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Battery Saving Greedy Forwarding with Classifying Inclusive Nodes Based on Two-hop Information over Ad-hoc Networks

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Abstract

Mobile Ad-hoc network (MANET) can be used as a communication method alternative to out-of-order infrastructure. This paper proposes an approach to reducing the energy consumption of battery-driven nodes over MANET by modifying location aided greedy forwarding protocol based on the two-hop neighbor information. This approach determines the best suitable path to make sure that path consumes low energy when the communication is attempted between same source and destination. Moreover, this algorithm can switch the relay nodes that are located between source and destination to satisfy the minimum energy consumption and prolong network lifetime. We compare our approach with Greedy Most Forward with Radius (GMFR), Greedy Random Selection (GRS) and Greedy Nearest with Forward Progress (GNFP) through computer simulation and evaluation. The simulation results show that our approach can achieve lower energy consumption than existing algorithms.

1. Introduction

A mobile ad hoc network (MANET) [1] is an infrastructureless network that is organized by collections of self-organizing mobile nodes. Recently, the technologies of MANETs have been widely used to support various organizations, including industry, education, military and emergency services. Let us consider the deployment of MANETs in disaster situations. In this situation, since consistent IP address assignment is difficult without a central server, a topology-based routing protocol is not suitable. Hence, we introduce a location-based routing protocol that can operate in a disaster area without specific IP addresses. Usually, a location-based routing protocol is designed for MANET by using the global positioning system (GPS), and location services are used instead of IP-addresses. Since nodes in such a network are driven by a battery, they should not consume much energy when data is sent from source (S) to destination (D). Here, the longer holding time of communication is, the more batteries of nodes are consumed. Hence, switching or swapping the relay nodes is a significant factor in prolonging the lifetime of node. Many location-based routing protocols have been proposed. Before discussing our proposed algorithm, let us describe existing approaches and their critical problems. The approach described in [2] is a typical geographical unicast routing, usually called Greedy forwarding (GF). We can classify improved GF to three types according to next hop node selection criteria to save more energy of mobile nodes than the existing GF algorithm. The first type is: 1) Greedy Nearest with Forward Progress (GNFP) [3]. A next hop is chosen as the nearest neighbor with positive progress. This idea tries to reduce the energy by adjusting transmission power according to the distance of two nodes and also reduce the probability of packet collision. However, this method cannot prolong the network lifetime because of redundancy of the relay nodes. The second type is: 2) Greedy Random Selection (GRS) [4]. This method uses random selection criterion. One node from the set of the senders with positive progress is randomly selected via probability properties. This method tries to trade off progress and transmission reliability performance and the transmission is adjusted to reduce the consumption of energy. However, GRS may give a very bad path by selecting unsuitable next relay nodes because a forwarder randomly selects the next relay node. Moreover, since GRS may select redundant relay nodes, this algorithm cannot save the energy and prolong network lifetime. The last type is: 3) Greedy Most Forward with Radius (GMFR) [5]. This algorithm processes the baseline as the orthogonal projection between S and D. A neighbor is in the forward direction if the progress is positive. This criterion tries to minimize the number of hops while a packet has to traverse in order to reach D and is related to performance such as packet delay as well. However, this algorithm cannot optimize the energy consumption because the same relay nodes always work hard when the same pair of S and D are attempted.

To solve the problems of these three existing location-based routing protocols (GNFP, GRS, and GMFR), we propose Greedy Forwarding with Classifying Inclusive nodes based on the two-hop information. By classifying inclusive nodes or swapping the choice of the forwarder, our proposals can reduce the energy consumption. The rest of this paper is organized as follows. Section II shows the evaluation criteria; next, section III proposes Greedy Forwarding with Classifying Inclusive nodes based on two-hop information and

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details of its algorithm. Section IV presents the performance and results. Section V concludes this paper.

