Abstract

A Mobile ad hoc network is a self-configuring, infrastructure less network; nodes are connected via a wireless link. Nodes move independently in any direction. Links of each node change frequently. To increase the reliability of data transmission with fault tolerance and it also provides load balancing. This paper proposes a new mechanism to achieve Balanced Reliable Shortest Routing (BRSR) in Ad Hoc On-Demand Multipath Distance Vector Routing Protocol (AOMDV) with Three-way Filter (TF) mechanism. The selection of BRSR between source to destination is done based on energy, link quality and inference noise in order to improve the data transmission and load balancing. The protocol performance is verified simulation done using NS-2 simulator. The experimental results showed that in BRSR-AOMDV protocol with TF mechanism decreases the packet loss rate, increases throughput and packet delivery ratio which reduce the average delay in an effective manner.

Keyword: MANET, BRSR-AOMDV, Fault tolerance, Load Balancing

1. Introduction

A mobile ad hoc network (MANET) is a dynamic topology and self-configuring infrastructure less network in which nodes are associated via a wireless link and they move autonomously in any direction. The mobile nodes communicate with each other via bandwidth, self-doubting wireless link, error-prone with changeable capacity. The nodes link are supposed to change frequently. One of the major challenges of MANET is maintaining link routes information of each node continuously. Generally MANET nodes have limited power, processing and memory resources as well as high level of mobility. Finding and maintaining routes in a MANET is a major challenge. Selection of best routing algorithm is a complicated task and the need arises to develop a new mechanism or novel ideas that will enhance the routing algorithm performance.
node may cause congestion and huge delays or reduce energy quickly.

Load balancing issue deals with increasing the performance of the network by reallocating the jobs from overloaded nodes to under-loaded nodes or idle nodes. By doing so, the total time to processes all the jobs may reduce considerably and also makes it sure that no node sits idle while some jobs are waiting to be processed. Routing protocols are vital for the proper functioning of ad hoc networks. Since routing is performed by nodes with limited resources and load should be efficiently distributed through the network. Otherwise, heavily-loaded nodes may make up a bottleneck that lowers the network performances by congestion and larger delays.

Different types of fault occur in the MANET, it consist of link failure, node failure, malicious node, error during transmission etc. It corrupts the routing protocol performance, because there is no centralized control over the node. This paper focused link failure in MANET.

2. LITERATURE REVIEW

In the recent past, lot of researches had been done in fault tolerance and load balancing individually. This proposed research mainly focuses on combined study of fault tolerance and load balancing in multipath routing to enhance the performance of routing protocol to minimize the failure rate. In this section, the research papers are reviewed and the methods that already exist to handle the failure and load balancing of the network are identified.

Routing decision operates in the presence of adversarial environments in MANET. The fault-tolerant routing identifies faulty node using address routing [4].

Wu et.al [5] proposed an algorithm to identify link or node failure in which they used the mechanisms based on timeout and mutual exclusion. Link quality is estimated based on battery power consumption and number of nodes [6]. In [7], link quality is estimated based on packet loss rate, available bandwidth and round trip time, to track error and collision probability using Unscented Kaman Filter (UKF).

The routes are identified based on link quality using link quality based hybrid routing (LQHR) – OLSR protocol to find the link quality of route according to neighboring nodes SNR and link utilization level of each node [8]. Malvankar [10] et.al proposed availability based link QOS. The available link is estimated where using the parameter mobility prediction, link quality and energy consumption.

The work done by Jiang and Hu proposed Multi-path load balancing protocol to achieve load balancing based on hop count and link loss rate [11]. Wadie et.al [12] formulated load balancing approaches which take metrics of path length and the interference of the path which reduce the power consumption ,balance the network delay and network load.

Multipath routing protocol based –Temporally-ordered routing algorithm (M-TORA) circulates MAC layer information to all the neighboring nodes [13]. Based on MAC information and hop count, when a node have multipath to the destination it is essential to compute the route selection. Using this routing mechanism the network load is to share among multiple paths through that it achieves automatic load balancing.

Oussama et.al [14] projected a new metric called node degree of centrality, using the mechanism to enhance the load distribution. It moves forward to the traffic from center of the network. The work given in Puri and Devene [15] Anticipated AOMDV which was used to avoid congestion, balance the load and also avoid link failure. To avoid link failure they selected the minimum hop count path. In case failures occurs to select the highest hop count path which is maintained in the routing table. The queue length and hop count value are jointly used to select the route between source and destination to avoid the congestion and balance the load. In [16] the selection of route depends on stability of a link-disjoint and hop count of node-disjoint in the multi-path sets from source to destination.

