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ORIGINAL CONTRIBUTION

Energy Efficient Probabilistic Broadcasting for Mobile Ad-Hoc Network

Sumit Kumar[1] · Shabana Mehfuz[1]

Abstract In mobile ad-hoc network (MANETs) flooding method is used for broadcasting route request (RREQ) packet from one node to another node for route discovery. This is the simplest method of broadcasting of RREQ packets but it often results in broadcast storm problem, originating collisions and congestion of packets in the network. A probabilistic broadcasting is one of the widely used broadcasting scheme for route discovery in MANETs and provides solution for broadcasting storm problem. But it does not consider limited energy of the battery of the nodes. In this paper, a new energy efficient probabilistic broadcasting (EEPB) is proposed in which probability of broadcasting RREQs is calculated with respect to remaining energy of nodes. The analysis of simulation results clearly indicate that an EEPB route discovery scheme in ad-hoc on demand distance vector (AODV) can increase the network lifetime with a decrease in the average power consumption and RREQ packet overhead. It also decreases the number of dropped packets in the network, in comparison to other EEPB schemes like energy constraint gossip (ECG), energy aware gossip (EAG), energy based gossip (EBG) and network lifetime through energy efficient broadcast gossip (NEBG).

Keywords Probability · Energy · Route discovery · Broadcast storm · Overhead · MANET · ECG · EAG · EBG · NEBG

✉ Sumit Kumar
   er.sumitkumar21@gmail.com

[1] Department of Electrical Engineering, Jamia Millia Islamia, New Delhi, India

Introduction

For transmitting information among mobile nodes of mobile ad-hoc network (MANETs), a fundamental practice is used called broadcasting which is also used in many standard protocols like dynamic source routing (DSR) as well as ad-hoc on-demand distance vector (AODV). Even though the broadcasting method is for distributing messages among all nodes, it has many issues that can reduce the efficiency as well as performance in MANETs, which includes redundant transmissions, collisions as well as contention. All these problems in conjunction are named as broadcast storm problem. In some traditional reactive routing protocols similar to AODV, a node broadcasts a route request (RREQ) to all its nearby neighbouring nodes so as to find out a route towards particular destination, after which, all neighbouring nodes again rebroadcasts the same RREQ control packet in anticipation that the route is found between source and a particular destination. The basic method used for broadcasting is flooding method, which is well suited for MANETs. This is because, for MANETs, geographical information of nodes is not required. Regardless of the fact that flooding may be used directly in ad-hoc networks, flooding is still a challenging problem as it produces the highest number of unnecessary messages, conflicts, contentions and squandering important inadequate resources like available bandwidth as well as battery energy.

The probabilistic broadcasting [1, 2] acquires considerably lesser overhead in contrast to blind flooding and at the same time achieves a soaring success rate of dissemination of the broadcast packets. Many probabilistic schemes for flooding have been proposed in recent times to resolve the broadcast storm problem. Both DSR and AODV have objective of finding the shortest path between the source and the destination as well as battery utilization of

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J. Inst. Eng. India Ser. B (June 2017) 98(3):289–294

surrounding neighbours information of the nodes is not taken into the consideration in these protocols while deciding the probability of the nodes. Therefore the shortest route may be overused as well as drain the node's batteries rapidly, which may further result in network partitioning and shrinking of the network lifetime.

In the past, various energy saving routing protocols have been proposed for solving node's energy issues. The RREQ packet is held [3] and forwarded after a small interval by intermediate nodes. The holding time depends upon the remaining energy of the nodes so that less energy nodes can be avoided for forwarding packets. The trade off among the energy expenditure [4] for dispersal traffic as well as the enhanced spatial allocation of energy load is analyzed. Energy utilization because of excess packet overhead [5, 6] is measured and combined with route awareness to improve network life time. The concept of [7] establishes the best possible data modelling of the collaboration sets at all hops on a route to reduce the complete energy expenditure per bit which has been communicated while [8] a traffic adaptive routing protocol was implemented to most favorably unite the proactive as well as on demand protocol approaches. The concept that all mobile nodes decide that the RREQ packet must be broadcasted by analysing its remaining energy with a predetermined threshold energy value [8, 9], and the threshold energy value is determined continuously as the packet moves in the network. The same concept was also implemented in AODV [10, 11]. All of these strategies which use the concept of threshold energy in routing protocols can efficiently save the most used nodes in the route detection phase. On the other hand, the criteria to adjust the rebroadcast probability P which further depends upon the remaining energy and properly adjusted threshold energy level is still missing.

