# Mitigating QoS Routing Challenges In Mobile Ad Hoc Networks Considering Lifetime And Energy Predictions With Traffic Distribution

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***Abstract***- **Mobile Ad hoc Networks are highly dynamic networks. Quality of Service (QoS) routing in such networks is usually limited by the network breakage due to either node mobility or energy depletion of the mobile nodes. To fulfill certain quality parameters, and to achieve network stability, presence of multiple node-disjoint paths becomes essential. Such paths aid in the optimal traffic distribution and reliability in case of path breakages. To maintain such stability requires that links. To cater such problem, we present a node-disjoint multipath protocol. The metric used to select the paths takes into account the stability of the nodes and the corresponding links, calculated through their position and the energy drain rate. Optimal paths are also selected and the load is distributed proportionally to avoid overburden on the nodes .The proposed technique is also illustrated with an example and compared with another similar protocol ENDMR using ns-2.**

Keywords-QoS Routing; Mobile Ad hoc Network; Energy-Aware Routing; Multipath Rrouting, Node-disjoint Routing

## I. Introduction

A Mobile Ad Hoc Network (MANETs) [1, 2] is collection of mobile/semi mobile nodes with no existing pre-established infrastructure, forming a temporary network. Such networks are characterized by: Dynamic topologies, existence of bandwidth constrained and variable capacity links, energy constrained operations and are highly prone to security threats. Due to all these features routing is a major issue in ad hoc networks. The traditional routing protocols for ad hoc networks, classified as Proactive/table driven e.g. Destination Sequenced Distance Vector (DSDV) [3], Optimized Link State Routing (OLSR)[4], Reactive/On-demand, e.g. Dynamic Source Routing Protocol (DSR) [5] , Ad hoc On-Demand Distance Vector routing protocol (AODV) [6], Temporally Ordered Routing Algorithm (TORA)[4] and Hybrid, e.g. Zone Routing Protocol (ZRP) [7], Hybrid Ad hoc Routing Protocol (HARP) [23], attempt to provide only best effort delivery. Their target is limited to finding the minimum hops or the shortest paths.

Quality of Service (QoS) based routing is defined in RFC QoS

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2386 [8] as a "Routing mechanism under which paths for The main objectives of QoS based routing are[8]:Dynamic determination of feasible paths for accommodating the of the given flow under policy constraints such as path cost, provider selection etc, optimal utilization of resources for improving total network throughput and graceful performance degradation during overload conditions giving better throughput. QoS routing strategies are classified as source routing, distributed routing and hierarchical routing [9]. QoS based routing becomes challenging in MANETs, as nodes should keep an up-to-date information about link status. Also, due to the dynamic nature of MANETs, maintaining the precise link state information is very difficult. Finally, the reserved resource may not be guaranteed because of the mobility-caused path breakage or power depletion of the mobile hosts. QoS routing should rapidly find a feasible new route to recover the service. Our motive in this paper is to design a routing technique, which considers all three above problems together. We define a metric that attempts to maintain a balance between mobility and energy constraints in MANETs. We use Dynamic Source Routing (DSR) [5], as the base protocol to design our model. The designed technique is compare to a similar protocol Energy Aware node Disjoint Routing (ENDMR) [17] using ns-2 simulator.

## II. Related Works

In the recent period lot of research has been done in QOS based, multi-path and node disjoint routing. Lately, the upcoming concern is the energy issues in mobile ad hoc networks (MANETs) The recent studies extensively focused on the multipath discovering extension of the on- demand routing protocols in order to alleviate single-path problems like AODV[6 ] and DSR[5], such as high route discovery latency, frequent route discovery attempts and possible improvement of data transfer throughput. The AODVM (AODV Multipath) AOMDV [10] , is a multipath extension to AODV. These provide link-disjoint and loop free paths in AODV. Cross-layered multipath AODV (CM-AODV) [11], selects multiple routes on demand based on the signal-to-interference plus noise ratio (SINR) measured at the physical layer. The Multipath Source Routing (MSR) protocol [12] is a multipath extension to DSR uses weighted round robin packet distribution to improve the delay and throughput. (Split Multipath Routing) [13] is another DSR extensions, which selects hop count limited and maximally disjoint multiple routes. Node-Disjoint Multipath Routing (NDMR) [14], provides with node-disjoint multiple paths.

