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MULTI-OBJECTIVE CROSS-LAYER BASED MULTIPATH ROUTING PROTOCOL IN MANET

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ABSTRACT

Mobile Ad Hoc Networks (MANETs) have unique challenges in the routing protocols like selecting a high energy efficient route to transmit the data packets between the nodes. To overcome these challenges in the paper we have proposed an approach Multi-Objective Cross-layer based Multipath Routing in MANET. In this approach the routes for the transmission of data packets are selected using hybrid routing. Also a cross-layer metric is been derived based on the Expected Transmission Time (ETT), Residual Energy and Load Balancing Factor. This cross-layer metric is combined with the hybrid routing protocol in order to find an optimum route based on the cross-layer metric.

Keywords: *MANETs, Hybrid Routing, Expected Transmission Time, Residual Energy and Load Balancing Factor.*

1. INTRODUCTION

1.1. MANET

MANET stands for "Mobile Ad Hoc Networks". These are wireless networks that consist of mobile nodes with no fixed infrastructure, where some intermediate node participates in forwarding data packets. [1].The main objective of mobile technologies is staying connected anywhere to a network. With the help of MANET all nodes and routers forward the packets without any infrastructure. It is a kind of spontaneous, self-organized and self-maintained network. [2].In this kind of network routing of data is big challenge as it requires many issues to be covered like scalability, security, and lifetime of network, wireless transmissions and increasing needs of applications. [2].The main problem in MANET arises due to the mobility such as high data delay and low packet delivery ratio and hence in order to achieve high stability and reliability in routing the node mobility has to be considered. [3].It can also be defined as an autonomous system of mobile routers and associated hosts connected by wireless links-the union of which forms an arbitrary graph. [4].Due to the limitation in transmission range the nodes in the network acts a router to forward packets to the other nodes and hence the need for suitable routing protocol is found. [4].

1.2 . Routing in MANET

Routing is one of the key issues in MANETs because of highly dynamic and distributed nature of nodes. [5].

The routing protocols of MANETs are divided into two categories that are as follows:

- Table-driven Routing protocol: In this protocol each node attempts to maintain the consistent, up-to-date routing information to every other node in the network. E.g.: Destination-Sequenced Distance Vector (DSDV) and Fisheye State Routing (FSR) belongs to this category.
- On-demand Routing Protocol: In these types of routing protocol, routes are created when it is required. Route discovery and route maintenance are the two main procedure involved in these type of routing protocol. E.g.: Dynamic Source Routing (DSR) and Ad-Hoc On-Demand Distance Vector (AODV) are popular on-demand routing protocols.[5]

  Some of the important properties that need to be considered while proposing an ideal routing protocol for MANET are as follows:
- A routing protocol for MANET should be distributed in such a manner to increase reliability for data transmission.
- It must be designed by considering unidirectional links as wireless medium may cause a wireless link to be opened in uni direction only due to physical factors.

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- It should be power-efficient.
- It should provide security in the network.
- A hybrid routing protocol should be much more reactive than proactive to avoid overhead.
- It should be aware of Quality of Service (QoS). [6].

1.2.1. Multipath Routing in MANET

Multipath routing provides multiple paths for the nodes in MANET. The multipath routing protocols discover proactively several alternatives routes and hence it is more efficient routing protocol where route failure events are more frequent. [8].The three components of multipath routing are route discovery, route maintenance and traffic allocation. [9]

The main challenges to create an appropriate routing protocol for MANETs is due to following characteristics of MANET:

- Autonomous and infrastructure less: As MANET does not contain the established infrastructure or the centralize administrator each node act as independent router and communicates with the other one under peer to peer communication under the distributed environment.
- Link Variation: In MANET each node is provided with one or more stations that vary with transmission/ receiving capabilities and is operated with different frequency bands that result in discontinuities or asymmetric links.
- Node Processing Capability: In MANET, each node is configured with different types of software and hardware that results as variation in processing capability of the concern node.
- Energy constrained operation: In MANET each node battery carries limited power supply and limited processing capabilities that in turns limits services and application.
- Scalability of MANET: Scalability for successful deployment of such large mobile adhoc network is critical and tough.
- Dynamic network topologies: As each node can move arbitrarily in MANET that results in frequent changes in the network. [10].

