

Data Quality Management in Wireless Sensor Networks: Guest Editorial

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As new fabrication and integration technologies continue to reduce the cost and size of wireless sensors, the observation and control of our physical world will expand dramatically with the temporally and spatially dense monitoring afforded by wireless sensor network technology [2, 3, 4]. Several applications such as ZebraNet [5], Counter-sniper system [8], environment sampling [1], target tracking [7], and structure monitoring [9] have been launched, showing the promising future of wide range of applications of networked sensor systems. Their success is nonetheless determined by whether the sensor networks can provide a high quality stream of data over a long period. The inherent feature of unattended and untethered deployment of networked sensors in a potentially malicious environment, however, imposes challenges to the underlying systems. These challenges are further complicated by the fact that sensor systems are usually seriously energy constrained.

Most previous efforts have focused on devising techniques to save the sensor node energy and thus to extend the lifetime of the whole sensor network. However, with more deployments of real sensor systems, in which the main function is to collect interesting data and to share with peers, data quality is becoming a more important issue in the design of sensor systems [6]. Consistency, accuracy, reliability, and survivability concerns have to be addressed in sensor data collection, storage, and processing.

This special issue collects five papers that represent recent progress in data quality management in wireless sensor networks, covering a broad spectrum of interesting results, including data collection, outlier data detection, fault tolerance and enabling technologies.

Many sensor applications often require collecting raw sensed values from many sensor nodes to one centralized

server. Sensor data collection typically comes with various quality requirements, e.g., the level of precision requested for temperature values, the time constraints for getting the data, or the percentage of data that is needed. Han, Hakkarinen, Boonma and Suzuki in their paper “Quality-aware Sensor Data Collection” proposes a quality-aware sensing framework that characterizes the quality needs of sensor applications and classifies different sensor data collection problems. The authors list several interesting research directions and provide a holistic approach to sensor data collection with diverse quality requirements.

Outlier detection plays an important role in wireless sensor networks applications in order to ensure high data quality and reliable detection of interesting and critical events. Unlike traditional outlier detection techniques that are performed offline, constrained resources available in wireless sensor networks necessitate identifying outliers in an online manner. This means that outliers in distributed streaming data should be detected in (near) real-time with a high accuracy while keeping the resource consumption of the wireless sensor network to a minimum. In the paper “Ensuring High Sensor Data Quality through Use of Online Outlier Detection Techniques,” Zhang, Meratnia and Havinga propose outlier detection techniques based on one-class quarter-sphere support vector machine to meet the constraints and requirements of wireless sensor networks.

Understanding anomaly of sensing data is the key for wireless sensor networks. Bigrigg, Matthews and Garrett in their paper “Fault Perturbations in Building Sensor Network Data Streams” investigate the causes of temperature sensor data perturbations (two temperature data readings taken within seconds of each other that differ by several degrees) in the context of a building monitoring application, by leveraging Critter data sensors, which are an analog computer-attached sensor device developed at Carnegie Mellon University. They argue that the technologies used in off-the-shelf integrated sensor devices hide the details of raw readings, limiting the effects of data outliers. The novelty of Critter is to provide raw instantaneous readings including outlier data that may be considered anomalies or perturbations. They found that temperature sensor data perturbations are actually the effects of user activity within buildings. By capturing the raw data without automatic processing, they are able to show a correlation between time of the work day, and the frequency of data perturbation.

In the paper “A Systematic Probabilistic Approach to Energy-Efficient and Robust Data Collections in Wireless Sensor Networks,” Zhao and Liang propose a systematic approach, based on probabilistic graphical model, to infer missing observations in wireless sensor networks for sustaining environmental monitoring. By leveraging a pairwise Markov Random Field to model the spatial correlations in a sensor network, they are able to address two critical challenges: (1) energy-efficient data gathering through planned communication disruptions resulting from energy-saving sleep cycles, and (2) sensor-node failure tolerance in harsh environments. They demonstrate the effective-

ness of their approach using real-world sensed soil moisture data and vegetation data on 32×32 grids. Empirical results show that their approach can achieve high rates of accurate estimation for unobserved nodes with minimal training data in the model construction, even when the unobserved nodes consist of more than 50% of the total sensor nodes.

Using multiple paths from source to destination is a popular technique to achieve the tradeoff between reliability and efficiency in volatile wireless networks. In the paper “Efficient Multipath in Wireless Networks using Network Coding over Braided Meshes,” Toledo and Wang argue that several challenges, such as high maintenance overhead and low energy efficiency, make efficient multipath transmission difficult to implement. They instead propose the use of network coding over a multipath braided mesh topology that exploits both the low cost mesh-topology construction, such as those obtained by diffusion algorithms, and the capacity achieving capability of linear network coding. Simulation results show that their approach is able to achieve the best energy efficiency of existing methods and it easily adapts to the changing conditions of the network and can be used to adjust reliability on demand.

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