



Energy-Efficient Position Based Routing protocol for Mobile Ad Hoc Networks

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Abstract: A mobile Ad-Hoc network is an infrastructure less temporary network without any centralized administration. In such network, all nodes are mobile and can be connected dynamically in an arbitrary manner. In mobile Ad-Hoc networks, limited power supply is a challenge. So energy efficient mechanisms should be combined with existing routing protocols to reduce node failure and improve the network lifetime. This paper presents an Energy-Efficient Position Based Routing protocol (EEPBR) for Mobile Ad Hoc Networks. The protocol deals with four parameters as Residual Energy, Bandwidth, Load and Hop Count for route discovery. The problem of the link failure in the channel during the call in progress thus lead in the degradation of the QoS (Quality of Service). To deal with this we are using a Backpressure Technique. The simulation results shows that the proposed algorithm is able to find a better solution, fast convergence speed and high reliability. The simulation results shows that the proposed EEPBR protocol achieve the above objectives and gives the better results than previous schemes like DSR. Our proposed scheme is useful for minimizing the overheads, maintaining the route reliability and improving the link utilization.

Key words: Bandwidth, Load, MANET and Residual Energy.

INTRODUCTION

Mobile ad hoc network is a collection of mobile devices which can communicate through wireless links. The task of routing protocol is to direct packets from source to destination. This is particularly hard in mobile ad hoc networks due to the mobility of the network elements and lack of central control. Source routing is a routing technique in which the sender of a packet determines the complete sequence of nodes through which it forwards the packet; the sender explicitly lists this route in the packet's header, identifying each forwarding "hop" by the address of the next node to which to transmit the packet on its way to the destination host. Source routing has been used in a number of contexts for routing in wired networks, using either statically defined / dynamically constructed source routes. The protocol presented here is explicitly designed for use in the wireless environment of an ad hoc network. When a host needs a route to another host, it dynamically determines one based on cached information and on the results of a route discovery protocol. Dynamic source routing protocol offers a number of potential advantages over conventional routing protocols such as distance vector in an ad hoc network. Source routing is a technique in which the source node determines the entire sequence of nodes through which a packet has to pass. The source node puts the list of addresses of all nodes in the header of the packet, so that the packet is forwarded to the

destination through those specified nodes. However source routing can be done statically or dynamically. Here it does dynamically. This is done using a procedure called route discovery. Whenever a node has packet to send to some other node, the first node initiates the route discovery. Each node maintains a cache called route cache to store the routes it has gathered to different destinations. To support efficient routing in energy constrained ad hoc networks, power-aware routing policies can be integrated and evaluated with existing features of routing protocol. Unlike conventional routing protocols, our protocol uses no periodic routing advertisement messages, thereby reducing network bandwidth. The proposed protocol enhances Dynamic Source Routing protocol with some Energy constraints to improve its performance [1] [12]. As the residual energy of nodes in an ad hoc network goes below threshold, some of the existing links break and the routes in the route caches of the nodes must be modified and alternative route may be used. The rest of the paper is organized as follows: we have given design space and related works in Section 2, Section 3 presents the proposed protocol, Section 4 discusses Simulation results and finally Conclusion and Future work is discussed in Section 5.

DESIGN SPACE AND RELATED WORK

The routing concept basically involves two activities first, determining optimal routing routes and secondly, transferring the information packets through network. There are various Energy-Efficient routing protocols which deal with the following constraints:

- Switching on/off radio transmitters to conserve energy [2][3],
- Power and topology control by adjusting the transmission range (power) of transmitters [4][5],
- Routings based on the energy efficient metrics [6][11].

