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Reducing Energy Consumption in Mobile ad hoc Networks Using Energy-aware Routing Algorithm Based on Multiple Routes

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Abstract

Today, reducing energy consumption is one of the most important design criteria of routing algorithms in mobile ad hoc networks. Mobile ad hoc networks are self-organized networks and include mobile sets which have been connected to each other via wireless connections. Energy of the nodes in ad hoc networks is supplied from battery. Since, the battery capacity is limited and there is no possibility of replacing or re-charging; energy loss of a node will affect not only on that node but also on its ability to lead the packets and consequently on network lifetime. In ad hoc networks, the rate of nodes displacement and movement is very high and excessive use of a node and its movement result in network division. In this article, an energy-aware routing algorithm is presented which increases network lifetime by minimizing energy consumption in the route from source to destination. In the proposed method, traffic is distributed among the routes using multiple routes and due to the weight of each route, so the traffic of nodes with the above mentioned usages is reduced.

Keywords: Remained energy, ad hoc networks, network lifetime, energy-aware routing.

1. Introduction

Mobile ad hoc networks include wireless sets that together create a network with self-organized capability. These networks have no fixed communication infrastructure. Since, wireless interfaces range is limited; communications in this type of networks depend on intermediate nodes. Thus, each node in the network also plays the role of router. Generally, the use of ad hoc network is maybe useful when there is no fixed infrastructure and the creation and installation of infrastructure is impractical and unaffordable. Some of these applications can be referred to private networks, military environments, emergency activities such as help and rescue, conferences and meetings, meeting rooms and etc.

In such networks, the network topology has constantly been changed; in fact it is cause of being mobile network nodes. In addition at any time, new nodes may be added to or removed from the network or some of the nodes may be in off state. Because of these special characteristics, a major problem in mobile ad hoc networks is dynamic routing for efficient data transmission in the network.

Energy consumption should be mentioned as another problem in these networks. Since, most of the mobile hosts work with battery and have limited energy; their energy consumption should be minimized as far as possible. More common protocols such as AODV (Ad hoc on Demand Distance Vector) and DSR (Destination Source Routing) choose their route on the basis of strategy of the shortest route or on the other word the minimum number of node in the route from source to destination; and therefore do not consider some of the resources that are consumed quickly. Thus, choice of the shortest route causes excessive use of sources such as energy and bandwidth [1]. Today, wide researches are being conducted with the aim of minimizing consumption power of CPU and other hardware of these networks. The results of these studies have shown that the maximum energy consumption in mobile ad hoc networks is related to the transmission of route request packets and data packets. These processes discharge node battery quickly and lead to the interruption in network communications.

In this article, a solution is presented for increasing the efficiency by optimizing energy consumption of nodes. Each node has its own radio range in ad hoc networks; and if another node enters this range, the initial node is able to recognize it. Therefore, there is the possibility that an intermediate node exists between two nodes. Excessive use of a special node or routing for data distribution between two areas may discharge node battery or the nodes in the route and leads to destruction of route and interrupt the communication between two parts of network. Finally, it leads to reduction of the network lifetime [2].

2. Related Work

So far, many efforts have been done to develop routing protocols in mobile ad hoc networks and reduce energy consumption. Three used approaches to minimize energy consumption in mobile ad hoc networks are load distribution, transmission power control and clustering.

Load distribution method balances energy consumption among nodes and maximizes network lifetime by no excessive use of nodes at the time of choosing a route in routing process [3, 4]. In another method, location energy aware routing (LEAR) protocol that is based on DSR modifies route discovery procedure to balance energy consumption [5, 6]. In LEAR protocol, the route request message to be forwarded depending on the remained energy of each node. In this protocol, a threshold value has been considered for the remained energy of nodes. When node energy is higher than threshold value, data is sent to other nodes. Otherwise, this node does not send any data. Conditional max-min battery capacity routing protocol (CMMBCR) is a synthetic protocol based on threshold in which total energy consumption and the remained energy of nodes are considered. In this protocol, traffic load is not balanced and may result in increasing end-to-end delay because of increasing selection of intermediate transmitter nodes [7].

In the method of transmission power control, stronger transmission power increases transmission range and reduces the number of observations; while weaker transmission power causes distributing topology and can lead to the division of network and increase end-to-end delay. In this method, consuming energy required for data transmission will reach to the lowest level. In fisheye state routing protocol (FSR) by assuming a static network, routing can be done to find an optimal route from source to destination and total costs of link along the route will be minimized [8]. Min-max online algorithm also reaches to the same goal without considering data production rate [9]. Another algorithm, power-aware localized routing (PLR) algorithm is aware and completely distributed energy which works based on this subject that source node has information about neighborhoods and destination node [10].

