2016 IEEE 14th Intl Conf on Dependable, Autonomic and Secure Computing, 14th Intl Conf on Pervasive Intelligence and Computing, 2nd Intl Conf on Big Data Intelligence and Computing and Cyber Science and Technology Congress

Applying Virtual Coordination Anchor Node to Routing Mechanism in Wireless Sensor Networks

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***Abstract*— the wireless sensor networks (WSNs) are one of the popular information and communication technologies (ICTs) in different application areas. One of the important issue and technology in WSNs is to collect sensing data efficiently and deliver them to base station (BS) reliably. In most previous researches and proposed methodologies are using Geographic routing techniques. Based on them, the sensors have to know not only their own location coordinate, but also have the location information of one hop neighbor and the destination node. In general, the Global Positioning System (GPS) is used to provide the location and time information, but the cost is higher, power consumption is increasing, and the lifetime of whole network is reducing. Therefore, this paper proposes a Virtual Coordinate System (VCS), which starts from sink to replace GPS. With the VCS, WSNs can find the four extreme nodes in the scene boundary as virtual anchor nodes. And, a shortest path between virtual anchor nodes and sink for transfer data in the random distribution wireless sensor network is created. In the proposed approach, a routing mechanism will be established with low-power, extending lifetime, efficient and fault-tolerant.**

Keywords- anchor node; routing; virtual coordinate system; wireless sensor networks

I. INTRODUCTION

Based on the development of network technologies, wireless networks become into a major choice other than wired networks, providing more multiplication of network kinds and making wireless networks become a hot issue. To meet various requirements, types of wireless specifications and technologies have been developed, especially Wireless Sensor Networks (WSNs) [1], which combines the techniques of sensors and wireless networks.

In the related technologies of WSNs, the routing mechanism is one of the important topic, it needs to achieve separate data transport, power saving and ensure data can be complete sent to sink. The main function of the routing mechanism is to transfer data separately, saving power, and to ensure data can be completely sent to the sink. However, many previous researches proposed used wireless sensor node with GPS as an anchor node to localization [2-4]. However, this approach increases power consumption. When the anchor node power is exhausted, other nodes could not replace the original one, resulting in the interruption of data transmission.

Therefore, under the premise of reducing the power consumption, GPS device is not applied in this research. On the other hand, since most the objectives of the many applications of WSNs are in a static environment, the mobility of the wireless is not the first concern and calculation ability is not strong calculation ability is not the necessary. In this regard, power consumption and cost are expected to be minimized. In this paper, a novel routing mechanism is proposed, called “A Routing Mechanism Using Virtual Coordination Anchor Node”. The mechanism applies to WSNs, which sensors are randomly deployed and the data is transferred through the specially designed routing mechanism. It is expected to expand the lifetime of WSNs, achieve the efficient transmission; meanwhile, the use of additional devices can be avoided to reduce energy consumption and cost. The mechanism can work with simple computing capability.

II. RELATED WORKS

Due to the highly progress of micro-electro mechanical systems in recent years, the size of sensor nodes becomes smaller and smaller. How to use effectively the limited battery power to achieve the highest efficiency is one of the important topics in WSNs. Because the main factor of power consumption is hardware and data transmission path, to reduce hardware and select a valid path is the focus of this research. The existed routing algorithms, can be basically divided into four classifications: they are Flooding [6], Chain [7], Clustering [8], and tree [9]. Each kind of routing method has its own advantages and disadvantages. In this section, we will give brief descriptions about relevant literature and technical.

A. Low-Energy Adaptive Clustering Hierarchy (LEACH)

LEACH[10] applies the clustering architecture, it also has the characteristics of the active routing protocol. This method will divide wireless sensor network into many different cluster regions, member node only can communicate each other in the same region. The whole process of long-distance transfer requires the following steps: Firstly, every region will choose a node as cluster

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DOI 10.1109/DASC-PICom-DataCom-CyberSciTec.2016.25

head and collect the data collected in the region; then, it will send the date to the base station or data sink, shown as figure 1.

