An Energy-Efficiency Routing Scheme Based on Clusters with a Mobile Sink for WSNs

Xiaodong Liu and Qi Liu*

School of Computing,
Edinburgh Napier University,
10 Colinton Road,
Edinburgh EH10 5DT, UK
q.liu@napier.ac.uk
* Corresponding author

Abstract. With the development of microelectronic devices and the radio, the application of WSN is more popular and can be applied in the various areas, which has attracted scholars. However, the requirements of performance for WSNs are becoming great in terms of reducing the energy consumption and prolonging the network lifetime. In the paper, an energy-efficiency routing scheme based on clusters with a mobile sink which consist of six parts is proposed. Through the simulation, we have demonstrated that the proposed routing algorithm has a higher performance which can reduce energy consumption on WSNs.

Keywords: Energy-Efficiency, Routing Algorithm, WSN, Sink.

1 Introduction

A wireless sensor network can be reviewed as a large-scale, self-organization and multi-hops communication network. It consists of a large number of sensor nodes which are small and cheap. Development of the microelectronic devices and the radio make the application of WSN [1] become broad which can be applied in military, healthcare, environmental [2], traffic and other civilian areas [3].

However, it also has grown a higher requirements on the performance of WSN in term of energy efficiency, the network lifetime and the rate of the packets delivered successfully [4]. Many scholars making the research on WSN have been a breakthrough continuously, though these constraints restrict the development of WSN, and make the WSN become more prefect [5]. We briefly introduce many changes of the way of data transmission in WSN below.

On the WSNs, there are two categories which are the traditional methods and the layered approaches on data transmission. Traditionally, sensor node only transfer the data to base station or user with a form of single hop. Although the source can transfer directly to the base station (BS), the energy consumption of the nodes is more serious, and these nodes are prone to fail, so it has a significant influence on the performance of WSN. Therefore, the communication mode of multi-hops is introduced that data is transmitted from source to BS indirectly. Compared with the traditional mode, the mode is more energy-efficient and can prolong the network life. For the further improvements, the sink which has more energy than general nodes is introduced into WSN. The sink is responsible for collecting the data from sources and aggregating the data, and then transmitting these aggregated data to BS or user. This kind of transmission mode can obviously save energy and prolong the network lifetime. It is can be said that the introduction of the sink is a significant breakthrough for WSNs. With the further research, the mode of the sink which can move in the network is proposed [6], so that it can save energy compared with the static sink in the network. For the movement of the sink [7], the assumption is that the sink move with a constant speed and along the predetermined routing at the beginning. The source can predict [8] the mobile trajectory of the sink and transmit data to the position predicted [9] advance, when the sink moves near the position, it can receive the data directly. These modes of data transmissions can save energy to a great extent. With the through research, the approach that multi sinks [10] can be used in network is proposed which can significantly increase the efficiency of data transmission and reduce the delay.

In the paper, we propose an energy-efficiency routing algorithm based on clusters with a mobile sink. In our scheme, data transmission is in the communication mode of multi-hops and sensor nodes are deployed at random in an environment of rectangular. The optimal routing will be acquired through our scheme. Compared with other routing algorithms [11][12][13], our proposed algorithm can improve the efficiency of data transmission on WSNs.

The rest of the paper is organized as follows. The system model is described in Section 2. Section 3, we describe our proposed algorithm in detail. Then the simulation and evaluation are presented in Section 4, and Section 5 concludes our paper.

2 System Model

In the section, the system model that we used in our scheme is introduced. First, many basic assumptions of the system model are introduced, then the network model is presented, finally we describe the energy model.

2.1 Basic Assumption

Before describing the network and energy model, many assumptions in our scheme are proposed as follows:

- All sensor nodes are randomly deployed in a regular rectangle network.
- For distinguishing with sensor nodes, each node has the unique identifier.
- In our scheme, the energy consumption of data transmission between the sink and the BS can be ignored.
- In the same region, if one node is selected as the relay node, then it cannot be the major node.

- In the first round of the routing, the energy of the whole nodes is enough to support data transmission of this round.

2.2 Network Model

The WSN is formed through randomly deploying the sensor nodes into a rectangle, which is expressed as a graph ‘G=<V, K>’ where V represents the each node and K represents the weight between two adjacent nodes. For example, k(i, j)represent the distance between the node i and it’s adjacent node j. Then, the network will be divided into several regions and the regulation of classification will be introduced in detail in section 3.