2. Evaluation Criteria

In this section, we show the assumption and criteria to be used in our proposal. Apparently, the energy consumption is the major concern for the MANETs because the mobile nodes are driven by the internal batteries which are mainly consumed to send, receive and relay the packets. Firstly, nodes are assumed to be deployed in the static network topology in free space. We consider actions occur in discrete time sequence, "t_n" (n=1,2,…). In other words, all the packets are assumed to be generated, sent, or received in the network at time "t_n". And the initial energy is given for each node i (where i =1, 2…N, N is the total number of nodes in the network). To calculate energy consumption, the energy functions (for the non-chargeable device) are very importance factors. The non-chargeable battery (cost energy consumption) for each node can be summarized by modifying functions given in [6] as equations below.

$$\partial_H(t_n) = \left(\sum_{\lambda=0}^{\lambda=H_i(t_n)} C_P(\lambda) + C_T(\lambda) \right) \tag{1}$$

$$\partial_R(t_n) = \left(\sum_{\lambda=0}^{\lambda=R_i(t_n)} C_P(\lambda) + C_R(\lambda) \right) \tag{2}$$

$$\partial_T(t_n) = \left(\sum_{\lambda=0}^{\lambda=T_i(t_n)} C_P(\lambda) + C_T(\lambda) + C_R(\lambda) \right) \tag{3}$$

$$\beta_i(t_n) = \beta_i(t_{n-1}) - \left(\partial_H(t_n) + \partial_R(t_n) + \partial_T(t_n) \right) \tag{4}$$

In eq.(1), the $\partial_H(t_n)$ represents the cost of energy consumption when a mobile node broadcasts hello messages. $\partial_R(t_n)$ refers to the cost of energy consumption when mobile node receives hello messages as shown in eq.(2). $\partial_T(t_n)$ in eq.(3) represents the cost energy consumption when mobile node relays the data packets. $H_i(t_n)$ is the number of Hello packets that are generated by node i at time tn; $R_i(t_n)$ is the number of Hello packets that are received by node i. Cp represents the processing power cost of the packet λ, C_T represents the transmitting power cost of the packet λ and C_R introduces the receiving power cost when a mobile node receives the packet λ. In eq.(4), $\beta_i(t_n)$ is the remaining energy of mobile node i when it broadcasts and receives Hello messages and relays data at time t_n .

3. Greedy Forwarding Based on Two-hop Information

A. Exchange Hello message

Sharing the information on two-hop neighbors: Before entering the main algorithm, we propose how to get two-hop neighbor information by referring to the literature. The hello message based on two-hop information is defined in [7]; the author shows how to optimize the number of forwarders by using two-hop information. Importantly, the sender collects two-hop neighbor information and so it has more information than just collecting one-hop neighbor information before relaying the data packet. Unfortunately, this algorithm is implemented only for a wireless sensor network and the energy consumption is not considered. According to the expediency of two-hop information, we propose the way of route selection when the packet is sent from S to D. Each node exchanges the hello messages by broadcasting with their one-hop neighbors. The initial hello message contains the location and battery information of the node. After receiving the first hello message, every node knows the location and battery information of its one-hop neighbors. Next, every node broadcasts the second hello message, which contains the information on its one-hop neighbors. After that, every node knows the location and battery information on its two-hop neighbors as well as on-hop neighbors (see Fig.1). We call the status after collecting two-hop neighbor information "the normal mode". In the normal mode, each node periodically broadcasts the hello message to its one-hop neighbors.

