International Journal of Applied Engineering Research ISSN 0973-4562 Volume 12, Number 15 (2017) pp. 5374-5382
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Energy Balance Packet Forwarding for Lifetime Maximization in Mobile Ad Hoc Networks

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Abstract

Nodes in in the mobile ad-hoc networks (MANETs) are equipped with battery of limited power. Energy is one of the prime issue in such networks. Therefore, energy should be used in efficient way. In this paper, we present a new energy balance packet forwarding (EBPF) approach to balance the energy consumption among the nodes in MANETS. The process of next hop selection function based on node degree, forward progress, and residual energy to forward the packet from a sender node to the next hop is presented. Mathematical formulation of energy consumption of a route and next hop selection function is proposed. Mathematical models for calculating the energy consumption of a route is proposed. A new approach for calculating expected number of node and degree of node is presented. The results have been obtained for the EBPF approach, and compared with DIR and GEDIR. Simulation results clearly show that the proposed EBPF approach outperforms in the terms of network lifetime, energy consumption, and standard deviation of energy.

Keywords: Energy balancing; node degree, expected energy consumption; Ad hoc networks

INTRODUCTION

A Mobile Ad-hoc Network (MANET) is infrastructure less network consisting moving nodes connected using radio links dynamically in arbitrary manner. The nodes themselves manage organizing and controlling functions of the network. The whole network is mobile, and the individual nodes are allowed to move freely. Every node in MANETs could be worked as router. The nodes, which may not connect directly to forward the packets using intermediate nodes so that the packets can be delivered to their destinations. Multi-hop forwarding concept increases the degree of node connectivity and minimize the energy consumption [1, 2]. The initial applications of MANETs are military and emergency relief operations, later, they have attracted researchers due to its applicability for other applications.

In MANETs, route is a sequence of mobile nodes that sends data packets from a given source to a destination. Due to node's mobility, the routes are prone to break rapidly which reduce the overall throughput as compared with wired networks. The hop count is the number of nodes in a route from the source to destination. There exist many packets forwarding algorithms [3-6] that minimizes the number of hops, and creates shortest route in the network. Such types of routing are known as position based greedy routing algorithms [7]. The route is established based on location of the source node, positions of the immediate nodes, and the destination. Few examples of these greedy forwarding algorithms are: most forward within radius (MFR)[3], Compass routing (it is referred to in the literature as DIR)[4-5], and Geographical distance routing (GEDIR)[6]. MFR choose a next hop node which has maximum progress towards destination.

DIR creates the routes by selecting the next forwarding node within its transmission range and which is the nearest to direction of the destination. It also reduces the hop count and restricts flooding of the packet in the networks. GEDIR routing algorithm is also as greedy routing algorithm, whose main aim is to same as of DIR and MFR but differ in next next hop selection logic. GEDIR choose a node from neighboring nodes as next hop that has the minimum forward progress distance between the node chosen as next forwarder and the destination. Although these greedy algorithms save energy consumption by restricting the flooding and minimizing the routing overhead and hop count.

In DIR, MFR, and GEDIR routing algorithms involve all the neighboring nodes in transmission range of the sender node in routing decision, leading in unnecessary overhead, and consume extra energy due to participation of all the neighboring nodes in routing. In our work, we consider only the neighboring nodes for participation in routing that belong to half of transmission range of the sender in forward direction towards destination, which reduces energy consumption.

In addition to above mentioned, many others studies have been suggested focusing on the impact of hop count of routes on the performance of MANETs. Authors in [8] proposed a routing algorithm known as nearest with forward progress (NFP) which chooses a next hop node for packet transmission from neighboring nodes that near to the sender. By utilizing the location information of nodes in location-aided routing (LAR) [9] protocol, the authors have claimed that there is significant improvement in the performance of MANET. LAR uses the location information to limits the search space for routing to a small request zone. LAR is two type of algorithms namely LAR1 and LAR2 for determining the request zone.

