International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 05, May - 2017

Energy-Distance Factor Aware (EDFA) Strategy in MANET Routing Protocol

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Abstract- **Critical energy constraint on nodes is among the factors that contribute to decreased lifetime network connection. In a Mobile Ad Hoc Network (MANET), this refers to the processing capability and ability of battery energy for packet transmission. This constraint may hinder the achievement of optimum route connection in extending the network lifetime. To address this problem, the Energy-Distance Factor Aware (EDFA) method has been proposed to sustain node lifetime. This technique is based on the energy-distance efficiency of transmission on relay nodes, which would become a potential candidate relay node in the routing protocol to sustain network lifetime connection. EDFA is a distributed and localized algorithm for the MANET environment. The algorithm scheme combines the methodology of interrelated efficient energy consumption with the distance factor in the routing protocol. The analysis of EDFA showed that the scheme has proven that the probability of quality relay nodes (largest ρ value) in the routing path is preferable for sustaining lifetime connection.**

Keywords—Energy constraint; lifetime connection; Relay node; Routing protocol.

INTRODUCTION

The Mobile Ad Hoc Network (MANET) is a collection of wireless mobile nodes (MN) that are equipped with wireless receivers and transmitters. The mobile nodes communicate with each other without being bounded by a fixed topology and spontaneously form and leave the network [1]. One node can directly communicate with other nodes that are situated within radio range and indirectly with those outside the range by using a dynamically-determined multi-hop communication method. Following the paradigm of multi-hop communication, other types of wireless network can be classified as wireless multi-hop network. The paradigm of today's networks include Wireless Sensor Network (WSN) [2], Wireless Mesh Networks (WMN) [2], and Vehicular Ad-Hoc Networks (VANETs) [3]. Being multi-hop networks, these paradigms depend on a sequence of intermediate nodes for routing packets from source to destination.

This type of communication represents a "multi-hop" communication where a node can act as a source, a destination, or a relay. By definition, a router is an entity that determines the path to be used in order to forward a packet towards its final destination. The router chooses the next-hop to which a packet should be forwarded according to its current knowledge of each node status. The network may also interface with the Internet when possible.

These characteristics set special challenges in routing protocol design. One of the most important objectives of the MANET routing protocol is to maximize network lifetime. Since there are limited energy resources on nodes, network lifetime can be achieved with efficient routing protocol. Therefore, establishing efficient routes is important, where the more challenging goal is to provide energy efficient protocols because the critical limiting factor for a mobile node is its operation time that is restricted by the battery energy [4]. Develop a routing protocol that can create energy savings is difficult and challenging in a MANET environment. The corresponding reduction of node lifetime directly affects the network lifetime since in a MANET, mobile nodes collectively form a network infrastructure for routing [5].

Therefore, the process of selecting a relay node in MANET must take into account current information related to energy, and the transmission distance and transmission control on each node. In fact, the development of an energy-efficient routing algorithm is one way of achieving optimum performance nodes [6]. Furthermore, the mobile node computational power for efficient energy use in routing packets will prolong the life of the network connection.

I. LITERATURE

Although many protocols have been proposed, there is still room to address the issue of increasing performance efficiency. In this scope, an efficient way of utilizing the existing technique involved a simple need-based approach for flooding the broadcasted and received messages in MANET. To our knowledge, attention should be given in developing an efficient routing algorithm with one primary objective, which is to overcome the limited lifetime of connection nodes by introducing an energy efficient algorithm from the first stage of route discovery. The node selection as a relay node must be scrutinized critically when considering the energy efficiency of the node, while distance factors need to be optimized with the aim to prolonging the life of a network connection. The study continues this investigation by looking into the influence of certain metrics, such as energy consumption and network capacity.

In previous research on route discovery routing protocol, the selection of the next hop node is based on different selection criteria. The selection criteria greatly influence network performance during the routing process within a mobile wireless network. The authors in [7][8] presented some related pioneering work of studying different energy models under the general wireless network environment. They mainly focused on the theoretical study and proof of route selection. However, they assumed every mobile node has equal battery power in terms of capacity and throughput. These is not true for a MANET device which has varied types of technology processors and electronic circuits. Obviously the source node and intermediate nodes would consume different amounts of

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
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energy, as can be seen from the related model [9] that illustrates different energy consumption for source and intermediate nodes. However, they only considered direct transmission for each cluster head under a small-scale network environment and did not consider multi-hop transmission or provide a further deduction of the optimal next hop for both linear and real ad hoc networks.

