

# An Optimized Multicast Backbone Routing for Increasing Residual Energy in MANET

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## Abstract

**Background/Objectives:** Due to the presence of mobility, the nodes may move out of the coverage region. Mobility of nodes causes network partition. This will lead to heavy overhead and less packet forwarding ratio. **Methods/Statistical Analysis:** In this research work, Residual Energy based Reliable Multicast Routing (RERMR) is proposed to increase the packet forwarding rate based on optimized multicast backbone construction. It consists of following phases. In first phase, the multicast backbone is constructed based on trustable loop and trust factors. The backbone is maintained by means of cluster group members. If the cluster head is not responding to cluster members or other cluster head, the secondary cluster leader checks whether it attains the latency threshold and announces that as a cluster head. Reliable path is calculated based on stability of links and residual energy is saved based on signal strength and distance. **Results:** For simulation, the network simulator tool (NS 2.34) is used. The QoS parameters and the proposed parameters are taken for analysis for performance of existing and proposed work. Based on the simulation results, the proposed work achieves better performance than previous protocols in terms of path reliability rate, network stability rate, end to end delay, end to end transmission and communication overhead.

**Keywords:** Communication Overhead, End to End Delay, End to End Transmission Multicast, Network Stability Rate, Optimized Multicast Backbone, Packet Forwarding Ratio, Path Reliability Rate, Reliable Path, Residual Energy

## 1. Introduction

Mobile ad hoc network is the kind of wireless ad hoc networks where it does not need any infrastructure. The information about neighbour nodes is communicated via wireless links with no access point. Compared with wired networks, MANET does not cost for network design, construction and management. It has the potential to improve fault tolerant with the help of distributed control. Due to instability of MANET, it is very hard to provide reliable communication among the moving nodes. Due to the high mobility nature, path breakdown may likely to occur. It leads to heavy network partitioning those damages the whole network connectivity.

In previous work, packet forwarding was implemented with geographic positioning protocols, buffer management and multipath delivery scheme etc. In order to provide the reliable communication, MANET needs a reliable data delivery method that can adapt to changeable network topology and an unstable wireless ad hoc network. Delivery of the packet is a challenging issue, because a MANET can have no static route and stable route.

Both network coding and opportunistic routing were deployed to enhance data delivery rate and prolonged the network lifetime in existing works. These schemes suffer from network unbalancing and frequent route failures that lead to heavy overhead. In the proposed scheme, we adapt stability model to monitor and improve the quality

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adapt stability model to monitor and improve the quality of link. The data delivery rate is improved with the means of selecting reliable path.

The remainder of this paper is organized as follows. Section two describes the related work that focus on previous approaches for data forwarding. The drawbacks are also analyzed in this section. Section three explores the proposed work implementation. Section four provides the simulation results and last section concludes the proposed work.

## 2. Related Work

Reliable Multicast Transport Protocol<sup>1</sup> reduces the acknowledgement traffic and end to end latency using local recovery and grouping receivers. Two level hierarchy was converted in to multi-level hierarchy and the packet throughput was improved using selective repeat transmission mechanism. The probability of retransmission of lost packets has also been dealt in this work. Dynamic Ring based Multicast Routing protocol was presented<sup>2</sup> where the radius of the ring can be adjusted according to the route maintenance. Expanding Ring Search [ERS] mechanism was used to recover the member nodes during path breakage conditions. This protocol proves the scalability. But in this work during high mobility environments, the performance of the system is getting degraded. In this work<sup>3</sup>, the author proposed efficient Position based Opportunistic protocol based on taking advantages of stateless geographic routing property and broadcast nature. The protocol was also integrated with virtual destination based void handling to avoid the communication holes. In case of link breakage, selecting forwarding nodes were specified. Youngmin Kim et al. proposed multicast data forwarding scheme<sup>4</sup> which can be used in multi-hop wireless networks without using either routing loops or packet duplication. The author introduced a table for the prevention of packet duplication in multicast tree based routing protocol. Tree based protocol achieves high packet delivery rate than mesh based tree routing protocol. Robust and Secure Routing scheme<sup>5</sup> was proposed and mainly intended for highly dynamic ad hoc networks to compute node disjoint paths. The author integrates the path reliability and security to achieve highly secure network routing. Moreover, Ad hoc on demand protocol (AODV) was modified with integration of proposed scheme and also comparison was also shown.