The theoretical analysis of expected link distances and their relationship with hop count in a route has been studied in many papers [10-12]. In [10], this relationship was developed assuming that a greedy packet forwarding approach which chooses a next hop with the least remaining distance (LRD) to destination. A mathematical model for LRD and bounds on hop count in a route for a given Euclidean distance between the sender node and destination node has been developed. In [11], authors consider four parameters namely the node degree, the distance of the sensor node from destination, angle between neighboring nodes to the sender node, and residual energy of nodes for selecting next hop node. An analytical model for estimating the expected energy expenditure per hop is proposed. In [12], authors proposed an analytical approach known as maximum hop distance (MHD) to compute expected number of hop in a route for a given Euclidean distance between the sender node and destination node. This paper also assumes that the shortest route for packet forwarding is similar to MHD. A relatively simple method that helps in the optimizing the energy expenditure per link or per route is used for MHD packet forwarding. The expected energy expenditure per hop or per route for greedy forwarding has been studied in limited number of papers [11]. The authors developed model for expected energy per link considering uniform random node deployment for stationary network. In paper [13] authors presented an analytical estimation of energy consumption for packet forwarding in MANETs where the nodes follows random waypoint mobility model. Mathematical formulation of energy consumption of a route is proposed. A model for computing expected link using random mobility in MANET is presented.

In this paper, we present a new energy balance packet forwarding (EBPF) approach to balance the energy consumption among the nodes in MANETS. The process of next hop selection function based on node degree, forward progress, and residual energy to forward the packet from a sender node to the next hop is presented. Mathematical formulation of energy consumption of a route and next hop selection function is proposed. Mathematical models for calculating the energy consumption of a route is proposed. A new approach for calculating expected number of node and degree of node is presented. The results have been obtained for the EBPF and compared with DIR and GEDIR.

The rest of the paper is organized as follows: Section 2 describes a proposed packet forwarding approach. In section 3, analytical model for node degree, expected energy consumption is proposed. In The simulation and results are described in section 4. Finally, section 5 concludes the paper.

ENERGY BALANCED PACKET FORWARDING APPROACH

In this section, we present the design of energy balanced packet forwarding algorithm. First the network and energy models used in this paper are presented and then forwarding search space, next hop selection logic, and packet forwarding are given. In this paper, we mainly focus on the lifetime maximization and energy conservation by load equalization among the nodes in the network. While minimizing the energy consumption, the number of hops along the computed path may be high. Because instead of using the shortest path, each time it uses a different path for the packet transmissions.

A. Network Model

We model the MANET as a undirected graph $G = (V, E)$, where V is a finite nonempty set of nodes and a set E of links between nodes. Each link corresponds to an ordered pair of distinct nodes (v_i, v_j), $\forall v_i \in V$, v_j is within transmission range of v_i (v_j is neighbor of v_i). A route in MANET is defined as a finite sequence of links which connect a sequence of nodes include the source node and destination node. We consider a single source and single destination network model in which packets generated by only the source and destined to the destination. No packet is generated by the intermediate nodes. If the destination node is not within direct transmission range of the source, then it relies on intermediate nodes to forwarded the packets to the destination node. The nodes in are deployed in square network area and movement of the nodes follows the random waypoint mobility.

B. Energy Model

Route energy is defined as the energy expenditure of a route due to transmission and reception packets across the links present in the route. To evaluate the energy consumption of the route, here only energy consumed in transmission and reception are considered. It is assumed that there are k links present in a route R. The k links connect $k + 1$ number of nodes including the sender and destination. Let v_i is the source node and v_z is the destination node in the route. Thus the route may look like as finite sequence of links

$$R = \{(v_i, v_j), (v_j, v_k), \ldots, (v_x, v_y), (v_y, v_z)\} \quad (1)$$

The total energy consumed in forwarding in the route R can be expressed as sum of energy expenditure of each link.

Therefore,

$$\begin{aligned} E_R &= E_t(b,r_{ij}) + E_t(b,r_{jk}) + \cdots + E_t(b,r_{yz}) \\ &= [E_{tx}(b,r_{ij}) + E_{rx}(b)] + [E_{tx}(b,r_{jk}) + E_{rx}(b)] \\ &\quad + \ldots + [E_{tx}(b,r_{yz}) + E_{rx}(b)] \\ &= [E_{tx}(b,r_{ij}) + E_{tx}(b,r_{jk}) + \ldots + E_{tx}(b,r_{yz})] \\ &\quad + k \times E_{rx}(b)\,, \end{aligned} \qquad (2)$$

