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Greedy Geographical Void Routing for Wireless Sensor Networks

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Abstract**—**With the advantage of wireless network technology, there are a variety of mobile applications which make the issue of wireless sensor networks as a popular research area in recent years. As the wireless sensor network nodes move arbitrarily with the topology fast change feature, mobile nodes are often confronted with the void issue which will initiate packet losing, retransmitting, rerouting, additional transmission cost and power consumption. When transmitting packets, we would not predict void problem occurring in advance. Thus, how to improve geographic routing with void avoidance in wireless networks becomes an important issue. In this paper, we proposed a greedy geographical void routing algorithm to solve the void problem for wireless sensor networks. We use the information of source node and void area to draw two tangents to form a fan range of the existence void which can announce void-avoiding message. Then we use source and destination nodes to draw a line with an angle of the fan range to select the next forwarding neighbor node for routing. In a dynamic wireless sensor network environment, the proposed greedy void avoiding algorithm can be more time-saving and more efficient to forward packets, and improve current geographical void problem of wireless sensor networks.

Keywords**—**Wireless sensor network, internet routing, wireless network, greedy void avoiding algorithm, bypassing void.

I. Introduction

WITH wireless network technology's advancement, there are a variety of applications in our life. Among that wireless sensor network is the popular research area in recent years. As the wireless sensor network node move at any time and the topology fast change feature, nodes often have void problem. When node transports packet, we can't predict void problem will occur in when and where. This will produce packet losing, resending, rerouting…additional transmission cost and electric power output. Thus, how to improve wireless network technology's geographic routing method is more important [1]-[10].

The greedy algorithm is a widely used method because of its low complexity and good scalability. The greedy algorithm is efficient, and the answer it obtained is relatively close to the best result. The greedy algorithm can also be used as the supportive algorithm. However, the greedy algorithm can't always solve the problem. When the communication void exists in the network, using the greedy algorithm may lead the surrounding void area to produce the stuck block, and reduce the life cycle of network and the efficient traffic [20]-[26].

The reason of the communication void's conformation is that, when the sending node failed to find the next valid node to reach the destination node's geographical phenomenon, is known as the communication void. Due to the unpredictability of the dynamic wireless sensor network environment, we can't predict when and where there will appear a void area. If there is no suitable void processing technology in place, some packets may lost in the network, waste the network resources, and block the wireless network communication between nodes [15].

The communication void is a challenging problem of geographic routing, in order to effectively use geographic routing in next-generation wireless network, this problem must be solved. Although some of the densely deployed wireless nodes can reduce the communication void in the likelihood of the network, but some data packets may still encounter obstacle void and the unreliable boundaries nodes of wireless network, and so on. The data packets must be discarded, even if only a greedy forwarding strategy use a valid path to the destination node may still exist. Therefore, we must design an effective and efficient way of geographic routing void processing technology.

The work of geographic forwarding has two modes, the greedy forwarding mode and the void processing mode. In the greedy forwarding mode, we select the next node to forward the packet is according to the location of the current node, the boundary node, and the destination node. If the sender needs to send the packet, but the current packet can't find the better next node in the transmission area to transfer the packet to the destination node, it will switch to the void processing mode. In this mode, the node tries to select the routing path which around the void area. It could be the valid routing path, which transfers from the source node to the destination node [17]-[19].

In this research, we use the find void algorithm to find void. Then we propose a greedy void avoiding algorithm to solve wireless sensor network's void problem. We use source node and void to draw two tangents form the announce void existence's fan range, then use source node and target node to draw a line with the fan range's angle to select next neighbor node for routing. In the rapidly changing dynamic wireless sensor network environment, we expect this research's greedy void avoiding algorithm that we proposed can be more time-saving and more efficient to forward packet. And improve current wireless sensor network's geographical void problem.

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II. Related Research Reviews

The geographic routing is initially a packet wireless network that has been proposed in the 1990's. It based on the location of mobile device or equipment as the basic for path selection algorithm, and based on location-based or direction-based routing algorithm. In recent years, with the global positioning system's application and their progress in positioning under the allocation mechanism, it became a hot research issue again. It provides a more attractive next-generation wireless network messaging solutions, such as MANETs, VANETs, WSNs and WMNs [3]-[6].