The work given in [17] proposed load balancing mechanism to calculate total load on a route and find relay node queue size.

This paper used on-demand routing protocols such as Ad hoc on-demand multipath distance vector routing protocol (AOMDV) with Balanced Reliable Shortest Routing (BRSR-AOMDV) is proposed, focusing on building a more reliable route and balancing load among various routes in multipath scheme.

A new scheme BRSR-AOMDV has been introduced which make use of the link quality, interference ratio, energy and hop count to determine the best reliable and balance route.

3. PROPOSED WORK

3.1 Overview of AODV and BRSR AOMDV

AOMDV is an extension to AODV protocol. AOMDV [3] is based on distance vector and hop-by-hop routing concepts. It finds number of routes on-demand using route discovery approach. The advertise hop-count to assure the loop-free feature, it maintains multiple paths from the same sequence number. Main aim of AOMDV is to find loop-free and link-disjoint multipath during the route discovery process. Advertise hop-count refers to the maximum hop count of multiple paths to a destination node available at an intermediate node. It ensures that alternate routes to every node are
disjoint and without using source routing to achieve path disjointness. AOMDV contains multiple paths for each destination which is maintained in a routing table. Each route have a sequence number. The same destination sequence number is used for all the paths to the destination. The highest destination sequence number route is maintain in the routing list, in case the route received higher destination sequence number during advertisement, the older sequence number removed from all the routes. It discovers multipath between source and destination in every route discovery. Multiple paths computed are guaranteed to be loop-free and disjoint. Unique aspects of AOMDV are that it does not have high inter-nodal organization overheads, it ensures disjointness of alternate routes and it computes the alternate path with minimal additional overhead.

The proposed BRSR-AOMDV mechanism to send multiple invite packets to the entire generated path, an estimation of the packet delivery ratio to all the paths is done first, and then an estimate of the interference noise ratio is done with the estimate of the remaining energy for all the path in order to select the balanced reliable shortest route with the three filter estimation mechanism is done finally. Finally the balanced reliable shortest route base on hop count to overcome and avoid link failure in high mobility with balanced load path is selected.

### 3.2 New Routing Table Structure for BRSR-AOMDV

<table>
<thead>
<tr>
<th>Destination</th>
<th>Sequence Number</th>
<th>Advertised hop count</th>
<th>Next Hop</th>
<th>Last Hop</th>
<th>IQ</th>
<th>ES</th>
<th>TimeOut</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

![Fig A.1BRSR-AOMDV Routing Tables](image)

Fig A.1BRSR-AOMDV Routing Tables

In the above figure (A.1) structure of routing table used in BRSR AOMDV is shown. AOMDV shares several properties with AODV. AOMDV is based on distance vector routing concepts; it finds the route on demand base and discovers the route based on route discovery process. In AOMDV RREQ established multipath between source to destination. AOMDV provides alternate paths with support of intermediate node, thus it reduces the RREQ frequency. There is a field advertised hop count; it is used to store extra information for each alternate path such as next hop, last hop, link quality value, remaining energy and time out. In our proposed protocol BRSR-AOMDV we additionally include two fields such link quality and remaining energy of the path. Node mobility the node changes their topology frequently and they move away from the transmission range. In this case AOMDV cannot choose the alternate path form source to destination. To avoid this kind of link failure we proposed a new field to find the link quality ratio and remaining energy for the entire path. Based on this value we have to select a reliable path. The estimation of link quality and interference ratio assure the reliable path.

Normally in AOMDV the initial copy of RREQ is used to form reverse path, the duplicate copies are discarded. In BRSR-AOMDV the duplicate copies can be used to form alternate paths.

### 3.3 Problem Definition

Many researchers have given major contribution to the development of MANET communication. They have created a number of routing protocols to enhance the performance of MANET. A method is proposed to find multiple paths between source to destination by applying three way filter mechanism using Balanced Reliable Shortest Routing – Ad Hoc On-demand Distance Vector (BRSR-AOMDV) protocol. Most of the existing works proposed to select the best path between source and destination using a single mechanism such as queue size, link cost, bandwidth, energy etc.

In our proposed method we taken into account three different metrics such as link quality, interference ratio, residential energy and hop count, then we find balanced reliable shortest routing path. The below fig A.2 shows the general view of our proposed work.

![Fig A.2 General View](image)

#### 3.3.1. Link Quality Estimation

In general AOMDV does not consider the link quality for the routing decision. In our work BRSR_AOMDV assumes that the transmission will be successful as long as the whole path is within the transmission range.