Other energy aware multipath protocols which give disjoint paths are Grid-based Energy Aware Node-Disjoint Multipath Routing Algorithm GEANDMRA) [15], Energy Aware Source Routing (EASR) [I6] and Energy Aware Node Disjoint multipath Routing (ENDMR)[I7]. The Lifetime-Aware Multipath Optimized Routing (LAMOR)[18] is based on the lifetime of a node which is related to its residual energy and current traffic conditions. Cost- effective Lifetime Prediction based Routing (CLPR) [19], combines cost efficient and lifetime predictions based routing. Minimum Transmission Power Routing (MTPR) [20], Power-aware Source Routing (PSR)[21].

2.1 Dynamic Source Routing Protocol (DSR)

The Dynamic Source Routing (DSR) [5] is a reactive unicast routing protocol that utilizes source routing algorithm. In source routing algorithm, each data packet contains complete routing information to reach its destination. In DSR each node also maintains route cache to maintain route information that it has learnt.

There are two major phases in DSR [5], the route discovery phase and the route maintenance phase. When a source node wants to send a packet, it firstly checks its route cache. If the required route is available, the source node includes the routing information inside the data packet before sending it. Otherwise, the source node initiates a route discovery operation by broadcasting route request packets. A route request packet contains addresses of both the source and the destination and a unique number to identify the request. Receiving a route request packet, a node checks its route cache. If the node doesn't have routing information for the requested destination, it appends its own address to the route record field of the route request packet. Then, the request packet is forwarded to its neighbors.

To limit the communication overhead of route request packets, a node processes route request packets that both it has not seen before and its address is not presented in the route record field. If the route request packet reaches the destination or an intermediate node has routing information to the destination, a route reply packet is generated. When the route reply packet is generated by the destination, it comprises addresses of nodes that have been traversed by the route request packet. Otherwise, the route reply packet comprises the addresses of nodes the route request packet has traversed concatenated with the route in the intermediate node's route cache.

## III. Problem Issue

Nodes in Mobile Ad hoc Networks (MANETs) [1, 2] are battery driven. Thus, they suffer from limited energy level problems. Also the nodes in the network are moving, if a node moves out of the radio range of the other node, the link between them is broken. .Thus, in such an environment there are two major reasons of a link breakage:

a) Node dying of energy exhaustion

b) Node moving out of the radio range of its neighboring node

Hence, to achieve the route stability in MANETs, both link stability and node stability is essential.

The above mentioned techniques consider either of the two issues. Techniques in [19, 10, 13, and 20] calculate only multiple paths. Both stability issues are neglected in these. The work in [11] measures route quality in terms of SINR, which gives reliable links, but overall networks stability is not considered. Though [19] uses lifetime of a node as a generalized metric, it does not considers the mobility and energy issues which are critical to network - lifetime estimation. The protocol in [17] considers the energy issues in terms of the energy expenditure in data transmission, but the lifetime of the node and mobility factor is not discussed [7, 15, 16, 21] consider only energy metric to route the traffic.

Also, to send a packet from a source to destination many routes are possible. These routes can be either link disjoint or node-disjoint. Node disjoint protocols have an advantage that they prevent the fast energy drainage of a node which is the member of multiple link disjoint paths [14]. Hence, a technique which finds multiple node-disjoint paths considering both link and node stability has been proposed. The attempt is to find multiple node disjoint routes which consider both link stability and the node stability on their way.

## IV. Metrics Used

To measure link and node stability together we are using two metrics, Link Expiration Time (LET) [19] and Energy Drain Rate (EDR) [22] respectively. These two metrics can be used to generate a composite metric which keeps track of the stability level of the entire path. .

