all links. Since we want to exclude the path that contains a link of very small LAT, it is reasonable to use 1/LAT as a metric. Therefore, we will define the broken index of a path as

$$BI = \sum_i \frac{1}{LAT_i}, \quad (4)$$

where LAT_i is the link available time of the i^{th} link of this path.

A smaller BI means the path tends to be good for a while. A larger one means the path tends to become broken in a short while.

3.3 AODV-DPWBB

In AODV, the destinations node will receive many copies of the RREQ packet from its neighbors. Since the first received RREQ packet go through the best path (with the smallest hop count) until then, the destination node will send an RREP packet through the reverse path of it. Later, the destination node will receive more RREQ packets, it will not respond with more RREP packets unless the RREQ packet has smaller hop count than the first one. In AODV-DPWBB, the destination node sends the first RREP packet as AODV does. However, the destination node will not respond with RREP packet unless the RREQ packet has smaller hop count and BI. In other word, the destination node will not choose a path with large BI and short available time. Since AODV has been prevailingly accepted, the hop count has been chosen as the main metric in our proposal. In our research, we want to study the performance of AODV after introducing the metric of BI into it. For the source node, it will take the first returned RREP as the one going through the best path since it's the one with the smallest count until then. Later, more RREP packets will arrive at the source node. However, their path will not be accepted as the best one unless it has smaller hop count and BI. In our proposal, the nodes of the network must measure RRS and ΔRSS of its link to the neighbors. With these, the nodes can calculate the LAT of all links. Before sending the RREQ packet, the mobile node has to calculate the value of BI until now. The hop count is increased as in AODV. Also, a path will not be chosen if it is an older one. Therefore, the counter of a node will be increased by one whenever an RREQ or RREP packet is generated. This number will be included in the RREQ or RREP packets as source sequence or destination sequence number. These sequence numbers will be used to decide which path is newer. With AODV, a path with the smallest hop count will be chosen as the best path even it has a very large BI. With AODV-DPWBB, a path with the smallest hop count and large BI will not be chosen as the best path unless it corresponds to the first arrival packet. If it corresponds to the first arrival packet, it has the smallest end to end delay. In this case, search of path costs less. A large BI hurts less. It should be noted a path with smaller BI can replace another one as the best path if both have the same hop count.

From the above discussion, let's summarize the AODV-DPWBB as follows:

1) Each mobile node has a table which marks the best path to the other node. Each entry represents the best path to some destination. It records the next hop and hop count of this best path. There is a sequence number for each entry which marks how old this path is?

2) Each node has a counter which is increased by one whenever a RREQ or RREP packet is generated by it.

3) Whenever an RREQ or RREP packet is generated, the number in the counter of 2 will be included in it as a sequence number.

4) Whenever a node takes the path of an RREQ or RREP packet as the best one to some node, it will record the sequence number in the packet into the entry. This sequence number represents how old this path is. A larger sequence number represents a newer path.

5) Each entry of the routing table has a lifetime. When time is up, this entry will be erased. This will present a very large sequence number (which is from an error received routing packet) occupy the entry for a very long time.

6) When the source needs a best path to some node and there is no such entry in its table (which has been erased), it will record the destination sequence number of RREQ packet as 0 and flood it into the network. If it has a best path, it will get the sequence number of this destination from the table and write it into the destination sequence number of RREQ packet. This RREQ packet will be forwarded.

7) Each node finds the LAT to each of its neighbors by equation (1),(2) and (3). This LAT is calculated periodically.

8) When an RREQ packet is received, the destination sequence number in it will be compared with the sequence number in its table. If the sequence number in the table, this node has newer path to the destination. The RREQ packet is discarded and an RREP packet is sent to the source node. Also, when an RREQ packet is received, the sequence number in it will be compared with the entry for the source node in the routing table. If this number is larger than that in the entry, this RREQ has gone through a newer path. This path will replace the one in the routing table. This represents a newer path to the source node of this RREQ packet. If the sequence number in the RREQ packet is smaller, this packet will be discarded. If the sequence number is the same, the hop count is increased by one and BI is calculated by equation (4). In this case, the calculated hop count and BI are compared with those in the routing table. If both are smaller, the RREQ packet has gone through a better path. This path will replace the one in the routing table for the source of this RREQ packet.

