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Signal Strength and Residual Power Based Optimum Transmission Power Routing for Mobile Ad hoc Networks

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Abstract

In general, mobile nodes operate with limited batter power which needs to be fairly utilized in order to perform network functioning activities such as routing, increasing network lifetime and network connectivity etc., Many protocols have been proposed to minimize energy consumption rate of nodes to maximize the network functioning without degrading the performance too much. This paper has proposed a signal strength and residual power based optimum Transmission Power Routing approach which use variable transmission power model with measured Received Signal Strength and low residual power parameters to achieve energy efficiency, and to increase the network lifetime and connectivity. The ns-allinone-2.34 simulator was installed in Fedora 15 operating system and has been used for implementing the proposed approach. The results were compared with Energy Consumption Routing (ECR) and Max-Min Battery Cost Routing (MMBCR), which showed that the proposed approach offered better performance than other protocols in terms of energy consumption rate, network lifetime and end to end delay metrics.

Peer-review under responsibility of the Organizing Committee of ICCC 2016

Keywords: MANET Routing; Energy Efficiency; Transmission Power Control; Received Signal Strength; Node Mobility; Residual Power, Network Lifetime.

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1. Introduction

A Mobile Ad hoc Network (MANET) is a collection of mobile nodes offering communication over shared wireless medium with limited battery capacity and without employing any centralized infrastructure in place. Therefore, utilizing nodes available power and having a mobility prediction method to update the node's status is very important in MANET routing[1]. The following features of MANET impose many challenges on its routing activities.

- **Limited Battery Capacity:** Mobile nodes are battery powered; therefore, the available battery capacity must be utilized efficiently to keep the network functioning.
- **Node Mobility:** Dynamic node movement in MANET results in time varying topology, thus route maintenance is vital for continuing communication when a link is broken.
- **Traffic Overhead:** Exchanging of control messages may often lead to increased network traffic overhead especially, when node density is high[2].

2. Energy Efficient Routing:

Basically, there are three approaches that are solely dedicated to achieve energy efficiency with increased network performances in terms of network connectivity, network functioning and network lifetime, namely, Transmission Power Control (TPC) Approach, Load Balancing Approach (LBA) and Sleep/ Power Down Approach, where TPC and LBA saves node's power when they actively participates in network activities and Sleep/Power Down approach saves node's power when they are idle. However, all these approaches aimed to maximize the network lifetime by minimizing the energy consumption of mobile nodes[3].

2.1 Transmission Power Control Approach:

This approach aims to minimize the total transmission cost required to complete a communication between the Source and Destination nodes. It is achieved in the following two ways: Constant Transmission Power and Variable Transmission Power. In variable transmission power model, node's radio transmission power is controllable and can be varied as required, whereas constant transmission power model works with fixed transmission power value. Protocols that belong to TPC select the path that consumes minimum energy to reach destination. Thus, nodes with high transmission power reduces the hop count and end to end delay to reach destination, whereas nodes with low transmission power results in increased hop length and end to end delay[4].

3. Literature Study:

Toh[5] developed an energy efficient routing MTPR (Minimum Transmission Power Routing) which considered a simple energy metric of TPC, minimizing total energy consumed by a route to reach destination node. Toh[5] proposed MBCR (Minimum Battery Cost Routing) which avoids low residual power nodes in a route and MMBCR (Minimum Maximum Battery Cost Routing) identifies weakest and crucial node in each route and selects the path with the best condition among available routes.Toh[5] proposed Conditional MMBCR routing had a predefined threshold value and aimed to select a route which consists of energy rich nodes (over threshold) as a best case, and to have at least one node in a route which has low residual power (less than threshold) as a worst case to balance the network functioning and increase the network lifetime. Kunz[6] stated that reducing overall transmission energy would be more advantageous when multiple short hops are used rather than using a single hop routing. Kim[7] proposed Minimum Drain Rate (MDR) which achieves maximum network lifetime by considering Drain Rate Index (DRI) and remaining residual power (RSP) to estimate the energy dissipation rate of an individual node in the network. Misra and Banerjee[8] added another metric of nodes energy consumption during possible retransmissions. Ingelrest et al., [9] have proposed protocols where mobile nodes can adjust its transmission power when required.

