View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by Directory of Open Access Journals

Sensors & Transducers, Vol. 23, Special Issue, July 2013, pp. 54-58

www.sensorsportal.com

Sensors & Transducers

© 2013 by IFSA

http://www.sensorsportal.com

Research of an Adaptive Optimization Topology Control for Heterogeneous Sensor Networks

Xuehai Pan
Zibo Vocational Institute, Zibo 255314, China
E-mail: xuehaipan@163.com

Received: 15 April 2013 /Accepted: 20 July 2013 /Published: 30 July 2013

Abstract: This paper has focused on the optimization of topology control for heterogeneous energy-saving sensor networks. In the heterogeneous sensor networks, there is initial heterogeneous energy in each sensor node which produces isomerism such as heterogeneous link in the process of wireless communication. Compared with the traditional energy conservation optimum algorithm which doesn't take fully consideration of the communication distance and the allocation of re-clustering after node failure, this paper proposes an network topology control algorithm with adaptive optimizing isomerism for wireless-sensors. In order to expand the life expectancy of network, this algorithm, firstly bases on hop-count of transmission data and the communication distance of adjacent sensors, and then does adaptive optimal control on clustering sensor nodes in specific environment, according to geometric principle of similar triangles. Simulation experiments have shown the improved algorithm can control network topology of all nodes in given data acquisition and monitoring area with high efficiency. Meanwhile, the life cycle of heterogeneous sensor network can be greatly expanded. *Copyright © 2013 IFSA.*

Keywords: Heterogeneous sensor networks, Network node, Topology control, Adaptive, Clustering algorithm.

1. Introduction

Nowadays, with the development of wireless-sensor network technique, heterogeneous sensor networks [1] are widely used. The research on its topology control corresponding to its results has aroused wide concern at home and abroad [2], such as the selection criteria of optimal topology in different conditions [3], the clustering scheme with dispersed energy efficiency applied in heterogeneous wireless-sensor network [4] and the distributed clustering algorithm of relative factorial estimates of current energy based on nodes' local information assessment etc [5]. In above results, the main techniques are power control and sleep scheduling to expand the lifetime of network to high limit [6]. The purpose of power control is to reduce the nodes' transmitting power of sensors and to save energy in data transmission. According to the collected data, sleep scheduling can adjust itself between working or sleeping condition so as to save energy.

However, all those techniques have not taken issues such as the communication distance and the allocation of re-clustering after node failure into fully consideration [7], therefore, this paper aimed to develop an adaptive topology control technique which is applicable to various situations, and finally provide effective communication properties for heterogeneous sensor networks, optimize topology structure and expend its life cycle.

Article number P_SI_402

2. Principle of Network Topology Control

2.1. Network Topology Control

A heterogeneous network consists of computers, network devices and systems with different producers [8]. In most cases, it can be operated in different treaties to support different functions and applications.

Network topology utilizes transmission medium to interconnect various kinds of physical layout devices, especially the layout of computers and wiring pattern [9]. Proper topology type should be selected in actual situation while designing network. Topology is a kind of touching in aggregation which remains unchangeable even if the transformation of geometry. So the topology control is necessary. This chapter firstly describes the flow of DRNGC clustering algorithm, followed by the analysis of its limitations, and then did optimal control on clustering operation.

2.2. DRNGC Clustering Algorithm

Clustering algorithm of DRNGC (directed relative neighborhood graph based on cluster), initially does clustering operation on wireless network and optimizes the whole network and clustering. The flows of DRNGC clustering are as follows:

1) Do clustering on the whole self-organization wireless network and the number of sub-clustering areas is n;

2) Do clustering on each network node due to the collected geographic position information and calculate the optimal number of cluster-heads ($Cluster_{opt}$) subsequently. From the center of a circle of data collection and monitoring area, do random selections to cluster the initial radius of communication;

3) Adjust energy transferring of each node to form network topology. Do isometric blocks on different data collecting and monitoring section on the basis of $2/3Cluster_{opt}$;

4) In selecting cluster-head node in sub-clustering section, do operation in line with point energy consumption and transmission distance. After first selection, there are $Cluster_{opt}$ spare cluster-head nodes;

5) In new cluster area, the new cluster-head node sends the flooding message to other sensors' nodes in monitoring section;

6) When all the nodes have received the flooding message, in the light of their positions these nodes judge the communication distance and then joint the corresponding sub-clustering area.

