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The research on cluster algorithm in WSN

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Abstract. Due to the problem of energy-constraint in WSN, how to make use of the energy and extend the lifetime of the network is the urgent problem needed to be solved by WSN. Cluster Algorithm is an important algorithm in Hierarchical routing. This paper analyzes the formation of cluster header and put forward a conclusion and expectation on the basis of some typical ways of Cluster Algorithm at present.

Introduction

As the technology of wireless communication, integrated circuit, sensor and MEMS developing, the mass production of low cost, low power consumption and multifunction miniature wireless sensor come to possibility. Those miniature wireless sensors have the functions of wireless communication, data acquisition and processing, and collaboration. Wireless Sensor Network (WSN) is set up by the collaboration of many sensor nodes. Nodes of sensor network can be located into the target area randomly or intentionally. They can connect together by some specific agreements, and collect information and collaborate to finish specific tasks.

In WSN, nodes are always operating in bad or dangerous environment that human being cannot get close to. The energy cannot be replaced, so how to make a design that can stretch the lifetime of WSN becomes the core of this problem. The shortcomings of WSN, such as small Communication bandwidth and easy to interrupt, make it more often to make mistakes and easy to be stolen. Therefore, a new design of WSN that is easier to install, longer lifetime, seldom to make mistake, and more secure to transferring information becomes the target for researchers.

Cluster Algorithm is an important way for hierarchical routing in WSN. The concept of ‘cluster’ first appeared in Packet Radio Network (PRNET). It divides nodes in the network, and every two nodes that are close to each other make a cluster. Every cluster has a cluster header. The connection of all the cluster headers forms the backbone network, and all the communications between clusters come through the backbone network. Cluster Algorithm is an important part of Sensor network topology control due to its advantages, such as convenient management of topology, efficient use of energy and easy data fusion. Choosing cluster headers and ways of data transmission are the core and basic parts in clustering. It not only can manage nodes in network effectively, but also carry out functions of choosing route and managing resource. Therefore it can decrease the energy cost in maintaining topology and broadcasting data, and also stretch the lifetime of network.

Many ways of Cluster Algorithm has been put forward in Wireless Ad Hoc Networks so far, such as Link Clustering Algorithm and Minimum Mobility Algorithm. However, the Cluster Algorithm in WSN is still under research. Comparing with Wireless Ad Hoc Network, Cluster Algorithm in WSN emphasizes more on the balance of the overall energy consumption of the network. It avoids ‘hot spot’ Problem and stretch the lifetime of the network.

Related Research

In WSN, the measurements for Cluster Algorithm are the stability of cluster structure, the number of cluster headers, the balance of load and the spread of energy.

Multilayer Cluster Algorithm is a new clustering mechanism in WSN. Figure 1.1 shows a cluster structure with more than three hierarchies. As is proved in theory and practice, the energy of nodes will decrease when hierarchies increase in WSN. However, too many hierarchies will lead to extra cost for the system. Therefore, we should keep a balance between low energy cost and low system cost.

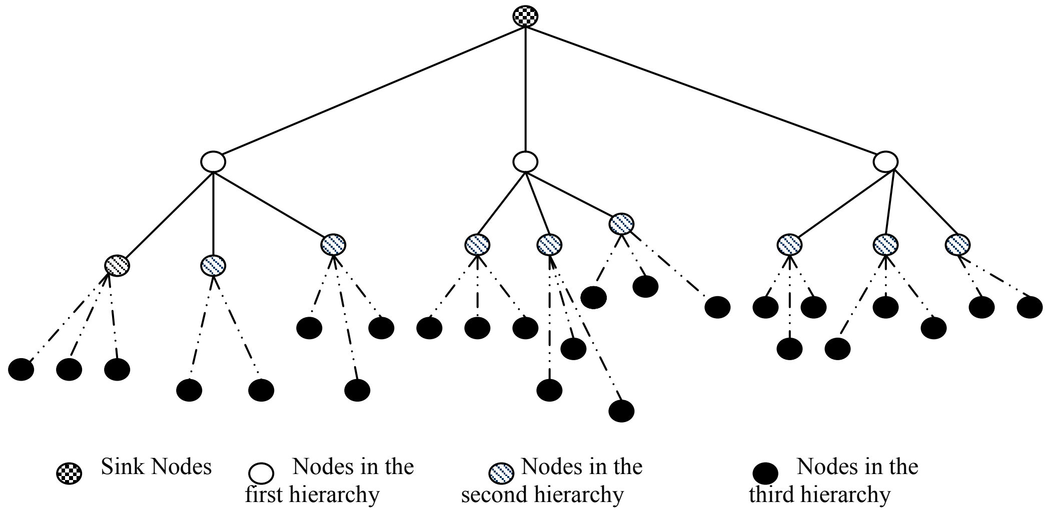

Figure 1 Multi-Hierarchy Clustering Structures

Typical Cluster Algorithms

LEACH (Low Energy Adaptive Clustering Hierarchy) first appeared as a representative Cluster Algorithm in WSN. LEACH can balance the load and promote different nodes as cluster heads at different time. It also shares the responsibility for Relay communication. Compared with Plane Routing Protocol, LEACH improves the performance of the network with sensors, and it saves the energy cost of nodes. Many cluster algorithms are founded and improved on the basis of LEACH.

leach

LEACH chooses cluster heads randomly, and it shares the load of power to every sensors. Therefore it saves the energy cost of network and stretches the lifetime of network.