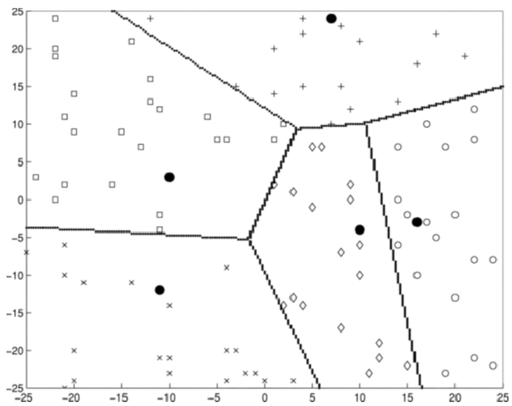


Figure 1.EACH clustering architecture diagram

In order to prevent the death of the previously-selected cluster, a new cluster head will be re-elected after each round of data transfer. Each round will compare and select a new cluster head, but it will shorten the lifetime of WSNs.

B. *Two-Tier Data Dissemination(TTDD)*

TTDD[11] creates virtual grid based on network environment. This method applies Advertisement phase as to find relative path. There will be many small grids, knows as "cell", in the grid structure. Data source will be the first Dissemination Nodes, then grids cross node as other Dissemination Nodes. Each grid node will be linked to a Dissemination Node and each Dissemination Node knows its upstream and downstream Dissemination Node. When Dissemination Node needs data, it will send a query message and this message will be transferred by Dissemination Node to data source. Then, data source transfers sensing data to Dissemination Node in reverse, shown as figure 2.

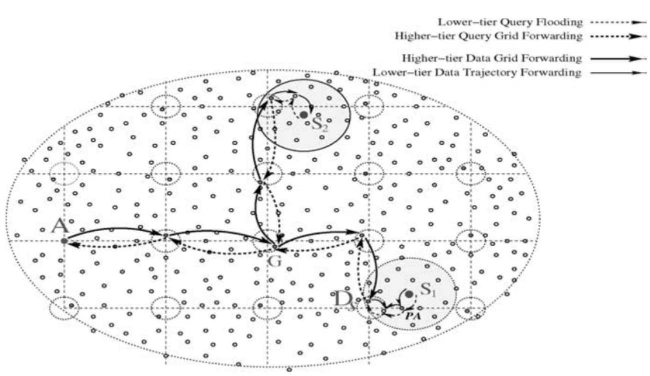


Figure 2.TTDD grid architecture diagram

With this method, the best path is not applied; instead, it will select the path which is along the grid crossing node, extending path and need to maintenance periodically. Before the grid is created, it needs to position, and position is cost-consuming. Each time when there is a need to recreate grid or node as Dissemination Node, these node swills cause the increase of power consumption.

C. *Anchor Node Based Sink Location Dissemination Scheme for Geographic Routing*

The scholars Fucai and others proposed routing protocols based on geographic routing, with GPS and anchor node [3]. This method starts at a node named Initiator Node which can be a general sensor network edge node or Personal Digital Assistant (PDA) equipment, then find the most easterly, westerly, southerly, northerly nodes as anchor nodes. When a node detected an event, it will be act as a source node and send Sink Location Query (SLQ) message to the most southerly and northerly node, which contains the source node location and the detected event type, then create a SLQ path by geographic routing, show in figure 3, all the sensor nodes which participated in the geographic routing process save the source location and event type in their source list table. When a sink exists in the sensor network, it sends a sink location announcement (SLA) message, which contains the sink location and the sink's interest, to the most easterly and western respectively by geographic routing, thus generating a SLA path, show in figure 3.

This method uses the concept of anchor node, but each node has to be equipped with GPS, leading to the increase in cost and power consumption. It uses flooding to let sensor nodes get the information of anchor nodes. When the cross node of SLQ and SLA is dead, this method have to recreate SLQ and SLA. In this way, it will increase the load and reduce the lifetime of WSNs.

