Node Selection Based on Energy Consumption in MANET

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Abstract: In a Mobile Ad-Hoc Network, the mobility of a node is unpredictable. The mobility is considered as one of the characteristics of a wireless network. In addition, the energy constraint of the nodes must also be taken into consideration when designing routing protocols. This is an important issue since energy consumption reduces the wireless network connection lifetime. The nodes in MANET are fitted with batteries with limited capacities. In order to achieve an optimum route connection by extending the network lifetime, the distance factor of the source-intermediate-destination needs to be combined with the initial energy of the node when selecting a participating node in a route path. A probability based node selection method is proposed in this paper for identifying the intermediate node with optimum stored energy that could withstand through duration of connection. The algorithm has been tested with simulations and it has been proved that the node with the largest probability consumes the lowest energy. This not only helps to sustain the communication with the lowest chance of interruption, but also prolongs the network lifetime due to the lowest possible consumption of energy for a given communication.

Keywords: Energy Constraint, Energy Consumption, Node Selection, MANET.

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1. Introduction

Mobile Ad-Hoc Networks (MANET) consist of wireless nodes that form a communications network among themselves without a fixed infrastructure [1]. MANET is frequently used in special situations such as in emergency operations such as natural or manmade disasters, rescue activities, battle fields or seminar halls particularly in areas where there is no fixed infrastructure or such infrastructure has been destroyed [2]. Topology changes in MANET usually occur due to the mobility of a participating node or breakdown of a node due to loss of energy in that node [3]. These dynamic conditions disrupt the smooth communication between needs in the network. Conceptually, in MANET, a node may either function as an end node or as a router forwarding data packets between end nodes [4]. An effective routing mechanism is required to maintain acceptable service quality during communication between nodes [5]. Hence the fitness of the node in terms of available energy in the node becomes an important issue during the selection of an intermediate node in order to maintain stable transfer of data between nodes.

Maintaining an optimized lifetime of a routing path in a network is a very challenging task because the power or energy of the nodes depends on the size, model, property, and capacity of the battery [3]. Energy in batteries continuously deplete due to node activities such as transmission, reception and overhearing [6]. Depletion of energy in nodes especially the intermediate ones disrupt communication and results in changes to the network topology. However disruption can be minimized through an efficient selection of intermediate nodes. Such selection criteria must be the first step in any route selection process in order to maintain a stable routing of data between the end nodes.

The node selection process has been included in many routing algorithms and techniques [4]. Hence these algorithms and techniques have considered the service quality an important factor. But these algorithms and techniques suffer from certain shortcomings especially during the route discovery process. These techniques do not consider the available energy of a node as a parameter, so they may select a node with low energy level as an intermediate node. Selection of a node with low energy level reduces the stability of the communication path as that node may run out of energy causing the breakdown of the communication channel. In this paper the authors propose a probability based node selection scheme where the available energy level of a node is an important parameter.

This paper consists of six sections which are organized as follows: Section 1 introduces the paper and Section 2 provides an overview of the energy constraint in mobile nodes. Section 3 discusses the related works and Section 4 presents the probability based method for node selection the main contribution of this paper. Sections 5 and 6 provide the experimental setup along with results and conclusions respectively.

2. Characteristics of Nodes with Constrained Energy

Each node in a MANET serves as a host and/or router generating, consuming or forwarding information [7].
These nodes are fitted with and powered by batteries. The depletion of participating nodes’ battery power in a routing path will shorten the network lifetime. As charging or replacing batteries on site is a difficult operation, it is necessary to use the available energy efficiently to extend the lifetime of the nodes [8-9]. Developing an energy efficient routing scheme is one way of achieving optimized performance of nodes.

Nodes consume energy while transmitting beacon signals to neighboring nodes for the purpose of detecting their existence or transmitting data to another node [4]. When an intermediate node has been selected as a router, it consumes more energy than an idle node as it is actively involved in communication [10]. Thus, the nodes’ residual energy is important in determining the path to successfully completing data transfer without interruption. Hence a routing protocol that considers the nodes’ residual energy will perform better than the protocols that do not.

3. Related Work

Several researchers have proposed protocols that suggest that the energy in the node plays a significant role in maximizing the network lifetime [9, 11-12].