where, $E_t(b,r_{ij})$ is the energy expenditure for transmitting and receiving b bits of a data packet through a link (v_i, v_j) connecting the sender node v_i to the receiving node v_j and r_{ij} denotes physical distance by which the nodes v_i and v_j are separated. The energy requirement $E_t(b,r_{ij})$ can be expressed as

$$E_t(b,r_{ij}) = E_{tx}(b,r_{ij}) + E_{rx}(b), \qquad (3)$$

where, $E_{tx}(b,r_{ij})$ and $E_{rx}(b)$ are energy expenditure for transmitting and receiving b bits of a data packet through a link (v_i, v_j) connecting the sender node v_i to the receiving node v_j being separated by a distance of r_{ij} , are respectively given by

$$E_{tx}(b,r_{ij}) = E_{el}b + E_{am}b{r_{ij}}^{\eta}, \qquad (4)$$

$$E_{rx}(b) = E_{el}b\,. \qquad (5)$$

where E_{el}(nJ/bit) represents the energy dissipated per bit by transmitter or receiver electronics and E_{am} (pJ/(bit m^{-2})) is the energy spend per bit to run the transmitting amplifier depending on the distance ${r_{ij}}^2$. The parameter η is known as path loss exponent. Its value may differ for line-of-sight and non-line-of-sight signals and takes between 2 to 6 depending on fading conditions of the environment where the nodes have been deployed. For line-of-sight, generally $\eta = 2$ and non-line-of-sight, $\eta > 2$. The constants used in the energy model are [8]: $E_{el} = 50$ (nJ/bit), and $E_{am} = 100$ (pJ/(bit m^{-2})). It is noted that the energy requirement for transmitting data packets is proportional to a power of the physical distance between the sending and receiving nodes.

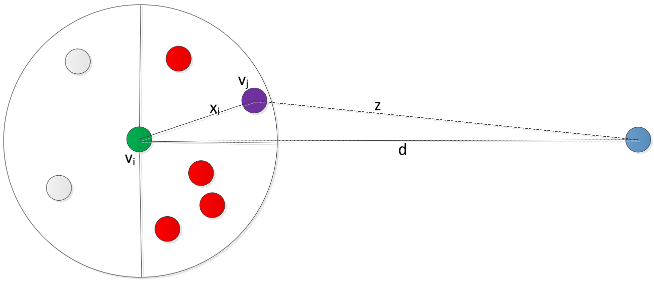

Figure 1: Forwarding search space

C. Forwarding search space

In this section, a forwarding search space of a sending node is defined to control the unnecessary transmission. The distance between the sender and destination nodes is to be d and transmission range or radius is r. The forwarding angle θ_i is defined as the angle between lines $v_i\ v_j$ and $v_i\ v_z$, and x_i is the distances between the sender node v_i and neighboring node v_i and X_i is the forward progress calculated as

$$X_i = \frac{x_i}{\cos\theta_i} \qquad (6)$$

The half-circular region in the direction of the destination v_z of the sender node v_i is known as forwarding search space (FSS).

D. Next forwarder selection function

Assume that n number of neighboring nodes are deployed in the FSS (half circle) of a sender node v_i. In proposed routing scheme, next hop (says node v_j) is selected based on the three parameters namely, d_j, E_r^j and α_j, where, d_j is forward progress of the node v_j towards destination, E_r^j is the residual energy of the node v_j and α_j is the degree of connectivity of node v_j.

The only nodes lies in FSS of the sender participate in the selection process of next forwarder. The sender node evaluates the following function g for all the nodes lying in its FSS. The function g defined as

$$g = w_1 d_j + w_2 E_r^j + w_3 \alpha_j \qquad (7)$$

Where w_1, w_2 and w_3 are the weights of the parameters d_j, E_r^j and E_r^j respectively and sum of these weights is equals to one i.e. $w_1 + w_2 + w_3 = 1$. Depending on the requirement of the applications, these weights varies. Hence, the selection of next forwarder may be curved with the different values of w_1, w_2 and w_3. In the scenario where time is critical, higher value of $w_1$is preferred so that the node which is near to the destination becomes as next forwarder to reduce the delay. A high value of w_2 increases the chance of selecting a node with the higher residual energy. To fairly equalize the energy consumption among the nodes, only the residual energy of the sensors may be taken into account, so that each time the node with high residual energy could get chance to become the next forwarder. For intermittently connected networks or nodes are mobile, a higher value of w_3 is preferred so that the node with more number of links could have high probability to become as next forwarder.

