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Probabilistic Mean Energy Flooding to Increase the Survivability of MANET

Thriveni J[a], Anita Kanavalli[a], K R Venugopal[a], L M Patnaik[b] *†

Abstract—**Wireless mobile ad hoc stations have limited battery capacity, hence, Ad Hoc routing protocols ought to be energy conservative. Route discovery is a common operation in routing to resolve many issues relating to energy conservation. In a Mobile Ad Hoc Networks (MANETs) in particular, due to host mobility, such operations are expected to be executed more frequently and a straightforward broadcasting by flooding is usually very costly and will result in serious redundancy, contention, and collision. In this paper, an algorithm is proposed to improve the flooding performance of an Ad Hoc On–Demand Distance Vector (AODV) routing protocol called, Probabilistic–Mean–Energy–Flooding (PMEF) which periodically performs an averaging algorithm Calculate–Average–Energy (CAE) to estimate the average energy E_{avg}. This algorithm is used in route discovery process to make a rebroadcast decision by the node. Route request message is rebroadcast with a probability that depends on the difference between the residual energy E_r and the calculated average energy. Our simulation results show an improvement in the network lifetime and the throughput compared to traditional AODV.**

Keywords: Ad hoc networks, Average energy, Lifetime maximization, Probabilistic flooding, Residual energy.

1 Introduction

MANETs are self–creating, self–organizing, and self–administrating without deploying any kind of infrastructure. These networks can be created and used anywhere and anytime and intrinsically fault resilient as they do not operate under a fixed topology. They offer special benefits and versatility for wide applications in military i.e., battlefields, sensor networks, distributed mobile computing, disaster discovery systems, educational environments such as conferences, conventions, etc. where fixed infrastructure is not easily acquired.

Flooding mechanism must balance both the requirements of the application and constraints of both the device and the MANET. Flooding is used by reactive routing protocols such as AODV [1] and Dynamic Source Routing [2] to obtain route information. Many protocols have been proposed for efficient flooding to reduce the redundant message forwarding, but, most of them do not take the remaining energy of each node into account. Draining of power by nodes leads to dead nodes, it may lead to network partition and shorten the network lifetime.

Ad hoc network have several limitations. The network being wireless and mobile operate on batteries which have limited life. These networks are not scalable. The nodes of the ad hoc network do not have any access points, they communicate without any centralized control and cooperate in the process of delivering the packets of data. Since recharging or replacing batteries is costly or, under some circumstance, impossible, it is desirable to keep the energy dissipation level of device low.

Motivation: The routing protocols in wireless ad hoc networks play a significant role in energy management and prolonging the lifetime of the network. The forwarding of a route request message in *route discovery process* of routing protocols should efficiently reduce redundant messages and should consider energy consumption issue. Routing protocols without consideration of energy consumption tend to use the same path for given traffic demands which results in a quick depletion of energy of the nodes along the path, if those traffic demands are long lasting and concentrated. One or several nodes drain power due to unbalanced energy consumption which may lead to network partition and reduce the network lifetime.

Contribution: We have proposed a flooding Algorithm that adopts a strategy that only the nodes with relatively sufficient energy are responsible to rebroadcast a route request message. The Probabilistic–Mean–Energy–Flooding uses an averaging algorithm Calculate–Average–Energy to estimate the average energy. The nodes rebroadcast a route request message when they have sufficient energy, that is computed as the difference between the residual energy and the average energy. The proposed algorithm give better performance compared to AODV protocol. The remainder of this paper is organized as follows: Section 2 presents related work; Section 3 presents a network model; Section 4 defines the problem and the proposed algorithms; Performance Analysis and Conclusions are presented in Section 5 and 6 respectively.

*a Department of Computer Science and Engineering, University Visvesvaraya College of Engineering, Bangalore University, Bangalore 560 001. (thrivenijgowda@yahoo.co.in)
†b Microprocessor Applications Laboratory, Indian Institute of Science, Bangalore.

2 Related Work

Energy efficient protocol design deals with all layers of protocol stack and usually spans the network layer and MAC layer, in particular there is an increasing interest in algorithms for the network layer, namely energy efficient routing algorithms. The design principle of an energy efficient routing is to equally balance energy expenditure among network nodes rather than allowing a node to drain off its energy completely resulting in network partition.

