Adaptive Beacon Transmission in Cognitive-OFDM-Based Industrial Wireless Networks

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***Abstract*— Wireless interferences from heterogeneous networks in the crowded industrial scientific medical band set up technical barriers for reliable communication of industrial wireless network (IWN). In this letter, an adaptive beacon transmission strategy is proposed for dynamically scheduling the cognitive-OFDM IWN to avoid channel interferences without using a dedicated control channel. Preambles of beacons are specifically designed in the PHY layer to embed specific information. A generalized likelihood ratio test (GLRT)-based approach is applied to detect the beacon transmission and a maximum likelihood estimator is employed to estimate the beacon information embedded in the preamble. The performance of the GLRT approach to detect the adaptive beacon transmission is evaluated through simulations and practical experiments. The detection and decoding accuracies of the proposed adaptive beacon transmission are close to 100% with reasonable signal-to-noise ratio even under interference.**

***Index Terms*— Beacon, ISM band, interference, IWN.**

I. Introduction

INDUSTRIAL wireless networks (IWNs) have been regarded as an attractive communication option for industrial automation systems because of their low cost, flexible configuration and easy deployment. IWNs are usually deployed in the Industrial Scientific Medical (ISM) band. However, numerous wireless applications (WiFi, ZigBee et al.) use this band for communication, which may result in narrowband interference (NBI) and wideband interference (WBI) to IWNs [1]. Hence, it is very challenging to guarantee reliable communication for IWNs in the crowded ISM band.

Industrial wireless standard WirelessHART [2] has been released for industrial wireless communications with channel blacklist and predefined channel hopping strategies to circumvent static interferences. However, it cannot adapt to dynamic and quickly changing interfered environments since the network neither adjusts the spectrum allocation timely nor senses the environments frequently. There is usually a dedicated control channel to transmit control messages if the the network dynamically changes its communication policy. However, it is very challenging and difficult to establish and maintain a common control channel under dynamic spectrum environments [3], especially in the unlicensed ISM band [1]. Related works using a channel hopping strategy to establish the control channel are also surveyed in [3]. Nevertheless, the communication efficiency is less attractive and the reliability may be influenced by WBI. Without using a control channel, lightweight coordination strategies are designed in [4] and [5] to reliably deliver coordination information between heterogeneous networks. However, the transmission reliability cannot be guaranteed under interference.

In this letter, without using a dedicated control channel, we propose an adaptive beacon transmission strategy for dynamically scheduling the IWN to avoid channel interferences. Cognitive orthogonal frequency division multiplexing (Cognitive-OFDM) technique is adopted in the physical layer of the IWN because of its flexibility on resource allocation and superiority on interference avoidance in the crowded ISM band [1]. In the Cognitive-OFDM IWN, two different beacons are adaptively transmitted by the access point (AP) for sharing different information with field nodes (FNs) under different interference situations. The preambles of beacons are specifically designed in the PHY layer to embed the information. A generalized likelihood ratio test (GLRT) based approach is proposed to detect the beacon transmission and a maximum likelihood estimation (MLE) based method is employed to estimate the beacon information embedded in the preamble. The proposed adaptive beacon transmission is evaluated and its effectiveness is demonstrated through simulations and experiments. A traditional fixed beacon transmission strategy is also evaluated, which is ineffective under interference. However, the detection and decoding accuracies of the proposed adaptive beacon transmission are close to 100% with reasonable SNR even under high power interference.

II. System Overview

The proposing Cognitive-OFDM IWN is a star network and consists of one AP and many FNs. The AP chooses one available channel from C discontinuous channels in initialization. As shown in Fig. 1, the bandwidth of each channel is B, each channel has N subcarriers, and all subcarriers are divided into Q subbands. A resource block is one subband with a timeslot, and it can be allocated to a FN to transmit a packet. The AP conducts interference detection at the beginning of each scheduling period to identify idle subbands, then two different beacons are adaptively transmitted by the AP for sharing different information according to different interference situations. One is the control beacon to deliver the allocation information of resource blocks using a single idle subband under NBI (see the first two periods in Fig. 1). After receiving the control beacon, the FNs begin data transmission according

Manuscript received August 24, 2016; revised October 9, 2016; accepted October 9, 2016. Date of publication October 13, 2016; date of current version January 6, 2017. The work was partially supported by NSF of China under 61622307, 61633017, 61521063, U1405251, 61221003, 61290322, and 61301223, by Ministry of Education of China under NCET-13-0358 and 20130073120055. The associate editor coordinating the review of this letter and approving it for publication was N. Tran.

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Digital Object Identifier 10.1109/LCOMM.2016.2617864