The operation of LEACH is periodic. At the beginning of setting up cluster, every node chooses a random number between 0 and 1. And if that number is smaller than some threshold, that nodes will become the cluster header. Then that cluster header will broadcast this news to all nodes.

Nodes decide to join clusters depending on the signal that received from the broadcast. In the process of data transmission, all the nodes in the clusters send data according to TDMA. Cluster headers get all data together and send the conclusion to base station. After a period of processing, network is in operation again, and will choose another new cluster header and set a new cluster.

Leach-C And Leach-F

LEACH-C (LEACH-centralized) and LEACH-F (LEACH-fixed) is centralized cluster algorithm and its cluster headers are chosen by base station. Nodes in LEACH are chosen to be the cluster headers by random numbers, so the number and location of cluster headers are uncertain. LEACH-C chooses its cluster headers according to the overall information, and every node's location and current energy can be reported to the base station. So the base station can calculate the energy that reported by nodes and some low energy nodes cannot be promoted to be cluster headers.

Base station calculates the distance between nodes and cluster headers and uses Simulated Annealing Algorithm to solve the problem of NP. In the end, the base station broadcasts the structure of clusters and cluster headers. LEACH-F is developed on the basis of LEACH. It has the same way of forming cluster with LEACH-C and also uses Simulated Annealing Algorithm to create clusters.

The base station creates a list of new clusters, making an order for the nodes to become cluster headers. As soon as the clusters are created, the structure of clusters cannot be changed anymore, and the nodes will promoted to be the cluster headers according to the list made by the station. Compared with LEACH and LEACH-C, LEACH-F saves the cost of creating clusters. But LEACH-F is not adapted to the real network, because it cannot process the addition, movement and failure of nodes. And it also adds the signal interruption between clusters.

Daea

DAEA (Data Aggregation-Exact and Approximate) is a clustering protocol with three hierarchies. Cluster is equal-sized, contiguous, non-overlapping square area which is divided according to locations. Just because of this special structure, DAEA use LA (Local Aggregation) and MA (Master Aggregation). The way of choosing LA is according to the energy of nodes and the times of being cluster headers. It chooses the best MA from LA, and MA takes the responsibility to transfer data to the base station. Therefore, it stretches the lifetime of network greatly. DAEA use ILP (Integer Linear Program) to solve problems.

$$\alpha * \sigma + \beta * \rho \qquad (1)$$

In this Figure, :σ represents the energy cost of every LA; ;ρ represents the number of chosen MA; α and β are two balancing elements. DAEA has nine restrictions on MA, and it uses ILP to solve problems. As for the MA chosen from LA, DAEA put forward three solutions: Genetic Algorithm, K-Means Algorithm and Greedy Algorithm

Those three Algorithms promoted by DAEA is a kind of compromise between energy and time delaying. Adding hierarchies can save the energy and stretch the time. So DAEA is more suitable for middle and small size network.

Heed

HEED (Hybrid Energy-Efficient Distributed Clustering) says that there are three important necessities in WSN, which are stretching lifetime, balancing load, and extensibility. And it spreads the energy cost all over the whole network to extend the cycle of lifetime.

Cluster headers are chosen by two major and minor parameters. The major parameter depends on the energy left. Nodes with more energy left will have more possibility to be chosen to be cluster headers. And whether nodes will become cluster headers or not depends on the speed of the process of iteration. The minor parameter depends on the communication with clusters. It decides which nodes belong to which clusters and also balances the load between cluster headers. Taking the cost of communication within clusters into account, HEED and AMRP become the measurement for the cost of communication within clusters.

The cluster header selection algorithm of HEED has characteristics as follows: it has fully distributed cluster headers creation; cluster headers are created with the limit of iteration; minimizing the cost; and it also balances the spread of cluster headers. The major improvement for HEED is that it takes the energy left in nodes into consideration and also sets up many restrictions during the process of choosing cluster headers. According to the result of experiment, the speed of HEED clustering is quicker; it creates more balancing cluster headers; and it sets up more logical network topology.

Conclusion

Using clustering is an efficient way for sensor network to save energy, to extend augment ability, to improve stability, and to increase robustness. Routing protocol based on clustering can improve the balance of load and data fusion. The researches afterwards should pay much attention on the problem of QoS. Qos is more and more important nowadays. It will be used in the area of target tracing, so stable band width and efficient route will be required in the future.

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