1.2.2. Issues in Multipath Routing in MANET

Some of the issues in creating multipath routing due to above mentioned characteristic of MANET can be stated as follows:

- Transmission errors: The unreliability of the wireless medium and the unpredictability of the environment may lead to transmitted packets being garbled and thus received in error.
- Link failures: Node failures as well as changing environmental conditions (e.g., increased levels of EMI (Electro-Magnetic Interference)) may cause links between nodes to break.
- Route breakages: When the network topology changes due to node/link failures and/or node/link additions to the network, routes become out-of date and thus incorrect.
- Congested nodes or links: Due to the topology of the network and the nature of the routing protocol, certain nodes or links may become over utilized, i.e., congested.

1.3. Cross Layer Based Routing

The traditional network protocol was based on the OSI 7 layer model that restricts the information exchanged between layers and hence efficient protocol design in MANET is not done.

The drawback of the traditional design model is that it is unable to retrieve energy and location information from the underlying data link layer and physical layer and hence it is unable to calculate good routes based on such information. [5].

Importance of Cross layer routing in MANET can be stated as follows:

- A cross-layer based routing protocol makes use of link quality information available at MAC/PHY layer directly or indirectly to make routing decision to avoid any kind of disruption at the time of data transfer in the network. [12].
- The cross layer approach enables congestion control mechanism in order to determine the cause of packet losses. [13]
- The routing protocol makes use of cross layer design in order to determine the available bandwidth in the network to increase the throughput. [11].
- It avoids use of stale route by the source by updating them with the availability of new routes through intermediate layers. [14].
- It applies energy management model and helps in improving overall network performance.

1.4 Objectives of Research

The main objective of this work is designing a cross-layer based multi path routing in MANET with the following features:

- Load balancing
- Reliability
- Energy Efficiency

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2. LITERATURE REVIEW

Jiazi YI et al in paper [2] have proposed the Multipath Optimized Link State Routing (MP-OLSR) protocol. The extension of the single path version includes a major modification of the Dijkstra algorithm (two cost functions are now used to produce multiple disjoint or non-disjoint paths), auxiliary functions, i.e. route recovery and loop detection to guarantee quality of service and a possible backward compatibility based on IP source routing. The MP-OLSR can effectively improve the performance of the network (especially in the scenarios with high mobility and heavy network load) and also be compatible with OLSR. The drawback of this paper is that they have not considered efficient utilization of bandwidth in the network.

Wenjing YANG et al in paper [11] have first analyzed the influence of the number of parallel paths on end-to-end throughput. It obtained that two parallel paths could significantly improve end-to-end throughput. Based on the analysis, this paper presented a bandwidth aware multi-path routing (BMR) protocol, in which path selection is based on path available bandwidth. BMR effectively improves end-to-end throughput through constructing multiple high-bandwidth paths between source and destination. Finally, the simulation experiments showed that BMR has a better performance in improving end-to-end throughput, packet delivery ratio, and end-to-end delay. The drawback of this paper is that the proposed method has not considered routing overhead in the network.

Xiaolong Li et al in paper [12] have proposed Hybrid Cross-Layer Routing (HCLR) protocol. They have demonstrated how HCLR can overcome the limitations of both proactive and reactive routing protocols in MANETs by combining their advantages. They have explained how HCLR generates the routing table globally but perform optimizations locally utilizing an on-demand approach. To the best of our knowledge, HCLR is the first work that takes advantage of Equal Cost Multi Path to perform cross-layer routing optimization in MANETs. They have also noted that HCLR can not only forward packets following a high link quality path, but also perform load balancing without being subject to out of order delivery problem by utilizing a 2-tuple metric. HCLR can achieve a significant performance improvement measured in terms of per flow throughput, average packet delay, and packet delivery ratio. The drawback of the proposed protocol is that it cannot guarantee that a packet can be transmitted immediately once it is delivered to MAC/PHY.

S.Venkatasubramanian et al in paper [15] have developed a cross layer based multipath routing (CBMR) protocol to improve QoS in mobile ad hoc networks to allot weights to individual links, depending on the metrics link quality, channel quality and end-to-end delay. In order to validate load balancing and interference between the links using the same channel, the individual link weights are integrated into a routing metric. Therefore, the weight value helps the routing protocol to avoid the routing traffic through the congested area hence the traffic is balanced and the network capacity is improved. Then the proportion of traffic to be routed to each neighbor is selected to execute routing such that the weight of the node is a minimum. They have also proposed an enhanced TCP congestion control mechanism for wireless networks, based on a cross-layer scheme. The drawback of this paper is that the proposed method has not considered the throughput metrics.