2.3 Energy Model

In our scheme, the first radio energy model is adopted. Then, many parameters used in our proposed algorithm are introduced and their meaning as showing in the following Table 1.

Table 1. The parameters and their descriptions

Notation	Description
E_0	the initial energy of general sensor node
E_{elec}	the energy consumption of running the radio device (nj/bit)
L	the length of data transmission(bit)
N	the total number of sensor nodes
V	the speed of the mobile sink
d_{ij}	the distance between node i and node j
d_0	a distance threshold that we set

The energy consumption of data transmission is based on the distance between the node *i* and the node *j*, so we set up a distance threshold called d_0, if the distance between the node *i* and the node *j* is less than the d0, then a free space model is adopted to calculate the energy consumption by the d_{ij}^2, otherwise we adopt the multi-path fading channel model to calculate the energy consumption by the d_{ij}^4. So the energy consumption of data transmission can be expressed as follows based on the distance between two nodes.

$$E_{Tx}(l,d)=\begin{cases} lE_{elec}+l\varepsilon_{fs}d^2, d<d_0 \\ lE_{elec}+l\varepsilon_{mp}d^4, d>=d_0 \end{cases} \tag{1}$$

And the energy consumption of receiving data can use the following formula to express.

$$E_{Rx}(l)=lE_{elec} \tag{2}$$

Hence, the total energy consumption of transmission and receiving data can be expressed as

$$E = E_{Tx} + E_{Rx} \tag{3}$$

3 Our Proposed Algorithm

In the paper, an energy-efficiency routing algorithm based on clusters with a mobile sink is proposed. In this section, our proposed scheme is described in detail as follows, which consists of six parts.

3.1 Network Partition

In this part, the regulation of network partition is described and it is a reference to [12]. In our paper, the number of the regions which is said to k is determined by the 5% of the sensor nodes and k can be expressed as the following formula:

$$k = \begin{cases} 4, N \times 5\% <= 5 \\ 9, 5 < N \times 5\% <= 10 \\ 16, 10 < N \times 5\% <= 15 \\ 25, 15 < N \times 5\% <= 20 \\ \ldots\ldots\ldots \end{cases} \tag{4}$$

3.2 Mobile Strategy of the Sink

The sink moves at the fixed speed along the predetermined routing in the deployed sensor networks. The sink can receive data request from the base station, and then begins to select the relay node. When the relay node is determined, the sink will sojourn at position near the relay node and collects the data from the source according to 3.6.

3.3 Selection of Relay Node

In our scheme, the selection of the relay node has two stages, the first stage is to select these nodes of the distance inside r0 between the sink and it adjacent node through the signal strength of nodes with the RSSI, the second is to select the maximum residual energy node as the relay node among these nodes according to the first stage. If the residual energy of nodes is the same, the node with the minimum identifier is as the relay node.

3.4 Selection of Major Node

Selection of the major node is dependent on the residual energy and the identifier of the node. First, the node which near to the center of the region can be regarded as the major node, and then it broadcasts a data packet which includes residual energy and identifier to neighbors. It needs to compare the residual energy and the identifier with neighbors for selecting the most suitable major node. If the residual energy of neighbor nodes is less than it, then it continues to compare with other adjacent nodes until all the nodes are involved in the comparison.

3.5 Routing Determining

In this part, the routing determining is described. When relay node is determined by the sink, the sink will broadcast the data packet named that which has the data to the whole network through the relay node. The data packet includes not only the requested data information, but also the current position of the sink. If a node receives the data packet, it will reply the packet of 'I have the packet' to the relay node along the reverse path and record the location of the relay node. At this time, it can be regarded as the source.

Since the source is determined, it sends a packet to next hop which is determined by the following regulation on the direction of the relay node according to the location of the relay node and itself.

The regulation of the routing is as follows:

1. calculating the distance between the source and it adjacent node to determine which node is the nearest to the source according to the signal strength of RSSI, then adding the identifier of the node that is nearest to the source into the routing table;
2. considering the node according to 1), the source sends a packet to the node which concludes updated information. the node also calculate the distance between the node and adjacent nodes to judge which node is closest to the node, then adding the identifier of new node in to the routing table;
3. considering the new node according to 2), the node sends the packet to the new node which concludes the latest hop count, the distance and the routing table;
4. repeating 2 and 3, until taking the all node on the direction of the relay node into account. At this time, the relay node sends a data packet of conformation which is set as OK along the reverse of the routing to show that the relay node has known the routing and the source can transmit the data to the relay node along the routing.