DRNGC algorithm topology control is usually used in solving connectivity problems caused by heterogeneous sensor networks. Owing to blending of network transmission data after clustering in the cluster-head, the rate of valid data and energy efficiency are improved. Meanwhile, network lifetime is expended. Suppose the information of each node such as geographic location etc is attained, this thesis stresses on how to optimize the clustering of sensors' nodes so as to expand the network lifetime and improve data communication performance.

By dividing the target monitoring section into several clustering areas, further refining clustering is done with reference to node energy consumption data transmission distance. To sum up, this kind of clustering algorithm would select the node as the cluster-head which has more dump energy and close communication distance to base station.

2.3. DRNGC Optimizing Clustering Algorithm

As shown above, in the control process of DRNGC clustering algorithm, the influence of communication distance on clustering is neglected. Besides, the proportional relationship between former and spare cluster-head nodes is not taken into consideration; stage treatment is not carried in the energy consumption of clustering and sensor point. Based on this, this section, optimizing topology control algorithm is introduced here. Specific descriptions are as follows:

1) Information collection.

If sensors with enough power exist within network, which is greater than threshold value of the sum of energy consumption of data collection and data switching, the flooding signal is released. If not, the structural topology table is set up in line with the collected location information of all sensors' nodes. This table records the current network topology including the position of adjacent nodes, current cluster and the number of clustering, distance between node and head node etc. The value of weighting between current and spare clustering information is especially presented.

2) The current cluster-head node sends flooding message to other nodes to broadcast probe request frame and the latest topology structural table. The flooding message is saved in topology structural table by other nodes to provide new-round selection of cluster-head.

3) Having received probe request frame and the latest topology structural table, each node compares the former with the latest topology structural table, and then calculates proportion weights to update the corresponding data in topology structural table. Then each node sends acknowledgment frame to the present head node with the purpose of updating communication distance, energy consumption and contrast weights of present information of the cluster-head.

4) Having received the present clustering acknowledgment frame, each node reads updated value and compares with its self topology structural table. If there is any change, the new cluster-head is ready to do.

5) The new cluster-head competition cycling and clustering.

Cluster head nodes are selected among spare cluster-head nodes. As the energy consumption of the former head node is lower than the average dump energy in all sensor nodes, this head node activates a new round selection. When the sensor node receive flooding message, step (3) and (4) are circularly executed until t new cluster-head nodes are formed and new clustering structures are constructed. Meanwhile, network topology is updated.

3. Adaptive Topology Control Algorithm for Heterogeneous Sensor Networks

On the basis of the optimal DRNGC clustering algorithm, combined the actual time pick-up information of all sensor nodes with timely updated network dynamic topology information, this paper finally builds an adaptive topology control algorithm, written as A-DRNGC. The arithmetic statement is following:

1) In each sub-cluster area, threshold value (written as $T_{Cluster}(i)$) belonging to its cluster and the weighting ratio parameter (written as k) between the former and new cluster-head node are calculated on communication distance and surplus energy. Those two values vary with the alteration of the lifetime of internal node of clusters and give automatically feedbacks to the information of bare life and dynamic network topology.

2) The communication distance bivariate table is built between cluster-head node and other nodes of sensors. In the light of the first communication distance, the best emission path and power is selected. Simultaneously, the topology structural table is under continuous updating. After comparison between the present cluster-head node and topological structure, the value of k is greater than some threshold value, namely, the present cluster-head could not provide reliable data transmission and there is a better choice of new cluster-head (the detailed process is shown in step (3)). The route optimization selection is on his way.