DuckSoo Shin et al in paper [16] have proposed an Adaptive Ad hoc On-demand Multipath Distance Vector Routing Protocol (A^2OMDV) routing protocol to resolve the problem through dynamic route switching method. Based on the delay of the multiple paths, a source node selects its route dynamically and checks the quality of the alternative routes according to the change of the ad hoc network. The results from their analysis and simulation show performance enhancements of the proposed scheme with respect to end-to-end delay and throughput. The drawback of this paper is that in the proposed method they have not considered the packet delivery ratio and overhead in the network.

David Espes et al in paper [17] have presented the importance of QoS routing in Ad hoc mobile networks. They have proposed a QoS routing protocol to be used in TDMA-based MANETs. Their protocol selects paths with a low impact on the network. Decreasing the impact (i.e. the amount of bandwidth consumed by admitted flows) of flows results in more accepted flows and/or more bandwidth used by established flows. To show the effectiveness of their protocol, they have compared it to the well-known QoS-AODV and AODV protocols. From a performance point of view, their protocol has less impact on the network than the other protocols. When the network load increases, their protocol provides a higher network

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throughput than other protocols. In such a case, more flows are admitted. The drawback of the proposed method is that they have not considered the delay in the metrics.

3. PROPOSED SOLUTION

3.1. Problem Definition

In [2], Multipath Optimized link state routing protocol (MP-OLSR) is proposed. They have modified Dijkstra algorithm that allows multiple paths both for sparse and dense topology. Two cost functions are used to generate node-disjoint or link-disjoint paths. The OLSR proactive behavior is changed for an on-demand computation to become a source routing protocol. To support the frequent topology changes of the network, auxiliary function like route recovery and loop check is implemented.

In MP-OLSR, the route computation method is not efficient as they have not considered about link reliability in the network. It does not propose any method for load balancing to avoid overhead in the network.

3.2 Research Methodology

In this paper, we propose to develop a Cross-Layer Based Hybrid Multipath routing protocol for MANET. In this protocol, the MP-OLSR is used to perform hybrid routing involving proactive and reactive routings. A cross-layer metric is derived based on the load factor of the link, Expected Transmission Time (ETT) [12] and Residual Energy. This cross-layer metric is integrated with the MP-OLSR routing protocol so that the optimum route is selected based on the metric. The load factor can be estimated from the MAC layer which is used for load-balancing and congestion avoidance. The ETT metric is derived from the packet loss rate which is obtained from MAC layer and used for reliable routing. The residual energy can be obtained from the physical layer which can be used for energy efficient routing.

3.3. Hybrid Routing

The topology sensing and route computation create it doable to search out multiple paths from source to destination. Within the specification of the rule, the methods are accessible and loop-free. Link sensing populates the native link info base (Link Set). It's solely involved with OLSR interface addresses and therefore the ability to exchange packets between such OLSR interfaces. Neighbor detection populates the neighborhood info base and considers itself with nodes and node main addresses. Each link sensing and neighbor detection square measure supported the periodic exchange of HELLO messages. Topology Discovery generates the data base that considers the nodes that are 2 hop nodes away. It supports the flooding of the TC messages. In OLSR, routes are generated by nodes when they receive a new topology management messages (TC or HELLO). The routes to all or any the potential destinations are saved within the routing table. For MP-OLSR, an on-demand scheme is employed to avoid the serious computation of multiple routes for each potential destination

3.3.1. Multipath Dijkstra Algorithm

For a source node s within the network, MP-OLSR can keep associate updated flag for each potential node within the network to spot the validity of the routes to the corresponding node. Initially, for each node i, the $updatedFlag_i$ is about to false, which suggests the route to the corresponding destination doesn't exist or must be revived. Once there is a route request to an exact node i, the source node can initially check the $updatedFlag_i$.

