Journal of Advances in Computer Research
Quarterly pISSN: 2345-606x eISSN: 2345-6078
Sari Branch, Islamic Azad University, Sari, I.R.Iran
(Vol. 6, No. 1, February 2015), Pages: 9-18
www.jacr.iausari.ac.ir

A New Greedy Geographical Routing in Wireless Sensor Networks

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Received: 2014/03/18; Accepted: 2014/04/29

Abstract

Wireless sensor network includes a large number of nodes which are distributed in a geographical location. The essential fact about WSN is that energy of nodes is limited. Therefore, presenting proper solutions as an optimized routing is crucial to equally use energy of all nodes. In this paper we propose a method which performs routing in WSNs using greedy approach. It is able to choose optimum rout based on energy level and distance. Since our method tries to equally utilize energy of different nodes, it will eventually result in lifetime increase. In addition to modifying energy consumption, simulation results show that proposed algorithm achieves considerable improvement in reduction of end-to-end delay and increase in packet delivery rate.

Keywords: *Wireless Sensor Networks, Greedy Geographical Routing, Node, Set Approach*

1. Introduction

The manner of transmitting information from nodes to base station and selecting the best possible rout is one of the most challenging issues in wireless sensor networks. The optimum rout may be affected by different factors such as consumed energy, response speed, delay and data transmission accuracy. Energy sources of nodes are limited. Hence, exploiting various methods to save energy during computation and communication is necessary [2,6].

Greedy methods are suitable techniques for locally selecting the optimum answer considering mentioned criteria. They are remarkably efficient when applied in WSNs because, firstly, one of the most prominent challenges of WSN designer is increasing the lifetime of the network. Thus, we should manage network operation in such a way that it continues working by employing the maximum energy from nodes and it does not shut down unless there is no remained energy in nodes. Secondly, objective function of greedy approach always produce an optimum expression locally, as greedy methods are the best choice for local optimization. We aim to present a method where information is transmitted to BS by passing through the nodes which have the shortest distance and the most energy level among neighboring nodes. In other words, we try to select a node which is optimum regarding distance and energy among its neighbors. Moreover, transmitting information via this node is supposed to have minimum cost. We named proposed algorithm Greedy Geographical Routing (GGR). Its beneficial as it always

seeks for the rout which is optimum regarding energy and distance. So in this algorithm nodes are used equally and we do not overload a specific node [1].

2. Related Work

Various methods have been proposed for routing in WSNs so far. None of these methods can operate as the most perfect and marvelous method in all conditions. In fact, considering aforementioned issues, there is always a tradeoff between different factors for choosing a routing algorithm [3].

Flood transmission employs passive method. Each node which receives a data or control packet, transmits it to its neighbors. After transmission, the packet follows all possible routs to reach destination. Furthermore, if network topology changes, transmitted packet follows new paths [2,3,6].

One of the most famous and efficient methods proposed for routing are those based on clustering. In these methods all nodes are divided into clusters. In each cluster one node is selected as cluster-head and other nodes are called normal ones. Different methods utilize various measures to select cluster-head. Usually clustering methods try to uniformly distribute energy consumption in nodes. If CHs are constant during network lifetime, evidently, cluster-heads will die very soon and lifetime of the cluster ends. To solve this problem, LEACH algorithm uses random rotation to avoid fast depletion of nodes batteries [2,5,6].

The most known routing algorithm which based on geographical routing is GEAR. In this algorithm cost of communication with destination node is maintained by source node and it uses them for current or future interactions. These costs include node energy level and distance from destination node. Similarly in our proposed algorithm each node knows about distance and energy of its neighbors. One advantage of GGR over GEAR is its scaling capability. Indeed, GGR is a proper supporter of network scalability. Since in GGR method energy consumption is uniformly distributed between all nodes, we can utilize the maximum energy of network. Thus, network lifetime in GGR method is longer in comparison with GEAR method [5].

