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Virtual connection routing based on node mobility in vanet

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Abstract. Due to the quick mobility of node in MANETs (Mobile Ad Hoc Networks), it makes the communication path maintaining the source node and destination node become a challenging work. The high-speed mobility of node results in the frequent disconnecion of communication link. Hence, to be able to better cope with the high-speed mobility environment, the router protocol for connection of Virtual router based on the mobility degree of node is proposed, denoted as MDNVRP (mobility degree of node-virtual router protocol). Even though MDNVRP protocol is connection-oriented, what is established prior to data delivery is virtual connection, but not physical connection. The virtual router is the logical router concerning specific geographic region, which is composed of one or multiple mobile nodes within geographic region. The physical node within the geographic region where the virtual router is sets the timer of forwarding packets in accordance with the mobility degree of node, in which the small the mobility degree is, the shorter the duration of timer is, that is, it has the precedence right to forward the packets . The simulation result shows that compared to AODV, the performance of EED (End-to-End delay) , route overhead and RPD (Ratio of Packets Delivered) of MDNVRP proposed in the router protocol proposed have all been significantly improved.

Key words. Ad Hoc Networks, Node mobility, Virtual connection, Virtual router, Geographic region.

1. Introduction

MANETs (Mobile Ad Hoc Networks) is a network[1] formed by self-mobility of MNs(Mobile Nodes). There is no need of any hardware equipment in MANETs, but MNs can communicate mutually. Each MN plays a role of router. Due to the free mobility of MNs, it makes the topological structure dynamically change, which is also the most significant characteristic[2] of MANETs. Because of this characteristic, a challenge for route technology is proposed. According to the fact that whether it is connection-oriented, the existing router protocol in MANETs

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can be divided into connection-oriented router protocol and connection-less router protocol[3]. In the connection-oriented router protocol, the logical connection shall be established prior to delivery of packets and the connectivity of connection shall be kept in the whole process of data delivery. Once some link is disconnected, the connection will be interrupted, so the data delivery fails and it needs to establish the connection again, which increases the router overhead. AODV protocol[4] is a typical connection-oriented router protocol, while in the contrary, there is no need for the connection-less router protocol to establish connection[5-9] in advance prior to data delivery. There is the route information and independent route leading to destination node inside each data packets. If some link is disconnected, the node can reselect the route again in accordance with the destination address.

2. MDNVR protocol

The existing router protocol schemes all have suffered serious link disconnection while faced with the high-speed mobility environment. The key point of MDNVRP scheme proposed in the Section is to prevent the disconnection of communication link instead of reestablishing the communication path having been disconnected.

2.1. Key concept

(1) Virtual router

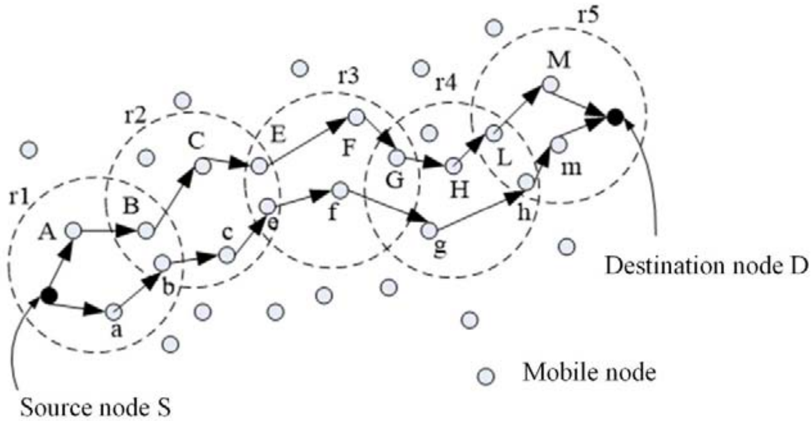


Fig. 1. Example of virtual router

The virtual router is the logical router[10] concerning the specific geographic region, which is composed of one or multiple mobile nodes within a series of geographic regions or multiple mobile nodes and can form multiple paths for data delivery. The one-hop communication scope of each node is a geographic region and overlapping is not allowed between adjacent geographic regions. As shown in Fig. 1, there is a virtual router $r1 \to r2 \to r3 \to r4 \to r5$ between source node S and destination node D, where $r1$, $r2$, $r3$, $r4$ and $r5$ represent geographic region, shown as dotted line circle in Fig. 1. There is one or are multiple sensing nodes within each geographic region, which transmit data packets s to destination node in the means of multihop. Besides, there are multiple paths in a virtual router, two of which have been described in Fig. 1 $S \to a \to b \to c \to e \to f \to g \to h \to m \to D$ and $S \to A \to B \to C \to E \to F \to G \to H \to L \to M \to D$.