A. Wireless Sensor Networks

Wireless sensor network is a number of wireless data collector as well as the large number of sensor posed by the network system, use Wireless Communicate way to communicate between components. Therefore, we can arbitrarily place the sensors and wireless data collection devices. Not only can save the wiring under the considerable costs but also bring great convenience benefits. In the wireless sensor network architecture, sensor design is based on power saving, small size, low price and has the environment sensor device for the target. The sensor is like a small computer with simple sensor device, computing device and wireless device. The sensor devices can be used for things that we are interested in (such as temperature, light, etc.) to do the detect behavior, and simple operation handling the data that collected first, and then through the wireless transmission device, transfer back the data to data collection device. Finally, we can use the data that data collector collected, to understand the environmental status and using in development and application [31]-[33].

B. Sensor Network Topology

The general sensor network to establish and maintain can be divided into the following three stages.The sensor deployment can be planned in advance,then according to the blueprint of the planned placed the sensors one by one. However, in certain special circumstances, such as: ocean, battlefield or forest, etc., the sensor arrangement can't be predicted. In this case, is often placing amount of sensors through ship, aircraft or other machinery, etc., scattered at random sensing environment [1]-[4].

Theoretically, the sensor deployment completed, it has formed a complete wireless network infrastructure. However, the sensor location susceptible to environmental factors, such as water force, wind or human movement and other factors to change, or when the sensor power damaged or weakened, it may produce the void, thus resulting in network topology change. The system must response immediately to face the topology's change, and make appropriate amendments quickly to the incomplete network topology [27]-[32].

After a while of time, many sensors may be broken due to insufficient power or serious damage, causing the nodes is not enough to detect the environment and transfer data in the sensor network. At this time, the system can't automatically repair the entire network infrastructure. We must rely on external force (personnel, machinery, etc.) add a number of additional sensors to compensate the problem of sensor insufficient quantity. In order to have these additional sensors, the original network is like inject new life. It can auto-configuration network architecture and continue to execute the task [14]-[17].

C. The Greedy Routing Algorithm

The geographic routing usually is based on the mobile device or the location of device's path selection algorithm, based on the geographical location or the direction-based routing algorithm. It's unlike the topological routing and the geographic routing is use of the geographic information, rather than the connectivity topology information between nodes to transfer data packets, and close to the final destination node until it arrive [11]-[15].

In most of geographic routing algorithm, only one-hop neighbor nodes' geographic information will be used. Therefore, the geographic routing algorithm does not require establishment or maintenance the complete line from the source node to the destination node. The intermediate nodes don't need to store the routing table, so there is no necessary to transfer routing information to update routing. The function of the node region makes the geographic routing become simple and scalable. The geographic routing also uses geographic building services to support the packet be passed to the designated geographical area of the node [8]-[11].

The greedy algorithm is a kind of method that in every step of the options, taking the best choice under the current state, and then hope that the result is the best algorithm. The algorithm in the best substructure's problem is the most effective, and the substructure means that the local optimal solution can determine the global optimal solution. The problem can be decomposed into sub-problems to solve, and the optimal solution of the sub-problem can be recursive to the final optimal solution. The geographic routing depends on a very simple geographic greedy forwarding mechanism. Whenever packet forwards to the destination from the nearest neighbor node, which is the best local next node. Try to search the most appropriate pathway to reach the destination node and avoid a cycle path. In the choice of the forwarding packet to the next node is a node based on the locations of current position and the next node, the next node and surrounding nodes and the next node and the destination node. The node can determine its own position, whether it is pre-configured, or the node is fixed, but it also can through the global positioning system receiver or by positioning algorithm [9]-[16].

The greedy algorithm is a widely used method because of its low complexity and good scalability. The greedy algorithm is efficient, and the answer it obtained is relatively close to the best result. The greedy algorithm can also be used as the supportive algorithm. However, the greedy algorithm can't always solve the problem. When the communication void exists in the network, using the greedy algorithm may lead the surrounding void area to produce the stuck block, and reduce the life cycle of network and the efficient traffic [5]-[7].

For example, if all the adjacent nodes relative to the sending node are away from the target node, the sending node can't find any active node to reach the target node. This is what we can research, and where we can improve [6]-[8].