Mobility Factor: The mobility factor Link Expiration Time (LET) was proposed in [19], by using the motion parameters (velocity, direction) of the nodes. It says that if r is the transmission distance between the two nodes, i and j, (xi, yi) and (xj, yj) be the position co-ordinates and (vi, θi) and (vj, θj) be the (velocity, direction) of motion of nodes. LET is defined as:

$$LET=-(ab+cd) +Q/(a^2+c^2) \qquad (1)$$

Where, $Q= \sqrt{\{(a^2+c^2) r^2- (ad- bc)^2\}}$ and,

$a= v_i \cos\theta i - v_j \cos\theta_j$, $b= x_i-x_j$, $c= v_i \sin\theta i - vj \sin\theta_j$ and $d= y_i - y_j$

The motion parameters are exchanged among nodes at regular time intervals through GPS. .The above parameter suggests that if the two nodes have zero relative velocity, i,e, vi =vj and θj = θj, the link will remain forever, as, LET will be ∞.

Energy factor: Most of the energy based routing algorithms [10, 17, and 21], send large volume of data on the route with maximum energy levels, As a result, nodes with much higher current energy levels will be depleted of their battery power very early. The mobile node also loses some of it energy due to overhearing of the neighboring nodes. Thus, a node is losing its power over a period of time even if no data is being sent through it. Viewing all these factors a metric called Drain Rate (DR) was proposed in [22], Drain Rate of a node is defined as the rate of dissipation of energy of a node. Every node calculates its total energy consumption every T sec and estimates the DR, Actual Drain Rate is calculates by exponentially averaging the values of $DR_{old}$. and $DR_{new}$ as follows:

$$DRi=\alpha DR_{old}+ (1-\alpha)\, DR_{new} \quad (2)$$

Where, 0< α <l, can be selected so as to give higher priority to updated information. Thus, higher the Drain Rate, faster the node is depleted of its energy.

## V PROPOSED WORK: NODE DISJOINT MULTIPATH ROUTING CONSIDERING LINK AND NODE STABILITY (NDMLNR)

The main aim of the proposed work is to find the multiple node disjoint routes from source to a given destination. The routes selected are such that all the links of the routes are highly stable. This will increase the lifetime of the route. Also it keeps track of the route bandwidth which can be further used by the source to select the optimal routes. From the factors Link Expiration Time (LET) [19] and Drain Rate (DR) [22] it is inferred that the Link Stability:

a) Depends directly on Mobility factor

b) Depends inversely on the energy factor

Hence, Link Stability Degree (LSD) is defined as:

LSD = Mobility factor / Energy factor (3)

It defines the degree of the stability of the link. Higher the value of LSD, higher is the stability of the link and greater is the duration of its existence. Thus, a route having all the links with LSD> $LSD_{thr}$ is the feasible route.

We choose the Dynamic Source Routing (DSR) [5] protocol as a candidate protocol, details of which are given in section 2. Modifications are made to the Route Request (RREQ) and Route Reply (RREP) packets to enable the discovery of link stable node disjoint paths. The proposed scheme has three phases:

I. Route Discovery

2. Route Selection

3. Route Maintenance

The various phases are described as follows:

### *A Route Discovery*

The source node when needs to send packet to some destination node, starts the route discovery procedure by sending the Route Request packet to all its neighbors .In this strategy , the source is not allowed to maintain route cache for a long time, as network conditions change very frequently in terms of position and energy levels of the nodes. Thus, when a nodes needs route to the destination, it initiates a Route Request packet, which is broadcasted to all the neighbors which satisfy the broadcasting condition.

The Route Request(RREQ) packet of the DSR [5] is extended as RREQ of the NDMLNR adding two extra fields, LSD and Bandwidth, B as shown in figure I. RREQ contains type field, source address field, destination field, unique identification number field, hop field, LSD, Bandwidth (cumulative bandwidth), Time -to-Live field and path field.

Type (T) field: It indicates the type of packet, SA (Source Address) field: It carries the source address of node. ID field: unique identification number generated by source to identify the packet. DA (Destination Address) field: It carries the destination address of node. Time to Live (TTL) field: It is used to limit the life time of packet, initially, by default it contains zero. Hop field: It carries the hop count; the value of hop count is incremented by one for each node through which packet passes. Initially, by default this field contains zero value. LSD field: when packet passes through a node, its LSD value with the node from which it has received this packet is updated in the LSD field. Initially, by default this field contains zero value. Bandwidth field carries the cumulative bandwidth of the links through which it passes; initially, by default this field contains zero value. Path field: It carries the path accumulations, when packet passes through a node; its address is appended at end of this field. The figure I. shows the RREQ packet.

| SA | DA | Type | ID | TTL | Hops | Bandwidth | LSD | Path |
|---|---|---|---|---|---|---|---|---|

Fig 1 RREQ packet

The Route Reply packet (RREP) of the DSR [5] is extended as RREP of the NDMLNR adding Bandwidth field. It is sent by the destination node after selecting the node disjoint paths among the various RREQ packets reaching it.

