Abstract

As a major component of Internet of Things or Everything, pervasive wireless sensor networks (WSNs) are now computing devices that seamlessly penetrate into all aspects of life such as environmental monitoring, military, medical healthcare and so on. An important functionality of WSNs is data gathering, in which sensor nodes collect environmental data and transmit them to the sink node. Sensing devices increase with an exploding speed, creating an even larger amount of data for collection, which poses a serious challenge to the energy-constrained sensor nodes. The sensor nodes are battery-driven and resource-constrained. Moreover, WSNs are often deployed massively in harsh environment, which makes it impractical to change the battery for sensor nodes. Therefore, how to achieve energy efficiency and prolong the network lifetime becomes a vital concern in WSNs. Meanwhile, in order to cater to the needs of different applications, WSNs have to guarantee different requirements such as delay constraint, accuracy, communication efficiency, security, etc.

In the past decade, data aggregation based algorithms for data gathering in WSNs became a hot topic due to their great potential to reduce data transmissions and energy consumption in WSNs. Broadly speaking, data aggregation algorithms can be categorized into two types, i.e. lossy data aggregation and non-lossy data aggregation. Lossy data aggregation extracts only specific statistical information of the data vector such as max/min, mean and median, the rest of information is lost. Non-lossy data aggregation guarantees the recovery of the full data vector with certain recovery accuracy.

Initially, this thesis proposes a lossy data aggregation algorithm for a single-hop sensor network. In certain applications such as alarm systems, only the maximum value is required. Therefore, lossy data aggregation can be used to reduce energy consumption as well as transmission delay. A priority-aware hybrid scheduling scheme is proposed to achieve fast decentralized energy-efficient max function computation in a single-hop network. In our proposed scheme, priority-aware TDMA scheme is used to schedule the transmission. CDMA is introduced to recover information whenever a collision occurs. The proposed scheme helps to reduce the number of transmissions and delay for a single computation.

Secondly, this thesis focuses on non-lossy data aggregation algorithms based on compressive sensing (CS). The application of CS technique into multi-hop wireless sensor networks is investigated under various network situations such as static network and changing environment. CS technique can guarantee the full recovery of sensor data while imposing simple computation load on the sensor. This formulation leverages on the load balancing features of CS, and a novel hybrid CS based data gathering algorithm with a dense measurement matrix for tree-based multi-hop data gathering network is developed. The proposed scheme significantly reduces total energy consumption and data gathering latency and dramatically improves network lifetime compared with benchmark algorithms.

Finally, in practical environment, the sensor network may experience changing environment where deterministic routing path is vulnerable to attacks and is less energy-efficient. In this case, it would be beneficial to allow a certain amount of exploration in the routing path. Taking the changing environment into account, a cost-aware stochastic compressive data gathering algorithm for wireless sensor network working in changing environment has been developed. The mathematical Markov chain based model is used to analyze the stochastic compressive data gathering process. A sparse random measurement matrix with optimized compression probability is constructed to minimize expected total cost while guaranteeing the recovery accuracy. Extensive simulations on both synthetic and real data show that the proposed algorithm requires less total expected cost to achieve a certain level of accuracy compared with benchmark algorithm. Finally, the proposed algorithm demonstrates prolonged network lifetime for a given recovery accuracy.