D. Communication Void

The survey of literature in recent years shows that, these communication void classification are divided into six categories, and are designed for different approach. Their classifications are the based on the plane and graphic routing, the geometric routing, the flood routing, the based on cost consideration routing, the heuristic routing, the hybrid routing, and so on [11]-[19].

In the wireless network's communication void of geographical greedy forwarding routing protocol, if it's unable to send the packets to the destination node, it will be an important issue. The reason of the communication void's conformation is that, when the sending node failed to find the next valid node to reach the destination node's geographical phenomenon, is known as the communication void. Usually be summarized as to the area maximize phenomenon or the area minimize phenomenon. One part of the void is also divided into two: open void and closed void [2]-[6].

The communication void is a challenging problem of geographic routing, in order to effectively use geographic routing in next-generation wireless network, this problem must be solved. Although some of the densely deployed wireless nodes can reduce the communication void in the likelihood of the network, but some data packets may still encounter obstacle void and the unreliable boundaries nodes of wireless network, and so on. The data packets must be discarded, even if only a greedy forwarding strategy use a valid path to the destination node may still exist. Therefore, we must design an effective and efficient way of geographic routing void processing technology [5]-[8].

There are two main factors in the geographic routing, the location of service and the geographic forwarding strategy. Before the source node sending the data packets, the location service is responsible for determining the location of the data packet's destination node. The location of the packet includes in the packet header, it makes the intermediate nodes can learn where the data packet forwarding to. The work of geographic forwarding has two modes, the greedy forwarding mode and the void processing mode. In the greedy forwarding mode, we select the next node to forward the packet is according to the location of the current node, the boundary node, and the destination node [1]-[7].

The nodes can determine their positions, whether it is the pre-configured fixed node, through the global positioning system receiver, or by the localization algorithm. Try to find a better choice node in the process of forwarding, you can choose to update the position and then forwards the packet header [16]-[17].

If the sender needs to send the packet, but the current packet can't find the better next node in the transmission area to transfer the packet to the destination node, it will switch to the void processing mode. In this mode, the node tries to select the routing path which around the void area. It could be the valid routing path, which transfers from the source node to the destination node. Due to the unpredictability of the dynamic wireless sensor network environment, we can't predict when and where there will appear a void area. If there is no suitable void processing technology in place, some packets may lost in the network, waste the network resources, and block the wireless network communication between nodes [21]-[24].

The easiest void processing technique for flooding broadcast. When sending the packet encounters the void boundary node, all the nodes for the first time receiving the stranded packets, and then perform the broadcast [24]-[25].

If it at least exist one routing path, the flooding broadcast technology can pass the packet to the destination node. However, this method in the efficiency of resource use, but the effect is very poor. Because all the other nodes in the network will forward the packet once, the destination node may receive the same unnecessary packet from the different routing path. If there doesn't exist the beneficial path progress's node, the data packet should be forwarded to the void node or the node of the dead end path, but it may lead to the cycle path [14]-[18].

III. Greedy Geographical Void Routing Algorithm

In the wireless sensor network's environment, the communication problem has been an uncertainty factor, it could produce data transmission's problem anytime. Therefore, how to solve the void problem between nodes effectively, and improve the transmission quality effectively is more important. Our research proposed the greedy geographical void avoiding algorithm consists of three steps: find void algorithm, announce void algorithm and select neighbor node algorithm.

A. Find Void Algorithm

When there do not have enough sensors in the communication range, there will produce the communication void, and the packet transmission will be unpredictable. What is the void, how to define the void, and how to pass around the void that is what we want to explore. At first, defining the position of the void distribution, the void is formed when the packets can't continue forwarding to the destination node's stuck node and the void boundary nodes. With the stuck node's information, the node combined all the void boundary nodes then we can get the void range.