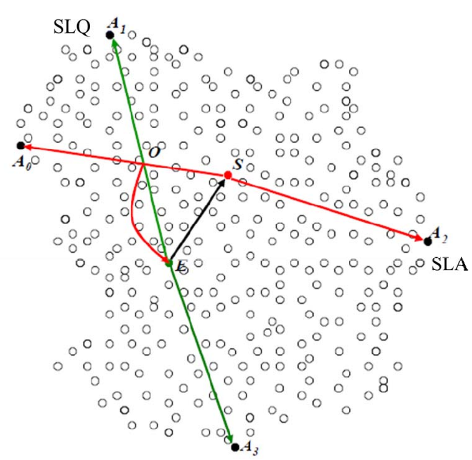


Figure 3.Anchor Node Based Sink Location Dissemination Scheme for Geographic Routing architecture diagram

III. A VIRTUAL COORDINATION ANCHOR NODE BASED ROUTING MECHANISM

This section will present the proposed routing mechanism to overcome the problem caused by holes of random deployment and unknown boundary in WSNs. The mechanism is organized as following components: (1) to create VCS and find virtual anchor node; (2) to create data transfer path; (3) to find alternative virtual anchor node and path node. It is also proved to (A) reduce the cost of hardware and (B) extend the lifetime of WSNs.

A. Network environment settings

In this paper, the environment of WSNs, lots of sensors are randomly deployed in the range wherever you want to monitor. When sensors are deployed, they can't move anymore and the computing, memory and battery are limited. Each sensor nodes has wireless communication, which can transmit detected data via wireless. There have a sink node, which has more power and better computing capability then other nodes. Normal nodes will send detected data to sink node, and sink node will use collectively. Each node has its own Node_ID to be recognized.

Each node has its transmission range. In our architecture, R is the maximum transmission range; m is the unit of meter, shown in figure 4(a). The transmission range is cut into four equal portions, each portion has its send priority, show in figure 4(b), it will send the packet or data according to their priorities via directional antenna to the direction.

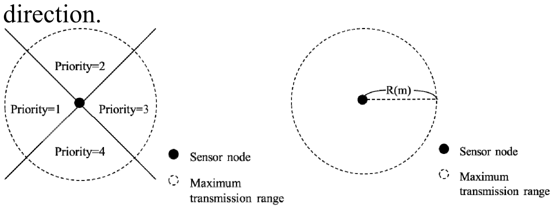


Figure4. (a) Transmission range (b) Priority diagram

B. Create virtual coordinate and find anchor node phase

When wireless sensor nodes settle down, sink node starts to create virtual coordinate, then it will find the four directions of the entire network environment as the virtual anchor nodes. Therefore, in this phase, sink node will set itself to act as a start node, and create a special ANS packet. The content of packet show in table 1, the packet has many different fields supply sensor nodes to record coordinate status.

Table 1.ANS packet

Node_ID	Rec_ID	Pre_Coor	Self_Coor	Next_Coor	Status	Left_Node	Up_Node	Right_Node	Down_Node
						A0(X0.Y0)	A1(X1.Y1)	A2(X2.Y2)	A3(X3.Y3)

Node_ID：Unique identify number of node.
Rec_ID：Unique identify number of destination node.
Pre_Coor：Coordinate value of preview node.
Self_Coor：Coordinate value of current node.
Next_Coor：Coordinate value of next node.
Status：Current state of node, have empty state (Null), warning state (Warning), no longer respond any packet (Bad), and no longer become virtual anchor (NA).
Left_Node：Leftmost virtual anchor coordinate value.
Up_Node：Topmost virtual anchor coordinate value.
Right_Node：Rightmost virtual anchor coordinate value.
Down_Node：Most below virtual anchor coordinate value.

After sink node creates ANS packet, the Self_Coor will be set as (0,0) and according to the priority of sensor node to send beacon toward the priority1 direction, show in figure 5.

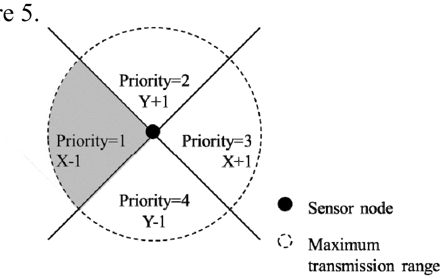


Figure5. Send beacon toward the priority1 direction

When other sensor nodes receive *beacon*, they response an *ack* message to sender immediately. The Sender will choose the nearest node as the next ANS packet, and according to the definition of priority1 X-1, take out (0,0) from Self_Coor then execute X-1 to get (-1,0). Then, set Next_Coor of ANS packet as (-1,0) then send the fastest reply node.

