# A New Dynamic Route Discovery Mechanism for Mobile Ad Hoc Networks

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## ABSTRACT

Nodes in a mobile ad hoc network have limited battery power for their operation. Energy efficient routing protocol such as Min-Max Battery Cost Routing (MMBCR) selects a path with nodes having maximum battery capacity for transmission of data packets from source to destination. Though MMBCR considers individual node battery power during route discovery process, the route selected does not change unless any node in that route is exhausted completely resulting in link failure. This paper proposes a new dynamic route discovery mechanism which adapts a new route periodically resulting in decreasing the probability of link failure and increasing the lifetime of the network. The proposed routing protocol is named Dynamic Route Discovery (DRD) protocol. In this DRD protocol, the energy and cost function of each node is computed periodically by initializing route discovery process at regular intervals. Simulation results show that the proposed algorithm not only increases the lifetime of the network but also gives better throughput, packet delivery ratio and delay performance at the cost of increased routing overhead and normalized routing load compared to the existing MMBCR protocol.

## Keywords

*Network lifetime, battery power, throughput, packet delivery fraction, delay, routing overhead.*

## 1. INTRODUCTION

Mobile ad hoc network [MANET] [1], [7] consists of a set of nodes that are mobile and are connected by wireless links. The topology of such a network keeps on changing randomly due to the mobility of nodes. Thus, routing protocols designed for wired networks are not applicable to mobile ad hoc networks. A variety of routing protocols [3] were designed for wireless ad hoc networks.

As the nodes in an ad hoc network are powered by batteries, battery power [9], [10], [11], [12] is a precious resource that must be efficiently utilized to avoid early termination of any node in the network. Thus, it is a challenging task to design an energy efficient routing protocol [4], [7], [8] for MANETS that increases the lifetime of the network by managing the battery power of individual nodes in the network. In this paper, we have proposed a new routing protocol that manages the battery power of nodes by reinitializing the route discovery process periodically and adapts a new route dynamically. The rest of the paper is organized as follows. Existing power aware routing protocol is discussed in section II. Section III discusses the proposed routing protocol. Simulation setup is described in section IV, section V gives the results and section VI concludes the paper.

## 2. EXISTING POWER EFFICIENT ROUTING PROTOCOL MIN-MAX BATTERY COST ROUTING (MMBCR) PROTOCOL

Here we present a brief description of the existing power efficient routing protocols. Power efficient routing protocol such as minimum battery cost routing (MBCR) at network layer proposed by C. K. Toh [2] selects the best path with minimum battery cost or maximum battery capacity to increase the network lifetime. But this algorithm considers the summation of values of battery cost functions, thus routes containing nodes with little remaining battery capacity may be selected resulting in early network failure. C. K. Toh in [2] presented a new approach in min-max battery cost routing (MMBCR) protocol to make sure that nodes will not be overused.

If $c_{it}$ denotes the battery cost at any time instant $t$, $f(c_{it})$ represents the battery cost function of node $n_i$ and if the function reflects the remaining battery capacity of the node, then

$$f_i(c_{it})=1/c_{it}$$

which means that higher the value of the function $f_i$, the more unwilling the node to participate in the route selection algorithm. If a route contains N nodes, then the total cost of the route $R_i$ is the sum of the cost functions of all these N nodes.

$$R_i = \min (R_j), \text{ for all } j \in A \, .$$

Here A is the set of all routes from source to destination. MMBCR selects a route based on the battery capacity of all the individual nodes. Battery cost for MMBCR is defined as

$$R_j = \max_{i \in route_j} f_i(c_{it}).$$

Therefore the desired route is given by

$$R_i = \min (R_j, j \in A)$$

where A is the set containing all possible routes. The disadvantage of this protocol is that the route selected does not ensure minimum transmission power and hence rapidly reduces the lifetime of all nodes. Thus the selected route may consume more power which actually reduces the lifetime of all nodes. Thus the battery power of nodes is not efficiently utilized. Hence there is a need to develop an energy efficient dynamic routing protocol to efficiently utilize the battery power of nodes in a mobile ad hoc network and to increase the lifetime of node and/or the network with good QoS provisioning.