In clustering method, nodes are put in sleep mode if there is not already any routing or data transmission process. These protocols divide network into clusters and each cluster has a head node or cluster head which is always power and its selection criterion depends on protocol. Other nodes are also considered as normal nodes. The node that transmitter should be sent by it, is activated by its head. Otherwise, sub cluster node remains in sleep mode. Icdp protocol is among these protocols [11].

3. The proposed method

In the proposed algorithm, during creation of route from source to destination it is tried to maximize network lifetime and minimize energy consumption. In this algorithm, the same structure existing in AODV algorithm has been used with this difference that energy fields of each node and each node location, energy field required for reaching to the next node of routing table, route energy fields, link stability degree and node location to route request packet and weight field are added to route reply packet.

Description of operations is that source node begins route request process to the destination node by referring to routing table. If there is a route that was previously used to the destination node; source node will distribute data using it. Otherwise, route request packet is sent to all nodes exist in node radio range by inserting energy fields, link stability degree and its location obtained by GPS location system.

Since, shut down of a node can lead to the loss of communication between two parts of network, it is tried to use high energy nodes. So, an energy threshold is defined for each node. If the considered node has lower energy than threshold value, it is not participated in routing process; this in turn will reduce sending the route request packets and also energy consumption in route discovery phase. Considering that each node knows the necessary information such as the remained energy, the distance

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from the next node, speed, direction and its radio range; by calculating energy required for the routes, source node sends route request packets with appropriate energy level into neighborhood nodes with energy higher than threshold. Route request packets are broadcast into neighborhood nodes. This approach prevents waste of energy and traffic load on the network. When route request packet passes each node, a unit is added to the number of stored transit nodes in HC field (Hop Count). The next field is link stability degree (LSD). Initial value of LSD is ∞ at the beginning. When route request packet passes each node, LSD of that node is compared to previous node. If the value of current LSD that is in route request to be less than previous value; current value is replaced in the field, otherwise no change occurs. The next field, B_S or route energy that is energy of the nodes that like LSD field are updated by passing from each node. When route request packet reaches the destination; B_S and LSD fields show route energy status and degree of route stability, respectively. In radio model, equation (1) is used in order to transmit k bits of data at a distance d [12]:

$$E_{TX}(k,d) = E_{elec} \times K + E_{amp} \times K \times d^2 \qquad (1)$$

Eelec consumed energy is to transmit one bit of data and equal to:

$E_{elec} = 50\text{njoule/bit}$

When the distance between two nodes is d, the amount of energy lost is obtained through this equation: d^2E_{amp}

That Eamp is consuming energy value to strengthen packet transmission. Consuming energy value to receive packet is obtained from equation (2):

$$E_{RX}(K) = E_{elec} \times K \qquad (2)$$

And total consuming energy value to send and receive data packets is obtained from equation (3):

$$E_{Total}(K) = E_{elec} \times K + E_{amp} \qquad (3)$$

Energy value of received signal should be larger than threshold energy. When a node has little remained energy, the use of that node as a guide node should not be allowed. According to the analysis, 2 thresholds of r1 and r2 are regulated to divide energy into three levels. In this article, r1 is regulated to 50% and r2 to 10%. Therefore, based on energy aware routing and area distribution; B_S should meet the following conditions. In this case we have [13]:

$(B\_S > r_1)$

$(r_2 < B\_S < r_1)$

$(B\_S < r_2)$

If $B\_S > r_1$, it means that the energy of each node is high, the route with the highest B_S is preferred as a rule for source node to select a route for packets transmission. If $r_2 < B\_S < r_1$, it means that some nodes consume more energy. For optimization, a route with the most remained energy is selected. If $B\_S < r_2$, the route to be protected for using. Degree of stability of a link is directly proportional to the energy of two ends of the link and conversely proportional to the velocity of the two nodes. When route request packet reaches to the destination node, LSD degree shows the maximum stability of route. Degree of connection stability among mobile nodes is calculated as the following method [14]:

Suppose that n1 and n2 nodes have the same operational radius and radio range with r radius. (x1,y1) and (x2,y2) are the coordinates of n1 and n2, respectively. Vi and Vj are the velocity of n1 and n2; and θ_1 and θ_2 are the directions of n1 and n2 nodes. Link stability duration between two n1 and n2 nodes is obtained through equation (4):

$$D_t = \frac{-(ab+cd) + \sqrt{(a^2+c^2)r^2 - (ad-cd)^2}}{(a^2+c^2)} \qquad (4)$$