A new scheme for buffer management<sup>6</sup> was presented for packet queues in mobile ad hoc networks through active queue management strategy. All the neighbor nodes share the buffer space. The buffer can be occupied through aggressively sending packets with lower data rate. Efficient Geographic Multicast Protocol<sup>7</sup> was introduced which uses virtual zone based structure to implement scalable and efficient group membership management. The overhead is also reduced during route searching and route maintenance process based on node position information. But the network progression is not implemented in this routing. Wenjing Lou et.al proposed multipath data delivery scheme called SPREAD<sup>8</sup> to provide more secure end to end delivery service in MANET. Based on security enhancement protocol, it was focused on improvement of data delivery service. The optimal share allocation schemes were used to provide certain degree of reliability. A mesh based multicast routing scheme was proposed<sup>9</sup> to find the stable multicast path from source node to destination node. The stable forwarding nodes are chosen based on high stability of link connectivity nodes. Link failure conditions are notified to source with route error packets. Multicast routes are found using route request packets and route reply packets with the help of routing information. In this paper, the author proposed both cluster based approach and location based approach<sup>10</sup>, to prevent the control traffic and to define each cluster area. The relationship between the moving speed of mobile nodes and cluster area suitable size was determined. Moreover, the number of cluster head nodes was reduced with the help of computation of cluster head value function. A data delivery method<sup>11</sup> was proposed by Shigeru et al. based on the Neighbor Nodes information in a MANET. This method employs opportunistic routing and network coding with MAC-independent Opportunistic Routing and Encoding (MORE) to improve reliable communication. Including this, the proposed method uses the location information and the transmission probability of its own Neighbor Nodes to efficiently deliver packets to the Destination Node. In this method, all of the nodes can hold the latest Neighbor Nodes information within two hops by updating periodically. A packet can be forwarded by Reliable Nodes that are appropriately selected based on the Neighbor Nodes information hop-by-hop. A new contention-based enhanced distributed channel access (EDCA) scheme and token bucket algorithm<sup>12</sup> were combined which provides a probabilistic QoS support and to

adjust the contention window. This proposed scheme provides traffic differentiation. A routing scheme was proposed<sup>13</sup> based on route stability and residual energy metrics during route discovery and maintenance. It computes the link stability based on measurement of received signal strength of successive packets and route stability is computed as the product of link stability of all links that make up the route. It allows nodes that satisfy required energy metric to act as intermediate nodes. New-Location-Aided Routing-1 was proposed<sup>14</sup> for reducing energy consumption in MANET. It achieves energy conservation along with sending successfully higher data packets to the destination. The optimal routing algorithm was proposed<sup>15</sup> to achieve high delivery rate in realistic bus network through minimizing the expected traversal time and maximizing the delivery probability over an infinite time horizon. The hybrid Content Delivery Network (CDN) system was proposed<sup>16</sup> that combine novel content routers in underlay with the server in overlay. It employs the prefix caching and the multicast schemes respectively. By using content routers, the proposed hybrid system can reduce delivery latency as well as traffic volume over the network significantly. Given the number of multicast streams in the server, it effectively solves the problem of both minimizing the delivery cost at content routers and determining the optimal prefix length with the in-network caching. Rajashekhar and Sunilkumar<sup>17</sup> proposed Bandwidth Delay Product (BDP) based multicast routing scheme with the help of ring mesh backbone. Reliable node pairs are computed based on mobility, remaining battery power and differential signal strength. The node pairs are used to compute BDP between them. BDP of a reliability pair is assessed using available bandwidth and delay experienced by a packet between them. Backbone ring mesh is constructed using reliable pair nodes and convex hull algorithm. Reliable ring mesh is constructed at an arbitrary distance from the centroid of the MANET area. Multicast paths are created by discovering a path from source to each destination of the group with concatenated set of reliability pairs that satisfy the BDP requirement. In case of node mobility and failures occurs, the ring mesh can be able to maintain high BDP on ring links and also it can be recovered.

In paper<sup>18</sup>, on Demand Multicast Routing Protocol is proposed to build routes and maintain multicast group membership. But, the stability of routes is not considered to defend against malicious activities.

In our approach, our protocol can be able to adopt in any scale networks.

In paper<sup>19</sup>, performance comparison of multicast protocols was analyzed with simulation results. Source Routing Multicast Routing (SRMP) achieves better performance based on node selection criteria during mesh construction. The probability of choosing reliable path is low in SRMP.