(2) Mobility degree of node

Mobility is the most significant characteristics of MANETs. To better describe this characteristics, MD(Mobility degree) of node is introduced in the Paper to quantify this characteristics and find and update the router with MD so as to find out the stable virtual router.

How to estimate the MD of node is analyzed in the Section and first, several identifiers are introduced prior to describing MD.

1) shows the communication scope of node;

2) shows the Euclidean distance between node i and j;

3) shows the one-hop neighbor node set of node i. If the Euclidean distance d_{ij} between node j and node i is less than or equal to R, node j is the neighbor of node i, that is:

4) ϕ_i:

$$\phi_i = \{j|d_{ij} \le R\} \ . \tag{1}$$

5) shows the number of elements in one-hop neighbor node set ϕ_i.

6) shows the kth element in neighbor node set ϕ_i and $k = 1, 2, \cdots, |\phi_i|$.

MD of node is calculated in accordance with the local and independent position information of this node. The MD of this node reflects the change situation of one-hop neighbor node of this node at some time, which is equal to the ratio between the number of nodes leaving or joining in the one-hop communication scope of this node and the number of neighbor nodes at the last time. Hence, $MD\,(i,t)$ of node i at time t is:

$$MD\,(i,t) = \frac{\sum\limits_{h=1}^{|\phi_i(t)|} \gamma_h + \left| \left(|\phi_i\,(t-\Delta t)| + \sum\limits_{h=1}^{|\phi_i(t)|} \gamma_h \right) - |\phi_i\,(t)| \right|}{|\phi_i\,(t-\Delta t)|} \, . \tag{2}$$

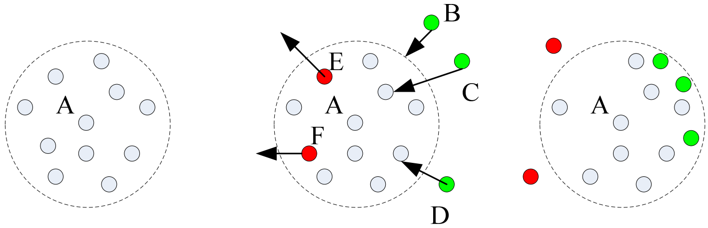
Where $|\phi_i\,(t)|$ and $|\phi_i\,(t-\Delta t)|$ respectively show the number of neighbor nodes of node i at time t and at the last time $t-\Delta t$. γ_h shows the mobility situation of the hth element in $\phi_i\,(t)$ and $\gamma_h \in \{0,1\}$ and $h = 1, 2, \cdots, |\phi_i\,(t)|$, as shown in formula (3).

$$\gamma_h = \begin{cases} 0, if \phi_i^h\,(t) \in \phi_i\,(t-\Delta t)\,, \\ 1, if \phi_i^h\,(t) \notin \phi_i\,(t-\Delta t)\,. \end{cases} \tag{3}$$

The first item of numerator $\sum\limits_{h=1}^{|\phi_i(t)|} \gamma_h$ in formula (2) shows the number of nodes joining in the neighbor of node i and the second item shows the number of nodes leaving the neighbor of node i.

As shown in Fig. 2, there are 11 one-hop neighbor nodes in node A at time

t_1. Node E and F leave after Δt and are not within the communication scope of node A anymore, while node B, C and D have entered the communication scope of node A and become the new neighbor nodes, as shown in Fig. 2(a). Hence, at time $t_2 (t_2 = t_1 + \Delta t)$, compared with time t_1, the one-hop neighbor of node A has changed 5 times, that is, two nodes have left and three node have jointed. Hence, MD of node A at time t_2 is 5/11, about 0.45.



