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OPTIMIZED RELIABLE AND LOAD BALANCED ROUTING PROTOCOL FOR MOBILE AD HOC NETWORKS

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ABSTRACT

In Dynamic Source Routing (DSR) protocol for mobile ad hoc networks (MANETs), high transmission overhead is involved since DSR header size comprises the IP addresses of all the nodes involved in the transmission of the data packet. By reducing the amount of the packets involved in routing, the DSR control overhead is reduced by most of the optimization techniques. In this paper, we develop an optimization technique for DSR to reduce the overhead during data transmission. The optimization is performed in two phases. In the first phase, the route for the data packet transmission is determined and the bloom filter is used for the estimation of the compressed source route at every node. In the second phase, before the transmission of the data packet, the related information of the transmitting intermediate node is deleted. This prevents the data packet from including all its intermediate node information on transmission, in turn maintaining the data packet size to the original size without overloading it. Thus this technique reduces the overall overhead in the network. By simulation results, we show that the proposed technique reduces the overhead and hence the energy consumption and delay.

Keywords: *Mobile Ad Hoc Networks (MANETs), Dynamic Source Routing (DSR), Overhead Reduction, Load balanced routing protocol, Caching*

1. INTRODUCTION

1. 1. Mobile Ad hoc Network (MANET)

Mobile ad hoc Network (MANET) is a unique type of wireless network in which a set of mobile network interfaces form a transient network without the support of any well-known infrastructure or centralized management. Some of the applications of Ad hoc wireless network include decision making in the battlefield, data acquisition operations in hostile environment, emergency search-and-rescue operations, etc. The characteristics of MANET include dynamic topology, limited resources (such as CPU, battery, bandwidth, etc.), multi-hop communication and limited security. These characteristics set special challenges in routing protocol design [1].

1. 2. On Demand Routing Protocols

In the case of ad hoc networks, since all the nodes cooperate dynamically, the nodes which are not directly connected within the transmission range can also communicates with other nodes for establishing, maintaining routes and forwarding packets. When a sending node originates a data packet addressed to the destination node, an on demand routing protocol searches for and attempts to determine a route to the destination node. An on-demand routing protocol must cache routes formerly discovered, in order to avoid the need of performing a route discovery before each data packet is sent [2]. Several routing protocols have used on-demand mechanisms including the following

Ad hoc On-Demand Distance Vector Routing (AODV): Adhoc on Demand Distance Vector Routing is a novel algorithm for the operation of adhoc networks. Each Mobile Host operates as a specialized router and routes are obtained as needed (i.e.) on demand with little or no reliance on periodic advertisements [3].

Dynamic Source Routing (DSR): The Dynamic Source Routing protocol (DSR) is a simple and efficient routing protocol designed specifically for

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use in multi-hop wireless ad hoc networks of mobile nodes. DSR allows the network to be completely self-organizing and self-configuring, without the need for any existing network infrastructure or administration. [4].

Temporally-Ordered Routing Algorithm (TORA): It uses a "physical or logical clock" to establish the "temporal order" of topological change events which is used to structure the algorithm's reaction to topological changes. The protocol's reaction is structured as a temporally-ordered sequence of diffusing computations; each computation consisting of a sequence of directed link reversals. [5].

Location-Aided Routing (LAR): It utilizes location information to improve performance of routing protocols for ad hoc networks. By using location information, Location-Aided Routing protocols limit the search for a new route to a smaller "request zone" of the ad hoc network [6].

Destination Sequenced Distance Vector Routing (DSDV): It operates in each Mobile Host as a specialized router, which periodically advertises its view of the interconnection topology with other Mobile Hosts within the network [7].

Associativity -Based Routing (ABR): It is a compromise between broadcast and point-to-point routing. ABR only maintain routes for sources that actually desire routes. However, ABR does not employ route re-construction based on alternate route information [8].

Caching and Multi-path Routing Protocol (CHAMP): It uses cooperative packet caching and shortest multi-path routing to reduce packet loss due to frequent route breakdowns [9].

1.3. Caching

To discover a route whenever required, DSR floods route requests. Because of the high cost of flooding, DSR maintains route caches to accumulate routes that have been established by means of flooding or through promiscuous overhearing [9]. In order to reduce the routing overheads with improved route discovery latency, on-demand routing protocols for mobile ad hoc networks make use of the route caching in different forms. They need to adjust to frequent topology changes for the route caching to be effective [10].