In our previous work<sup>20</sup>, optimized multicast routing scheme was proposed to attain more network stability. In this work, the estimation of link stability, path stability and node stability is given to provide more network stability. Optimized multicast backbone construction is developed to provide trustable network. In our proposed scheme, we have utilized this model.

Our aim is to arrive at a multicast protocol which strikes a balance between defending against unreliable path and more energy consumption of nodes.

### 3. Overview of Optimized Multicast Routing Scheme

The optimized multicast routing scheme consists of two phases i.e. detection of malicious nodes and handling link failure and path failure by choosing the stability ratio of link and path. In the first phase of the scheme, the malicious node is detected by means of trust threshold which contains the values of node familiarity and node proposal. In second phase of the scheme, estimation of stability ratio for link, node and path is proposed.

#### 3.1 Network Model

It is assumed that nodes are moving with transmission range. Network topology is represented by  $G(K, L)$ , when  $K$  (Vertices) &  $L$  (Edges) are the set of mobile models (vertices) & wireless links. Nodes forward the packet via multicast routes Viz.  $R$ .

All the mobile nodes are assigned with unique identifier individually. The packet delivery route of  $(u, v)$  where  $u$  and  $v$  are the sending and receiving node

If link connectivity occurs bandwidth  $u$  &  $v$ , the received signal strength of  $v$  will be above threshold. The path is represented as  $P(m_1, m_{u+1}) = \{m_1, m_2, \dots, m_{u+1}\}$

$m_1$  – Source node,  $m_{u+1}$  – Receiving node

The following assumptions are made:

- The message will be delivered in multi-hop behavior.
- Packets should be transmitted through reliable link.
- The link error probability should satisfy the transmission power.
- If transmission power is adjusted, the data delivery rate should not be changed.
- If nodal degree is getting increased, the number of packets destination should be
- $N(n, h) \geq N(k, h) \geq 0$ .
- Packets should be forwarded based on random walk. It is described as,
- $0 \leq N(k, h) - N(k, g) \leq N(l, h) - N(l, g)$ .
- It states that, if nodal degree is high, the packet rate will be increased.

### 3.2 Optimized Multicast Backbone Construction

Optimized multicast route acts as a backbone for multicast routing in MANET. In order to create an optimized multicast backbone, it is needed to have a complete topological knowledge. The MANET boundary area is determined by using the Jarvi's convex hull algorithm<sup>17</sup> from computational complexity. If the boundary is known, the area and centroid can be determined which helps in the construction of optimized multicast backbone. In Figure 1, the convex hull creation is illustrated. The angles P, Q correspond to two extreme neighbours on negative x-axis. An angle is supposed to calculate at node  $A(u_0, v_0)$  that is assumed to be a starting node to initiate convex hull formation on all the boundary nodes. The angle at  $A(u_0, v_0)$  selects a neighbour node  $B(u_1, v_1)$  as it makes minimum angle P rather than neighbour node  $C(u_2, v_2)$  which makes an angle Q with the condition that  $P < Q$  once if traced in clockwise direction. This procedure is repeated at node B and its next boundary node (tracing all the boundary nodes) till it reaches to the original node  $A(u_0, v_0)$  through opposite direction. Thus, the convex hull is created. Once the convex hull is created, optimized multicast backbone is constructed that serves as a backbone for multicast routing.

The creation of optimized multicast backbone is shown in Figure 2. Optimized multicast creation is initiated based on two assumptions: 1. Establishing a trustable loop that should be located at 4/6 th of an average

radius from the centroid so as to be reached by all the nodes with least hop distance whether they are either towards the centroid or towards the boundary nodes on the convex hull and 2. This loop is established by connecting links formed by trustable factors of node familiarity, node proposal, link stability and path stability.