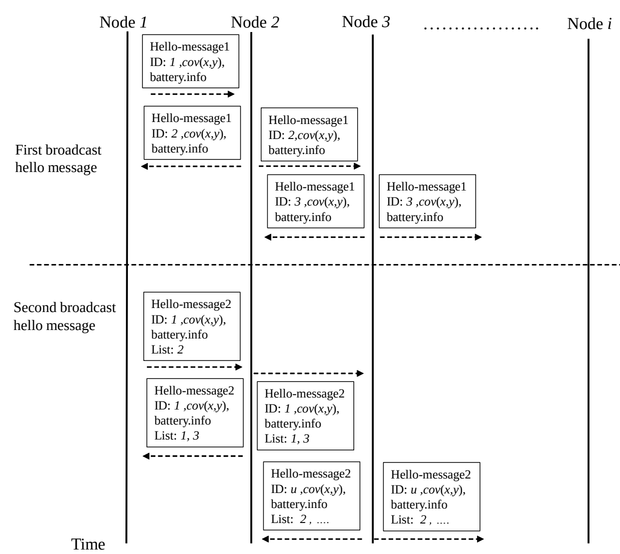

Figure 1. Exchange Hello message

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B. Virtual Destination

Virtual destination and inclusive nodes: Before sending data packets, all the nodes in the network have same remaining battery capacities. We assume communication is made between node *u* and *D*. The node *u* needs to find appropriate next forwarder (relay node) to relay a packet to node *D*. Before *u* selects the next relay node, we assume the node u must set a virtual destination as (*D'*), which is a two-hop neighbor that is closest to real destination (*D*) among all the two-hop neighbors. Fig.2 shows the area where two-hop neighbor nodes of node *u* exist that may be set to the virtual destination node. The area is shown as a dark area in Fig.2. We define node v_x ($x \in \{1, 2, 3, \ldots, n(u)\}$) is the neighbor of one-hop of node *u* and node v_y ($y \in \{1, 2, 3, \ldots, n(v_x)\}$) is the one-hop neighbor of v_x and the two-hop neighbor of *u*. Here, the notation "*n*(*foo*)" means the number of neighbors of node *foo*. In Fig.2, the node v_y will become a virtual destination (*D'*) if it is closest to *D* among all the two-hop neighbors. In this case, the node v_x is called an "inclusive node" which is the one-hop neighbor of both nodes *u* and *D'*. On the other hand, after sending a data packet, the relay node will consume battery. So, we have to consider the remaining battery capacity of relay nodes to select the route with a longer lifetime.

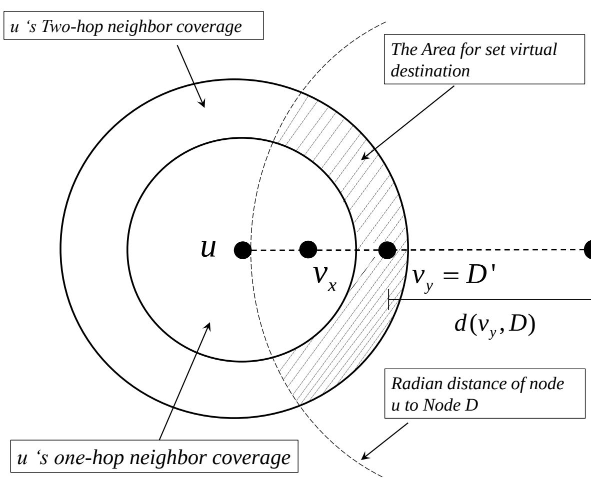

Figure 2. Virtual Destination

Here, we assume the node *u* can set the virtual destination by calculating the probability about the average distance of node v_y ($y \in \{1, 2, 3, \ldots, n(v_x)\}$) to *D* and the probability about the maximum remaining battery capacity of node v_y or *D*'. At first, we find the total average distance from all the virtual destination candidates, i.e., node v_y ($y \in \{1, 2, 3, \ldots, n(v_x)\}$) to *D* by eq.(5); where d_T is the total average distance and $d(v_y,D)$ is the distance between node v_y and *D*. Then we calculate the probability by eq.(6); where P_{avg} is the probability of average distance. If node v_y is closest to *D*, it will have the lowest probability. In the second phase, we calculate the total of the maximum battery capacity of node v_y by eq. (7); where β_T is the sum of remaining battery capacities of all the nodes v_y ($y \in \{1, 2, 3, \ldots, n(v_x)\}$) and β_{vy} is the battery capacity of a specific node v_y at time t_n. Then, we can find the probability of maximum battery capacity by eq. (8). If a node v_y has the maximum remaining battery capacity, it will have the highest probability. Finally, from eq. (6) and eq. (8), we get a probability that is a combination of the probabilities of distance and the probability regarding v_y, which is a neighbor node of v_x and two-hop neighbor of the node *u*. Here, $p_{avg}(v_y)$ and $p_\beta(v_y)$ are considered mutually independent since the average distance of node v_y and their battery's capacity are an independent event each other. So, we can calculate the joint probability in eq. (9).