3.6 Data Transmission

In this part, the regulation of data transmission for our scheme is detailed described from the source to the sink as follows:

1) when the region which the sink sojourns at and the region that the source located is the same, the major node is responsible for collecting the data from the source

and aggregating them in together. Then the shortest routing is constructed from the major node to the relay node. The aggregated data is transmitted from the major node to the relay node along the routing, finally the data is transmitted to the sink by the relay node;

2) when the region which the sink sojourns at and the region that the source located is not the same, but the two regions are adjacent. First the major node of the region which the source locates in collects the data from the source and aggregate them. There are two kinds ways of next data transmission which are shown on Fig. 1 and Fig. 2;

- with major node: first is that the major node directly transmits the aggregated data to the major node of the region which the relay node locates in. When the major node of the region which the relay node locates in receives the aggregated data, then the sink collects these data.
- without major node: second is that data transmission is without the major node of the region where the relay node located. It is means that the relay node directly collects the data from the major node. In this case, the data is directly transmitted from the major node to the relay node, and finally is sent to the sink.

3) when the region which the sink sojourns at and the region that the source located is not the same, but the two regions are not adjacent. First for the each region, the major node of these regions collects the data from the source and aggregates them together. Then the routing is constructed by these major nodes in addition to the major node of the region which the relay node located. The aggregated data is transmitted from the first major node to the major node of the last hop region which the relay node located. Finally, the sink collects the aggregated data according to 2).

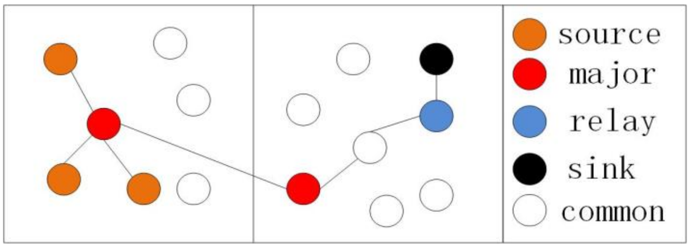

Fig. 1. Data transmission with major node

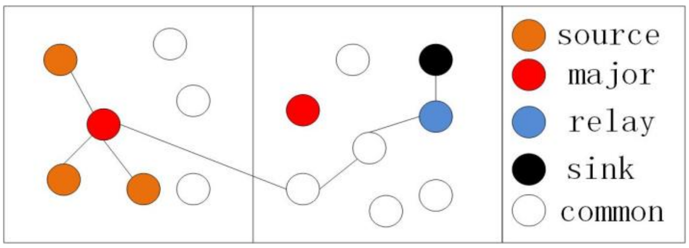

Fig. 2. Data transmission without major node

4 Performance Evaluation

In this section, the simulation is conducted on the MATLAB and the experimental results is evaluated and analyzed for the performance of the routing scheme.

4.1 Simulation Environment

In our experiment, the number of the sensor nodes is set to 500, and then the value of several parameters we used is shown on the Table 2

Table 2. The value of several parameters

Parameter	Value
N	500
R	300m
E_0	2J
E_{elec}	50nJ/bit
l	500$bits$
v	1m/s

4.2 Performance Evaluation

Here, in order to determine to select the appropriate way on data transmission, through the energy consumption of two ways which are shown on Fig. 3. The energy consumption depends on the distance between the major node and the relay node, so judging to how to use which kind ways of data transmission according the energy consumption. We can see from the Fig. 3, these two ways have the convergence value. When the distance between the major node and the relay node is less than the convergence value, the second way is adopted in data transmission, or else adopting the first way.

For our scheme, these constraints of the residual energy in our proposed algorithm are compared with that of the MEAR [11], VGDRA [12] and IAR [13], since these factors are important for evaluating the performance of the network.

The residual energy of four algorithms is compared which are shown on Fig. 4. The residual energy is determined through the rounds of the data transmission.

Through the Fig. 4, we can see that the residual energy of nodes that we proposed algorithm is more than residual energy of other algorithms. That is means the energy consumption on the network for our proposed algorithm is less compared with other algorithms. It is obviously that the energy consumes faster than our proposed algorithm for the MEAR.

The Fig. 5 shows the comparison of the packets delivered successfully for the four algorithms. The number of packets delivered successfully also is an important factor to measure the performance of the network. Here, through judging the number of the packets delivered successfully after many rounds of data transmission, to compare the four algorithms on the performance of the network.