When sensor nodes received ANS packet, it will copy Self_Coor from ANS packet to Pre_Coor as the coordinate of previous node, and copy Next_Coor to Self_Coor as the current coordinate to save to memory of node. We do this to ensure the link between each sensor node is correct. Then, we take Self_Coor respectively compare with the Left_Node, the Up_Node, the Right_Node and the Down_Nodeto see if that should Self_Coor replace anchor nodes of four corner or not. Checking logic is shown in figure 6.

```
if ( Xn < Min{X0, X1, X2, X3})
        insert N(Xn,Yn) into A0 field and replace the original one;
else  if ( Xn > Max{X0, X1, X2, X3})
        insert N(Xn,Yn) into A2 field and replace the original one;
else  if ( Yn > Max{Y0, Y1, Y2, Y3})
        insert N(Xn,Yn) into A1 field and replace the original one;
else  if ( Yn < Min{Y0, Y1, Y2, Y3})
        insert N(Xn,Yn) into A3 field and replace the original one;
else
        do nothing;
end
```

Figure6. Code of checking logic

If there is no ack packet response when sensor node send beacon toward the priority1 direction, it means priority1 direction doesn't have any sensor nodes, or the status of sensor nodes is bad, shown in figure7. Sensor node A doesn't sense any node in priority1 direction; thus, sensor node A doesn't receive ack packet.

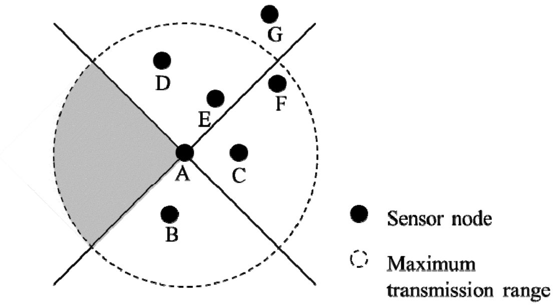


Figure7. Node A couldn't find other nodes in priority1 direction

At this moment, the status of node A will be set as Warning, then it will seek the node in sequence according to its priority until it find the next node, shown as figure8.Then, it will find node D and node E.

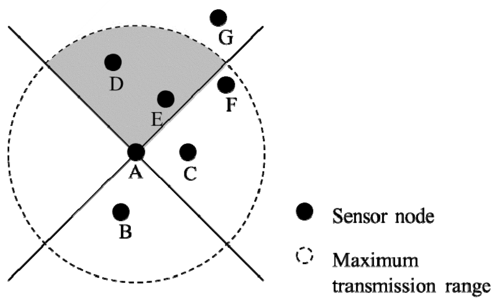


Figure8. Node A switch to priority2 and find node D and node E.

Then it will seek according to the priority. The purpose of this method is to give the priority1 direction a chance again owning to the random distribution of sensor node, it is possible that the current direction temporary doesn't have any nodes and it will revise its direction by switching to the next priority, finding the sensor node again.

If sensor node in priority1 direction can't find any sensor (include node status is Bad) and status is W, then priority will change to the next set priority, and clean the value of status, re-find nodes from priority1 direction.

Shown as Figure 9, the switching sequence of the Priority group is from top-left to bottom-right. The purpose of the design is to seek the boundary node in the network counterclockwise, which is the way that Priority1 is deigned. The rest of the Priorities are designed according to the extra chance of the previous Priority1 given by the sequence of the previous group of Priority.

The process of establishing virtual coordinates and searching of virtual anchors will last repeatedly until the ANS packet is received repeatedly by wireless sensor node. Those wireless sensor node receiving ANS packet repeatedly will produce Final Coor according to the packet it has received, shown as Figure 2. The repeatedly-received packet will be abandoned after the production of Final Coor; meanwhile, this packet will be sent to the previous wireless sensor node according to the record in the previous coordinate recorded in ANS packet in the wireless sensor node. When the wireless sensor node receive the last two Final Coors, the packet transfer will come to a halt and the stage of the establishing of virtual coordinate and the searching of virtual anchor is then accomplished.

