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Dynamic Route Shortening and Route Repairing Mechanism for Mobile Ad Hoc Networks

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Abstract: Problem statement: Ad hoc Networks are wireless networks without any fixed infrastructure. The network topology changes frequently and unpredictably due to the random movement of the nodes. The Ad Hoc on Demand Distant Vector Routing (AODV) protocol works in a dynamic fashion, by establishing a route on demand and continues that route until it breaks. Due to the changing network topology of ad hoc networks, if other routes with less hop count become available, the network topology is not able to adapt until the route break occurs. Hence in the route shortening scheme is some redundant nodes in the active route is replaced with a node that is not on the active route. When there is any link failure between any two nodes, the alternative route with optimum route to be constructed and not sending RRER message to the source node to initiate the route discovery process again. **Approach:** This study proposes a new routing protocol called, Dynamic Route Shortening and Repairing Mechanism (DRSR). The route shortening is incorporated with route repairing mechanism, to improve the performance of the AODV. The route shortening scheme works by replacing some redundant nodes in the active route, with a node that is not on the active route. If there is a link failure between the two nodes, the route repairing mechanism repairs the route, by using the nodes that are close enough to the route to overhear the message. Whenever the links go down, the DRSR replaces the failed links with the optimum route that is adjacent to the main route and not sending and RRER message to the source node to initiate the route discovery process again. The alternative route construction process could be initiated at any time, not just when a route has failed. The dynamically constructed alternative route's information is passed on to the upstream nodes, which then determine by themselves when to direct their packets to the ‘‘optimal’’ alternative route. **Results:** Our protocol performs better than the original (AODV), in terms of the packet delivery rate, average hops and packet loss. **Conclusion:** Our proposed routing protocol constructs the alternative route with the optimal route in the Dynamic Route Shortening scheme when there is a link failure between any two nodes.

Key words: Dynamic Route Shortening and Repairing Mechanism (DRSR), Ad Hoc on Demand Distant Vector Routing (AODV), Minimum Hop Count Neighbor Table (MHNT)

INTRODUCTION

In recent times, a number of techniques and applications have been used widely for transmitting information through heterogeneous wireless networks.
Wireless is a new technology that allows users to access information and services regardless of the geographic position.People can utilize and surf the Internet with computers (e.g., laptop, palmtop, smart phone and PDA) whenever and wherever possible Kumaran and Sankaranarayanan (2011). In general, a wireless network may belong to one of the two types: infrastructure network and ad hoc network. Adhoc networks are usually defined as an autonomous system of nodes connected by wireless links for communicating in a multi-hop fashion Kumaran and Sankaranarayanan (2012). A mobile ad hoc network is a group of computing devices (nodes) which communicate with one another, using multi-hop wireless links. It does not require any stationary infra structure, such as a base station. Each node in the network can act both as a host and a route, forwarding data packets to other nodes. (2010) In the MANET, nodes move arbitrarily; therefore, the network may experience rapid and unpredictable topology changes. Additionally, because nodes in the MANET normally have limited transmission ranges, some nodes cannot communicate directly with others. Hence, the routing paths in MANETs potentially contain multiple hops and every node has the responsibility to act as a router. (2011).

In the Ad hoc On Demand Distance Vector (AODV) protocol, there is only a single path is established during the route discovery process. At any time, the route established may fail due to the movement of the node from one transmission region to another. The data packets are simply dropped by the

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nodes along the broken path. Many on-demand routing protocols with multi paths or back up routes have been proposed, in order to solve the above problem. When the rate of topological changes in the network is sufficiently high, most of the AODV protocols may not be able to react fast enough to maintain the necessary routing information(Murthy and Manoj 2004; Khatri *et al*., 2010; Kuang *et al*., 2007; Cheng *et al*., 2010).

Route shortening: Bilgin *et al.* (2010) and Gui and Mohapatra (2008) proposed a route optimization technique to shorten unnecessarily long paths by eliminating inessential hops. But the protocol fails to detect the shortcuts between any pair of nodes on a connection.

