Predictive Routing For Mobile Sink Routing Algorithm

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Abstract

Recent work shows sink mobility can improve the energy efficiency in wireless sensor networks. However, the mobile sink often leads to increasing the energy consumption and routing protocol variation, so support mobile sinks, energy efficient routing protocol is essential. In this light, the Minimum energy consumption relay node is proposed, which plays a import role to broadcasting the estimated sink's location information to the nodes which take data packets to establish the efficient routing. Meanwhile the periodic broadcast scheme to provide the sink's location information is broadcast to entire network in order to increase the data packet delivery ratio. The simulation and experiments show that the proposed routing algorithm reduces the energy consumption of the network node, and at the same time keep the network higher data rate.

Keywords: mobile sink, energy consumption, relay node, broadcast to entire network

1. Introduction

Wireless sensor network (WSN) is a kind of new information retrieval technology, which combined the integration of information collection, signal transmission, and the embedding. The perception of sensor nodes by wireless communication mode can build up a wireless network [1]. In wireless sensor network (WSN) of the still Sink, the Sink node deployed around not only send his perception of the data to the Sink, but also as a relay nodes send data which other nodes sent to the Sink. Therefore the energy around the Sink node significantly more than the Sink node far away, which leads to uneven node energy consumption, affecting the network life [2]. To solve the contradiction between more energy consumption of mobile sink nodes and the lower transfer rate. This paper tries to seek the best mobile sink routing strategy. While satisfying the requirement of data transfer rate, minimizing the overall energy consumption.

At present, the related literature in view of prolonging the network lifetime of mobile Sink methods have been proposed [3-5]. These methods are conditioned by the distance between the node and the Sink; Sink mobile maximum distance; staying time of Sink; energy of node around Sink etc., therefore, this method has high complexity and poor flexibility. According to the complexity of WSN routing protocols for mobile Sink, literature [6] proposed a WSN energy balance clustering routing protocol. This method divided the entire network into several grids. Each grid selects cluster head using the cluster evaluation model. The cluster head is responsible for collecting interesting events within the cluster, and send the data fusion event to the Sink. However, the nodes which the protocol defines are uniform, which is not tally with the actual application, defining the scope of the protocol. In literature [7], the double data distribution TTDD model is put forward. This method based on the location of the source node, divided the network into the grids with the size of $\alpha \times \alpha$, and found the

nearest node near intersection as the transmitting nodes. Each TTDD data source built mesh structure to receive data content which nodes broadcast to the Sink. Although TTDD proposed methods to solve the mobile Sink and the flooding when it moved, the use of unit length query algorithm will limit the notifying information flood within the scope of smaller grid, leading the change of routing information is not timely, also increasing the network energy consumption. In addition, choosing the nearest node in the intersection will enormously consume the node energy consumption. If the node itself has lower energy consumption, it will be very easy to cause the death nodes, affecting the entire network performance.

In order to improve the WSN network flexibility of mobile Sink, literature [8] put forward energy-efficient target detection in sensor networks using line proxies (LPTD). LPTD made all nodes as the candidate of collection node in order to realize the load balance, so the time synchronization between all nodes is difficult to achieve. Literature [9] put forward an adaptive location updates routing protocol (ALURP). This protocol uses the updates location of the mobile Sink to flood in the scope of node communication. However, when the Sink is beyond the scope of communications (faster move), it still needs to flood in the network, increasing energy consumption. Literature [10] put forward an Agent routing algorithm, which is flexible and is based on local routing updates. This algorithm uses Agent between the Source node and mobile Sink to realize the dynamic maintenance of the shortest transmission path.

Literature [11] put forward the Elastic routing, which used the broadcast to receive the routing (ER). Literature [12] put forward a predictive flooding routing algorithm. This algorithm chooses relay nodes according to the random selection. It may lead that lower energy consumption nodes become relay nodes of routing updates, affecting the routing performance. In addition, the above protocols all assume that there is only one data source that sends packets. If several data packets appear in the same network, which will greatly reduce the network transmission rate.

