An Improved Rumor Routing Protocol Based on Distance Constraint in Wireless Sensor Network

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Abstract—In rumor routing, the generated message transmission path is not optimal and the routing loop may be existed under randomly forwarding mechanism. An improved rumor routing based on distance constraint (DCRR) is proposed in this paper. The distance from point to line is brought into DCRR as a metric of route selection. In DCRR a linear equation is solved between current node and the sink node, and then a node whose distance is shortest to the line is selected as the next hop from the candidate neighbor set of current node, so that the routing loop is effectively avoided and an optimal routing path is built. Simulation experimental results show that the DCRR saves energy of the entire network by up to 81.7%, and prolongs the network lifetime.

Keywords- Wireless Sensor Network; Rumor Routing; Energy Saving; Network Lifetime

I. INTRODUCTION

Wireless sensor network (WSN) is a multi-hop wireless network, consisting of a group of sensor nodes deployed in the monitoring area [1]. Those nodes collaborate to collect the information that the users are interested and further transmit the data packets to the terminal users. WSN has been widely used in environment monitoring [2, 3], military [4], traffic control [5], medical nursing [6] and etc. The routing protocols of WSN guarantee the effective transmission of the acquired data. Comparatively to the traditional wireless network, the foremost responsibility of WSN is to save energy and prolong the lifecycle of the entire network [7]. Therefore, lots of routing protocols for WSN have been proposed, which can be divided to four categories: data-centered routing protocol, hierarchical routing protocol, geography-oriented routing protocol and Qos perception routing protocol. Directed diffusion and rumor routing (RR) are inquiry-based routing protocols. The former diffuses the information though flooding, which consumes great energy. RR introduces the diffusing mechanism of randomly unicast that effectively reduces the energy consumption. However, the generated path by RR is not the most optimal path and there may exist a loop.

To solve the above issues, this paper proposed an improved rumor routing protocol based on distance constraint (DCRR). This protocol is able to find the optimal routing by using the distance constrains mechanism, avoid the routing loop and further optimize the data transmission path.

II. RELATED WORK

RR protocol is suitable for the scenarios that the events area is already known or there is little information. In RR, convergent nodes and source nodes in the event area produce delegate information and inquiry information respectively. Meanwhile, both types of nodes generate the information transmission paths through random unicast. As long as there is an intersection between the two transmission paths, a complete routing is found from the source nodes to the destination nodes.

Fig. (1) Illustrates the RR principle, where the spots represent the sensor nodes. To be more specific, the gray spots represent the sensor nodes transmitting the inquiry message while the black spots represent the sensor nodes diffusing the delegate message. The complete routing from the event area to the convergent node is the trajectory connected by some black nodes and all the gray nodes.

RR reduces the routing consumption from the directed diffusion routing protocol. However, the routing may not be the optimal path and there may exist the loop. [10] Proposed a WSN routing protocol realizing the energy consumption balance from the perspective of the energy management. [11] Suggested an improved protocol that made a trade-off between the start cost and the transmission reliability. [12] Improved the RR protocol based on the cellular automata and applied ant colony algorithm to search the optimal path. Suppose each sensor node is a cellular. The event ant and the inquiry ant search the path through every possibility, which increases the cost of operating the algorithm. Based on ant colony algorithm, [13] provided a optimization distance-based transmission strategy that determines the transmission path though calculating the local optimized transmission
distance, i.e., energy-efficiency distance and energy-balance distance. [14] Proposed a zone rumor routing protocol (ZRR). Dividing the network into several areas, this protocol improves the energy efficiency of message diffusion in the area and decreases the energy consumption for transmission. With regards to the characteristics of WSN, this paper suggested light-weight establishment strategy for optimal path that is found through distance restrictions. This algorithm requires less cost.

III. DCRR ALGORITHM

DCRR algorithm establishes the optimal path under the constraints of the distance from the node to the line. Firstly, the linear equation from the current node to the convergent node is built. After, the neighbor nodes are collected and their distance to the line is calculated. The neighbor who has the shortest distance will be the node of the next hop. The message diffusion path is established though the above process.

A. Algorithm assumptions and definitions

DCRR has the following assumptions:
(1) Isomorphic sensor nodes with limited energy are randomly distributed in the monitoring area. Each node has a unique identity and keeps still.
(2) The sensor nodes have the timers and are able to converge the data.
(3) The position information of all the sensor nodes is known.
(4) The initial energy of the convergent node is unlimited.
(5) The end of the life cycle of the network is the time when all the nodes in the event area are dead.

Definition 1: the set of the candidate neighbor nodes: Comparing the position relation between current nodes to its neighbor nodes, the candidate neighbor nodes are those that meet certain position requirement and whose left energy is above certain threshold.

Definition 2: neighbor list: the list records the current state of the neighbor nodes, ID and etc.

Definition 3: event list: this list records the event ID, next hop and other event related information.

B. Algorithm execution process

DCRR adopts the round mechanism. The delegate message in the event area is a packet of event information including TTL and etc. The convergent node generates an inquiry message for the particular event. At the beginning of executing the algorithm, the node has to establish a neighbor list itself. The process is as follows:

(1) When the sensor node detects an event, the node will add an item in its event list to set the event related information and send a delegate message in a certain probability. As soon as receiving the delegate message, other nodes will search their event list by the delegate message ID. If there exists an item corresponding to this event, the hop value in the item will be compared with that in the delegate message. If the former is smaller, the hop in the delegate message will be updated and vice versa. If there is no such event in the list, the event information of this delegate message will be added to the event list and the TTL in the delegate message will subtract 1. The delegate message will be forwarded though next hop selected according to the restriction mechanism based on distance until the TTL is 0. Finally, an optimal diffusion path for the delegate message is found from the source node.