(a) Original state (b) Occurrence of node mobility (c) After node mobility

Fig. 2. Sketch of node mobility

2.2. Route request

When the source node needs to send packets to destination node, first the source node generates route request message M_req(route request Message), where it includes ID No. of source node and then broadcasts M_req and the adjacent nodes receives M_req. Even though each node receiving M_req can simply forward this M_req, to avoid network storm, the prrobabilistic delay technology[11] is adopted. Hence, each mobile node receiving M_req probabilistically delays some time T and $T \in [0\ ,\ T_{\max}]$. $T_{\max}$ shows the longest delay time, during which whether there are other nodes forwarding M_req in node monitoring. If there are other nodes having forwarded this M_req prior to the accomplishment of this delay, this node will not forward M_req anymore. If no, the node will embed its ID No. in M_req and then forward after the accomplishment of delay. By means of multihop forwarding, finally the destination node receives M_req message. Besides, the node forwarding M_req message is called RN (reply node) in the Paper.

2.3. Route reply

Once the destination node receives M_req message, it will generate M_rep(route reply Messages) messages and establish communication path. M_rep message include source node, ID No. of destination node, router ID and a series forwarding nodes forwarding M_rep message, as shown in Table 1. After the destination node has generated M_rep message, it broadcasts M_rep message. RNs located in M_rep message then recognizes this router.

Table 1. M_req message format

Set point ID	Destination node ID	Router ID	List of reply nodes

During transmitting *M_ rep* message, some neighbor nodes might monitor *M_ rep* message. These monitoring nodes can join in the communication path and become a potential member of transmitting packets. Hence, as is the same as RNS, the monitoring nodes can also forward the packets along the router. For the mobile node in any router, including RNs and monitoring nodes, whether it will forward the packets depends on its MD, that is, the node with the minimum MD has the right to first forward the data packets .

2.4. Forwarding of data packets

Once the communication path has been established, the source node can forward packets to the destination node along this router. Before the source node forwards the packets, first load an information header which contains the ID of source node, ID of destination node, router ID, MD and TNs (Traversed nodes) region in front of data packet. The ID domain of packets is used for storing the packets identification needing to be sent to destination node by source node. MD domain is used for storing MD of node having forwarded the data packets. TNs means a series of nodes having forwarded the data packet.

Once node i receives the packets from node j, first node i checks to see whether it is the destination node of this data packet. If so, do not forward this data packets, otherwise further test whether it has received this packet before, that is if so, do not forward this data packet; if not, node i shall check to see whether it is in this path, that is, if not, do not forward this data packets , either, but if so, node i will set the timer waiting for forwarding the packets in accordance with its own MD. The $Times$ of timer is in direct proportion to MD, as shown in formula (4).

$$Times = \lfloor Times_{\max} * MD\,(i,t) \rfloor \ . \tag{4}$$

Where $MD\,(i,t)$ shows MD of node i at time t, $Times_{\max}$ shows the longest time of timer and $\lfloor\cdot\rfloor$ shows the floor.

If node i has monitored the packets forwarded from the other nodes prior to the accomplishment of timer's timing, then node i do not forward the packets and the timer shall be set as 0. Otherwise, while waiting for the timer to time, node i immediately forwards these packets when the time is accomplished. Meanwhile it handles the packets from node j, the specific flow of which is shown in Fig. 3.

2.5. Route update

If some nodes break away from the virtual router, it can result in the disconnection of link. To decrease the probability of link disconnection, the destination node shall periodically send *M_ Rup*(route update message) which contains ID of destination node, ID of source node, router ID and node set traversed by the newest packets received by destination node from source node. The destination node forwards *M_ Rup* to source node through these nodes. Once the source node receives *M_ Rup,* it will lose the old virtual router and adopt the new router.

