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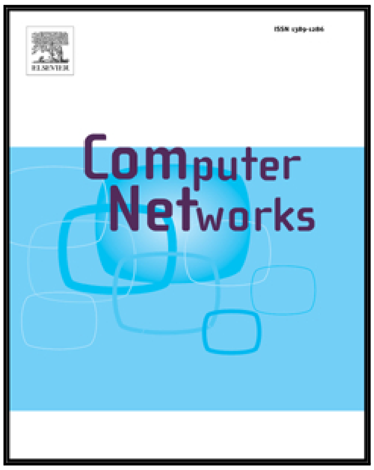


# Autonomous and Traffic-aware Scheduling for TSCH Networks

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# Autonomous and Traffic-aware Scheduling for TSCH Networks

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***Abstract*—Wireless Sensor Networks (WSNs) have been recognized as a promising communication technology for smart grid monitoring and control applications. However, the deployment of WSNs in smart grid brought new challenges that pertain to the harsh electrical grid nature, and the different and often contradicting communication requirements of smart grid monitoring applications. MAC protocols play a crucial role to meet the reliability and latency requirements of WSN-based smart grid communications. In particular, the IEEE 802.15.4 TSCH (Time Slotted Channel Hopping), the latest generation of low-power and highly reliable MAC protocols, orchestrates the medium access according to a time-frequency communication schedule. However, TSCH specification does not provide any practical solution for the establishment of the schedule. Orchestra is a recent scheduling solution for TSCH that brings significant advantages such as, the use of simple scheduling rules, the low signaling overhead, and the high delivery ratio. Despite its unique features, Orchestra has the limitation of computing the TSCH schedule at each node independently from its traffic load, which can drastically affect the communication delay. This limitation makes Orchestra not sufficiently convenient for several delay-sensitive smart grid applications. Further, the current TSCH specification does not support traffic differentiation (i.e. handle all packets equally regardless of their criticality levels). In this paper, we propose an enhanced Orchestra-based TSCH protocol, called e-TSCH-Orch, that dynamically adjusts time slots assignment according to traffic load and criticality level. The performance analysis of e-TSCH-Orch shows that it significantly reduces the communication delay compared to the original Orchestra-based TSCH, while preserving the low signaling overhead and the high packet delivery ratio.**

*Keywords— Wireless sensor network, smart grid, TSCH MAC, Orchestra scheduling, RPL routing, traffic differentiation, communication delay.*

## I. Introduction

WSNs have been recognized as a promising communication technology for the Internet of Things (IoT). In particular, smart grid applications rely on WSNs for enabling the pervasive monitoring and control of electric grid networks from the power generation plants to the transmission and distribution systems [1, 2]. The deployment of WSNs in smart grids brings new challenges. For instance, electric grid environments are typically characterized by highly corrosive conditions (e.g. rain, humidity, electric equipment's noise, electromagnetic interference, obstructions and vibrations), which turns radio links extremely unreliable and contributes to sensor nodes failures [3]. Further, WSN-based smart grid applications have different and often contradictory QoS requirements in terms of reliability and latency [4]. For example, overhead transmission line monitoring [5] and substation automation [5] represent critical smart grid applications that require an almost deterministic (and highly reliable) service, whereas other applications, such as Demand Response and Advanced Metering Infrastructure (AMI) [6], entails more relaxed requirements. Importantly, the QoS requirements can also differ within the same application [7], according to the importance of the sensed information (e.g. temperature information, vibration information and alarms). The resulting heterogeneous data traffic can be classified into different classes, where each traffic class has particular QoS requirements (e.g. in terms of latency and reliability) and also particular characteristics (e.g. data rate and traffic distribution).

The challenges raised by the application of WSNs in smart grids should be properly considered in the design of efficient communication protocols. Especially, MAC protocols play a crucial role to meet the reliability and latency requirements of WSN-based smart grid applications. The Time Slotted Channel Hopping (TSCH), part of the IEEE 802.15.4 standard [8], represents the latest generation of low-power and highly reliable MAC protocols. It has been specifically proposed to meet the requirements of industrial applications, including smart grid applications. Further, the IEEE 802.15.4 TSCH along with the IETF 6LoWPAN (IPv6 over Low power Wireless Personal Area Networks) [9] and RPL (Routing Protocol for Low Power and Lossy Networks) [10] protocols are considered as key building blocks of the emerging 6tisch architecture [11], under standardization within the IETF 6tisch Working Group. These features motivate us to investigate the use of TSCH protocol for WSN-based smart grid applications.

With TSCH, channel hopping is added on top of time slotted MAC in order to counteract frequency selective fading and improve the reliability of radio links. TSCH orchestrates the medium access according to a communication schedule that indicates to each node what to do in each slot and frequency channel: transmit, receive, or sleep. The IEEE 802.15.4 standard only specifies how the MAC layer executes the schedule. However, it does not define how to establish it. Therefore, several scheduling algorithms have been proposed for TSCH networks. They can be broadly classified as either centralized [12–14] or distributed [15–