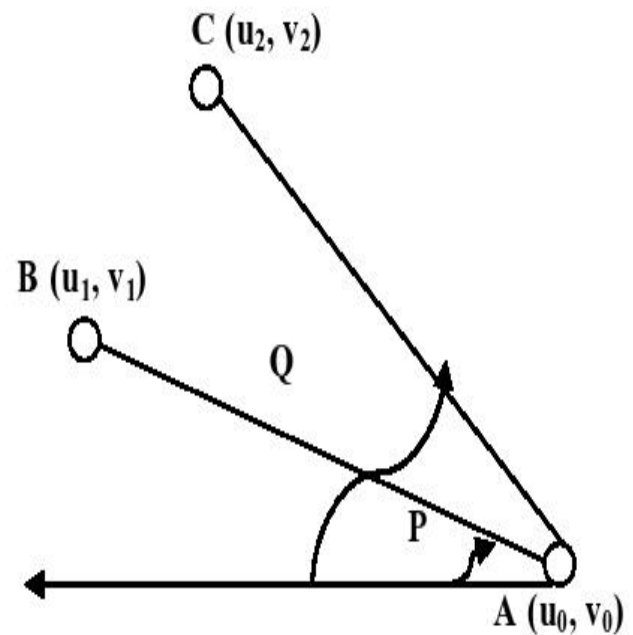


Figure 1. Accepted angle to create convex hull.

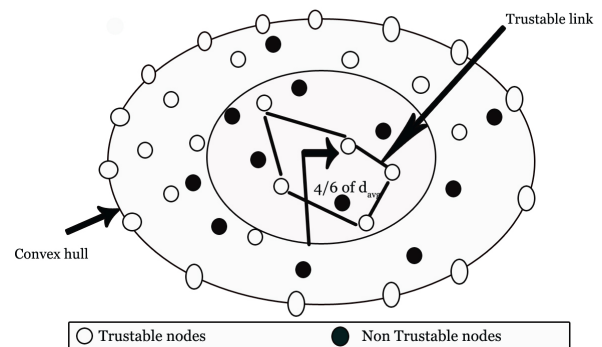


Figure 2. Optimized Multicast Backbone creation.

Average radius is obtained by,

$$d_{averradius} = \frac{1}{N} \sum_{i=1}^N \sqrt{(u_i - u'_i)^2 + (v_j - v'_j)^2} \quad (1)$$



Where  $N$  = number of nodes and  $u_i$  and  $v_i$  are the convex polynomial created by nodes. The optimized multicast routing is constructed at an arbitrary distance  $d_{averradius}$  measured from centroid of the convex hull. It is given

by  $d_{avg} = \frac{4}{6} \times d_{averradius}$ . All the nodes at  $d_{avg}$  are joined together to form an optimized backbone.

### 3.3 Data Forwarding through Reliable Path

Due to mobility of nodes, topology changes frequently & unpredictably. If node moves out of transmission ranges, and alternative path must be found to forward the packets immediately. If the packets would not be able to relay to the neighbor nodes with less node degree, the route discovery process will be reinitiated by source to find a new route to the destination. When some of the neighbor nodes or destination node moves out of range, the path maintenance will be initiated to correct the broken links or paths. If a nodes locality is identified, the upstream node of broken path will send RREQ messages to the destination. Otherwise it will send the Route Error (RERR) message. Destination will choose alternative path to send ACK messages, otherwise it request source to reinitiate route discovery. The path reliability criterion is useful to choose the best path for packet transmission. If multi paths are available, the route with path reliability is desired.

In order to efficiently deliver the data, source node generates the forwarders list which specifies the neighbor relay node that forwards a packet via reliable path. Source node multicasts the data packets with forwarders list. The data packets include geographical position of source node and destination node. It also includes next neighbor forwarding node information from source node to destination node. The forwarders list is always updated in hop by hop fashion and its size depends on number of forwarding neighbor nodes. The relay node can be replaced with new relay by means of changing forwarders list with the new one.

In network, each path link has a packet error rate indicator. It is desired to choose path which has links with higher quality and lower bit error rate to increase packet transfer reliability. Based on the path reliability criterion, the reliable both can be chosen among several paths.

The path reliability criterion ( $P_R$ ) can be calculated as,

$$P_{RC} = \prod_{k=1}^{Hopcount} (1 - LER_k) + \sum_{p=1}^P (1 - P_{LR}) \quad (2)$$

Where  $k$  = number of hops that the link carries.

$\{p_1, p_2, \dots, p_P\}$  is the number of packets travelling along the path.

$P_{LR}$  is the packet loss rate.

The advantage of the path reliability criterion is to choose a higher quality path with minimum number of retransmissions, minimum energy consumption and thereby prolongation of network lifetime. In the following section, we have provided residual energy estimation to prolong the network lifetime.