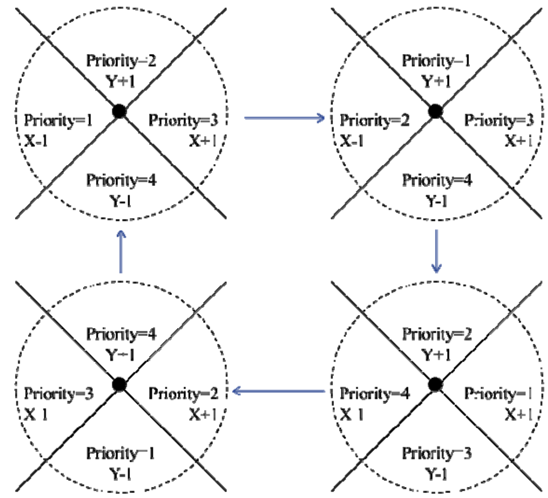


Figure 9 Switching of Priority group

Table 2. Final_Coor packet

Node ID	Dest ID	Left_Node	Up_Node	Right_Node	Down_Node

Node_ID：The only Node_ID

Dest_ID：The onlyNode_ID of the destination node

Left_Node：The leftmost coordinate of the virtual anchor in the network

Up_Node：The uppermost coordinate of the virtual anchor in the network

Right_Node：The rightmost coordinate of the virtual anchor in the network

Down_Node：The lowermost coordinate of the virtual anchor in the network

C. To establish the routes of the virtual anchors and Sink Node

After the stage of the establishment of the virtual coordinate in wireless sensor network, all the sensor on the borders of wireless sensor network are given virtual coordinates; meanwhile, each sensor can obtain information of the virtual anchors and their coordinates of the sensors through ANS packets, together with the information of the coordinate of Sink Node.

In this stage, the establishment of routing begins with the four virtual anchors in Final Coor. If the virtual nodes are Left_Node or Right_Node, Pre_Coor and Next_Coor in ANS packet of the exact virtual node will be applied to search for the Y coordinate equal/lager than that of Self_Coor until it reaches the virtual node when Y coordinate is 0. If the virtual node is Up_Node or Down_Node, Pre_Coor and Next_Coor in the ANS packet of the exact virtual node will be applied to find the X coordinate which is smaller/equal to that of Self_Coor until it reaches the virtual node when X coordinate is 0.

Next, Path_Link will be sent to Sink Locatin (0,0) according to the Self_Coor in the ANS packet of the virtual anchor, shown in Table 3. When the wireless sensor node receives the packet, it will record its Node_ID and Anchor_Coor. Then, it will search for Pre_ID and Next_ID. Finally, the packet will be sent to the next wireless sensor node until the packet is transferred to the Sink Node.

Table 3. Path_Link packet

Node_ID	Anchor_Coor	Next_ID	Pre_ID

Node_ID：The only identification number of the node

Anchor_Coor：The coordinate of the source anchor

Next_ID：The identification of next node

Pre_ID：The identification of previous node

Figure 10 illustrates the virtual coordination anchor nodes in the wireless sensor network after the establishment of virtual anchors and Sink Node routes. A route begins with four virtual anchor nodes link to each Sink Note separately and serves as substitute to send the data detected on the wireless sensor nodes which are on the boundary of non-wireless sensor network.

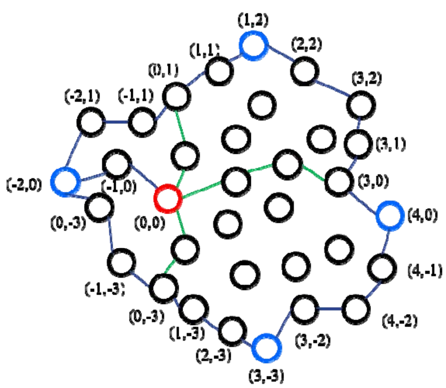


Figure 10 Route of Virtual Coordination Nodes and Sink Node

D. To create data transfer path

When an event is detected by a wireless sensor node, the node will sent Request Packet to its One Hop. While the wireless sensor node receives the packet, it will send a Response Packet back to the one detected the event. If the Request Packet is sent to the wireless sensor node that is on the border of wireless sensor network or on the route of Sink Node, a mark will be attached on the Response Packet so as to raise its priority. If the Response Packet is marked, the date will be sent to the wireless sensor node so as to send data back to Sink Node as soon as possible; if not, data will be sent back to the first wireless sensor node which responds to the Request Packet. The node which an event takes place will record the sent Node_ID and the request of the Node_ID will be neglected in the future. At the same time, the node will take itself as the wireless sensor node with an event detected and repeat the process of the stage.