Selecting and employing mobility models and mobility prediction techniques are extremely important in MANETs because it describes the node's movement (node's location, transmission range) from time to time[10]. In Random Walk Mobility (RWM) model, a mobile node moves in any direction randomly, where the ranges are predefined with speedmax and speedmin, and $[0, 2\pi]$, respectively. In this model, node's movement can be estimated in the following two ways: (1) with a constant time interval *'t'* or with a constant distance travelled *'d'*[11]. H Moustafa and H Labiod[12] have predicted future link states of a node to offer stable paths with increased energy efficiency. This was achieved by updating node's neighbour stability table based on Received Signal Strength (RSS) value of its neighbour nodes. S MacLean and S Datta[13] have applied WMCL-B node positioning algorithm to collect local connectivity information of all nodes that exists within its range *R.* Each mobile node is equipped with GPS and a sample based positioning was used to set node positions which offered more flexibility and efficiency in node positioning.

A Zadin and T Fevens[14] have proposed GBR-NP which achieved path stability with node failure by calculating node protection backup path. GBR-NP achieved both node protection and link protection with node failure in MANETs. It avoids the need of recalculating the complete path when a node exhausted during packet transmission. In our previous work[15], both Received Signal Strength and Node Mobility Distance parameters were considered to achieve energy efficiency using Location Aided Algorithm with base station coordinator. In this proposed work, we have considered node's residual energy and variable transmission power model along with received signal strength and node mobility distance to enhance energy efficiency, network connectivity and lifetime.

4. Proposed Work

We assume that each mobile node in a network maintains its neighbour index routing table which is used as a reference while performing routing activities such as packet transmission and packet forwarding. Each field will be updated when a node receives new information from its neighbouring nodes (nodes within its range). Table.2 represents the neighbour index routing table format.

Table 1.Neighbor Index Routing Table Information

Neighbor	Received Signal Strength Power Consumption Value	Node Position	Distance	Residual Power

The proposed approach considers the following parameters determine the energy efficient route by adjusting its transmission power to reach the destination node with minimized energy consumption rate.

4.1 Measuring Received Signal Strength

The higher Received Signal Strength Value, the closer is neighbour to Node 'A' (Sender). The Friss transmission equation is commonly used to calculate the received signal strength of a mobile node. The equation is given as[16],

$$P_R = \frac{P_T * G_T * G_R * \lambda^2}{(4 * \pi * d)^2} \quad (1)$$

4.2 Measuring Mobility Movement

While receiving a packet both the transmitter and receiver calculate the RSS value in order to estimate the location of each other. The difference between successive hello messages helps them to estimate the mobility between a pair of nodes in a network and it can be calculated as follows,

$$d_t = \frac{k}{\sqrt{P_R}} \quad (2)$$

Where, k is a constant, d_t is the distance and P_R is received signal strength.

