IOP Conf. Series: Materials Science and Engineering **322** (2018) 052038 doi:10.1088/1757-899X/322/5/052038

Topology control algorithm for wireless sensor networks based on Link forwarding

Cairen Pucuo*, Ai-qin Qi

School of mathematics and computer science, Northwest University for Nationalities, 730030 Lanzhou Gansu, China

*Corresponding author e-mail: 1224717240@qq.com

Abstract: The research of topology control could effectively save energy and increase the service life of network based on wireless sensor. In this paper, a arithmetic called LTHC (link transmit hybrid clustering) based on link transmit is proposed. It decreases expenditure of energy by changing the way of cluster-node's communication. The idea is to establish a link between cluster and SINK node when the cluster is formed, and link-node must be non-cluster. Through the link , cluster sends information to SINK nodes. For the sake of achieving the uniform distribution of energy on the network, prolongate the network survival time, and improve the purpose of communication , the communication will cut down much more expenditure of energy for cluster which away from SINK node. In the two aspects of improving the traffic and network survival time, we find that the LTCH is far superior to the traditional LEACH by experiments.

1. Introduction

In recent years, a number of clustering protocols for network based on wireless sensor have been raised, and these representative algorithms include LEACH(low energy adaptive clustering hierarchy) [1] [2] adaptive clustering topology algorithm, proposed by Heinzelman et al. LEACH algorithm cannot calculate the dump energy of nodes, and there is a phenomenon of uneven distribution of cluster heads in network partition, so it is not fit for massive wireless sensor networks. On this basis, for the sake of solving the problem of uneven distribution of LEACH cluster heads, Younis and others invented a algorithm called HEED (hybrid energy-efficient distributed clustering). The characteristic of this method is to balance the dump energy of the node and the communication cost of setting up the cluster head node. Because it requires several message iterations in the implementation process and the value of the worst message complexity is O(N), the N is the number of nodes in circumstance, the algorithm will sacrifices a certain amount of communication overhead. Then, researchers have proposed three layer clustering algorithm, such as DAEA (data aggregation-exact and approximate) [6]. It will cluster the whole network, first select cluster heads, and then select second layers of cluster heads from cluster head nodes. Data are transmitted to the base stations by second layers of cluster heads. So implementation of this algorithm is complex and leads to certain delays. The EEMC（energy-efficient

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.
Published under licence by IOP Publishing Ltd

multi-level clustering) algorithm[3] proposed by YAN et al is a multi-layer clustering algorithm. It builds N layer clusters recursively, and the cluster heads in i layer are the members of i+1 cluster. The flow of data is like this. The data is delivered from the non-cluster head sensor node to the first layer of cluster head, and then from the first layer of cluster head to second layer cluster head, and so on. Because the algorithm has many layers and requires higher time synchronization, the clustering process is more complex and the clustering's expenditure of energy is larger. In document [4] and [10], a heterogeneous clustering algorithm is proposed, which constructs clusters according to the distance of nodes from SINK nodes. By constructing clusters of different sizes, it solves the problem of "hot zone" in the case of multi-hop communication, and reduces the number of clusters nearby the base station and increases the number of clusters relatively distant from the base station, so as to ensure that cluster heads nearby base station possess enough energy to provide other cluster heads for their forwarding data. Ultimately it achieves the purpose of balancing cluster head energy consumption.

On the basis of previous research results, a hybrid clustering topology control algorithm called LTHC (link transmit hybrid clustering) based on link forwarding is proposed. LTHC algorithm is an improvement to the algorithms in document [4] and [10]. The main principle of the algorithm is that first, the sensor network is decomposed into many clusters. Every one cluster contains a head node and multiple member nodes. The role of members is to deliver information to cluster heads. Secondly, a number of nodes are selected as relay nodes in these non-cluster head nodes, which is used to transmit data to the base station. In this way, it establishes a forwarding link between cluster head and base station, and the cluster heads will relay the information to base station through this lowest energy expenditure path. In this paper, the proposed method uses a non-cluster head node with less energy consumption as a forwarding node, which effectively lightens the "hot zone" problem, and balances expenditure of energy, and ultimately improves the network survival time. It is different from the method of transmitting node through cluster head node in document [4] and [10].