Liang *et al*. (2011) and Chen *et al*. (2010)proposed two automatic route shortening schemes to optimize the route during successful packet forwarding, without causing extra control overhead.

Yunsheng *et al.* (2010) and Yena *et al.*(2010) proposed a routing protocol, it automatically tries to keep the shortest path in order to improve the network performance. The shortcut process by the source and destination node of path length 1 is not detected.

Sethi and Udgata (2010) proposed an Optimized Ad hoc On Demand Distance Vector (ORAODV) scheme that offers quick adaption to dynamic link conditions, low processing and low network utilization in ad hoc networks.

Route repairing: Many route repair processes have been proposed by Jeon *et al*. (2011), Yu *et al*. (2007) and Kuang *et al*. (2007). These protocols repair the broken route by using information, provided by the nodes overhearing the main route communication. When the links go down, the protocol replaces the failed links with backup ones that are adjacent to the main route. But, the backup ones do not maintain the latest optimized route information. Due to node mobility, some shorter route may be possible in that route, but that route will not be utilized.

Qingsong *et al*. (2010) proposed a novel AODV algorithm-the LRM-AODV, based on local route maintenance. The LRM-AODV adopts the reverse route search procedure for idle nodes to produce many local routes and increase the route redundancy in the network; this speeds up the route discovery and makes fast route repair possible.

In this study, we propose a new routing protocol, which repairs broken routes by using the information provided by the nodes overhearing the main route communication. The proposed protocol not only repairs the route, but also performs route shortening, while the data is being forwarded from the source to the destination; hence the optimum route is present in the main route. When links go down, the protocol replaces the failed links or nodes that are adjacent to the main route, with a shorter route.

In our previous study, a secure route optimization mechanism, called Secure Dynamic Route Shortening (SDRS) (Revathi and Rangaswamy, 2012), to detect optimized route if there is some short cut available for the active route in a secure manner have been proposed. Our proposed Route Repair with Dynamic Route Shortening (RRWDRS), able to quickly repair a link or node failure with Dynamic Route Shortening. Hence the optimized route can be found without restarting the route discovery process by the source node to find the alternate optimized route.

MATERIALS AND METHODS

In the following sections, we present a new fully distributed and on-demand based ad hoc routing protocol that handles broken link recovery with an optimized route in an efficient way. The routing protocol begins by finding a route from the source node S to the destination node D. After discovering the route, the data packets proceed to move along the primary route. Nodes that are close enough to the path will overhear the messages. All the neighboring nodes monitor the route and try to optimize it if and when a better local sub-path is available. When there is a link failure between any two nodes, the upstream node tries to replace the failed links with the optimum route that is adjacent to the primary route, without initiating the route discovery process again.

The proposed algorithm consisting of (i) Route Construction ii) Route Maintenance is given below.

Route construction: In the proposed routing protocol, the AODV, a routing path is constructed only when a node needs to communicate with another node. Assume that a source node S wants to send a packet to the destination node D. If the destination node D is a neighbor of source node S, the packet is directly sent to the destination node D. Otherwise, the source node S will check if the destination node D is in the Primary Route Table (PRT). If it is, the packets will be sent directly to the next-hop node as specified by the corresponding entry in PRT. If there is no route present in the PRT, a primary route from the source node S to the destination node D needs to be constructed. This process is called Primary Route Construction.

The source node S sends a Primary Route Request (PREQ) to all its neighbors, as the AODV does. Every neighbor receives the PREQ and broadcasts it to its neighbors. Thus, the PREQ is flooded over the network and will arrive at node D if there is a path for it. When destination node D receives the PREQ, it replies the PREP and a value H, representing the hop count number, to the node (say p1) from which the PREQ was received. Once node P1 receives the PREQ, it adds a primary route entry for node D to its PRT. It then propagates the PREQ, together with value H+1, to the host from which p1 receives the PREQ. This process continues until node S receives the PREP and updates its PRT accordingly.