- **Path cache:** In the case of path cache, a node stores each route including the route from itself to another node.
- **Link cache:** In the case of link cache, a node adds a link to a topology graph, which represents the node's view of the network topology [11].

1.4. Drawbacks of DSR

1) In mobile ad hoc networks, flooding at the time of route set up creates high overhead, which is the major drawback of DSR protocol [12].
2) In DSR, every route that is being cached by the nodes in the original DSR begins from the node but every node is capable of including only the route consisting of "forwarding" directional links to its cache [13].
3) Scalability Limitation: Source routing is utilized by DSR and hence scaling to larger networks is not possible [14].
4) IPv6 unfriendly: The performance of the DSR is largely limited by the higher address space of the IPv6. In accordance to the increasing importance in the wireless community for IPv6, DSR performance faces a major drawback [14].
5) Multicasting is not sustained by the Dynamic Source Routing (DSR).
6) In dynamic source routing (DSR), the intermediate route address along with the address of the source and the destination is stored in the data packet header and hence reducing the throughput.
7) In DSR the route reply packet is sent from all the paths that were used by the route request packet. This maximizes the possible routes to the source and simultaneously maximizes the load of the routing packet in the network.
8) When provided with multiple routes, the existing specification of DSR does not support any of the means for either route entry invalidation or route prioritization, resulting in cache entries that are corrupted specially due to high mobility. DSR is mainly a source routing technique and hence with the increase in the network size, the header size also increases, which in turn increases the routing overhead.
9) The design of the Dynamic source routing protocol is mainly done for the utilization in the mobile nodes of multi-hop wireless ad hoc networks. Source routing is utilized by DSR and is not dependent on the activities which work in accordance with the use of timer. Since the route discovery procedure is activated only when the data transmission has to be performed, DSR is completely reactive protocol [15].

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1.5. Issues of Our Previous Works

The major limitation related to DSR is scalability. As the hops between the source and the destination increases, the scalability problem also increases, leading to the rise in overhead.

As the DSR header size comprises the IP addresses of all the nodes involved in the transmission of the data packet, the transport overhead increases highly in the network [19].

At the time of route discovery stage in the protocol, flooding routing request and cached route reply can overload the network to a bad extent even though normally the routing overhead offered by the DSR is low when compared to the proactive routing protocols. Performance of the entire network gets degraded when the number of nodes in the network is high whereas for networks with small number of nodes flooding does not affect the network performance. By reducing the amount of the packets involved in routing, the DSR control overhead is reduced by most of the optimization technique.

For instance, in the ad hoc network, the investigation for a new path towards a smaller “request zone” is restricted by the Global Position System (GPS) Routing. Thus the flooding of the request packets is reduced. Reduction of the number of cached route replies that are produced by the nodes except the non destination nodes is another option for optimization. The control overhead comprises of the data packet header and the routing packets. There will be degradation in the performance of DSR as the data is carried through the entire path. But very little work is done in minimizing the overhead related to data forwarding [17].

In our first work [21], we have proposed a technique to estimate a combined weighted function for each route stored in the cache for DSR routing protocol. Then based on the combined weight function, the routes are arranged such that routes with minimum length and traffic load, maximum energy level and freshness are listed first in the route cache. The route cache is updated such that routes with least weight functions are removed from the list. In the route prediction mechanism, when a link is likely to be broken, it will select the most reliable route as an alternate route from the sorted route cache, before the link breakage.

In second work [20], a technique is proposed which initially determines a combined weighted function based on route length, traffic load, energy level and freshness for each route and stores in the route cache. Best paths are selected based on their combined weight value among the selected paths. Then traffic is distributed over these paths using the network diversity coding. The original message can be reconstructed if at least few blocks out of given number of blocks reach the destination using diversity coding.

In both the works, the path may get overloaded, hence overcoming the overload using an appropriate protocol is considered in our present work.

In this work, we take reduction of the overhead using the DSR into consideration.