3) In new-round cluster-node selection, if a sensor node in present cluster does not receive any flooding information from the new cluster-head, it will send this flooding information to other sensor nodes in the cluster and then compete cluster-head node. If this is successful, then turn to step (2). Otherwise, it will send request information to cluster-head nodes in other clusters and decide to join in this cluster or not according to the feedbacks of other clusters click to communication distance bivariate table.

4) In different scenes, the communication distance of sensor nodes ($SNode_{dis}$), transmitting power ($PNode_t$), the communication distance of receiving data ($ClusterNode_{dis}$) and receiving power ($PClusterNode_r$) of cluster-head are significantly different, therefore, the communication distance, data emitting, the value of receiving power and the contrast weight with former cluster-head should take into consideration while selecting cluster-head and sensor-node.

In heterogeneous sensor network, sensor-node by first step routing the data information to the cluster-head node in its sub-cluster, and the energy consumption is shown in equation (1).

$$\begin{aligned} &E_{Snode(i)}(p,dis,k) = p * E_{SNode\_elec} \\ &+ k * E_{SNode\_start} \\ &+ p * \varepsilon_{f\_amp} * dis^2 (dis < dc) \end{aligned} , \quad (1)$$

where dis represents the communication distance between sensor-node and cluster-head node. In this paper it is supposed that each cluster area in heterogeneous sensor network monitoring section is $\pi R^2 / M$, since the monitoring section is a round with communication semidiameter R . So the data transmission semidiameter in each cluster is $r = R / \sqrt{M}$. Then the energy consumption of sensor node is calculated via equation (2).

$$\begin{aligned} E_d &= (M / \pi R^2)(\pi R^4 / 2M^2) \\ &= R^2 / 2M \end{aligned} \quad (2)$$

The aim of the clustering-head node in each cluster is mainly to search and collect data from sensor nodes, then send them to base or control center, so the energy consumption of cluster-head in each cluster is expressed as equation (3).

$$\begin{aligned} &E_{ClusterNode}(p) = k * E_{SNode}(p) \\ &+ k * E_{SNode\_gather}(p) \\ &+ E_{Cluster\_Node\&SNode} \\ &(p, dis(SNode, ClusterNode, k)) \end{aligned} \quad (3)$$

where $E_{SNode}(p)$ is the cluster-head in cluster receiving energy consumption from sensor node; $E_{SNode\_gather}(p)$ represents energy consumption when cluster-head receiving collecting data from sensor-node; $E_{Cluster\_Node\&SNode}(p)$ stands for energy consumption while sending&receiving data and accepting control messages from the cluster-head and base station. $dis(SNode, ClusterNode, k)$ is the previous communication distance of cluster-node on the basis of comparing with former cluster-head.

According to equation (1), (2) and (3) the energy consumption of cluster-node and sensor-node are obtained and based on A-DRNGC algorithm, the whole energy consumption of heterogeneous sensor network is obtained, which is shown in equation (4).

$$E_{HSN} = k * E_{NECC}(p)/(P * P_{AP\_success}(p)) \quad (4)$$

where $P_{AP\_SUCCESS}(p)$ represents the probability which node accurately received the data from the heterogeneous sensor network.

4. Simulation Experiments and Results Analysis

This paper tested the performance of adaptive heterogeneous sensor network topology control by NS-2 simulating experiment and MATLAB mathematical analysis [10]. The monitoring area range of data collection is set as 180m×100m, and the sensor nodes with different power are selected randomly. In simulation experiments, the same semi-diameter of launching power and data transmission of the nodes are set both in sensor and cluster. The relevant parameters of simulation experiments and mathematical analysis are shown in Table 1.

Table 1. Setting up of testing parameters.