Route maintenance: The route maintenance process consists of 3 parts:

- Finding neighbor nodes through the primary route
- Route Shortening
- Primary Route Repairing

Finding neighbor nodes with a hop count through the Primary route: Some modifications are required in the packets delivery phase (i) Insert H field into the header of the data packet (ii) A node promiscuously "overhears" packets transmitted by its neighboring nodes that are within the transmission range. A neighbor node of the primary route overhears a data packet transmitted by the primary route node and stores the H value within the packets header into the Hop table. If more than one such packet is received, the average of the received H value is computed and stored in the hop table.

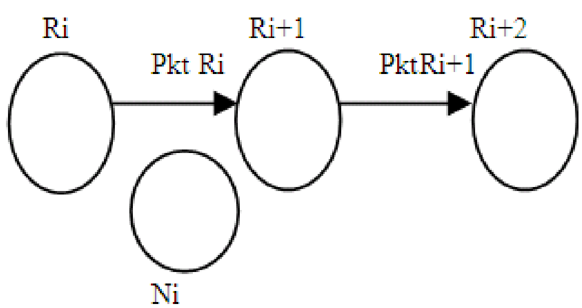


Fig. 1: Calculation of the hop value of Ni

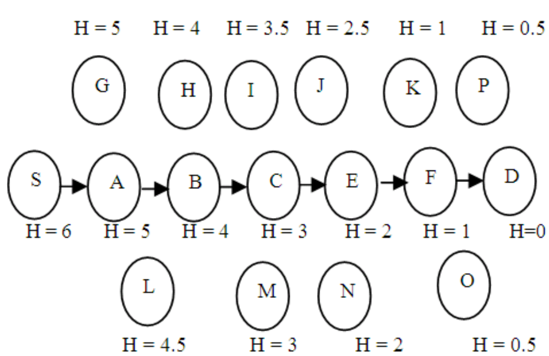


Fig. 2: Neighbor nodes with hop count on the Primary route

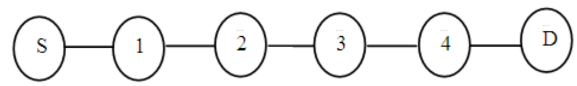


Fig. 3: Original route

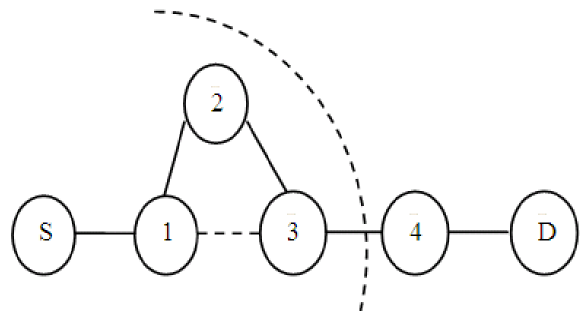


Fig. 4: One-hop shortcut detection

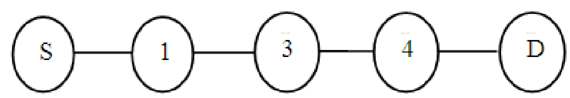


Fig. 5: After one-hop Shortcut mechanism

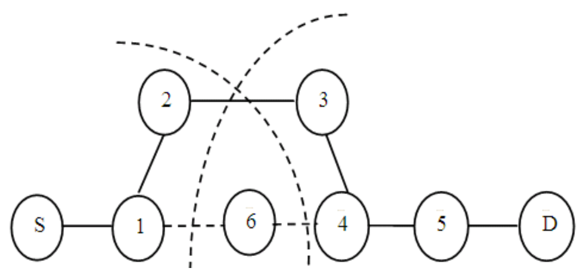


Fig. 6: Two-hop shortcut detection

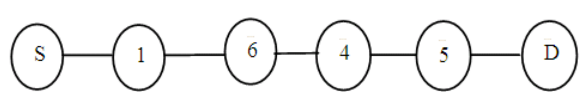
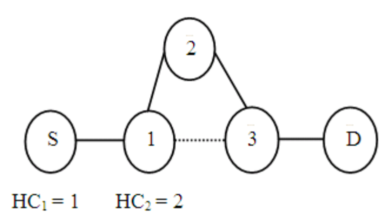