The establishment process of new router is described in Fig. 4. Assuming that

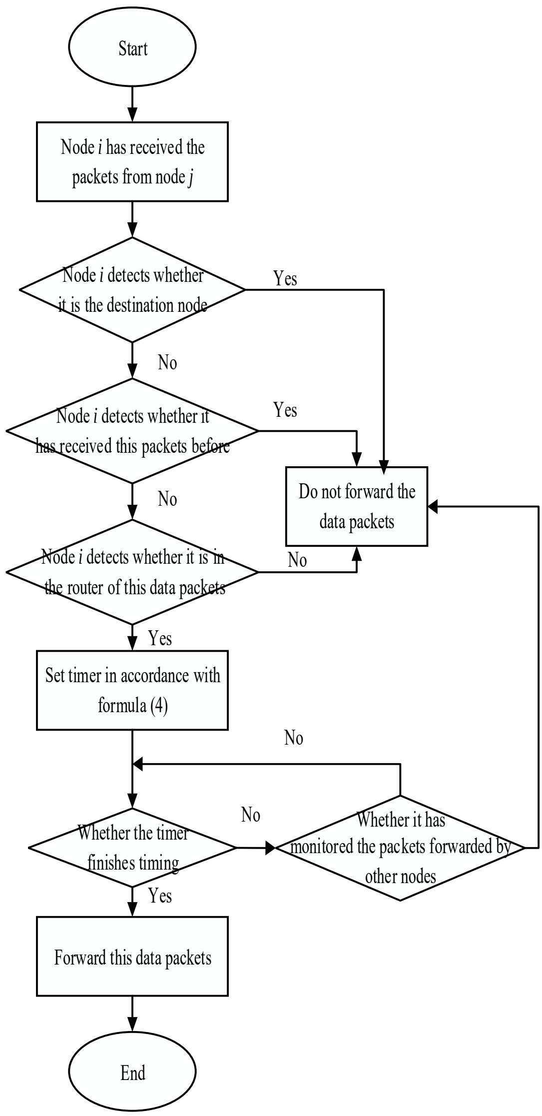


Fig. 3. Flow on node i handling packets from node j

there is a new virtual router which is composed of a series of regions like $r1 \to r2 \to r3 \to r4 \to r5$. Once there is link disconnection in this virtual router, the destination node will send M_Rup. It is noticed by destination node D that the packets newest received is transmitted through $S \to a \to b \to c \to e \to f \to g \to h \to m \to D$. Hence, the destination node transmits M_Rup to source node along $D \to m \to h \to g \to f \to e \to c \to b \to a \to S$. In the process when M_Rup is transmitted to source node through $D \to m \to h \to g \to f \to e \to c \to b \to a \to S$,

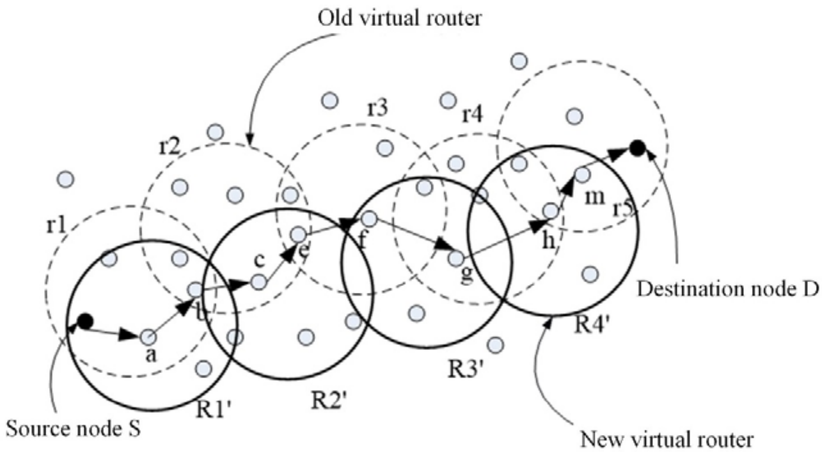


Fig. 4. Replacement of new and old virtual router

the neighbor nodes of these nodes monitor *M_ Rup,* so that the new virtual router $R1' \to R2' \to R3' \to R4' \to R5'$ is formed, as the thick line circle shown in Fig. 4. Once the source node receives *M_ Rup,* the subsequent packets will be forwarded along the newest virtual router. It is noticed that during the route update, there is no need for the node to periodically broadcast beaconing message, so that the route overhead has been decreased.

3. System simulation and performance analysis

To better estimate the performance of MDNVRP proposed, the simulation is carried out with GloMoSim[12] and the performance of it is compared with AODV and SVR[13]. The reason why to select AODV and SVR lies in: AODV is the most typical router protocol in MANETs, with the best reference value; SVR (Static Virtual Router) is the static virtual router, in which the virtual router is presetted and there is a distribution diagram for virtual router in each mobile node, while MDNVRP proposed is dynamic virtual router. By comparing it with SVR, the performance of MDNVRP can be better analyzed.