Input: MultiPath Dijkstra(s, d, G, N)
Output: Calculate paths in network from s to d
$c_1 \leftarrow c$
//c is the cost
$G_1 \leftarrow G$
For i ← 1 to N do
$s_i \leftarrow$ Dijkstra(G, s)
$P_i \leftarrow$ GetPath(s_i, d)
//P is the path between the s and d
For all edges e in E do
If (e OR Reverse (e)) ∈ P_i then
$c_{i+1}(e) \leftarrow f_p(c_i(e))$ //f_p is employed to extend the cost of the edges that belong to the previous path P_i
Else if the vertex Head (e) is in P_i then
$c_{i+1}(e) \leftarrow f_e(c_i(e))$ //f_e is employed to extend the cost of the edges that belong to vertices of the previous path P_i
Else
$c_{i+1}(e) \leftarrow c_i(e)$
End if
Cross Layer Metric(e); // Cross Layer Metric is estimated in **equation (7)**
End for
$G_{i+1} \leftarrow (V, E, c_{i+1})$
End for
Return ($P_1, P_2, ..., P_N$)

Each time when the node receives a new TC or HELLO message and this results in the variations in the network topology information base. When these variations occurs all the updatedFlags will be set to false. To obtain the routes between the nodes in the network is detailed in the above algorithm. In

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this algorithm, it considers a graph as a network where vertices are the nodes and edges are the links between the nodes G=(V,E,c). This algorithm extracts N paths from the graph G. Dijkstra(G, n) is the standard algorithm which delivers the source tree of the shortest paths from vertex n in graph G, GetPath(s, n) is the function that. This function extracts the shortest-path to n from the source tree Source Tree; Reverse(e) gives the opposite edge of e.

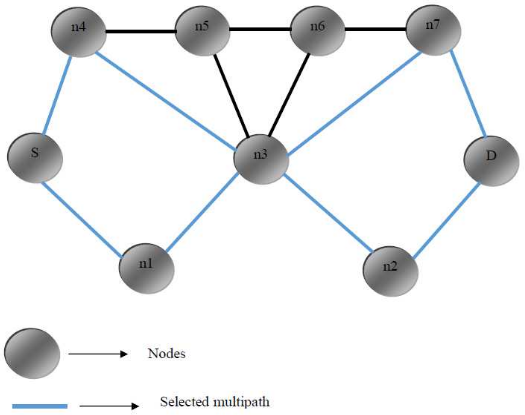

Fig 1(a): Multipath Dijkstra Algorithm (link-disjoint paths)

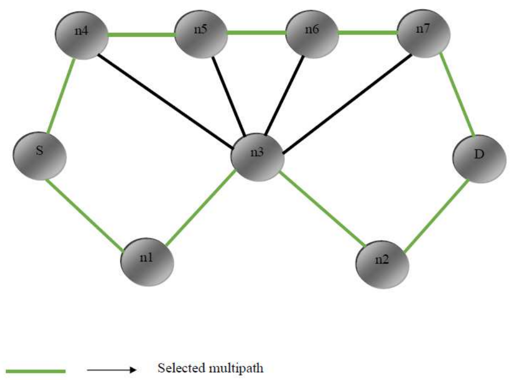

Fig 1(b): Multipath Dijkstra Algorithm (node-disjoint paths)

Here in the above figures the benefits of choosing different cost function for the multipath set (node-disjoint or link-disjoint) during the transmission is shown according to the network requirements. In the fig 1(a), If the network assumes $f_p(c)$ = 3c and $f_e(c)$ = c (also penalty is applied to the used edges in the network), the paths network obtained are two link-disjoint paths: S→n1→n3→n2→D and S→n4→n3→n7→D. In the fig 1(a), If network assumes $f_p(c)$ = 3c and $f_e(c)$ = 2c (also penalty is applied to used vertices in the network), then the algorithm tends to pursuit for node-disjoint paths and the paths founds are S→n1→n3→n2→D and S→n4→n5→n6→n7→D.

3.4. Estimation of Cross-Layer Metric

3.4.1. Expected Transmission Time [18]

The cross layer routing metric is prolonged to work with the changes in the routing protocol of the network. So the network develops a link value metric which is known as Expected Transmission Time (ETT) that accounts for change value and link quality. The Expected transmission time is also a factor of packet loss rate (PLR).

$$ETT = (\text{ETX} * \frac{s}{b_{rate}}) + c_i(e) \qquad (1)$$

where, ETT is Expected Transmission Time, ETX is expected transmission count, s is the average packet size, b_{rate} is the data rate of the link and $c_i(e)$ is the cost of the edge e.

Here ETT is also a function of the PLR (packet loss rate). This packet loss rate considers both the PLR of forward link and PLR of reverse link. This packet loss rate is obtained by sending probe packets at the network layer.

3.4.1.1. ETX (Expected Transmission Count)

The Expected Transmission Count (ETX) is completely dependent on the Expected Transmission Time in the above equation [1]. The ETX of a link depends on the forward packet loss rate from S to D on edge e (e_f), and the reverse packet loss rate from D to S on edge e (e_r).

$$P_{loss} = 1 - (1 - e_f) * (1 - e_r) \qquad (2)$$

where, P_{loss} is the packet loss, e_f is the forward packet loss on edge e and e_r is the reverse packet loss on edge e.