C. Efthymiou et al. in [10] studied the selection of a transmission manner from the probability point of view. They presented a probability of P_i to transmit data through a multi-hop transmission and a probability of (1- P_i) to transmit through a single-hop transmission to the destination node. S. Fedor and Collier in [11] looked into the energy consumption under both single-hop and multi-hop manners. They claimed that the preference of a multi-hop routing to single-hop routing depends on the source to destination distance and reception cost, which is consistent with the analysis in this research. However, the authors in [11][10] only treated two-hop routing as the multi-hop transmission in their environment and did not provide further analysis with efficient energy nodes for multi-hop transmission in practical ad hoc networks.

J. Deng in [12] proposed a data forwarding scheme by splitting the data into direct transmission and h-hop multi-hop transmission. Thus, the selection of splitting ratio is a critical issue therein. However, these authors mainly focused on the theoretical analysis and there was no consideration on optimal efficient nodes. In addition, the simulation work was not sufficient.

A. *Related Model*

Meanwhile, the research in [13] proposed the On-Demand Multicast Routing Protocol (ODMRP), where the selection of intermediate node is based on calculation of the residual energy over the transmission packet to the next hop as weightage for the candidate relay node. It considers minimum energy consumption per transmitting without evaluating for the next hop. In a similar line of investigation, the research in [14] considered the Remaining-Energy Based Routing (REB-R) protocol that requires nodes to broadcast their energy level alongside the transmitted data to their neighbors and let other nodes choose their parents with the highest energy level and forward data to it.

In this research, however, the focus was on dealing with the main function of the following network layers: the third layer of the protocol stack (where its performance is highly affected by the lower layers), the physical, and data link layers. On the one hand, node selection of these layers is based on the energy e_i and distance d_i of the nodes in the network. The study of the energy model, on the other hand, is related to the physical layer. For a specific communication task, the physical layer determines a series of characteristics such as the operation frequency, modulation type, data coding, and interface between hardware and software. The network layer is in charge of transmitting packet from source to destination node with certain QoS (Quality of Service), such as energy latency or packet delivery ratio.

i. Energy Consumption Model

One of the most important components of the radio power unit in mobile nodes is distance measurements and triangulation algorithms [15][16]. Distance or range measurement of radio location in mobile nodes is based on different physical attributes, such as received signal strength (RSSI). Based on the RSSI, the distance between transmitter and receiver is determined by the transmission power, received power, and a good model of the wireless channel. Meanwhile in signal attenuation, power of receiver signal is measured by the mobile node. By determining the signal strength emitted by the source node and the attenuation relationship with distance (such as, $1/d^2$, where d is the separation distance), the relative distance can be calculated.

ii. Propagation Model

In this research, the most common propagation model adopted in a MANET simulation to predict the received signal power of each packet was used. The following free space and multipath transmission models for issues of short and long distance communication were studied. The free space model assumes the ideal propagation condition of clear line-of-sight path between the transmitter and receiver. If the distance is less than $d_{crossover}$, the transmit power is attenuated according to the free space model. This is considered as a single line-of-sight path, and it is the most popular model of radio propagation in computing the received signal power.

II. DESIGN OF ENERGY-DISTANCE FACTOR AWARE (EDFA)

B. *New Algorithm Design*

Inspired by the work in [6][7][8][9][13][14], the technique used to make the relay node selection is based on efficient energy capacity on the node and the optimum distance for the transmission of packets to the next node, by taking into account the hardware parameter. Therefore, it is worth to emphasize that the selection criterion of the next hop node is purely from the intermediate node point of view in the EDFA technique.

To deal with the node lifetime for MANET, we had proposed the algorithms to select nodes in route discovery. The development of these strategies includes the development of basic mathematical models of each strategy in the proposed algorithm.

To give an illustration of the network environments, Figure 1 shows an arbitrary arrangement of nodes in a given situation. The placements of these nodes are arbitrary in the sense that there is no coordination between the nodes either in their location or the direction of their movement. Nodes S represent source node, D as destination, and i any arbitrary node in tier 1, respectively, as shown in Figure 2.

