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An Energy Aware Routing for Manets Using Dynamic Power Threshold with Load Balancing

R. Pushparaj and M. Dinakaran

SITE School, VIT University, Vellore, Tamilnadu, India

Abstract: Mobile Ad hoc Networks (MANET) are highly becoming an important part of all kinds of mobile users i.e. both in commercial and non-commercial based organizations and its future products. Routing in MANET has been the most over researched topic as it requires more reliability while forwarding the packets to the neighbor or a destination with promising routing constraints in place. Developing a more scalable, energy efficient and reliable routing protocol for MANET is largely limited by its design constraints such as Size, Width Adaptability and Portability. This research paper has proposed a Dynamic Threshold Value Calculation algorithm and also proposed a neighbor discovery procedure to reach the destination. With these parameters, the proposed algorithm found an optimum transmission power route to the destination without overloading the network nodes too much. The proposed work was implemented in NS 2.34 simulator in Fedora Operating System, where the results showed that the proposed approach has offered better results than Maximum Battery Cost Routing (MBCR) and Minimum Cost Routing (MCR) in terms of Energy Consumption rate, Remaining Residual Energy and Packet Loss Ratio.

Key words: Mobile Ad hoc Networks · Energy Efficient Routing · Dynamic Threshold · Neighbor Discovery · Optimum Power Transmission

INTRODUCTION

Mobile Ad Hoc Networks are self-organizing and self-configuring networks made up of a collection of mobile nodes on demand, which routes packets through wireless medium where each node can act as a host and a router [1]. MANET does not require any existing infrastructure or centralized administrative management. It has limited operational resources that need to be effectively utilized to improve the performance of the entire network [2]. The Key challenge in Mobile Ad Hoc Networks (MANETs) routing is to achieve energy efficiency and to increase network lifetime without degrading the network performance too much [3, 4]. Though, military applications are considered as the primary application of MANETs, commercial interests on MANETs are also growing in the recent past such as emergency applications, Educational Uses and Law enforcement operations and environmental applications and so on [5].

Energy Consumption Model: According to the authors [4], a single node failure in MANETs can lead to the loss of connectivity, which in turn, can affect the communication activities of other nodes in the network. In MANETs, mobile nodes are equipped with either replaceable or rechargeable batteries which has limited energy quantity. Therefore, energy efficiency continues to be the key challenge and factor in determining the network lifetime and network performance [6]. In MANET, generally, energy efficiency can be achieved, by avoiding routing packets through low residual power nodes, by reducing routing overhead caused by flooding and by minimizing packet loss caused by medium collisions and interference.

Basically, a wireless network medium can be in the following states: Transmit, Receive and Idle or Sleep. An experimental study conducted by [7] has found that handheld devices spend only 50% of its battery power for network related activities (where a node can decode a packet) and the rest on overhearing and packet forwarding activities (no decode takes place). The power consumed by a node while transmitting and receiving can be represented as follows [8],

$$E_{tx}=P_{tx}*\text{Duration}; \quad (1)$$

Corresponding Author: R. Pushparaj, SITE School, VIT University, Vellore, Tamilnadu, India.

where, E_{tx} = Transmitting; P_{tx} =Power value per packet to transmit

$$E_{rx}=P_{rx}*Duration; \quad (2)$$

where, E_{rx} = Receiving; P_{rx} =Power value per packet to receive

Energy Efficient Approaches

Objectives: According to C Yu, B Lee and H.Y. Youn [9], mobile nodes consume energy during both active and inactive communication. Transmission Power Control (TPC) and load balancing approaches (LBA) achieves energy efficiency when the nodes are actively participating in active communication, whereas Sleep/Power Down approach only minimizes node's energy when they are idle or inactive. R Pushparaj and M Dinakaran [8] highlighted that TPC achieves energy efficiency by reducing the total transmission cost with an increase in hop length, but this leads to over utilization of individual nodes or group of nodes [10] stated that load balancing approach achieves energy efficiency by effectively distributing network loads among the energy rich nodes of MANETs.

Sleep/Power Down approach utilizes the advance features of mobile nodes to save its energy by putting them into sleep mode whenever possible. To help network functioning, it adopts Master-Slave rule, where master node will be listened by other network nodes periodically [11].