After the computation of the packet loss considering both the forward packet loss and reverse packet loss on the edge e, Expected Transmission Count is successfully given by

$$ETX = \frac{1}{1 - P_{loss}} \qquad (3)$$

where, ETX is the Expected Transmission Count and P_{loss} is the packet loss from equation (2).

For link 1 in Fig 2, assume e_f = 0.7 and e_r = 0.5, then calculate

$$P_{loss} = 1 - (1-0.7)*(1-0.5) = 0.85$$

Expected Transmission Count is calculated as

$$ETX = \frac{1}{1-0.85} = 6.67$$

By using this ETT is calculated from Eq. (1)

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$$ETT = (6.67 * \frac{20}{10}) + 8 = 21.34 \approx 21 \text{(Approximately)}$$

where s =20, b_{rate} = 10 Mbps and $c_i(e)$ =8

Similarly, we can calculate the ETT value for all the other links in the network.

3.4.2 Residual Energy

The present routing protocols discover the routes with maximum bottleneck residual energy at once among the intermediate nodes. These routes minimizes the total end-to-end transmission energy for a packet. The main of use of these routing protocols is to cut back energy consumption and to extend node life which leads in enhanced network life and performance. By minimizing the energy consumption only short hop route differs if nodes will regulate transmission power levels such that multiple short hops are more advantageous, from an energy perspective, than a single long hop [19].

In a network a mobile node performs power control in time of packet transmission, this transmission energy for each packet relative to the node distance is given by

$$E_T = c * dist^{\alpha} \quad (4)$$

where, E_T is the energy required for the transmission for each packet, *c* is the proportionality constant, *dist* is the distance between the two adjacent nodes, and α is a parameter that depends on the network's physical environment.

At every node, the total energy required is given by

$$T_{ENERGY} = d_{pac} * (E_T + E_{PRO}) \quad (5)$$

where, T_{ENERGY} is the total energy required by each node in the network. d_{pac} is the total number of data packets, E_{PRO} is the energy required for the packet processing which is much smaller than that required for packet transmitting and E_T is the energy required for the transmission for each packet (estimated in (**4**)).

The energy left after the data packet transmission is the residual energy of the node. This residual energy is given by [21]

$$T_{RES} = I_E - T_{ENERGY} \quad (6)$$

where, T_{RES} is the total residual energy of the node, I_E is the initial energy of the node and T_{ENERGY} is the total energy required by each node.

For link 1 in Fig 2, in order to find residual energy, we assume that c = 0.6, dist = 10 m, α=0.7, then $E_T = 0.6 * 10^{0.7} = 3$ J.

T_{ENERGY} = 10*(3+0.2) =32 J, where d_{pac} = 10 and E_{PRO} = 0.2 J

Hence the residual energy is calculated as

T_{RES} = 35-32 =3 J , where I_E = 35 J.

Similarly, we can calculate the residual energy for all the other links in the network shown in fig 2.

3.4.3. Load Balancing Factor

In the process of discovering routes for the transmission of data packets in the network, the available bandwidth may be used. The control packets may not consume a huge amount of bandwidth. But these control packets may interfere with the transmissions. In general, the normalized load during the routing in the network is the number of routing packets "transmitted" per data packet "delivered" at the destination node. Every hop by hop transmission of a routing packet is counted as one transmission.

$$LBF = \frac{1}{S_{rev}} \sum_{i=1}^{S_{rec}} H_i \quad (7)$$

where, LBF is the load balancing factor, S_{rev} is the number of successfully received packets, I is the unique packet identifier and H_i is the total hop count of the routing packets corresponding to data packet i.

For link 1 in Fig 2, to calculate LBF, assume S_{rev} = 7, H_i = { 3,4,5,6,7,8,3} for i =1,2,3....7, respectively.

$$LBF = \frac{1}{7}(3+4+5+6+2+5+2) = 3.86 \approx 4 \text{(Approximately)}$$

Similarly, the LBF of all other links in the network shown in fig 2 is calculated.

