Efficient and Reliable Reactive Routing Protocol for Mobile Ad-Hoc Network

Shariq Mahmood Khan†, Muhammad Mubashir Khan††, Najeed Ahmed Khan†††, Waseemullah†††

Department of Computer Science & Software Engineering
NED University of Engineering & Technology, Karachi Pakistan

Summary
Mobile Ad-Hoc Network (MANET) is a group of mobile nodes in which every node can communicate with each other without any fixed infrastructure. The Importance of MANET increases due to their application in rescue operation, military communication and disaster management. Movement of nodes, which makes the topology of MANET highly dynamic, cannot be neglected. Because of mobile nodes establishment of new connections and disconnection of old paths is a logical expectation. Performance of the network is highly affected because of frequent connection-disconnection of paths. In this paper a Efficient Reliable Reactive Routing Protocol (ERRRP) for MANET is proposed that optimizes the disconnection of routes among the mobile nodes. We introduce the so-called Reliability Factor in our scheme by means of which we select the reliable route. The RF is calculated as a function of Hop Count and Route Expiration Time, on the basis of which a route is established with less number of hops and high reliability. The scheme guarantees the reduction in network routing load by 30% and 6% enhancement in the packet delivery fraction (PDF) as compared to standard AODV protocol.

Key words:
Reliable Routing, Efficient Routing, MANET.

1. Introduction

Mobile Ad-Hoc Networks (MANET) are autonomous systems in which nodes are wirelessly connected without a pre-existing infrastructure for communication (Benhaddou, Al-Fuqaha 2015, Papavassiliou, Ruehrup 2015). Nodes in MANET are generally characterised to be highly mobile without any bound in direction (Conti, Giordano 2013, Loo, Mauri et al. 2011). In many important applications including military operations, surveillance and disaster management the inherent characteristics of MANET are ideal (Boukerche, Turgut et al. 2011, Moussaoui, Boukeream 2015). The dynamic nature of MANET gives rise to challenges like frequent path disconnection, between the communicating nodes. As shown in Fig.1 a pre-existing active route is present between node A and E. When node ‘D’ moves to a new position at time ‘t+1’ it becomes unreachable because of the limited transmission range of node ‘C’ cf. (Fig. 2). As a result, an active link from node ‘C’ to node ‘D’ becomes invalidates that in turn disconnects the route from node ‘A’ to node ‘E’. Hence, the validity of a particular path between two communicating nodes relies on all separate links between the active paths.

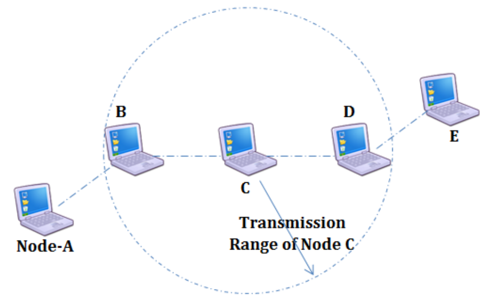

Fig. 1 Route from Node 'A' to Node 'E' through multiple intermediate nodes

Standard protocols such as Ad-Hoc On-Demand Distance Vector (AODV) (Perkins, Royer 1999) and Dynamic Source Routing (DSR) (Johnson, Maltz 1996), select shortest possible paths from source to destination for transferring data. Owing to mobile nature of nodes the network topology does not remain same at all times that is why it is not always guaranteed that the shortest possible path would also be the reliable path. The network performance is highly dependent on the frequency of breaking old paths the establishment of new paths (Song, Ning et al. 2012).

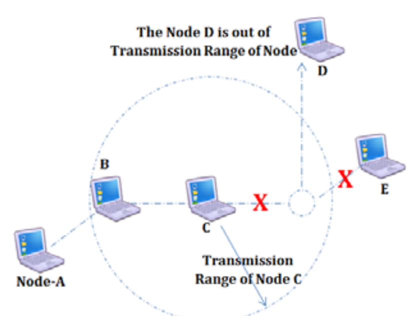

Fig. 2 Influence of node mobility on pre-established path

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As a result of breaking pre-established routes between source and destination nodes route maintenance procedures are executed by routing protocols. The maintenance procedures also have a negative impact on the overall network performance because of the consumption of network resources during route maintenance process (Wu, Wang et al. 2012). Instead of only finding a shortest route from source to destination nodes it is equally important that the route will remain active and established for longer interval of time (Lim, Shin et al. 2002, Tseng, Li et al. 2003). Selection of routes with longer life reduces the frequency of route maintenance and rediscovery and procedures that consequently improves the network functioning (Al-Hemyari, Hassan et al. 2013). Hence, node mobility factor should be considered as an important factor to discover an optimal reliable path that have minimum impact on the overall performance degradation of the network. (Moussaoui, Semchedine et al. 2014).