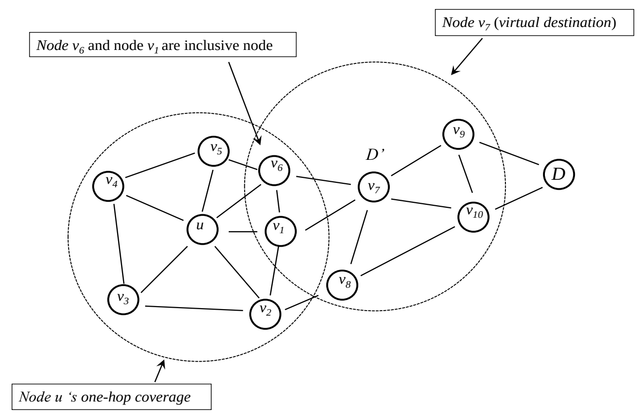

Figure 3. An example to classify the inclusive node

Fig. 3 shows an example: node v_7 is closer than node v_8 therefore the sender node *u* sets node v_7 as a virtual destination or *D'*. Let's define node v_1 and v_6 be inclusive nodes of sender *u* and *D'*. The node *u* has the battery information of nodes v_1 and v_6 that are located in the intersection coverage of sender *u* and *D'*. The neighbor nodes to be considered are inclusive nodes between node *u* and *D'*. Hence, forwarder node *u* can make the decision on which of v_1 or v_6 is selected by classifying the battery information of node v_1 and v_6.

$$d_t = \sum_{y=1}^{n(v_x)} d(v_y, D) \tag{5}$$

$$p_{avg}(v_y) = \frac{d(v_y, D)}{d_T} \tag{6}$$

$$\beta_T = \sum_{y=1}^{n(v_x)} \beta_{v_y}(t_n) \tag{7}$$

$$p_\beta(v_y) = \frac{\beta_{v_y}(t_n)}{\beta_T} \quad (8)$$

$$\Pr(v_y) = (1 - p_{avg}(v_y))\, p_\beta(v_y) \quad (9)$$

C. Algorithm Classifying Inclusive Node

We assume the data packets are sent by the source to destination through the relay nodes. The processing of the algorithm is shown in Table 1. In line 1 of Table 1, the sender node checks the location of destination and then if it finds the destination is its neighbor, the operation will be terminated in line 2. If not, the sender must select a virtual destination. It will sort a list of candidates of virtual destinations in the ascending order of the distance to real destination in line 3. Then, the sender checks the battery capacity of candidates of the virtual destination before choosing the virtual destination in line 4. If the closest virtual destination candidate has lower battery capacity then the sender will change the virtual destination by considering $\Pr(v_y)$. However, if the battery capacity of the closest virtual destination is still maximum, then the sender will select it as shown in line 5. Next, the line 6 shows the sender always compares the battery capacity of inclusive nodes before selecting the relay node. The sender will select the next relay node considering which node has maximum battery capacity by referring to the value of $\beta_i(t)$in line 7. In line 8, the simulation process is repeated and the next relay node will become the sender node and go back to line 1 until the processing is terminated or data packet is received by the destination.

