An Intelligent Clustering Mechanism by Fuzzy Logic Inference

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요 약

Wireless sensor networks enable pervasive, ubiquitous, and seamless communication with the physical world. In this paper, we are concerned for clustering sensors into groups, so that sensors communicate information only to cluster heads and then the cluster heads communicate the aggregated information to the sink node, that the network can save energy. In this paper, we propose the algorithm for electing the cluster head and fuzzy registration of cluster head in a dynamic cluster wireless sensor networks. For making decision for clustering we will use fuzzy logic system. In simulation, we could achieve power regulation of total consumption and also the stabilization of the networks energy efficiency.

1. Introduction

Wireless sensor networks (WSNs) consist of small sensor nodes that are low-cost, low-power and multifunctional and also able to interact with their environment by sensing or controlling physical parameters. WSN is a modern paradigm for data sensing and monitoring [1]. Each sensor nodes have capability of monitoring any kinds of physical entities such as, temperature, light, humidity, etc. One of the important requirements in WSN is power availability, because battery life is considered to extend network life.

Sensors networks are generally considered as composed of randomly and densely deployed large number of nodes [2]. Therefore, it is important to make an efficient mechanism for routing and aggregating data from one node to another, to extend network lifetime.

A sensor network with intelligent behavior is a system that can adapt to the situation, present information that is relevant for the moment and a system that has reasoning parts that are designed to function with low-level rules and work together to accomplish a high-level goal. Sensor technology has been improving significantly in recent years. The main development is based to improve sensitivity, power consumption, reliability, repeatability; compared to existing sensor products and technologies. Sensing accuracy can be improved significantly by processing and combining collected data within the network itself.

In addition, the information of interest is not generally the data at a single node, but an aggregate of these data such as the minimum temperature in the network. This characteristic can also help reduce energy consumption because aggregation allows limiting transmission and reception of messages and therefore reducing the time in which the radio is on [3].

Many clustering algorithms in various contexts have been proposed, but to our knowledge none of these algorithms aim at minimizing the energy spent in the system. These algorithms are mostly heuristic in nature and aim at generating the minimum number of clusters such that any node in any cluster is at most d hops away from the cluster head. In our context, generating the minimum energy usage.

In this paper, we propose an algorithm for data aggregation using fuzzy logic. The proposed data aggregator and fuzzy filter are based on a typical application, the disaster relief in wildfire detection. The scenario we assume is the sensor will deploy in the forest by airplane and each sensor node is equipped with thermometer sensors. We assume that all sensor nodes can determine their own location so that sensor nodes will produce temperature map to generate aggregated information about temperature.

In the proposed scheme each node maintains an estimate of the aggregated value. Two kinds of information can specify the real condition of the area that has been monitored. Data should be sent by each source node to the sink node, but need some typical pattern for interaction between the source and the sink node. In this case, we assume sensor nodes will sent report only when detect occurrences of specified event, for safe energy life. Sink usually do the function approximation and edge detection for approximate mapping, for example find isothermal point in a forest fire application to detect the border of the actual fire. For instance, if the objective of the application is to monitor that the temperature in the network does not exceed an alarm threshold, each node maintains the estimate of the maximum temperature. For taking the measurement error, the value measured can be represented by trapezoid membership function. Aggregation will be performed by each node in the network when either a new value has been received from neighbor nodes.

The remainder of this paper is organized as follows. Section 2 describes related works considering the data aggregation and fuzzy logic. Section 3 presents design of our approach for cluster head election by power evaluation and dynamic cluster registration by fuzzy decission. Section 4 shows an analysis of modeling result, and in section 5, the conclusion is stated.

2. Related Works

A typical WSN architecture is shown in Figure 1. The nodes send data to the respective cluster-heads, which in turn aggregate the data and transmit it to the base station.

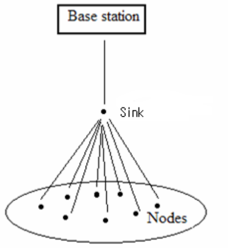

Figure 1. WSN architecture

In wireless sensor networks, it is important to design an efficient algorithm to organize sensors into clusters for minimizing the energy usage in transmitting information from all nodes to the processing center.

In the Linked Cluster algorithm [4], a node becomes the cluster head if it has the highest identity among al the nodes within one hop of itself or among all nodes within one hop of one of its neighbors. This algorithm was improved by the LCA2 [5], that generates a smaller number of clusters. The LCA2 algorithm elects as a cluster head the node with the lowest id among all nodes that are neither a cluster head nor are within 1-hop of the already chosen cluster heads.

The Weighted Clustering Algorithm [6] elects a node as a cluster head based on the number of the neighbors, transmission power, battery-life and mobility rate of the node. The algorithm also restricts the number of nodes in cluster so that the performance of the MAC protocol is not degraded.