In DSR [5], when an intermediate node receives a RREQ packet, it checks whether its own address is already listed in the path list of received RREQ packet. If its address is not found, it appends its address to the route record of received RREQ and it is broadcasted to all its neighbors. Otherwise, the received RREQ packet will be dropped.

In the NDMLNR when an intermediate node receives a RREQ packet, it performs the following tasks:

I. Checks whether its own address is already listed in the route record of received RREQ packet. If its address is not found, it appends its address to the path list.

2. When an intermediate node receives a RREQ for the first time, it introduces a Wait Period, W. for the subsequent packets if any, with same identification number, traveling through different paths. It updates the value of LSD corresponding to the link on which it received the RREQ packet in the LSD field. It then checks its neighbors for QoS parameters, bandwidth here. Only those neighbors having LSD> $LSD_{thr}$ and Link Bandwidth >= B are considered for broadcasting. Once the neighbors with required LSD are selected, node forwards packet. Later if an intermediate node receives duplicate RREQ packets with same (Source address and ID), as received from other paths, those duplicate RREQ packets will be dropped.

3. Every node maintains a Neighbor Information Table (NIT), to keep track of multiple RREQs. With following entries Source Address, Destination Address, Hops, LSD, ID and bandwidth.

| SA | DA | ID | Hops | LSD | Bandwidth |
|---|---|---|---|---|---|

Fig 2. Neighbor Information Table (NIT)As a RREQ reaches a node it enters its information in the NIT. It makes all the entries for the requests till Wait Period. At the end of

the Wait Period, it accepts the request with the highest value in LSD field. It adds the value of the link bandwidth to the Bandwidth field of the RREQ packet. If two RREQs have same LSD values, the one with lesser value of hop count isselected. In case, hops are also same, one with higher bandwidth is selected. In the worst case, RREQ is selected on First-come-first -serve basis. This prevents loops and unnecessary flooding of RREQ packets.

4. None of the intermediate nodes is allowed to send RREP if it has the current route to the destination. As doing this may lead to those paths which do not fulfill current QoS requirements.

In the NDMLNR, when the destination receives multiple RREQs it selects the paths with disjoint nodes. It then generates several replies and unicasts them to the source. Before that it appends its address and adds total bandwidth to each route request. Now each route reply that reaches the source contains a node-disjoint path from source to destination. Hence, source knows all the paths to the destination and their respective bandwidths. In case of two paths with one or more nodes common, the path with higher bandwidth is selected.

### *B. Route Selection*

When the source node receives the RREPs from the multiple paths, it sorts the paths in the order of the increasing bandwidth. Depending on the bandwidth the source decides to use the single path, or all of the paths. In case of the multiple paths with same bandwidths, path with minimum number of hops is selected. If the paths conflict on the number of hops, the source node selects the path on First-come-First-Serve basis.

### *C. Route Maintenance*

In case, LSD of a node falls below $LSD_{thr}$, it informs its predecessor node of the node failure by sending the NODEOFF message. Once a node receives such a message, it sends the ROUTEDISABLE message to the source node. Source can then reroute the packets to the backup routes. If no backup route exists, the source then starts the route discovery procedure again. We explain this technique with a suitable example in section 7.

## VI. Traffic Distribution

The above discussed technique may result in many paths from a given source to a destination. To achieve fairness in traffic allocation based on energy and stability constraints, there is a need to select few optimal paths and divide traffic over them. To select optimal paths, we use Average Bandwidth of all the paths as the deciding factor. Let B1, B2, B3 ….Bn be the bandwidths of n disjoint paths. Thus, average bandwidth, $B_{avg}$, will be:

$$(B1 + B2 + B3 \ldots + Bn) / n \quad (4)$$

The optimal paths are only those paths which have their respective bandwidths equal to or greater than Bavg. Through this, we attempt to achieve the stable and long lasting paths. Also, the paths are given load based on their capacity.