E. To Solve Hole Problem

When data transfer is taking place within wireless sensor nodes, a Request Packet will be sent to a receiving wireless sensor node. If no response is received by the wireless sensor node which sending the Request Packet, a hole is recognized. In this situation, date should be transferred back to the mechanism immediately to ensure that it can be sent to the destination.

When a hole is found, the wireless sensor node which sends the Request Packet will regard itself neglected to any Response Packet and sent Rescue (see Table 4) to its One Hop. In this scenario, only Pre_Node will receive packet since no neighboring nodes exist other than the sending node. Therefore, when Pre_Node receives a Rescue, it will choose a new transfer node to send Request Packt.

Table 4. Rescue packet

Node_ID	Data

Node_ID：The only Identification of each node

Data：Data send from one node to another

F. Search for the substitute virtual anchor or route

We design a new mechanism which will search for a neighboring wireless sensor node and regard it as a new one if the power of the virtual node is exhausted and failed to transfer data. In this regard, that the interruption of data transfer can be avoided and the data can be ensured to be transferred to the destination.

When the electric quantity of a wireless sensor node—which serves as a virtual node or a route node—is lower than 20% as the sensor node A in Figure 11, the node will send Low Energy Message to its One Hop and inform the neighboring nodes that its power is exhausted and need to find a new node to replace it; meanwhile, it will regard itself as NA and will merely transfer data but will not serve as a virtual node, shown as Table 5.

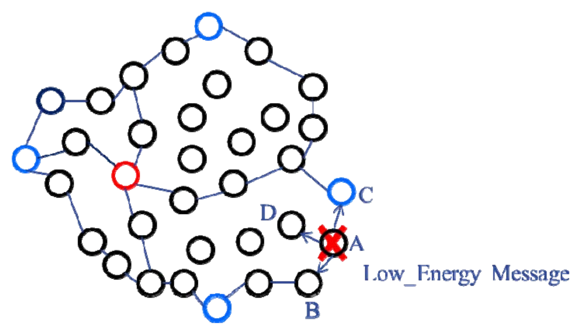


Figure 11 power-exhausted Node Sending Low Energy Message

Table 5. Low_Energy Message packet

Dead_ID	Dest_ID	Energy_Remain

Dead_ID：The only identification of dead node

Dest_ID：The only identification of the destination node

Energy_Remain：The remaining energy

When the node receives a Low Energy Message, it will make sure if it is the one on the border or the route; if not, it will send a New Anch Message Packet to One Hop, shown as Figure 12 and Table 6.

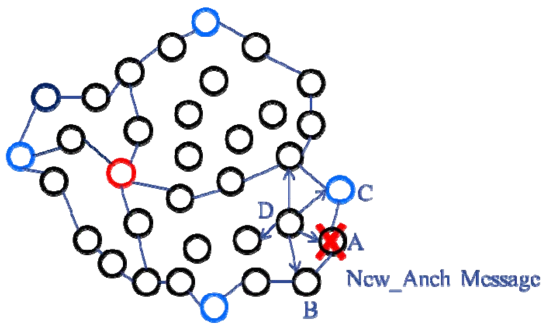


Figure 12 Sending Arch_ID to One Hop

Table 6. New_Anch Message Message packet

Dead_ID	Anch_ID	Node_ID

Dead_ID：The only identification of the dead node

Anch_ID ：The only identification of the node receiving Low Energy Message

Node_ID ：The only identification of each node

When the node receive the packet, it will check if it has receive the same message before and to check if the messages refer to the identical node. If confirmed true, it will send a New_Anch_Chk Packet to the node which is searching for a new one and to create a new route.

G. Feature of Routing Mechanism Using Virtual Coordination Anchor Node

In the routing mechanism using virtual coordination anchor node proposed in this paper, the system will firstly find the node on the border of wireless sensor network; then, four virtual anchors on the leftmost, the rightmost, the uppermost, and the lowermost of the network will be chosen after comparison so as to create virtual nodes as well as Sink Node. In the way, routes for detecting date to Sink Node can be shortened. Moreover, both hole problem and the malfunction of route node or virtual node are solved by preventing their influences to the data transfer in the network.