Table 1. Algorithm's classifying the inclusive node

1: Check location of node (D)
2: Check (D) is covered or not
  If not, **then** (go to 3)
  If (D) is covered, **then** Select (D) End (Algorithm is terminated)
3: Sort list of candidates of virtual destinations in the ascending order of the distance to the real destination.
4: Check battery of candidates of virtual destination by considering $\Pr_{(vy)}$
5: Then set virtual destination which has maximum $\Pr_{(vy)}$
6: Find inclusive nodes Then find a node v_i which has maximum remaining battery $\beta_{i(t)}$
7: Select (v_i) as the next relay node
8: Change relay node u to v_i, go to 1 (**repeat**)

4. Performance and Results

A. Simulation parameters and network topology

we evaluate our proposal by comparing with existing methods GNFP, GRS and GMFR using computer simulation based on MATLAB [8], [9]. The simulation parameters and value setting are shown in Table2. Here, we assume the network is static (nodes do not move). For each topology of each simulation scenario, we assume a position for S is located on the left most and the position D is located in the rightmost position of the network as shown in an example of Fig.4.

Table 2. Simulation parameters

Symbols	Description	Value
t_n - t_{n-1}	The time interval	1s
$\beta_i(0)$	The initial battery capacity for node i at time 0	80000 joule
C_P	The processing power cost	0.1 joule
C_T	The transmitting power cost	0.8 joule
C_R	The receiving power cost	0.3 joule
-	The number of mobile nodes	15 nodes
-	Transmission range	150 m
-	Exchange hello message	1 packet /s
-	The number of data packet	1 packet /s
-	Simulation trials	100 topologies
-	Simulation time	1000s

B. The simulation result

As for the example 1 in Fig.4, the result is given in Fig.5 and Fig.6. Fig.5 shows the total remaining energy and Fig.6 shows the remaining lifetime per mobile node. Those two values are the metric for simulation. The Fig.5 shows the total remaining energy, comparing the proposed method with GMFR, GSR and GNFP. Through four simulation's outputs, GNFP consumes the energy much more than any other methods. Since GNFP creates the redundant relay nodes when sending the data packet, this method could not guarantee the network lifetime. GSR is better than GNFP because it uses random selection criterion. One node from the set of the forwarders with positive progress is randomly selected via probability; GSR doesn't create the redundancy of relay nodes. However, as the problem was shown in section I, GSR could not reduce the energy consumption be-

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cause it gives a very bad path by selecting an inappropriate forwarder which relays the data packet to *D*. So, GSR is not the best method for saving energy. The other method is GMFR, this algorithm uses baseline as the orthogonal projection between *S* and *D*. A neighbor is selected in the forward direction to *D* if the progress is positive to minimize the number of hops. However, the result shows GMFR could not optimize the energy consumption compared with our proposal because the same relay nodes always relay the data when the same pair of source and destination is attempted. On the other hand, our proposal can guarantee the minimum energy consumption. Total energy is slowly decreasing to the final time slot (t_{1000}) and the total remaining energy is higher than any other existing algorithms.

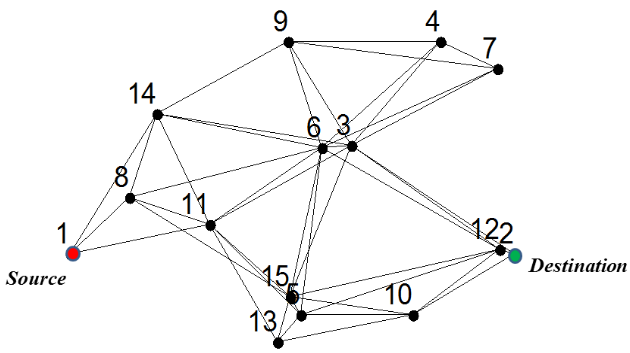

Figure 4. An example of network topology (300 x 300 m^2)