This paper presents a new routing protocol called Efficient and Reliable Reactive Routing Protocol (ERRRP) for MANET that calculates a reliable route between any two nodes of MANET. The selection of routes on the basis of reliability decreases the number of new routes to discover and maintain that eventually increases the packet delivery ratio and minimises the routing overhead. In the proposed protocol reliable routes are discovered using Reliability Factor (RF) that utilises hop count and node mobility to find the reliable and efficient route. In the rest of this paper, Section-2 explains the Reliability Factor in detail Section-3 explain the proposed protocol in detail. Simulation environment and discussion of results are represented in Section-4; finally Section-5 is devoted for conclusion.

2. Reliability Factor (RF)

To emphasise the reliability of the optimal selected route the proposed protocol calculates the Reliability Factor (RF) (Khan, Nilavalan et al. July 2015). RF is calculated on the basis of maximum route expiration time with little number of Hops. Hence a route will be considered reliable for data transfer from source node to destination node if it has higher value of RF (Wu, Wang et al. 2012). RF is calculated as

$$RF = \frac{RET}{MaxRET} - \frac{HC}{MaxHC} \quad (1)$$

Route Expiration Time (RET): It is the minimum time of a link expiration out of all the intermediate links from source to destination node is called Route Expiration Time (RET). It means that the complete route from source to destination will only remain valid if all of its sub-links are valid. Similarly, the projected time-interval for which the link between two mobile communicating nodes remain alive i.e. the two nodes continuously linked together is called Link Expiration Time (LET) (Su, Gerla 1999, Su, Lee et al. 2001). Greater value of RET of a route shows that the link if stronger and reliable. The LET is calculated using equation (2).

$$\text{LET} = \frac{-(ab+cd)+\sqrt{(a^2+c^2)r^2-(ad-bc)^2}}{a^2+c^2} \quad 2)$$

Where
$a = v_1 \cos \Theta_1 - v_2 \cos\Theta_2$
$b = x_1 - x_2$
$c = v_1 \sin \Theta_1 - v_2 \sin \Theta_2$
$d = y_1 - y_2$
(x_1, y_1) : Co-ordinate of Node N1
(x_2, y_2) : Co-ordinate of Node N2
v_1 and Θ_1 : Speed and angle of Node N1
v_2 and Θ_2 : Speed and angle of Node N2
r : Transmission range

3. Explanation of ERRRP Protocol

The optimal route in this scheme is selected using the RF that has been explained earlier. A routing path selected on the basis of RF guarantees the high reliability with less number of hop counts. ERRRP selects the optimal path on the basis of RF for routing between any two communicating nodes.

The underlying routing protocol for the proposed scheme is Ad-Hoc On Demand Distance Vector (AODV) (Perkins, Royer 1999). AODV is categorised as a reactive protocol for routing in MANET, builds a route from source node to destination node on demand. Route request (RREQ) packets are broadcasted from source node to all neighbouring nodes when it is required to send data packets from source to destination. The propagation of RREQ packet to the neighbouring nodes is illustrated in **(Fig. 3)**.

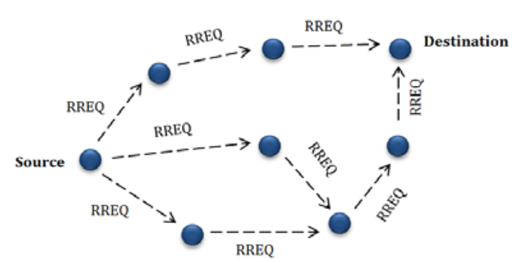

Fig. 3 RREQ Packet broadcast and propagation in AODV

When a RREQ packet is broadcasted then every node that receives this packet record the information of the packet-originating node. If the intermediate node is itself a destination node for a requested route then it stops propagating the route request packet further and send back the route reply (RREP) packet towards the source node. It is also possible that the node itself is not a destination node but it has a valid route to the destination node. In either case the receiving node prepares the route reply (RREP) packet and send back to the source node cf. (Fig. 4). The source node after receiving the RREP from the destination or intermediate node starts sending the data packets on the newly discovered route.

