A Hole Avoiding Routing Protocol with Relative Neighborhood Graph for Wireless Sensor Network

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Abstract:

In wireless sensor networks, "holes" are hardly to know its location and avoid either because of various actual geographical environments. A hole can be dynamically formed due to unbalanced deployment, failure or power exhaustion of sensors, animus interference, or physical barriers such as buildings or mountains. Hence, we hope to propose the RNG Hole Avoiding Routing protocol, RNGHAR which can model "holes" existed in wireless sensor network and event packets can avoid meeting a "hole" in advance instead of bypassing a hole when it meets the hole.

This paper proposes a novel algorithm RNGHAR which uses RNG (relative neighborhood graph) modeling holes then we can collect hole information in order to construct in advance hole avoiding routing path. Hence event packets will be guided to overcome the hole and move along the shortest path from source node to the sink node. Simulation studies show that my proposed method achieves good performance in terms of average hop count, packet delivery success rate and power consumption in comparison with the existing protocols.

Keywords：wireless sensor network, hole detection, relative neighborhood graph, hole avoiding routing

1. Introduction

Sensor networks consist of a large number of tiny sensors with limited computational capability, sensing, energy and memory [1]. Among this limitation, every kind of issue is studied, such as [2-4]. Recently, the portion of routing studied focus on establishing efficient routing paths [8-10]. Since shorten the route length can help to reduce the delay time and energy consumption as well as increase the successful delivery rate. Hole problem [3], nevertheless, are hardly avoided in wireless sensor networks. Specifically, existence of holes may baffle the establishment of routing path, packet lost or increase the route length. Most existing geographic routing protocols use greedy algorithm to forward data packets to the destination, that is, the forwarding node selects the node from its neighbors whose distance to the destination is the shortest one, as the next-hop node. In the past few years, a number of routing protocols that consider holes have been addressed for the WSNs.

Hole can be dynamically formed due to the several causalities [3] in wireless sensor network. However, most existing geographic routing protocols find out the position of hole by node[14 - 17],so we have a thought whether or not can make use of a certain structure to model the existence of hole in WSN, such as tree-base, hierarchical base, graph[5] [6]. Thus, this paper use RNG approach [5] [6] to make whole wireless sensor network construct a graph which is like tree framework, therefore can use this graph to model holes in WSN and then reduce hole detection overhead. Recently, significant approaches [11 - 14] were proposed to resolve the packet baffling problem. These approaches only deal with the hole problem when packets encounter a area of hole.

This paper proposes the RNG Hole Avoiding Routing protocol, RNGHAR which detects the position of hole in advance in a wireless sensor network. Sensors that are located around the holes will cooperate to establish in

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advance a hole boundary and then use the hole information not only to prevent the packets meeting the hole but also move to the destination along the shortest path.

The rest of this work is organized as follow. Chapter 2 discusses the related work. Chapter 3 presents the details of protocol that deal with the hole. Chapter 4 shows the simulation results. Finally, conclusions and future research direction are drawn in Chapter 5.

2. Related Works

2.1 Non-Prediction Approaches

GPSR [10] recovers by using the "right-hand rule "to route data packets along the boundary of the hole. However, GPSR deliveries packets not always using optimal path. However, the GPSR's routing path is not always efficient that is longest routing path. Furthermore, it does not guarantee that it always find the routing paths when they exist.

2.2 Prediction Approaches

HAIR [14] uses prediction function to prevent the packets meeting the hole. HAIR applies a data packet can avoid meeting a "hole" in advance instead of bypassing a hole, this approach, however, find out the hole's location that makes use of broadcasting of packet to detect in advance in WSN, but not employ a certain structure to formulate the existence of hole in WSN.

2.3 Relative Neighborhood Graph (RNG)

In our RNG Construction, we use the relative neighborhood graph (RNG) [5] [6]. RNG was already applied for solving problems in wireless networks. For instance, Borbash and Jennings [7] described the localized construction of RNG in details and proposed to use it as connected topology to minimize node degrees, hop-diameter, Maximum transmission radius and the number of biconnected components. However, [7] do not describe the use of RNG in solving any specific problem.

