Performance Evaluation of Industrial Wireless Sensor Network Technologies: ZigBee, WirelessHART, and Isa100

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ABSTRACT

This article describes how with the continuous developments in communication technology, the use of wireless network devices is increasing rapidly. However, most companies still rely on wired networks and do not trust wireless networks, especially for process control applications. The confidence in wireless technologies can be built by first evaluating the technology before using it for industrial applications. To this end, the performance of three wireless sensor networks (WSNs) standards, namely, ZigBee, WirelessHART and ISA100, is evaluated. The performance metrics are the throughput, the end to end delay, and the energy consumption. The results show that ISA100 and WirelessHART perform better than ZigBee in large networks. In addition, ISA100 is more flexible than WirelessHART, since it allows using the combination of slotted and slow hopping and configurable timeslot sizes.

KEYWORDS

AODV, CSMA/CA, Full Function Device (FFD), Reduced Function Device (RFD), Slotted Hopping, Slow Hopping, Wireless Sensor Network

1. INTRODUCTION

Wireless sensor network (WSN) technology is a new area for both research and industry. IEEE 802.15.4 is a standard for low cost, low power, and low data rate transmission that perfectly suits the WSN requirements. Because of these features, it has been always attracting a lot of attention in both industry and research communities (Pedro, 2013).

The IEEE 802.15.4 standard works in three channel bands and has three different data rates, namely, 2.4 GHz /250kbps, 915 MHz /40 kbps and 868 MHz /20kbps. The IEEE 802.15.4 physical layer has 27 channels, out of which 16 channels are in the 2.4 GHz band, 10 channels are in the 915 MHz band, and one channel is in the 868 MHz band (Marina, 2006).

The standard defines two types of devices, namely, the reduced function devices (RFDs), and the full function devices (FFDs). The RFD is an end node that works as an I/O device only. On the

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other hand, the FFD is a router node that works as an I/O device and it has routing capabilities. The RFDs can communicate with FFDs only. If two RFDs want to communicate with each other, they must talk to the FFD to which they are connected.

The 802.15.4 standard specification deals with medium access control sub-layer (MAC) and physical layer (PHY) aspects of many standards such as ZigBee, WirelessHART, and ISA100.11a. Therefore, the performance study for IEEE802.15.4 is very important for the design of wireless sensor networks. The IEEE 802.15.4 standard defines the PHY and MAC layer specifications for low data rate wireless connectivity among relatively simple devices that consume minimal power and operate in the Personal Operating Space (IEEE, 2006; Sofie, 2008; Iyappan, 2007).

New technologies have launched for low cost and low data rate industrial applications on top of the 802.15.4 standard, and the main three wireless technologies are ZigBee, WirelessHART, and ISA100. The following subsections provide a detailed overview of the three standards.

1.1 ZigBee

The ZigBee standard, developed by the ZigBee alliance based on the IEEE 802.15.4 standard, offers long battery lifetime, transmits at low data rates, and is cost-efficient. ZigBee is intended for short-range wireless communication applications, and it provides long battery lifetime. The technology defined by ZigBee is cheaper and simpler than other Wireless Personal Area Networks (WPANs), such as Bluetooth. Because of these reasons, ZigBee Technology is vastly deployed in wireless control and monitoring applications (Pedram, 2010; Bo, 2006; Tomas, 2008).

1.1.1. Basic Features

ZigBee is a characterization for the upper protocol layer, and it has been built upon the PHY and MAC layers of the 802.15.4 standard. ZigBee supports ad-hoc on-demand distance vector (AODV) routing algorithm, hence route discovery and peer-to-peer communication are possible. It also supports mesh-networking topologies, but it does not support frequency hopping. The only option to mitigate interference is to scan for a channel with the minimum amount of interference at startup (Tomas, 2008; TianWen, 2008).

ZigBee supports two types of devices, namely, FFDs and RFDs. Thus, ZigBee can form mesh and star networks by using a combination of FFDs and RFDs (Tomas, 2008).

ZigBee has two operational modes: beacon-enabled and non-beacon mode. In beacon-enabled mode, there are up to seven timeslots that can be used as dedicated timeslots. These time slots, also called guaranteed timeslots (GTS), increase the transmission reliability of the standard (Jaslin, 2016).

1.1.2. Protocol Devices

Coordinator: This device is responsible for starting and controlling the network. It stores information about the network, so it can act as a Trust Centre that stores security keys (Daintree Networks, 2008).

Router: this device enlarges network area coverage, acts as an emergency node because it provides backup routes in case of network congestion or device failure, and dynamically routes around obstacles. It connects to the coordinator and other router nodes, in addition of that it supports child nodes (Daintree Networks, 2008).

End Devices: These devices can only send or receive messages. They must be connected to either the coordinator or a router, and do not support child devices (Daintree Networks, 2008).

1.2. WirelessHART

WirelessHART is designed to be simple, self-organizing, self-healing, flexible, scalable, reliable, secure, and it supports the existing HART technology. WirelessHART is based on the IEEE 802.5.4
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