When the transmission node can't continue to forward by the void problem, that node is considered the stuck node. We can contain the stuck nodes on the boundary of the void and other node that can't continue to transmit forwarding stuck nodes by the algorithm to identification, and then link all the nodes to form the range of the closed void range.

$$y = m \cdot x + c \quad (1)$$

$$y = n \cdot x + c \quad (2)$$

$$m \cdot n = -1 \quad (3)$$

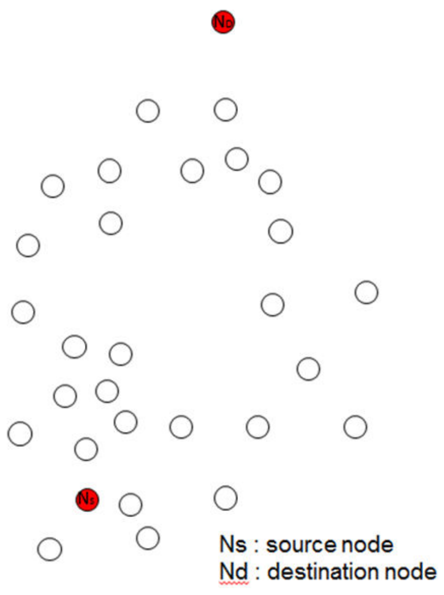

Fig. 1 Definition of the initial node and the destination node

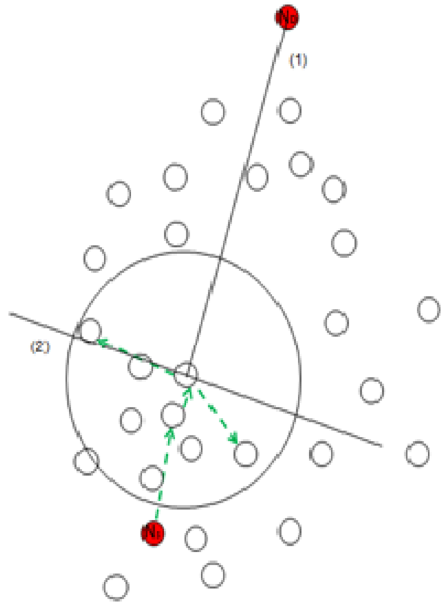

Fig. 2 Selection of the void boundary node

At first we define the initial node and the destination node, as shown in Fig. 1. We use the transmission node and the destination node's straight line to draw the horizontal and vertical lines(1) (2), the slope of the horizontal and vertical lines is -1 (3), as shown in Fig. 2. We based on the horizontal line to look for the next void boundary node in the transmission range, and the node in the transmission range can be divided into two kinds. The one kind of node is that backward looking for nodes in the transmission range, as the stuck node. The other one is the node that forward looking for nodes in the transmission range as the void boundary node.

To choice the next boundary node, we will select the node in the transmission range. If it starts from the left side to finding, then according to the horizontal line's left side and using the left hand rule to find the next void boundary node. Otherwise, if it starts from the right side to finding, then according to the horizontal line's right side and using the right hand rule to find the next void boundary node. Finally, it returned to the original stuck node, and formed a cycle path then stopped, producing a set of void boundary node.

When two nodes in the transmission range and have the same angle, we find the void boundary node from left and right two-way. According to the right hand rule and the left hand rule find the void boundary node separately. Finally, two- way has the link to each other, and we finished the void boundary range.

The packet transfers along the edge, when the node is recognized as the void boundary node, it will add the node. When the transmission is finished and returned to the start stuck node, each edge node's location will be encoded in the find void packet, and establish a set of all boundary nodes, SBN. Then selecting two nodes from SBN, the distance between two nodes is the longest in SBN, and we calculate the midpoint v of segment, as shown in Fig. 3.

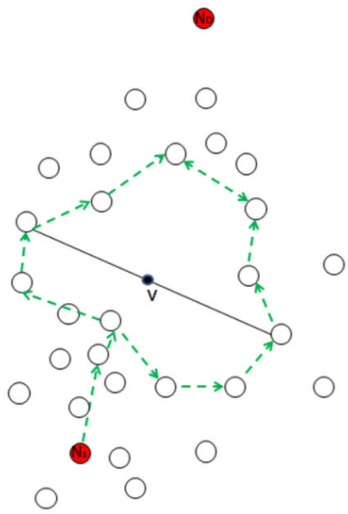

Fig. 3 Definition of the void range

B. Announce Void Algorithm

After the void is found, the location of the void center v's coordinate are xv and yv. Let notice to all known the nodes in the announce range. With the void range of location, and then notice the nodes in the announce range. It can take some actions to avoid the void before meet it, as shown in Fig. 4.