To divide the traffic among these optimal paths we use proportional distribution. If suppose, $B_1$, $B_2$ and $B_3$ are the bandwidths of the three selected optimal paths. Then $B_1$ gets $B_1/(B_1+B_2+B_3)$ percent of the total traffic, $B_2$ gets $B_2/(B_1+B_2+B_3)$ percent of the traffic and, so on .

For example, let there be three paths $P_1$, $P_2$ and $P_3$ with total bandwidths 20, 10, 15 Mbps respectively. Their Average bandwidth, $B_{avg}$ , according to equation (4) is 15 Mbps. Thus, only paths $P_1$ and $P_3$ are optimal paths.

To distribute the traffic on these paths, $P_1$ gets 20/(20+15) = 57% of the traffic and $P_3$ gets 15/(20+15) = 43% of the traffic.

## VII. Example

Let us illustrate our technique with the following example network shown in figure 3. Suppose node 1 is the source node and node 6 is the destination. Let LSDthr equals to 15. Let B equals to 5 mbps.

To send the packet, node 1 checks its neighbors (2.4.7) for their LSD value Out of these node 7 has value 9<15. So, node 1 sends the packets only to nodes 2 and 4.

Node 2 receives this packet for the first time, makes entry in its NIT for the RREQ packet as (1, 6, 1, 1, 20, 8) and starts Wait Time, 5 secs here. Node 2 now checks its neighbors, updates the path field as,1-2 and the bandwidth field to 8 and forwards RREQ to both 4 and 3. At node 4, it may receive two RREQ packets during Wait Time. One from node 1 directly, and, the other via node 2. It has two entries in its NIT (1,6,1,1.20,8) and (1,6,1,2,17,13). At this moment it selects the one from node 1 with higher LSD value, 20. It updates the path field of the RREQ packet as 1-4 and the bandwidth field to 7. It forwards the packet to both its neighbors, 5 and 8, with LSD values 16 and 18 respectively. Node 3 has only one neighbor, 6 which satisfies the LSD value and hence, it updates RREQ path field as 1-2-3 and the bandwidth field to 14 and forwards the packet to node 6. Node 6 now receives a path from source node 1. It appends its own ID to it. Thus, first path is 1-2-3-6 and bandwidth of this path is 17. Node 5 after receiving the RREQ packet with path 1-4, checks for its neighbors and forwards RREQ with updated path field to 1-4-5 and bandwidth field to14 to nodes 9 and 6 Node 6 now receives another path,1-4-5.It appends its ID to it, to get the path, 1-4-5-6 with bandwidth 19. Node 8 after receiving the RREQ packet forwards it to its neighbor, 9, after updating path field to 1-4-8 and bandwidth field to 15 Node 9 can receive two packets in its wait time, one from node 5 and the other from node 8. It updates its NIT as (1,6,1,3,16,22) and (1,6,1,3,18,21). To select from the one, it chooses one from node 8 as its LSD value is higher, 18. It then forwards the request after updating the path field as 1-4-8-9 and bandwidth field to 21. Node 6 again receives another path 1-4-8-9.It appends its ID to this path to get 1-4-8-9-6 with bandwidth 28.Now node 6 receives two paths 1-4-5-6 and 1-4-8-9-6 with node 4 as common node. It selects the one with higher bandwidth i.e. Path, 1-4-8-9-6 with bandwidth 28.

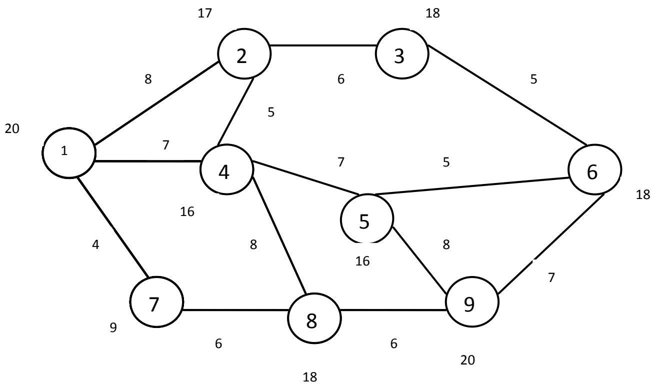


Fig 3. An example network.