3. Primary Concepts of Proposed Method (GGR)

In GGR method base station should announce its geographical coordinates to all nodes as soon as network is setup. Source node and other nodes on the path which are going to transmit information to BS, avoid inefficient execution of algorithm as they know their distance from BS. In other words, criterion which stops algorithm is that distances of source node from its neighbors become the same as its distance from BS. In GGR method, each node knows energy of its neighbors and distance from them. This information is saved in nodes. In each round we want to choose the node which is the closest one to source node while its energy level is higher than other neighboring nodes (Even if this node does not exist we should choose a node which can transmit information from source node to BS with minimum cost regarding distance and energy consumption). The basis of GGR method is greedy. As it is known, in greedy methods each time the element (here elements are nodes) is checked according to determined criteria; afterwards, ignoring previous selections and future selections, the desired element will be chosen. In greedy algorithms selecting procedure begins with an empty

set and step by step some elements are added to this set. At last, the created set will be a solution for an instance of a problem.

3.1 Procedure of Proposed Algorithm (GGR)

Generally GGR algorithm can be divided into three phases which are as follows:

a) *Selection Phase:* In this phase next node which is going to be added to the set should be selected in accordance with our determined greedy criteria.
b) *Evaluation Phase:* In this phase we check whether it is possible to add node which is selected in previous phase to the set or not. It is necessary as adding a node may violate one of the primary criteria of the algorithm. If adding the node do not violate any criteria, it will be added to the set. Otherwise, we switch to selection phase and choose another node. Finally we should investigate if the created set helps us with finding a solution or not.
c) *Solution Check Phase:* In this phase we should find out whether the obtained set will solve the problem or not. That is to say we should see if it is desired set or not.

As mentioned before, we aim to choose a path from source node to its neighbors which is efficient considering both distance and energy consumption. This procedure should be performed by other intermediate nodes until the information reaches BS (destination). Before source node starts searching for optimum path, it transmits a request message to its neighbors which are inside its covering range. The neighbors are supposed to transmit their geographical coordinates (distance which is denoted by D in this article) and energy level (E) as soon as they receive the message. This transmitted message by neighbors is called acknowledge in this paper. The source node stores distance and energy parameters of its neighbors when it receives acknowledgements so that it can use them for current computations and probably future ones.

After conducting previous steps, the optimum neighbor considering distance and energy level will be selected for information transfer. The same steps will be re-traced for the node which receives information in order to find its best neighbor. We will go through these stages continuously till information reaches BS. So in each stage source node wants to select a subset of neighboring nodes with respect to two parameters; the first, their energy level is maximum; the second sum of their distances do not exceed distance of source node from BS. As a matter of fact, criterion which stops the algorithm is that sum of passed distances should not exceed distance of source node from BS. Additionally, each node has a threshold voltage (V_{th}). If energy level of a node drops this threshold voltage, it will temporarily go to sleep and its neighbors perform its tasks. If there is no eligible neighbor we have to use sleep node again. According to above explanations, to select optimum path from distance and energy point of view we need to consider the following items:

1) Distance of source node from its neighbors
2) Energy of neighbors of source node
3) Distance of source node from BS
4) Distance of all neighboring nodes from BS

We should check whether adding an element to the set will violate one of the primary criteria or not. If distance of source node from BS is less than its distance from

neighboring nodes, information is directly transmitted to BS. In this condition, there is no need for adding new element to the set because adding a new element will violate one of the primary criteria [1,4,7,8].

3.2 Operation Principles of Proposed Method (GGR)

We assume that source node is called X_0. Set S includes all neighbors of X_0. It consists of ordered pairs which denote distance of X_0 from its neighbors and energy of its neighbors, respectively (neighbors of X_0 are shown as X_1, X_2, X_3, ...). In this case we have:

$$S = \{(X_1D_1, X_1E_1), (X_2D_2, X_2E_2), (X_3D_3, X_3E_3), \dots\} \quad (1)$$

Where (X_1D_1, X_1E_1) means that distance of X_1 from source node is D_1 and energy of X_1 is E_1. To select or reject node X_n for next destination we have two options:

State one: $X_n=0$; in this case the node will not be selected. In this state distance of source node from BS is less than source node from X_n. As a result we do not need to add energy level of mentioned node to set of energy levels.