3.4.4 Cross-Layer Metric

The network chooses the best energy efficient route based on this cross layer metric. This cross layer metric is found by combining ETT, T_{RES} and LBF of the network.

$$CLM = \frac{\alpha.\text{ETT} * \beta.\text{LBF}}{\gamma.T_{RES}} \quad (8)$$

where, CLM is the cross layer metric, ETT is the expected transmission time, T_{RES} is the total residual energy and LBF is the load balancing factor. α , β and γ are normalization constants whose values ranges from 0 to 1.

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3.5. Overall Algorithm

In this approach a Multi-Objective Cross-layer based Multipath Routing protocol has been proposed. Through this protocol it is possible to increase the efficiency of the network and also it is possible keep the nodes active for long period in the network. The steps involved to achieve these are

Step 1: Initially the network finds the multipath (link-disjoint paths or node-disjoint paths) for the transmission between the nodes s and d. During the selection of theses paths the network also considers the expected transmission time and residual energy of the nodes which explained in further steps 2 and 3.

Step 2: During the selection of paths between the nodes the network estimates the expected transmission time (ETT). This estimation of ETT considers ETX (Expected Transmission Count), average packet size and data rate of the link which is shown in the **equation 1**.

To estimate the Expected Transmission Count network considers the packets loss occurred (shown in **equation 3**)

Step 3: After the estimation of the ETT, the network estimates the residual energy of the nodes in the network. To get this residual energy network considers the residual energy of the node n at time t (shown in **equation 6**).

Step 4: Finally the load balancing factor of the nodes is calculated in the network. to estimate the load balancing factor the network considers the number of successful received packets and total hop count (shown in **equation** 7)

Step 5: combining all these steps 2, 3 and 4 we form cross layer metric. Based on this cross layer metric the network finds the best route with minimum cost for the transmission of data packets.

In below fig 2, we can observe that the network has found the multiple routes between the nodes S and D. The found multiple routes are S→n1→n3→n2→D and S→n4→n3→n7→D. But in these routes the only the energy efficient route will be selected for the transmission of the data packets between the nodes. This best route is selected with the help of the cross layer metric. Let us assume that the estimated cross layer metric for the route S→n1→n3→n2→D be 32 (ETT=3, T_{res}=3 and LBF=3) and the estimated cross layer metric for the route S→n4→n3→n7→D be 25 (ETT=5, T_{res}=4 and LBF=5). Finally route with the minimum value will be selected for the transmission of the data packets between the nodes i.e. route S→n4→n3→n7→D will be selected.

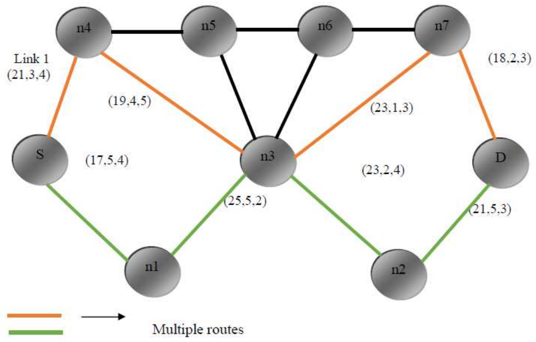

Fig 2: Route Selection Based On Cross Layer Metric

Assume α=0.3, β=0.6 and γ=0.4

For route 1,

$$CLM = \frac{(0.3*81)*(0.6*15)}{0.4*10} = 72.9$$

(ETT=42, T_{res}=10 and LBF=20)

For route 2, $CLM = \frac{(0.3*86)*(0.6*13)}{0.4*17} = 50.3$

(ETT=12, T_{res}=26 and LBF=18)

Route	ETT	T_{res}	LBF	CLM
S→n1→n3→n2→ D	81	10	15	72.9
S→n4→n3→n7→ D	86	17	13	50.3

The route S→n4→n3→n7→D is selected since it has less CLM value.

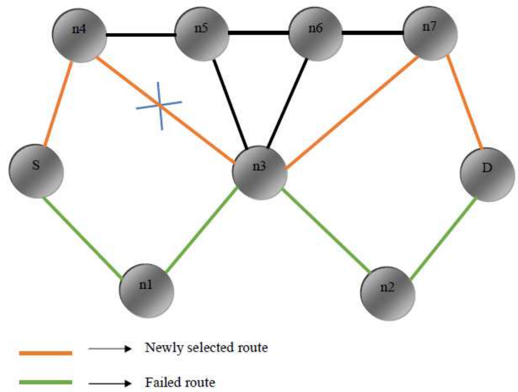

Fig 3: Route Selection In Case Of Link Failure

If link failure occurs in the selected route, then the route with next minimum CLM value which is shown in Fig 3. Here, the route S→n4→n3→n7→D fails, so the route S→n1→n3→n2→D is selected for transmission.