This paper puts forward a new broadcasting algorithm, namely, energy efficient probabilistic broadcasting (EEPB) that improves probabilistic broadcast methods to broadcast the RREQ packets and gives better results as compared to other EEPB schemes like energy aware gossip (EAG) [12], energy constraint gossip (ECG) [13], energy based gossip (EBG) [14] and network lifetime through energy efficient broadcast gossip (NEBG) [15].

The simulation results illustrate that the implementation of AODV with EEPB further assists to decrease the general routing overhead with less power consumption of nodes. The performance of protocol while broadcasting routing messages is analyzed in this work. The performance of the proposed protocol has been compared and analyzed with the performance of the following energy efficient protocols: EAG, ECG, EBG and NEBG. The rest of the paper is ordered as follows.

Energy Efficient Probabilistic Broadcasting (EEPB) Scheme

In this paper, a new scheme EEPB is proposed which overcomes the shortcomings of previously proposed scheme AODV_EAPB [16] as mentioned earlier while using the same concept of categorising the nodes as DNs and NDNs and changing the fixed timer used in a previous scheme to variable timer depending on the DNs and NDNs. In this segment, the proposed EEPB technique will be explained in details. The definition of various EEPB parameters is specified in Table 1.

The method for determining the energy threshold is calculated [11, 16–18] by using local average energy of all the nodes. The objective of our algorithm is to broadcast a control packet depending upon their remaining energy and also balancing energy utilization among all nodes in the network. For calculating the average energy of the network one needs to have information of all nodes of network for this exchange of packets. Therefore in place of adding new control packets for this purpose, the existing control packets in AODV for sending the essential energy knowledge of other nodes are changed. The remaining energy of all nodes in EEPB is exchanged between all nodes by using HELLO packets in AODV. For accumulating this knowledge a fresh field named remaining energy (P_r) is inserted in HELLO packet. EEPB uses the modified RREQ of AODV for broadcasting in the route discovery process and as well as to get the local average remaining energy knowledge down side the node path traced by the packets. When a source node sends a RREQ for route discovery it adds its local average energy as a new field denoted by P_{avg}. Every intermediate node will revise P_{avg} field by adding its local average energy possessed by that node to it. The instant when RREQ packets are being sent

Table 1 Definition of EEPB parameters

Parameter	Definition
n	Number of nodes in a network
P	Forwarding probability of a node
I	Number of nodes along backward path (for RREQ packet)
n_s	Source node neighbours
n_i	Neighbours of ith node
P_r	Remaining energy of node inserted in Hello packet
P_{rs}	Remaining energy of source node
P_{ri}	Remaining energy of ith node
P_{avg}	Local average energy of node inserted in RREQ packet
P_{lavg}	Local average energy of node
P_{iavg}	Instantaneous average energy of network
A	System parameter
P_{th}	Threshold energy of a node

on the forward path, at the same time the local energy information of all the nodes in that route, reaches to each and every node in the backward path. The instantaneous average energy of all nodes of the network can be considered as

$$P_{iavg} = (P_{avg} + P_{lavg})/i \qquad (1)$$

where P_{avg} is the local average energy of node inserted in RREQ packet; P_{lavg}, the local average energy of node; i, the number of nodes along the downside path traced by the node; and P_{iavg} is the instantaneous average energy of network.

As the exact average energy of the network is not available, such instantaneous average energy of network is just an approximation of it. While sending a RREQ packet, the sender node has inserted its own local average energy to the P_{lavg} field as well as every intermediary nodes which broadcasts this RREQ has revised P_{lavg} by adding its own local average energy. As a result, P_{iavg} is a fine estimation of average remaining energy, as it takes average energy information from all nodes on the route as well as from their neighbours.

While knowing the instantaneous average energy of the network, the threshold energy of a node is set as

$$P_{th} = \alpha P_{iavg} \qquad (2)$$

where α is the network parameter, for which the range is $0 < \alpha < 1$. α stands for various safety levels. By setting smaller values of α, the intermediate nodes can be more often made to participate in the route discovery procedure.

A description of EEPB algorithm is given in Fig. 1.

An illuminating example: This example demonstrates the EEPB scheme given in Fig. 2. Here sender and 4 nodes out of 8 nodes are considered for an explanation of the example.