Distance-based Energy Aware Routing (DEAR) [11] is a routing algorithm that considers both route setup and route maintenance. During the route setup phase, the algorithm first computes the distance between the source and sink nodes \(d_n\). If \(d_n \leq 100\), a direct transmission is used, otherwise multi-hop routing will be selected. This algorithm can also determine the number of nodes to function as relay nodes, and the last node in the sequence closest to the sink. This algorithm assumes that high transmission power will drain a significant amount of energy from the nodes. That is, attempting to transmit over long distance consumes more energy compared to low power multi-hop transmission covering the same distance. The downside of this algorithm is that it increases the traffic at intermediate nodes unnecessarily. Due to the increased traffic carried by the node closest to the sink, it will drain out faster than the nodes that are away from the sink. Also DEAR does not measure or base decision on the available residual energy of a selected node. This may result in an intermediate node becoming totally drained of its energy during transmission interrupting the communication.

The author in [12] proposed the Distance-Based Energy Efficient Sensor Placement (DBEEP) for lifetime maximization, which jointly optimize the load balance, communication range, and network size in a time-driven linear WSN. DBEEP identifies the traffic load balancing as a critical issue that must be addressed at each node in a balanced traffic flow. This is important since the load balancing on a particular node can increase the network lifetime. The DBEEP comes with an energy model that assumes those nodes, which only relay data to the next node in the direction of the radius is lost. In this model, the configuration refers to the arrangement of those related nodes that are deployed along the radius. If the adjacent node have \(d_1 > d_2 \ldots > d_n\), the connected coverage of the inside nodes will be ensured. Similarly, in [13], the author described the control of energy consumption can be done by controlling the optimum router location, identifying the number of nodes involved, and taking into account the communication costs and the shortest route.

The literature investigated shows that the Energy-Awareness technique has helped to improve the network connection lifetime. However, the proposed techniques have failed to focus on the energy possessed by individual nodes. By only focusing on the energy consumption, it does not reflect the accurate value of the node capacity.

4. Probability Based Node Selection Method

The proposed probability based node selection method considers a new parameter known as the energy distance factor. This factor helps to select the best next hop node for optimizing the energy efficiency of the network. The scheme also considers the residual energy of the nodes as a fraction rather than the absolute energy levels. Based on this scheme of selecting nodes with sufficient residual energy, an energy aware routing protocol for MANETs is proposed in this paper. The aim of this scheme is to improve the performance of the path lifetime by selecting the best nodes along the path from the source to destination.

It is common for each node in a network to have a different energy level. Hence it is important to select the best intermediate node in terms of residual energy. If the energy in a node runs out during the transmission of data, it will force a new route discovery process interrupting the data transmission. Route discovery is costly in terms of both
transmission delay and energy consumption. During the route discovery, multiple nodes will have to be contacted for the purpose of identifying and establishing the route again. This would consume more energy than that required for transmitting data.

The nodes between the source and destination are divided into tiers as shown in Figure 2. The tier arrangement is as follows; every node that can be reached directly or by one hop from the source is considered a Tier 1 node, Tier 2 nodes can be reached with only two hops. Similarly, Tier 3 nodes need three hops from the source and so on. Figure 3 shows the distribution of nodes between the source and destination. Depending on the availability of nodes, node distribution can be symmetrical by the straight line connecting the source and destination nodes. The straight line path between the source and destination is the most preferable as it would create the shortest possible path consuming the lowest energy.

Figure 2. Energy Reachable Zone

Figure 3. Farthest Distance Deviation Discovery

4.1. Mathematical Formulation

Figure 4 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, D and i represent source, destination and any arbitrary node in tier 1 respectively.

![Figure 4. Arbitrary Placement of Mobile Intermediate Nodes](image)

If the energy level and the distance of the node i are given by $e_i$ and $d_i$ respectively.

The energy-distance factor ($\rho_i$) is computed as follows:

\[
\text{energy-distance product of node } i = e_i \times d_i \quad (1)
\]

\[
\text{energy-distance factor of node } i = \frac{e_i \times d_i}{\sum_{i=1}^{n} e_i \times d_i} \quad (2)
\]

Where, $n$ – number of nodes in the Tier 1

**Properties of Energy-Distance Factor:**

(i) $\rho_i$ lies between 0 and 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 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 $(\rho) = \frac{ed}{ed} = \frac{ed}{ed} = 1$

For all other cases where there are more than one node in the vicinity of the source.