According to the above problem, this paper proposes a predictive routing for mobile Sink routing algorithm. This algorithm is mainly for monitoring applications by the use of wireless sensor network, and the Sink node is the data transmission in the mobile condition. This Algorithm introduced the concept of minimum energy consumption relay node, through the node periodic broadcast mechanism to realize the balance of energy consumption. The simulation and experiments show that this algorithm performance is better than the existing algorithms.

2. System Energy Consumption Model

In the study of wireless sensor network (WSN), the energy communication model of First Radio Order [13] was proved to be the best approach to send compute nodes and receive the energy consumption. In the First Radio Order energy consumption model, node sending energy consumption is proportional to the square of the propagation distance. This article does not consider the energy consumption produced by power control as well as some other external factors leading to the change of energy consumption, and assume that all nodes use fixed transmitting and receiving power, and energy consumption has nothing to do with the physical distance between nodes. Therefore, the energy consumption model is defined as:

$$p \approx e(k_r + k_t) \tag{1}$$

Here, p is the energy consumption of the nodes, k_r is the receiving data, k_t indicates the amount of data sent. e is the sending and receiving unit data amount of energy consumption . The energy consumption of sending $m\ bit$ is:

$$k_t(m,d) = m \times E_{elec} + m \times \varepsilon \times d^2 \tag{2}$$

Among them, d is the node communication radius, $k \times E_{elec}$ is the energy consumption of sending or receiving circuit ε is the amplifier parameters of amplifier power. The energy consumption of receiving $m\ bit$ is

$$k_r(m,d) = m \times E_{elec} \tag{3}$$

The energy consumption of entire wireless sensor network is defined as:

$$p_{total} = \sum_{i=1}^{n} p_i \approx \sum_{i=1}^{n} e(k_r^i + k_t^i)i \tag{4}$$

Here, k_r^i, k_t^i is the sending and receiving data of the i th node to.

3. The Relay Node of Minimum Energy Consumption and the Update Process of Sink Location

In the wireless sensor network of mobile Sink, the broadcast of the Sink node location information is the key to realize routing transmition; however, this process will produce large amounts of energy consumption. So in the WSN of the mobile Sink, the computing of location of Sink nodes and the relay node selection in the mobile area will greatly influence the performance of the network. In this article, the mobile Sink nodes can compute the coordinates of its new location without changing its direction by formula (5):

$$Sink_{new}(X,Y) = Sink_{current}(X,Y) + \overline{Sink} \tag{5}$$

Here, $Sink_{new}(X,Y)$ is the coordinates of the new location after Sink moves, and $Sink_{current}(X,Y)$ is the coordinates of the current location, the vector $\overline{Sink}$ is the mobile speed and direction. Once the Sink node changes the direction, the coordinate of new location is calculated by the formula

$$Sink_{est}(X,Y) = Sink_{current}(X,Y) + \overline{Sink} \times \frac{Sink_{total\_working\_time}}{Sink_{number\_of\_times\_changing}} \tag{6}$$

Here, $Sink_{total\_working\_time}$ is the working time in a direction, and $Sink_{number\_of\_times\_changing}$ is the number of changing direction times when working. By formula (5) and (6), it can be accurately estimated the Sink node mobile location.

This article introduces the Relay nodes (RN) as the RN of the routing information updates of mobile Sink in the moving process. When the Sink changes the direction of transmission, at this time it is need to find a new RN node. The selection of RN node is based on the maximum residual energy nodes as an RN node according to the Sink node data transmission radius. This will make balanced energy consumption in the range of mobile Sink node communication radius, improving the network lifetime.

$$E_{current}^{i} = E_{init}^{i} - p^{i} \tag{7}$$

By comparison, it should choose $Max(E_{current}^{i})$ as an RN node. Once the Sink chooses an RN node, RN will receive the previous RN node information from the Sink.