Issues: Transmission power optimization approach not only minimizes the energy conservation but also controls the network interferences. Moreover, it works better when node's transmission power is controllable i.e. Power variable model. But, reducing transmission power does not imply a decrease in the receiver's sensitivity. Preventing nodes from overloading approach is more appropriate where the network traffic and node density is higher than a normal uniform network. Thus, mobile nodes can be prevented from overloading and under-utilized nodes can be used efficiently in order to keep the network functioning. At times, this approach results in high end to end delay and fails to achieve QoS provisioning. Idle/Power down approach is more suitable for the network with less traffic and communication as it focuses on nodes inactive energy.

Structure of the Paper: This paper was aimed to utilize the available mobile nodes limited energy by calculat 6t5ying and assigning dynamic energy threshold value for the entire network. Significant research works has been carried out on energy threshold optimization to increase the network lifetime and improving the entire network performances with minimum degradation. The rest of the paper is organized as follows: Related work of this research study, proposed work methodology and network scenario and experimentation results analysis. The paper ends with conclusion and future research ideas.

Related Work: Thus far, many routing schemes have been proposed to achieve energy efficiency in both active and inactive states of mobile nodes in a network. In [12], energy threshold value was assigned each node in the network and nodes that have less residual energy than the threshold value are avoided and optimum path with energy rich nodes was followed. Another approach [13], avoids nodes with less residual power than the threshold energy to achieve fair use of nodes energy and achieves equal power consumption by transmitting equal length of packets where packets are divided into equal lengths at the source node before transmission. Smallest Common Power [14] was aimed to maintain connectivity of the entire network by just adjusting its power level as needed. This approach has adopted variable transmission power model which allows every node to adjust its power just enough to proceed with packet forwarding or transmission to ensure network connectivity. But, this approach suffers of high routing overhead in the network, thus results in degraded network performance. LEAR [15] protocol follows a simple power threshold value, where a node participates in the network activities if its residual energy is greater than the threshold value. Conditional Min-Max routing [16] approach is an enhanced LEAR approach. It selects the min power nodes among the route where all the nodes have higher residual energy than the power threshold and selects the max power nodes from the route where all the nodes have lower residual energy than the power threshold. Minimum Energy Dynamic Source Routing [17] used two power levels during route discovery process. Initially, a source node tries to discover a route to destination with low power level, if destination could not be reached with that level; it increases its power value to reach the destination. This approach focused on energy consumption related to data packet.

Proposed Method

Parameters Considered: This study assumed that for a given data rate R_b and node spatial density ρs, the required minimum transmit power for achieving full connectivity over network can be denoted as follows:

$$P_{t\min} = \frac{\rho \min energy Rb}{\rho s} \tag{3}$$

In general, while considering a mobile ad hoc network with fixed number of nodes with movement over a large surface, the minimum transmit power would increase proportionally to maintain network connectivity as the node movements decrease the network spatial density. To control transmit power increase, the data rate has to be kept reduced to achieve network lifetime and connectivity [18].

Dynamic Threshold Value: A mobile node's residual energy after participating in network activities for time period 'k' can be written as,

$$E_{res} = E_i - E_c(k) \tag{4}$$

where E_{Res}represents the mobile nodes residual energy at time 'k', where k=t_1, $t_{2, \ldots,}$ t_n.
$E_{c(t)}$ represents the energy consumed by a mobile during time interval 'k'.
$E_i$represents the initial energy of a mobile node at the beginning of time interval 't_i'.

A mobile Ad hoc network has 'n' number of nodes which can be represented by,

$$U = \{M_1, M_2, M_3, \ldots, M_n\}$$

This work assumes that the source node is always '1' and destination can be more than '1'. So, the source node is part of the universal set 'U', which can be written as, $S \in U$.