The radio transmitters are turned off for an adaptively varying period to save power when there is no traffic [2]. In order to adapt to operational environment, several algorithms are proposed, for examples, using application level information and node density [2], and routing fidelity and location information [3]. Topology control is another approach, in which the transmission power is adjusted to achieve energy efficiency. For instance, the transmission power is changed while maintaining a connected topology by observing local and global topology information [4]. The node battery life is extended by using the radio's minimum power level. A distributed power control scheme is proposed, in which power control level is established by exchanging

control messages, according to the estimated minimum and maximum power level [5]. There will be frequent link ups and downs, causing more link errors. Retransmission due to link breakage will consume extra energy and network bandwidth. For Metric-based routing [6][7], different kinds of metrics are used to maximize the lifetime of networks by evenly distributing the energy consumption among all nodes. MBCR (Minimum Battery Cost) algorithm incorporates the battery capacity into the metric. In addition, the expected energy spent in reliably forwarding a packet over a specific link is considered in [8][11]. In order to maximize the network life time, the cost function defined in [9] takes into account energy expenditure for one packet transmission and available battery capacity. Furthermore in [10], the queue load condition and the estimated energy spent to transmit all packets in the queue are considered.

Dynamic Source Routing Protocol (DSR)

The Dynamic Source Routing (DSR) protocol is an on-demand routing protocol. Mobile nodes are required to maintain route caches that contain unexpired routes and are continually updated as new routes are learned. The protocol consists of two major phases: **route discovery and route maintenance**.

Route Discovery is done by the source if it doesn't find any route for the destination in its route cache. It is done by broadcasting a RREQ packet to all the neighbors initiated by source then by every node that receives the RREQ packet, till the destination is found. When destination receives a RREQ packet, it replies source with a RREP packet along the reverse of the route recorded in RREQ. **Route maintenance:** Route maintenance is done by the use of route error packets and acknowledgments. RERR packet is sent by a node to the source when the data link layer met a fatal transmission problem. When a RERR packet is received, the erroneous hop is removed from the node's route cache and all routes that contain that hop are truncated at that point [6].

PROPOSED ENERGY EFFICIENT ROUTING PROTOCOL

DSR is selected as the baseline routing protocol because it is an On-Demand routing protocol. It consists of two main phases: Route Discovery and Route Maintenance. Consider a Mobile Ad-Hoc network (MANET) with a collection of mobile nodes connected with each other through some routes shown in Fig 3.

Proposed Model for Route Discovery

The specific goal of this approach is to select a route that contain underutilized nodes so that the energy usage among all nodes can be balanced because underutilized nodes usually have more energy than utilized nodes. The approach compares not only energy but other parameters also for the route selection so this may result in shorter, best and energy-rich routing. Thus, ensures longevity of network lifetime.

Route Discovery: In this protocol the procedure of broadcasting the RREQ packet for Route Discovery is same as the DSR; the difference is in the **RREQ packet format**, shown in Fig1:

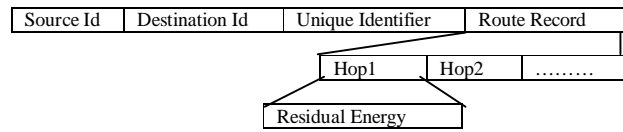


Fig 1: RREQ packet format

The intermediate node which receives the RREQ packet does the following:

- a) It checks in its Route Cache for the existence of a route for the destination, if found it appends that route in a RREP packet and sends it to the source.
- b) If the node had already received the request with the same Unique Identifier, it drops the arrived request packet.
- c) If the node recognizes its own address as the Destination, then the packet reached the target.
- d) Otherwise, the node appends its own address in the Route Record and its residual energy in RREQ and rebroadcasts it to all its neighbors.

The destination selects the best route on the basis of different parameters like max Energy, max Bandwidth, min Load and min Hop Count among the entire route requests arrived. The destination replies to the source by sending a RREP packet (Fig. 2). The RREP packet goes along the reverse hop sequence of the best route and also contains the Final Route Table (Table 4). The Final Route Table is saved by each intermediate node and the source node in its route cache. The **RREP packet format** will be as

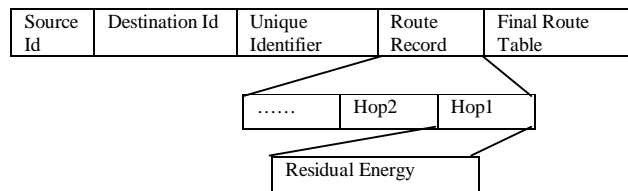


Fig 2: RREP packet format

Proposed Algorithm and Analysis

Let us consider few parameters as for a MANET shown in Fig 3:

H = Hop Count i.e. no. of edges in a route between source and destination

D_{ij} = Distance between any two nodes i and j

L = Load at a node

BW = Available Bandwidth at each node

E = Energy at each node

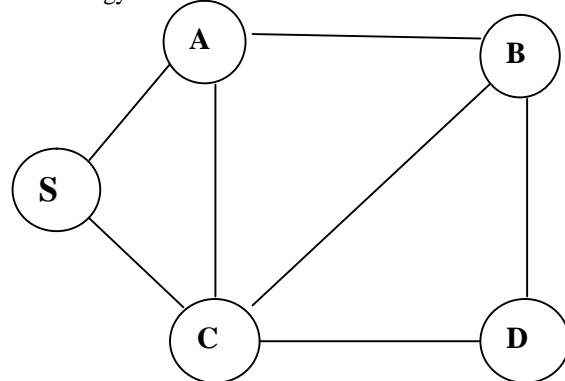


Fig 3: A mobile Ad-Hoc network

Table 1 show the total number of routes available between source S and Destination D with their Hop Count are:

Table 1: Routes with their Sequence and Hop Count

Routes	Complete Route Sequence	Hop Count
R1	S - A - B - D	3
R2	S - C - D	2
R3	S - A - C - B - D	4
R4	S - C - B - D	3
R5	S - A - C - D	3
R6	S - C - A - B - D	4

The Distance D_{ij} of route between nodes (i) to node (j) are:
 $D(S, A)=5, D(S,C)=6, D(A, B)=12, D(A, C)=4, D(C,D)=15,$
 $D(C, B)=10, D(B,D)=7$

The load at the each node (Traffic Load) is:
 $L(S)=40, L(A)=25, L(B)=15, L(C)=15, L(D)=30$

The Bandwidth of each node is:
 $BW(S)=40, BW(A)=50, BW(B)=30, BW(C)=35,$
 $BW(D) =40$

The Energy of each node is:
 $E(S)=50, E(A)=25, E(B)=15, E(C)=20, E(D)=40$

Now combined representation of all the routes with minimum possible values of all the parameters on each route is shown in Table 2.

Table 2: Minimum Value of all Parameters in each Route

Routes	Load	Bandwidth	Energy	Hop Count
R1	20	30	15	3
R2	15	35	20	2
R3	15	30	15	4
R4	15	30	15	3
R5	15	35	20	3
R6	15	30	15	4

For choosing an optimal route, following **Rule Set** should be taken into account:

<p>Rule 1: If the routes are of equivalent Energy Then Route with maximum available Bandwidth will be considered.</p> <p>Rule 2: If the routes are of equivalent Energy and equivalent Bandwidth: Then Route with minimum Load will be considered.</p> <p>Rule 3: If the routes are of equivalent Energy, equivalent Bandwidth and equivalent Load also Then Route with minimum Hop Count will be considered</p>

Rule 4: If the routes are not of equivalent Energy:
 Then

- 1) Route with maximum Energy should be given preference
- 2) Route with maximum bandwidth should be given preference
- 3) Route with minimum Load should be given preference.
- 4) Route with minimum Hop Count should be given preference.

The preference of order for selecting optimal route is as follows

Energy > Bandwidth > Load > Hop Count

Now tabular arrangement of the routes on the basis of above rule set and their positions is shown in Table 3:

Table 3: Position Based Arrangement of all Routes

Position	Hop Count	Load	Bandwidth	Energy
1	R2	R2	R2	R2
2	R1	R3	R5	R5
3	R4	R4	R1	R1
4	R5	R5	R3	R3
5	R3	R6	R4	R4
6	R6	R1	R6	R6

Now calculating the sum of positions of routes for all the different parameters (Hop Count, Load, Bandwidth and Energy) shown in Table3:

- For R1: $2+6+3+3 = 14$
 For R2: $1+1+1+1 = 4$
 For R3: $5+2+4+4 = 15$
 For R4: $3+3+5+5 = 16$
 For R5: $4+4+2+2 = 12$
 For R6: $6+5+6+6 = 23$

Now the **Final Route Table** (FRT) that will suggest the best and all the alternative routes:

Table 4: Final Route table

S. No.	Routes	Complete sequence	Position Count
1	R2	S - C - D	4
2	R5	S - A - C - D	12
3	R1	S - A - B - D	14
4	R3	S - A - C - B - D	15
5	R4	S - C - B - D	16
6	R6	S - C - A - B - D	23

From the Table 4, it is clear that the position count for route R2 is minimum. So R2 will be selected as the best route for sending data packets. The table contains alternate routes for sending data packets whenever a link failure occurs.