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4. SIMULATION RESULTS

4.1.Simulation Model and Parameters

In the simulation, the mobile nodes move in a 1250 meter x 1250 meter region for 50 seconds of simulation time. All nodes have the same transmission range of 40 meters. The simulated traffic is Constant Bit Rate (CBR). In our simulation, 7 source nodes send their sensor data to the receiver.

The simulation settings and parameters are summarized in table.

No. of Nodes	30,50,70,90,110
Area Size	1250 X 1250
Mac	IEEE 802.11
Transmission Range	250m
Simulation Time	50 sec
Traffic Source	CBR
Packet Size	512
Sources	7
Rate	50,100,150,200 and 250kb
Protocol	MOCMR
Initial Energy	10.3J
Transmission Power	0.660
Receiving Power	0.395
Speed	10m/s

4.2. Performance Metrics

The proposed Multi-Objective Cross-layer based Multipath Routing (MOCMR) is compared with the MPOLSR technique [2]. The performance is evaluated mainly, according to the following metrics.

- **Packet Delivery Ratio:** It is the ratio between the number of packets received and the number of packets sent.
- **Throughput:** It refers the average number of packets received during the transmission
- **Residual Energy:** It is the amount of energy remaining in the nodes.
- **Delay**: It is the amount of time taken by the nodes to transmit the data packets.

4.3 Results

A. Based on Nodes

In our first experiment we vary the number of nodes as 30,50,70,90 and 110.

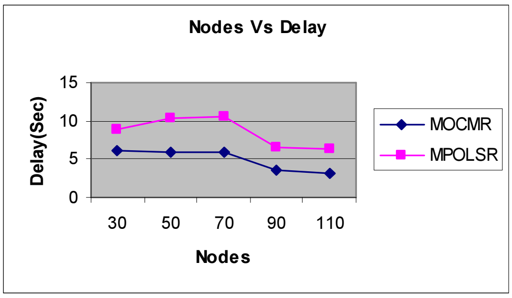

Fig 4: Nodes Vs Delay

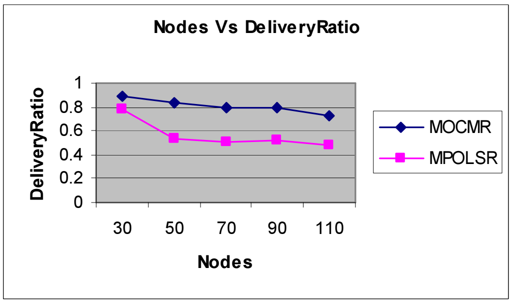

Fig 5: Nodes Vs Delivery Ratio

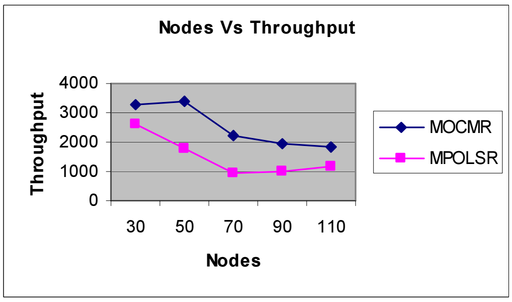

Fig 6: Nodes Vs Throughput

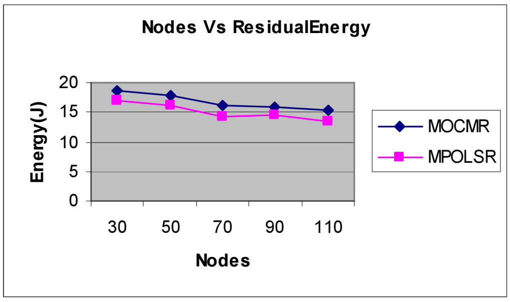

Fig 7: Nodes Vs Residual Energy

Fig 4 shows the delay of MOCMR and MPOLSR techniques for different number of nodes scenario. We can conclude that the delay of our proposed MOCMR approach has 42% of less than MPOLSR approach.

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Fig 5 shows the delivery ratio of MOCMR and MPOLSR techniques for different number of nodes scenario. We can conclude that the delivery ratio of our proposed MOCMR approach has 30% of higher than MPOLSR approach.

