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Parallel distributed computing based wireless sensor network anomaly data detection in IoT framework

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Abstract

To reduce the energy consumption of wireless sensor networks (WSNs) and prolong the network lifetime, non-uniform clustering routing (DUCF) of WSNs based on distributed fuzzy logic interference is proposed. DUCF protocol fully considers the residual energy of node, the node degree and distance from the base station. Fuzzy rule is formulated based on experience and the probability of node being elected as cluster head and the size of cluster are obtained through fuzzy interference system. DUCF protocol forms non-uniform cluster and further balances the energy consumption among cluster heads. Simulation result indicates that the performances of DUCF protocol in network lifetime and energy consumption are superior to that of LEACH, CHEF and EAUCF protocol.

Keywords: Wireless sensor networks (WSNs); Route; Fuzzy logic inference; Distributed clustering algorithm; Residual energy

1. Introduction

With the development of modern electronic technology, wireless sensor networks (WSNs) have been widely used in various fields, such as rehabilitation therapy, battlefield, field environment monitoring, etc. (Chan, Zhang, & Uhrich, 2015; Ghebrebrhan et al., 2017; Kurup et al., 2017) These sensing nodes firstly senses the environment data, processes them and transmits them to the base station. WSNs are usually deployed in the severe field environment, so it is unpractical to change the node battery. Thus, energy consumption becomes a research topic of WSNs. Compared with data sensing and processing stage, the data transmission at communication stage consumes more node energies (Malarkodi, Arunkumar, & Venkataraman, 2013). Enhancing data aggregation and transmission efficiency can save the node energy effectively. It is very important to save node energy. Once the node energy is exhausted, the node cannot work any longer, and the node is called failure node. It affects the network lifetime directly. To save the sensing node energy, usually the sensing node is not allowed to communicate with base station directly. Thus, to save the node energy, the neighbor nodes or nodes with the same feature aggregate to a cluster (Pan and Chen, 2012; Stephygraph and Arunkumar, 2016). A node in each cluster is selected as the cluster head and the sensing data of node within the cluster are collected by the cluster head, fused and transmitted to the base station. The cluster structure is good for reducing energy consumption. At present, different cluster protocols have been proposed by researchers. These protocols are different in cluster selection or cluster

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formation. LEACH (Arunkumar et al., 2012) is a typical distributed cluster protocol. LEACH protocol firstly computes the threshold value, and then produces a random number. If the number is greater than the threshold value, it is called cluster head. Such cluster head generation strategy has randomness, doesn't consider the individual characteristics of node. Meanwhile, LEACH protocol also has the common problem of uniform cluster.

To this end, non-uniform cluster route DUCF is proposed based on analytic fuzzy logic reference based on the advantages of fuzzy logic system. Using the advantages of fuzzy logic algorithm in processing uncertain system, DUCF takes the distance from the node to base station, node residual energy and node degree as the input of fuzzy logic system and further produces the probability of cluster being elected as cluster head and cluster size. DUCF produces better cluster head through fuzzy logic system. In addition, it controls the node number in the cluster (cluster size) according to local information. Simulation result indicates that the proposed DUCF protocol can reduce the energy consumption and prolong and extend the network lifetime.

2. Preliminary knowledge

2.1. Network model and constraint condition

Considering network model shown in Fig. 1, the sensing nodes in the network is divided into different clusters and a cluster head is generated within each cluster. The cluster head fuses the data of member nodes within the cluster and transmits the data to the base station directly or indirectly by means of multihop.

Considering isomorphic WSNs, all the sensing nodes have the same initial energy E_{init}. Once sensing nodes are deployed in the monitoring area, the sensing nodes will not move any more, namely static WSNs. Each sensing node has the same handling capacity, and the transmission radius of nodes is R. In addition, the base station is not limited by energy and has global knowledge of network.

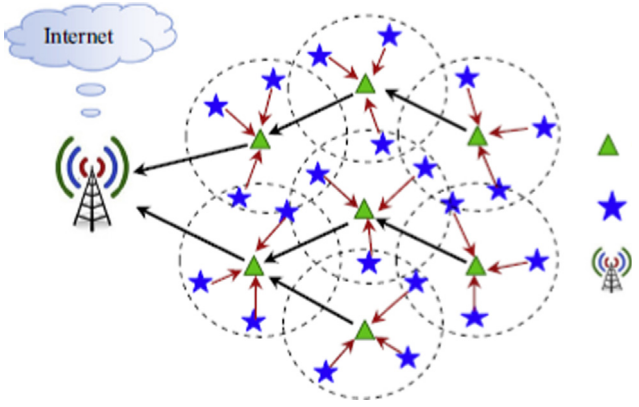

Fig. 1. Network model.

2.2. Energy model

Radio energy consumption is mainly composed of two parts: energy consumed by operating electron components and power amplifier and energy consumed by receiver. As is shown in Fig. 2, energy consumed by transmitting q bit data information between two nodes with the distance d.

$$E_{TX}(q,d) = \begin{cases} q * E_{elec} + q * E_{frris} d^2, if\ d < d_{co} \\ q * E_{elec} + q * E_{tworay} d^4, if\ d \geqslant d_{co} \end{cases} \quad (1)$$

Here into, E_{elec} is the fixed energy consumption by operating transmitter or receiver. E_{frris} and E_{tworay} means the energy consumption of unit power amplifier of transmitter in the space and two-ray ground model, and the definition of $d_{co}$is shown in Formula (2):

$$d_{co} = \sqrt{\frac{(4*\pi)^2 * l * h_t^2 * h_r^2}{\lambda^2}} = \sqrt{\frac{E_{frris}}{E_{tworay}}} \quad (2)$$

Here into, λ is wave length, and l is system loss. h_t and h_r represent the gain coefficient of transmitting antenna and receiving antenna. Correspondingly, the energy consumed by data package that receives q bit is:

$$E_{RX}(q) = q * E_{elec} \quad (3)$$

3. DUCF protocol

The proposed DUCF protocol divides the protocol time into uniformly-spaced round r, as is shown in Fig. 3. Each round includes clustering stage and data aggregation stage. The former is further divided into cluster head selection and cluster formation. The data aggregation stage is divided into uniformly-spaced frames. Each frame has fixed time slot, which is used for transmitting data from member nodes in the cluster to the cluster head.

4. Cluster head selection stage

This section describes the cluster head selection stage in details. DUCF protocol selects cluster head using fuzzy logic system. Firstly, it calculates the distance d from the node to base station, residual energy E_{res} of node and node degree ρ, and takes these three variables as the input of fuzzy logic system. The output variable ζ of system represents the probability of node becoming the cluster head, as is shown in Fig. 4.

Node energy has direct impact on the network lifetime. When selecting cluster head, the residual energy of node is considered. Suppose the residual energy of node i is E_{res}^i. Low, Medium and High, such three fuzzy language variables represent the residual energy of node, and the membership function is shown in Fig. 5(a). "Low" and "Medium" obey triangle function, and "Meidum" obeys trapezoid function.