3. Protocol Design

3.1 Network Environments and Assumptions

The sensor nodes are distributed randomly and densely in the sensing field. A network composed of a sink node, hole and many wireless sensor nodes in an interesting area is considered. The sensor nodes are assumed to be fixed for their lifetimes and each sensor node is aware of its location. Each sensor node has unique ID number. Additionally, these sensor nodes have limited processing power, storage and energy, while the sink nodes have powerful resources to perform any tasks or communicate with the sensor nodes.

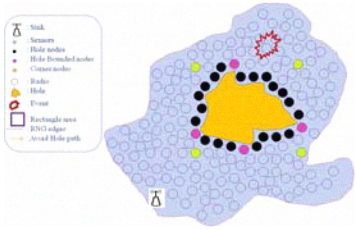


Figure 3-1: Sensor network environment

3.2 The process of Protocol

The RNGHAR protocol mainly consists of three phases. Three phases processing shown as Fig.3-2.

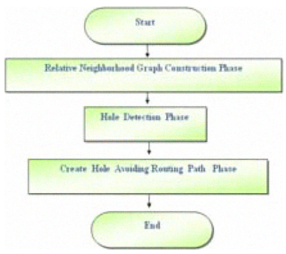
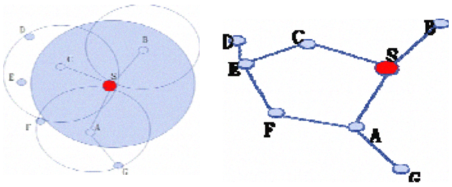


Figure 3-2: Process Flow Chart

3.2.1 Relative Neighborhood Graph Construction Phase

The proposed Protocol forms relative neighborhood graph relations with a Construction Packet (CP). The major activities in the phase are relative neighborhood graph construction and RNG neighbors list creation. The sink node wants to send CP, it transmits it with the range which allows to join its Associated-Neighbors, such as Fig. 3-3 (A) S emits its CP with d(S, A), furthermore A, B and C are cover S with their range, so when S generate the list of Associated-Neighbors and A,B,C in the list. Finally all sensor nodes accomplished to join to RNG graph, we will acquire, such as Fig.3-3 (B), RNG graph.



(A) (B)

Figure 3-3: Example of RNG Graph Construct

3.2.2 Hole Detection Phase

The phase is divided into three steps, **Circle detection Step, Hole Estimation Step and Hole Boundary Step.** Three steps processing shown as Fig.3-4.

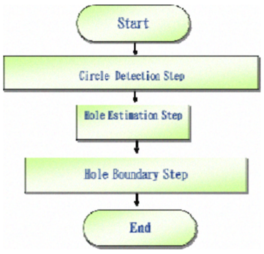


Figure 3-4: Hole Detection Flow Chart

3.2.2.1 Circle Detection Step

Firstly, we will handle RNG graph that construct from phase 1 transform a tree-base graph, then broadcasting the Circle Detection Packet (CDP) to children node by sink node, if RNG have circle in the graph we will detection circle from the tree, thus acquired we need circle information from CDP, and then traversal all sensor nodes in the tree will get into the step2, Hole Estimation Step.

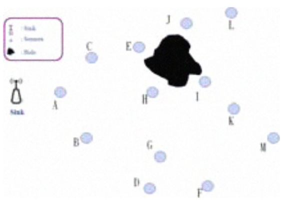


Figure 3-5: Wireless Sensor Network Framework

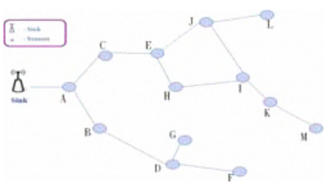


Figure 3-6: RNG Graph

For example suppose Fig.3-5 to a wireless sensor network framework. Make use of RNG algorithm to construct RNG graph for the wireless sensor network framework. Result was shown in Fig.3-6. Then handle RNG transform a tree-base graph.