## VIII. Experimental Evaluation

simulate Node Disjoint Multipath Routing Considering Link And Node Stability (NDMLNR). We compare our NDMLNR protocol with the Energy Aware Node Disjoint Multi path Routing (ENDMR)[17] protocol In our simulation the channel capacity of mobile hosts is set to the same value: 11 Mbps. We use the distributed coordination function (DCF) of IEEE 802.11 for wireless LANs as the MAC layer protocol. It has the functionality to notify the network layer about link breakage. Mobile nodes move in a 1500 meter x 300 meter rectangular region for 100 seconds simulation time. We assume each node moves independently with the same average speed. All nodes have the same transmission range of 250 meters. In our simulation, the speed is set as 10m/s. The simulated traffic is Constant Bit Rate (CBR). The number of mobile nodes is varied as 10, 20,….50 and the pause time of the mobile node is varied as 10,20,30,40 and 50 seconds. Table 1. summarizes various simulation parameters.

Both NDMLNR and ENDMR use energy awareness; generate multiple paths that are node disjoint paths. The NDLMNR adds to the stability of ENDMR by considering the stability of the nodes and the links containing those nodes. The ENDMR protocol balances node energy utilization to increase the network lifetime. It takes network congestion into account to reduce the routing delay and increases the reliability of the packets reaching the destination.

The performance of the two protocols is compared using following metrics: Average Packet Delivery Ratio, throughput and average energy of the nodes.

In simulation we increase the number of nodes as 10, 20, 30….50.We study the performance of our protocol under this scenario. The graphs show the results for various metrics. Thus, the scenario presents the performance of the protocols under varying density of nodes

| | |
|---|---|
| No. of Nodes | 10,20,30,..50 |
| Area Size | 1500 X 300 |
| Mac | 802.11 |
| Radio Range | 250m |
| Simulation Time | 100 sec |
| Traffic Source | CBR |
| Packet Size | 512 |
| Mobility Model | Random Way Point |
| Speed | 10m/s |
| Pause time | 10,20,30,….50 |
| Initial energy | 5.1 J |
| Sending power | 0.660 |
| Receiving power | 0.395 |
| Idle Power | 0.035 |

Table 1 Simulation parameters

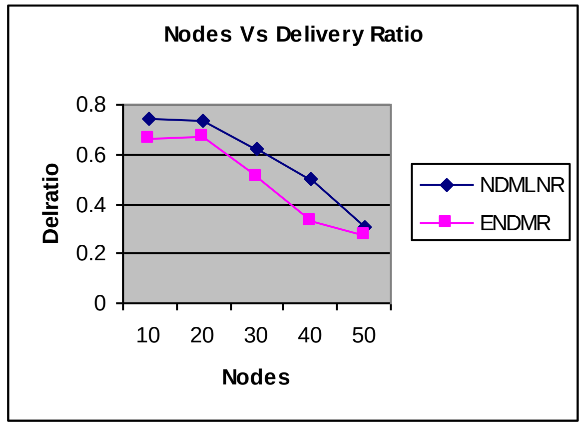


Fig 4. Nodes vs Delivery Ratio

The results from figure 4 show that considering the combined effect of energy and mobility factors, NDLMNR gives higher average packet delivery ration than ENDMR. Through this, it can be inferred that the paths found by NDLMNR are stable and have higher network lifetime as compared to ENDMR. ENDMR considers paths with nodes having the highest reaidual energy. In case, few nodes are not capable to comply with the needs and lifetime of traffic, they will die soon and hence, lower delivery ratio. Proportional distribution of load on the paths also leads to higher average delivery ratio.

The throughput of NDLMNR is higher as compared to ENDMR, as inferred from figure 5. This shows that selecting the paths considering the drain rate of nodes as energy parameter is more efficient than the residual energy of the nodes. Also, the higher throughput also accounts from the balanced traffic distribution on the node disjoint paths. The stability of both the nodes, from the drain rate and links, from link expiration time, results in the overall highly stable network and hence, higher throughput.

