Author's Accepted Manuscript

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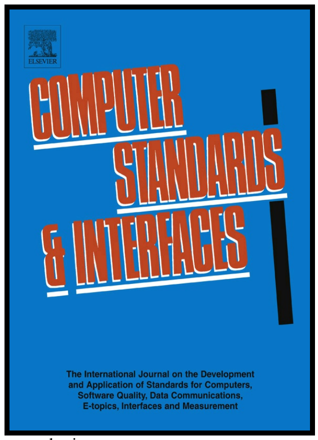

www.elsevier.com

PII: S0920-5489(16)30160-X
DOI: http://dx.doi.org/10.1016/j.csi.2017.03.003
Reference: CSI3207

To appear in: *Computer Standards & Interfaces*

Received date: 4 November 2016
Revised date: 6 March 2017
Accepted date: 7 March 2017

Cite this article as: Muhammad Faheem and Vehbi Cagri Gungor, Capacity anc Spectrum-Aware Communication Framework for Wireless Sensor Network based Smart Grid Applications, *Computer Standards & Interfaces* http://dx.doi.org/10.1016/j.csi.2017.03.003

Capacity and Spectrum-Aware Communication Framework for Wireless Sensor Network-based Smart Grid Applications

Muhammad Faheem[a], Vehbi Cagri Gungor[a]

[a]*Department of Computer Engineering, Abdullah Gül University, Kayseri 38039, Turkey*

Abstract
Recently, wireless sensor networks (WSNs) have been widely recognized as a promising technology for enhancing various aspects of smart grid and realizing the vision of next-generation electric power system in a cost- effective and efficient manner. However, recent field tests show that wireless links in smart grid environments have higher packet error rates and variable link capacity because of dynamic topology changes, obstructions, electromagnetic interference, equipment noise, multipath effects, and fading. To overcome these communication challenges, in this paper, we propose a data capacity-aware channel assignment (DCA) and fish bone routing (FBR) algorithm for WSN-based smart grid applications. The proposed DCA framework deals with the channel scarcities by dynamically switching between different spectrum bands and employs a network for organizing WSN into a highly stable connected hierarchy. In addition, the proposed FBR mechanism provides robust loop free data paths and avoids high transmission cost, excessive end-to-end delay and restricts unnecessary multi-hop data transmission from the source to destination in the network. Thus, it significantly reduces the probability of data packet loss and preserves stable link qualities among sensor nodes for load balancing and prolonging the lifetime of wireless sensor networks in harsh smart grid environments. Comparative performance evaluations show that our proposed schemes outperform the existing communication architectures in terms of data packet delivery, communication delay and energy consumption.

Key Words

Smart grid, Wireless sensor network, Fish bone routing, Cognitive radio, Multi-channel

1. Introduction
The smart grid (SG) is the next-generation power system where power distribution and management is upgraded by employing advanced bi-directional communications, pervasive computing and sensing to significantly improve the agility, efficiency and reliability of the power grid [1]. It offers a way to maintain real-time awareness of operating requirements and capabilities for the electricity providers, distributors and consumers. To this end, an integrated high performance, reliable, scalable and robust communication architecture plays a crucial role to collect timely information from different areas of the grid [2-6]. For the last few years a steep growth has been observed in wireless sensor networks (WSNs) for monitoring applications in various scientific and engineering domains [7-13]. Recently, WSNs have been widely recognized as a promising technology for enhancing various aspects of electric power grid and realizing the vision of next-generation electric power system in a cost-effective and efficient manner. However, the design of WSNs-based reliable communications networks for smart grid has considerable unique challenges, including multipath fading, extremely high attenuation and excessive interference due to nonlinear electric power equipment. This brings several dramatic challenges to static channel, which result in high data packet loss for WSNs-based SG applications [14]. In smart grid, diverse WSN-based SG applications have diverse QoS requirements as shown in Table.1.
Due to late recognition of smart grids, the studies about smart grid communication protocols are found to be limited. Though quality-of-service (QoS) aware routing protocols [15-22] for smart grid exist, but their foci are limited to certain applications, such as price signaling and emergency handling. The majority of these existing solutions have been designed to meet application-specific design objectives and requirements in a particular scenario. Although these studies provide valuable insights and guide design decisions for WSN-based smart grid applications, most of the existing routing schemes achieve one or two of these design objectives at the expense of others. For example, energy saving during data collection introduces excessive delay in the network. Moreover, they generally ignore the impact of external interference and noise on transmission reliability in harsh SG environments. Furthermore, they do not have the ability of channel adaptation to alleviate the interference induced at a certain channel due to the power grid equipment. Recently, cognitive radio sensor networks (CRSNs) have been proposed to serve as a reliable,