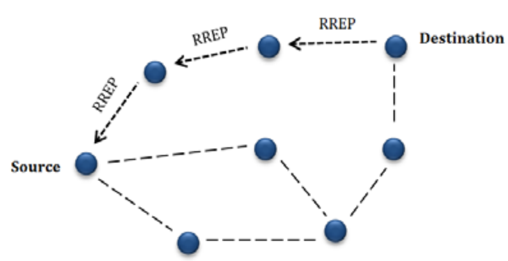

Fig. 4 Route of RREP from Destination to the Source node in AODV

Efficient and Reliable Route Request (ER-RREQ) packet:

In the proposed scheme the route request packets are also generated to discover the optimal reliable route. These route request packets are not the same as those of AODV because it contains some additional fields which are not present in conventional AODV protocol. Because of these additional features the route request packets in the proposed scheme is called Efficient and Reliable Route Request (ER-RREQ) as shown in (Fig. 5). The five additional fiels of ER-RREQ is the proposed schemes are:

- ***XPos, YPos*:** The (X, Y) coordinates of a node.
- ***Speed:*** The speed of the mobile node.
- ***Direction:*** The angle or direction of the moving node.
- ***LET:*** The Expiration Time of Link.

.	**X.Pos**	**Y.Pos**	**Speed**	**Direction**	**LET**

Fig. 5 ER-RREQ Message Format for ERRRP Protocol.

A. ERRRP Route Discovery Mechanism

The nature of the proposed ERRRP scheme is reactive. The route discovery process is initiated as soon as the source node 'S' needs to send data to any destination node 'D' for which there is no already established route available. The source node starts sending the ER-RREQ in a broadcast manner to all neighboring nodes in order to discover an optimal route. As explained earlier that the ER-RREQ is a variation in AODV RREQ packet, which has been shown in **(Fig. 5)**.