State two: $X_n=1$; in this state distance of source node from X_n should be subtracted from BS (if distance of source node from X_n is denoted by D_n and distance of source node from BS is denoted by L, we have $L - D_n$). When $X_n=1$, this node will be an optimum and suitable option for transferring information. Obviously, since information is transmitted to it from source node, we should subtract distance between source node and X_n from distance between source node and BS. We have to do this because our final objective is transferring information to BS and we have already passed a part of path needed to reach BS (the path between X_0 and X_n). Consequently, in this state energy level of node X_n will be added to energy set (which means that E_n is added to the set). However, decisions we make for other neighbors of X_0 should be optimum disregarding our decision about X_n. We denote the maximum value of energy levels in the set selected according to our decisions by $f_i(X)$. Then, based on optimization principle we have:

$$f_n(L) = \max\{f_{n-1}(L), f_{n-1}(L - D_n) + E_n\} \quad (2)$$

If we assume that 1<i<=n we can say:

$$f_i(X) = \max\{f_{i-1}(X), f_{i-1}(X - D_n) + E_n\} \quad (3)$$

Consider distance and energy components of each neighboring node as an ordered pair. We may state that if we have *k* ordered pairs, we can use them to define $f_i(X)$ via $S^i = \{(X_i, Y_j) | 1 \le j \le k\}$ Also we have $S^0 = \{(0,0)\}$ each pair of S^i is defined as (D_i, E_i) where $E_i = f_i(X_j)$ and $D_i = X_j$ i.e. energy level of each node equals to the value of *f* in X_j. Besides, distance equals to X_j. We can write Eq. (4):

$$S_1^i = \{(D + D_i, E + E_i) | (D, E) \epsilon S^{i-1}\} \quad (4)$$

Therefore, members of S^{i+1}can be obtained by merging ordered pairs of S^i and S_1^{i+1}. We should pay special attention to ordered pairs which we want to merge. We should notice that if we have (D_i, E_i) and (D_j, E_j) and also we have $D_i \ge D_j$ and $E_i \le E_j$ we should omit (D_i, E_i) according to Eq. (3). It means that if distance between a neighbor node *A* and source node is more than distance of neighbor node *B* from source node and

meanwhile its energy is less than node *B*, node *A* should not be considered in the final set. In this circumstance this node goes to sleep. We will not use this node unless we had no other choice. Each node whose distance from source node is more than the distance between source node and BS (*L*) should be ignored during merging procedure. If the answer vector includes more than one proper option, we choose the node which has the shortest distance from source node.

Before execution of proposed algorithm, source node should also calculate ratio of energy to distance for itself and all other neighboring nodes (here by distance we mean distance of nodes from BS). Subsequently, all nodes whose energy-distance ratio is less than energy-distance ratio of source node, will be excluded from GGR algorithm; because they are not recognized as suitable nodes. The stages of mentioned algorithm which is prior to GGR algorithm is represented by below algorithm:

```
X0 = E0 / D0
 for (i=1;i<=n;i++)
 {calculate Ei / Di
  Xi = Ei / Di
  if(Xi <= X0)
    Reject Xi
  else
    Xi is selected}
  if (distance of Xi to BS > distance of X0 to BS)
  Reject Xi
```

In the above mentioned algorithm, the ratio of energy to distance from BS is calculated for source node and saved. Afterwards, the same ratio is calculated for neighboring nodes. If the ratio of one neighbor node is less than the ratio derived for source node, it will be considered as an improper option and will be rejected. Otherwise, in next step, two distances are compared; first, distance between neighbor node (which is considered as a suitable option) and BS; second, distance between source node and BS. If the former is larger than the latter, the neighbor node will be rejected [1].