$a = v_1\cos\theta_1 - v_2\cos\theta_2 \qquad b = x_1 - x_2$

$c = v_1\sin\theta_1 - v_2\sin\theta_2 \qquad d = y_1 - y_2$

Link stability duration (LSD) between two nodes is obtained according to the above equation. Also, route stability degree (RSD) is obtained through the minimum degree of LSD in existing links. This means that the minimum degree of LSD, specifies the maximum degree of RSD [15]:

$$RSD_i = \min(LSD_i) \qquad (5)$$

In the route discovery phase when a node receives route request packet, compares its own identifier with identifier of destination node (that is within route request packet) to find that whether destination node belongs to itself or not. If it is not destination node, after calculating the minimum energy to neighborhood nodes that are able to participate in routing process (have threshold energy) it embeds node energy (B_S) within route request packet and transmits it broadcast into neighborhood nodes. During passing route nodes, B_S and LSD fields are updated. The process of updating is in this form: B_S and LSD values for route request packet are compared to the values of passing node. If B_S and LSD values of current node to be lower than the values of route request packet, they are substituted with the values of route request packet; otherwise no change will be occurred. Route request packet continues its way to reach destination node. Across the way, when route request packet passes from each node;

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each node updates its routing table for inserting energy required to distribute route request packet or data packets that are previously inserted by previous node. In this method, the routing tables of all nodes in the path between source and destination have enough information about energy required to distribute data in future. When route request packet reaches the destination node, the value of current B_S shows maximum energy value which can be supported by route. Similarly, the value of current LSD shows maximum RSD of route. Destination node waits during T time to receive route request packet from all routes. When destination node receives route request packet from all reliable routes, calculates weight of each route through equation (6) and puts weight and also data routing information in route reply packet of the same route and through the same route distributes it back into source node. In the following equation, RSD value belonging to ith node is final value put in route request packet which has been divided into maximum value of RSD in all routes. HCi and B_Si values are also expressed respectively and placed in the following equation:

$$W_i = C_1 \times (\frac{RSD_i}{MaxRSD}) + C_2 \times (\frac{HC_i}{MaxHC}) + C_3 \times (\frac{B\_S_i}{MaxB\_S}) \quad (6)$$

In the above equation, C1, C2 and C3 are variables that can change depending on demand. Absolute value of sum of these variables will be equal to 1.

$$|C_1| + |C_2| + |C_3| = 1$$

When source node receives route reply packet from all nodes, sorts them discerningly. Then, the data that should be transmitted into destination node are distributed among routes due to the weight of routes and using equation (7) in order to balance energy consumption. In this method, data are driven into destination node with high level of velocity and reliability. Because, the data have been distributed based on nodes energy level and routes weight among the routes and also node energy level for data transmission was previously predicted and placed in routing table. The presented equation is as follows:

$$Data_{size} = (\frac{W_i}{\sum_{i=1}^{n} W_i}) \times FileSize \quad (7)$$

In the above equation, W_i route weight; $\sum_{i=1}^{n} W_i$ total weight of all routes and File Size is size of a file that should be transmitted into destination. Use of equation (7) creates a balance between routes with high energy and routes with low energy, such that routes with high energy transport high volume data while routes with low energy transport less data and this leads to increasing network lifetime.

4. Simulation and evaluation

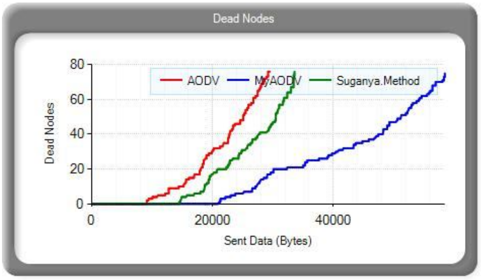
In this part, the proposed method is compared with AODV routing protocol which is one of the most applicable routing algorithms and Sugayana method in mobile ad hoc networks in terms of network lifetime, energy consumption, and the rate of packs successful delivery, volume of data transmission and the rate of energy alterations. In order to simulate the proposed MYAODV algorithm and base AODV algorithm and Sugayana method for unicast energy-aware routing in mobile ad hoc networks, programming language C# has been used. Some parameters applied in simulation are shown in table (1).

Also in figure1, analogue graph of network lifetime, value of energy consumption, the rate of packs successful delivery, volume of data transmission and the rate of energy alterations for AODV routing protocol and Sugayana method and the proposed MYAODV algorithm have been shown, respectively. In the proposed MYAODV algorithm and according to figure 1 (a), network lifetime has been increased by reducing number of dead nodes. Also in figure 1 (b), reducing energy consumption or in other words increasing the rate of remained energy of alive nodes are observable compare to AODV protocol and Sugayana method.