(2) When the convergent node generates the inquiry message for a particular message, the node searches the event list using this message ID. If the inquiry fails, the inquiry message will be forwarded through the restriction mechanism based on distance. Otherwise, the node forwards the message by the next hop in its list and establishes a transmission path for the inquiry message.

(3) If there is an intersection between delegate message path and the inquiry message path, the node of the intersection will forward the data to the convergent node along the opposite direction of inquiry message path. If the convergent node does not receive the monitoring data in a period, it will assert that the inquiry message does not reach the event area and will re-broadcast the inquiry message or give up.

C. Path selection mechanism

The delegate message and the inquiry message in DCRR diffuse the path by adopting the distance-based constraints mechanism. Thus, this paper only describes how the path for the delegate message is selected. As shown in Fig. (2), the black spots represent the sensor nodes while the red spot labeled with Sink represents the convergent node. Node A is the source node, producing delegate message. Suppose that the initial energy of nodes is Einit, the left energy is Eleft, and the threshold of energy is Et, with the condition Einit >Et. The process of how to select the neighbor node as the next hop for node A is as following:

Step1: According to the position coordinates of node A and node Sink, the line l is constructed. The equation for l is:

Step2: In the neighbor nodes set of A, any node whose coordinate in x axis is larger than that of node A and meanwhile Eleft >Et will be put into the candidate neighbor nodes set Sr of node A;

Step3: According to the formula, the distance from each neighbor node of A to line l is calculated;

Step4: The minimum distance from node A to line l is estimated. The neighbor node will be the next hop of A if its distance to l is equal to. In figure 2, node C is the next hop of A.

Figure (2). the path selection under distance constraints.
Though the above method, the next hop to forward the delegate message is found through calculating the minimum distance from the node to the line and further establish the transmission path for the delegate message. The convergent message selects the next hop in the same way until there is an intersection between the transmission path for delegate message and that of inquiry message. Thus a complete routing path is found from the source node to the convergent node.

IV. SIMULATION EXPERIMENTS AND RESULTS ANALYSIS

A. Simulation environment and parameters

To validate the feasibility and effectiveness of this proposed DCRR, we simulated it under MATLAB R2011b and compared the results of DCRR with those of RR. The simulation parameters are shown in Table 1.

<table>
<thead>
<tr>
<th>Simulation parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size of the monitoring area</td>
<td>100*100</td>
</tr>
<tr>
<td>Numbers of sensors</td>
<td>200</td>
</tr>
<tr>
<td>Distribution type of nodes</td>
<td>random</td>
</tr>
<tr>
<td>Size of the event area</td>
<td>1/9 of the monitoring area in the bottom left corner</td>
</tr>
<tr>
<td>Initial energy of nodes</td>
<td>0.5J</td>
</tr>
<tr>
<td>Communication radius of the node</td>
<td>40m</td>
</tr>
</tbody>
</table>

B. Performance analysis and comparison

Fig. (3) compares the routing path of RR and that of DCRR. The red thin line represents the transmission path of inquiry message in RR protocol while the red thick line is the diffusion path of inquiry message in DCRR. The black thin line is the communication path of delegate message in RR while the black thick line transmission path of delegate message in DCRR. From figure 3, we can see that DCRR avoid the loop problem in RR and the routing established by DCRR is better than that of RR, because it reduces the numbers of hops for data transmission.

Fig. (4) shows the comparison of the left energy of the entire network. When all the nodes in the event area are dead, i.e. the number of the rounds of RR is 2185 while that of DCRR is 2275, the total left energy of RR is 29J while there is 87J left in DCRR. According to comparison of the energy consumption, DCRR saves 81.7% energy of the entire network compared with RR. This is because DCRR optimizes the data transmission path and avoids the loop.

Five separate experiments are executed according the initial energies. Table 2 shows the data.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial energy of each node</td>
<td>0.1J</td>
<td>0.3J</td>
<td>0.5J</td>
<td>0.7J</td>
<td>0.9J</td>
</tr>
<tr>
<td>Round numbers when all the nodes in event area are dead in RR</td>
<td>435</td>
<td>1282</td>
<td>2185</td>
<td>2723</td>
<td>3760</td>
</tr>
<tr>
<td>Round numbers when all the nodes in event area are dead in DCRR</td>
<td>458</td>
<td>1344</td>
<td>2275</td>
<td>3128</td>
<td>4004</td>
</tr>
</tbody>
</table>
As illustrated in Fig. (6), with the increase of the initial energy, the round numbers become larger and larger when all the nodes in the event area are dead. With the same initial energy, there are more rounds in DCRR, which shows that DCRR is able to prolong the life cycle of the entire network effectively.

From Fig. (7) to Fig. (9), when the size of the monitoring area enlarges to 200m*200m and the other parameters are still the same, the transmission path established by DCRR protocol is still better than that by RR. Meanwhile, it decreases the energy consumption in the network and makes more nodes survived. Further to compared with Fig. (3) - Fig. (5), with enlargement of the monitoring area, the distribution of the sensor nodes is of less density and the distance between nodes is longer. As a result, it consumes more energy consumption to transmit the information with more hops. With the same initial energy, the round numbers becomes smaller when all the nodes in the event area are dead.

V. CONCLUSION

Considering the problems of loop and the possibility that the routing path may not be optimal in rumor routing, this paper proposed an improved rumor routing protocol based on distance constraints (DCRR). DCRR selects the routing path according to the distance from the node to the line. Combining the position information of neighbor node, DCRR solves the loop problem and optimizes the routing path. The simulation results show that DCRR saves energy by up to 81.7% and prolongs the life cycle of the entire network. This proposed protocol is application to the scenario where the data flow is not large.

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