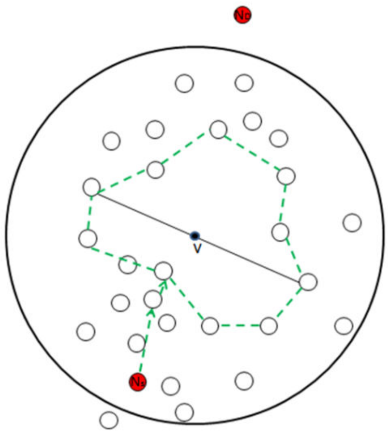

Fig. 4 The announce range of the void

When the distance between the node's coordinate and the center of the void is less than the radius of announce range, the node is located in the void (4).

$$(x_v-x_i)2+(y_v-y_i)2<R2 \quad (4)$$

The announce range of radius R is calculated by the formula (5) with the transmission range of wireless sensor SR and the void's radius r.

$$R= r+n/2\times SR, \text{ with } n= 1, 2, 3\ldots \quad (5)$$

Then taking two points of the edge of the void and draw two tangents form the angle's void avoid range to cover the void. To extend two tangents to intersect with original announce range's circle. After that, produce two points j and k by intersection and from a new range of fan-shaped void avoid range, as shown in Fig. 5.

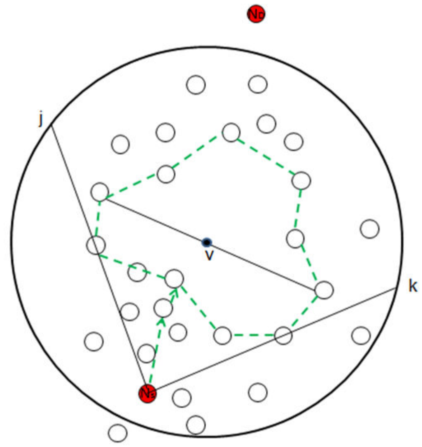

Fig. 5 The fan-shaped void avoid range

As the wireless sensor network nodes have characteristics of always moving and rapidly changing topology, the original void will be bigger or change the shape. Therefore, the node which has responsible for announce the void will period send the find void packet and re-execute the steps of finding void algorithm to update the find void packet. If there is any change of the void, it will announce to all nodes in the announce range at next updating time.

C. Select Neighbor Node Algorithm

In the immediate geographic routing protocols, nodes forward the packet to the next neighbor node, and the node selection area for the forwarding range. The forwarding range is the area of the source node s reach to the destination node d's forwarding neighbor node range.

When the node s receives the packet that will transfer to the destination node d, it will scan the forwarding range first. Then the node s will implement the following rules:

The transmission node s and the destination node d's straight line, two tangent lines intersect, and generated two angles. Then, we choose the side with the smaller angle from two tangent angles (6). If the tangent is near the transfer point and the destination node line's left side, using the counter-clockwise way to search neighbor node in the transfer area.

In Fig. 6, the angle ∠dsj is smaller than the angle ∠dsk, then choosing the smaller one ∠dsj. The node s starts from to select the neighbor node in the forwarding range by counter-clockwise way, and selecting the node which is near the tangent as the next forwarding node. The neighbor node m in figure is the nearest node to tangent by counter-clockwise way to find it, as the next forwarding node. Conversely, if it is near the transfer point and the destination node's right side, it will search neighbor node by clockwise way.

$$\angle dsj < \angle dsk \text{ (choose smaller side)} \quad (6)$$

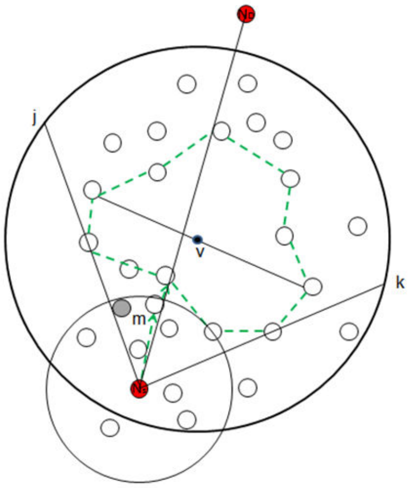

Fig. 6 Selection of neighbor node

In the greedy forwarding algorithm, when the transmission node wants to transmit the packet to the destination node, it will select the node which has the shortest path to the destination node from the transmission range. The node which has shorter distance to the destination node than the distance between the current node to the destination node as the next node.