Fig.1 Workflow of the Proposed Approach

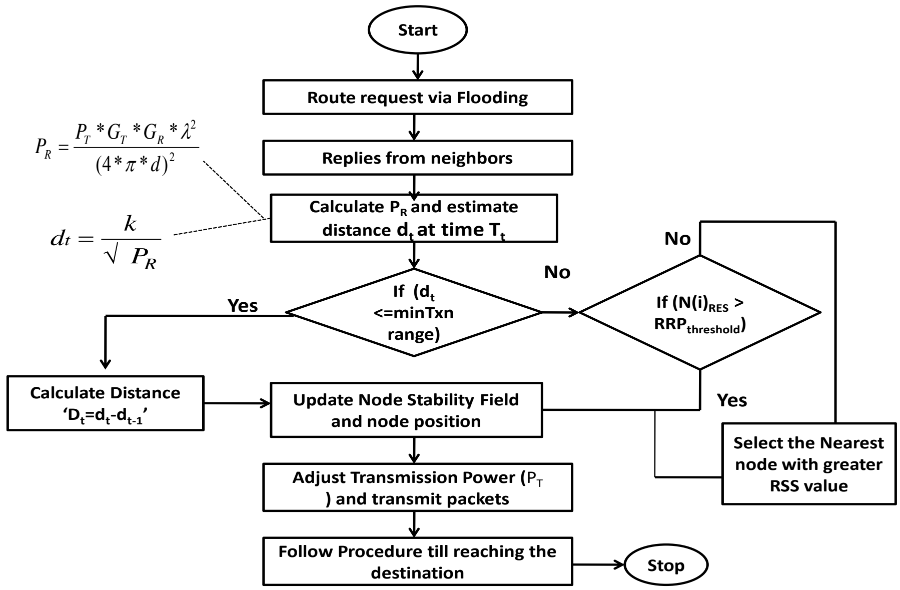


Fig.1 represents the overall working methodology of this research work represented as a flowchart.

4.3 Measuring Node Distance

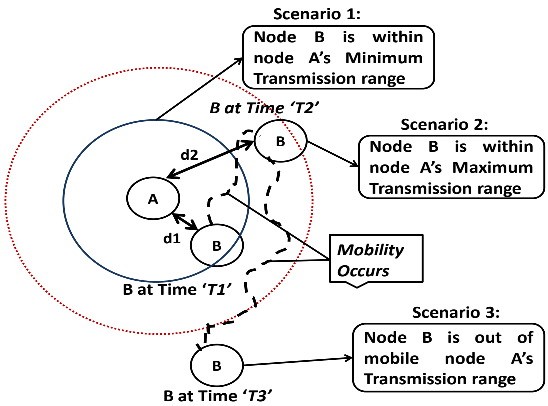
Now, node A calculates the difference of the estimated distance to the neighbouring node B at two successive time intervals at T_1 and T_2.

$$D = d2 - d1 \quad (3)$$

Where, D is difference between d_1 and d_2 estimated at time intervals T_1 and T_2 [17]. Here, we have defined a threshold value for the distance which is greater than the minimum transmission range and less than the maximum transmission range.

Fig.2depicts the node's minimum and maximum transmission range with mobility movement in the network. Node A's transmission range is shown in fig. 2 and node B's mobility at different time intervals T_1 and T_2 are shown with distance d_1 and d_2. At time T_3, node B moves away from node A's transmission range, thus it cannot be reached from node A. In fig. 2 represents that node 'A' initiates transmission by flooding route request packets to all the nodes within its transmission range and waits for the reply messages. Upon receiving reply messages from its neighbours, it selects its next hop based on the proposed algorithm (see Algorithm 1). In this example scenario, it selects node 'B' as its next hop, since it have higher received signal strength than other neighbour nodes which allows the sender to minimize its transmission power just enough to reach node 'B'. Thus, node 'A' saves its valuable limited energy while transmitting packets to node 'B'.

Fig.2 An example Scenario for Mobility Movement in a MANET

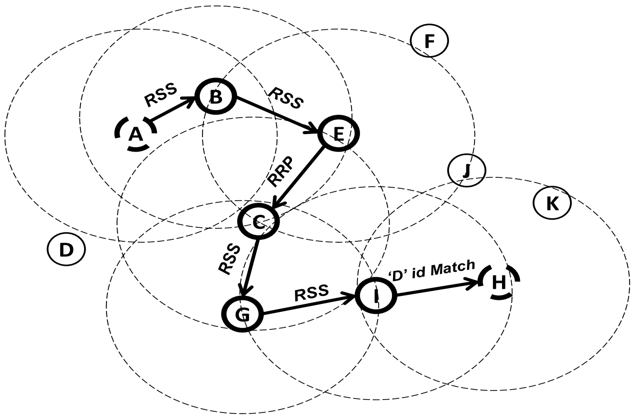


Algorithm 1: Signal Strength and Residual Power based optimal transmission power routing
Inputs: Predefined Network scenario, received signal strength (P_R) and residual power
Output: Energy efficient routing path to destination

