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A Emerging Scheme for Cluster Based Sensor Network

Abstract

Grouping sensor nodes into clusters [3] has been used widely in order to achieve the network scalability objectives. Every cluster would have a leader, often referred to as the cluster-head. Although many clustering algorithms have been proposed [3,9,10,12] in the literature for Wireless Networks , the objective was mainly to generate stable clusters in environments with mobile nodes. This paper, includes the objectives of clustering that specifically designed for sensor networks.

Keywords: Clustering Algorithms, Intra-Cluster, Adaptive Clustering, Wireless Ad-Hoc Networks , Cluster Head

Sashi Bhusan Nayak
Lecturer ,
Deptt. of Computer Science,
Ravenshaw University,
Odisha

Anil Kumar Biswal
Lecturer ,
Deptt. of Computer Science,
Udayanath Autonomous College of Science & Technology,
Odisha

Introduction

Recent advances in miniaturization and low-power design have led to the development of small-sized battery-operated sensors that are capable of detecting ambient conditions such as temperature and sound [1,2,13]. Sensors are generally equipped with data processing and communication capabilities. The sensing circuitry measures parameters from the environment surrounding the sensor and transforms them into an electric signal [4]. Processing such a signal reveals some properties about objects located and/or events happening in the vicinity of the sensor.

Challenges of Sensor Network

Routing in sensor networks is very challenging due to several characteristics that distinguish them from contemporary communication and wireless ad-hoc networks [1,2,5,6].

1. It is not possible to build global addressing scheme for the deployment of sheer number of sensor nodes. Thus classical Internet Protocol based routing protocols can not be applied to sensor networks.
2. In contrary to typical communication networks almost all applications of sensor networks require the flow of sensed data from multiple regions (sources) to a particular sink.
3. Generated traffic has significant redundancy in it since multiple sensors may generate same data within the vicinity of a phenomenon. Such redundancy needs to be exploited by the routing protocol to improve energy and bandwidth utilization.
4. Sensor nodes are tightly constrained in terms of transmission power, on-board energy, processing capacity and storage and thus require careful resource management.

Applications

Each sensor has an onboard radio that can be used to send the collected data to interested parties. Such technological development has encouraged practitioners to envision aggregating the limited capabilities of the individual sensors in a large scale network that can operate unattended. Numerous civil and military applications can be leveraged by networked sensors.

A network of sensors can be employed to gather meteorological variables such as temperature and pressure. These measurements can be then used in preparing forecasts or detecting harsh natural phenomena. In disaster management situations such as earthquakes, sensor networks can be used to selectively map the affected regions directing emergency response units to survivors [1,2,14,15]. In military situations, sensor networks can be used in surveillance missions and can be used to detect moving targets, chemical gases, or the presence of micro-agents.

One of the advantages of wireless sensor networks is their ability to operate unattended in harsh environments in which contemporary human-in-the-loop monitoring schemes are risky, inefficient and sometimes infeasible. Therefore sensors are expected to be deployed randomly in the area of interest by a relatively uncontrolled means e.g. dropped by a helicopter, and to collectively form a network in an ad-hoc manner. Given the vast area to be covered, the short lifespan of the battery-operated sensors and the possibility of having damaged nodes during deployment, large population of sensors are expected in most Wireless Sensor Networks applications. It is envisioned that hundreds or even thousands of sensor nodes will be involved. Designing and operating such large size network would require scalable architectural and management strategies. In addition, sensors in such environments are energy constrained and their batteries can not be recharged. Therefore, designing energy aware algorithms becomes an important factor for extending the lifetime of sensors. Other application centric design objectives, e.g. high fidelity target detection and classification are also considered.

Clustering Objectives in Sensor Network

Clustering algorithms in the literature varies in their objectives. Often the clustering objective is set in order to facilitate meeting the applications requirements. For example if the application is sensitive to data latency, intra and inter-cluster connectivity and the length of the data routing paths are usually considered as criteria for Cluster Head selection and node grouping. The following discussion highlights popular objectives for network clustering. [7,8,9,10,11,12]

Load Balancing

Even distribution of sensors among the clusters is usually an objective for setups where Cluster Heads perform data processing or significant intra-cluster management duties. Given the duties of Cluster Heads, it is intuitive to balance the load among them so that they can meet the expected performance goals.