In the forwarding process, such as the transmission node s and destination node d's straight line is no longer covered in the sector void avoid area. It will return to use the greedy geographic routing algorithm mechanism for delivery. Then it forwards the packet to the destination from the nearest neighbor node, which is the next best local node, actively seeking the most appropriate pathway to reach the destination node, and to avoid produce the cycle path.

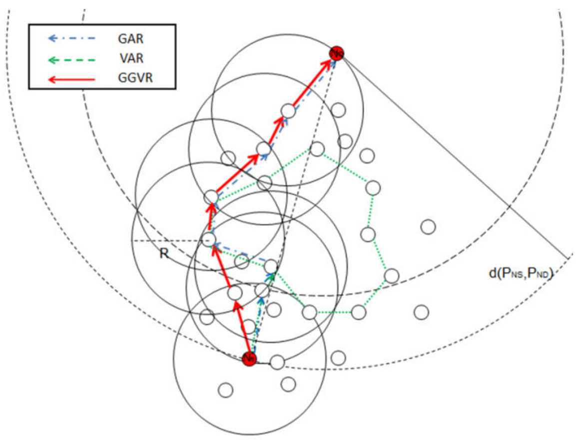

Fig. 7 The comparison of algorithm routing

In Fig. 7, that is our algorithm GGVR and GAR's routing simulation figure. In this study, we expected to discover and define the void, have effective way to avoid the void ,and reduce the the number of forwarding times. Reducing routing distance can be more economical and efficient to forward packets to improve the current geographical void problem in wireless sensor network, and to enhance the performance of network routing.

IV. Simulation

NSG is a special tcl script designed for NS2, when using NSG2 it is divided into five modes. These modes are mostly designed in accordance with NS2's several objects. Fig. 8 is designed by NSG2 tcl script generator's diagram of the NS2 wireless network's experimental simulation. Then use this tcl script file to adjust and modify the experiment. Trying to measure the application's packet loss rate, packet delay, jitter, and throughput which rely on UDP's transport protocol.

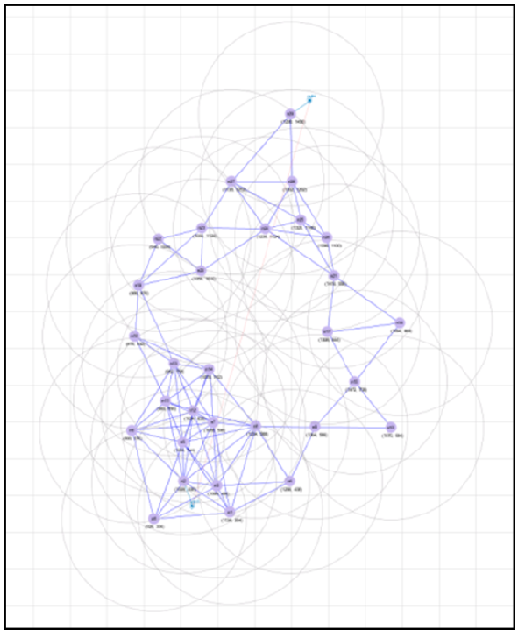

Fig. 8 NSG2 tcl script

For packet loss rate, we can calculate the number of records in the sender log file, each record represents a packet information that has been send. Therefore, the number of records means how many packets have been sent. We have to calculate the number of records in the receiver log file, each record means each received packet information. Therefore, the number of records means how many packets have been received. The difference between these two values, we can know that how many packets have been dropped in the process of transmission. Then the difference is divided by the amount of all packets that have been sent. Finally, you can get the packet loss rate. The packet delay is the difference between packet arrival time and packet transfer time. You can directly get it from the fourth column of the receiving log file.