1. Source node (S_i) initializes the transmission by flooding route_req () msgs to its neighbors
2. For every neighbor node i=1, 2 ….n, node (S_i) computes the RSS value upon receiving route_rep () msgs.
3. // P_R calculation from eqn. (5) and distance d_t calculation at time T_t from eqn. (6))
4. If (d_i <=minTxn range)
   a. Calculate Distance $D_t=d_t-d_{t-1}$ at time T_t, where t=1,2….n.
   b. Update the node stability index and node's position with D_t
   c. adjust transmission power of node (S_i)
   d. Proceed with packet forwarding and follow step 8 for each stage;
5. Elseif ($N(i)_{RES}> RRP_{threshold}$)
   a. update the node stability index and node's position
   b. adjust transmission power of node (S_i)
   c. Proceed with packet forwarding;
6. Else
   a. Select the nearest node with greater RSS value
   b. update the node stability index and node's position
   c. adjust transmission power of node (S_i)
   d. Proceed with packet forwarding;
7. Repeat the procedure from 5 to 9 till reaching the destination.
8. Update the route and Terminate Algorithm.

Fig. 3 represents the sample routing path selection using the proposed algorithm (Algorithm 1), where A is source node and H is the destination node. Each transmission link in Fig. 4 represents the parameter considered for selecting a node as next hop or neighbour node. Received signal strength value (P_R) was considered by nodes A, E, C, I to select its next hop node to reach destination 'H', whereas node 'E' considers residual energy because node J, F and C are present within node E's maximum transmission range. In order to reach C, node E has to maximize its transmission power, so to achieve energy balancing it selects the node with maximum residual power than the $RRP_{threshold}$ value. Even though node E spends more of its remaining energy to transmit packets to node C, it selects the energy rich node within its transmission range. Thus, node E adjusts its transmission power and maintains network connectivity by selecting energy rich nodes in the network. For node G, node I is the only node which exists in its range, so it is the nearest neighbour of node G. so, it selects node I as its next hop to reach the destination. Thus, an optimal energy efficient route is established between the sender A and destination H.

Fig.3 Energy Efficient Routing Path between Node 'A' and Node 'H": Example Scenario



Note: RSS- ***Received Signal Strength,*** **RRP-** ***Remaining Residual Power***

5. Network Simulation

For this research study, necessary literature study was learned during the learning phase and findings were analysed as a first step. NS 2.34 version of Network Simulator was downloaded from (www.nsnam.com) and installed in Fedora 15 Linux Operating System and configured. Based on the defined network scenario, number of nodes was defined with relevant connections and network traffic patterns.

Table 2 Network Parameters for the simulation study

Network Parameters	**Parameter value or description**
Simulation Coverage Area	800*1200
Number of mobile nodes	30, 50 and 90
Number of Connections	10, 20 and 40
Simulation duration	90 (in seconds)
Network Protocols	ECR, MMBCR and Proposed
Transport Layer Protocol	Transmission Control Protocol (TCP)
Propagation Model	Two Way Ground
Mobility Model	Random Way Point
Type of Antenna	Omini-directional

6. Performance Metrics

The NS2.34 network simulator was used to implement and evaluate the protocols of study. The experimental study has considered a network scenario with varying number of nodes 30, 50 and 90 with 10, 20 and 40 connections respectively. To determine and compare the performance of these protocols, the study has used the following performance metrics:

Network Lifetime: In MANET, network lifetime is measured as the time to the first node failure. With 30 and 50 nodes proposed approach performed over ECR and MMBCR by far, but with 90 nodes ECR and MMBCR achieved almost similar performances where ETPCR bypassed the performances of other two protocols of this study shown in Fig. 4 (a). Since proposed approach aimed to attain balance between node stability, RSS value and residual power of a node, it achieved higher network lifetime in all scenarios of 10, 20 and 40 connections.