ANALYTICAL FRAMEWORK

In this section, we define mathematical models of the parameters used in (2). These are the expected energy expenditure of a node, connectivity degree of a node, and expected forward progress per hop under varying parameters.

A. Expected node degree

The essential characteristic of a node in ad-hoc network is the number of neighboring nodes. A node without neighbors cannot exchange any data with other nodes, is useless for the entire network. In mobile network, an isolated node may send or receive data only it moves to the transmission range of others nodes. A higher degree of a node makes robust against movement and failure of links. Therefore, we show how to compute the degree of node represented by the random variable D, and its expected value $E(D)$.

Assume that there are N number of nodes are arbitrary distributed over the network area A. A given node is connected with α arbitrary nodes is follows binomial distribution. The probability of the given node has α degree is given by

$$P(D=\alpha)=C(N-1,\alpha)\,L^{\alpha}(1-L)^{N-\alpha-1} \tag{8}$$

Where, L is the probability that any two nodes establishes a link in the network area. The expected degree is calculated as

$$E(D)=\ (N-1)L \tag{9}$$

When L is very small, and N is large, the probability $P(D=\alpha)$ is follows Poisson distribution. It is given by

$$P(D=\alpha)\ \cong\ \frac{\left((N-1)L\right)^{\alpha}}{\alpha!}e^{-\left((N-1)L\right)} \tag{10}$$

The probability that there is no neighbors $(\alpha=0)$ for a given node is given by

$$P(D=0)\ \cong\ e^{-\left((N-1)L\right)} \tag{11}$$

The probability of at least node having one degree is defined as

$$P(D\geq 1)\ \cong\ 1-P(D=0)=1-\ e^{-\left((N-1)L\right)} \tag{12}$$

Assuming that uniform random node distribution is used to deploy nodes over a finites area A. The link probability L depends on the transmission coverage area A_c of a node and the network area A, thus, the link probability is given by

$$L=\ \frac{A_c\cap A}{A} \tag{13}$$

Ignoring the border nodes, thus the expected degree of node is expressed as

$$E(D)=\ \frac{(N-1)\pi r^2}{A}, \tag{14}$$

where r is the transmission range of the node.

B. Connectivity degree of a route

Let v_i is the source node and v_z is the destination node in the route. A route from v_i to v_z exists if at least one neighbor presents in the FSS of the all nodes in the route. Therefore, the probabilistic degree of a route from v_i to v_z can be expressed as

$$\alpha_R=\ \prod_{i=1}^{E(h)}P_i(D\geq 1) \tag{15}$$

C. Expected forward progress

To compute the expected forward progress analytically, Assume that n number of neighboring nodes are deployed in the FSS of a sender node towards destination. The distances between the sender node and neighboring nodes are x_i, the angles between from neighboring nodes to the sender and from sender to the destination are θ_i, and their respective forward progress are X_i where $i=1,2\ldots n$. Let v_j be probable forwarder situated at maximum forward progress d from v_i . To calculae the expected value $E(X)$, cumulative density function (CDF) $F\ (X)$ and probability density function (PDF) $f(X)$ are calculted.

$$F(X)=\prod_{i=1}^{n}P[X_i\leq X]=(\frac{X}{r_{max}})^n$$

The PDF of X can be expressed as

$$f(X)=\ \frac{d}{dy}F(X)=\frac{1}{r_{max}^n}nX^{(n-1)}=\frac{n}{R}(\frac{X}{R})^{(n-1)}$$

The expected value of d is

$$E(X)=\int_0^{r_{max}}Xf(X)dx$$
$$=\frac{n}{r_{max}^n}\int_0^{r_{max}}X^n dx=\frac{n}{n+1}r_{max} \tag{16}$$