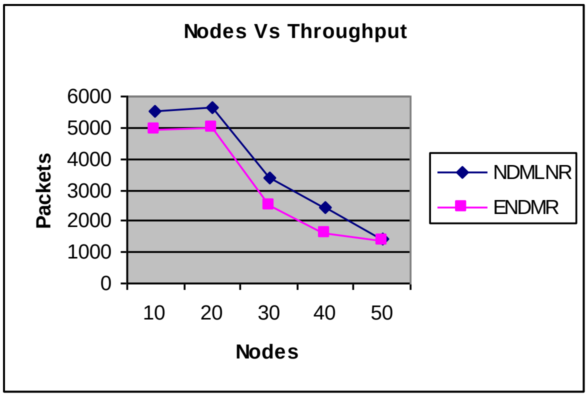


Fig5. Nodes vs Throughput

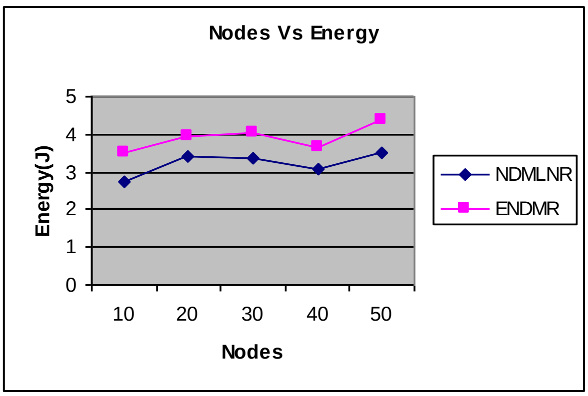


Fig 6. Nodes vs Energy consumed

The results in figure 6 clearly depict that the energy consumed by the nodes is lesser in NDLMNR as compared to ENDMR. This may be due to the selection of the nodes having higher stability and efficient distribution of traffic along the paths.Higher the stable nodes, higher is the path stability. High stability of the paths leads to lesser control packets needed for path maintenance and lesser energy consumption

## IX Conclusion

The above mentioned technique considers the stability of the network from all aspects. The lifetime of the network can be reduced primarily by two causes. First, the node moving out of the radio range can lead to link breakage. Second, the node can be drained of its energy leading to network partitioning. The metric used in the proposed technique measures the stability of the network based on these two factors. The routing decisions at each node leads to the multiple paths, which are node disjoint. Doing this we attempt to prevent over usage of a single path nodes of which may drain out soon. Thus, this technique provides highly stable, reliable, robust node disjoint paths. As the paths are node disjoint, energy drain rate of the nodes is be less and hence longer lifetime. Also the paths are selected on the bandwidth constraints; they are the ones with higher capacity. The selected paths with higher bandwidth are further refined to select optimal paths having bandwidth higher than a threshold. This attempts to achieve stable and high capacity paths. The balancing of load on multiple paths also enhances the stability and lifetime of the networks and hence, higher throughput.Thus in this technique, as the routes are selected completely satisfying stability and capacity constraints, it fully complies with Quality of Service objectives.