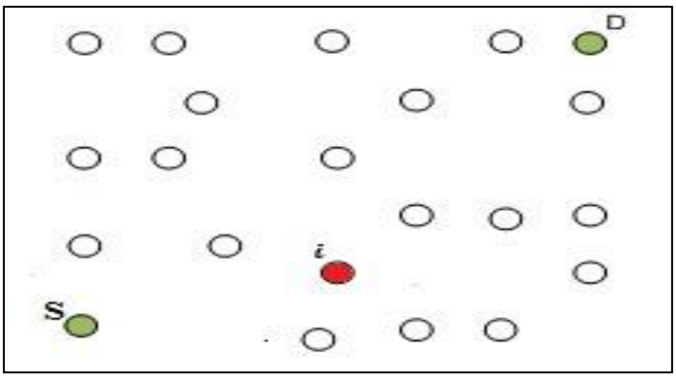

Figure 1. Arbitrary Placement of Mobile Intermediate Nodes

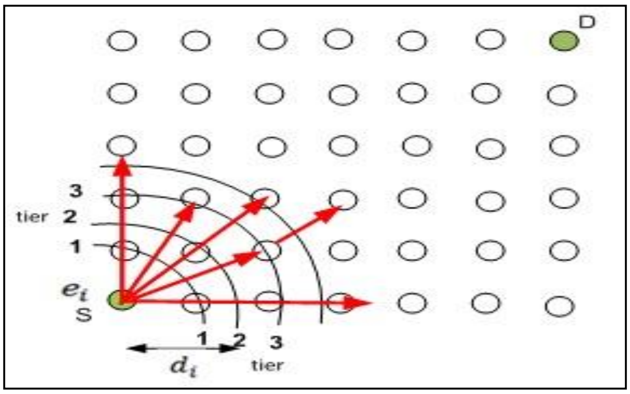

Figure 2. Overview of the Candidate Nodes Selection Phase

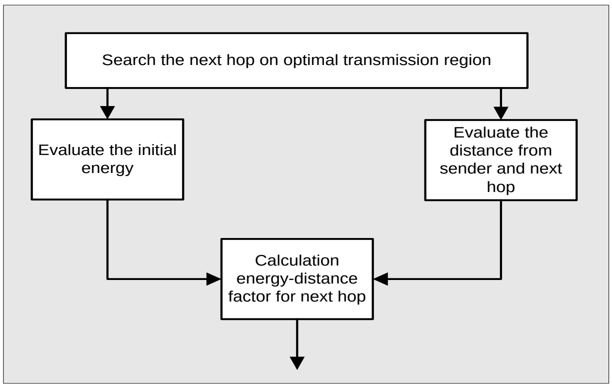

Figure 3. Detail workflow of the EDFA

If the energy at node *i* exceeds the threshold, it will be selected based on the proposed algorithm to calculate the energy distance factor as a *rho* value. The *rho* value on each node will reflect whether that particular node type has good energy efficiency or otherwise.

The energy level and the distance of the node *i* are given by e_i and d_i respectively.

The energy-distance factor *rho* (ρ_i) is computed as represented by the following mathematical model below.

e_i : energy level of node *i*

d_i: distance between the source node and node *i*

ρ_i: energy-distance factor of node *i*

m_i: energy-distance product of node *i*

If the energy level and the distance of node *i* are given by e_i and d_i respectively, then:

the energy-distance product of node *i* (m_i)= $e_i * d_i$ (1.1)

the energy-distance factor of node *i* $(\rho_i) = \frac{e_i d_i}{\sum_{i=1}^{n} e_i d_i}$ (1.2)

where, number of nodes is in tier 1.

Properties of energy-distance factor is given by,

$\rho_i \epsilon$ [0, 1] for all i

Proof:

Consider the extreme case of no other nodes in the vicinity of the source node. Then $e_i = 0$.

Thus $\rho_i = 0$

The other extreme case is when there is only one node in the vicinity of the source node with energy level *e* and at a distance *d*.

Energy-distance product $(m) = ed$

Energy-distance factor $(\rho) = \frac{ed}{\sum ed} = \frac{ed}{ed} = 1$

All other cases are when there is more than one node in the vicinity of the source node.

Energy-distance product of node

$(m_i) = e_i d_i < \sum e_i d_i$

Hence, Energy-distance factor of node

$$(\rho_i) = \frac{e_i d_i}{\sum e_i d_i} < 1$$

Thus, for all cases,

Energy-distance factor of node i is $0 \le \rho_i \le 1$

$\sum \rho_i$ =1

Proof:

Consider that there are *n* nodes in tier 1 of the source node *S*.