### 3.4 Estimation of Residual Energy

Due to frequent path breakdowns it is necessary to choose the mobile nodes with more residual energy. Before the optimized multicast backbone construction, the number of mobile nodes is unknown. Once multicast backbone creation is finished, nodes communicate and send their data to source node at most once per frame during allocated transmission slot. The number of frames can be obtained as

$$M_{frame} = \frac{t_p}{m * \tau_{slot} + \tau_{NtoD}} \quad (3)$$

Where  $t_p$  is the operation time of source node to send the data packets.  $\tau_{slot}$  is slotted time required for the

transmission from source node to neighbor node.  $\tau_{NtoD}$  is the time required for the transmission from neighbor node to destination node.

The expected energy of a node to reach source node after the operation time could be represented as,

$$E_{expconsump}(k, d_{toD}, m) = M_{frame} * (E_X(k, d_{toD}) + m * E_R(m))$$

It is assumed that all the mobile nodes transmit and receive the same size of packets i.e. bits of data. The distance to the destination could be computed based on received signal strength. The expected residual energy of a mobile node during mobility conditions,

$$E_{\text{exp residual}}(k, d_{\text{toD}}, m) = E_{\text{residual}} - E_{\text{exp consump}} \quad (4)$$

$E_{\text{residual}}$  is the residual energy of a mobile node before the route discovery process. Among several paths, the path with “High Expected Residual Energy (HERC)” parameter will be given with higher priority for packet transmission. The factor RE is expressed as

$$R_E = \frac{\text{HERC}}{E_I} \quad (5)$$

The initial value for this factor is Initial Energy ( $E_I$ ). The proposed protocol can reduce the route request packets and packet loss with our stability model in the presence of energy dissipation of mobile nodes. Consequently more residual energy can be saved for relaying the data packets instead of being wasted on excessive path discoveries.

### 3.5 Packet format of RERMR

| Source ID | Destination ID | Hop Count | Data Forwarding Status | Residual Energy Level | FCS |
|-----------|----------------|-----------|------------------------|-----------------------|-----|
| 2         | 2              | 1         | 4                      | 4                     | 2   |

**Figure 3.** RERMR Packet Format.

In Figure 3, the proposed packet format of RERMR is shown. Here the source and destination node ID carries 2 bytes. The third field hop count determines the number of nodes connected to the particular node in the cluster. It occupies 1 byte. The data forwarding status occupies 4 bytes. Each mobile node checks residual energy level of other remaining mobile nodes. The last field FCS i.e. Frame Check Sequence which is for error correction and detection in the packet while transmission.

### 3.6 Description of RERMR

The proposed scheme is to identify the optimal route in the network. For that, optimized multicast backbone is constructed to find the trustable and non trustable nodes using the link and node stability ratio estimation. In previous multicast routing schemes, either link or node stability is focused. Here node stability, link stability and

multicast route. Estimation of residual energy and path criterion is shown to improve the network availability and prolong the network lifetime.

## 4. Performance Evaluation

The performance of the proposed approach is evaluated in this section. The simulation model is discussed in Section 4.1 and the simulated results are presented and described in Section 4.2.

### 4.1 Network Model

In the proposed network model, it is assumed that  $K+1$  mobile nodes are present in the network while taking the source node is  $K$  and destination node is  $(K+1)$ . The packets are received in a queuing order from the rest of  $K$  nodes. The proposed model is symmetric and synthetic model. Here the mobile node may in the transmission range or out of the range. The packets are transmitted in a fixed size and the route discovery time is deterministic. Packets are arrived to the destination according

path stability are estimated to identify the optimal to the Markovian Arrival Process in discrete time (DBMAP/D/1/N). Here,  $N$  is the buffer size of the destination mobile node. So, the process is in the queuing condition. Mobility nodes are randomly chosen while considering the packet loss probability which involves transition matrix is  $(K+1)(N+1) \times (K+1)(N+1)$ .

### 4.2 Mobility Model

Mobility model we have chosen for our proposed scheme is Random Waypoint Mobility model. The node pause time is changed between in direction or speed i.e. node starts by staying in one location for certain period of time. If the pause time is expired, the mobile node will choose a random destination and speed which are uniformly distributed between 0 and MAXSPEED. After that the node moves towards the destination at the selected period.