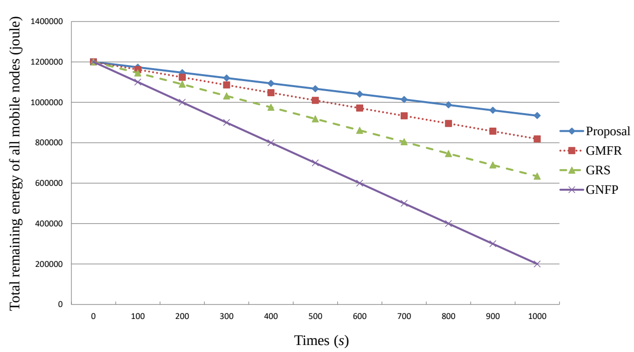

Figure 5. The total remaining energy in each event for an example

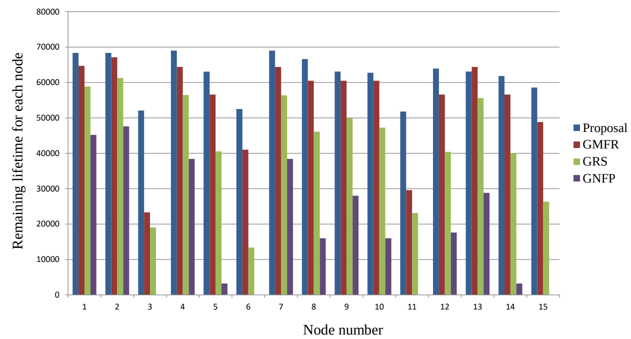

Figure 6. The remaining lifetime per mobile node for an example

The next results are the remaining lifetime per mobile node as shown in Fig.6. This is the comparison of our proposal with GMFR, GSR and GNFP for 15 nodes topology as Fig.4. The result shows our proposal is longer than other three methods. On average, GNFP, GRS and GMFR cannot guarantee a long lifetime of the network. Here, GNFP is the worst because many nodes consume much more battery and especially the nodes 3, 6 11 and 15 ran out the battery. Hence, choosing the nearest neighbor with positive progress as a next hop is not efficient for saving energy. GRS is better than GNFP because the battery lifetime per mobile node of GRS did not run out the battery like GNFP. As shown in section I, GRS could not guarantee the energy consumption and therefore GRS is lower than GMFR. GMFR is better than GRS because this criterion can minimize the number of hops. However, in this algorithm, some relay nodes always work hard and the nodes consume much energy, for example in Fig.6, we can see that node 3 and node 11 consumes much energy than other nodes.

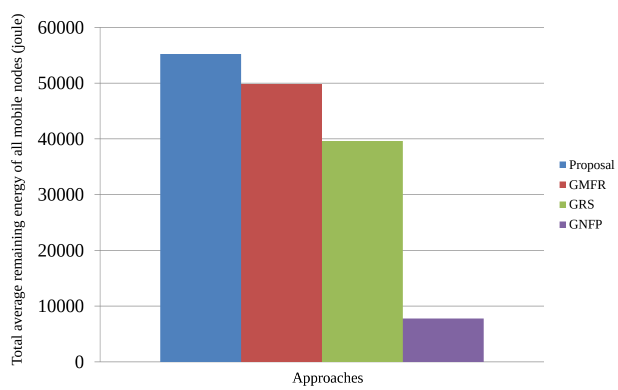

Figure 7. The total remaining lifetime per method

To make sure of the investigation, we made the measurement of total average remaining energy for 15 nodes and 100 simulation trials as illustrated in Fig.7. The result shows the average lifetime of our proposal is longer or higher than existing methods. As estimation and prediction in section I, GMFR, GRS and GNFP cannot guarantee the long lifetime of the network. Most important thing is that our proposal can increase the lifetime of the network by 10.5 %, 28.6%, and 82.2% compared with GMFR, GRS and GNFP, respectively.

5. Conclusion

In this paper, we address the problem of energy reduction in a mobile ad hoc network. Reducing energy consumption and increasing network lifetimes are very difficult in existing location-aided routing algorithms. To overcome these problems, we proposed Greedy Forwarding with Classifying Inclusive nodes based on two-hop information about an ad hoc network inspired by geographic routing. Simulation outputs showed how our proposal can optimize the energy consumption and improve several aspects of performance with a time interval and network topologies. Specifically, our proposal has the best and stable performance in terms of increasing lifetime compared with existing approaches. A future study is needed for more detailed evaluations, including loss path energy consumption and mobility.

Acknowledgments

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Biographies

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