## 3. PROPOSED ROUTING PROTOCOL: DYNAMIC ROUTE DISCOVERY (DRD) PROTOCOL

In the existing energy efficient protocols such as MBCR and MMBCR, once a route is selected by the route discovery process, same route is used until the data transmission is completed or until the selected route fails due to exhaustion of battery of a node in that route. If a node in the selected route has less battery power, then certainly that node will die out causing route failure and thus results in total network failure. Nodes acts as routers in a network and thus the nodes in the selected route has to forward packets continuously from other nodes. Thus to avoid the problem of overburdening the intermediate nodes in the selected route, a mechanism of dynamic route discovery is introduced in which the route discovery process is initialized periodically at regular intervals and a new route is adapted taking into consideration the battery power of intermediate nodes. This results in battery power management of nodes avoiding failure of routes and increasing the network lifetime.

## 4. SIMULATION SETUP

The Network Simulator (NS-2) [5], [6] environment is used to conduct the simulation that uses the ad-hoc networking extensions provided by the University of California at Berkeley. UDP with CBR as the traffic source is used in the simulation process. A terrain size of area 1000m*1000m with varying number of nodes from 0 to 50 are used for various network scenarios. The size of the data packet used is 1000 bytes. The number of source-destination pairs is varied to change the offered load in the network.

**Table 1. Simulation Parameters**

| Parameter | Value |
|---|---|
| Terrain Size | 1000*1000 |
| MAC layer | 802.11 |
| Routing Protocols | MMBCR, DRD |
| Number of nodes | 10,20,30,40,50 |
| Radio Propagation Model | Two Ray Ground |
| Simulation Time | 100sec |
| Traffic Source | CBR |
| Packet Size | 5KB |
| Initial Energy | 1000Joules |
| Tx, Rx & Idle Power Consumption | 0.1W |
| Bandwidth | 11MB |
| Data rate | 11Mbps |

## 5. SIMULATION RESULTS

A network scenario is created as an example network and is developed in Network Animator as shown in fig.1 using the script with Tool Command Language to compare the performance of both the proposed and existing routing protocol in terms of route failure time and network lifetime. The network scenario shown in fig.1 below consists of 10 nodes. For comparing the behavior of the two routing protocols, the positions of nodes in the network is fixed. Each node is assigned an initial energy of 1.5W. The TCL script is written in such a way that initially node 4 sends data packets to node 1 after initializing route discovery process at 0.5 seconds. By the end of simulation i.e., at 10 seconds node 4 has energy level of 1.046582W and node 1 has energy level 1.360537W. The neighboring nodes which have not contributed in data transmission process but were active during this period have their residual energies as shown in fig.2.

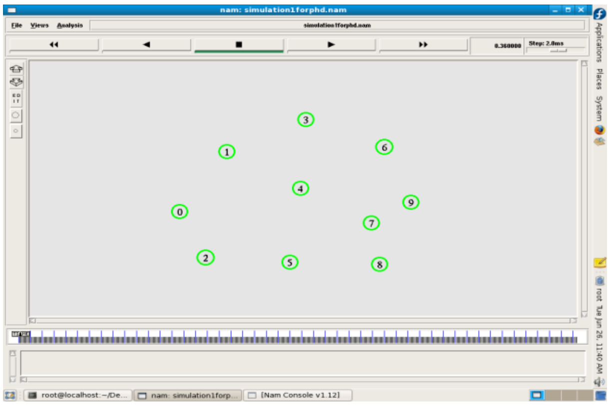


**Fig:1 A snapshot of example network to show the route selected by MMBCR and proposed DRD protocol**

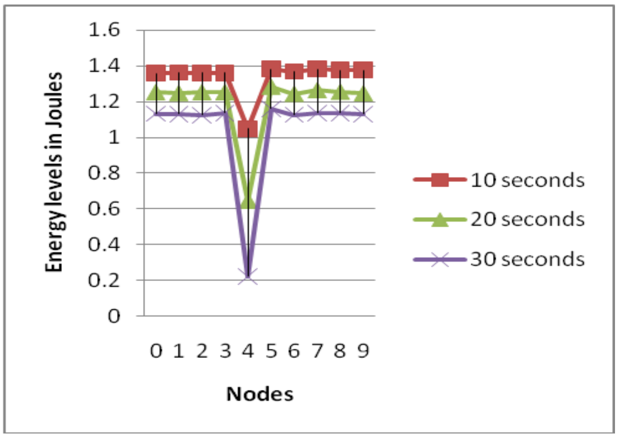


**Fig:2 Energy levels of nodes at various pause times**

At 11 seconds, node 4 is made to transmit data to node 6 after initiating route discovery process and the simulation stops at 20 seconds. At 21 seconds, node 4 is made to transmit data packets to node 7 after initiating route discovery process. The simulation stops at 30 seconds and the energy level of each node is given in fig.2 above.The main idea behind the above three simulations is to drain the energy of node 4 and it should be easy to observe the behavior of the two routing protocols as each node has a different energy level at a certain period Consider another data transmission between node 0 and node 9 i.e., node 0 is the source node and node 9 is the destination node. The route discovery process is initialized at 31 seconds.