### 4.3 Simulation Model and Parameters

We have simulated our results using NS2.34 simulator. It is an object oriented discrete event simulator to identify the performance of proposed scheme. The Backend language of NS2.34 is C++ and front end is Tool Command Language (Tcl). NS2 is user friendly and easy to fabricate our own protocol. Tcl is a string-based command language. The language has only a few fundamental constructs and relatively little syntax, which makes it easy to learn. The syntax is meant to be simple. Tcl is designed to be a glue that assembles software building blocks into applications. Here we made the assumption that adopted for simulation is all nodes are moving dynamically including the direction and speed of nodes. Mobility scenario is generated by using random way point model with 300 nodes in an area of 1000 m × 1000 m. Our simulation settings and parameters are summarized in Table 1.

**Table 1.** Simulation and Settings parameters of RERMR

|                     |                   |
|---------------------|-------------------|
| <b>No. of Nodes</b> | <b>300</b>        |
| Area Size           | 1000 X 1000       |
| Mac                 | 802.11g           |
| Radio Range         | 250m              |
| Simulation Time     | 50 sec            |
| Traffic Source      | CBR               |
| Packet Size         | 512 bytes         |
| Mobility Model      | Random Way Point  |
| Initial energy      | 75 Joules         |
| Transmitted power   | 0.879 milli watts |
| Received Power      | 0.08 milli watts  |
| Pause time          | 150 s             |
| Communication range | 540m              |

### 4.4 Performance Metrics

We evaluate mainly the performance according to the following metrics.

#### 4.4.1 Average Packet Delivery Ratio

It is the ratio of the number of packets received successfully to the total number of packets transmitted.

#### 4.4.2 Communication Overhead

The control overhead is defined as the total number of routing control packets normalized by the total number of received data packets. It suppresses the communication between the source and destination nodes.

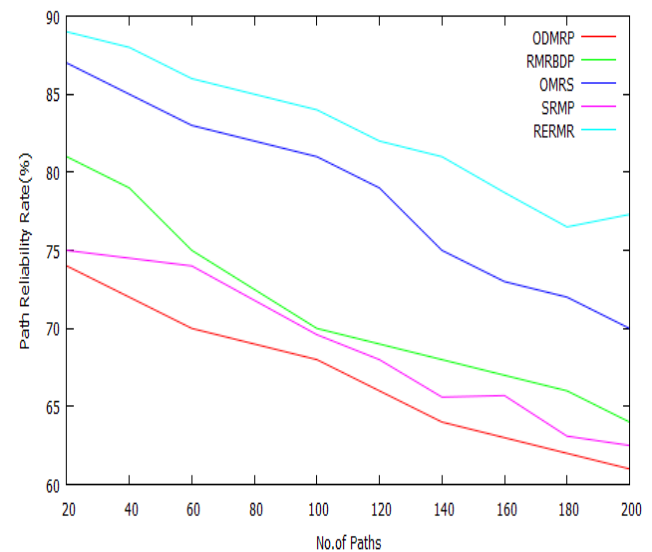
#### 4.4.3 End-to-End Delay

It depends on the routing discovery latency, additional delays at each hop and number of hops.

### 4.5 Results

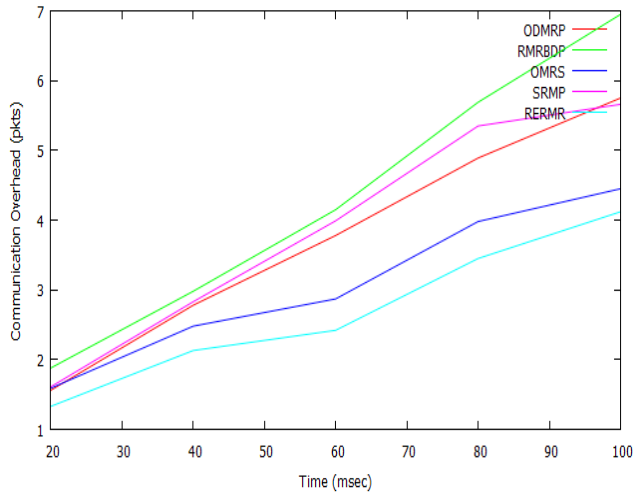
We compared our proposed scheme with OMRS<sup>20</sup>, SRMP<sup>19</sup> and Bandwidth Delay Product based Multicast routing Scheme<sup>17</sup> and On Demand Multicast Routing Protocol<sup>18</sup>. The results are examined by using performance metrics end-to-end delay, packet delivery ratio, malicious node detection ratio, network lifetime, end to end delay and overhead.