Route Maintenance Model

The Route maintenance is required when residual energy of any node goes below the threshold. After each transmission of packet, the energy factor is computed.

Energy consumed in one Transmission = (Available Energy before transmission - Remaining Energy after transmission)

The energy available for next transmission is computed as

Residual energy = (Remaining Energy after transmission - Energy consumed in one transmission)

```

If (Residual energy > Threshold)
Then
{
    The node is capable of transmitting the next packet.
}
Else
{
    The node is unable of transmitting the next packet;
    send a RERR packet to source.
}
    
```

If any node tries to send the packet even when its energy is below threshold of the required energy then data packet will definitely be lost. If any node detects that its energy is not sufficient so it is not capable of transmitting the next packet resulting in link failure then in such condition, they need for maintenance of the route

Proposed model for Route Maintenance

The RERR is generated by the predecessor of the sinking node and send to source by hop by hop, then source re-discover the route consumes much time. This time consumption can be minimized if adoption of the alternate route is done by the predecessor node of the sinking node. This can be done in the following way:

- a) The dying node sends a RERR packet to its predecessor. If the predecessor doesn't contain the Final Route Table then it will forward the RERR to its previous node, it will continue till the Final Route Table is found at any node or RERR reaches the source. If RERR reaches source then apply proposed route maintenance model 1 else proceed to next step.
- b) The predecessor searches for the alternate route from its Final Route Table that will not contain the sinking node.
 - i) If found, the predecessor node informs the source and the other intermediate nodes, if any, about the alternate route and the updated Final Route Table.
 - ii) Else, informs that no such route exists that doesn't contain the sinking node and that have the sufficient energy for next transmission.

- c) The RERR packet will be send to the source back tracking the route. The RERR packet contains:
 - i) Sinking node Id
 - ii) Residual energy, and
 - iii) Alternative routes, if found.
- d) On receipt of a RERR packet by intermediate nodes, they update their Final Route Table by discarding all the other routes that contain sinking node.

Thus, the communication between source node and destination will not face link failure and time delay in next transmission of data packet (between the same source and destination) due to the loss of node's energy. This protocol minimizes the source's overhead of finding the alternate route; source has only work to send the packet and to initiate rediscovery when needed.

Validation and Testing

Case 1: Let us consider above network and the route selected as P2 (S – C – D) for sending data packet, the residual energy of the node C is less than Threshold then C generates a RERR packet and send it to its predecessor. Its predecessor is node S; it will check its Final Route Table for the alternate route that will not contain node C. The alternate route is found then it updates its Final Route Table resulting Table 5 by discarding all the routes that contain node C and re transmitted next data packet, preventing the network failure.

Table 5: Table with alternate routes without node C

S. No.	Routes	Complete sequence	Position Count
1	P1	S - A - B - D	14

Case 2: Let us Consider Case 1, now if residual energy of node B of route P1 (Table 5) is less then threshold, then it will send a RERR packet to its predecessor node A, it will check table 5 for alternative route, but no route exist. Then it will resend the RERR packet to source S, to rediscover the route by retransmitting the CTS/RTS for new route discovery.

Case 3: Now consider if the route P1 was selected as P1 (S - A - B - D) and the node B detects insufficient residual energy then B will send RERR packet to its predecessor node A. Here node A itself was capable of selecting the alternate route because it also had Final Route Table, so it selects the alternate route from its Final Route Table and inform it's all predecessor nodes (in route P1)even to source. So, all nodes will be updating their tables by discarding all the routes that contain node B. So the job of the source node was done by a intermediate node. Thus, minimizing the source's overhead. If alternate route selection was not done by the intermediate node and before the RERR received by source and the source is unaware of the link failure, the source sends the next packet then due to link failure and no alternate route selection, the data packet would be lost. Thus, this approach

also minimizes the risk of loss of data packet due to link failure.