Singh et al., [3] have proposed the Min–Max Battery Cost Routing, that considers the residual battery energy capacity of nodes as the operative metric. It extends the lifetime of nodes, but does not guarantee that the total transmission energy is minimized over a chosen route. C. K. Toh [4] has introduced a Conditional Max–Min Battery Capacity Routing to maximize the lifetime of an ad hoc networks. The algorithm does not guarantee that the nodes with high remaining energy will survive without energy breakage even when heavy traffic is passing through the node. Dongkyun Kim et al., [5] described two route selection mechanisms for MANET routing protocol namely Minimum Drain Rate and the Conditional Minimum Drain Rate that uses the drain rate to forecast the lifetime of nodes according to current traffic conditions. Mortez Maleki et al., [6] suggested a lifetime prediction routing protocol for ad hoc networks that maximize the network lifetime by finding routing solutions that minimize the variance of the remaining energies of the nodes in the network. This metric works well for static networks but not for dynamic networks since the location of the nodes and their neighbors constantly change.

Senouci et al., [7] have proposed three algorithms to increase the lifetime of the network. These algorithms reduces the energy consumption of the nodes by routing packets to their destination using energy optimal routes. Jin–Man Kim et al., [8] introduced an Energy Mean Value algorithm to enhance AODV routing protocol and to improve the network lifetime of MANET. The approach in those was to minimize the total energy consumed to reach the destination, which minimizes the energy consumed per unit flow or packet. The delay time of the *request* is set based on the energy remaining in the node. Gil Zussman et al., [9] have proposed an iterative algorithm to maximize the time until the first battery drains out. The authors have also derived an upper bound on the network lifetime for specific topologies, a polynomial algorithm for obtaining the optimal solution in such topologies is also described.

Sumathy et al., [10] have developed a location based throughput maximization routing to maximize the lifetime of ad hoc mobile network. It reduces drop rate of data packet by evenly distributing the power consumption rate of each node and by minimizing the overall transmission range of each node. The algorithm increases the lifetime of the network with homogeneous nodes. Misra et al., [11] developed a Maximum Residual Packet Capacity which is conceptually similar to the conditional Min–Max battery cost, but it identifies the capacity of a node not just by the residual battery capacity, but also by the expected energy spent in reliably forwarding a packet over a specific link. Maleki et al., [12] proposed a Power–Aware Source Routing which is an On–Demand Source Routing that uses state of the charge of battery to maximize the lifetime of a MANET. This algorithm solves the problem of finding a route path route discovery time.

Kamrok lee et al., [13] proposed an energy efficient contention–based MAC protocol for wireless ad hoc networks by combining the protocol of the power management scheme and the collision avoidance scheme of the IEEE 802.11 DCF to reduce the energy consumption of a node and to increase the network lifetime and packet delivery. The algorithm gives the different probability to each node by reflecting a node's remaining energy degree into the contention window size of the node. Osama H. Hussein [14] et al., developed an algorithm Application of a Probabilistic–based *ant* routing algorithm to achieve a fair network resource distribution by combining the advantages of both on demand and table driven routing algorithms.

3 Network Model

Energy management in wireless ad hoc networks comprises of designing radio frequency components for adaptive physical and MAC layer protocols in addition to efficient routing techniques. The nodes of the network are randomly distributed with uniform density over a specified two dimensional region in a wireless medium. The links between nodes are symmetrical. We have considered a mobile wireless network, where all mobile nodes are equipped with identical communication devices such that each node may act as a transmitter or a receiver as needed and the nodes co–operate on the packets delivery. Let N denote the set of nodes in the network, which are labeled *1, . . . , N*. We assume a constant transmission rate and fixed packet length, such that the time for each packet to travel any one hop is a constant. Initially all nodes have same residual energy which is equal to maximum energy of the node. Energy is consumed whenever a node sends data or any control packets (route request, route reply, data packet etc.). In order to study the energy efficiency of the network, the following performance metrics are used:

(i) $Network\ Lifetime$: is defined as the active period of the network nodes that have been able to process and transmit data until a node fails due to exhaustion of its battery, resulting in the partition of the network.

(ii) *Network Latency*: is the difference between receiving time and sending time of a data.

(iii) *Network Throughput*: Throughput is defined as the number of packets that were successfully received by the receiver divided by latency.

3.1 Mobility Model

Random Walk Mobility Model is chosen in which a node movement is determined by the following rules. First, each node decides the direction in which to move. Once it starts moving, it goes on for a predefined move time, at the end of which it selects a new direction. At every random decision of movement direction, the speed is also randomly chosen from an interval (speedmin, speedmax). When a node reaches the system boundary, it bounces off the border with an angle equal to the incoming angle, and continues until movetime expires. For Simulation, mobility parameters are set as follows: movekind = toroidal i.e., whenever the node hits the boundary of the domain, it wraps around, distance = 250, minspeed = maxspeed = 10, speedvariator=2, moveinterval = 0.5 and anglewidth= 3.14.