Sink (S) broadcast the Circle Detection Packet (CDP). The CPD forward to C, then CDP continuously record some information in its field and downward the next layer till to node E, because of node E already received the message so processing degree identification, however, the degree is greater than four, hence the path Fig.3-7 shows the circle detection processing flow chart.

Degree=Hop_CurrentDegree-Det_PacketDegree (1)

- **Isn't a circle** **Degree < 4**
- **Is a circle** **Degree =>4**

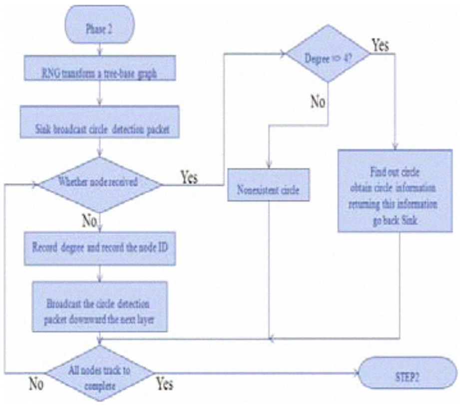


Figure 3-7: Circle Detection Flow Chart

3.2.2.2 Hole Estimation step

This step we use a concept that we will to detect the hole nodes' (form circle that information obtained from Step1) cross point location (which acquired perpendicular bisector of adjacent edge) whether or not fall in the radio of all hole nodes, if no that is the circle is hole then we will record the hole information (include hole nodes, hole nodes location..). Furthermore all circle sets detect achievement, and then get into the next step, Hole Boundary step.

Moreover, we will define an estimation expression, name cross point location criterion. Shown as (2). Make use of distance formula to calculate the one of hole nodes between with them whichever cross points distance then use this criterion to judge the distance whether cross point is fall at all sensor's radio. If any one of cross point between with hole node is distance greater than the sensor node's radio, then represent the circle is hole, whereas is not hole.

- **Cross point location criterion:**

$$d<=r \qquad (2)$$

- **the circle is not hole** **if d<=r**
- **the circle is hole** **otherwise**

$$d=\sqrt{(Cross_{(ID,ID)}\_X-Hole\_Node\_ID_x)^2+(Cross_{(ID,ID)}\_Y-Hole\_Node\_ID_y)^2}$$

d: Hole node with cross point distance.

r: Radio range.

Hole_Node_ID$_x$, Hole_Node_ID$_y$: Coordinate of hole node (∀ ID ∈ hole node ID of circle set).

Cross $_{(ID, ID)}$ _X, Cross $_{(ID, ID)}$ _Y : Coordinate of cross point of perpendicular bisector of adjacent edge (ID≠ID).

When we acquired circle set from step2 and then processing the hole estimation that judge whether existence hole in the circle set. However we will how to define hole estimation concept. Firstly we will be taken out hole nodes which a set of circle from the circle set then clinging find out cross point corresponsive. (A,B) is hole node A and B's cross point which acquired by perpendicular bisector the AB edge, because of all hole nodes' cross points fall in the radio of all hole nodes as well as all cross points fall on a same point, therefore the circle is not hole. Fig.3-8 shows the hole estimation processing flow chart.

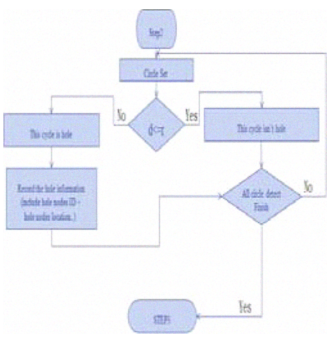


Figure 3-8: Hole Estimation Flow Chart

3.2.2.3 Hole Boundary Step

In this step, firstly we will find out the four hole bounded nodes that located at the extreme location from hole nodes. Then bounded a rectangle by four hole bounded nodes, and then find out four corner nodes which coordinates are close to the rectangle four corner's location, finally broadcast the corner nodes information to each sensor nodes, then these information will should be used for erection of hole avoiding routing path.