The jitter is delay variance, due to network traffic's variance. When the internet traffic flow is high, many packets should stay in the waiting queue to be transmitted. Therefore, each packet from the transfer mode to the destination node's during time is not the same, and this difference is jitter. The higher the jitter rate, express the network is more unstable. The throughput is the packet capacity that it can load in per unit time. For the throughput, you can get it from the sum of receiving packet sizes divided by the spending time.

TABLE I
EXPERIMENT PARAMETERS

Parameter Setting	
Node	150
Start time	5 sec
Stop time	100 sec
Simulation time	120 sec
Transmission range	250m
Queue	50
Packet size	512 bytes
Rate	0.2 Mb

The initial experiment setting is 150 nodes, and includes a void area in the environment. In the experiment, it starts to send packets at the fifth second, and stop sending packets at the one hundred second. The simulation time is finished at the one hundred and twenty second, and the node's transmission range is two hundred and fifty meters. In the initial experiment parameters, the default value of the queue is 50, the packet size is 512 bytes, and the transmission rate is 0.2 Mb. We simulated GGVR, GAR, and AODV partly in the communication void environment, and measured the routing performance. In the experiment, our control variables are the queue, the packet size, and the transmission rate. We adjust them to measure and compare the network performance in different environments.

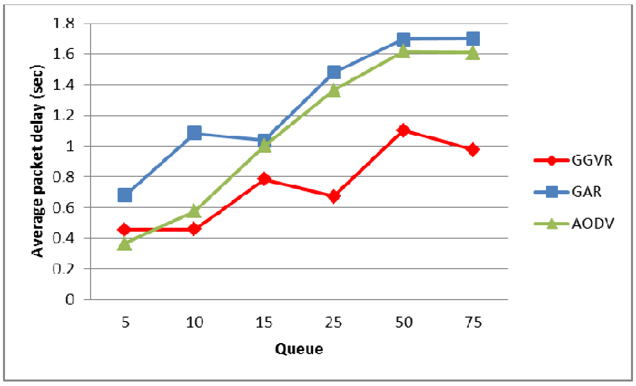

Fig. 9 Average packet delay – Queue

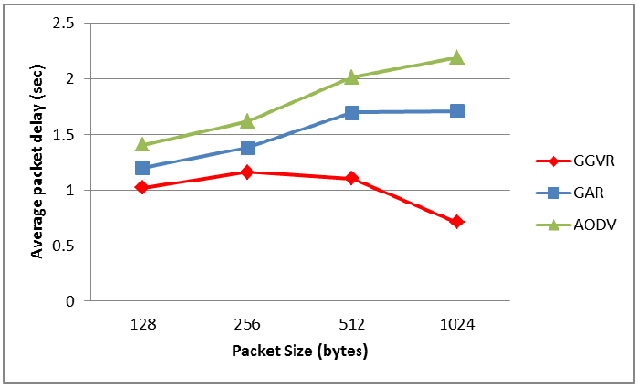

Fig. 10 Average packet delay – Packet size

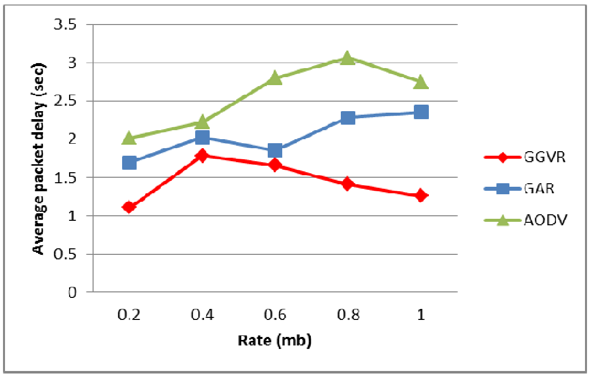

Fig. 11 Average packet delay – Rate

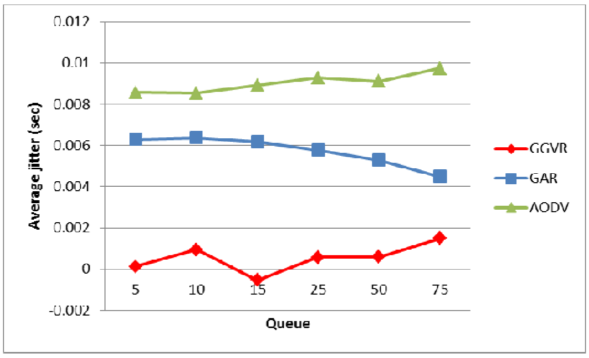

Fig. 12 Average jitter – Queue

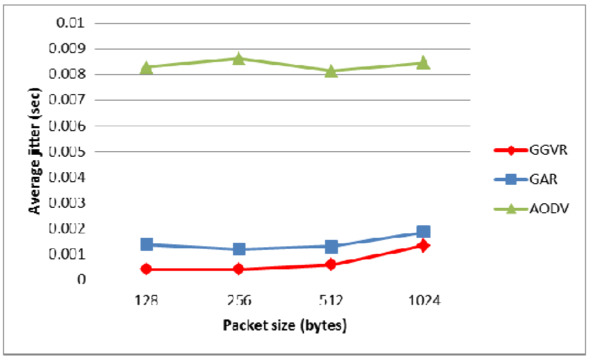

Fig. 13 Average jitter –Packet size

In this study we proposed the GGVR to resolve, and to avoid the void problem. In the experimental simulation results, we compared the network performance measurement with GAR and AODV routing protocol. When the control variables are the queue, the packet size, and the rate's changing, GGVR's average packet delay are lower, and they have good performance. When the control variables are the queue, the packet size, and the rate's changing, GGVR's peak packet delay are lower, and they have good performance. When the

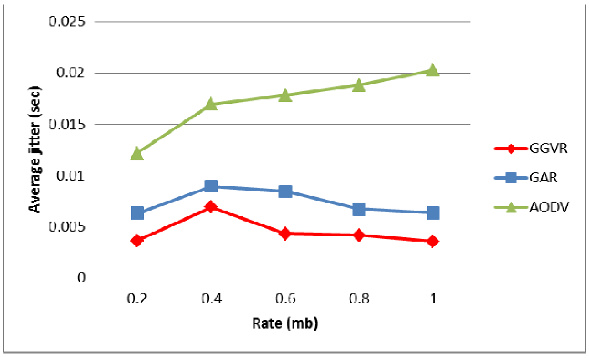

Fig. 14 Average jitter – Rate