We calculate dynamic threshold value (D_{Thr}) with the following equation, A^k.

$$D_{Thr} = \left[\frac{Total\ Network\ Cost}{No.\ of\ Nodes\ alive}\right]_{at\ time\ 'k'} \tag{5}$$

The 'total network cost' can be represented by the following, where P_i^k is the power of i[th]node at time interval 'k'.

$$Total\ Network\ Cost = \sum_{i=1}^{n} P_i^k$$

After time interval 'k', the network set 'U' can be written by identifying number of nodes exhausted (N_{Exh}) during time interval 'k'. This can be written as,

$$B = \{N / N = N_{Exht}\} at\ time\ 'k'$$

Therefore, the number of nodes alive (A) after time interval 'k' can be written as $A = U - B$. The above equation can be mathematically written as follows,

$$D_{Thr} = \frac{\sum_{i=1}^{n} P_i^k}{A^k} \tag{6}$$

Neighbor Discovery: When a source node initiates route request by broadcasting route_req () messages, it get replies from its neighbors (nodes within sender's transmission range). Source node has to select one of its neighbors as its next hop to proceed with the transmission. Here, source node S_i gets replies from its neighbors N_r and, N_r can range from 1 to n. We assume that source node have at least one neighbor in its transmission range. One of the nodes from the set N_r would be chosen as next hop and considered as a new source node SN_i. That is,

$$N_r = \{N_1, N_2, \ldots\ldots, N_n\}$$

from the above set, source node S_i selects next hop, ie. N_i.

$$SN_i = N_i \in U \ni N_i \in N_r{}^j,\ where\ j = t1, t2, t3 \ldots tn.$$

$$SN_{i+1} = N_{i+1} \in U \ni N_{i+1} \in N_r{}^{j+1},\ where\ j = t1, t2, t3 \ldots tn.$$

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$$SN_j = N_i \in U - \sum_{l=1}^{j-1} SN_i \ni N_i \in N_r{}^j,\ where\ j = t1, t2, t3 \ldots tn.$$

$If\ SN_j = D,$ then $Stop.$

$$E_{route} = S_i \rightarrow SN_i \rightarrow SN_j (or) D \tag{7}$$

where, E_{route} represents the energy efficient routing path to the destination D. The route begins with the original source node S_i and moves to new source nodes (next hops) SN_i. This steps continued until the packets reaches the destination SN_j (ie. D).

Optimal Transmission with Load Balancing: To achieve energy efficiency, variable transmission power model was adopted during the transmission of packets. Determining dynamic threshold value helped to achieve load balancing among the network nodes to keep the network functioning, thus, to make an increase in network lifetime parameter.

