Advanced Redeployment Point Determining Method in Sensor Networks

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Summary
Routing protocols, authentication algorithms, and key management protocols in wireless sensor networks have been researched considering the energy saving aspect. Generally, the power resource of sensor nodes is limited power, irreplaceable and can not be recharged. After the deployment of sensor nodes in the surveillance region, the number of living nodes decreases and the functionality of the network gradually reduce as time elapses. Accordingly, the network manager should redeploy the sensor nodes in the surveillance region for the efficient monitoring. In many applications, the sensor nodes are redeployed from airplanes which require a high cost. In this paper, we propose a fuzzy system for reducing the redeployment cost by appropriately monitoring the surveillance region. The fuzzy logic can aid a network manager's decision of the redeployment strategy of sensor nodes by considering the number of living sensor nodes and the area of all clusters.

Key words:
Sensor networks, fuzzy system, redeployment, cluster

1. Introduction

Recent advances in micro electro mechanical systems and low power highly integrated digital electronics have led to the development of micro-sensors [1]. Wireless sensor networks comprise a large number of sensor nodes that have limited processing power, small storage space, narrow bandwidth and limited energy, and a few base stations (BS) that collect the sensor reading. Sensor nodes are usually scattered in unattended and open areas. These sensors measure the ambient conditions in the environment surrounding them and then transform these measurements into signals that can be processed to reveal some characteristics of the phenomena located in the region around these sensors. A large number of these sensors can be networked in many applications that require unattended operations, hence producing a wireless sensor network (WSN) [2]. These systems enable the reliable monitoring of a variety of environments for applications such as home security, machine failure diagnosis, chemical/biological detection, medical monitoring, habitat, weather monitoring and a variety of military applications [3].

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Sensor nodes are mass-produced anonymous commodity devices that are initially unaware of their location [4]. Individual sensor nodes typically have limited power, are irreplaceable and can not be recharged. After the deployment of nodes in the surveillance region, the number of living sensor nodes decreases and the network functionality gradually reduces as time elapses. Therefore, the periodic redeployment of the sensor nodes is necessary to ensure the continuous functionality of the sensor network [5]. The deployment of nodes generally involves trained personal and specialized equipment that may include airplanes to drop the sensor nodes over the surveillance region that can not be accessed otherwise. Some sensor nodes require a careful placement in the region thus consuming many hours of qualified labors [5].

In this paper, we propose a fuzzy-based redeployment method for reducing the redeployment cost by appropriately monitoring the surveillance region. Since the efficiency of data sensing depends on the number of the living sensor node in the surveillance region, the network manager should maintain an appropriate proportion of the area with the nodes by periodically redeploying the sensors.

The remainder of this paper is organized as follows. Section II provides a brief description of related works and the motivation of this research. Section III shows the sensor network architecture and the details of the nodes redeployment using the fuzzy logic. The conclusion and future work are provided in Section IV.

2. Related Works and Motivations

2.1 *LEACH*

There are many types of routing protocols to reduce the consumption energy during the transmission of messages or to ensure a secure routing path in the WSNs. *LEACH*, witch is one of the routing protocols in WSNs, is a clustering based protocol that utilizes a randomized rotation of cluster-heads (CHs) to evenly distribute the energy load among the sensor nodes in the network. *LEACH* is organized into rounds, where each round begins with a set-up phase and is followed by a steady-state phase [6]. In the set-up phase, the clusters are organized and

CHs are selected. The actual data transfer to the BS occurs in the steady-state phase. The duration of the steady-state phase is longer than of the set-up phase in order to minimize the overhead. During the set-up phase, a predetermined fraction of nodes, *p* of the nodes, elects themselves as the CH as follows. A sensor node selects a random number, *r*, between 0 and 1. If this random number is less than the threshold value, *T*(n), the node becomes a CH for the current round. The threshold value is calculated based on the equation (1) which incorporates the current round, the desired percentage to become a CH, and the set of nodes that have not been selected as a CH in the last (1/P) rounds, denoted by G. Equation (1) is given by

$$T(n) = \frac{p}{1 - p(r \bmod (1/p))} \quad \text{f n} \in \text{G} \qquad (1)$$

