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Information quality model and optimization for 802.15.4-based wireless sensor networks

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ABSTRACT

High information quality is a paramount requirement for wireless sensor network (WSN) monitoring applications. However, it is challenging to achieve a cost effective information quality solution due to unpredictable environment noise and events, unreliable wireless channel and network bandwidth, and sensor resource and energy constraints. Specifically, the dynamic and unreliable nature of WSNs make it difficult to pre-determine optimum sensor rates and predict packet loss. To address this problem, we present an information quality metric which characterizes information quality based on the sampling frequency of sensor nodes and the packet loss rate during network transmission. Our fundamental quality metric is based on signal-to-noise ratio and is therefore application independent. Based on our metric, a quality-aware scheduling system (QSS) is developed, which exploits cross-layer control of sensor nodes to effectively schedule data sensing and forwarding. Particularly, we develop and evaluate several QSS scheduling mechanisms: passive, reactive and perceptive. These mechanisms can adapt to environment noise, bandwidth variation and wireless channel collisions by dynamically controlling sensor rates and phase. Our experimental results indicate that our QSS is a novel and effective approach to improve information quality for WSNs.

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1. Introduction

Wireless Sensor Networks (WSN) are currently omnipresent (Lan et al., 2008; Samundiswary et al., 2009; Pal et al., 2009), with applications in agriculture, health-care, military and structural health modeling (Akyildiz et al., 2002). For example, bridge health monitoring systems (BHM) that consist of physical sensors installed on bridges and cyber links to transmit data from the field to remote home stations for analysis have been widely accepted as a promising solution to the aging national transportation infrastructure. Since the outcome has significant consequences on public safety, high quality information is a paramount requirement for such sensor network-based monitoring systems.

However, WSNs suffer from unpredictable environment changes, unreliable communication, energy constraints and resource constraints such as channel usage, which pose an extreme challenge to deliver high quality information to data collection servers. Specifically, the dynamic and unreliable nature of WSNs make it difficult to pre-determine optimum sensor rates and predict packet loss. To address these challenges, the ideas of adaptive sampling (Marbini and Sacks, 2003; Wu and Luo, 2007; Jain and Chang, 2004), information fusion (Nagayama and Spencer, 2007; Du et al., 2003; Przydatek et al., 2003) and optimized routing (Ngai et al., 2009; Zhang and Cui, 2008; Yi and Shakkottai, 2007) have been explored to try and adapt sensor data collection to current network conditions; however, most work in this realm concentrates on energy savings (Gedik et al., 2007; Alippi et al., 2007; Willett et al., 2004) instead of quality of information (Vespa and Weng, 2010).[1] To mitigate the effect of unreliable sensors, redundant sensors have been deployed (Nagayama and Spencer, 2007) to improve data accuracy. However, this resulting data implosion and redundancy require complicated data aggregation (Rice et al., 2009), fusion techniques (Du et al., 2003) or quality-aware routing (Tan et al., 2010) to achieve high quality of information. Our work is different in that it addresses the home station view of information quality, which depends on environmental noise, sensor sampling frequency and packet loss inside the network.

In this paper we address quality of our information sensing and forwarding in the basic network, where sensors send periodic sampled data to a base-station which forwards the data to the collection server, or home station. Many factors can contribute to quality degradation in this setup such as, increased sampling

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[1] This is the preliminary work which has not considered important wireless channel collision and large-scale verification. This extended paper has entirely new results.

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