4. An Applied Example for GGR Method

Now, we clarify GGR algorithm by an example. In Figure 1, source node (X_0) requests for transmission. It wants to select one of its neighbors ($X_1 - X_{10}$) as the next step for information transfer. This selection should be optimum considering energy and distance. It is assumed that the allowed energy range is between 0-10 (0 to 100% interval) and distance allowed range is 20 meters. At the beginning, ratio of energy to distance from BS is calculated for all nodes:

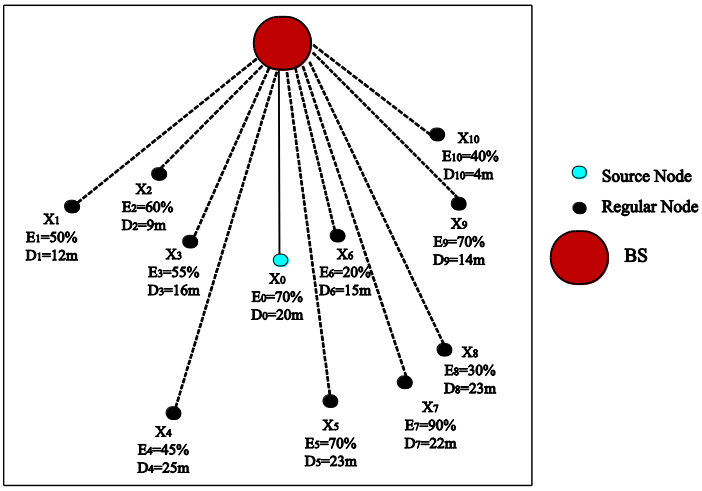

Figure 1. Information transfer approach and selecting next hop

$X_0 = \frac{E_0}{D_0} = \frac{7}{20} = 0.35$
$X_1 = 0.42$
$X_2 = 0.67$
$X_3 = 0.34$
$X_4 = 0.18$
$X_5 = 0.30$
$X_6 = 0.13$
$X_7 = 0.40$
$X_8 = 0.13$
$X_9 = 0.50$
$X_{10} = 1.00$

Now, according to elaborated algorithm and derived ratios for source node and neighboring nodes, we may conclude that X_3, X_4, X_5, X_6 and X_8 are not suitable nodes for data transfer. Because their energy to distance from BS ratio is less than source node ratio. In addition, distance between X_7 and BS is longer than distance between source node and BS. As a result, considering algorithm criterion, this node will be rejected. Hence, we apply set approach to nodes X_1, X_2, X_9 and X_{10}:

$X_1 = (8,5), X_2 = (11,6), X_9 = (6,7), X_{10} = (16,4)$

We rewrite the mentioned nodes by subscripts 1-4:

$X_1 = (8,5), X_2 = (11,6), X_3 = (6,7), X_4 = (16,4)$

The first component of ordered pairs is distance of node from source node and the second component is energy of the node. Based on GGR algorithm we can write:

$S^0 = \{(0,0)\}$ $S_1^1 = \{(8,5)\}$
$S^1 = \{(0,0),(8,5)\}$ $S_1^2 = \{(11,6)\}$
$S^2 = \{(0,0),(8,5),(11,6)\}$ $S_1^3 = \{(6,7)\}$
$S^3 = \{(0,0),(6,7)\}$ $S_1^4 = \{(16,4)\}$
$S^4 = \{(0,0),(6,7)\}$

While adding new pair (11,6) to S^1 in order to built S_1^2, we avoid writing (19,11) because allowed range of energy is 0-10. Also, (8,5) and (11,6) are omitted while merging S^2 and S_1^3 .While adding new pair (16,4) in order to built S_1^4, we avoid writing (22,11). Now, we should see whether last component of S^4 is a member of its previous set S^3 or not:

$(6,7)\epsilon S^3 \rightarrow X_4 = 0$
$(6,7)\epsilon S^2 \rightarrow X_3 = 1$
$(6,7) - (6,7) = (0,0)$
$(0,0)\epsilon S^1 \rightarrow X_2 = 0$
$(0,0)\epsilon S^0 \rightarrow X_1 = 0$

Node X_3 which is X_9, is the most optimum node for data transfer [1].