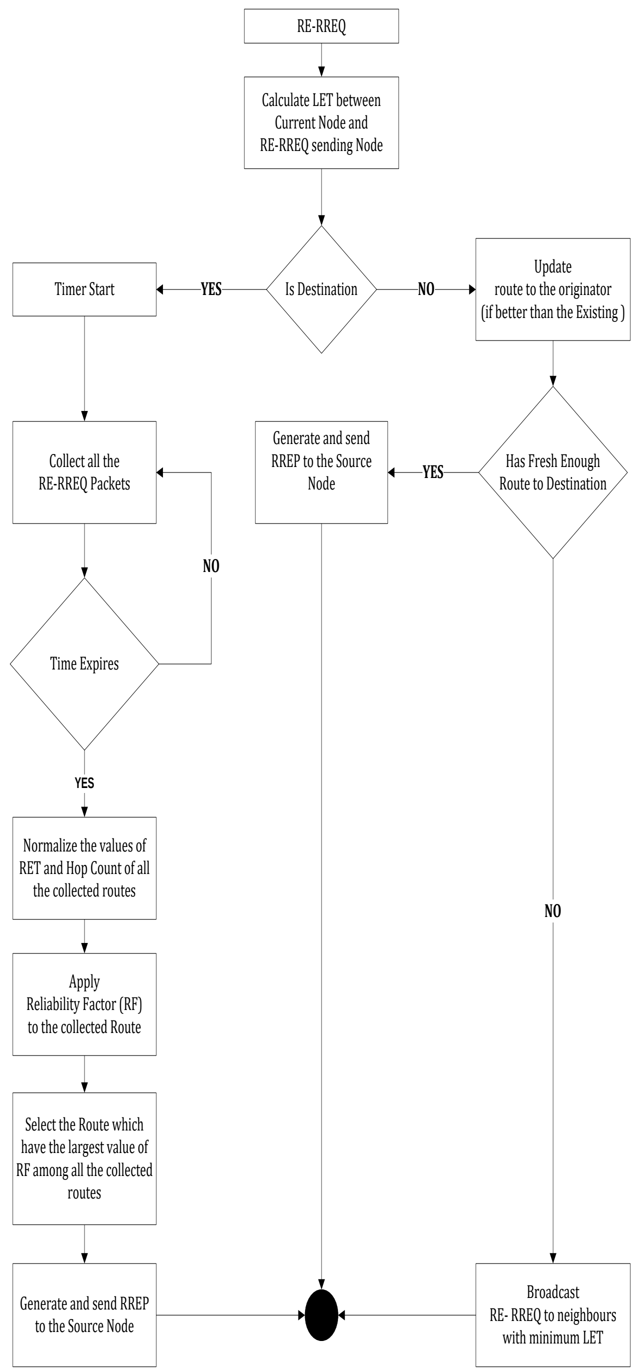

Fig. 6 The Route Discovery Process Flow

Any node that receives the ER-RREQ packet first explores the way back towards 'S' in its own routing table. If a route is found in the routing table, it updates the existing route in the table else it makes a reverse route towards 'S'. If the node that receives the ER-RREQ is not the desired destination node and if it does not find a valid route in its routing table for the destination node, it computes LET from source node to the current node. Furthermore, it also calculates the minimum value of LET between the current node and the source node. Finally, the hop-count is incremented and the ER-RREQ packet is broadcasted to all neighboring nodes. Refer to (Fig. 6) which explains the flow of route discovery process.

It is possible that the intermediate nodes receive multiple ER-RREQ packets from neighboring nodes. These packets are immediately discarded to avoid duplication. ER-RREP message is generated by the intermediate node if a valid active route towards the destination node is already present in its routing table. Similarly, if the packet-receiving node is itself a destination node then it selects the optimal reliable route. The complete process of selecting a reliable route has been explained in the next section.

B. Selection of Reliable Route at Destination Node

The first ER-RREQ packet when reaches at the destination node 'D' a timer starts and waits for a certain interval of time. Meanwhile the destination node starts gathering other ER-RREQ packets that are destined for it. For each route the destination node calculates the RF after the expiration of time delay and selects the route that has highest value of RF. The pseudo-code for route selection is given in **(Fig. 7)**.

```
Suppose Source Node is "SN", Destination Node is "DN" and
Current Node is "CN"
IF CN is DN then
    Calculate the RET and the HC of all feasible routes.
    Computes the RF of each feasible route
    Selects one with the largest RF value.
    Sends a RREP packet to that selected route.
End IF
    SN receives the RREP packet from DN.
    SN starts sending data to DN
```

Fig. 7 Selection of Optimal Route at Destination Node

4. Performance Evaluation

The performance of ERRRP is evaluated via simulation on NS-2.35 simulator (Fall, Varadhan Retrieved in 2012). The simulation is based on Random Waypoint Mobility (RWM) model (Navidi, Camp 2004, Papageorgiou, Birkos et al. 2012). **Table. 1** shows the simulation parameters that are set for the performance evaluation of the ERRRP protocol as a result of variable node speeds. Traffic sources parameter is configured to Continuous Bit-Rate (CBR) for a maximum of 25 connections. A shared-media radio was set with a trifling radio range with in 250 m. The simulation is done with 512-Byte data packets at the rate of four packets per second.

The random selection of source-destination pairs was done with a zero pause-time to simulate the mobility level with continuously mobile nodes. Each data point is taken as an average of many runs with mutable seed values usually used for the traffic models. The mobility scenarios are also selected on random basis.

A. Experiment: Consequences of Nodes Speed on ER-RRP

In order to analyze the impact of different speeds of nodes on the performance of proposed scheme the speeds of mobile nodes were varied between 5ms-1 to 50ms-1 in a network of 50 nodes.

Table. 1: Simulation Parameters

Parameters	Value
Protocols	RERRP, AODV
No of Nodes	50
Nodes Speed	5, 10, 15, 20, 30, 40, 50 ms^{-1}
Simulation Area	1000m X 1000m
Mobility Model	Random Waypoint
Traffic Type	Constant Bit Rate (CBR)
Queue Length	50
Transmission Range	250m
Propagation Model	Two Ray Ground
Simulation Time	300 s

B. Performance Metrics for Evaluation

For evaluating the proposed scheme following metrics were used (Adlakha, Arora 2015).