G is the set of nodes that are involved in the CH election. All the elected CHs broadcast an advertisement message that they are the new CHs to the rest of the nodes in the network. After receiving this advertisement, all the non-CH nodes decide the cluster to which they want to belong. This decision is base on the signal strength of the advertisement. The non-CH nodes inform the appropriate CHs that they will be the members of the cluster. After receiving the entire message from the nodes that would want to be included in the cluster, the CH creates a TDMA schedule and assigns a time slot to each node for transmitting. This schedule is broadcast to all the nodes in the cluster [1][2].

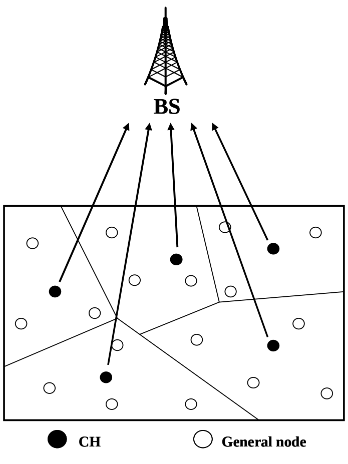

Fig. 1 LEACH-based sensor networks.

During the steady state phase, the sensor nodes can begin sensing and transmitting data to the CHs. After receiving all the data, the CH aggregates it before sending it to the BS. After a certain time, which is determined a priori, the network goes back into the set-up phase and enters another round of selecting new CHs. Each cluster communicates using different CDMA codes to reduce the interference from nodes belonging to other clusters [7]. Figure 1 shows the LEACH-based sensor networks architecture.

2.2 Motivations

Each sensor node uses a small battery with a limited capacity. It is infeasible to recharge all the batteries since the WSN can comprise a large number of sensor nodes and the sensor nodes are deployed in the open environment. Therefore, the network manager should redeploy the sensor nodes in the surveillance region to maintain the sensing coverage. The sensor nodes are densely scattered in the surveillance region. In this case, the sensing area of the sensor nodes covers majority of the surveillance region. However, sensor nodes cannot always cover the surveillance region. After the deployment of the nodes, the number of living nodes gradually decreases as times elapses.

The figure 2 shows a deployment shape of the sensor network. The sensor nodes in the shaded area cannot collect the data since the sensor nodes in this area exhaust the battery energy. Therefore new sensor nodes should be redeployed in the shaded area in order to maintain its sensing coverage. The redeployment of the sensor nodes usually requires the use of airplanes, which require a high cost in the large-scale sensor networks. The purpose of this research is to reduce the redeployment cost by maintaining the shaded area at a certain level using the fuzzy logic.

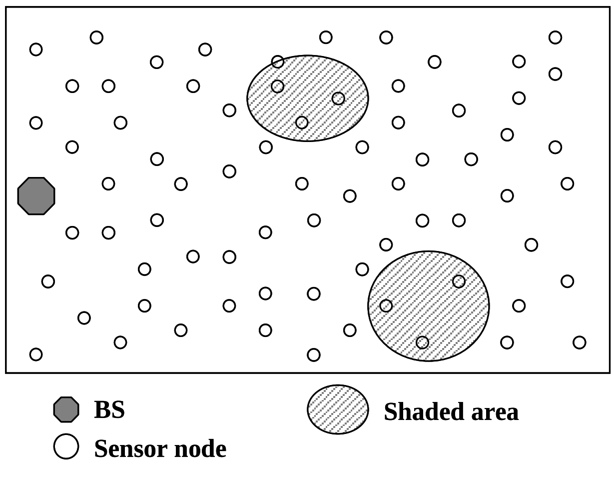

Fig. 2 A deployed shape of sensor nodes.

