Query Processing in Mobile Sensor Networks

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1 Mobile Sensor Networks

With the advent of low-power micro-sensors, actuators, embedded processors, and RF radios, it becomes feasible to deploy large scale networks of sensing devices. In the past few years, much research effort has been put forth to instrument the physical world with a large number of networked sensor nodes that are collaborating while self-configuring. As a result, wireless sensor networks are revolutionizing the ways that information from the physical world is collected and used. This has significant impacts on a wide array of applications in various fields, including military, science, industry, commerce, transportation and health-care. In many of those projects, sensor nodes may be *mobile* as they can move around by self-propelling (e.g., via wheels, micro-rockets, or other means), or attaching themselves to transporters (e.g. robots, vehicles, animals, air, and water). With self-propelling sensor nodes, a mobile sensor network is self-adjustable to achieve better area coverage, load balances, lifetime, and other system functionalities and requirements. It can be controlled by the network administrator and adaptable to the queries or commands from the applications. On the other hand, for the sensor nodes attaching to transporters, their moving patterns are dependent on the transporters. The applications may have little control or influence on the movement of these sensor nodes. The mobility of sensor nodes is essential in a wider range of applications. For example, a sensor network for air pollution test, where all sensors are scattered in the air and transported by the wind; and a vehicle network, where sensor nodes are carried by moving vehicles. Applications are able to collect the data from the sensors about air pollution and traffic conditions. In comparison with their stationary counterparts, however, the mobile sensor networks have more challenges due to mobility of the sensor nodes.

2 Query Processing Issues

Querying data and monitoring happenings/events of the physical world are important operations to be supported by sensor networks. However, the sensor networks are typically constrained by limited resources (e.g., computation, memory, and power), short-range communications, unreliable links, node failures, etc. Additionally, the sensor node mobility brings tremendous challenges. Thus, design of query processing techniques for sensor networks has to take into consideration various factors, including *energy efficiency*, *service latency*, *quality of service*, *reliability*, and *scalability*.

We consider the processing of queries in mobile sensor networks, which consist of large number of mobile sensor nodes deployed within a vast field. The sensor nodes communicate with each other through short-range radios. The long-distance data communication among them is accomplished by transmissions across multiple hops. Each sensor node is capable of only limited processing of queries. However, when collaborating with a large number of other nodes, they have the ability to instrument physical environments and measure data in much greater detail.

Traditional query processing techniques, designed for centralized data collections, are not suitable for mobile sensor networks. In the following, I will discuss some issues that are important to efficient and effective query processing in mobile sensor networks.

Location information. A primary goal for many sensor applications is to to fuse data collected at a number of sensor nodes into globally meaningful information. To achieve this goal, collection, aggregation, analysis, and monitoring of data associated with *location* information is fundamental to many sensor systems and applications. These applications typically concern more about physical phenomena or events associated with a geographical location or region than the raw data on a specific sensor node. Therefore, it is important to enable applications to collect, process and analyze sensor readings based on spatial location instead of sensor identification. Moreover, location-awareness of sensor nodes is not only important to applications, this feature can be used to enable location-based routing. Of course, due to signal noises, errors and other limitations in localization schemes and positioning techniques, location imprecision which may lead to service malfunction and performance deterioration is expected. Thus, it's critical alleviate the impact of location imprecision on query processing.

Queries. As indicated above, location-based queries are particularly important. The queries may be in various forms, continuous or snapshot, and their scopes may be based on point, region, proximity, or trajectory. It is not appropriate to expect an *exact* query semantic for queries in mobile sensor networks. Thus, the notion of queries in mobile sensor networks needs to be further developed to clarify the the semantic of queries and to specify validity and imprecision of queries.

Localized and Collaborative Processing. In mobile sensor networks, continuously sensed data is distributed in the sensor nodes. Due to the resource constraints of the network, it may not be feasible to collect all the raw data back to the sink nodes for processing. Thus, in-network processing is desirable. Sensor nodes need to process data locally and collaborate with other sensor nodes in order to support global operations and to extend the lifetime of the networks.

Stateless Routing. Most existing routing protocols make routing decisions based on cached state of neighboring sensor nodes. However, node mobility and failures result in dynamic networks with frequent topology transients, and thus pose a major challenge to stateful routing algorithms. Our work [1] in this area propose a stateless geo-routing protocols for dynamic wireless sensor networks by leveraging an idea of *volunteer forwarding* in which the relay node is not chosen by the packet holder (the node presently holding the packet), but instead by a set of volunteering neighbor nodes based on their geographical locations. Volunteer forwarding avoids the communication overhead of exchanging state information among sensor nodes, which in turn effectively reduces communication collisions and improves the energy efficiency of a routing protocol.

Network Infrastructures. In a stationary sensor network, a network infrastructure can be constructed by "linking" up sensor nodes (i.e., data sources) and the sink node where queries are issued. Most existing query processing techniques for sensor networks rely on a network infrastructure for query propagation and data collection. However, such an infrastructure is very susceptible to network topology transients in mobile sensor networks. To address this issue, an infrastructure-free query processing strategy based on itinerary can be used [2]. In this approach, query propagation and data collection are combined into one single step while visiting sensor nodes along a well-designed itinerary.

References

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[2] Y. Xu, W.-C. Lee, J. Xu, and G. Mitchell. Processing window queries in wireless sensor networks. In *Proceedings of IEEE International Conference on Data Engineering*, Atlanta, GA, April 2006.