CLUSTERING PROTOCOLS

Clustering protocols specify the topology of the hierarchical nonoverlapping clusters of sensor nodes. A robust clustering technique is essential for self-organizing sensor networks. An efficient clustering protocol ensures the creation of clusters with almost the same radius and cluster heads that are best positioned in the clusters. Since every node in a clustered network is connected to a cluster head, route discovery among cluster heads is sufficient to establish a feasible route in the network. For a large sensor network, clustering can simplify multihop route discovery and limit the number of transmissions compared to a flat, nonclustered network.

Classification of Clustering Protocols

Clustering techniques can be either centralized or decentralized. Centralized clustering algorithms require each sensor node to send its individual information, such as energy level and geographical position, to the central base station. Based on a predefined algorithm, a base station calculates the number of clusters, their sizes, and the cluster heads' positions and then provides each node with its newly assigned duty.

Given the assumption that sensor networks might consist of thousands of nodes, it is impractical, if not impossible, for a base station to collect information about every node in the network prior to route setup. Therefore, centralized clustering is not an option for large sensor networks. Since a sensor node begins a clustering process without any knowledge about its location relative to the corresponding base station, a clustering algorithm should be able to form clusters without the help of the base station and knowledge of node positioning. Although location-finder devices can also be deployed to perform this task, they are often either costly or add too much overhead on the network.

Decentralized clustering techniques create clusters without the help of any centralized base station. An energy-efficient and hierarchical clustering algorithm can be such a way whereby each sensor node becomes a cluster head with a probability of p and advertises its candidacy to nodes that are no more than k hops away from the cluster head. Given the limited transmission range of wireless sensor nodes, a hierarchical structure with an arbitrary number of levels has its limitations. As the number of hierarchical levels grows, the distance between upper-level cluster heads may increase to the point that they are no longer able to communicate with one another. The Low-Energy Adaptive Clustering Hierarchy (LEACH) algorithm and the Decentralized Energy-Efficient Cluster Propagation (DEEP) protocol are two examples of the decentralized clustering protocols and are explained next.

LEACH Clustering Protocol

The Low-Energy Adaptive Clustering Hierarchy (LEACH) protocol is a decentralized clustering algorithm that does not offer a complete energy-optimization solution, as it has no strategy for specifying cluster-head positioning and distribution. LEACH is an application-specific protocol architecture that aims to prolong network lifetime by periodic reclustering and change of the network topology.

LEACH is divided into rounds consisting of a clustering phase and a steady-state phase for data collection. At the start of each round, a sensor node randomly chooses a number between 0 and 1 and then compares this number to a calculated threshold called T(n). If T(n) is larger than the chosen number, the node becomes a cluster head for the current round. The value T(n) is calculated using the following formula:

Equation 20.11

$$T(n) = \begin{cases} \frac{p}{1-p(r \bmod (1/p))} & \text{for } n \in G \\ 0 & \text{otherwise} \end{cases},$$

where p is the ratio of the total number of cluster heads to the total number of nodes, r is the number of rounds, and G is a set of nodes that have not been chosen as cluster heads for the last 1/p rounds. For the first round (r=0), T(n) is equal to p, and nodes have an equal chance to become cluster head. As r gets closer to 1/p, T(n) increases, and nodes that have not been selected as cluster head in the last 1/p rounds have more chance to become cluster head. After 1/p - 1 rounds, T(n) is equal to 1, meaning that all the remaining nodes have been selected as cluster head. Thus, after 1/p rounds, all the nodes have had a chance to become a cluster head once. Since being the cluster head puts a substantial burden on the sensor nodes, this ensures that the network has no overloaded node that runs out of energy sooner than the others.

After cluster heads are self-selected, they start to advertise their candidacy to the other sensor nodes. When it receives advertisements from more than one cluster-head candidate, a sensor node starts to make a decision about its corresponding cluster head. Each node listens to the advertisement signals and chooses the candidate whose associated signal is received with higher power. This ensures that each sensor node chooses the closest candidate as cluster head. The LEACH algorithm is distributed, as it can be accomplished by local computation and communication at each node, rather than the transmission of all the nodes' energy level and geographical position to a centralized point. However, cluster heads are chosen randomly, and there is no optimization in terms of energy consumption.

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