3.2 Notations

(i) E_{max}, Maximum Battery Capacity of a node

(ii) E_r, Residual Energy of a node at that particular instance

(iii) E_{avg}, Average Energy calculated using E_{avg} of its neighbors

(iv) P_t, Threshold Probability set to some predefined value say 0.8, 0.6, 0.4, or 0.2

(v) P_{max}, P_{min}, P_{fr} Maximum, Minimum, and Forwarding Probability to flood a request packet

(vi) n_x, Node x

Flooding mechanism is used by reactive routing protocols to obtain route information. For efficient flooding, forwarding of redundant messages have to be minimized, considering remaining energy of each node into account. In the proposed algorithm, the probability of rebroadcasting a route request packet is calculated to inhibit redundant rebroadcast by referring to the maintained average energy E_{avg}. Rebroadcast probability is based on the principle that nodes with more energy capacity should be responsible for forwarding more route request messages. Rebroadcasting of a request by a node is dynamically adjusted to the difference between its E_r, and E_{avg}. The rebroadcast probability based on the above principle is depicted in Figure 1. The rebroadcast probability is set to some predefined threshold P_t, when its residual energy is equal to its average energy. Increase the rebroadcast probability to P_{max}, when its E_r is greater than its E_{avg} and decrease the probability to P_{min} otherwise. The solid line in Figure 1 depicts the rebroadcast probability based on the principle mentioned above. Forwarding probabilities P_{max} and P_{min} is calculated using equations shown below.

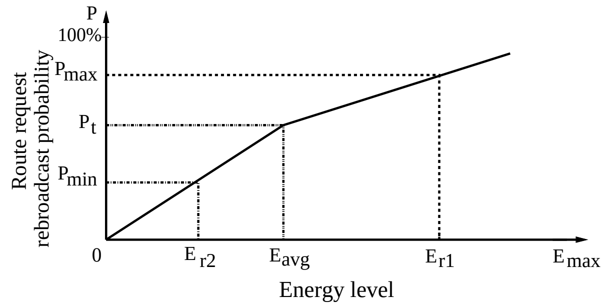

Figure 1: Strategy for Route Request Rebroadcast Probability

$$P_{max} = P_t + (1.0 - P_t) * (E_r - E_{avg})/(E_{max} - E_{avg}) \quad (1)$$

$$P_{min} = P_t * (E_r/E_{avg}) \quad (2)$$

4 Problem Definition

Given an ad hoc wireless network with finite number of nodes and finite number of links and if the two nodes n_1, n_2 are within the transmission range of each other, then the objectives are to:

- Improving the lifetime of the network by minimizing the energy consumption.
- Maximizing the network throughput thereby decreasing the Latency.

4.1 Algorithm

In this section, we present an algorithm to alleviate the broadcast storm problem. They are designed to increase the network survivability and increase the battery life of the nodes by dropping the redundant requests based on E_{avg} during route discovery. The proposed algorithm, Probabilistic–Mean–Energy–Flooding periodically performs an averaging algorithm CAE to estimate the average energy E_{avg}.

Table 1 gives the algorithm to calculate the E_{avg}. Initially a node's average energy is set to its residual energy. Periodically E_{avg} is calculated by collecting energy information from its neighbors. An *hello* message is sent

Table 1: **Algorithm : Calculate–Average–Energy (CAE)**

```
CAE()
begin
    let E_avg := E_r
    send hello  message periodically to its neighbors
    send reply(E_avg) to n_x
      on receiving an hello Message from neighbor n_x
    calculate new E_avg := average(received E_avg's, E_r)
      on receiving (reply, E_avg) from neighbors
    E_avg := new E_avg
end
```

Table 2: **Algorithm : Probabilistic–Mean–Energy–Flooding (PMEF)**

```
PMEF(route_request)
begin
    if (newrequest)
      if (E_r == E_avg)
        P_fw := P_t
      else if (E_r > E_avg)
            P_fw := P_max
          else
            P_fw := P_min
          end
      end
      rebroadcast with probability P_fw
    end
end
```

to learn about the neighbors. On receiving an *hello* message, a node responds by sending its E_{avg} value in its *reply* message. On receiving the reply message from neighbors, a node calculates a new average by averaging all the received energy and its residual energy E_r and updates its E_{avg} with the newly calculated average energy.