2. Problem Description

2.1 network model

Just like methods in document [3][4][5][6], we need to construct a network model before proposing LTHC algorithm. Therefore, we propose several hypotheses, such as the network based on wireless sensor with N nodes, the node distribution is approximated by a square with a length of M, and there is a base station SB (SINK node) outside the network. This model has some following attributes:

(1) Nodes and base stations are no longer moved after deployment;

(2) Each node is determined by a unique ID, its function is used to perform data fusion, and all nodes are isomorphic;

(3) The node can accommodate the transmitted capacity factor according to the need of communication;

(4) The network response is periodically sampled and transmitted to the data;

(5) Calculating the range between nodes based on the intensity of the transmitted and received signals.

2.2 wireless communication model

In this article, the expenditure model of energy of wireless communication is the same as that of document [2]:

$$E_T(l, d) = \begin{matrix} lE_{elec} + l\varepsilon_{fs}d^2, d < d_c \\ lE_{elec} + l\varepsilon_{mp}d^4, d > d_c \end{matrix} \qquad ①$$

The energy consumed by the transmission of l-bit data to a distance of d is expressed as $E_T(l, d)$, and the loss energy of the transmitting unit data on the circuit is expressed as E_{elec}. The ε_{fs} and ε_{mp} represent the expenditure of energy by the signal amplification gain. The d_c is the threshold of a communication distance. When the communication distance is less than the threshold, the energy needed to transmit the signal is proportional to the square of the distance, and it is proportional to the 4

IOP Conf. Series: Materials Science and Engineering **322** (2018) 052038 doi:10.1088/1757-899X/322/5/052038

square of the distance when the distance is greater than the threshold. The node receives data also need to consume energy, the nodes' expenditure model of energy receives data is shown in the formula ②:

$$E_R(l, d) = lE_{elec} \qquad ②$$

The reference value of each parameter is[2]:

E_{elec} =50nJ/bit， E_{BF} =5nJ/bit， ε_{fs} 15pJ/bit/m^2， ε_{mp}=0.0015pJ/bit/m^4 d_c=87m ③

Document [9] demonstrates the energy saving of multi-hop transmission of data during long distance communication between nodes. All of these are shown in Figure 1 below:

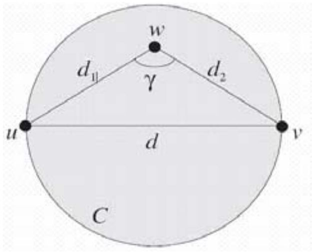

Fig.1 Expenditure of energy analysis model of multi-hop communication

There are three sensor nodes in round C: u, v and w. It is easy to get by geometric knowledge: $d^2=d_1^2+d_2^2-2d_1^2d_2^2\cos\lambda$, it is obvious that $d^2>d_1^2+d_2^2$ because of $180^0>\lambda>90^0$ and $\cos\lambda<0$. The total energy consumption of communication when the node u transmits l-bit data to the node v can be calculated by using formula ① and ②. The total expenditure of energy of communication is the sum of emission consumption of node u and reception consumption of node v. As follows:

$$E_{total1} = E_{T1} + E_{R1}$$

Therefore: $$E_{total1} = \begin{cases} 2lE_{elec} + l\varepsilon_{fs}d^2, d < d_c \\ 2lE_{elec} + l\varepsilon_{fs}d^4, d > d_c \end{cases} \qquad ④$$

Similarly, it can be calculated that the total energy consumption is E_{total2}, when the node u first sends l-bit data to the node w, and then forwards it to the node v by w.

$$E_{total2}=\begin{cases} 4lE_{elec}+l\varepsilon_{fs}(d_1^2+d_2^2) & : d_1<d_c, d_2<d_c \\ 4lE_{elec}+l\varepsilon_{mp}(d_1^4+d_2^4) & : d_1>d_c, d_2>d_c \end{cases} \qquad ⑤$$

(1) when d < dc, it is obtained by formula ③ and ④, and formula ③ and ⑤ respectively:

$$E_{total1}=l \bullet 2\times50\times10^{-9}+l \bullet 10\times10^{-12}\bullet d^2 \qquad ⑥$$

$$E_{total2}=l \bullet 4\times50\times10^{-9}+l \bullet 10\times10^{-12}\bullet(d_1^2+d_2^2) \qquad ⑦$$

It is obvious that $E_{total1}<E_{total2}$ because of $d^2<87^2=7569$ and $d_1^2+d_2^2<d^2<7569$. Therefore, when the threshold dc is greater than the distance between the nodes, the energy required for multi-hop communication is higher than the energy required for single hop communication.