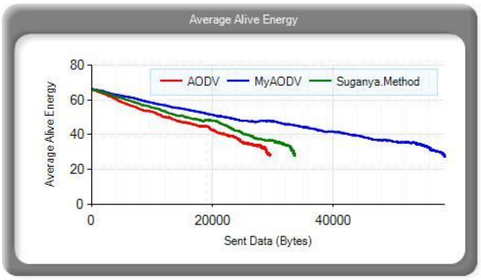
The diagram in figure 1 (c) shows that, the rate of packs successful delivery or in other words; ratio of the transmitted packets to packets delivered into node has increased significantly compare to AODV protocol and Sugayana method.

The diagram in figure 1 (d) shows that, volume of packet transmission to destination node has increased significantly compare to AODV protocol and Sugayana method.

Figure 1 (e) shows that in the proposed MYAODV algorithm; energy consumption is distributed among nodes and lower energy nodes reduced, because the packets are transmitted to destination from multi-route instead of a route.



a



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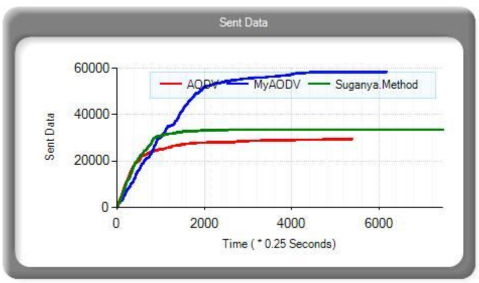

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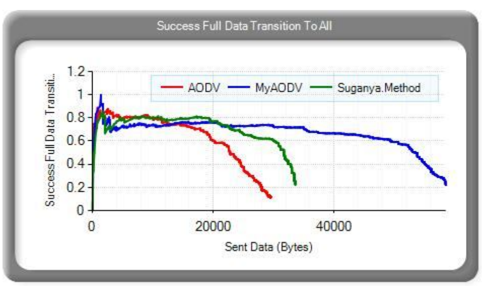

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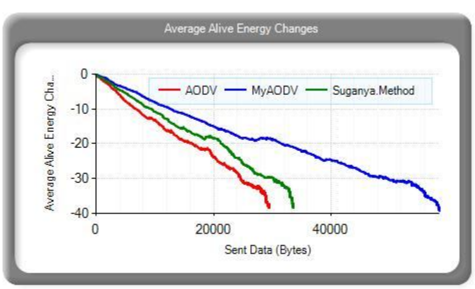

e

Fig. 1 Analogue graph of the proposed method and AODV protocol and Sugayana method in terms of (a) network lifetime, (b) value of energy consumption, (c) the rate of packs successful delivery, (d) volume of data transmission and (e) the rate of energy alterations.

Table 1. Parameters required for simulation

Parameters	***Characteristics***
Area	250 x 250 m
Number of nodes	100
Simulation time	140 min
Movement	Accidental movement
Maximum velocity of the nodes	25 m/sec
Interruption time	10 sec
The initial battery energy on each node (B_S)	20 mw
Traffic	From a source (10 packets per sec)
Receiving power in AODV	0.0001 mw
Transmission power in AODV	0.0005 mw
Packet size	1024 byte
Link bandwidth	2 mbps
Maximum transmission range of each node	280 m
Physical layer protocol	802.11

5. Conclusion

More applicable nodes in ad hoc networks lead to rapid battery discharge and network division; consequently, nodes and network lifetime will be reduced. In this article, an optimal routing algorithm of aware energy has been presented based on demand that causes to increase network lifetime by reducing energy consumption. Also, the proposed method causes distribution of traffic among nodes and divides energy consumption evenly among network nodes, and prevents from division of network into smaller regions.

In route discovery phase in AODV algorithm, the only criteria for selecting of the optimal route to the destination among the discovered routes is the number of route hops that is not adequate and appropriate criterion for this work; and the low number of hops in a route is not always a reason for optimal route and the criteria such as energy, reliability and traffic should also be considered.

The results of simulation show that the proposed MYAODV algorithm toward AODV algorithm and Sugayana method reduces energy consumption significantly and also increases network lifetime. Considering aware energy strategy and also threshold value, this method reduces the waste time for information about route request packet and routing traffic. Also, due to considering multi-routes causes a balance in energy consumption of nodes; and rerouting is not required in case of route destruction, and data can be transmitted to destination from other routes. In fact, the fault-tolerant in the proposed method will significantly increase.

Although, in the proposed method there is the possibility of limited increase in delay in discovery phase due to calculations done for reducing energy consumption and also selection of the most reliable route for data transmission toward AODV algorithm, but it results in increasing the rate of packs successful delivery by preventing from the death of nodes due to energy loss.

It is suggested that in future studies, intermediate layer design between physical layers and network and also sleep mode and power control mechanism to be also considered in algorithm. Moreover in the proposed algorithm, after route request, data are transmitted from source to destination from multiple routes and the obtained routes are separated as node; due to operation improvement, separate regional routes can be offered for algorithm.

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