Fig. 7: After two-hop shortcut mechanism



SID	DID	MH	MNID	ET
S	D	1	1	t+1

Fig. 8: Minimum hop count neighbor table

The hop count value of Ni is calculated as shown in Fig. 1. The hop value of Ni, i.e., H (Ni) is calculated when the packet is transferred from Ri to Ri+1; if Ni overhears, the hop value of Ri is stored in the hop value of Ni. If Ni also overhears the packet transfer from Ri+1 to Ri+2, the average hop value is calculated and stored:

H(Ni) = H(Ri) if N_i overhears the packet transfer from Ri to Ri+1.

$H(N_i)$ = (H(Ri)+ $H(R_{i+1})$)/2 if Ni overhears the packet from Ri to Ri+1 and Ri+1 to Ri+2.

H(Ni) = (H(Ri)+$H(R_{i+1})$+H(Ri+2))/3 if Ni overhears when the packet transfers from Ri to Ri+1, Ri+1 to Ri+2 and Ri+2 to Ri+3

In Fig. 2 the primary route nodes and neighbor nodes hop count values are shown. Node G is within the transmission range of node A and its hop value is assigned as 5. Node L hop value is calculated as the average of the hop value of A and B; i.e., (5+4)/2 = 4.5. Similarly, the hop value of the other neighbors is calculated.

Route shortening: Node mobility causes topology changes that may incur some route redundancy. Suppose the original route is S-1-2-3-4-D as shown in Fig. 3.

Case (i) It is assumed that, node 3 moves into the transmission range of node 1. Hence, node 1 can directly transmit data packets to node 3, without the participation of node 2 and the hop count difference is greater than or equal to 1 as shown in Fig. 4, which shortens the route to S-1-3-4-D (shown in Fig. 5).

Case (ii) Some redundant nodes in the active route are replaced by a node that is not on the active route. From Fig. 6, Node 6 can overhear packets sent from the two nodes 1 and 4 on the active route. Node 6 enters the transmission region of 1 and 4 and the hop count difference between these two nodes is greater than two; so a Two-Hop Shortcut Detection mechanism is activated. Hence, the route S-1-2-3-4-D can be replaced by S-1-6-4-D as shown in Fig. 7.

Each node records the minimum hop count that it overheard, which is maintained in a data structure, called the Minimum Hop Count Neighbor Table (MHNT) is depicted in Fig. 8. The structure contains the Source Id (SID), Destination Id (DID), minimum hop count (MH), the id of the node with the minimum hop count (MNID) and the Expiration Time of this record.

Whenever there is node mobility, the hop value of the primary route and its corresponding neighboring hop values are also to be updated. Route shortening takes place, when node F comes into the transmission range of C and E. Now F can directly communicate with C and the new route becomes S-A-B-C-F-D and is shown in Fig. 9. The Primary Route Table is also updated.

