A Novel Source Based Min-Max Battery Cost Routing Protocol for Mobile Ad Hoc Networks

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***Abstract*—In the existing energy efficient routing protocols for mobile ad hoc networks such as minimum battery cost routing (MBCR) and min-max battery cost routing (MMBCR) the cost functions are calculated in the route request phase and the decision of selecting a route is taken by the destination node. It is more cost effective and energy efficient if the cost functions are calculated in the route reply phase and the decision of selecting a route for data transmission is taken by the source node. In this paper I propose a novel routing algorithm for mobile ad hoc networks called Source based min-max battery cost routing (SBMMBCR) protocol wherein the routing decision is taken by the source node considering the changes in energy levels during the route reply phase. The performance of the proposed protocol is compared with the existing MMBCR protocol based on application oriented metrics such as throughput, packet delivery ratio, end-to-end delay, normalized routing load and residual energy. Simulation is carried out using NS2. From the simulation results it is observed that the proposed protocol SBMMBCR outperforms MMBCR by giving more network lifetime as well as better throughput, packet delivery ration. Average end-to-end delay is less and the residual energy is also more for SBMMBCR as compared to MMBCR protocol.**

***Index Terms*—Cost function, Energy level, Routing protocols, MANETs, Network lifetime, Throughput, Packet delivery ratio, Delay, Residual energy, Normalized routing load.**

I. INTRODUCTION

Mobile ad hoc networks [MANETS] [10], have gained significant attention in the past several years due to the characteristics of being infrastructureless, mobile and robust. Nodes in MANETS generally rely on batteries for their operation [4]. Due to the limited lifetime of these energy sources, battery power [1], [3] is one of the most important constraints for the operation of the ad hoc network. Extensive research efforts have been dedicated to both developing energy efficient protocols and improving the throughput of a MANET [5], [6], [7]. In this paper I have considered the problem of routing in an ad hoc network from energy efficiency point of view. Other quality of service parameters like throughput, delay, packet delivery ratio, residual energy and routing overhead are also evaluated and compared with the existing routing protocol.

The rest of the paper is organized as follows. In section 2 we present the theoretical analysis of existing energy efficient protocols. The concept of designing the proposed SBMMBCR protocol is described in section 3. The simulation scenario is presented in section 4 followed by the simulation results in section 5. Finally, section 6 concludes the paper.

II. THEORETICAL ANALYSIS OF EXISTING ENERGY EFFICIENT ROUTING PROTOCOLS

Here I present a brief description of the existing energy efficient routing protocols-MBCR and MMBCR [2]. In minimum battery cost routing (MBCR), individual battery costs are taken into consideration while selecting the route i.e., the path selected must not contain the nodes that have less remaining battery capacity. The route cost function is the sum of the individual cost functions of the nodes and a route with less energized node may be selected which is a demerit. Whereas min-max battery cost routing (MMBCR) selects a route based on the battery capacity of all the individual nodes. The cost functions are calculated during the route request phase and the decision of selecting a route is taken by the destination node. 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. Also since the cost functions are calculated in route request phase there are chances of changes in energy levels of nodes during route reply which are not considered in MMBCR. In order to overcome the above mentioned problems a new mechanism is proposed and is implemented in MMBCR. This new protocol is named Source based min-max battery cost routing (SBMMBCR) protocol.

III. PROPOSED ROUTING PROTOCOL-SBMMBCR

The proposed routing algorithm aims to increase the network lifetime by considering the changes in the battery cost functions during the route reply phase thereby making the protocol more energy efficient. The basic idea used in this protocol is described below.

In the existing MMBCR protocol, the cost functions are computed and stored in route request (RREQ) packet header while these packets are sent from source to destination. The selection of a route for data transmission is done by the destination by calculating the cost functions stored in the route request (RREQ) packets. It actually takes some time for the route reply (RREP) packet to reach the source. The energy levels of the nodes

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in the network may change during this period. Thus, the protocol does not consider these changes in energies while selecting a route. The proposed source-based MMBCR protocol overcomes this problem by calculating the cost functions in the route reply phase i.e., after receiving the RREP packets from each route; the source node selects a route for data packet transmission. The destination node receives RREQ packets through various routes and then replies to the source node immediately through the corresponding routes with RREP packets. During the process, the intermediate nodes calculate their cost functions, record the value in the RREP packet and follow the same process as was in MMBCR protocol. The source node waits for some time, receives the RREP packets and finally makes a decision of selecting the route with maximum lifetime. The route selected is used for sending the data packets. Another advantage of this SBMMBCR is that the source node receives all possible routes, stores it in the routing cache for future use. This feature is not available in MMBCR protocol.