RN receives information packets from the Sink node mainly includes the following content, format, as shown in Table 1:

Table 1. Update Location of Data Packets

Relay node ID	Previous relay node	Sink energy	Estimate Sink location	Generate time	Relay node location

The described packet of information is:
(1) Relay node ID: ID number and coordinate information of the nearest node to Sink node;
(2) Previous relay node: coordinate information of previous RN node;
(3) Sink energy: Sink node residual energy;
(4) Estimate the Sink location: the coordinates of the new location of Sink by the formula (2);
(5) Generate time: the time of completing RN node selection and new location estimation;
(6) Relay node location: an RN coordinate information.

The last three are the routing information which reaches the Sink node. RN will send the Sink node location and routing information table item in accordance with the greedy routing approach to the previous RN node. Algorithm 1 describes the process of Sink node radio location information. Algorithm 2 describes the process of RN's updating routing information as a relay node.

Algorithm 1 Sink node's broadcast

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① If you find a new neighbor node
②According to the formula (5), calculate the new coordinates of the Sink node
③According to the table (1), broadcast the Sink location information data packets within the Sink radius
④ If the Sink node change the direction of transmission ⑤According to the formula (6), calculate the new coordinates of the Sink node
⑥According to formula (7), calculate the node with the maximum residual energy in Sink node communication radius, and select it as the RN node
⑦ RN node broadcast Table 1 data packet according to the greedy routing algorithm, in order to update node routing information in the course of transmission path.

Algorithm 2 Node target information updates

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① RN node sends the Sink node updating location information (Table 1 format)to the previous RN node based on the greedy routing algorithm
② During the process of sending, still choose the relay node with the maximum residual energy in the communication radius
③ All the relay node will receive the latest location information of the Sink node in the whole updating process

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As shown in Figure 1: it can be seen that in the process of the movement of the Sink, 2 RN nodes are produced. RN sends the Sink node information table item to the previous RN node in accordance with the greedy routing approach. During this process, Sink node location information which is in the node communication radius will be updated.
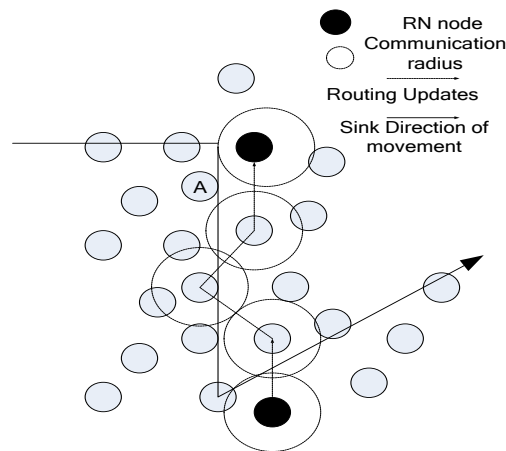

Figure 1. Sink Information Update Process

4. Routing Strategy

4.1. Routing

After the sensor nodes obtain routing data update, and the new data packet was generated. The format and content of the packet is Relay node ID, Estimate Sink location, Generate time, Relay node location and data. The sent routing information is the final routing information.

As shown in Figure 1, when node A receives the packets from other nodes, node A compares the Generate time from the receiving data packet and the Generate time from node A. If the Generate time from the receiving data packet is greater than the Generate time from node A, then node an update the Generate time of nodes. By executing the above update process, the node routing information of the whole Sink moving path will be updated, and update all node routing of the node communication radius.

When the data according to the updated path reach the Sink predictive location, there are the following two cases:

 (1) The Sink node is over the predictive location, which is as shown in Figure 2 (a). At this time the data packet will update the routing information along the Sink transmission path.

(2) The Sink does not reach the previous routing predictive location, but change the direction somewhere in the middle, which is as shown in Figure 2 (b). At this time, the RN node directly transmits the data packets to the Sink node.