9) When an RREP packet is received, the sequence number in it is compared with that in the table for the source of this RREP packet. If the sequence number in the packet is smaller, it is discarded. If it is larger, the path of this packet is recorded as the best one in the routing table of this node. Then, the hop count and BI are calculated and write into the RREP packet. Then, this packet is forwarded to the destination of it. If the se-

quence number is the same, the hop count and BI are calculated. If both are smaller than those in the table, the path of RREP packet is better than that in the table. This path will replace the one in the table for the source of this RREP packet.

10) If a node gets a better path through receiving an RREQ or RREP packet, this packet will be forwarded. Otherwise, this packet is discarded. In other word, good news (hop count and BI) will be propagated and bad news will be discarded. This is a nature of distance vector protocol.

4 Simulation results and performance analysis

4.1 System framework and simulation settings

In this research, NCTUns3.0 developed by NCTU has been used as the platform of simulation. The AODV protocol has been modified into AODV-DPPWBB. We simulate 64 mobile nodes move within a range of 1200 m2 on this platform. In Tab.1, the range of signal receiving is 250m. The mobile nodes move in a model of Random Way Point.

Tab.1 The environment parameters of simulation

Parameter of simulation	Parameter value
Number of obile nodes	64 (8×8 matrix)
The distance to next node in the beginning	150 m
Transmission range	250 m
Area of simulation	1 300 m×1 300 m
Time of simulation	800 s
Traffic class	UDP
Packet size	512 Byte
Mobile model	Random way point

The packet arrival in each node is in a model of Constant Bit Rate(CBR). The length of arrival packet is 512 Bytes. The time of simulation is 800 seconds. In the simulation, the network layer use AODV-DPWBB and IP. IEEE802.11 is used at the MAC layer. Then, UDP is used (User Datagram Protocol) at the transportation layer.

To understand the influence of mobility on the performance, the speeds have been set as 2,4,6 and 8(meter/second) and four rounds of simulations have been performed for each case There are two types of competition mode have been set up for the simulation. For the first type, five source nodes send data to one destination node. For the second one, three couples of source node and destination node are in the network. Other mobile nodes only work as moving routers for them. The throughput is set as the average number of bytes per second received at the destination node. The end to end delay is set as the average delay from the source node to the destination node.

4.2 Simulation result and analysis

In Fig.4 and Fig.6, the performance of throughput for AODV-DPWBBI and AODV are shown. In Fig.5 and Fig.7, the performance of end to end delay for AODV-DPWBBI and AODV are shown. As we can see from the figures, the throughputs are higher and delays are smaller for AODV-DPWBBI. The unit of throughput is Bytes/s and that of end to end delay is s here. In the first two figures, five source nodes send data to one destination node. In the last two figures, there are three couples of source and destination and each source node sends data to its own destination. The simulation has been performed for 4 different mobile speeds for each figure. The lines with square points are the performance of AODV and the other lines are that of AODV-DWPBBI.

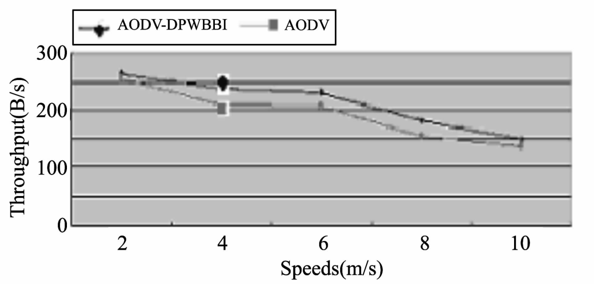

Fig.4 The throughput (B/s) versus speed (m/s) with 5 sources and 1 destination

As we can see from the figures, the throughput is decreased as the mobility is increased for both contention modes (5 to 1 and 3 to 3). Also, the end to end delay is increased as the mobility is increased. In other word, the performance will be degraded as the speed of mobile nodes is increased. Higher speed means high BI and the path tends to become broken. In this case, each transmission needs more times of routing and the performance is degraded. As we can see from Fig.4 and 6, the throughput is higher with AODV-DPWBB comparing with AODV. The throughput is lower and the end to end delay ishigher in the second mode of contention (3 to 3). This is because more paths may share the same links in this case. This will cause more contention in the MAC layer and the performance will be degraded.