IV. SIMULATION SETUP

The proposed algorithm is implemented using NS2 simulator [11], [12]. Fedora version 8 is used as operating system. The parameters used for carrying out simulation are summarized in table1 below.

TABLE I.
SIMULATION PARAMETERS

Parameter	Value
Routing Protocol	MMBCR & SBMMBCR
MAC layer	IEEE 802.11
Terrain Size	1000m*1000m
Number of nodes	10,20,30,40,50
Packet size	512 KB
Initial Energy	1.5 Joules
Idle power consumption	0.1W
T^x power consumption	0.1W
R^x power consumption	0.1W
Simulation time	100 seconds
Traffic source	UDP

V. SIMULATION RESULTS

A network scenario is created as an example network and is developed in Network Animator as shown in figure1 with Tool Command Language.

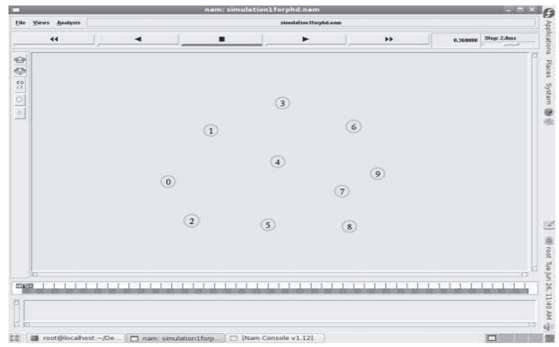

Figure 1. Screenshot showing a network scenario of 10 nodes

The network scenario shown in fig. 1 above consists of 10 nodes. For comparing the behavior of the two 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 more than nodes 1 and 4. 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 reinitiating route discovery process. The simulation stops at 30 seconds. 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.

A. Route selection by MMBCR

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) during the route request phase. The destination node selects that route with the minimum value of the total cost among all the routes that exists between the source and the destination and sends it to the source node through route reply.

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The routing protocol 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 monitor the individual node battery once a route is selected and does not consider the changes in energy levels during the route reply phase. At 47.9 seconds, node 5 dies due to exhaustion of its battery power 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.

B. Route selection by proposed protocol SBMMBCR

In case of SBMMBCR protocol, the route selection decision is taken by the source node after receiving the RREP packets from the destination node. At 31 seconds, route discovery process is initiated and after receiving the RREP packets with the updated cost functions in the route reply phase stored in it, the source node decides which route to be selected for transmission of data packets. This gives more accurate information of the energy levels of each node. The route failure time for the proposed SBMMBCR protocol is found to be 50.1 seconds which is much better compared to the existing MMBCR protocol. Fig. 2 below shows the network failure time of both MMBCR and SBMMBCR routing protocols.

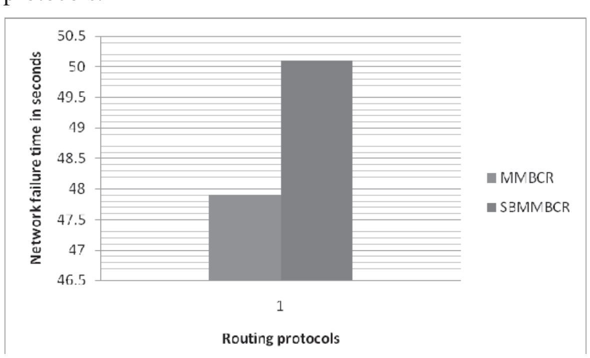

Figure 2. Comparison of route failure times of MMBCR and SBMMBCR

The following figures from 3 to 7 gives the performance comparison of both the routing protocols- MMBCR and SBMMBCR using UDP as the traffic source by varying the number of nodes. The performance comparison is based on residual energies of nodes, delay, packet delivery ratio, throughput and normalized routing load.