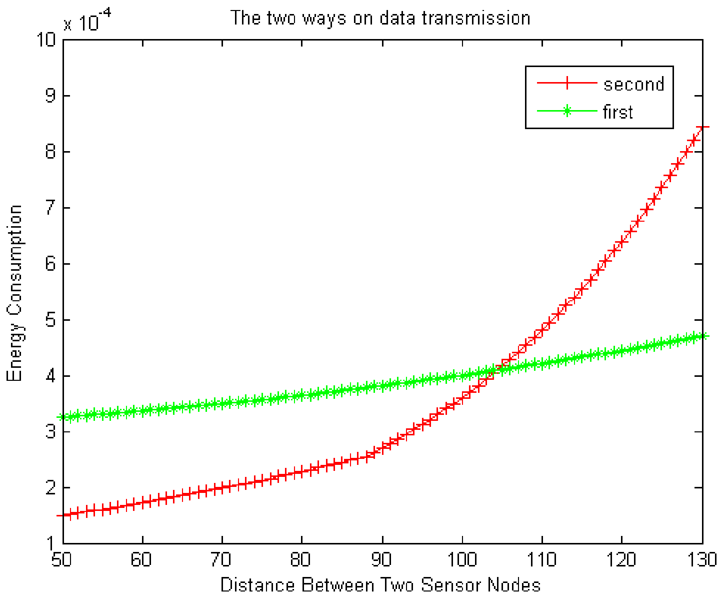

Fig. 3. The two ways on data transmission

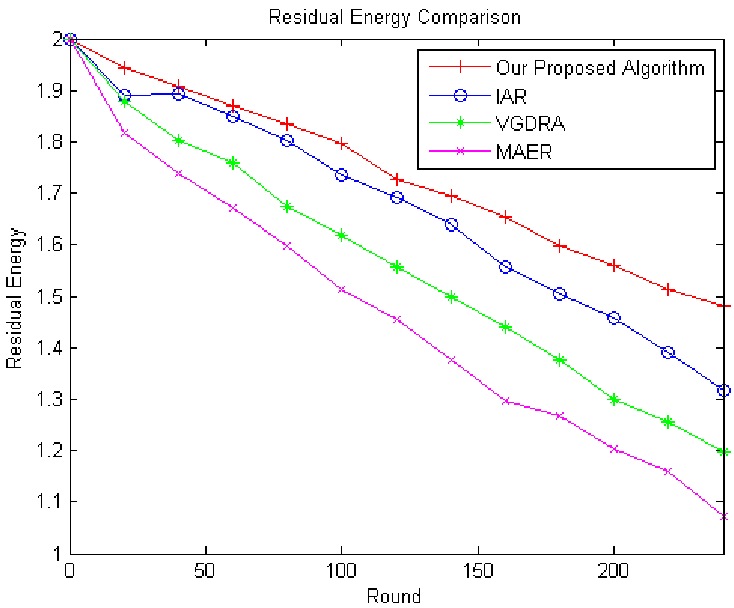

Fig. 4. Residual energy of the four algorithms

According to the Fig. 5, we can conclude that the number of the packets delivered successfully of our proposed algorithm is obviously larger than the other algorithms.

The number of the packets delivered successfully is larger than the MEAR, but is little than the VGDRA and is significantly little than our proposed algorithm. This suggests that our proposed algorithm has the best performance on the packets delivered successfully compared with other algorithms.