## 5.1 Route selection by MMBCR

At 31 seconds the cost functions of each node is calculated from the trace file generated. MMBCR finds the maximum battery cost (i.e., minimum battery capacity) in a route, stores the value and then selects the route with minimum total cost function (i.e., the maximum battery capacity). The routing protocol selects that route with the minimum value of the total cost among all the routes that exists between the source and the destination. It also considers the individual node battery capacity apart from the total cost function in the selected route. The routes available between node 0 and node 9 are 0-1-3-6-9, 0-4-9, 0-5-7-9, 0-2-5-7-9, 0-5-8-9, etc. with respective cost functions 4.4145326, 6.298343, 3.507176, 4.38851, 3.505405, etc. Hence the route 0-5-8-9 is selected as it has the minimum cost function (i.e., maximum battery capacity) among all the routes mentioned above. Also each of the nodes in this route has maximum battery capacity compared to other nodes in other routes. For example 0-5-7-9 and 0-5-8-9 has almost same cost function but node 8 has more battery capacity and minimum cost function as compared to node 7. Thus, the route 0-5-8-9 is selected by the route discovery process. The advantage of MMBCR is that it avoids the route that has minimum battery capacity leading to enhancing the network lifetime. But the main disadvantage is that once a route with minimum cost function is selected; same route is used unless the data transmission is completed or unless the network fails due to exhaustion of less energy nodes in that route. The protocol does not consider the individual node battery. At 47.9 seconds node 5 dies resulting in route failure and partitioning of network. Node 5 as such was only an intermediate node in the data transmission process from 0 to 9. At 48 seconds, again the route discovery is initialized and the route 0-1-3-6-9 is selected as this is the next minimum cost function route available.

## 5.2 Route Selection by the proposed DRD protocol

In the proposed routing protocol, route selection process is initialized periodically to know the battery capacity of each node. If a node battery capacity becomes very low compared to other nodes in a route, the route discovery process selects an alternate route to avoid the exhaustion of that node in the network. The route discovery process is initialized after certain period and a new route is selected if the energy level of any node in that route is found to be low. Same TCL script is used for transmitting data packets from node 4 to node 1, node 4 to node 6 and node 4 to node 7 till 30 seconds. Due to periodic route discoveries and new routes selection, the energy levels of all the nodes may not be same as it was in case of DSR and MMBCR. To transmit data from node 0 to node 9, the route discovery is initiated and route 0-5-8-9 is selected as it has the minimum cost function among the routes available between 0 and 9.

Route discovery process is initialized again at 42.1 seconds. Unlike MMBCR, the route 0-2-5-7-9 is selected. The process repeats periodically unless the nodes in the network are exhausted or the data transmission is completed. Fig.4 below shows the network failure time of MMBCR and DRD protocols.

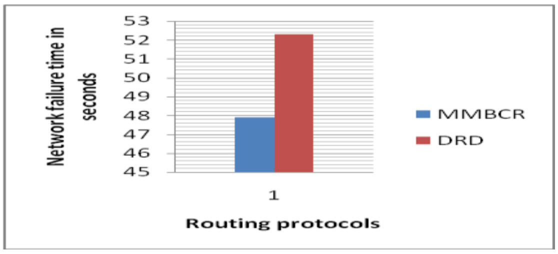


**Fig: 3 Network failure time Vs routing protocols**

Figures 4 to 8 below gives the performance comparison of DRD and MMBCR protocols in terms of throughput, packet delivery ratio, delay, residual energy and normalized routing load with varying number of sources. Throughput and packet delivery ratio increases and is more for DRD protocol due to increase in network lifetime. Average delay is somewhat more for DRD protocol due to route discovery process and also increases with number of sources. Residual energy decreases with increasing number of sources and with time but is comparatively more for DRD protocol. Normalized routing load is more for DRD protocol compared to MMBCR protocol as the number of routing packets are increased for route discovery process.