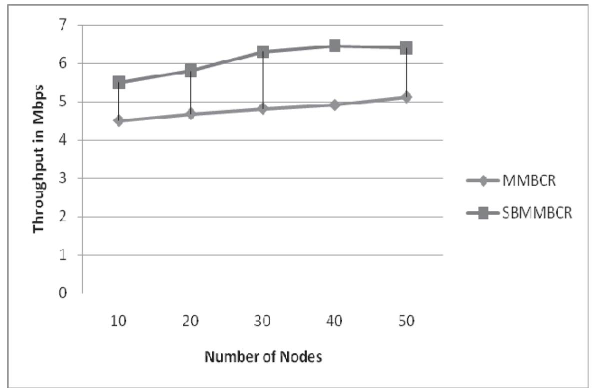

Figure 3. Throughput versus number of nodes

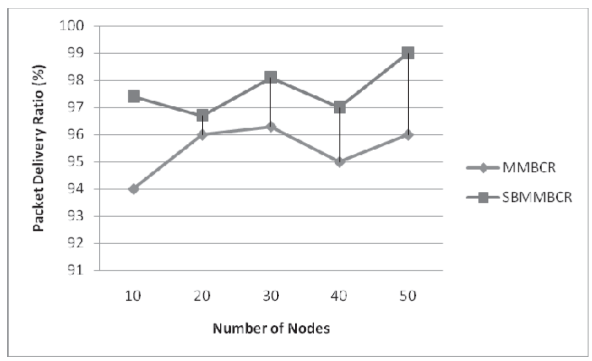

Figure 4. Packet delivery ratio versus number of nodes

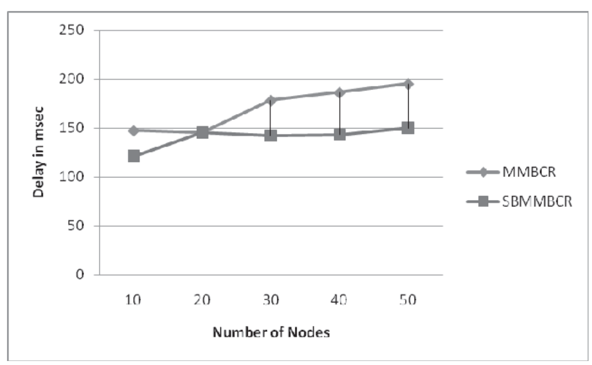

Figure 5. Delay versus number of nodes

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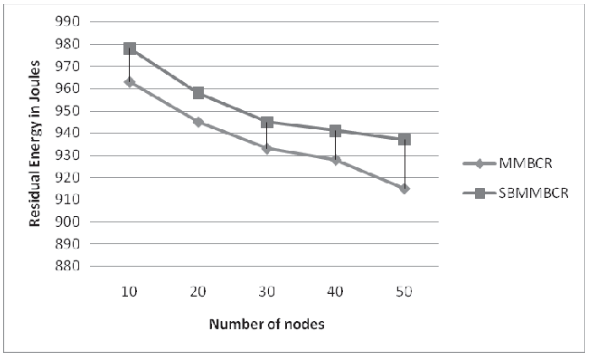

Figure 6. Residual energy versus number of nodes

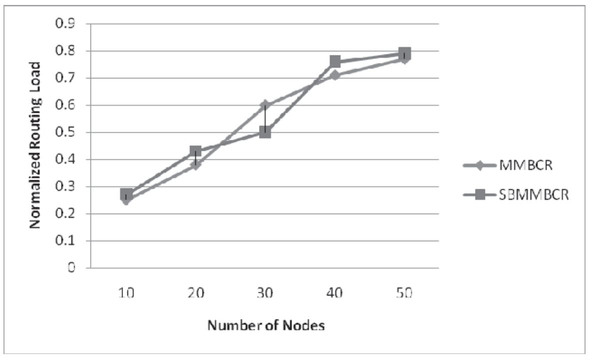

Figure 7. Normalized routing load versus number of nodes

CONCLUSIONS

In this paper, the existing MMBCR protocol is analyzed where the cost functions are calculated in the route request phase and the decision of selecting a route is taken by the destination node. A novel routing algorithm for mobile ad hoc networks called Source based min-max battery cost routing (SBMMBCR) protocol is proposed wherein the routing decision is taken by the source node instead of destination node considering the changes in energy levels during the route reply phase. The performance of the proposed SBMMBCR protocol is compared with the existing MMBCR protocol based on application oriented metrics such as throughput, packet delivery ratio, end-to-end delay, normalized routing load and residual energy. From the simulation results it is observed that the proposed protocol SBMMBCR outperforms MMBCR by giving more throughput and packet delivery ratio due to extended network lifetime. The network lifetime for a 10 node network with UDP as traffic source is found to be 47.9 seconds whereas for the proposed protocol it is 50.1 seconds. Delay and normalized routing load is also comparatively less for SBMMBCR as compared to MMBCR. Residual energy though decreases with time is more for SBMMBCR as compared to MMBCR protocol.

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