So when the sensor nodes collect the data and begin choosing the routing, the clustering wireless sensor network data will converge the transmission method [14], through clustering method of balanced energy consumption and data prediction transmission mechanism, which can effectively prolong the network life span, and after reaches the Sink node communication radius, the path choice depends on the routing method proposed in this paper.
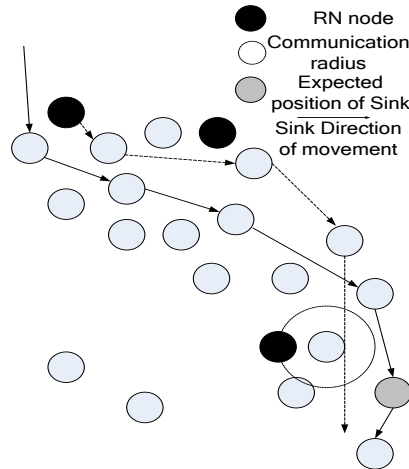
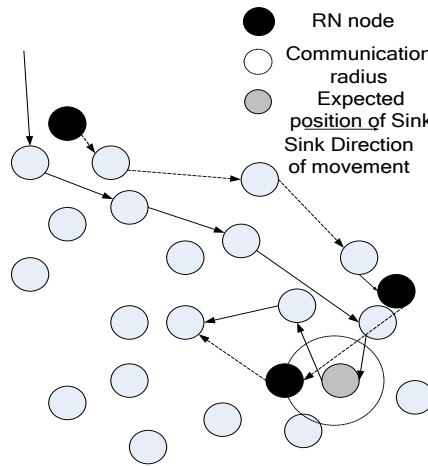

Figure 2. (a) Two Special Cases of Routing Updates

Figure 2. (b) Two Special Cases of Routing Updates

4.2. Entire Network Periodic Broadcast Sink

In order to better realize the routing information update, guarantee the accuracy of the data transition, this paper puts forward a method of entire network broadcast of Sink location information, as shown in formula (8):

$$Broadcast = \frac{\alpha}{V_{\sin k}} \tag{8}$$

$Broadcast$ Is the periodic broadcast, $\alpha = k \times T \times \dfrac{E_{aver}}{E_{current}^{\sin k}}$ indicates the radio control condition, k is the number of random distribution, and its scope is [1, 10], T is broadcast

duration time, E_{aver} is the average residual energy for all nodes in the network, $v_{\sin k}$ is the Sink node movement speed. By the formula (7), it can be seen that the residual energy of Sink node is greater, the broadcast cycle is shorter. Although the entire network broadcast the location of Sink will consume the energy of nodes, more nodes can accurately identify the location of the Sink, and find better routing.

5. The Simulation Experiment and Result Analysis

The Simulation experiment evaluates the performance of the algorithm from two important aspects: the data transmission rate and energy consumption. Data transfer rate is defined as a certain number of data packets which involves from the target node transmition to the Sink node transmission rate. Energy consumption is defined as the consumed energy of node dealing with the routing updates and data transmission. Here the additional energy consumption factors are ruled out. Comparing MECRN with ALURP [19] and ER [18] algorithm, the obtained simulation results will be compared and analyzed.

The specific parameter Settings of simulation experiment are as follows: (1) The nodes number of simulation environment is set to [500, 1000]; (2) The Sink node mobility rate is [5, 20] m/s. (3) The number of data packets is set to 100; (4) the simulation cycle is set to 100s. (5) Node communication distance is set to 30m. (6) The energy consumption of the node model is consistent with the literature [13], constant e is set to 015 LJ/bit, delay requirement D is set to 600 seconds, that is, all data must be transmitted to the mobile sink points within

10 minutes. (7) In order to better verify the algorithm performance, $\dfrac{E_{aver}}{E_{current}^{\sin k}}$ is set to 2, that is,

the current Sink node energy consumption is the half of the average energy consumption. The duration of the broadcast is set to 5, so the maximum value for α is 100. (8) All nodes have the same initial energy--20J. To reduce the error, all the data in the simulation experiments are the average of 50 times randomized trials. Parameters are shown in Table 2:

In addition, in order to better verify the validity of the entire network broadcast Sink node, the data transfer rate and energy consumption of the MECRN with and without the presence of entire network broadcast mode will be compared.