D. Expected hop count

Here, it is considered that the network area is square in shape with side a. If the sender node v_i, and the destination node v_z are located at corner of diagonalof the region , diagonal $a\sqrt{2}$ is the maximum distance between v_i, and v_j. Let $E(l)$ be the expected value of distance l between v_i and v_j. The CDF $F(l)$ and PDF $f(l)$ of l can be expressed as $\frac{l}{a\sqrt{2}}$ and $\frac{1}{a\sqrt{2}}$, respectively. By definition, the expected value of l is

$$E(l) = \int_0^{a\sqrt{2}} l f(l) dl = \frac{a}{\sqrt{2}} \qquad (17)$$

Therefore, expected hop count $E(h)$ can be calculated as

$$E(h) = \frac{E(l)}{E(X)} = \frac{a}{\sqrt{2}\, r_{max}}\left(1 + \frac{1}{n}\right) \qquad (18)$$

E. Expected energy consumption

The first involves consumption of energy by the transceiver at the source, intermediate and destination nodes. The transceiver consumes the energy in transmission and reception of data bits. It is known that the energy consumed in transmission is proportional to the link distance r^2. The expected energy consumption per hop $E_t(b,\mathrm{r})$ for transmitting of b bits data between two nodes, can be expressed as

$$E_t(b,\mathrm{r}) = \left[2E_{el} + E_{am}\left(\frac{n}{n+1} r_{max}\right)^{\eta}\right] b \qquad (19)$$

Thus, the expected route energy E_R of a route for forwarding b bits of data packet from the source to destination can be expressed as

$$E_R = E_t(b,\mathrm{r}) \times E(h) \qquad (20)$$

RESULTS AND ANALYSIS

In this section, to evaluate the performance of the proposed energy balanced packet forwarding approach, the experiment is conducted with different values of weights w_1, w_2 and w_3. The routes computed by the proposed packet forwarding approach are shown in Table I and Table II. The set of independent parameter that decides the routes residual energy include transmission range, number of hops, and node degree. Nodes are randomly distributed over a squre network area of 500 × 500 m^2 . The number of nodes deployed for this simulation is 100-300. The transmission range of the nodes is assumed to be $r_{max} = 100\, m$. The size of the data packets is taken to be 512 bits. The constants used in the energy model (4), (5) are $\mathrm{E_{el}} =$ 50 (nJ/bit), and $\mathrm{E_{am}} = 100$ (pJ/(bit m-2)). The path loss $\eta = 2$, and d=1000 m have been considered. Perfect localization of the nodes has been considered in each scenario. The proposed forwarding approach is validated by comparing the experiment results obtained in the simulation and for analytical models. To compute the routes, initially, a random network topology (c.f. Fig.2) is created in a network region of area 500 × 500 m^2, and each node have been assigned their positions. Links are established between nodes if the distance between two nodes is less than or equal to the transmission range.

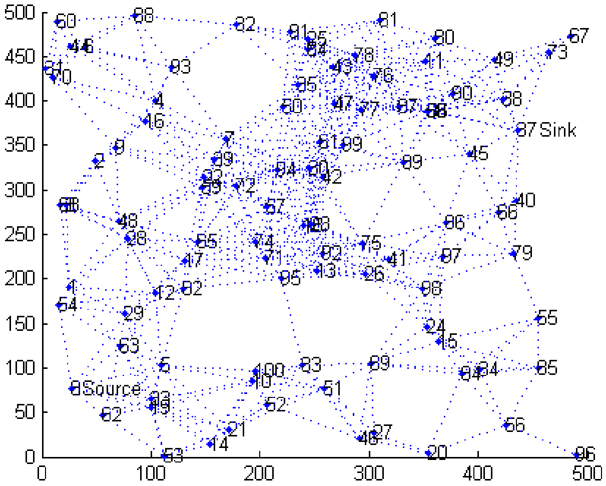

Figure 2: Random network topology with 100 nodes

Table I shows different routes obtained by the proposed packet forwarding approach. The source and the destination nodes are numbered 8 and 37, respectively. It is notice that for number of node $N = 100$, and the initial energy of each node is 10 units, the routes changes for each packet. Here, 15 packets are forwarded from the source node number 8 to destination node number 37. For energy equalization in the networks, a higher value of w_2 is chosen. For this simulation, $w_1 = 0, w_2 = 1$, $w_3 = 0$ are taken. Each time next forwarder is selected with higher residual energy. Table II shows the routes obtained for DIR, MFR, and GEDIR algorithms. It can be clearly observed that in packet forwarding between a source-destination pair, these greedy algorithms always forward the packet through the same route. Consequently, the energy of the nodes of the route depletes early which produces more number of dead nodes in the networks. These dead nodes partitioned the network, which results in shortening the networks lifetime. From the above study, the proposed packet forwarding approach better results in terms of energy consumption equalization and network lifetime.