5. Simulation Results

The proposed algorithm was compared with SPIN [10], EAR [9] and GEAR [10] protocols and the results obtained from the simulations were examined. Values considered in this simulation are given in Table 1. In this experiment the sensor nodes are randomly distributed within the network and the place of the base station is considered out of the network.

Table 1. Simulation parameters

Network size	100*100
Number of nodes	100
Location of base station	(50,150)
Initial energy	2J
E_{Elec}	50 nJ/bit
ε_{fs}	1pJ/bit/signal
Threshold distance	80m
Packet size	50 bytes
Number of rounds	500

Figure 2 shows the end-to-end delay of packet delivery rate in the network and the proposed algorithm is much better in this case. As we know, the average amount of time that a packet takes to reach from one node to the other node in the network is called delay. In GGR method, it has been tried to transport the packets by the nearest neighbor node that has the maximum energy between the other neighbor nodes. In other words, in the proposed method it has been tried to transport the data through the shortest path that has the ability to transfer information, as a result the end-to-end delay improves compared with other methods. GGR method has reduced the end-to-end delay as 60, 10 and 15 percent compared to SPIN, EAR and GEAR methods.

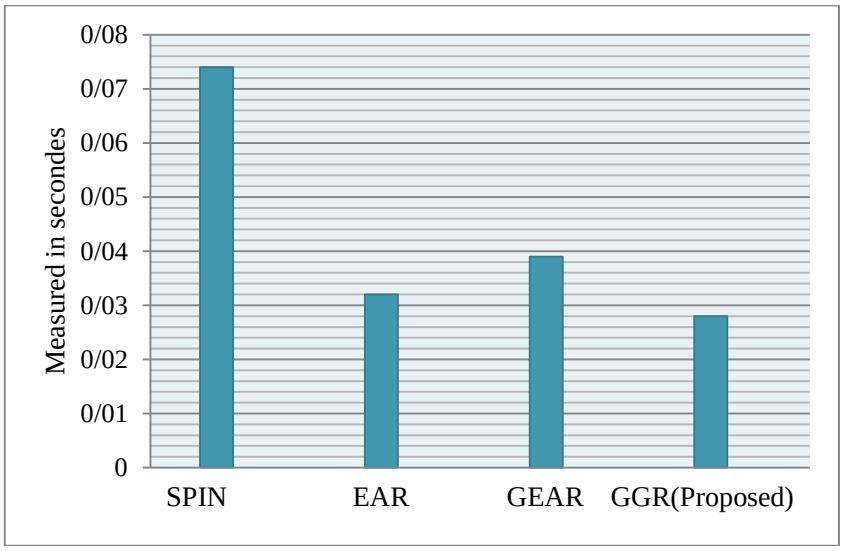

Figure 2. End-to-end delay of packet delivery (measured in seconds)

Figure 3 shows the rate of packet loss. As is known, in this parameter GGR method has presented a significant improvement over other available methods. As we know, most of the energy spent in each node is sending data; therefore, to ensure the proper receipt of the data by destination and prevent data loss, the selection of high-energy intermediate step is necessary. Since GGR method tries to transmit the packets through the nearest neighbor with the highest energy as step-by-step, therefore sending the information is done through a reliable and stable way. Obviously, the rate of packet loss will be significantly reduced than other methods. GGR method has reduced the rate of packet loss as 51, 23.5 and 7.25 percent compared to SPIN, EAR and GEAR methods.