The Distributed Clustering Algorithm [7] uses weights associated with nodes to elect cluster heads. These weights are generic and can be defined based on the application. It elects the node that has the highest weight among its 1-hop neighbors as the cluster head. The DCA algorithm is suitable for networks in which nodes are static or moving at a very low speed. The Distributed and Mobility-Adaptive Clustering Algorithm (DMAC) modifies the DCA algorithm to allow node mobility during or after the cluster set-up phase[8].

All of the above algorithm s generate 1-hop clusters, require synchronized clocks and have a complexity, so only suitable for network with small number of nodes.

In Max-Min D-Cluster Formation introduced by Amis et al [9] cluster heads are selected such that they form a d-hop dominating set. By definition, if an ad hoc network is modeled as a graph $G = (V,E)$, a set C of vertices is ad-hop dominating set of G if every node in V is at most d ($d > 1$) hops away from a vertex in C. Cluster head election is based on node id in four logical stages. Since d is an input value to the heuristic, it enables control over the density of cluster heads in the network. Authors also prove that the minimum d-hops dominating set problem is NP-complete.

The clustering goals are network lifetime maximization, scalability and load balancing. It is assumed that each node has a fixed number of transmission power levels. Transmission power control is further applied to define cluster radius by the transmission power level used for intra-cluster announcements. If cluster head selection is based on node id or node connectivity, or randomness, it does not guarantee that cluster head location is reasonable in terms of spatial attributes. If one operates with received signal strength, the correspondence between geographic distances and received signal strength is often weak in real applications.

In the context of clustering less attention is paid for the problem how to cluster network such that clustering improves data compression. Furthermore, one is able to achieve savings in data aggregation and communication costs, if as much redundancy as possible can be eliminated in lowest possible hierarchy level in the network and clustering with respect to spatial attributes enables lower transmission power in intra-cluster communication.

3. Constructing the Cluster using Fuzzy Logic

3.1 Cluster Head Election by Power Evaluation

Since usage of the energy is most important issue in sensor network, so in this paper we want to propose another way of communication method in between nodes. Nodes will communicate only when it is necessary. Generally, for a wireless sensor network we can make just as shown in the assumption.

- The base station is located far from the sensor nodes and is immobility.
- All nodes in the network are homogeneous and energy constraint.
- Base station and sink performs the cluster-head election.
- Nodes have location information that they send to the base station with respective energy levels during set up phase.
- Nodes do not have mobility.

Clustering is a process of grouping a set of physical or abstract objects into classes of similar objects. Cluster is a collection of data objects. Similar to one another means within the same cluster. And dissimilar to the objects means go in other clusters. Groups of data makes into a tree of clusters.

In this paper we assume that the referenced wireless sensor network consists of a 100 x 200 grid of sensor nodes. Our clustering approach is motivated by the requirements of the sensor network domain. More specifically, a clustering algorithm should partition the network so that the nodes inside each cluster have high correlation in sensor measurements and are evenly spaced in order to maximize gains and reduce errors due to ill geometric positioning as in the case of node localization. In non-uniform network, node density variations are globally big but there exist subgroups of nodes such that density variations are locally small. We assume that 1) each node can measure distances to its one hop neighbors and 2) each node has knowledge of its 2-hop neighborhood.

In algorithm execution, each node considers its hops neighborhood. We need other pre-specified parameters are the required cluster size and the density reach ability parameter. Cluster head selection and cluster formation will define in a few phases:

1. Each node computes its own power level, position and temperature information
2. Each node broadcasts its own information to its neighborhood and receive information from current cluster head, based on the belonging of the information.
3. Each node have to belong to cluster A or B based on the temperature.
4. Every 5 times sending information, the algorithm should find the largest remaining power level among all the nodes to become the new cluster head.
5. Each node ends up in a cluster.

3.2 Dynamic Cluster Registration by Fuzzy Decision

For making decision of cluster registration, we are using temperature difference and distance in between nodes. Temperature difference is the difference between node's temperature and the temperature that can be handled by the cluster head. Distance also use to calculate the difference between node's position and the cluster head's position.

The linguistic fuzzy variables used to represent the temperature difference (TD), distance from cluster A (DA) and distance from cluster B (DB), are divided into three levels: Negative (N), Medium (M) and Positive (P), respectively, and there are three levels to represent the output that means the decision of the cluster: Direct (D), Direct/Indirect (DI) and Indirect (I), respectively. The fuzzy rule base currently includes rules like the following: if the temperature difference is positive and the distance from cluster A is positive and the distance of the cluster B is positive then the output is indirect, because need a long path to cluster B. For making decision, we use the point of view from cluster A, so if indirect it means need a few hops to reach the cluster head in cluster B.