Table I. Simulation results of computed routes for the weights $w_1 = 0, w_2 = 1, w_3 = 0$

Packets	*Routes*															*Hop count*
1	8	63	82	95	92	98	97	86	79	40	37					11
2	8	62	53	21	10	83	69	24	15	97	66	37				12
3	8	33	14	52	51	46	69	24	97	79	40	37				12
4	8	29	28	65	74	94	99	89	90	49	38	37				12
5	8	19	10	10	52	83	51	46	69	98	86	45	37			13
6	8	5	10	10	83	51	46	69	24	15	97	79	40	37		14
7	8	62	53	14	10	52	83	51	46	69	98	24	97	66	37	15
8	8	33	10	10	83	51	46	69	98	86	45	38	37			13
9	8	29	17	72	71	75	41	24	15	97	79	40	37			13
10	8	5	10	10	52	83	51	46	69	24	97	79	40	37		14
11	8	63	12	65	59	57	61	87	80	49	38	37				12
12	8	19	21	10	10	83	51	46	69	98	86	45	37			13
13	8	62	53	21	10	52	83	51	46	69	24	15	97	66	37	15
14	8	29	28	22	30	77	76	58	36	80	38	37				12
15	8	5	82	95	26	41	98	79	40	37						10

Table II. Comparison of routes obtained by DIR, MFR, GEDIR for N=100.

Algorithm	*Routes (For packets 1 to 20)*										*Hop count*
DIR	8	29	12	65	39	61	43	58	49	37	10
MFR	8	5	82	95	26	41	98	79	40	37	10
GEDIR	8	5	82	95	26	41	98	66	45	37	10

Table III: Lifetime;

Initial Energy (mJ)	Network Size=50			Network Size=100			Network Size=150			Network Size=200			Network Size=250		
	EBPF	DIR	GEDIR	EBPF	DIR	GEDIR	EBPF	DIR	GEDIR	EBPF	DIR	GEDIR	EBPF	DIR	GEDIR
5	10	8	6	15	8	6	22	8	6	28	8	6	42	8	6
10	18	14	11	28	14	11	34	14	11	40	14	11	58	14	11
15	28	20	16	40	20	16	45	20	16	57	20	16	70	20	16
20	39	28	24	60	28	24	63	28	24	67	28	24	88	28	24
25	57	40	34	75	40	34	79	40	34	85	40	34	92	40	34

Table IV: Energy Consumption

Packet forwarded	Network Size=50			Network Size=100			Network Size=150			Network Size=200			Network Size=250		
	EBPF	DIR	GEDIR	EBPF	DIR	GEDIR	EBPF	DIR	GEDIR	EBPF	DIR	GEDIR	EBPF	DIR	GEDIR
5	6.12	8.45	10.12	7.54	9.04	11.73	8.01	10.99	12.12	8.95	11.69	15.04	9.05	12.45	16.12
10	14.68	14.99	16.96	15.34	15.99	17.83	14.99	16.60	19.04	15.43	17.65	21.63	16.77	18.56	24.96
15	23.67	28.98	30.58	25.23	28.33	33.39	24.01	30.98	33.99	26.65	32.00	35.49	28.06	34.52	37.58
20	30.83	34.65	36.53	32.43	36.06	38.03	31.42	37.65	39.06	33.42	38.08	41.06	34.83	40.93	45.53
25	40.03	42.65	45.68	42.76	44.90	47.88	41.64	48.65	50.06	42.64	52.65	56.06	44.03	53.04	56.68