## X. References

1) D. Perkins, H. D. Hughes & C. B. Owen, (2002) “Factors Affecting the Performance of Ad Hoc Networks,” Proceedings of the IEEE International Conference on Communications (ICC), 2002, pp.2048-2052.
2) Imrich Chlamtac, Marco Conti, Jennifer J.-N. Liu, (2003)"Mobile Ad hoc networking imperatives and challenges" Ad Hoc Networks, Vol 1, pp.13-64.
3) C.E. Perkins & P. Bhagwat (1994)" Highly Dynamic Destination-Sequenced Distance Vector Routing (DSDV) for Mobile Computers", ACM SIGCOMM Conference on Communications Architectures, Protocols and Applications, Vol. 24, pp. 234-244.
4) M. Abolhasan, T.A. Wysocki, & E. Dutkiewicz, (2004) "A Review of Routing Protocols for Mobile Ad hoc Networks", Ad hoc Networks, Vol. 2, pp. 1-22.
5) David B. Johnson, David A. Maltz, & Josh Broch, "DSR: The Dynamic Source Routing Protocol for Multi-Hop Wireless Ad Hoc Networks", (2001), Ad Hoc Networking, Addison-Wesley , pp. 139-172.
6) C. E. Perkins & E. M. Royer,(2003) "Ad hoc On-Demand Distance Vector Routing (AODV) ", IETF RFC 3561
7) .Z. Hass & R. Pearlmann, "Zone routing Protocol"(1999),IETF Internet DraftRFC2386.
8) Shigang Chen & Klara Nahrstedt, (1998) ".An Overview of Quality-of-Service Routing for the next Generation High -Speed Networks: Problems and Solutions", IEEE Network Magazine, vol12, pp. 64 -79.
9) M. K. Marina & S. R. Das, (2001) "On-Demand MultiPath Distance Vector Routing in Ad hoc Networks",Proceedings of the Ninth International Conference on Network Protocols (ICNP},IEEE Computer Society Press, pp. 14-23.
10) Jiwon Park, Sangman Moht & Ilyong Chung (2008),” Multipath AODV Routing Protocol in Mobile Ad Hoc Networks with SINR-Based Route Selection”, International Symposium on Wireless Communication Systems, IEEE ,pp:682-688.
11) Lei Wang, Lianfang Zhang, Yantai Shu & Miao Dong (2000) ,” Multipath source routing in wireless ad hoc networks”, Proceedings of Canadian Conference on Electrical and Computer Engineering, Vol 1, pp. 479-483.
12) S. J. Lee and M. Gerla (2001) "Split Multipath Routing with Maximally Disjoint Paths in Ad hoc

Networks",Proceedings of the IEEE International Conference on Communications(ICC), Vol 10, pp. 3201-3205.
13) X.Li,(2006), Ph.D thesis on "Multipath Routing and QoS Provisioning in Mobile Ad hoc Networks", Queen Mary University of London.
14) Zhengyu W, Xiangjun D & Lin C,(2007), " A Grid-Based Energy Aware Node-Disjoint Multipath Routing Algorithm for MANETs", Proceedings of International Conference on Natural Computation, Vol. 5, pp. 244-248.
15) Do-Youn H, Eui-Hyeok K & Jae-Sung L, (2006)," An Energy Aware Source Routing with Disjoint Multipath Selection for Energy- Efficient Multihop Wireless Ad hoc Networks", Proceedings of International Federation for Information Processing, 2006, pp. 41-50.
16) M. Bheemalingaiah, M. M. Naidu, D. Sreenivasa Rao & G. Varaprasad (2009)," Energy Aware Node-Disjoint Routing in Mobile Ad Hoc Networks", Journal of Theoretical and Applied Information Technology, pp 416-431.
17) Liansheng T, Ling X, King T. K, M. Lei & Zukennan,(2006), "LAMOR: Lifetime-Aware Multipath Optimized Routing Algorithm for Video Transmission over Ad hoc Networks", Proceedings of IEEE Vehicular Technology Conference, Vol. 2, pp. 623-627.
18) W.Su,Sung-Ju Lee & M.Gerla (2000)," Mobility Prediction in Wireless Networks".,MILCOM 2000, Vol l, pp.491-495.
19) M. K. Marina & S. R. Das,(2001), "On-Demand MultiPath Distance Vector Routing in Ad hoc Networks", In Proceedings of the Ninth International Conference on Network Protocols (ICNP}, IEEE Computer Society Press, pp. 14-23.
20) M. Maleki, K. Dantu & M. Pedram, (2002) "Power-aware source routing protocol for mobile ad hoc networks", Proceedings of the IEEE international symposium on low power electronics and design, pp.72-75.
21) D.Kim, Garcia-Luna-Aceves, J.J. Obraczka, K. Cano & J.-C. Manzoni, P.(2003)"Routing mechanisms for Mobile Ad hoc Networks Based on Energy Drain Rate", Mobile Computing, Vo12, page(s): 161- 173.
22) Navid Nikaein, Christian Bonnet and Neda Nikaein," HARP - Hybrid Ad Hoc Routing Protocol" (2001), In proceeding of IST 2001: International Symposium on Telecommunications.