Fig 6 shows the throughput of MOCMR and MPOLSR techniques for different number of nodes scenario. We can conclude that the throughput of our proposed MOCMR approach has 41% of higher than MPOLSR approach.

Fig 7 shows the residual energy of MOCMR and MPOLSR techniques for different number of nodes scenario. We can conclude that the residual energy of our proposed MOCMR approach has 10% of higher than MPOLSR approach.

B. Based on Rate

In our second experiment we vary the rate as 50,100,150,200 and 250Kb

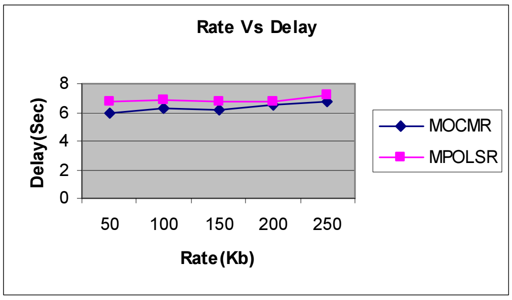

Fig 8: Rate Vs Delay

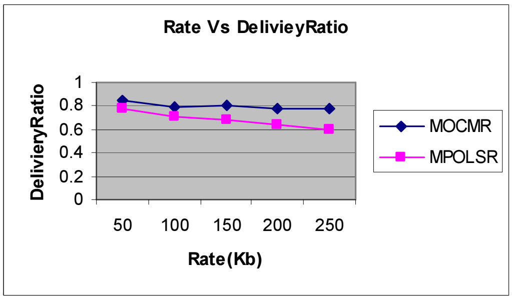

Fig 9: Rate Vs Delivery Ratio

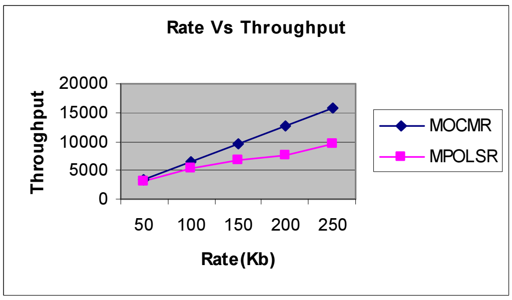

Fig 10: Rate Vs Throughput

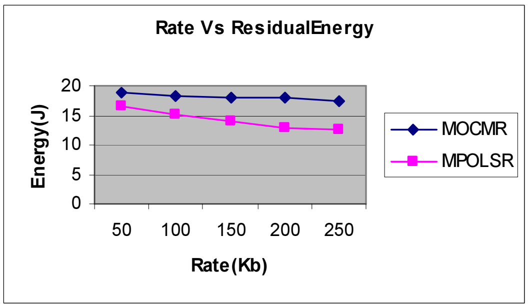

Fig 11: Rate Vs Residual Energy

Fig 8 shows the delay of MOCMR and MPOLSR techniques for different rate scenario. We can conclude that the delay of our proposed MOCMR approach has 7.5% of less than MPOLSR approach.

Fig 9 shows the delivery ratio of MOCMR and MPOLSR techniques for different rate scenario. We can conclude that the delivery ratio of our proposed MOCMR approach has 15% of higher than MPOLSR approach.

Fig 10 shows the throughput of MOCMR and MPOLSR techniques for different rate scenario. We can conclude that the throughput of our proposed MOCMR approach has 27% of higher than MPOLSR approach.

Fig 11 shows the residual energy of MOCMR and MPOLSR techniques for different rate scenario. We can conclude that the residual energy of our proposed MOCMR approach has 21% of higher than MPOLSR approach.

5. CONCLUSION

In Mobile Ad Hoc Networks (MANETs), selecting a highly energy efficient route is the main goal. To face these challenges in a Multi-Objective Cross-layer based Multipath Routing approach has been proposed. In this approach initially a route to transmit the data packets is selected with the help of a hybrid routing approach. Also a cross layer metric is proposed based on ETT, residual energy of the nodes in the network and Load Balancing Factor of the nodes also have been estimated. Finally this cross layer metric is combined with the hybrid routing to get a high energy efficient route to transmit the data packets between the nodes. Through this approach it is possible to make an energy efficient transmission between the nodes and prolong the network's lifetime. Simulation results show that the proposed cross-layer based multipath routing protocol attains higher delivery ratio with reduced delay and energy consumption.

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However the proposed routing protocol is proactive which may not be suitable in high mobility scenario. Hence the future work focus on extending this work to reactive routing protocols.

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