IV. COMPARISON AND ANALYSIS OF SIMULATION

This session presents “A Routing Mechanism Using Virtual Coordination Anchor Node” proposed above have been programmed and stimulated in C++ language and compared with Flooding, TTDD, LEACH, and Anchor Node Based Sink Location Dissemination Scheme for Geographic Routing. Analysis of the results will be provided in the following sections to prove the mechanism proposed in this paper is more sufficient than the approaches above.

A. Simulation

Setting and parameters of the environment of wireless sensor network used in the stimulation:

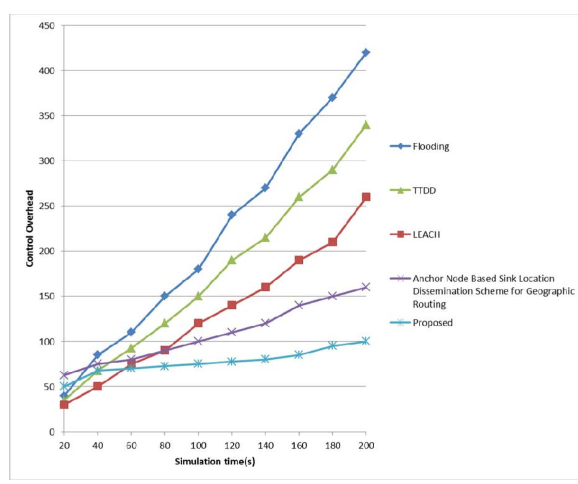
- Range of the network: 100M X 100M
- Number of wireless sensor: 50
- Range of wireless transfer: 10M
- Transmission cycle: 10 seconds
- The deployment of wireless sensor: random

B. Analysis and Comparison of The Results

In the beginning, time is taken as the parameter to see its impact to the packet control by the wireless sensor node. The stimulating time ranges from 20 seconds to 200 seconds, shown as Figure 13.

From the result, it is clear to find that the number of the controlled packet is much higher than that in other routing, mainly owing to reason that each wireless sensor node needs to participate in Flooding. For TTDD, a grid is established by the wireless sensor nodes which serve as the sources. The grid need to be maintained regularly, therefore the number of its controlled packet is lower than that in Flooding. In each round of LEACH, cluster head need to be compared and re-elected, resulting in the number of controlled packet lower than the previous two kinds of mechanisms. In “Anchor Node Based Sink Location Dissemination Scheme for Geographic Routing”, a sink location announcement packet and a sink location query packet are sent along two respectively on the sink node location query route and sink location announcement route, so two routes are required in the query. In the first stage, Flooding is applied in order to make each wireless sensor node obtain anchor data, which results in the higher number of controlled packet. Once the anchors are failed, the sink location query route or the sink location announcement route need to be recreated. Since there is no repair mechanism, an enormous amount of controlled packet is seen when the anchor break down.

Figure 13 Diagram of the number of the controlled packet and time



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In the paper, ANS packet produced by the Sink Nodes will be transmitted along the border nodes and send back the anchor data along the same route. In this way, Flooding is not applied; instead, a substitute mechanism is available and substitute node is expected to be found once the route node is dead or breaking down. There is no need to rebuild the route, reducing the number of controlled packet compared with other routing mechanisms.

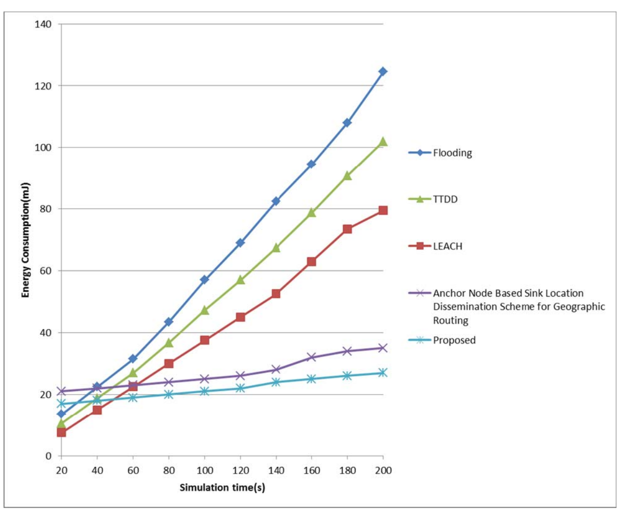

Figure 14 Diagram of relation of time and energy consumption of wireless sensor node

In addition to the comparison of the number of controlled packets, the relation between energy consumption and time of the wireless sensor node is stimulated and analyzed. Figure 14 shows the diagram of time and energy consumption of wireless sensor nodes. The stimulating time ranges from 20 seconds to 200 seconds.