Acquired each hole node coordinates from hole estimation step then compare all hole nodes' X-axis to find out maximum and minimum value. Hole node of minimum located extreme left, name to Left Hole Boundary Node, LHB. Hole node of maximum located extreme right, name to Right Hole Boundary Node, RHB. Finally, hand over to connect out four coordinates of points, find out most four corner nodes close to these positions. Therefore we acquired the four corner nodes information then broadcast the information to whole WSN. Sensor nodes will use the information delivery the event packet to sink along the shortest path. Fig.3-9 shows the create hole avoiding routing path processing flow chart.

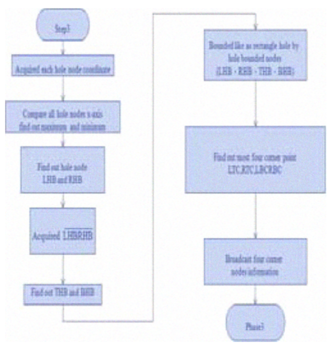


Figure 3-9: Hole Boundary Flow Chart

3.3 Create Hole Avoiding Routing Path Phase

After obtained Bounded hole and Corner node information by Phase2, when event occur, have a event packet need to deliver to sink, we will establish a avoid hole in advance routing path by bounded hole information, then we can the very efficient achieve for event packet transmissions.

When we accomplished phase 2, sink and all sensor nodes acquired the hole information and corner nodes information. When event occur in WSN, firstly sensor node will compare the related position of sink, hole and event. If event packet delivers to sink will not pass hole, then use greedy method to deliver event packet to sink.

On the other hand, if the event packet will pass hole. Then the sensor node which detected the event will find out which two corner nodes are close to sink from information table and then according to these directions of two cross points deliver event packet to sink as well as along shortest path. Finally, the whole sensor nodes return to listening condition. Fig.3-10 shows the processing flow chart.

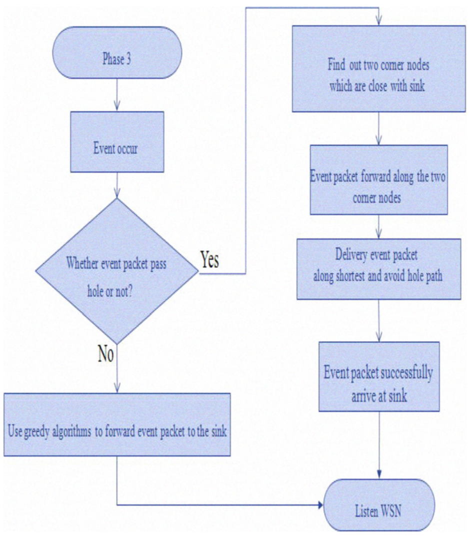


Figure 3-10: Hole Avoiding Routing Path Flow Chart

4. Simulations

This chapter focuses on the simulation and analysis of RNGHAR protocol compared with other protocols. To simulation the performance of RNGHAR, we make some basic assumption to observe and evaluate the performance of RNGHAR under a variety of conditions.

4.1 Simulation Environment

The environment with single hole is considered in the simulation. To evaluate the performance of RNGHAR, simulation were run by using C++ The performance of RNGHAR was compared with the following other protocols: GPSR. The aim of the experiments was to measure the average hops, packets delivery success rate and remaining energy. Network of 500 * 500 m² with 500 nodes and different hole size were simulated. Table 4-1 gives the parameters for simulation. Among them the energy dissipation of the radio in order to run the idle, transmitting or receiving circuitry.