Load balancing is a more pressing issue in Wireless Sensor Networks where Cluster Heads are picked from the available sensors. In such case, setting equal-sized clusters becomes crucial for extending the network lifetime since it prevents the exhaustion of the energy of subset of Cluster Heads at high rate and prematurely making them dysfunctional.

Even distribution of sensors can also leverage data delay. When Cluster Heads perform data aggregation, it is imperative to have similar number of node in the clusters so that the combined data report becomes ready almost at the same time for further processing at the base-station or at the next tier in the network.

Fault-Tolerance

In many applications. Wireless Sensor Networks will be operational in harsh environments and thus nodes are usually exposed to increased risk of malfunction and physical damage. Tolerating the failure of Cluster Heads is usually necessary in such applications in order to avoid the loss of important sensors data. The most intuitive way to recover from a Cluster Head failure is to re-cluster the network.

However, re-clustering is not only a resource burden on the nodes, it is often very disruptive to the on-going operation. Therefore, contemporary fault-tolerance techniques would be more appropriate for that sake. Assigning backup Cluster Heads is the most notable scheme pursued in the literature for recovery from a Cluster Head failure.

The selection of a backup and the role such spare Cluster Head will play during normal network operation varies. When Cluster Heads have long radio range, neighboring Cluster Heads can adapt the sensors in the failing cluster. Rotating the role of Cluster Heads among nodes in the cluster can also be a means for fault-tolerance in addition to their load balancing advantage.

Increased Connectivity and Reduced Delay

Unless Cluster Heads have very long-haul communication capabilities e.g. a satellite link inter-Cluster Head connectivity is an important requirement in many applications. This is particularly true when Cluster Heads are picked from the sensors population. The connectivity goal can be just limited to ensuring the availability of a path from every Cluster Head to the base-station or be more restrictive by imposing a bound on the length of the path.

When some of the sensors assume the Cluster Head role, the connectivity objective makes network clustering one of the many variant of the connected dominating set problem. On the other hand, when data latency is a concern, intra-cluster connectivity becomes a design objective or constraint. Delay is usually factored in by setting a maximum number of hops ‘K’ allowed on a data path. K-hope clustering is K-dominating set problem.

Minimal Cluster Count

This objective is particularly common when Cluster Heads are specialized resource-rich nodes. The network designer often likes to employ the least number of these nodes since they tend to be more expensive and vulnerable than sensors. For example, if Cluster Heads are laptop computers, robots or a mobile vehicle there will be inherently some limitation on the number of nodes.

The limitation can be due to the complexity of deploying these types of nodes e.g. when the Wireless Sensor Network is to operate in a combat zone or a forest. In addition, the size of these nodes tends to be significantly larger than sensors, which makes them early detectable. Node visibility is highly undesirable in many Wireless Sensor Networks applications such as border protection, military reconnaissance and infrastructure security.

Maximal Network Longevity

Since sensor nodes are energy-constrained, the network’s lifetime is a major concern; especially for applications of Wireless Sensor Networks in harsh environments.When Cluster Heads are richer in resources than sensors,

it is imperative to minimize the energy for intra-cluster communication. If possible. Cluster Heads should be placed closed to most of the sensors in its clusters. On the other hand, when Cluster Heads are regular sensors, their lifetime can be extended by limiting their load as we mentioned earlier. Combined clustering and route setup has also been considered for maximizing network’s lifetime. Adaptive clustering is also a viable choice for achieving network longevity.

Conclusion

The paper begins with a brief introduction in Wireless Sensor Networks and then we are discussed the clustering objectives i.e. Load balancing, Fault-tolerance, Increased connectivity and reduced delay, Minimal cluster count, Maximal network longevity in Wireless Sensor networking.

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