SIMULATION RESULT

The performance of the protocol is evaluated using simulation experiments with C++, Ns-2 simulator with Mobility Framework .A flat network is assumed as clusters Networks. A Node sends a packet, to set RTS (Request-to-Send) flags of its neighbors and the intended receiver sets CTS (Clear-to-Send) flags of its neighbors. Nodes whose RTS or CTS flag is set cannot transmit data, except the sender. Control packets have higher priority over data packets in simulations Propagation delay is assumed to be negligible, and it is assumed that packets always arrive without any bit error. The source Node generates packets at a constant rate. Extensive simulation results obtained by varying several network parameters and workload configuration The values of the network parameters used in simulations are those specified in the IEEE 802.11. We evaluate the performance improvement in terms of throughput due to the use of a densely populated network. Specifically, we consider a network of 5 to 40 Nodes with an increasing number of neighbors from 5 to 10 nodes. Each Node has a traffic flow with infinite demands towards one of its neighbors. Fig 4, Fig 5 and Fig 6 shows the throughput of all traffic flows, with available Energy and Channels Bandwidth.

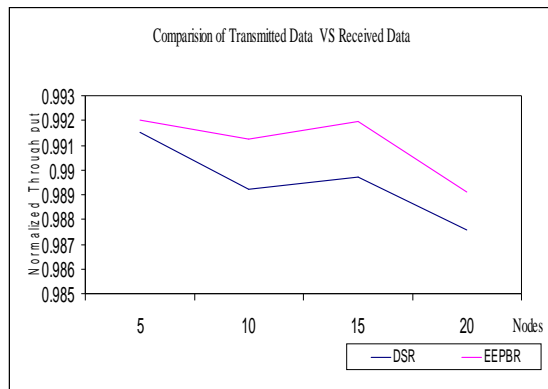


Fig 4: Comparison of Transmitted data with Received data

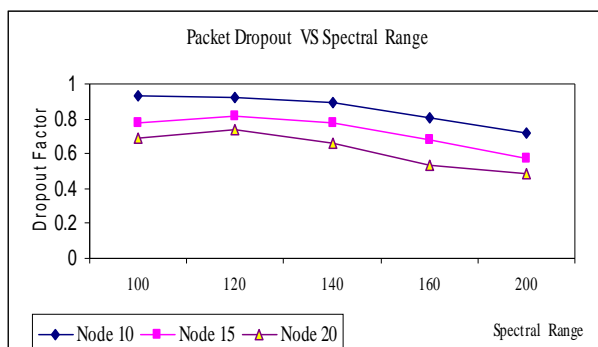


Fig 5: Comparison of Packet Dropout with Spectral Range

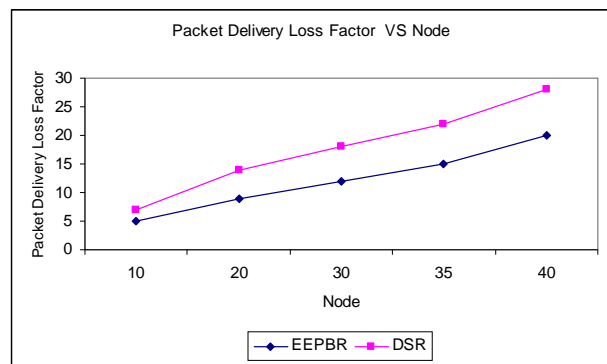


Fig 6: Comparison of Packet Delivery loss factor with node

CONCLUSION

The proposed energy efficient routing protocol works on DSR minimizes the overhead of source by distributing route information among the intermediate nodes and giving its control of finding the alternative route. It saves energy which is consumed in generating RERR by the sinking node and then traversing to all intermediate nodes to source for rediscovering route from source to destination. It reduces network failure due to loss of node’s energy and minimizes loss of data packets. It also balances the consumption of energy between utilized nodes and the underutilized nodes.

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