2. RELATED WORK

Roy Leung et al., [16] in this paper designed a QoS-aware multi-path source routing protocol (MP-DSR) focusing on a new QoS metric, *end-to-end reliability*. In order to select a subset of end to end paths to provide increased stability and reliability of routes, a new QoS metric, end-to-end reliability, is defined and emphasized in this paper. A distributed multi-path dynamic source routing protocol (MP-DSR) for wireless ad-hoc networks to improve QoS support with respect to end-to-end reliability is presented. This protocol forwards outgoing packets along multiple paths that are subject to a particular end-to-end reliability requirement.

Shusen Yang et al., [17] proposed a Deleting Redundant Address (DRA) technique to minimize data packet header overhead, which is a significant source of the total control overhead for dynamic source routing. It introduced a technique to reduce control overhead and enhanced the performance of DSR by deleting redundant addresses carried in data packets.

M.Tamilarasi et al., [18] proposed an algorithm for modifying DSR to reduce overhead by reducing the number of route reply packets and the header size of DSR data packets. Besides this, an algorithm for energy management is incorporated in the Modified DSR by transmitting the data packets with minimum required energy.

Tatiana K. Madsen et al., [19] focused on transport overhead reduction by means of header compression techniques. The potential of header compression in ad hoc networks is not fully exploited yet and is mostly based on tag switching approaches or full decoding of the routing information at each node. In this paper a new joint approach is advocated where compression is

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closely coupled with ad hoc routing. To keep the processing overhead low, end-to-end compression is suggested. Packet routing can be implemented by using layer III-to-layer II routing mapping. This approach facilitates fast forwarding, since compressed IP headers are not examined at every node.

3. OVERHEAD REDUCTION DURING THE DATA TRANSMISSION

In our previous work [20], we have designed the Reliable and Efficient Load Balanced Routing Protocol based on the DSR protocol. For optimizing this protocol, the data overhead and control overhead are to be reduced. For reducing these overhead, in this paper, Bloom Filter technique is used for the compression of the source routing.

In this technique, in the first phase the source route is compressed by the DSR technique which uses the bloom filter thus reducing the overhead to some extent in the network. In the phase 2, the overhead reduction of the data is performed using the Deleting Redundant Address (DRA) technique. In this technique, the DSR is optimized by removing all the additional address entries from the compressed source route during the transfer of the data packets towards the destination.

Due to the compression technique and redundant overhead reduction used, this work efficiently reduces the overhead during data transmission. Thus this technique can be used in our Reliable and Effective Load balanced Routing Protocol for Mobile Ad hoc Networks for reducing the overhead in the network for a larger extent.

The overall process of data transmission is given in an algorithm as follows

Phase 1

1. In order to estimate the routes for the transmission of the data packet towards the destination from the source, route discovery process in DSR is utilized. The list of the addresses is determined along the path by the source in accordance to the Route Reply received. As a result, all the paths from the source, towards the destination are determined.

2. Next the bloom filter for the corresponding addresses is estimated by the source. Let z be the length of the path and k is the number of hashes used

```
For each node j, j =1, 2, 3……...., z;
    For each hash p, p=1, 2, 3,………., k;
        BF1[ hash("p"| Adj).mod (m)] = 1;
    End for
End for
```

where the Bloom filter, BF_1 is a bit-string of size m for that generated at the source and Ad_j are the addresses on the path from the source to destination.

3. When the source sends packets to destination, it inserts a new compression option that carries the bloom filter to all the intermediate nodes and the number of hashes to be used.

4. Upon receiving a packet, a node verifies whether the destination address is one of its addresses.
4.1 If the destination address is one of its addresses, then
    4.1.1 packet has reached its destination
4.2 If destination address is not one of its addresses and the TTL is zero, then
    4.2.1 packet is dropped
4.3 Else
    the node verifies if any of its neighbors' addresses except the one it received the packet from, are contained in the Bloom filter carried in the packet using the following algorithm.

```
For each node j, j = 1, 2, …………., R
      match(j) = 1;
  For each hash p, p = 0, 1, …………., k  .
    If BF[hash("p"| Adj ).mod(m)] == 0
       match(j)=0;
    End if
  End for
End for
```

where R is the number of neighbors defined by their address, Ad_j

5 When the algorithm terminates,
5.1 If match(j) is set to 1, then
    5.1.1 neighbor Nj belongs to the filter and is therefore a node on the path from source to destination
5.2 Else
    5.2.2 Nj does not belong to the filter.