- The source node (S) broadcasts a modified RREQ packet with adding its P_{avg} to the RREQ packet header to discover a route to the destination D.
- Neighbours of source node S compare their remaining energy and the value of threshold energy is calculated using Eq. (2). The value of remaining energy of nodes 1, 2, 3 and 4 as taken from the neighbour remaining energy table and are equal to 76, 73, 84 and 89 J, respectively, where their initial energy is taken as 100 J as shown in Table 2.
- As $P_r < P_{th}$ for nodes 1 and node 2, so they are considered as NDN and starts T_{LONG} with counter C_{HIGH} and similarly $P_r > P_{th}$ for nodes 3 and Node 4 are DN, so these nodes starts T_{SHORT} with counter C_{LOW}.
- After the timer of dependable nodes DNs have expired, these nodes rebroadcast with high probability P. Therefore the probability of rebroadcasting

of dependable nodes, DNs is decreased when rebroadcast raises the value of counter at the dependable node.

- Now, when source node S broadcasts a packet to nodes 1,2,3 and 4 then all of these four nodes after receiving a packet initiates the counter with a value C = 1.
- Let us assume that firstly node 4 rebroadcasts with a probability P = (0.75/1) = 0.75 (assuming $P_{iL} = 0.75$), as this node has the shortest timer T_{SHORT} out of these four nodes. And immediately as soon as duplicate packet is received by other three nodes from node 4 they increment the counter by one, that is, C = 2 and the rebroadcast probability P for nodes 1, 2 and 3 can be calculated as P = (0.75/2) = 0.375.
- The second rebroadcast is disseminated now from node 3. It starts the second rebroadcast as it has the second short timer $TIMER_{SHORT}$ with probability P = 0.35. The new value of counter C is again incremented by one and it becomes C = 3. Therefore, for nodes 1 and 2, the rebroadcast probability P is calculated as P = (0.95/3) = 0.3167 (assuming $P_{iH} = 0.75$). The same procedure can be applied to remaining nodes 5, 6, 7 and 8 until RREQ reaches the destination D. So this example clearly shows that proper rebroadcast probability can be set using suitable timers.

So in our proposed scheme (EEPB) following are the advantages as compared to other existing protocols:

- The proposed algorithm decreases the rebroadcast figure without considerable negotiation on its reachability.
- In EEPB scheme the RREQ packets are broadcasted with less number of nodes than the original probability schemes where fixed probability or blind flooding is used.
- By using the EEPB scheme, the nodes having more energy are used which further increases the network lifetime.

Performance Analysis

In this section, the performance of proposed EEPB algorithm are evaluated and compared with the performance of the following energy efficient protocols: EAG, ECG, EBG and NEBG. Network simulator NS2 has been employed to assess the modified AODV using EEPB scheme. The rest of the simulation parameters are depicted in Table 3.