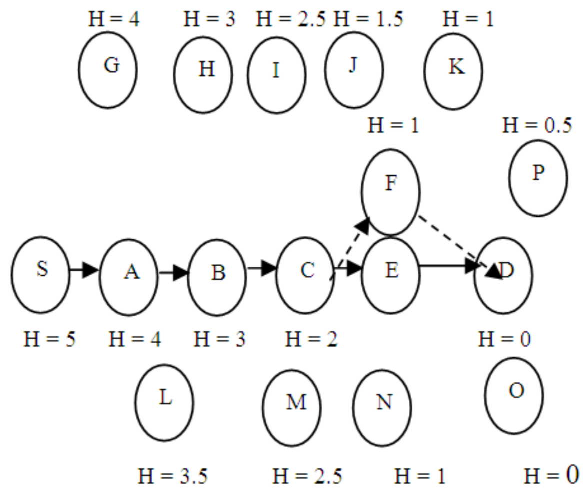


Fig. 9: After route shortening of the primary route

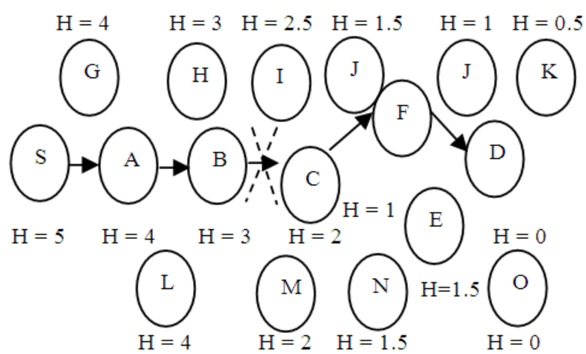


Fig. 10: Primary route repair between B and C

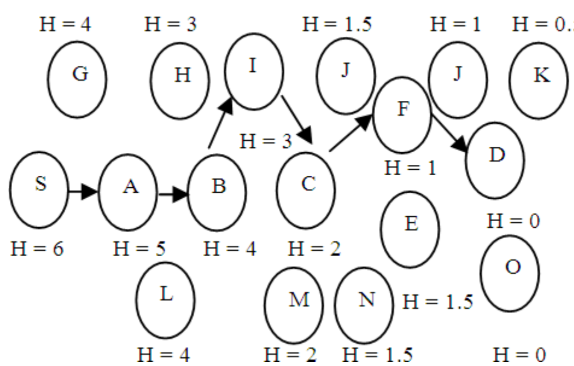


Fig. 11: After primary route repair

Primary route repairing: The primary route between S and D may fail to transfer the data packet, if there is any link failure. Eg. If there is a link failure between B and C, the proposed protocol finds the alternative route, using the neighboring node's hop value. Finding the alternative route is calculated as follows:

PRH(Ri)>H(Ni) =	Unfavorable Communication Range to find the alternative route
PRH(Ri)<H(Ni) =	Good communication range to find the alternative route
PRH(Ri)=H(Ni) =	Medium communication range to find the alternative route

If there is a link failure between B and C is shown in Fig. 10, the upstream node B may start to find the alternative route by sending the PREQ to its neighbors. From B, the node H, I, A and L may overhear. The value of A is high, compared to the primary route upstream node hop value. Hence, this is considered as an unfavorable communication range to find the alternative route. Hence it is rejected. The node H is considered as being in the medium communication range. It may be considered to find the alternative path. The node I hop value is in a good communication range to find the alternative path. Hence, the node I rebroadcasts the PREQ to its neighbor. Now node I starts to send an overhear message. H, J, B and C may overhear. Now, C may act differently due to the fact that it has a route to the Destination in its Primary Route Table and hence the new optimized alternative route is S-A-B-I-C-F-D is shown in Fig. 11.

The following different performance metrics are adopted, to evaluate whether the proposed protocol has performed well, compared to the original AODV.

Effects of node mobility-The protocols are more sensitive to node mobility and are less adaptive to network topology changes.

Effects of node density-The data delivery rate of each protocol is comparatively lower in the cases of lower node density. Apparently, in a lower node density condition, there is lesser chance of successfully finding an available route.

RESULTS AND DISCUSSION

The proposed routing protocol has been evaluated and compared with the original AODV, using the Network Simulator (NS2). The main parameters of the simulation are shown in Table I. The important metrics on which the AODV and the proposed protocol are evaluated, are the data delivery rate, control overhead, average hop count and packet loss.

Table 1: Simulation parameters

Parameters	Values
Power range(Transmission Range)	250 m
Number of nodes	100
Number of comm. Pairs	10
Topology size	2200×600 m^2
Mobility model	Random Waypoint
Mobile speed	0-20 m/s
Routing policy	AODV
Traffic type	CBR: constant bit rate
Packet rate	3 packets/s
Packet size	64 bytes
Path loss model	Two-ray ground
MAC protocol	802.11 DCF
Interface queue type	Drop Tail/PriQueue

Data delivery rate- The ratio of the number of successfully delivered data packets to the total number of data packets sent.