Let

$\sum_{i=1}^{n} e_i d_i = e_1 d_1 + e_2 d_2 + \ldots + e_n d_n = c$

$$\rho_i = \frac{e_i d_i}{\sum_{i=1}^{n} e_i d_i} \quad (1.3)$$

$$\sum \rho_i = \sum \frac{e_i d_i}{\sum_{i=1}^{n} e_i d_i}$$

$$\sum \rho_i = \frac{e_1 d_1}{c} + \frac{e_2 d_2}{c} + \ldots\ldots + \frac{e_n d_n}{c}$$

$$\sum \rho_i = \frac{e_1 d_1 + e_2 d_2 + \ldots\ldots\ldots + e_n d_n}{c}$$

$$\sum \rho_i = \frac{c}{c} \quad (1.4)$$

$$\sum \rho_i = 1$$

Therefore, probability energy distance factor identifies the node with the highest energy level at the optimal distance possible, so it may be used to select the next hop node for forwarding the packet towards the destination. The node possessing the largest ρ value may be preferred compared to the other nodes as the next hop in the direction of the destination.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 05, May - 2017

EDFA Algorithm

Input: e_i - of the mobile node, d_i - of the adjacent-neighbor nodes

Output: ρ_i – rho (ρ) is the highest energy-distance factor

(1) Each node *i*, with transmission distance d_i, broadcasts the hello packet to *n*-hop neighborhood to obtain the node *IDs* of their mutual distances and the directions of the systems coordinates.

(2) Each node *i* locally evaluates the initial energy e_i if $e_i \geq e_t$, accept as candidate node.

(3) Each node *i* locally evaluates the current distance d_i of the adjacent-neighbor. If $d_i < d_o$, accept as a candidate node.

(4) When node *i* updates its initial energy e_i, update the current distance d_i, *i* checks for all neighbors.

(5) Calculate $E_{Tx}(l,d)$ /*equation 4.1

(6) Calculate $E_{Rx}(l)$ /*equation 4.2

(7) Calculate $E_{Fx}(l,d)$ /*equation 4.3

for node$_i$

(8) Calculate remaining energy

(9) if ($Ere \geq E_{Th}$) then

(10) Add node$_i$ to candidate_list

(11) else if ($E_{re} < E_{Th}$) then

(12) Add node$_i$ to unwanted_list

(13) Each node *i* locally computes the ρ of energy-distance factor of the node as $\rho_i^1, \ldots \rho_i^c, \ldots \rho_i^k$.

(14) Compute the position of the n-hop neighbors in its Local Coordinate System.

(15) Compute the *n*-hop neighborhood center as:

$$c_x = \frac{\sum j_x}{m}$$

$$c_y = \frac{\sum j_y}{m}$$

(16) Compute the *n*-hop neighborhood direction as the average of the Local Coordinate System direction of the nodes that belong to its *n*-hop neighborhood and for which it can obtain the positions.

(17) Each node *i* updates its neighbor list and updates the transmission range according to the new neighbors.

IV. SIMULATION

The proposed algorithm was tested in a simulation environment using the ns2 [17]. The experiment was setup with hardware parameter setting as follows: energy dissipation (E_{elec}) = 50nJ/bit, free space model (ε_{fs}) = 10pJ/bit/m2, multipath model (ε_{mp}) = 0.0013pJ/bit/m4, and data length (l) = 2000 bits. The network coverage area was assumed to be a circle with radius of 100 meters with nodes ranging from 50 to 200. Locating the nodes at different distances creates different energy-distance factors for the nodes, though they possess the same level of energy. The results showed the energy consumption of the intermediate node during a unit size packet transmission.

Based on the energy-distance factors of the intermediate node, the highest probability of the node (ρ = 0.45) showed the lowest energy consumption. The lowest energy consumption at the three nodes involved was in the position closest to the origin line between the source to destination. This was due to the fact that as the angle of deviation increases, so does the distance between the intermediate and destination nodes. The *rho* (ρ) value output at each node indicated the optimum distance transmission of the node. The *rho*(ρ) value was listed in a routing table and selected to establish the route according largest ρ to lower value.

V. RESULTS

The protocols were evaluated as a function for the selection process of relay nodes in route discovery in free space and multi-path network environments. Figures 3 and 4 show the energy consumption on each relay node which was evaluated and selected based on *rho* values. The relay node positioned farther from origin to destination node meant that the higher the required energy consumption. This indicates that the transmission distance to the next node will affect the energy at each node whether it is the energy consumped or remaining energy.

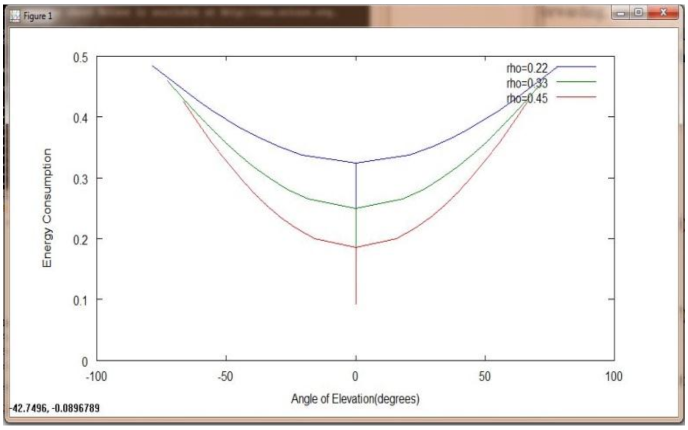

Figure 3. Energy Consumption in the Intermediate Node – Multi Path Transmission

The energy consumption on the intermediate node increased drastically with the increase of the distance to next hop. Therefore, the lifetime of relay nodes in the path were more likely to survive as shown in Figure 5 and Figure 6. The relay node that has a high *rho* value would sustain more lifetime followed by a node that has a lower *rho* value.