Energy-distance product of node $i$

\[
(m_i) = e_i d_i < \sum e_i d_i
\]

Hence, Energy-distance factor of node $i$

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

Thus for all cases,

Energy-distance product of node $i$ is $0 \leq \rho_i \leq 1$
(ii) Sum of all individual $\rho$ values is equal to 1 ($\sum \rho_i = 1$)

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

Let

$$\sum_{i=1}^{n} \rho_i = \frac{\epsilon_i d_i}{\sum_{i=1}^{n} \epsilon_i d_i} = c$$

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

Thus, we can prove that $\rho$ behaves like a probability since $\rho$ behaves like a probability and identifies the node with the highest energy distance product, it may be used to select the next hop node for forwarding the packet towards the destination. The node possessing the largest $\rho$ value may be preferable compared to the other nodes as the next hop in the direction of the destination. Hence, when selecting an intermediate node, it is necessary to consider both free space and multipath transmissions.

**Energy Behaviour of the Intermediate Node:**

The energy required to forward a packet of data to the next node is given by [5]:

$$E_{\text{elec}}(l, a) = E_{\text{fs}}(l, a) + E_{\text{mp}}(l)$$

$$= \begin{cases} 2l \cdot E_{\text{elec}} + l \cdot \varepsilon_{fs} \cdot d^2, & \text{if } d < d_0 \\ 2l \cdot E_{\text{elec}} + l \cdot \varepsilon_{mp} \cdot d^4, & \text{if } d \geq d_0 \end{cases}$$

$$d_0 = \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}}$$

$E_{\text{elec}}$: Energy dissipation to run the radio device

$\varepsilon_{fs}$: Free space model of transmitter amplifier

$\varepsilon_{mp}$: Multi-path model of transmitter amplifier

$l$: Data length

$d_0$: Distance threshold

Hence, when selecting an intermediate node, it is necessary to consider both free space and multipath transmissions.

**5. Simulation**

The energy behaviour of the intermediate nodes was investigated using simulations. A simulation environment was setup using the GNU Octave 3.2.4 software. Figure 5 shows the energy consumption of the intermediate node during a unit size packet transmission. The experiment has been setup with three intermediate nodes between the source and the destination nodes located at different distances but having the same energy levels. Locating the nodes at different distances create different energy-distance factors for the nodes though they possess the same level of energy. Energy consumption has been computed by subtracting the initial energy from the rest energy using formula (6). The angle of deviation is the deviation of the intermediate node from the line connecting the source and destination nodes. Based on the energy-distance factors of the intermediate node, the highest probability of the node ($\rho = 0.45$), shows the lowest energy consumption. The lowest energy consumption at the three nodes involved is in the position closest to the origin line between the sources to destination.

$$E_C = E_I - E_L$$

$E_I$: Initial Energy

$E_C$: Energy Consumed

$E_L$: Energy Left

Figure 6 shows the same information but confined to a narrow angle of elevation. Figure 6 has been plotted specially to clarify the confusion created in Figure 1 near the origin (0°). From Figure 2, it can be seen clearly that the sharp rise in the consumption energy is due to the data point located at a distance away from 0°. Apart from that, it clearly follows the general trend. From these figures, it can be seen that the consumption energy increases as the angle of deviation rise away from the origin. This is due to the fact that as the angle of deviation increases so does the distance between the intermediate and destination nodes. The energy consumption by the intermediate node increases drastically with the rise of distance as they are related through higher orders of the distance as shown in Formula (1).
These figures also show that the node with highest energy-distance factor (ρ) has the lowest consumption energy meaning that the intermediate node has higher residual energy compared to other intermediate nodes. Figure 7 shows the results of the experiment that has been set up using intermediate nodes with different initial energy levels but located at the same distance.

6. Conclusion
The concise discussion in this paper shows that, despite the large efforts of the MANET research community and the rapid progress made during the last years, many issues that affect the energy at the node still has space for improvements, particularly involving the routing protocol. The algorithm of nodes selection based on energy consumption is essential in improving the lifetime of network nodes by considering the individual energy. Energy consumption level at the node and the distance factor can be used to determine the probability of intermediate node to be selected as relay node to destination. This algorithm can prevent the early failure of a node and reflected to reliability of route path. The node with the largest ρ provides the highest remaining energy meaning that it has more energy left after the transmission of a data packet. This will extend the route path connection in the entire network path.

References:


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