Table 2. Simulation parameter

Simulation parameter	**Value**
Delivery scope of node	133m
Mobile model of node	Random Way point
Dimension of data packets	512 byte
$T_{\max}$	70ms
Simulation time	15min

During the simulation, first it shall consider the 100×1000 simulation region, the delivery node is evenly distributed in simulation region and the communication radius of delivery node is 133m. Mobile model[14] of Random Waypoint is adopted. In this model, each node randomly selects a destination node for mobility, with 15-min simulation time. The specific simulation parameter is shown in Table 2.

3.1. Performance index

During analyzing the performance of MDNVRP, it mainly considers three indexes including RPD(Ratio of Packets Delivered), EED(End-to-End delay) and NRO(Normalized RouteOverhead).

(1) RPD: means the ratio between the packets received by destination node and the packets sent by source node, which reflects the ability of router protocol on delivering packets.

(2) EED: shows the time needed for transmitting packets from source node to destination node, which has reflected the speed of router protocol while delivering packets;

(3) NRO: shows the number of control packet each time when the destination node receives a packet, which reflects the efficiency of router protocol and expandability.

3.2. Simulation result and analysis

During the simulation, three different scenarios are set to have respectively examined the influence of mobile speed of node, node density and size of simulation region on router protocol.

(1) Mobile speed

To analyze the influence of mobile speed on the performance of router protocol, change the mobile speed of node from 10 to 25m/s during simulation process. The simulation result is shown in Fig. 5.

It can be know from Fig. 5 that RPD, EED and NRO of MDNVRP scheme proposed are all superior to AODV. Specifically, on the aspect of RPD, MDNVRP is superior to AODV, but similar to SVR. The high-speed mobility can be copped with by adopting both MDNVRP and SVR of virtual router to reach high RPD, while on the aspect of EED, similarly, both MDNVRP and SVR are superior to AODV and MDNVRP is also superior to SVR, which is mainly because: the communication path in SVR is formed by virtual router preset, while MDNVRP adopts dynamic virtual router, which can better cope with the mobility of node. On the aspect of NRO, both MDNVRP and SVR are superior to AODV, but MDNVRP is slightly superior to SVR, the reason which lies in the fact that MDNVRP adopts dynamic virtual router, so that the probability of link disconnection is decreased, while SVR adopts the virtual router preset, which is difficult to cope with the link disconnection arising from mobility of link, so that the route overhead has been improved.

(2) Node density

To analyze the influence of node density on the performance of router protocol, change the number of nodes from 600 to 3000 in 100×1000 simulation region, in

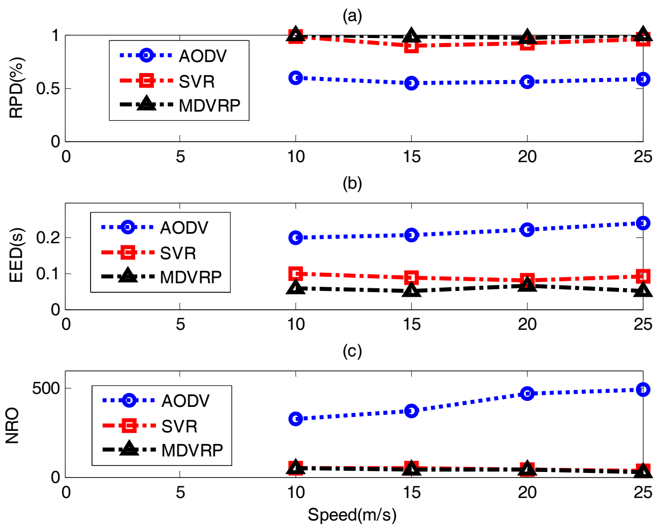


Fig. 5. Changing curve of RPD, EED and NRO with mobile speed of node

other words, the node density in simulation region is changed. The simulation result is shown in Fig. 6.

It can be known from Fig. 6 that the increasing of node density has improved route overhead ((c)) and it has a negative influence on RPD ((a)), which has resulted in higher delivery delay ((b)). It is mainly because the increasing of node density increases the number of nodes involved in route request, which has increased the probability of network congestion.