To easily perceive the energy consumption of the network, we integrate average energy into the rebroadcasting of a request message. Only the nodes with relatively higher energy forwards the request messages. Algorithm PMEF in Table 2 determines the rebroadcast probability based on the principle that nodes with more energy capacity should be responsible for forwarding more route request messages. Rebroadcasting of a request by a node is dynamically adjusted to the difference between its E_r, and E_{avg}. The rebroadcast probability is set to some predefined threshold P_t, when its residual energy is equal to its average energy. Increase the rebroadcast probability to P_{max}, when its E_r is greater than its E_{avg} and decrease the probability to P_{min} otherwise.

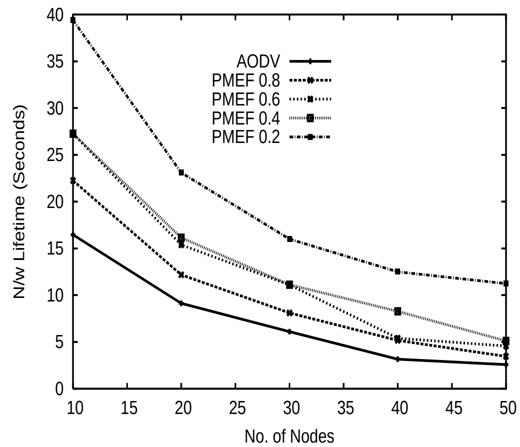

Figure 2: Network Lifetime and Varying Network Density

5 Performance Analysis

In this section, we discuss our Simulation studies to compare the performance of AODV with PMEF with different threshold probability 0.2, 0.4, 0.6, and 0.8 with respect to its lifetime, throughput and latency. We conducted the simulation experiments using *OmNet++*. Nodes in the simulation are placed randomly in a 700 X 700 m^2 terrain and move in random walk mobility patterns. The simulation time was set to 1 hour. Power consumption rates for transmitting receiving etc are assumed same. A node is considered dead if its energy reaches zero. Three packets of length 4096 bits were generated every second. Nodes have same battery capacity in the first simulation run and have varying battery capacity in the second simulation run.

5.1 Nodes with same battery capacity

For simulation we have considered a maximum residual energy of all the nodes equal to 1000 units. Figures 2, 3, and 4 are the results showing network lifetime, throughput and latency for varying network densities in this run.

Figure 2 is the plot of network lifetime with varying network density. It clearly shows the increase in network lifetime with the proposed algorithm PMEF with varying threshold probability as compared to existing AODV routing protocol. It is also observed that as the threshold probability is decreased, a node processes less route request packets, energy consumption is reduced and network lifetime is increased. It is observed that lifetime of the network for a specified number of nodes increases when the threshold probability is decreased from 0.8 to 0.2. When P_t is 0.8, traffic load is more and as more packets are forwarded, energy consumption increases and the network lifetime decreases whereas when P_t is 0.2, less packets are forwarded, energy consumed is less and network lifetime increases. It is observed that the through-

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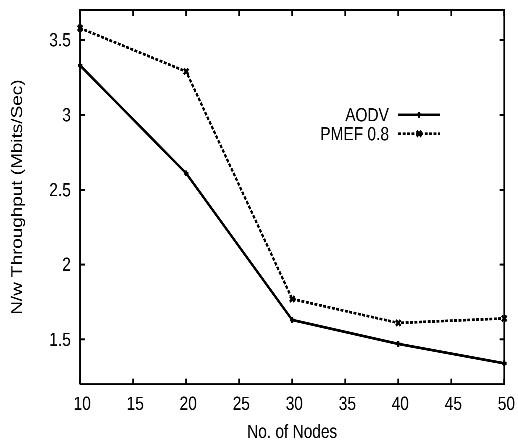

