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IEEE802.15.4e Based Scheduling Mechanisms and Systems for Industrial Internet of Things

Authors : Ho-Ting Wu, Kai-Wei Ke, Bo-Yu Huang, Liang-Lin Yan, Chun-Ting Lin

Abstract : With the advances in advanced technology, wireless sensor network (WSN) has become one of the most promising candidates to implement the wireless industrial internet of things (IIOT) architecture. However, the legacy IEEE 802.15.4 based WSN technology such as Zigbee system cannot meet the stringent QoS requirement of low powered, real-time, and highly reliable transmission imposed by the IIOT environment. Recently, the IEEE society developed IEEE 802.15.4e Time Slotted Channel Hopping (TSCH) access mode to serve this purpose. Furthermore, the IETF 6TiSCH working group has proposed standards to integrate IEEE 802.15.4e with IPv6 protocol smoothly to form a complete protocol stack for IIOT. In this work, we develop key network technologies for IEEE 802.15.4e based wireless IIoT architecture, focusing on practical design and system implementation. We realize the OpenWSN-based wireless IIOT system. The system architecture is divided into three main parts: web server, network manager, and sensor nodes. The web server provides user interface, allowing the user to view the status of sensor nodes and instruct sensor nodes to follow commands via user-friendly browser. The network manager is responsible for the establishment, maintenance, and management of scheduling and topology information. It executes centralized scheduling algorithm, sends the scheduling table to each node, as well as manages the sensing tasks of each device. Sensor nodes complete the assigned tasks and sends the sensed data. Furthermore, to prevent scheduling error due to packet loss, a schedule inspection mechanism is implemented to verify the correctness of the schedule table. In addition, when network topology changes, the system will act to generate a new schedule table based on the changed topology for ensuring the proper operation of the system. To enhance the system performance of such system, we further propose dynamic bandwidth allocation and distributed scheduling mechanisms. The developed distributed scheduling mechanism enables each individual sensor node to build, maintain and manage the dedicated link bandwidth with its parent and children nodes based on locally observed information by exchanging the Add/Delete commands via two processes. The first process, termed as the schedule initialization process, allows each sensor node pair to identify the available idle slots to allocate the basic dedicated transmission bandwidth. The second process, termed as the schedule adjustment process, enables each sensor node pair to adjust their allocated bandwidth dynamically according to the measured traffic loading. Such technology can sufficiently satisfy the dynamic bandwidth requirement in the frequently changing environments. Last but not least, we propose a packet retransmission scheme to enhance the system performance of the centralized scheduling algorithm when the packet delivery rate (PDR) is low. We propose a multi-frame retransmission mechanism to allow every single network node to resend each packet for at least the predefined number of times. The multi frame architecture is built according to the number of layers of the network topology. Performance results via simulation reveal that such retransmission scheme is able to provide sufficient high transmission reliability while maintaining low packet transmission latency. Therefore, the QoS requirement of IIoT can be achieved.

Keywords : IEEE 802.15.4e, industrial internet of things (IIOT), scheduling mechanisms, wireless sensor networks (WSN)
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