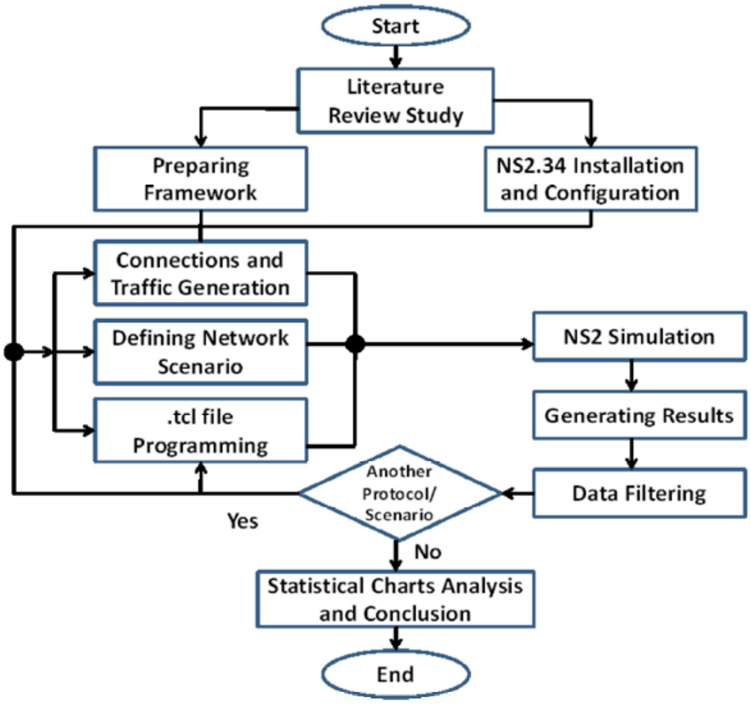

Fig. 1: Workflow of Proposed Method

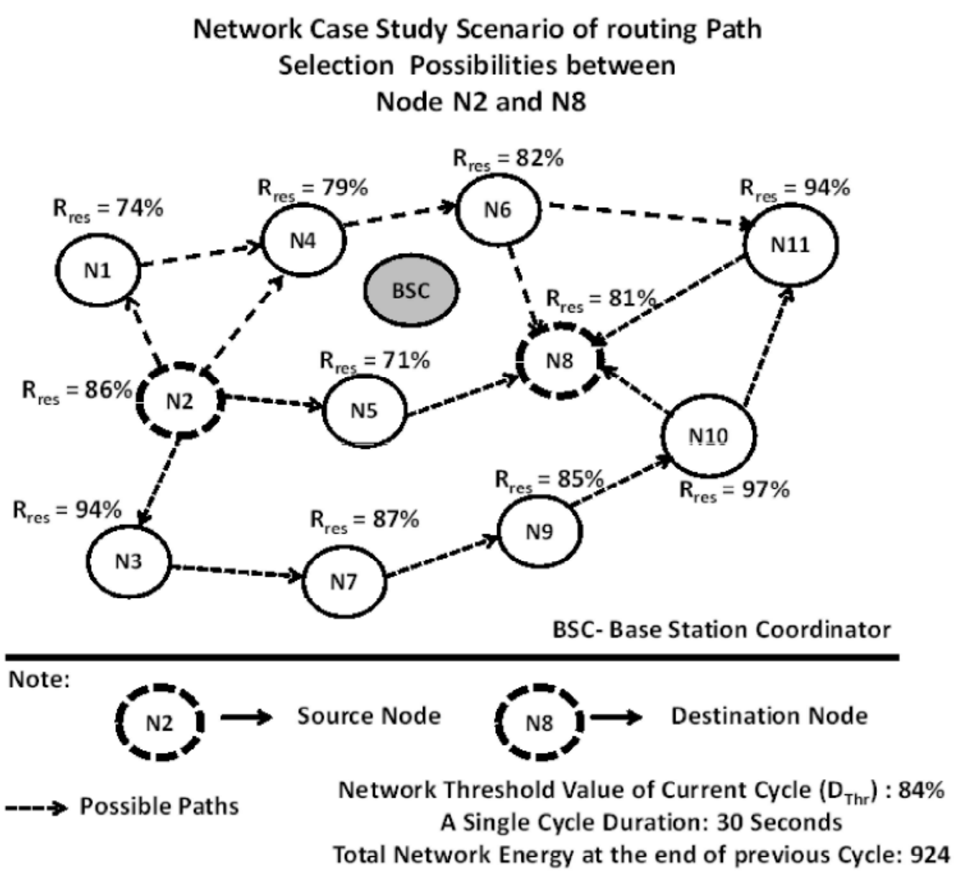

Fig. 2: Possible routes between node N2 and N8

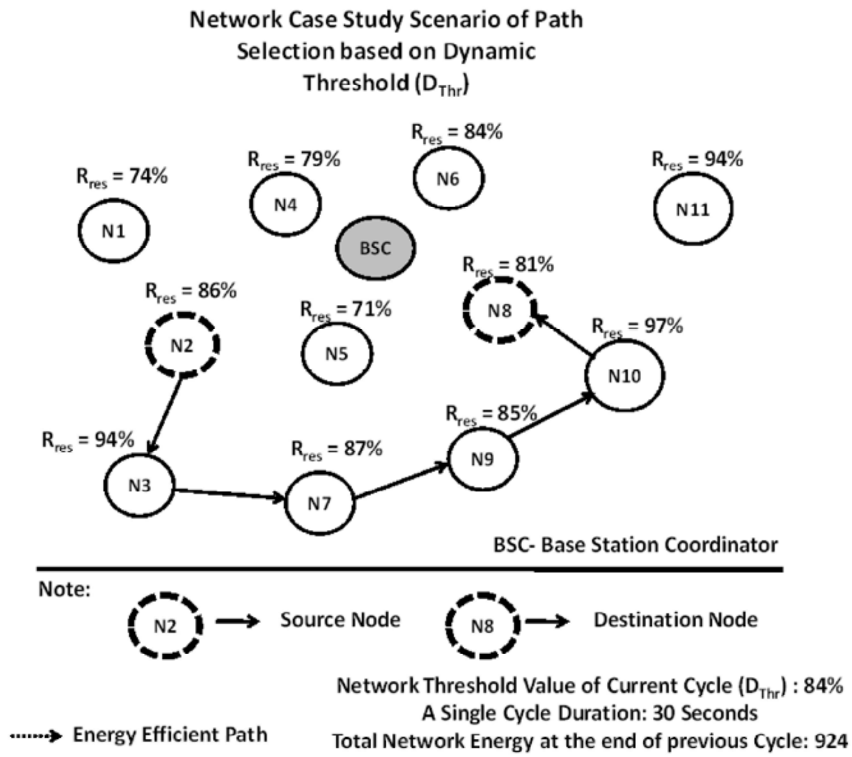

Fig. 3: Possible routes between node N2 and N8 with Dynamic Threshold Value (D_{Thr})

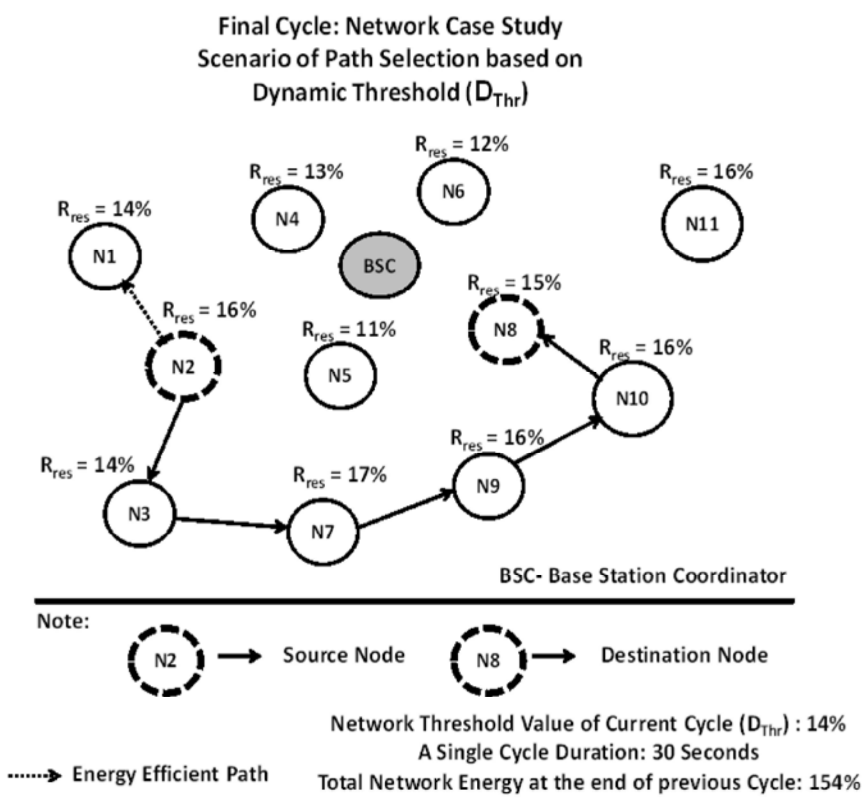

Fig. 4: Possible routes between node N2 and N8 with Dynamic Threshold Value (D_{Thr})

Network Scenario: Assigning dynamic threshold value helps to maintain the network connectivity and also stabilizes network lifetime of the entire network. It also achieves load balancing by effectively utilizing the available nodes energy and by maintaining network balance throughout. The following figures illustrates that the possible routes to reach the destination and also shows the optimal route to the destination by calculating Dynamic Threshold Value for every cycle of the network activities. Determining and assigning threshold value for every cycle not only helps to increase network connectivity and lifetime, it also prevents the nodes from being overloaded. Thus, distributing the network activities among all the noes in the network helped balancing the nodes lifetime.