Table 2. Simulation Parameters

Network size	1000×1000 m^2
Node communication distance	40 m
Number of nodes	[500,1000]
Sink node mobility rate	[5,30] m/s
The simulation duration	600 s
The number of packets	100
Node initialized energy	20J
The times of experiment	50

5.1. Changes of Nodes Number

Figure 3 and Figure 4 respectively shows the effect of ALURP's, ER's and MECRN's changes of nodes number to the data transmission rate and energy consumption. Data transfer rate here is defined as the ratio of data packet number that the source node successfully transmitted to the Sink node, and the number of all data packets. The energy consumption is

defined as the total energy consumption of updating Sink node location information for data node, as well as data transmition process. Its unit is J. In the simulation experiments, α are 50, the mobile rate of the Sink node is set to 25 m/s. It can be seen that ER showed less data transfer rate and lower energy consumption. Because in the ER, the source node's data packets can be sent directly to the Sink node, and the data transmission efficiency is low. Since there is no routing and update process lead to a lower energy consumption. On the other hand, ALURP showed better data transmission rate and higher energy consumption. This is because ALURP applies the flooding mechanism, therefore all the nodes can quickly know the location of the Sink, thus showing better data transfer rate, and consuming large amounts of energy. MECRN due to apply predictive higher energy consumption nodes as the transmit relay node updating routing information, thus it can effectively save energy consumption, also in the use of regular entire network broadcast mechanism, routing performance is better. Choosing the RN as a relay node makes the network energy consumption more balanced.
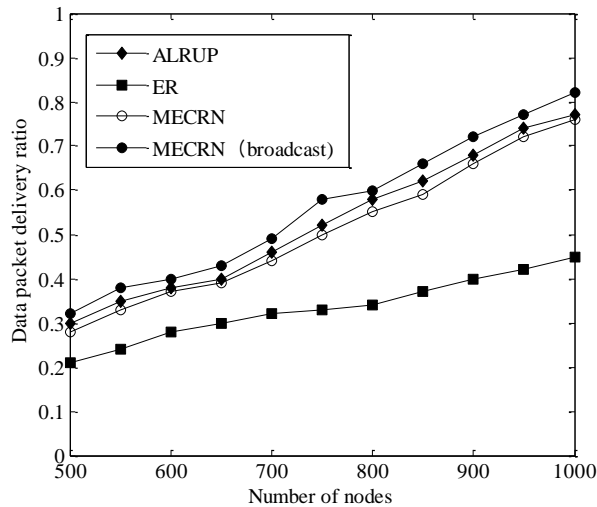

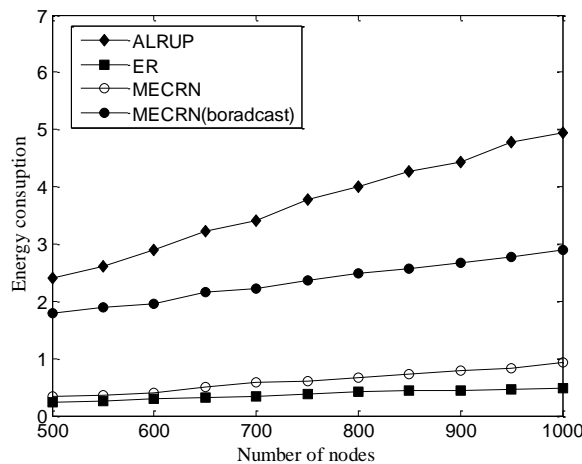**Figure 3. Node Number's Effect to the Data Transfer Rate**
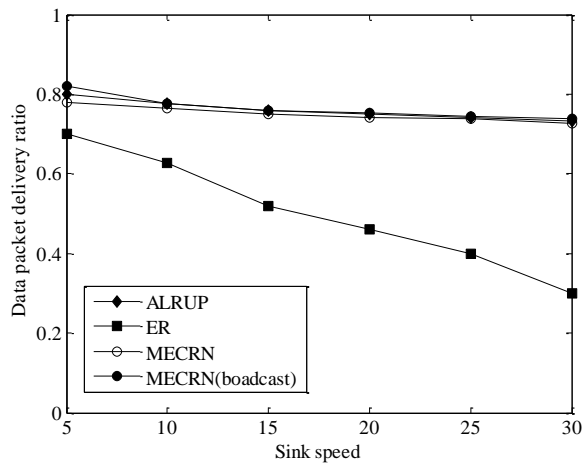