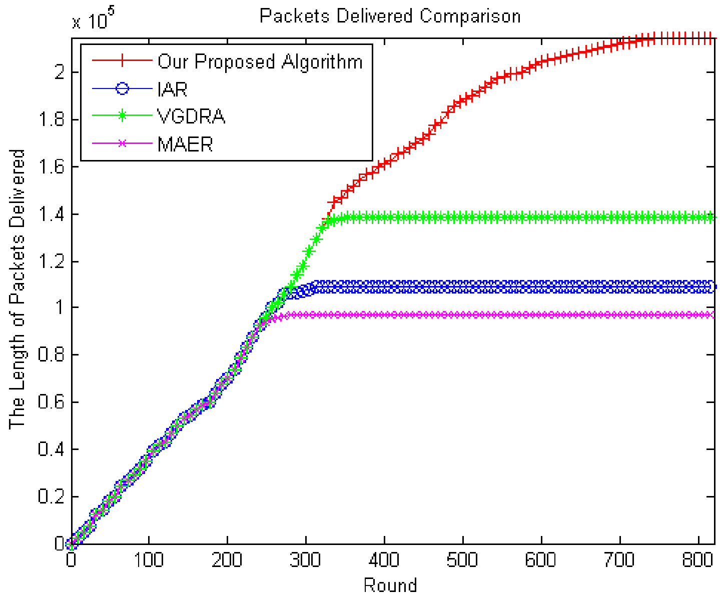

Fig. 5. Packets delivered successfully of the four algorithms

5 Conclusion

In this paper, the energy-efficiency routing scheme based on clusters with a mobile sink for WSNs is proposed. Compared with other algorithms, our proposed scheme has the less energy consumption. So it is effective to improve the performance on the sensor network.

However, it is not enough for conducting the evaluation in an ideal environment. We ignore several factors and many parameters. In the future, we will try our best to take these factors into account for the further research

Acknowledgment

This work has received funding from the European Union’s Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 701697.

References

1. Zhiguo, Q., John, K., Sebastian, R., Faisal, Z., Xiaojun, W.: Multilevel Pattern Mining Architecture for Automatic Network Monitoring in Heterogeneous Wireless Communication Networks. China Communications 13(7), 108-116 (2016).
2. Qianping, W., Yan, Z., Yu, S., Hongmei, L., Ke, W.: A Routing Algorithm Based on Mobile Agent for Mine Monitoring. IEEE Computer Society, 16-21 (2009).
3. Jin, W., Yue, Y., Jianwei, Z., Sungyoung, L., Robert, S.S.: Mobility based Energy Efficient and Multi-Sink Algorithms for Consumer Home Networks. IEEE Transactions on Consumer Electronics 59(1), 77-84 (2013).
4. Xiaobing, W., Guihai, C.: Dual-Sink: Using Mobile and Static Sinks for Lifetime Improvement in Wireless Sensor Networks. In: 16th International Conference on Computer Communications and Networks, pp. 1297-1302, Honolulu, Hawaii, USA (2007).
5. Chufu, W., Jau-Der, S., Bohan, P., Tinyu, W.: A Network Lifetime Enhancement Method for Sink Relocation and Its Analysis in Wireless Sensor Networks. IEEE Sensors Journal 14(6), 1932-1943 (2014).
6. Azadeh, L., Abolfazl, H., Arash, E.: Extending Directed Diffusion Routing Algorithm to Support Sink Mobility in Wireless Sensor Networks. In: 9th IEEE Malaysia International Conference on Communications, pp. 541-546, (2009).
7. Hyungjoo, L., Jeongcheol, L., Ssungmin, O., Sangha, K.: Data dissemination scheme for Wireless Sensor Networks with mobile sink groups. IEEE International Symposium on Personal Indoor & Mobile Radio Communications 45(2), 1911-1916 (2010).
8. Hamidreza, S., Kwanwu, C., Fazel, N.: An Energy-Efficient Mobile-Sink Path Selection Strategy for Wireless Sensor Networks. IEEE Transactions on Vehicular Technology 63(5), 2407-2419 (2014).
9. Bin, G., Victor, S.: A Robust Regularization Path Algorithm for ν-Support Vector Classification. IEEE Transactions on Neural Networks and Learning Systems 28(5), 1241-1248 (2017).
10. Dongliang, X., Xiaojie, W., Dan, L., Jia, S.: Multiple Mobile Sinks Data Dissemination Mechanism for Large Scale Wireless Sensor Network. China Communications 11(13), 1-8, (2014).
11. Elhadi, S., Xinyu, X., Haroon, M.: Mobile Agent for Efficient Routing Among Source Nodes in Wireless Sensor Networks. In: International Conference on Autonomic & Autonomous Systems, pp. 39-39, Athens, Greece (2007).
12. Abdul, W.K., Hanan, A., Mohammad, A.R., Javed, B.: VGDRA: A Virtual Grid-Based Dynamic Routes Adjustment Scheme for Mobile Sink-Based Wireless Sensor Networks. IEEE Sensors Journal 15(1), 526-534 (2015).
13. Jae-Wan, K., Jeong-Sik, I., Kyeong, H., Jin-Woo, K., Doo, S.E.: An intelligent agent-based routing structure for mobile sinks in WSNs. IEEE Transactions on Consumer Electronics 56(4), 2310-2316 (2010).