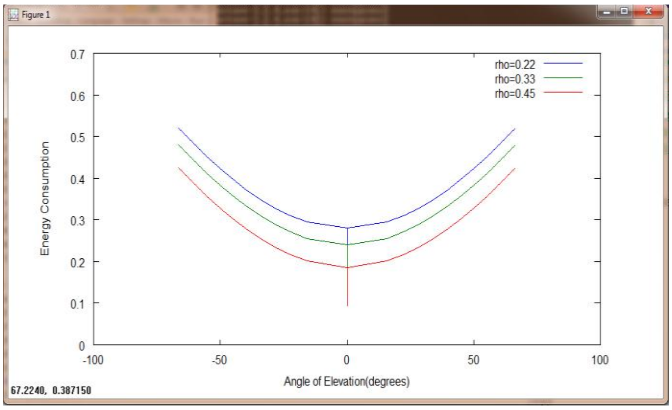

Figure 4. Energy Consumption in the Intermediate Node - Free Space Transmission

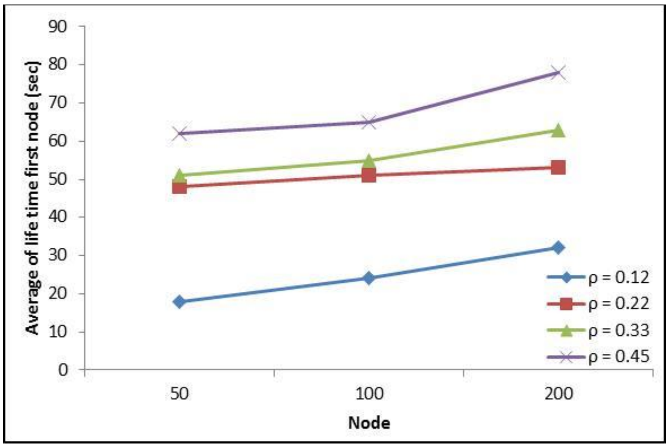

Figure 5. Average Lifetime of the First Node: Free-space Transmission.

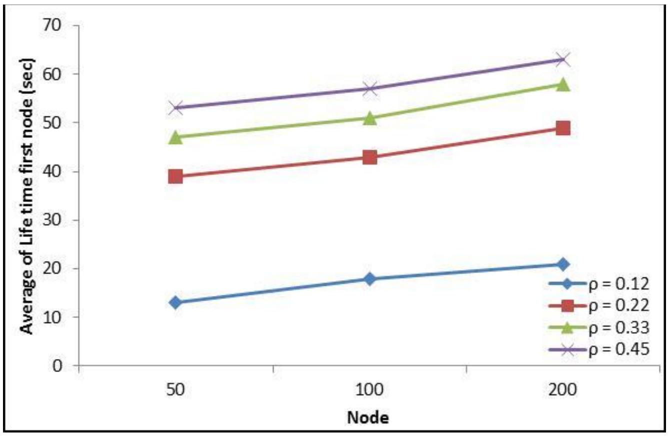

Figure 6. Average Lifetime of First Node: Multi Path Transmission

VI. Conclusion And Future Work

In this paper, we have studied and analyzed the performance of MANETs with a new algorithm in the selection technique of relay nodes through simulations. The obtained results showed that the EDFA algorithm can implement an effective selection of relay node by evaluating every node within the coverage area and choosing an intermediate node that has the best *rho* value. In this EDFA algorithm technique, it was found that the life of network connection is extended longer. This is because the relay nodes that make up the route for packet forwarding consists of energy efficient nodes. This algorithm can operate on scalable networks with high density of multiple nodes.

In the EDFA, whenever possible, the nodes would select neighbors inside a restricted neighborhood (defined by a density of *rho* (ρ_i)) that has the optimum energy mileage (i.e., the distance traveled per unit energy consumed) as the next hop node. This helps to achieve both energy efficiency by carefully selecting the forwarding neighbors and high scalability based on information obtained locally from each node to decide routes. This also is able to reduce energy consumption during the multi-hop routing process in a MANET.

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