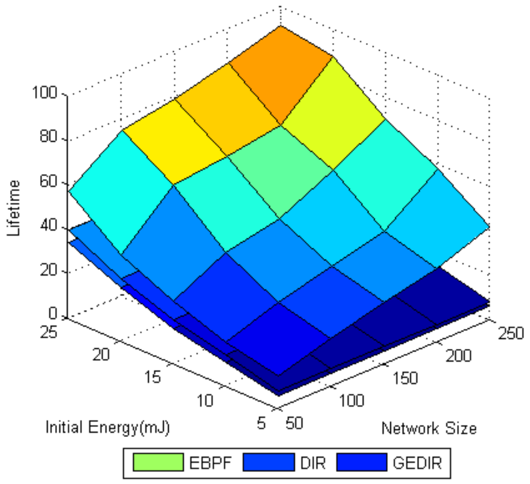

Figure 3: Lifetime comparison with network size and initial energy

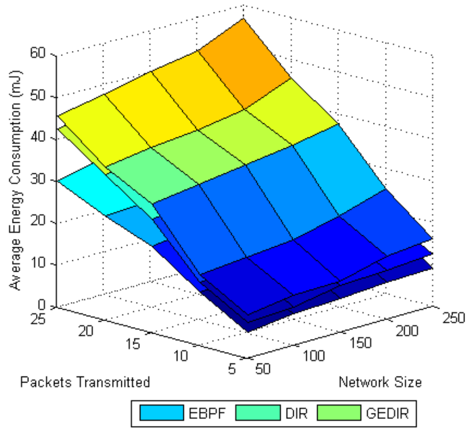

Figure 4: Energy consumption comparison with network size and number of packet transmitted

The outcome of simulation for the network are shown in fig. 3 and table III. These shows the comparison of lifetime between proposed EBPF approach and state of art techniques as a function of network sizes and initial energy. It is observed that as the network size increases from 50 sensor nodes to 250 nodes, the lifetime remains same for state of art techniques and it is increases for EBPF, for which it is 10 to 42 for initial energy 5 mJ. This is because there will be more number of sending node are available and, which led to change the next forwarder each time and hence reduce the chances of dean node which led to enhance the lifetime of the network. It is also observed that as the initial energy increases from 5 mJ to 25 mJ, the lifetime of the network also increases for the proposed approach and start of art techniques. When the network size and initial energy increase, the lifetime for EBPF increases more as compare to DIR and GEDIR, this is because in EBPF the routes for all the packets keep changing whereas state of art techniques use the same route for all the packets.

The outcome of simulation for the energy consumption are shown in fig. 4 and table IV. These shows the comparison of average energy consumption between proposed EBPF approach and state of art techniques as a function of network sizes and number of packets. It is observed that as the network size increases the energy consumption is also increases for the techniques. This is because there will be more number of node and more number of transmission, which led to increase in traffic and hence more energy will be used.

Table V: Energy balance factor

Packet Transmitted	Network Size=50			Network Size=100			Network Size=150			Network Size=200			Network Size=250		
	EBPF	DIR	GEDIR	EBPF	DIR	GEDIR	EBPF	DIR	GEDIR	EBPF	DIR	GEDIR	EBPF	DIR	GEDIR
5	0.975	0.970	0.955	0.976	0.971	0.956	0.978	0.972	0.957	0.980	0.973	0.958	0.980	0.974	0.959
10	0.974	0.965	0.945	0.975	0.966	0.946	0.977	0.967	0.947	0.979	0.968	0.948	0.979	0.969	0.949
15	0.973	0.955	0.930	0.974	0.956	0.931	0.976	0.957	0.932	0.978	0.958	0.933	0.978	0.959	0.934
20	0.972	0.935	0.910	0.973	0.936	0.911	0.975	0.937	0.912	0.977	0.938	0.913	0.977	0.939	0.914
25	0.970	0.920	0.890	0.971	0.921	0.891	0.973	0.922	0.892	0.975	0.923	0.893	0.975	0.924	0.894

Table VI: Dead node

Packet Transmitted	Network Size=50			Network Size=100			Network Size=150			Network Size=200			Network Size=250		
	EBPF	DIR	GEDIR	EBPF	DIR	GEDIR	EBPF	DIR	GEDIR	EBPF	DIR	GEDIR	EBPF	DIR	GEDIR
5	1	3	4	2	5	6	3	8	8	3	9	10	4	10	12
10	1	5	6	2	7	8	3	10	12	4	12	13	5	13	15
15	2	7	8	3	10	12	4	12	12	5	13	14	6	14	17
20	5	10	14	5	13	15	6	14	14	7	15	15	7	16	18
25	8	12	18	8	15	19	9	17	19	9	17	21	10	19	21