In this work multiple ‘handshake’ RREQ packets are send to all the route list paths, in that we find
LQ_node based this value to find all the packet delivery ratio on all the nodes in the route list path. Where LQ_node indicate the each individual node packet delivery ratio, LQ_path indicate the packet deliver ratio of finded paths. A path with the highest packet delivery ratio will be selected with respect to the values of LQ_node and LQ_path.\n
\[ LQ_{node} = \frac{n_{pa}}{n_{pa}} \]  
\[ LQ_{path} = \sum_{m=1}^{n} LQ_{nodes} \]  

3.3.2. Energy Estimation

Energy utilization is a critical design concern in wireless networks since wireless nodes are typically battery limited. It is one of the most important performance metrics for mobile ad hoc networks because it directly relates to the operational lifetime of the network. Inefficient energy utilization of the network can cause node failure and network partition. To find remaining energy RE_pointer for all routes, select the best available route to avoid node failure. The remaining energy RE_pointer, depends on the packet volume, packet transmitting energy, and band width of the path. Then find the remaining for the path using the equation 8 of the path at time t. The packet transmitting energy depends on node distance, physical environment and proportionality constant. The total energy concern with number of packets, packet transmitting energy and packet processing time.

\[ RE_{pointer} = P_v \times P_{te} / P_{bw} \]  
\[ E_{cons} = \sum_{i=1}^{n} E_{init} - RE_{pointer} \]  

3.3.3. Interference Estimation

Any node can act as a sender or as a receiver, so we find the interference noise ratio INR [1] [23] and [24] using the common equation 5 and 6. A receiver node \( r \) at a time is capable of receiving data at a given transmission rate of \( X \) bits/sec from the sender node \( s \) (equation 3).

\[ INR = \frac{TP_{si}(t) \times P_{S_{ini}}(t)}{N_0 + \frac{1}{2} \sum_{m=1}^{n} TP_{k}(t) \times P_{S_{ini}}(t)} = \frac{TP_{si}(t) \times P_{S_{ini}}(t)}{N_0 + \frac{1}{2} I} \geq \beta \]  

Where \( TP_{si}(t) \) is the transmitting power of the sender node \( s \), \( P_{S_{ini}}(t) \) is the channel path gain from the node \( s \) to \( r \), \( \beta \) is the INR threshold value for reliable communication, \( N_0 \) is the noise power density, processing gain \( L \), total interference at node \( r \). The channel path gain (equation 6) is measured to be a function of the distance, signal weak and path loss so that

\[ \frac{d_{rm}^2}{d_{rm}(t)} \geq \beta \]  

The \( d_{rm}^2 \) Rayleigh fading node \( s \) to node \( r \). \( d_{rm} \) is the Euclidean distance between nodes \( s \) and \( r \), and \( \alpha \) is the path loss parameter.

As the above eq-5 and eq-6 the INR value for the individual nodes alone a modified eq-7 based on multi path route, calculate the modified cumulative path gain that is \( mpg_{srm} \) from node 1 to \( n \) for the particular path this way to find the path gain value for the entire route

\[ mpg_{srm} = \sum_{i=1}^{n} d_{srm}^2 / d_{srm} \geq \beta \]  

The main aim is to find the total interference measured by a receiver node \( r \) that is communicating with an intermediate node in the route. The threshold value \( \beta \) calculate using the general formula in equation 8

\[ \beta = \frac{SS}{IS} = \frac{SS}{\sum_{l=1}^{n} IS_l} \]  

Where \( SS \) signal strength, IS co-channel interference strength and \( IS_l \) power of co-channel interference from \( l \)th node.

3.3.4 Sample Route Selection Table

The priority of routes selection which in turn computed values of Link Quality, Interference Noise Ratio and Remaining Energy of the path. The table A.3 depicts the difference priority levels of route selection.
3.3.5 Steps for choosing the reliable path using BRSR-AOMDV

Step 1: Send multiple RREQ packets to all the routes available in the route list
Step 2: Estimation of link quality pointer $LQ_{path}$ is obtained using packet delivery ratio
Step 3: Determine the remaining energy to all the routes $RE_{pointer}$
Step 4: Determine the interference ratio to all the routes $INR_{path}$

// Check the following Metrics
Step 5: For each path
(i) Check $LQ_{path} > LQ_{thr}$
(ii) Check $RE_{pointer} > E_{thr}$
(iii) Check $INR > INR_{thr}$

Step 6: All the above conditions are true, set the priority for the routes and select the balanced reliable shortest route
Step 7: If two routes have same priority, select the route with least hop count.