Figure 4. Node Number's Effect to the Energy Consumption

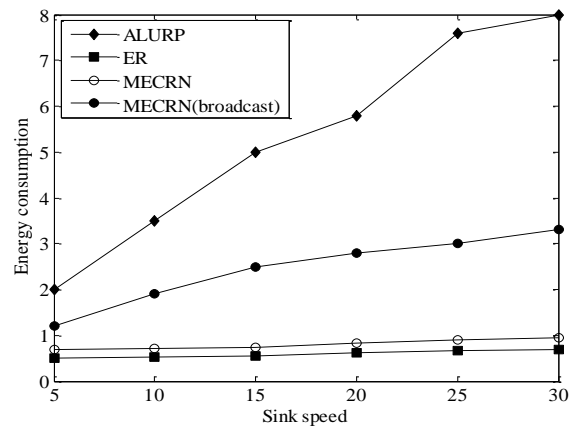**Figure 5. Sink Mobile Speed's Effect to the Data Transmission Rate**

Figure 6. Sink Mobile Speed's Effect to the Energy Consumption

5.2. The Change of Sink Node Mobile Rate

Figure 5 and Figure 6 respectively shows ALURP's, ER's and MECRN's data transmission rate and energy consumption along with the changes of Sink node's mobile rate. In the simulation experiment, α is 50, the number of nodes is set to 1000. When ALURP and MECRN protocols' nodes mobile rates of changed, their data transmission rates were closed to each other. While ER protocol showed relatively poor data transmission rate, which is due to the fact that ER directly sent data packets to the Sink node, and its efficiency is much lower than using multipath routing strategy. In the experimental results of the energy consumption, we can see the ER showed lower energy consumption, and MECRN showed the highest energy consumption without using the entire network broadcast.

The above two experiments reflect that MECRN protocol reduces the energy consumption of network nodes, while maintaining higher data transmition rate of the network.

5.3. The Change of α

In order to find the effect of α value to the performance of algorithm, in the experiment, node number is 1000; Sink node mobile speed is 25 m/s.

Figure 7 and Figure 8 respectively MECRN's data transmission rate and energy consumption as α changes the value. From Figure 7, we can see that, as α increasing, broadcast cycle becoming greater, and the network nodes dynamism entire network update cycle also changes. It may not be updated timely, data mobile rate were under certain influence. Due to α changed in Figure 8, energy consumption also increased gradually, this is because when the node energy work is looking for routing power launch, the network burden is increased.

6. Conclusions

In the wireless sensor network that supports the mobile sink, every time the sink node moves, the routing should be rebuilt. If the routing is frequently rebuilt, it not only causes unnecessary energy consumption, but a large number of the broadcast news will cause the network storm. According to the above problems, this paper introduces the concept of minimum energy consumption relay node (RN). By RN, it can be estimated the location coordinates of Sink node. It can also guarantee the accurate routing information by the update mechanism and the periodic entire network. The simulation experiments show that the proposed routing algorithm reduces the energy consumption of the network node, and at the same time keep the network higher data rate.

Acknowledgements

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