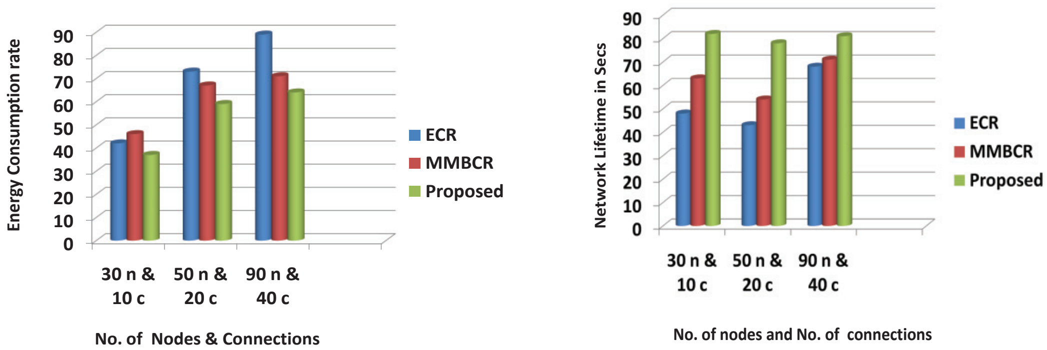


Fig. 4. Energy Consumption Rate (a) and Network lifetime (b) with varying Nodes and connections

Energy Consumption rate: The overall energy consumed by all nodes to perform routing related activities was considered as energy consumption rate. We employed common network traffic for all the given protocols; with 90 nodes proposed approach performance was much greater than ECR and MMBCR. Therefore, proposed approach has efficiently utilized mobile nodes power for routing packets over the network shown in Fig. 4 (b).

Remaining Residual Power: This metric represents the remaining power of mobile nodes after its participation in the network related activities. Since proposed approach reduced the overall transmission cost of the network, it stayed at top with high percentage of remaining power shown in Fig. 5 (a).

End to End Delay: It is an important metric of this study as the nodes has to share and update network management information as quick as possible. With the specified network scenarios, proposed approach suffered small delays as number of nodes increase shown in Fig. 5 (b), but it still offered better performance than ECR and MMBCR.

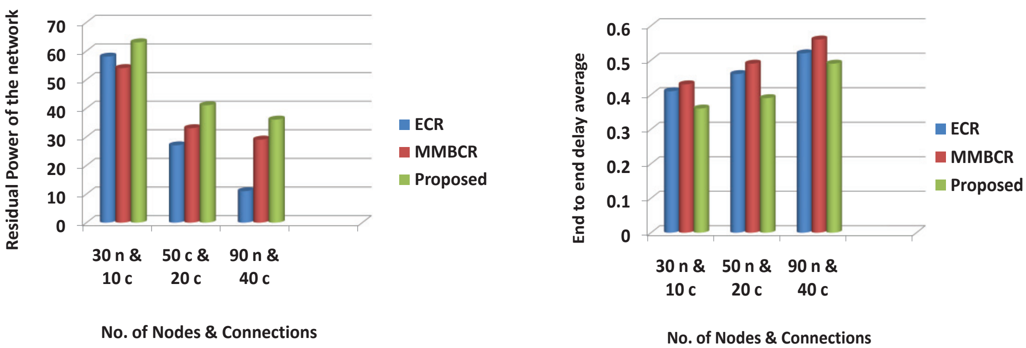


Fig. 5. Residual Power of the Network (a) and End to end delay average (b)

7. Conclusion and further research

A routing protocol cannot satisfy the need of minimizing energy consumption of MANET for all given network scenarios. It encourages the researchers to study the existing protocol's functionalities and help them to come up with new approaches which are efficient than existing approaches. This research study has evaluated ECR, MMBCR and compared the results with proposed approach, where results showed that proposed approach attains increased network lifetime and minimizes energy consumption rate of mobile nodes with minimum end to end delay. Thus, proposed approach improves the overall network performance by considering the factors such as Received Signal Strength, residual energy and variable transmission power model to determine an optimal route to destination. For future research, we will consider retransmission rate of the nodes to ensure the routing path reliability. Furthermore, determining dynamic residual power threshold value would help to develop a hybrid routing approach, which combines transmission power control model with load balancing approach.

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