From the diagram, it is revealed that both of the approach in this paper and that in “Anchor Node Based Sink Location Dissemination Scheme for Geographic Routing” share higher level of energy consumption in the beginning compared to other three routing since both approaches require more energy in initialization which involves the coordinates of a Pre_Node, a Next_Node and the coordinates of four border nodes. However, GPS devices is not necessary in this paper, therefore it causes lesser energy consumption than that in “Anchor Node Based Sink Location Dissemination Scheme for Geographic Routing”. Hence, the approach in the paper is expected to increase the lifetime of the system, extend life cycle, provide more processing time for wireless sensor network, and increase the efficiency of the mechanism.

Finally, success rates of detecting and sending data to the sink node per unit time is also compared. Figure 15 shows the comparison of success rates of each mechanism in detecting event and sending data to Sink Node. The success rate of data transfer in Flooding decreases with the most rapid speed since the collision may cause failure in data transmission to Sink Node and the loss of data. As for TTDD, the grid is sufficient to separate the risk; however, only four routes reach the Sink Node. Furthermore, every time an event is detected, a new grid is needed to build, which might be contributable in the increase of the possibility of collision when the grid is under construction together with the increase of the number of event. For LEACH, since it need cluster head to transmit data back to Sink Node; however, serious collision might be likely to occur while an enormous amount of data flood into the cluster head. When different types of event take place in “Anchor Node Based Sink Location Dissemination Scheme for Geographic Routing”, it will recreate sink location query route and sink location announcement route to separate date. In this paper, instead, the node will search for the nearest wireless sensor node to send data when an event is detected. Meanwhile, the virtual anchors and the route nodes can send data back even though no data has been sent to them. Therefore, the loss of data is unlikely to happen.

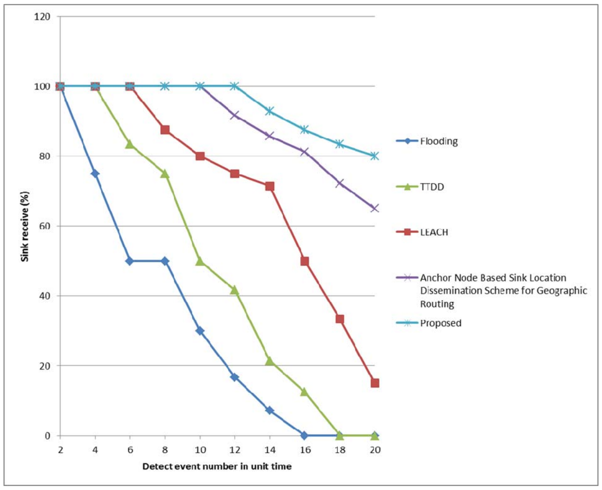

Figure 15 Diagram of Comparison of numbers of data sending to Sink Node in per unit time

From three sets of stimulating experiment, it is apparent that "A Routing Mechanism Using Virtual Coordination Anchor Node" in this paper is a sufficient routing which can save energy, expand lifetime of the wireless sensor network, and reach a high delivering rate. Finally, the purpose of the research is achieved.

V. Conclusion and Future Research

In the mechanism proposed in this paper, GPS is not applied in the process so as to save the consumption of energy and cost. with the application of virtual coordination anchor, the function of the mechanism is expected to be sufficient. From the result of the stimulation, it is obvious that the number of controlled packets as well as energy consumption is reduced under the routing protocol even the density of transferring packets is high; and the success rate of date transmission is raised as the survival rate of each node rises, which further ensures the function of the network and expand the lifetime of wireless sensor network. Meanwhile, power-saving mechanism is anticipated to be involved in the future research to lower the energy consumption in the initializing level of the network. In addition, cluster routing or tree routing protocol are wished to join the working of the network so the efficiency of the Internet could be maximized.

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