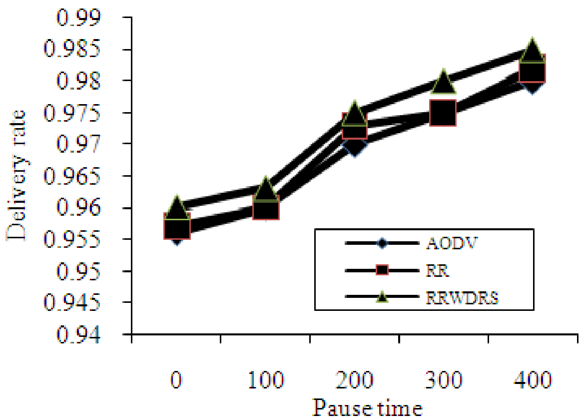
Control overhead-The total number of control packets sent out by all the nodes divided by the total number of successfully delivered data packets.

Average hop count- The average number of hops a data packet needs to traverse to reach its destination.

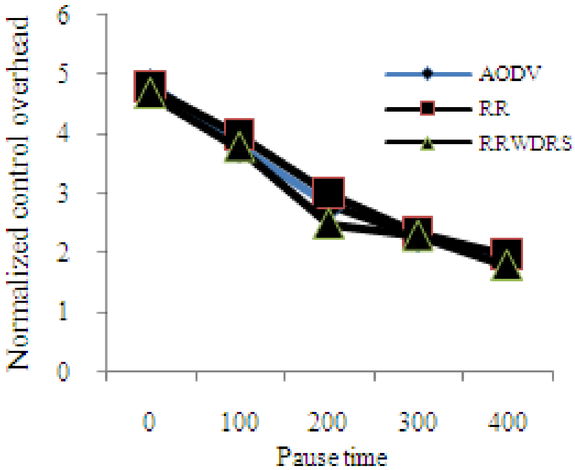
Effect of node mobility: The objective of the simulation setting is to evaluate how the three protocols, namely, the AODV, Route Repair without Dynamic Route Shortening (RR) and Route Repair with Dynamic Route Shortening (RRWDRS), perform under various node mobility conditions. Node mobility is reflected by varying the pause time. A larger pause time implies that nodes stay at a specific location longer, which again indicates a more stable network topology.

Figure 12a show how the AODV, after establishing routes upon request, makes no effort to adjust the routes according to the changing topology until link failure. As a result, the AODV is sensitive to node mobility and is less adaptive to network topology changes. Figure 12 b: The AODV has a higher control overhead, which is a direct consequence of its attempts to find a new route upon link breaking. Figure 12c: A longer path (more intermediate nodes) implies that the route is more vulnerable, as the probability of any given node failure or any given node moving out of range, also increases. The average hop counts consistently reduce in the RRWDRS.

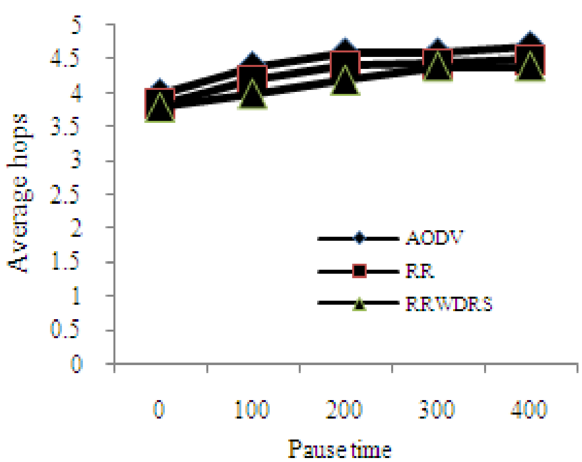
Effect of node density: The objective of the simulation setting is to evaluate how the three protocols, viz., the AODV, Route Repairing Without Dynamic Route Shortening (RR) and Route Repair With Dynamic Route Shortening (RRWDRS), perform under various node density conditions. The number of nodes within the simulation region is set to 50, 100, 150, 200 and 250, respectively. The results are presented in Fig. 13 a-c.