control variables are the queue, and the rate's changing GGVR's average jitter situations are not serious, and they have good performance. When the control variable is the queue's changing, GGVR's peak jitter situation is not serious, and it has good performance. When the control variable is the queue's changing, GGVR's average throughput is higher, and it has good performance. When the control variable is the queue's changing, GGVR's peak throughput is higher, and it has good performance. The GGVR has good performance in the comparison of network performance measurement. To prove the GGVR that we proposed in this study, it can effectively avoid the void and solve the problem of communication void, and it has good results.

V. Conclusion

As technology advances, one day any communication may be regarded as a node. Such as the growing popularity of smart phones, tablet PC, and e-book, the mobile devices are increasing quickly. So how can we provide better quality, and stable connection is currently an important issue. As the Internet environment, the communication void issue has been an uncertainty factor in the wireless network. It may produce problems on the communication at any time. So how can effectively avoid the generation void problems, and design an effective and efficient geographic routing's void avoiding technology, to improve transmission quality becomes very important.

The reason of communication void is formed by the sending node can't find the next active node to reach the destination node in the transmission area's phenomenon, and it is named as the communication void. Although the densely deployed wireless nodes can reduce the communication void happening in the wireless sensor network. Some of the data packets could face the void problem by the communication void, the unreliable boundary nodes' attracted in the wireless sensor network, and so on. Thus, how to effectively avoid the void problem, design an effective and efficient way of the geographic routing void processing technology, and enhance the quality of the data transmission is very important.

This study proposes the greedy void avoid algorithm, this method has found and defined spaces, and passed the void before data transmission to the void. Using the void area's tangent to guide the routing, to reduce the forwarding nodes, to shorten the routing distance, and it can be more high efficiency and saving time to forward packets. To ensure the stability of data transmission, reduce data losing, and re-sending. In the wireless sensor network, node just knows void information before transmission. It can effectively avoid the void, and to ensure data transmission. To reduce network traffic in order to achieve energy saving's purpose, and solving the current geographical void problem in wireless sensor networks.

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