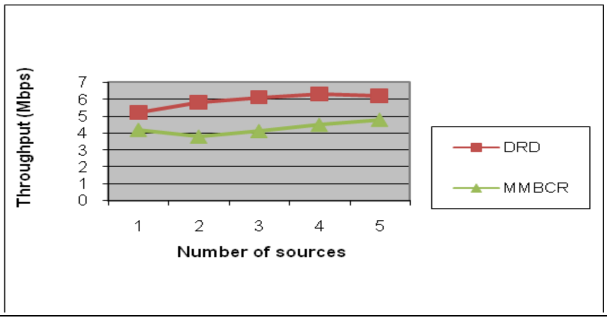


**Fig:4 Throughput Vs Number of Sources**

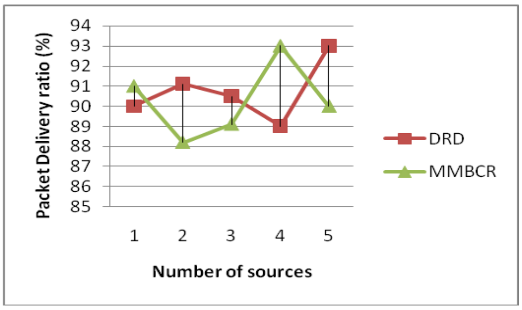


**Fig: 5 Packet delivery ratio Vs Number of Sources**

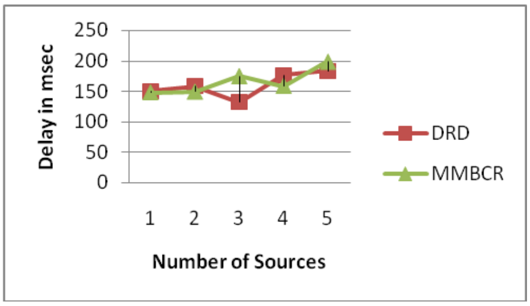


**Fig:6 Delay Vs Number of Sources**

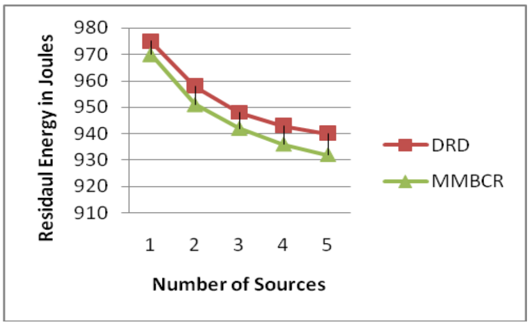


**Fig:7 Residual Energy Vs Number of Sources**

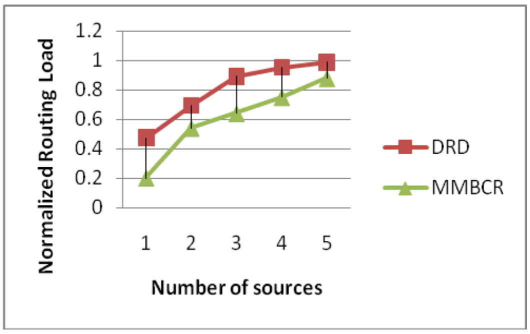


**Fig:8 Normalized Routing Load Vs Number of Sources**

## 6. CONCLUSIONS

In this paper, a new dynamic route discovery algorithm is proposed based on MMBCR in which route discovery process is initialized periodically, updating the cost function and adapting a new the route based on the battery power of nodes in that route. In MMBCR, the chances of link failure are more as the route selected is not changed unless a node in that rote is terminated due to battery exhaust. This results in network breakdown or partitioning of network. The proposed DRD protocol avoids the early termination of nodes by selecting different route through route discovery process if it finds any node in that route with less battery energy. Thus, from simulation results we conclude that the new routing mechanism provides an efficient way of utilizing the energy of nodes. The performance of the protocols is measured using throughput, packet delivery ratio, end-to-end delay, average residual energy and normalized routing load. These metrics are evaluated and compared with existing protocol by varying the number of sources. DRD protocol achieves high throughput and packet delivery ratio but has more delay and routing overhead as compared with MMBCR due to periodic route discovery. Network failure time increases by 20% with DRD protocol as compared to that of MMBCR.

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