Name	Value
Power loss of reference point	65 dB
Transmitting power	1 dBm
Noise power	-100 dBm
Communication distance of sensors' node	30 m
Simulation time	500 seconds
Treaty in MAC	IEEE 802.15.4
Routing protocol	AODV

Based on the above experimental platform, this paper will do analysis on the energy consumption and the number of death nodes of the proposed technology in this paper.

From Fig. 2, the number of death node in DRNGC clustering algorithm is correspondence with those of A-DRNGC technology before 100 seconds. After the competition of clustering and clustering head, the number of death nodes in DRNGC clustering is markedly increased, much more than those in A-DRNGC technology. Started from 100 seconds, the difference in the number of death nodes increased linearly. For DRNGC clustering algorithm, 50 % of the nodes (11 nodes) will become invalid in 400 seconds, which will have great effect on the communication on the whole heterogeneous network. In this moment, the number of death nodes is 8 in A-DRNGC technology. According to the adaptive and competition mechanism in A-DRNGC technology, the rest nodes will re-cluster and compete to be the node-head. At the same time the communication in networks is continuing. Fig. 2 indicates that A-DRNGC topology control can choose the new node-head which has more dump energy and superior performance than former node-head. When there is an uneven distribution after the random arranging of nodes in heterogeneous sensor, by this way, a reasonable clustering area will be established.

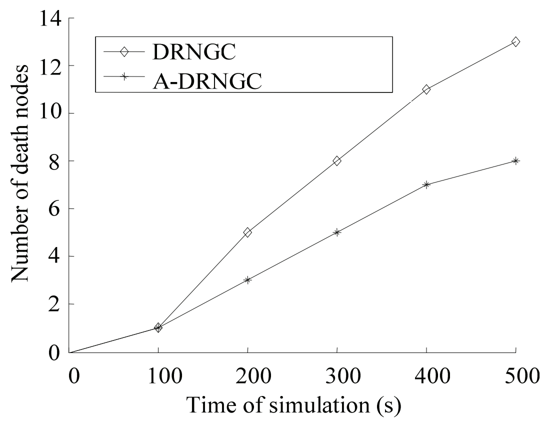

Fig. 2. Comparison of the number of death nodes.

Fig. 3 has shown that the energy consumption of data transmission in DRNGC clustering algorithm is more than A-DRNGC technology all along. Besides, from 100 seconds, some parts of cluster-head in heterogeneous network have lost its efficacy, and the re-clustering and competition within cluster-head are necessary. Owing to this reason, the energy consumption, which is obviously increased in A-DRNGC topology, is still smaller than DRNGC clustering algorithm. After then, this algorithm continuously consumes the energy in node; however, due to the high proportion of the invalid node, the most nodes cannot transmit data normally leading to the vanishing of nodes. After 400 seconds, the energy consumption is decreasing distinctly, since the new cluster-head can provide superior communication performance.

To sum up, in heterogeneous network, when some cluster-nodes are invalid, the competition between re-clustering and cluster-head are necessary, in order to set up new topology. Otherwise, this will lead to the interrupting of some parts of sensor' nodes and even to the paralysis of the whole network. Fig. 2 and Fig. 3 indicate that A-DRNGC topology can solve this problem by providing superior communication performance and expanding the lifetime of heterogeneous networks.

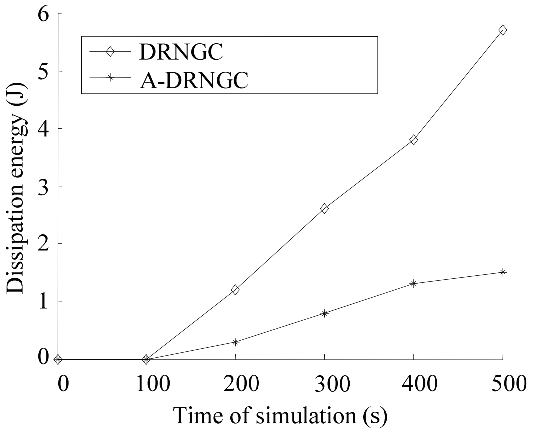

Fig. 3. Comparative analysis of dissipation energy for transmitting one bit.