6. If a neighbor belongs to the Bloom Filter, then
    6.1.1 packet's TTL is decremented and the packet is forwarded to that neighbor.
6.2 Else
    6.2.1 packet is silently dropped.

7. If there are several neighbors that are contained in the packet's filter, then
    7.1.1 the packet is duplicated and forwarded to each of these neighbors.

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Phase 2

8. Assume route in the data packet header P_k as determined by the bloom filter has the following form:

$$P_k = < s, n_1, \ldots\ldots, n_i, \ldots\ldots, n_{k-1}, d >$$

where s, d, n_i represent the source, destination, and an arbitrary intermediate node, respectively. P_k has $k+1$ nodes, and the hop count is k.

9. The upstream route of n_i (including n_i and excepting s) is defined as:

$$u_i = < n_1, \cdots, n_i >$$

the control information in u_i is redundant.

10. The downstream route of n_i is defined as:

$$d_i = < n_{i+1}, \cdots, d >$$

For each node n_i and all the downstream nodes, the necessary control information for transmitting data packets to the destination node d is the addresses of the nodes in d_i.

11. While data forwarding, each intermediate node between a source and destination node deletes its own address in the data packet header before forwarding the data packet to the next hop, thus eliminating redundant information.

For example, in P_k, s generates a data packet, and when this packet passes each intermediate node n_i, the address of n_i in this data packet header is deleted before n_i sending this data packet to n_{i+1}. As a result, the data packet transmitted by each intermediate node n_i only carries the necessary route d_i instead of the complete route u_i+d_i.

12. As the packet gets transferred to the next hop n_{i+1} from node n_i , then the bloom filter will be estimated at that node n_i to compress the source route. The bloom filter at the node n_i after the hop is given by

$$BF_i\,[\,\text{hash}(\text{"p"}|\,\text{Ad}_j).\text{mod}\,(m)] = 1;$$

Then during the forwarding of the data, the intermediate node information is again deleted.

13. Similarly, the bloom filter (BF1,BF2,…..BFd) is generated after each hop along the route d_i towards the destination to compress the source route.

Hence as the data packet is transferred, only the relevant data gets forwarded. The upstream data is completely removed from the data packet hence the control overhead is reduced to a greater extent.

As an example, consider the following topology given in figure 1.

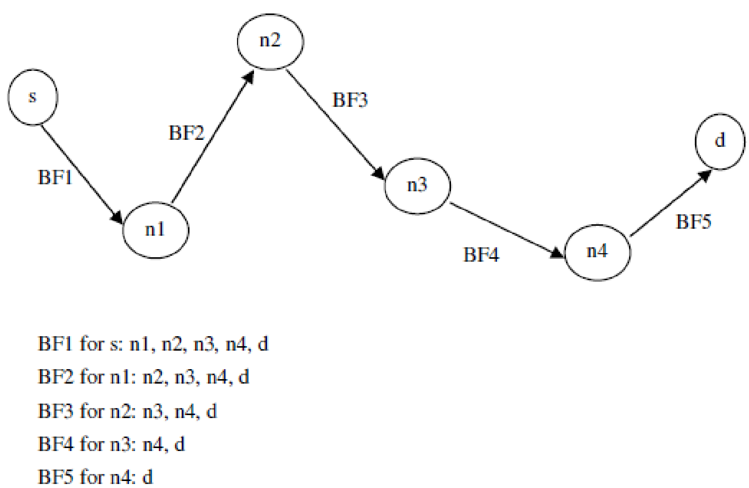

Figure 1: Bloom Filter construction for a given Path

The Figure.1 shows the estimation of the bloom filter along the path towards the destination. The given example shows a path with four intermediate nodes n1, n2, n3 and n4 between the source node, s and the destination node, d. The bloom filter determined at the source corresponds to all the addresses i.e., n1, n2, n3, n4 and d, that are relevant for the transfer of the data to the destination. As the data gets transferred from the source to the next node, a bloom filter is generated in it. When the data packet gets moved to the next node, its address information will be removed from the data packet hence reducing the additional overhead. This is followed at every intermediate node and thus maintaining reduced overhead in the network.

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4. SIMULATION RESULTS

4. 1. Simulation Model and Parameters

We use NS2 [22] to simulate our proposed protocol. In our simulation, the channel capacity of mobile hosts is set to the same value: 2 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.