Thus we used $3^3 = 27$ rules for the fuzzy rule base. We used triangle membership functions to represent the fuzzy sets medium and direct/indirect and trapezoid membership functions to represent negative, positive, direct and indirect fuzzy sets. The membership functions developed and their corresponding linguistic states are represented in Table 1 and Figures 2 through 5.

Table 1. Fuzzy rule base

TD	DA	DB	Decision
N	N	N	Cluster A (D)
N	N	M	Cluster A (D)
N	N	P	Cluster A (D)
N	M	N	Need short path to Cluster A (DI)
N	M	M	Need short path to Cluster A (DI)
N	M	P	Need short path to Cluster A (DI)
N	P	N	Need long path to Cluster A (DI)
N	P	M	Need long path to Cluster A (DI)
N	P	P	Need long path to Cluster A (DI)
M	N	N	Cluster A or Cluster B (DI)
M	N	M	Cluster A (D)
M	N	P	Cluster A (D)
M	M	N	Cluster B (I)
M	M	M	Need short path to Cluster A or Cluster B (DI)
M	M	P	Need short path to Cluster A (DI)
M	P	N	Cluster B (I)
M	P	M	Need short path to cluster B (DI)
M	P	P	Need long path to cluster A or B (DI)
P	N	N	Cluster B (I)
P	N	M	Need short path to Cluster B (DI)
P	N	P	Need long path to Cluster B (I)
P	M	N	Cluster B (I)
P	M	M	Need short path to Cluster B (DI)
P	M	P	Need long path to Cluster B (I)
P	P	N	Cluster B (I)
P	P	M	Need short path to Cluster B (DI)
P	P	P	Need long path to Cluster B (I)

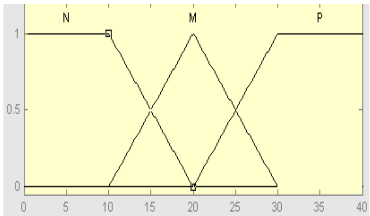

Figure 2. Fuzzy set for fuzzy variable temperature difference (TD)

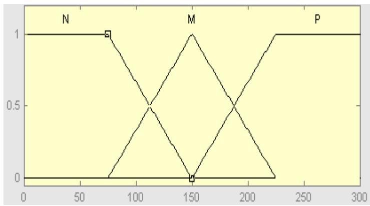

Figure 3. Fuzzy set for variable distance from cluster A (DA)

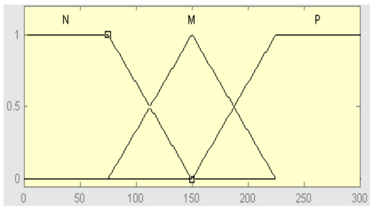

Figure 4. Fuzzy set for variable distance from cluster B (DB)

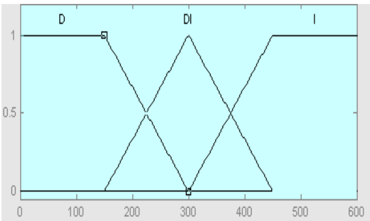

Figure 5. Fuzzy set for variable output

4. Result

In the simulation, we checked if the nodes already sent 5 messages, and the system should stabilize the status of all the nodes according to the power consumption. The largest remaining power level, will be the new cluster head. After the new cluster head already elected, then have to register to the base station. So, the nodes will send the information to the new cluster head.

This paper, specified the algorithm to find new cluster head and also construct a cluster among nodes so that the similar data can be aggregated together. With this kind of feature of this algorithm, we also can save the energy usage. The output surface in the MATLAB will show this kind of figure.

In the figure below, for example if the node is placed around 200 m (P) from cluster A, 100 m (N)from cluster B, and the temperature difference is 25 (M) then the output is Direct/Indirect (DI). It means need hops to reach the cluster head.

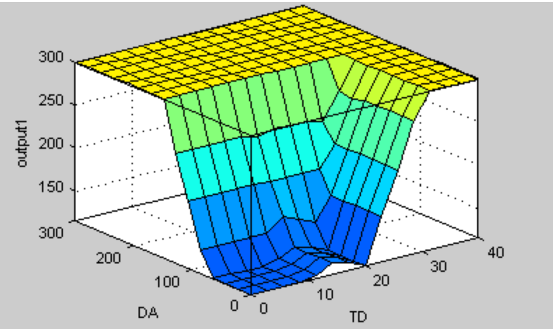

Figure 6. Display output

5. Conclusion and Further Works

Within this paper, we conclude the fact that all the nodes power in a certain wireless sensor network could be regulated by means of dynamic adjustment of cluster head responsibility according to the power consumption status of each current cluster head. For further research, we are still developing and improving this system and also have to enhanced this system by doing research about the routing in between nodes of many hops transmission.

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