Consumed Power

As seen in the Fig. 3, EEPB use less energy per node as compared with other four protocols. Mainly the battery
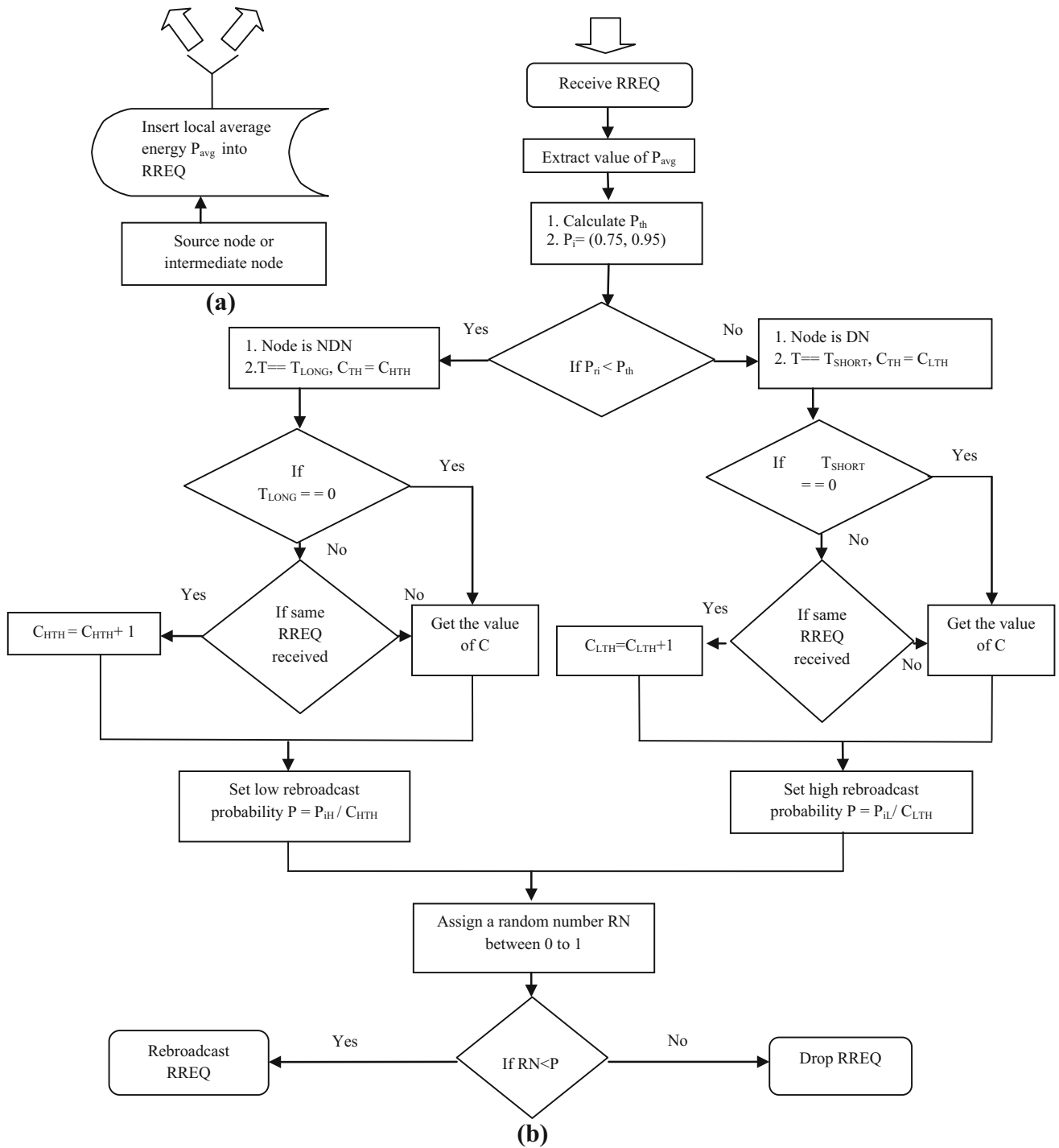
Fig. 1 Description of EEPB algorithm **a** sending node, **b** receiving node

usage of EEPB gets better in contrast to that of traditional AODV with fixed flooding. The EEPB performs best at each and every point of the node density range as compared with other four protocols. The reason for this improvement is mainly due to categorization of nodes as DNs and NDNs on the basis of remaining energy of nodes whereas the

other four protocols do not use categorization concept. The EAG protocol uses additional battery in contrast to NEBG and EBG because they employ multipoint relay scheme. Other than this it performs exceptionally well in contrast to ECG as the node number within the network is near about 100 nodes because of stochastic traffic (Pareto traffic) use
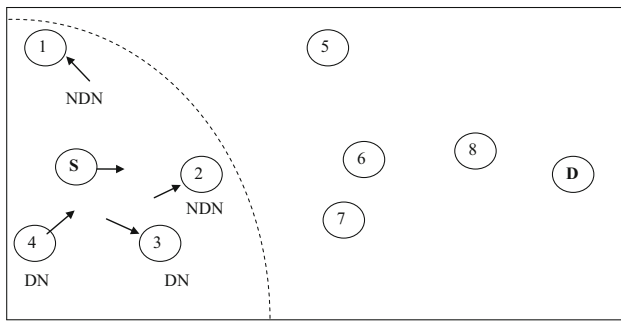
Fig. 2 Example of energy efficient probabilistic broadcasting

instead of CBR in ECG. In contrast, the energy usage within any network implemented with ECG as well as EAG increases rapidly starting from quite elevated levels. As the number of nodes increases, the energy consumption of ECG implemented networks enhances as compared to all protocols taken into consideration because out of four protocols this is the only one which applies stochastic traffic (Pareto traffic).

Throughput

Data throughput of all five protocols is shown in Fig. 4. NEBG presents appreciable performance. EEPB performs well with average dense networks till the network size remains within 50 nodes. The NPEG calculates the probability based on the maximum and minimum battery level so NEBG outperforms the other three protocols, that is, EAG, ECG and EBG. The EAG only decides the probability of broadcasting on the basis of current energy status of broadcasting node and that's why it is having low throughput. Also in EEPB, P_{iavg} has been used which is a fine estimation of average remaining energy as well it takes average energy information from all nodes on the route as well as from their neighbours which results in higher throughput.