Table 4-1: Parameters for simulation

Parameter	Value
Network Size	500 M * 500 M
Sink Location	Corner
Hole Location	Central
Number of Sink	1
Number of Hole	1
Number of Sensor Node	500
Initial Energy of Sink	Not limited
Initial Energy of Sensor Node	15W
Energy consumption of transmitting	14.88mW
Energy consumption of receiving	12.50mW
Energy consumption of idle	0.5mW
Transmission range	30m
Hole Size	adjustment

4.2 Results and Analysis

Fig. 4-1 compare the average hops of RNGHAR and GPSR in different Hole size of circular (Radius: 40, 70,100 and 130, respectively). Because of HAIR inquire into that the pattern of hole is fixedly a rectangle so didn't imitate here. Moreover, this is also the part that my method superior to HAIR. That is I inquire into hole don't that the hole of a certain pattern. Clearly shows that my method used average hops less than GPSR. However, the difference of simulation result diminished; because of the GPSR is hole avoiding routing path to use in hole of circular type that can reduce hop counts.

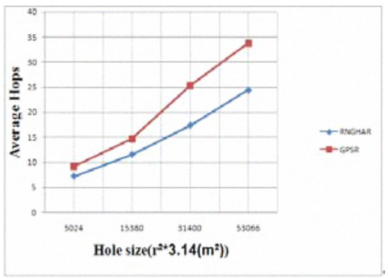


Figure 4-1: Average Hops

Fig. 4-2 shows the comparison of packet delivery success rate of RNGHAR and GPSR mechanisms. The hole size is set by r²*3.14 (Radius: 100) (m²). In simulation the GPSR is adopt right-hand-rule (counterclockwise). The course reflected the result for simulation. Therefore we can see that the simulation result is show that the GPSR's packet delivery success rate has been gradually decreasing, because of the routing path concentrate too much in a certain part sensor nodes, then exhaustion of the sensor nodes energy of this part very soon. Therefore propagation range of the hole, induce that can't find out a path to successfully delivery the event packet to sink. However we can find that the packet delivery success rate is stable for my approach, because of the routing path that event packets walked will not concentrate too much somewhere. Although some sensor nodes can run down, but it have no great influence. That is to say that it doesn't propagation range of the hole, with the result that influence the successfully delivery the event packet to sink.

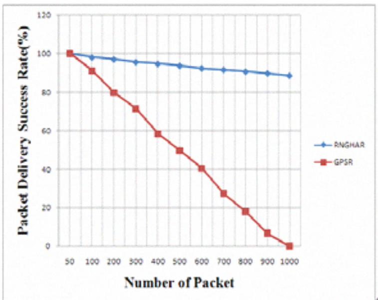


Figure 4-2: Packet Delivery Success Rate

Fig.4-3 compares the GPSR mechanism and RNGHAR in terms of the remaining energy of nodes on boundary of hole in a single hole environment. The hole size is set by r²*3.14(m²) (Radius: 100). GPSR utilize right hand rule to route data packet to sink when the packet encounter a hole, in other words, as long as hole locate between source and destination the data packet must be sent along then boundary of the hole. Thus the energy consumption of the nodes on the boundary of hole is quite high in GPSR. However RNGHAR is a hole avoiding in advance routing, so they can to prevent data packet go along the boundary of hole. Thus reduce energy consumption of the nodes on the boundary of hole. Therefore, the remaining energy of nodes on boundary of hole of RNGHAR performs better then GPSR for remaining energy of nodes on boundary of hole.

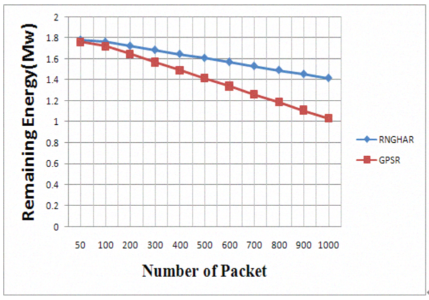


Figure 4-3: Remaining Energy

5. Conclusions and Future Works

In this paper we propose the RNGHAR protocol that can be used RNG (relative neighborhood graph) modeling holes then we can collect hole information in order to construct in advance hole avoiding routing path. Hence event packets will be guided to overcome the hole and move along the shortest path from source node to the sink node. However shorten the route length can help to reduce the delay time and energy consumption as well as increase the successful delivery rate. So we can see that RNGHAR outperforms GPRS mechanism in terms of the average hop count, packet delivery success rate and power consumption from simulation results.

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