In our simulation, mobile nodes of sizes 25, 30, 35, 40, 45 and 50 move in a 1500 meter x 300 meter 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 minimal speed is 5 m/s and maximal speed is 20 m/s. The pause time is varied as 10,20,30,40 and 50sec. The simulated traffic is Constant Bit Rate (CBR).

Our simulation settings and parameters are summarized in table 1

Table1: Simulation Parameters

No. of Nodes	25,30,35,40,45,50
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
Rxpower	0.395
Txpower	0.660
idlepower	0.035
Initial energy	5.1 Joules
Speed	5m/s to 20m/s
Pause time	10, 20, 30, 40 and 50

4. 2. Performance Metrics

We compare our ORLBR protocol with the RECM [20] protocol**.** We evaluate mainly the performance according to the following metrics.

Control overhead: The control overhead is defined as the total number of routing control packets normalized by the total number of received data packets.

Average end-to-end delay: The end-to-end-delay is averaged over all surviving data packets from the sources to the destinations.

Average Packet Delivery Ratio: It is the ratio of number of packets received successfully to the total number of packets sent.

Average Energy: It is the average energy consumption of all the nodes (denoted by Joules) involved in sending, receiving and forward operations.

4. 3. Results

A. Based on Nodes

In the first experiment, we measure the performance of both the protocols by varying the no. of nodes as 25, 30,35,40,45 and 50.

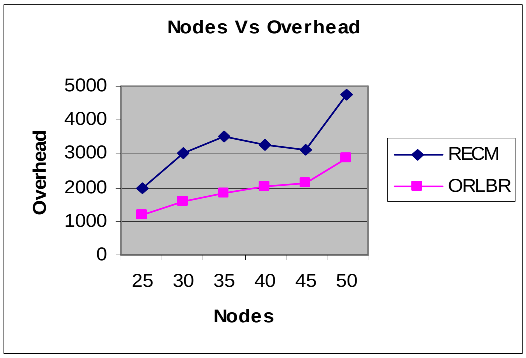

Figure 2: Nodes Vs Overhead

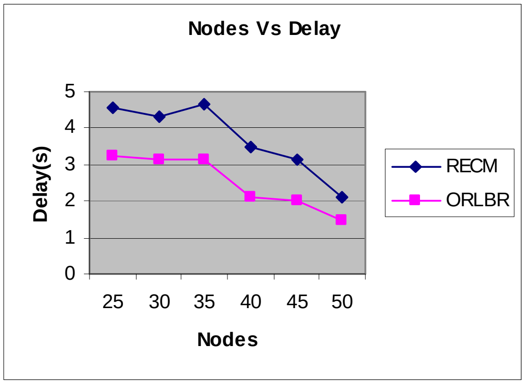

Figure 3: Nodes Vs Delay

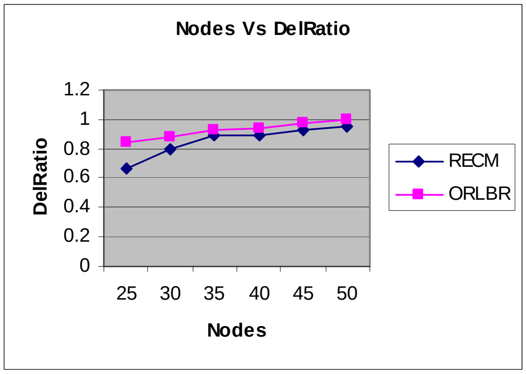

Figure 4: Nodes Vs Delivery Ratio

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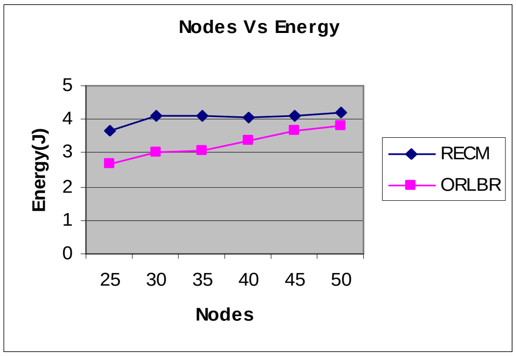

Figure 5: Nodes Vs Energy

Figure 2 shows the control overhead of the protocols. The values are considerably less in ORLBR when compared with RECM.