(a)

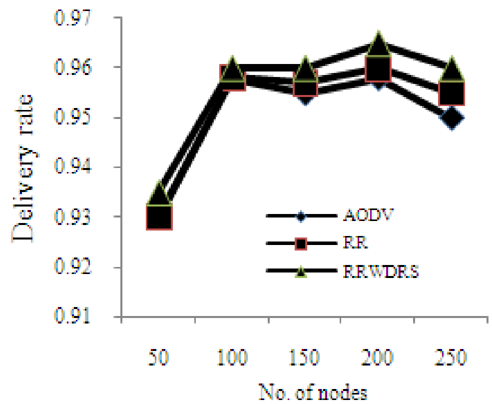


(b)

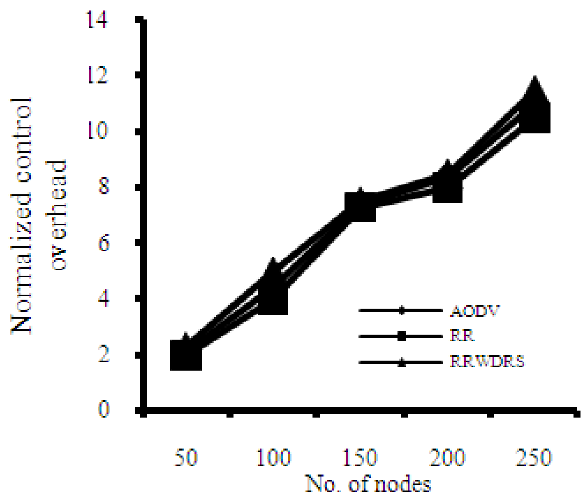


(c)

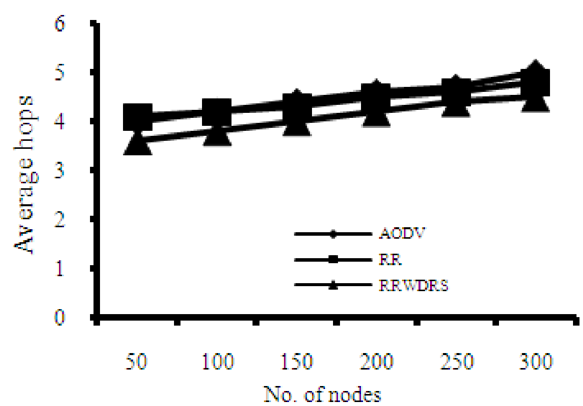
Fig. 12: (a) Packet delivery rate Vs pause time , (b) Control Overhead Vs pause time, (c) Average hops Vs pause time



(a)



(b)



(c)

Fig. 13: (a) Packet Delivery rate vs. no. of nodes, (b) normalized control overhead, (c) Average hops Vs no. of nodes

Figure 13a shows how, in the case of lower density, the data delivery rate of each protocol is low. At a lower node density, there is lesser chance of successfully finding an available route. Figure 13 b shows how the greater the node density, the greater is the control overhead. From Fig. 13c it is seen that the average hops is high in the AODV compared to the RRWDRS.

CONCLUSION

In this study, we present a new on-demand routing protocol that is able to quickly repair a link or node failure with Dynamic Route Shortening. The Ad hoc On Demand Distant Vector Routing Protocol (AODV) works in a semi-dynamic fashion, which may establish a route whenever required. Once the route discovery process is established, it continues using that route until it breaks. However, to suit the changing network topology of ad hoc networks, an adaptable routing strategy is required. The proposed routing protocol constructs the alternative route with the optimal route in the Dynamic Route Shortening scheme. The alternative route construction process could be initiated at any time, not just when a route has failed. The dynamically constructed alternative route's information is passed on to the upstream nodes, which then determine by themselves when to direct their packets to the ''optimal'' alternative route.

The proposed protocol significantly improves the performance of the original AODV routing protocol. It adapts itself well in a very dynamic network environment. Overall, the new proposed protocol is capable of achieving a higher data delivery rate with less average hop count.

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