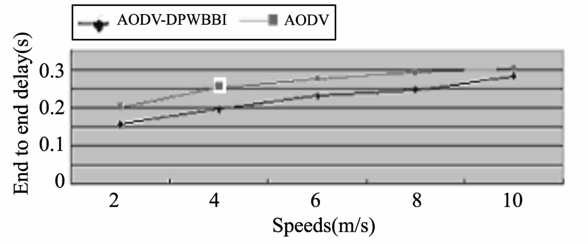

Fig.5 End to end delay (s) versus speed (m/s) with 5 sources and 1 destination

As we can see from the figures, the throughput is decreased as the mobility is increased for both contention modes (5 to 1 and 3 to 3). Also, the end to end delay is increased as the mobility is increased. In other word, the performance will be degraded as the speed of mobile nodes is increased. Higher speed means high BI and the path tends to become broken. In this case, each transmission needs more times of routing and the performance is degraded. As we can see from Fig. 4 and Fig. 6, the throughput is higher with AODV-DPWBB comparing with AODV. The throughput is lower and the end to end delay is higher in the second mode of contention (3 to 3). This is because more paths may share the same links in this case. This will cause more contention in the MAC layer and the performance will be degraded.

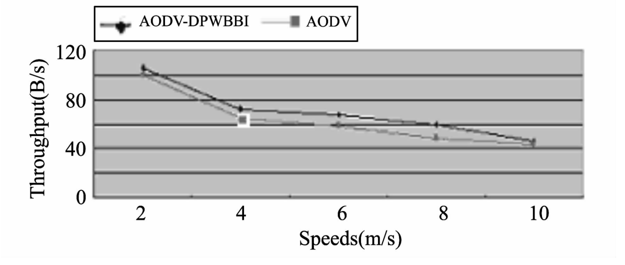

Fig. 6 Throughput (B/s) versus speed (m/s) with 3 sources and 3 destinations

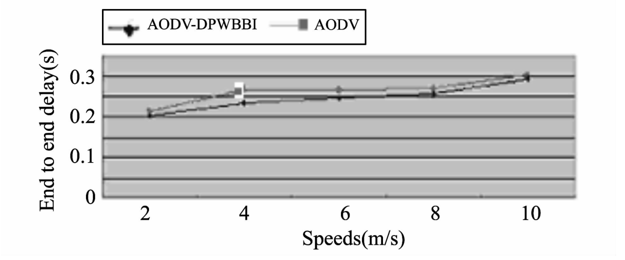

Fig. 7 End to end delay (s) versus speed (m/s) with 3 sources and 3 destinations

As the speed approaches zero, the performance of AODV-DPWBB will approaches that of AODV. The performance of these two protocols makes no difference. Also, the performance at this point will be much higher since the path will not be broken and one time of routing is enough. If we show the performance at this point, we will need much larger scale for the figure and the performance at other points will look like a horizontal line. This will make the comparing of the two protocols difficult. Therefore, we neglect this point since there is nothing to compare for the same protocol. As the speed increased, the difference of performance for two protocols becomes larger since BI become more important. However, the difference will become very small as the speed of mobile nodes is 10 m/s. At this speed, all possible paths tend to be broken. Therefore, the introducing of BI metric makes little difference and the difference of performance becomes not so clear. This can be seen from the left end of the curve.

5 Conclusion

In AODV, the hop count has been as the metric to choose the best path. Since smaller hop number for each path means less resource used for each transmission, itseems a right way to go. However, this logic may become not so sure if more times of transmission is needed for each data frame. Since larger BI will cause broken path during the transmission and more times of transmission for one data, it's reasonable to introduce the metric of BI into AODV for a mobile system. For this, we modify the contents of AODV and propose AODV-DPWBB in this paper.

The simulation result shows the performance will become better with AODV-DPWBB. Also, the improvement is not so clear when the speed of mobile node is very high. This is because the BI will be very large for every path. In this case, the path will become broken during transmission in any way. Since AODV-DPWBB is more complex than AODV, it is not recommended that this protocol is used in network with very high mobility.

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