This study has assumed a network scenario shown above (for understanding purposes), where the source node is N2 and the destination node is N8. Fig. 2 represents the all the possible routes to reach the destination through different nodes of the network with different number of hops, end to end delay and transmission cost. Fig. 3 shows the optimal route to reach the destination N8 from N2 with dynamic threshold value of the current network cycle. Fig. 4 depicts the worst case or possible final cycle of the given network scenario, where optimal route to the destination was found with dynamic threshold value calculation.

RESULTS

Network Simulator 2 was widely used network simulation tool among the academicians and the researchers for implementing the proposed methodology and algorithms in order to obtain the results and analyze its performance with various network parameters, in some cases, with other existing protocols. To evaluate this proposed approach, the researcher has installed NS 2.34 simulator in Fedora 15 operating system. The simulation setup has 100 mobile nodes, two way ground propagation model and random way point mobility model and TCP was used as a network layer protocol. The results were analyzed using the following parameters:

- Remaining residual energy
- Energy Consumption Rate and
- Packet Loss Ratio.

Network traffic trace files were drawn and analyzed and the analyzed results were presented here in the form of graphical representation using Microsoft Excel 2010.

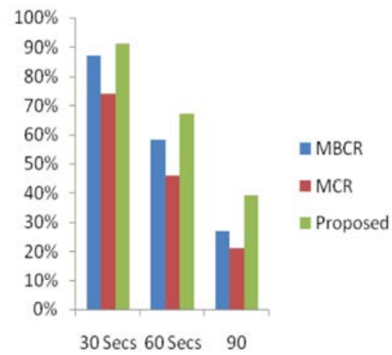

Fig. 5: Remaining Residual Energy (Every 30 Secs)

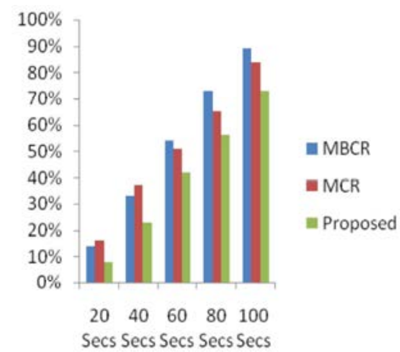

Fig. 6: Energy Consumption Rate (Every 20 Secs)

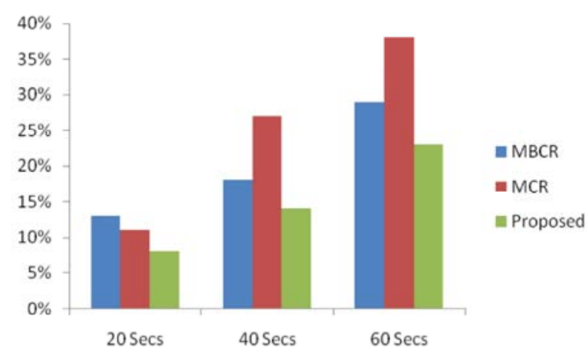

Fig. 7: Packet Loss Ratio (% Pkts)

Bar charts were used to represent the data findings of this research study. In Fig. 5 and 6, x-axis represents the simulation time in seconds and y-axis represents percentage of energy remaining (Fig. 5) and percentage energy consumed (Fig. 6), respectively. In Fig. 7, x-axis represents the percentage of packets lost during the packet transmission to neighbor nodes or to the destination and y-axis represents the simulation time in seconds. From these findings, it is evident that the proposed approach has performed well in terms of remaining residual energy, energy consumption rate and packet loss ratio when compared with Maximum Battery Cost Routing and Minimum Cost Routing.

CONCLUSION

As the technological world is going wireless, the demand to develop and have a more reliable, scalable and energy efficient routing protocols has become increasing. Energy efficiency is the most talked about phenomenon in MANETs, where numerous number of routing protocols had been proposed and practiced. In this study, we proposed and implemented a routing protocol with dynamic threshold value to distribute the network load among all the mobile nodes. Dynamic threshold value enabled the nodes to remain active and alive, which also helps in distributing network activities among the mobile nodes to increase the network lifetime and connectivity. Optimal transmission power model adjusts its transmission power in order to reach its nearest neighbor node in the network. Thus, nodes are saving its residual energy and also reduce the total transmission cost to reach the destination node. The proposed approach has outperformed the performances of MBCR and MCR protocols.

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