- **Throughput:** The amount of data bits received by the destination per second.
- **Average End-to-End Delay:** The delay between the packet origination time at 'S' and the time it is received at node 'D'. Lost packets are not considered.
- **Routing Packets:** Routing packets which are sent from source to destination.
- **Normalized Routing Load:** The number of routing packets transmitted per data packet reached at the destination.
- **Packet Delivery Fraction:** The ratio of the number of data packets successfully delivered at the destinations to those originated by the sources.
- **Received Packets:** The total number of data packets successfully received by the destination node.

C. Simulation Results and Discussion

Fig. 8: Node Speed vs. Packet Delivery Fraction

The result of node mobility on the Packet Delivery Fraction (PDF) with variable speeds is illustrated in **(Fig. 8)**. It is observed that PDF of both protocol decreases as soon as the node speed increases. It is a logical expectation that more number of routes will be broken because of the mobility of nodes with higher speed. It may however be observed that the ERRRP protocol has better packet delivery as compared to standard AODV protocol. This improvement in the packet delivery ratio of the ERRRP is due to the novel way of route selection procedure in which a most reliable route is selected on the basis of RF with maximum possible expiration expiration time. On contrary, the AODV selects the shortest path regardless of its reliability between two endpoint nodes. Moreover, AODV does not consider the route expiration time while discovering the optimal route. As a result, it faces more route cracking and packet drops. Another important observation is that ERRRP improves around 2 to 3 percent PDF at lower speeds as compared to AODV. Because less number of route become invalid at reduced speeds, but when the speed of nodes is increased the PDF of ERRRP improves around 5 to 8 percent as compared to standard AODV protocol.

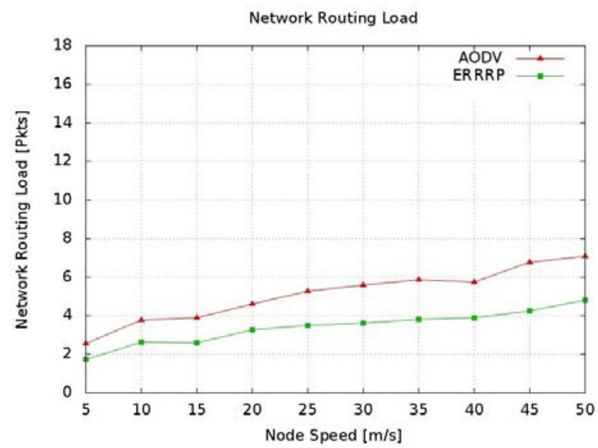

Fig. 9: Node Speed vs. Network Routing Load

Simulation results shown in **(Fig. 9)** prove that the network routing load of ERRRP is less than that of AODV. This is because of the selection route on the basis of reliability between the source node and the destination node. Owing to the selection of optimal reliable route, route failures were minimized and hence reduce the route discovery and maintenance overhead. The more number of invalid routes we have the more it will be required to explore and maintain new routes. It can be seen that ERRRP has achieved better performance in term of routing load. The overall reduction in the ERRRP overhead is 30% as compared to AODV.

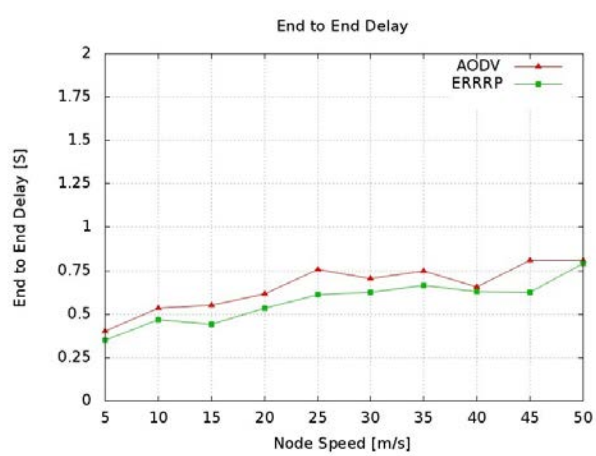

Fig. 10 Node Speed vs. End-to-End Delay

The average End-to-End delay comparison, as shown in **(Fig. 10)**, illustrates that the average end-to-end delay of ERRRP is slightly lower than that of AODV.