3. Node Redeployment using Fuzzy Logic

In this section, we describe the proposed method in detail.

3.1 *Sensor Networks*

The primary functionality of a sensor network is to collect data, such as light and temperature, from a surveillance region and transmits the acquired information to a BS. Sensor nodes usually are deployed from airplanes. The network manager also deploys sensor nodes to collect the data in the surveillance region. The redeployment of the sensor nodes in the interest region is important since they have limited battery power and the number of living nodes in the deployed area is gradually reduced. If a few sensor nodes are in the interest region, they cannot obtain the requisite information from the interest region; therefore the number of the living nodes should be maintained such that they are sufficient to collect the requisite information from the region of interest.
We assume that the energy resource of the sensor nodes in the same cluster region is randomly depleted and the sensor nodes contain a mechanism to organize a cluster automatically. We further assume that the sensor nodes can know their position. Figure 3 shows the basic sensor network architecture. The network comprises two classes of sensor nodes. The first class is the general sensor node composed of a large number of sensing nodes and other class is the CH composed of a small number of non-sensing nodes.

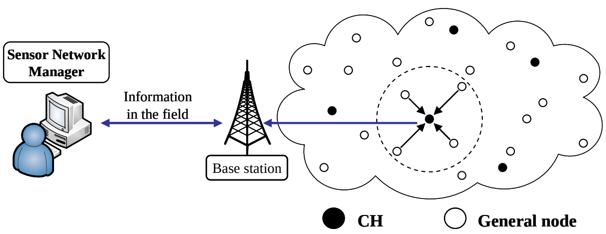

Fig. 3 Sensor network architecture.

The white circles and the shared circle in figure 3 represent the sensing nodes in the dotted circle. When an event of interest occurs, the shaded circle (CH) organizes a cluster and aggregates data from the nodes within the cluster (dotted circle). As a representative, the CH transmits the sensed data to the base station (BS) to avoid duplicate reports and conserve the forwarding energy.

3.2 Redeployment Using Fuzzy Logic

As shown in figure 4, a fuzzy based redeployment pointer determination (FRPD) decides whether or not the sensor nodes should be redeployed and the number of nodes to be redeployed based on the threshold value. This value is calculated by the fuzzy rule-based system. When the CH forwards the data to the BS in the sensor network, the information on the number of living nodes and region of the cluster in the sensor networks is included in this data. In the BS, the FRPD decides whether or not the nodes should be redeployed and the number of nodes that are redeployed based on the data, and it transmits a redeployment request message to the sensor network manager.

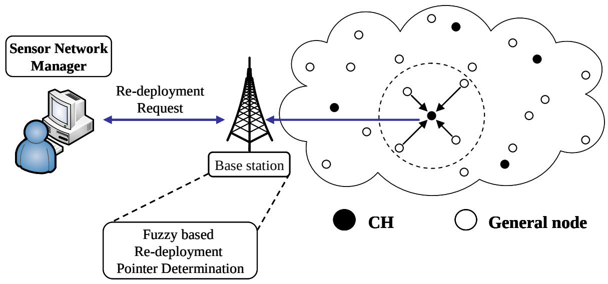

Fig. 4 The fuzzy-based redeployment pointer determination.

The fuzzy input sets are the number of living sensor nodes (NLSN) and the area of all the clusters in the field (AAC). Figures 4 and 5 illustrates the mapping of the inputs of the fuzzy logic into some appropriate membership function for the number of living nodes and area of all clusters, respectively.

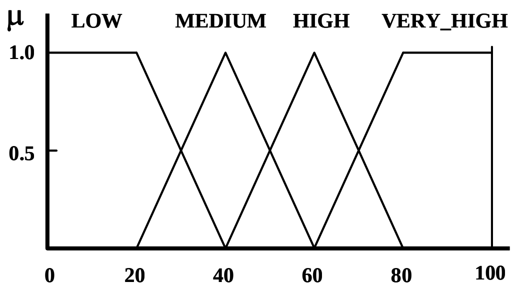

Fig. 5 Membership functions of NLSN for the number of living nodes in the sensor field.