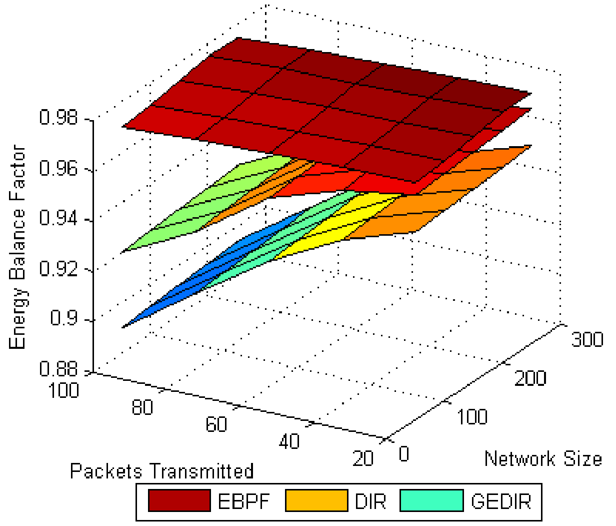

Figure 5: Energy balance factor with network size and packets transmitted.

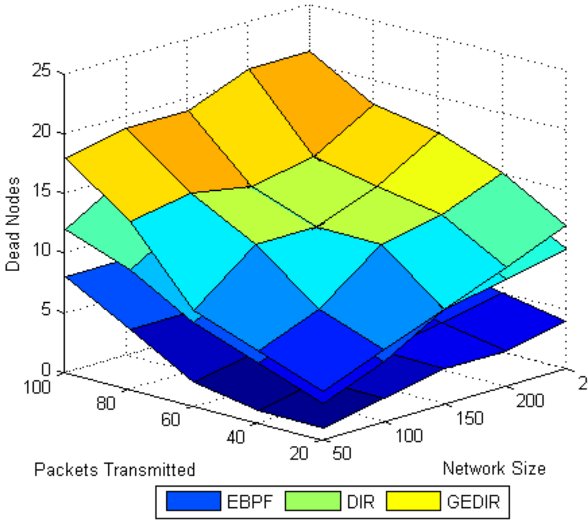

Figure 6: Comparison of dean nodes with network size and packets transmitted.

Fig 5 and Table V show the results obtained in the simulation for energy balance factor for different number of packets transmitted and for different network sizes. It is observed that as the network size increases the balance factor of energy increases for all the techniques. This is because there will be more number of node, the variances of energy is reduced. It is also observed that when the number of packet transmission increases from 20to 100, the energy balance factor for state of art techniques is less as compere with the proposed EBPF technique. This is due the fact that EBPF selects the next hop node based on its proposed selection function which changes the route for each packet transmitted, which fairly balance the energy among nodes.

Fig 6 and Table IV show the results obtained for dead nodes for different number of packets transmitted and for different network sizes. It is observed that as the network size increases the number of dead nodes increase for all the techniques. This is because there will be more number of node; the more traffic generated which consumes more energy. It is also observed that when the number of packet transmission increases from 20 to 100, the dead nodes for state of art techniques is more as compere with the proposed EBPF technique. This is due the fact that EBPF selects the next hop node based on its proposed selection function which changes the route for each packet transmitted, which fairly balance the energy among nodes whereas state of art of techniques use same route for packet transmission.

CONCLUSION AND FUTURE WORKS

In this paper, an analytical estimation of optimum use of energy for packet forwarding in MANETs for random point mobility model is proposed. An optimization function of expected route energy is presented. Mathematical formulation of energy expenditure of a route and optimization function is proposed. A new approach for calculating expected link energy using expected one maximum distance is presented. The simulation of the proposed greedy packet forwarding approach is conducted. The proposed analytical approach of computing the route energy is validated through the results obtained in the simulation.

ACKNOWLEDGEMENTS

The research is supported by the Jawaharlal Nehru University (JNU) through a grant from Department of Science and Technology (DST), Government of India for promotion of university research and scientific excellence (PURSE-II).

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