### 4. PERFORMANCE EVALUATION

#### 4.1 Simulation Setup

In order to evaluate BRSR-AOMDV, we have compared its performance with AODV using several performance metrics. We have used NS-2 as the simulation environment in corresponding parameters and their values are given in the Table A.4. In our scenario both algorithms use TF mechanism to find the balanced Reliable Shortest Route to solve the link failure problem and balance the load of the route. The area in which the nodes are spread is 1000 X 1000 meters and there are 50-60 nodes which can move in a range of 250 meters in random directions. In this work we adapted CBR traffic model and each node uses the IEEE802.11 protocol in its MAC layer and the total simulation time is 10 minutes.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmission Range</td>
<td>500 m</td>
</tr>
<tr>
<td>Topology Size</td>
<td>1000 m X 1000 m</td>
</tr>
<tr>
<td>Number of Nodes</td>
<td>50 – 60</td>
</tr>
<tr>
<td>Number of Destination</td>
<td>1</td>
</tr>
<tr>
<td>Traffic Type</td>
<td>CBR</td>
</tr>
<tr>
<td>Packet Size</td>
<td>512 byte</td>
</tr>
<tr>
<td>MAC Layer</td>
<td>802.11</td>
</tr>
<tr>
<td>Node Placement</td>
<td>Random</td>
</tr>
<tr>
<td>Simulation Time</td>
<td>10 minutes</td>
</tr>
</tbody>
</table>

Table A.3 Simulation Setup

### 4.2 Performance Metric

This paper compares the performance of TF mechanism in terms of packet delivery ratio, packet loss rate, average end to end delay and throughput and energy consumption through simulation. Four performance metrics were evaluated in our simulation: (i) Packet Delivery Ratio (ii) Throughput (iii) End-to-End Delay (iv) Packet loss rate

#### 4.3 Simulation Results

##### 4.3.1 Packet Delivery Ratio

The simulation result BRSR-AOMDV achieves better rate of packet delivery compared to AODV. Evaluate Packet delivery ratio $PDR_{S:path}$ based on number of packets accepted and number of packet launched by the selected shortest path, fig A.3 shows the result.

$$PDR_{S:path} = \frac{NPA_{S:path}}{NPL_{S:path}}$$

Fig A.3 Packet Delivery Ratio
The result shows that the packet deliver ratio depends upon the number of nodes, our proposed BRSR_AOMDV is compared with AODV and increase the packet deliver ratio up to 30% because of LQ\textsubscript{path}.

### 4.3.2 Throughput

Generally AOMDV achieves low throughput, but our proposed BRSR-AOMDV achieves better throughput up to 50% compare to AODV because of LQ\textsubscript{path} and RE\textsubscript{pointer}, the evaluation of throughput based on packet delivery ratio and simulation time, the result showed in fig.A.4.

\[
\text{Throughput} = \frac{\text{Packet Delivery Ratio}}{\text{Simulation Time}} \quad (10)
\]

![Fig A.4 Throughput](image)

### 4.3.3 Average End-to-End Delay

The result for average end-to-end delay of our proposed approach was compared with AOMDV based on nodes maximum speed. BRSR-AOMDV achieves less average end to end packet delivery delay than AODV. The equation 11 Avg\textsubscript{ee\_delay} represent average end to end delay it considers the difference between arrival time AR\textsubscript{time} and start time ST\textsubscript{time} and depends on number of nodes N\textsubscript{node}. BRSR-AOMDV achieves less delay due to LQ\textsubscript{path}, RE\textsubscript{pointer}, and INR.

\[
\text{Avg}_{ee\_delay} = \frac{\sum \text{AR}_{time} - \text{ST}_{time}}{\sum N_{node}} \quad (11)
\]

![Fig A.5 Average End-to-End Delay](image)

### Packet Loss Rate

Our proposed mechanism reduce the packet loss rate P\textsubscript{lr} up to 80% compare to AODV. To evaluate packet loss rate (P\textsubscript{lr}), difference between number packet launched and number of packet accepted.

\[
P_{lr} = npl - npa \quad (12)
\]

![Fig A.6 Packet Loss Rate](image)

### CONCLUSION

In this paper we proposed a new Balanced Reliable Shortest Routing (BRSR) in AOMDV with Three way Filter (TF) mechanisms to deal with fault tolerance and load balancing. The result show BRSR-AOMDV performs much better in terms of high packet delivery ratio, average end-to-end delay, throughput, reduces the packet loss rate and energy when compared to AODV. We assumed a predefined threshold value for interference and energy. Our proposed algorithm chooses reliable shortest route based on minimum hop count path and in addition it chooses the reliable route based on link quality, interference and energy.

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### REFERENCES


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