5. Conclusions

Dealing with the high energy consumption in clustering, this paper puts forward an adaptive heterogeneous network for optimizing topology control to solve the problem that network topology control for heterogeneous sensors are difficult to meet the demands in practical uses. This technology is based on the dump energy, communication distances, and geometric principle of triangles to build an adaptive clustering and cluster-head competition mechanism. The advantage of this method lies in that the energy of rest nodes in network will be fully and reasonably used. Besides, the collecting and managing ability of the cluster-head will be expressed to improve the reliability of dada collection and transmission. NS-2 simulation experiments and MATLAB mathematical analysis have proved this technology can greatly improve the use ratio of heterogeneous network and extend the lifetime of the network.

References

[1]. Akyildiz L. F., Su W. L., et al, Survey on Sensor Networks, *IEEE Communications Magazine*, Vol. 40, Issue 8, 2002, pp. 102-104.

[2]. Liu Yang, Liu Quan, A Topology Control Algorithm using Power Control for Wireless Mesh Network, in *Proceedings of the 3rd International Conference on Multimedia Information Networking and Security (MINES' 2011)*, Shanghai, China, 4 November 2011, pp. 141-145.

[3]. Soro S., Heinzelman W., Cluster Head Election Techniques for Coverage Preservation in Wireless Sensor Net-works, *Ad Hoc Networks*, Vol. 7, Issue 5, 2009, pp. 955-972.

[4]. Bingcai Chen, Huazhuo Yao, et al, Energy Consumption Research of Fixed Cell Orientation Jump Grid-Clustering Routing Protocol, in *Proceedings of 2012 IEEE 2nd International Conference on Cloud Computing and Intelligence Systems*, Hangzhou, China, 30 October 2012, pp. 1468-1470.

[5]. Lin Jinzhao, Zhou Xian and Li Yun, A Minimum-energy Path-preserving Topology Control Algorithm for Wireless Sensor Networks, *International Journal of Automation & Computing*, Vol. 6, Issue 3, 2009, pp. 295-300.

[6]. L. Mucheol Kim, Sunhong Kim and Hyungjin Byun, Optimized Algorithm for Balancing Clusters in Wireless Sensor Networks, *Journal of Zhejiang University (Science A: An International Applied Physics & Engineering Journal)*, Vol. 10, Issue 10, 2009, pp. 1404-1412.

[7]. U. S. Sutar, Shrikant K. Bodhe, Energy Efficient Topology Control Algorithm for Multi-hop Ad-hoc Wireless Sensor Network, in *Proceedings of the 3rd IEEE International Conference on Computer Science and Information Technology*, Chengdu, China, 10 July 2010, pp. 418-421.

[8]. Cai Wenyu Zhang Meiyan, Mst-Based Clustering Topology Control Algorithm for Wireless Sensor Networks, *Journal of Electronics (China)*, Vol. 27, No. 3, 2010, pp. 353-362.

[9]. S. Emalda Roslin, C. Gomathy, A Novel Topology Control Algorithm for Energy Efficient Wireless Sensor Network, in *Proceedings of the 1st International Conference on Network and Electronics Engineering (ICNEE'11)*, Singapore, 16 September 2011, pp. 76-81.

[10]. D. Adami, C. Callegari, et al., Distributed and Centralized Path Computation Algorithms: Implementation in NS2 and Performance Comparison, in *Proceedings of the Symposium on Communication Quality, Reliability, and Performance Modeling of ICC*, Beijing, China, 19 May 2008.

2013 Copyright ©, International Frequency Sensor Association (IFSA). All rights reserved.
(http://www.sensorsportal.com)