(2) when d > dc, it is obtained by formula ③ and ④, and formula ③ and ⑤ respectively:

$$E_{total1}=l \bullet 2\times50\times10^{-9}+l \bullet 1.3\times10^{-16}\bullet d^4 \qquad ⑧$$

$$E_{total2}=l \bullet 4\times50\times10^{-9}+l \bullet 1.3\times10^{-16}\bullet(d_1^4+d_2^4) \qquad ⑨$$

It is obvious that $E_{total1}>E_{total2}$ because of $d^4 > d_c^4=87^4=5.73\times10^7$ and $d^4 > d_1^4 + d_2^4$. Therefore, the energy required for multi-hop communication is far less than that for single-hop communication when the interval between nodes is higher than the threshold dc. The farther the communication distance is, the more energy is saved by multi-hop than single-hop. So in the actual communication process, we usually choose the corresponding communication mode according to the distance between nodes, including single-hop and multi-hop.

3. Summary

In terms of the two indicators of the amount of communication and the time of life, we can infer that the performance of LTCH algorithm is much better than that belongs to LEACH algorithm through the experiment, but the implementation of LTCH algorithm is also relatively complex. LTCH algorithm needs to take account of the network size and density, and other network environments, such as the interval between the network and SINK nodes. If the network is too dense, the number of candidate forwarding nodes may be excessive in the process of link establishment, resulting in energy consumption, but if the network is too sparse, it may lead to failure to establish the link. Therefore, only when the network environment is clear, the cluster head forward link can determine the appropriate parameters in the establishment process and establish a reasonable forwarding link. This paper discusses the influence of different parameter values on the performance of LTCH algorithm in a given network environment. Through results of computer simulation, We could deduce that the key to promote the performance of LTCH algorithm is to choose the corresponding forwarding link candidate area span and angle according to the density of network nodes. Due to limited space, this paper does not make a thorough study of various specific networks. It is an important content of the next step of the research is how to adjust the link parameters d_{turn}, θ and $d_{i,next}$ value dynamically according to the change of the distribution of network nodes ,and a reasonable link is established by considering the candidate forwarding node residual energy and other factors. At the same time, the adaptability of the algorithm is also the main content of LTCH algorithm needs to be further improved in the case of cluster head distribution, as well as the degree of sparsity and network size.

4. Acknowledgments

The work is supported by Natural Science Foundation of China (No. 61662065) and Scientific and New Silk Road Economic project of Northwest University for Nationalities (No. XSCZLl201605)and Lanzhou science and Technology Bureau project : The Research of monitoring technology on Tibetan public opinion based on Web(NO:2016-3-68)

References

[1] Estrin D, Govindan R, Heidemann J, Kumar S. Next century challenges: Scalable coordinate in sensor network. In: Proceedings of the 5th ACM/IEEE International Conference on Mobile Computing and Networking. Seattle: IEEE Computer Society, 1999,263～270.

[2] Heinzelman W. Application-Specific protocol architectures for wireless networks [Ph.D. Thesis]. Boston: Massachusetts Institute of Technology, 2000.

[3] Yan Jin,Ling Wang:An energy-efficent multi-leverl clusering algorithm for large-scale wireless sensor networks[J]. Computer networks,52(2008)542-562.

[4] LI Cheng-Fa, CHEN Gui-Hai: An Uneven Cluster-Based Routing Protocol for Wireless Sensor Networks[J]. Chinese journal of computers.jan.2007 vol.30 No.1.

[5]Younis O, Fahmy S. HEED: a hybrid, energy- efficient,distributed clustering approach for ad hoc sensor networks[J]. IEEE Transactions on Mobile Computing,2004, 3(4) : 660- 670.

[6]Al-Karaki JN, Ul-Mustafa R, Kamal AE. Data aggregation in wireless sensor networks—Exact and approximate algorithms. In: Proc. of the IEEE Workshop on High Performance Switching and Routing. Phoenix: IEEE Communications Society, 2004. 241−245. http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=1303478

[7] Paolo Santi. Topology Control in Wireless Ad.Hoc and Sensor Networks[M]. 2005 http://as.wiley.com/WileyCDA/Section/index.html

[8] EstrinD. Wireless sensor networks tutorial part Ⅳ:Sensor network protocols//Proceedings of the ACM Mobile Computing and Networking(MobiCom),Atlanta,GA,2002.