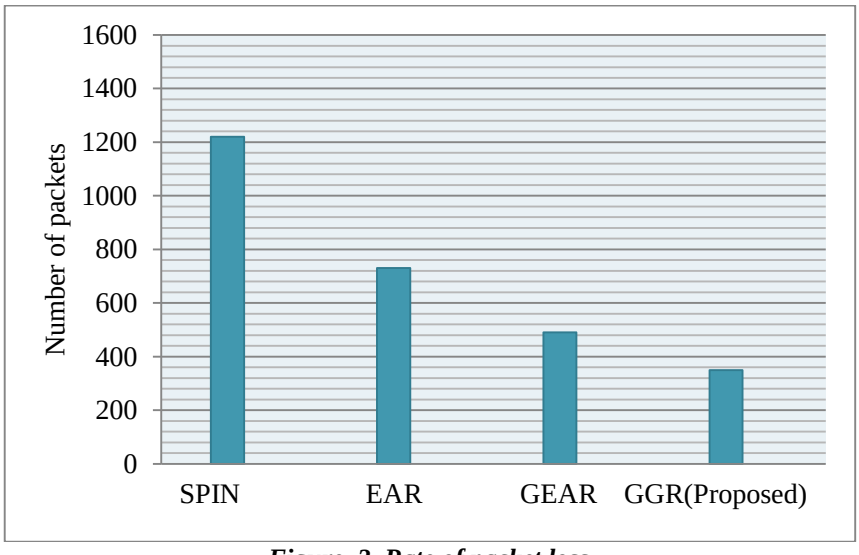

Figure 3. Rate of packet loss

Figure 4 shows the average residual energy of nodes after a certain period of time. As is known, GGR method made the average residual energy of nodes higher in comparison with other methods. Since GGR method always tries to look for the most appropriate neighbor that has the highest energy to send the data, so that the energy consumption for data transmission is distributed equally between nodes in the network

and leads to the balanced energy consumption in network nodes. As a result, the average residual energy of the nodes in the network will be high in the proposed method. GGR method has increased its remaining energy to 40 percent compared to SPIN method and has increased its energy to 20 and 23 percent, compared to EAR and GEAR methods.

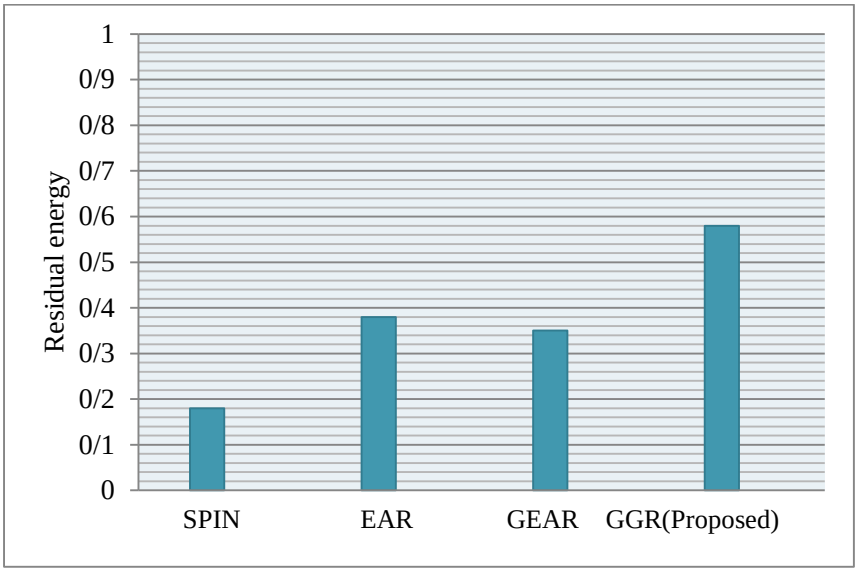

Figure 4. Average remained energy of nodes

6. Conclusion

One existing problem of routing in wireless sensor networks is finding the best path. By the best path, we mean the path where all nodes have highest energy level and shortest distance from base station so that data transfer consumes the least amount of energy. Routing can be considerably optimized using proposed greedy method. In this paper a greedy method is applied which choose the optimum neighbor among large number of neighbors considering energy and distance. This selected node will be utilized for data transfer in next step. Simulation results revealed that proposed method leads to significant improvement in reducing end-to-end delay and energy consumption.

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