Figure 3: Network Throughput and Varying Network Density

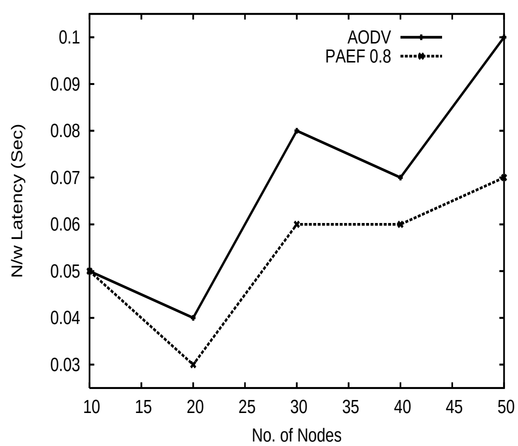

Figure 4: Network Latency and Varying Network Density

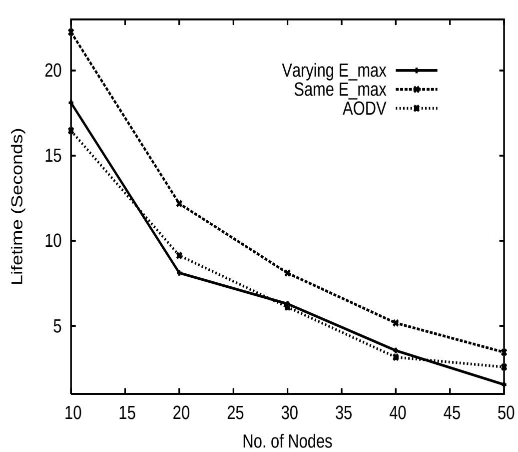

Figure 5: Network Lifetime and Varying Network Density

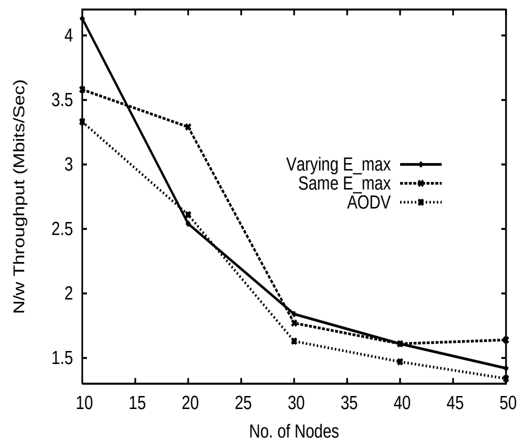

Figure 6: Network Throughput and Varying Network Density

put of the proposed algorithm for different threshold probability is comparatively more compared to AODV. When throughput for different threshold probability is compared, it is observed that there is a consistent behavior when the threshold probability is 0.8. Therefore we have compared the throughput and latency of AODV and the proposed algorithm with threshold probability 0.8.

Figure 3 shows the network throughput with varying network density. Throughput of the PMEF is comparatively high for different network densities compared to AODV. It is observed that the throughput of the network decreases when the network density is increased. When the network traffic is heavy, congestion happens, more packets are dropped, and network throughput is decreased. When the network density is light, the network does not incur congestion or packet drop even though the routing overhead is larger, it does not affect the packet delay very much. It is observed that when the network density is 30, throughput is almost half of when the network density is 20. This is due to random movement of nodes in the network.

Figure 4 is a graph of network latency with varying network density. Latency of the proposed algorithm for different network densities is lower compared to AODV. When the network density is 10, the latency is same as the packet load is less and forwarding probability is almost 1 and packet drop is less. As the network density increases, latency increases. When the network density is increased, more requests are generated, packet load is heavy and thus the delay increases very fast.

5.2 Nodes with varying battery capacity

For simulation we have considered a varying maximum residual energy i.e, maximum battery capacity (E_max) by randomly generating a value between the range 500–

1500 units. Figure 5 and 6 are the results showing network lifetime, throughput for varying network densities in this run.

Figure 5 and Figure 6 compares lifetime and throughput of PMEF (0.8 P_t and nodes with varying battery capacity) with PMEF (0.8 P_t and nodes with same battery capacity) and AODV respectively. It is observed in Figure 5. that the lifetime of the network decreases when the nodes have varying battery capacity. This is basically depends on the average energy which is calculated by collecting the energy information from the neighbors. We can observe that lifetime of PMEF with varying battery capacity is more when the network density is 10, 30, and 40 but less when the network density is 20 and 50. This is because the battery capacity of the nodes is varied within a specified range and are randomly generated.

From Figure 6 it is observed that throughput of AODV is less compared to PMEF. Throughput of PMEF with varying battery capacity is more when the network density is 10 and 30, less when the network density is 20, 50 and is same when the network density is 40 compared to PMEF with constant battery capacity because the nodes move randomly and varied maximum battery capacity.

6 Conclusions and Future Work

One critical issue of almost all kinds of portable devices supported by batteries is power saving. Battery power is a limited resource, hence to lengthen the lifetime of batteries is an important issue, especially for MANET, supported by batteries. In this paper, we present an energy efficient algorithm PMEF which utilize a localized averaging algorithm CAE to estimate the average energy. The node determine an appropriate rebroadcast probability for forwarding a route request message in route discovery using the average energy. As compared to the existing AODV, our proposed schemes in forwarding a route request are more effective in reducing the flooding overhead and increase the network lifetime and throughput thereby decreasing the network latency. There exists a trade–off between the energy saving and the throughput according to the value of threshold probability P_t. Future, we need to find the effect of this algorithm for different mobility models and compare with other energy aware routing protocols of Mobile Ad hoc Networks.

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