Figure 4 shows the analysis of number of paths Vs. Packet reliability rate. From the results, our proposed scheme achieves high packet delivery ratio than the existing schemes namely SRMP, OMRS, ODMRP and RMRBDP because of stability deployed in the optimized routing.



**Figure 4.** Packet Reliability Rate Vs. Number of paths.

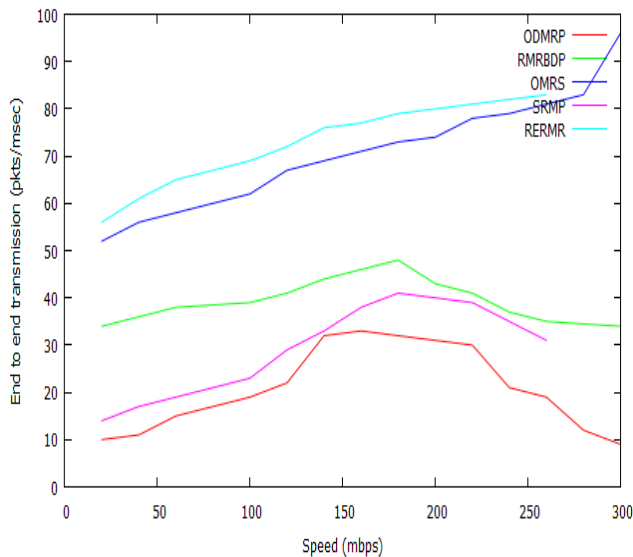
In Figure 5, we vary the time from 10 to 100. While increasing the time, the communication overhead of proposed algorithm RERMR has low than OMRS, SRMP ODMRP and RMRBDP. This is achieved by employing the trustable packet loss ratio in the transmission process.



**Figure 5.** Communication Overhead Vs. Time.

In Figure 6, speed is varied from 0 to 300 mbps. The end to end transmission of proposed scheme achieves high than OMRS, SRMP, ODMRP and RMRBDP because of high path reliability criterion.

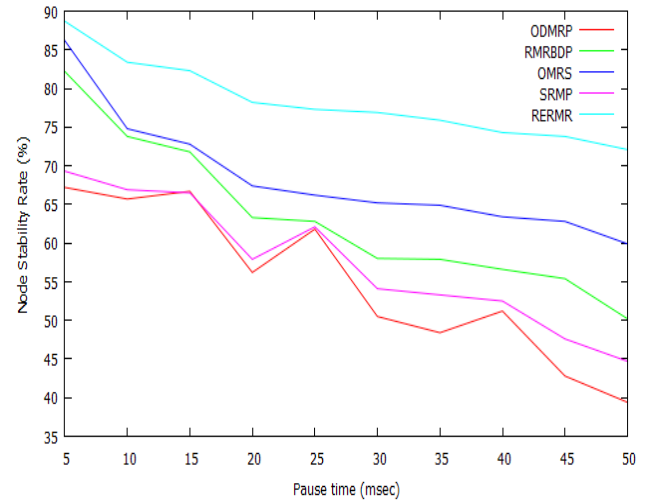
In Figure 7, we vary pause time from 5, 10,...50 msecs. The network stability rate of RERMR achieves higher than OMRS, SRMP, RMRBDP and ODMRP.



**Figure 6.** End to end transmission Vs. Speed.

## 5. Conclusion

In this research work, Residual energy based Reliable multicast routing scheme is proposed for handling link, node path failures in ad hoc networks. The proposed



**Figure 7.** Network Stability Rate Vs. Pause time.

proposed scheme is based on threshold value to maintain the reliable multicast routing which enhances the stability and connectivity of the network. Network model is designed to achieve more packet delivery rate criterion. Optimal multicast backbone is constructed to improve reliability of multicast routes. Data packets are successfully forwarded through the reliable path. The best path is chosen based on high residual energy. By simulation results, the RERMR is better than OMRS, RMRBDP, SRMP, and ODMRP in the presence of high mobility environment. The proposed work can be a suggestive approach for a real life approach such as military search and rescue operations. Future studies can be extended to implement the authentication and security in the optimized multicast routing scheme to make more integrity that the information is carried out among the mobile nodes. We plan to choose the cryptographic schemes to make network more secure.

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