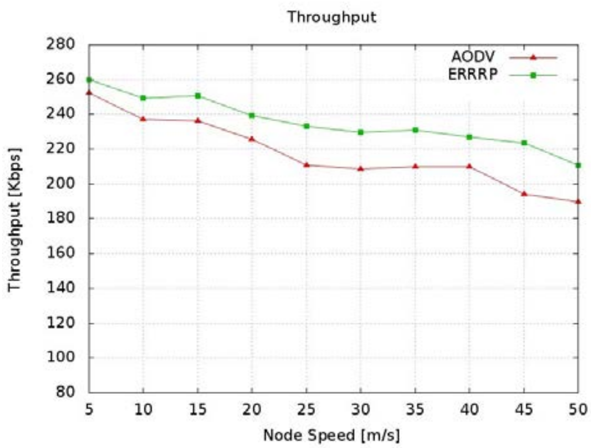

Fig. 11 Node Speed vs. Throughput

The comparison of the impact of node speed on the throughput for proposed protocol and AODV protocol is shown in **(Fig. 11)**. The result of simulation illustrates that the increase in node speeds decreases the throughput of both protocols, which is not surprising in view of the increased number of invalid routes as a result of higher node speed. As the faster mobility of nodes makes the routing paths unreliable, the ERRRP selects the reliable route in such a way that the throughput of ERRRP is better than that of standard AODV at all speeds.

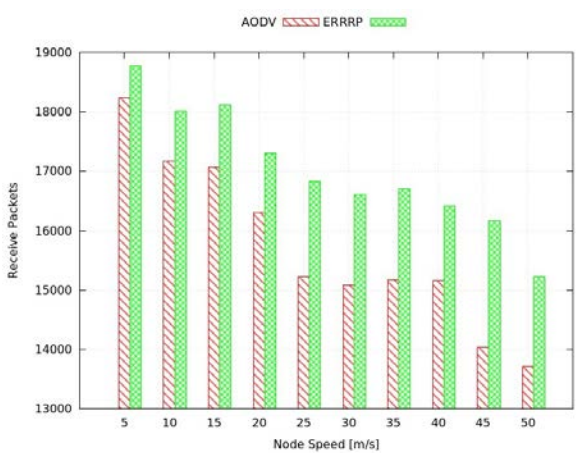

Fig. 12 Receive Packets vs. Node Speed

The comparison of number of received packets versus the node speed is shown in **(Fig. 12)**. It can be seen that the number of received packets drop gradually for both the protocols when the node speed improves. But it may be seen in the plot that ERRRP receives more number of packets as compared to the AODV. This is because of the reason that ERRRP protocol selects the reliable and efficient route based on RF hence it has less number of route breakage and consequently more packets are received.

Fig. 13 shows the comparison of node speed against routing packets of the network. It can be seen that increasing the node speed increases the route breakage and hence the more routing packets are needed to find the route. It was found that ERRRP has less number of invalid routes because it selects reliable routes, which require less number of routing packets as compared to standard AODV.

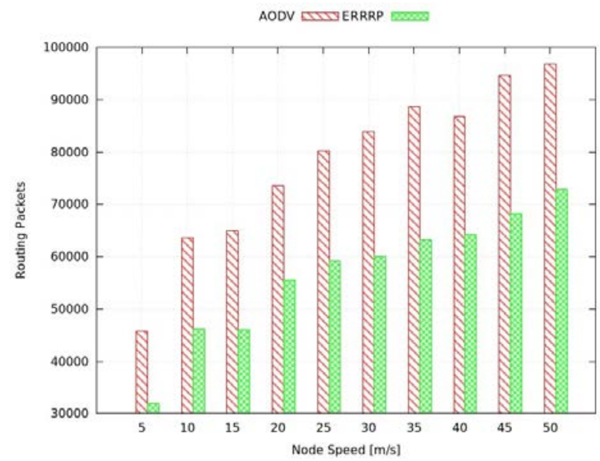

Fig. 13 Node Speed vs. Routing Packets.

5. Conclusion

A new routing protocol ERRRP has been proposed for dependable and reliable routing in MANET that selects the reliable route based on the value of RF. RF is a function of RET and the Hop Count that selects an optimal routing path with high reliability and less hop counts. The value of RF has a major contribution in the selection of reliable route; higher the value of RF the higher the reliability of the path between the source and destination nodes. Hence ERRRP always selects the highly reliable path for routing in MANETs. Owing to the reliable-route selection the link breakage between the active paths has been minimized. The simulation results show that ERRRP outstrips AODV and improves the PDF by almost 6 percent and decreases the network routing load (NRL) by almost 30 percent.

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