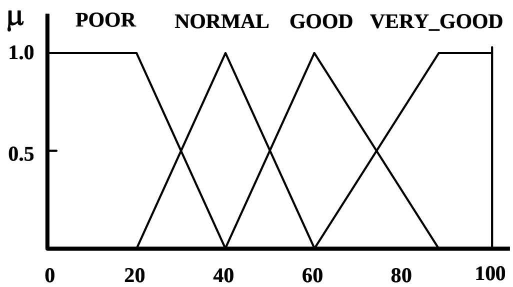

Fig. 6 Membership functions of AAC for the region of all clusters in the sensor field.

Figures 5 and 6 illustrate the membership functions of the two fuzzy logic input parameter. The labels of the fuzzy variables are represented as follows:

· NLSN = {LOW, MEDIUM, HIGH, VERY_HIGH}
· AAC = {POOR, NORMAL, GOOD, VERY_GOOD}

The output parameter of the fuzzy logic is THRESHOLD = {VERY_FEW, FEW, NORMAL, MANY, VERY_MANY}, which is represented by the membership functions as shown in figure 7.

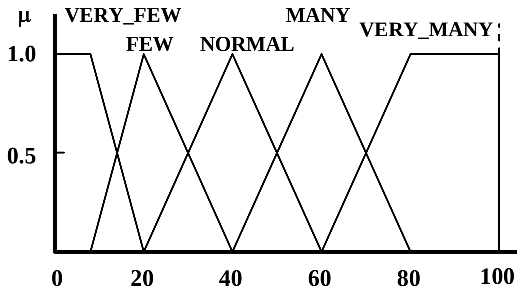

Fig. 7 Membership functions of THRESHOLD.

If NLSN is LOW and AAC is POOR, the value of THRESHOLD is VERY_MANY. Some of the rules are as follows. :

- RULE 1: IF NLSN IS LOW
  AND AAC IS POOR
  THEN THRESHOLD IS VERY_MANY
- RULE 2: IF NLSN IS LOW
  AND AAC IS POOR
  THEN THRESHOLD IS VERY_MANY
- RULE 3: IF NLSN IS LOW
  AND AAC IS NORMAL
  THEN THRESHOLD IS MANY
- RULE 4: IF NLSN IS LOW
  AND AAC IS GOOD
  THEN THRESHOLD IS NORMAL

The manager can determine where to deploy the sensor nodes and how many nodes deploy to maintain the sensing coverage by using the result of the fuzzy system. The manager also can determine the shortest path for deployment, and can reduce the deployment cost and time (figure 8).

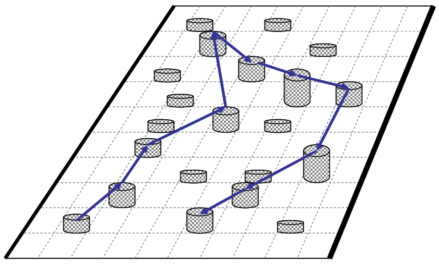

Fig. 8 Redeployment of sensor nodes by using the shortest path.

The shaded cylinders in the figure 8 are the number of sensor nodes for maintaining the sensing coverage.

4. Conclusion

Since each sensor node in the WSNs uses a small battery and cannot be recharged, the network manager should redeploy the sensor nodes for the efficient collection of the information in the surveillance region and increase the lifetime of the network. The redeployment of the nodes requires high cost. In order to efficiently collect information and reduce the redeployment cost, we have proposed a method of the redeployment of the nodes using the fuzzy logic. This logic decides whether or not the nodes should be redeployed and the number of nodes that are redeployed based on the number of living nodes and the area of all the clusters in the surveillance region.

The future areas of research include the reinforcement of the membership function and simulation of the nodes redeployment for efficient monitoring and a reduction in the redeployment cost.

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