From Figure 3, we can see that the average end-to-end delay of the proposed ORLBR protocol is less when compared to the RECM protocol.

From Figure 4, we can see that the packet delivery ratio for ORLBR increases, when compared to RECM, since it utilizes robust links.

Figure 5 shows the results of energy consumption. From the results, we can see that ORLBR protocol has less energy than the RECM protocol, since it has the energy as a routing metric.

B. Based on Pause Time

In the second experiment, we measure the performance of both the protocols by varying the pause time as 10, 20, 30, 40 and 50 for 50 nodes.

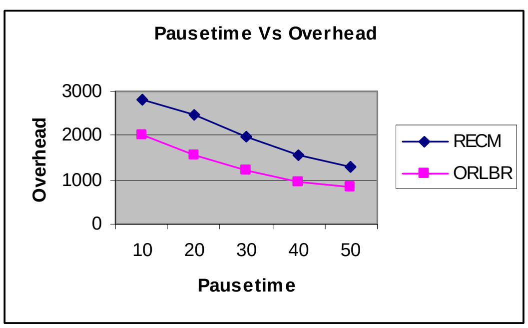

Figure 6: Pause Time Vs Overhead

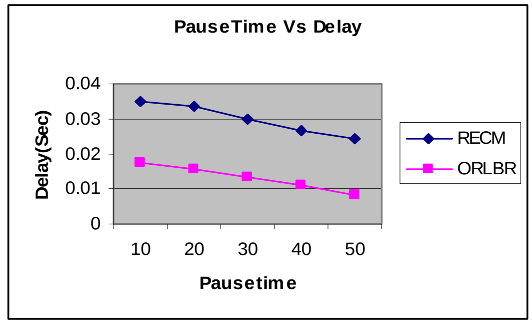

Figure 7: Pause Time Vs Delay

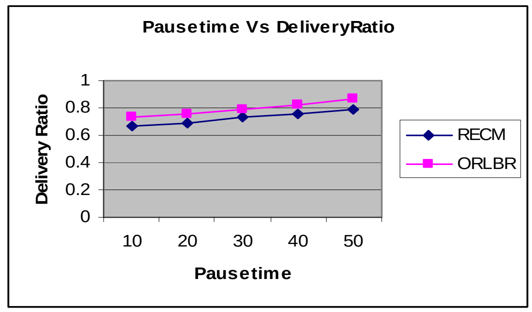

Figure 8: Pause Time Vs Delivery Ratio

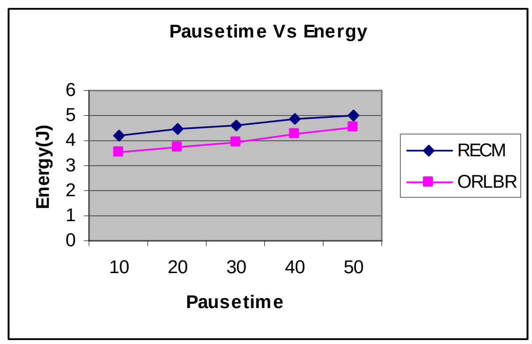

Figure 9: Pause Time Vs Energy

Figure 6 shows the control overhead of the protocols. The values are considerably less in ORLBR when compared with RECM.

From Figure 7, we can see that the average end-to-end delay of the proposed ORLBR protocol is less when compared to the RECM protocol.

From Figure 8, we can see that the packet delivery ratio for ORLBR increases, when compared to RECM, since it utilizes robust links.

Figure 9 shows the results of energy consumption. From the results, we can see that ORLBR protocol has less energy than the RECM protocol, since it has the energy as a routing metric.

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5. CONCLUSION

In this paper, we have developed an efficient technique for the reduction of the overhead in our reliable and efficient load balanced routing protocol. This technique works in two phases. In the first phase, the path for the data packet transmission is determined by the DSR route discovery process. During the transmission of the data packets, at every node the bloom filter is used to estimate the compressed source route. Whereas in the second phase, as the data leaves the node the intermediate node information is deleted so as to remove all the redundant information during data transmission. Due to this overhead check procedure, the control overhead is reduced to a great extent and hence this technique proves to be a very efficient in protocol in MANETS. . By simulation results, we have shown that the proposed technique reduces the overhead and hence the energy consumption and delay

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