Control Message Overhead

Figure 5 illustrates control message overhead of all protocols. As seen in the figure, EEPB has lower control message overhead than all other four protocols mainly due to categorization of nodes as DNs and NDNs which results

Table 3 Summary of the parameters used in simulations

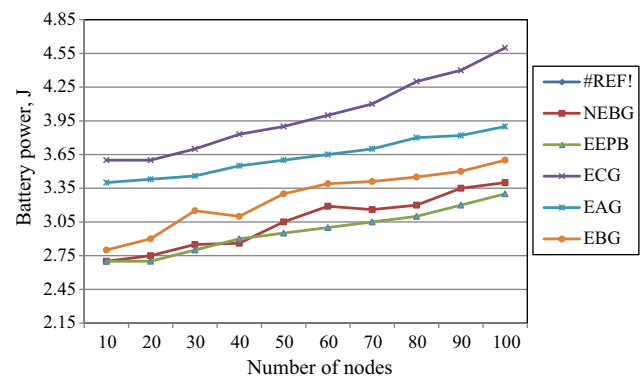| Parameter	Value
Transmitter range	100 m
Simulation time	400 s
Scenario simulation repetitions	10
Interface queue length	50 messages
Pause time	0 s
Topology size	1500×1500 m^2
Packet size	512 bytes
Mobility	1–30 m/s
Number of nodes	100
Data traffic	CBR
Initial energy of the nodes	100 J
Mobility model	Random way-point

Fig. 3 Consumed power against node density

in sensible broadcasting of control packets by nodes whereas EAG as well as NEBG presents a superior result because they use the maximum and minimum battery level information, but does not use the battery information of all nodes. Also NEBG and EBG employ multipoint relay scheme. ECG protocol shows poor performance as compared to all other protocols which further worsens the situation when the number of nodes increases from 30 to 40. This is because ECG employs stochastic traffic (Pareto traffic) instead of CBR in other protocols.

Table 2 Timer type and value of rebroadcast probability P

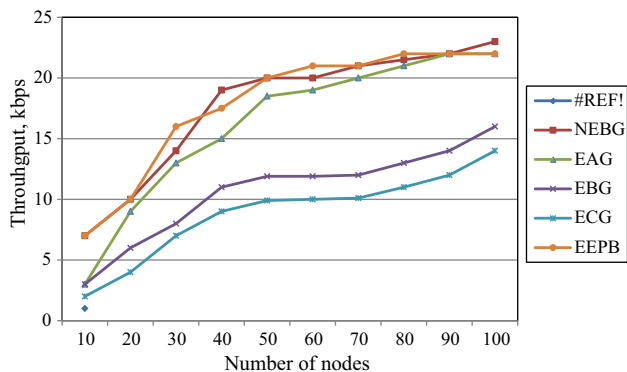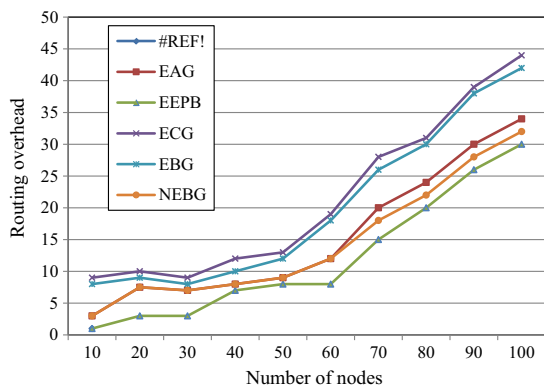| Node Id	P_r, J	Initial energy, J	Node type	Timer type	Value of P
1	76	100	NDN	T_{LONG}	0.3167
2	73	100	NDN	T_{LONG}	0.3167
3	84	100	DN	T_{SHORT}	0.375
4	89	100	DN	T_{SHORT}	0.75

Fig. 4 Throughput against node density

Fig. 5 Routing overhead against node density

Conclusion

In this paper an EEPB technique for transmitting RREQ packets is proposed and implemented in the AODV routing protocol for MANETs which outperforms the other EEPB techniques. As compared with other probability based broadcasting techniques where every node broadcasts with fixed probability without considering the remaining energy of the nodes. The proposed scheme in this paper decides probability of RREQ broadcast depending on the remaining energy of the nodes. Further, one may intend to implement a new parameter such as velocity and node density along with remaining energy of nodes in the route discovery phase, which involves another extensive research for analysing, whether it can remove the broadcasting storm problem or not with increasing link stability.

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