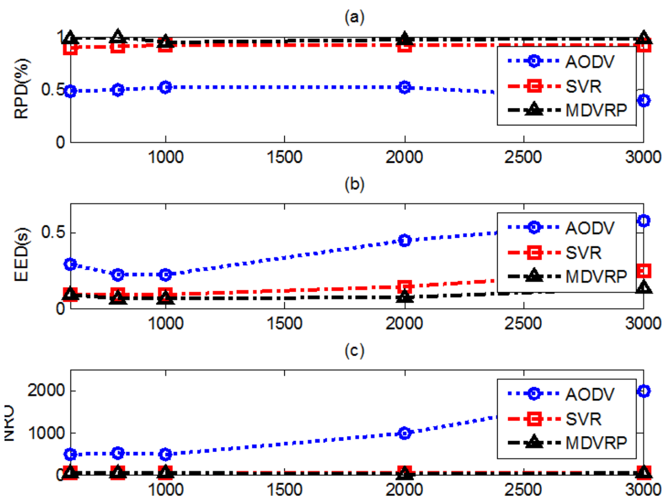


Fig. 6. Changing curve of RPD, EED and NRO with node density

Specifically, as shown in Fig. 6(a) and (c), with the increasing of node density, AODV has adopted more control packets to repair the router, but RPD is not improved. On the contrary, with the increasing of node density, the route overhead of MDNVRP is increased a little bit and still keeps high RPD. It can be known from Fig. 6(b) and (c) that, in the high density region, the delivery delay of MDNVRP has decreased 6 times than it of AODV and the route overhead has reduced 20 times. Besides, the performance of RPD and route overhead of SVR and MDNVRP are similar, but EED of MDNVRP is superior to SVR.

Size of simulation region

To analyze the influence of the size of simulation region on the performance of router protocol, set the size of four simulation regions and keep the node density equal. The size of four regions respectively is: $500m \times 500m$ region, with 250 nodes inside; $1000m \times 1000m$ region, with 1000 nodes inside; $1500m \times 1500m$ region, with 2250 nodes inside; $2000m \times 2000m$region, with 2250 nodes inside. The simulation result is shown in Fig. 7 where 500, 1000, 1500 and 2000 in the X-coordinate of Fig. 7 respectively show $500m \times 500m$ region, $1000m \times 1000m$ region, $1500m \times 1500m$ region and $2000m \times 2000m$ region.

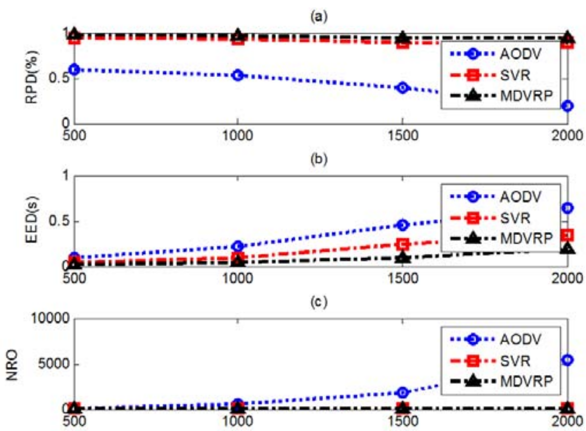


Fig. 7. Changing curve of RPD, EED and NRO with simulation region

It can be known from Fig. 7 that it is difficult for AODV to maintain the long router. With the expansion of simulation region, the length of router increases and the probability of router disconnection also increases with the same ratio. Because the fixed hop-by-hop router is not adopted, compared with AODV, MDNVRP only gets RPD (as shown in Fig. 7(a)) with the increasing of small route overhead (as shown in Fig. 7(c)). With the expansion of simulation region, the delay of MDNVRP increases a little bit, as shown in Fig. 7(b). It is mainly because the expansion of simulation region has increased router and correspondingly, the delay of packets for reaching the destination node has increased.

Besides, it is noticed that in Fig. 7(b) and (c), the performance of EED of MDNVRP has been improved 3 times than it of AODV in $2000m\times2000m$ region and the performance of route overhead has been improved almost 40 times. Compared with AODV, SVR still has favorable performance, but EED of SVR is still inferior to it of MDNVRP.

4. Conclusion

Aimed at the router protocol of MANETs, MDNVRP protocol is proposed in the Paper. By adopting virtual router, MDNVRP makes multiple communication paths exist from the source node to destination node and according to the mobility degree of node, the excellent forwarding nodes for packets shall be selected to improve the stability of link and to be able to effectively cope with the mobility of node. The simulation result shows that EED, RPD and NRO of MDNVRP is obviously superior to AODV.

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