Demo: Mitigating Multiple Narrowband Interferers in SDR IEEE 802.11g Diversity Receiver

Sumit Kumar
Eurecom, France
sumit.kumar@eurecom.fr

Florian Kaltenberger
Eurecom, France
florian.kaltenberger@eurecom.fr

ABSTRACT

Narrowband transmitters such as IEEE 802.15.4 (ZigBee) operating in 2.4 GHz ISM band cause significant degradation of throughput to the co-channel IEEE 802.11g (WiFi). The phenomenon is common in smart factories and smart homes which generously use ZigBee sensors for process monitoring and automation. This interferes with omnipresent WiFi in the same 2.4 GHz ISM band. In our demonstration, we will present Software Defined Radio (SDR) based single antenna and multi-antenna prototype of standard-compliant IEEE 802.11g receiver. Our receiver prototype is capable of significantly reducing the packet error rate while facing multiple co-channel narrowband ZigBee interferers. We also demonstrate a real-time SDR implementation of Soft Bit Maximal Ratio Combiner capable of decoding frames from standard compliant IEEE 802.11g transmitters. This is a first of its kind implementation to the best of author's knowledge. The demonstrations use Ettus B210 as SDR hardware and a combination of signal processing modules from two different SDR packages: GNU Radio and Openairinterface.

CCS CONCEPTS

• **Networks → Network experimentation**; *Network architectures*;

KEYWORDS

WiFi; ZigBee; Co-Channel Interference; Interference Mitigation

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1 INTRODUCTION

The rapid increase in heterogeneous wireless devices and limitation of RF spectrum in ISM band is causing Co-Channel Cross-Technology Interference (CC-CTI). Lack of centralized control in ISM band aggravates CC-CTI. For example, IEEE 802.11g (WiFi), IEEE 802.15.1 (Bluetooth), and IEEE 802.15.4 (ZigBee) operate in 2.4 GHz ISM band without any mutual coordination. Consequently, all of them suffer significant throughput degradation even though they possess CSMA/CA [7]. In this work, we choose 2.4 GHz IEEE 802.11g (WiFi) as the desired signal and IEEE 802.15.4 (ZigBee) as the co-channel interferer. We demonstrate simple yet effective methods to reduce Packet Error Rate (PER) in WiFi facing interference from multiple co-channel ZigBee interferers. In modern automated industries and smart homes, wireless ZigBee sensors are generously used and this causes CC-CTI to omnipresent WiFi devices [7] [7].

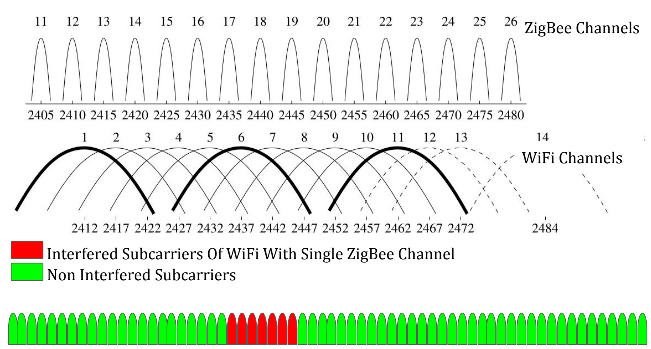

Fig. 1. WiFi Subcarriers and Single ZigBee Channel Overlap

The physical layer (PHY) of 2.4 GHz WiFi is based on OFDM which is 20 MHz wide and has 64 orthogonal subcarriers, each 312.5 kHz wide. ZigBee operating in the same 2.4 GHz is a narrowband system with a bandwidth of 2 MHz and uses Offset QPSK for its PHY. Fig. 1 shows every single channel (20 MHz each) of WiFi and 4 channels of ZigBee (2 MHz each) overlapping each other resulting in CCI. In

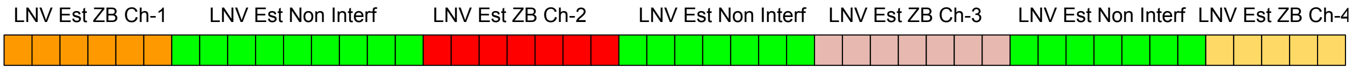

Fig. 2. LNV Vector

the event of CCI, each interfering ZigBee channel overlaps with 7 subcarriers of WiFi as shown in a zoomed view at the bottom of Fig. 1. We refer to this set of 7 subcarriers as S_{interf} (marked red) and set of the rest of subcarriers as $S_{\text{non-interf}}$ (marked green).

In the event of CCI, noise variance on S_{interf} becomes higher than $S_{\text{non-interf}}$. A naive WiFi receiver fails to capture this phenomenon which causes increased Packet Error Rate (PER) [4]. Hence, it is crucial to estimate the noise variance on S_{interf} and $S_{\text{non-interf}}$ separately and appropriately account for it during the decoding process of WiFi.

A typical WiFi receiver either uses Hard Decision Viterbi Decoder (HDVD) or Soft Decision Viterbi Decoder (SDVD). Performance of SDVD is significantly better than HDVD in an interference-limited environment because SDVD additionally takes into account the information of noise variance [4]. Hence, more accurate the noise variance estimation, better the performance of SDVD. In the presence of CCI, conventional method of noise variance estimation in WiFi [4] fails to capture the Local Noise Variance (LNV) estimates of S_{interf} and $S_{\text{non-interf}}$ region. A flat black line in Fig. 3 illustrates the noise variance estimated by a conventional method for the case when a single WiFi channel is interfered by 4 co-channel ZigBee. It clearly shows that the conventional method fails to capture the LNV of interfered WiFi subcarriers. In our work [4], we proposed to perform localized estimation and frequency averaging of noise variances, i.e., estimation of LNV corresponding to S_{interf} and $S_{\text{non-interf}}$ separately which results in elevated red lobes as shown in Fig. 3. Green circled regions in Fig. 3 show LNV of interference-free subcarriers. Further, we create a vector of noise variance estimates over entire used subcarriers of WiFi as shown in Fig. 2 and use them in SDVD to scale the Log-Likelihood Ratios (LLRs). As shown in our work [4], this results in significant reduction in PER compared to a WiFi receiver using SDVD and conventional method of noise variance estimation.

Knowing that in commercial WiFi systems, multi-antenna receivers are being widely applied such as IEEE 802.11n and IEEE 802.11ac, we have further enhanced our method for multi-antenna receivers [5]. The indoor channel, especially inside the home and industries are rich in multipath. With the appropriate spatial separation between receiver antennas, the extent of multipath fading on different antennas will be different. Hence, for WiFi and ZigBee transmitters positioned at different locations, the extent of ZigBee interference to WiFi signal on different antennas of multi-antenna WiFi receiver will be different. We use this intuitive case for applying multi-antenna diversity techniques on WiFi receiver in [5]. Our work in [5] supplemented by our previous work on LNV estimation achieves a further reduction in PER of WiFi receiver facing CCI from ZigBee.

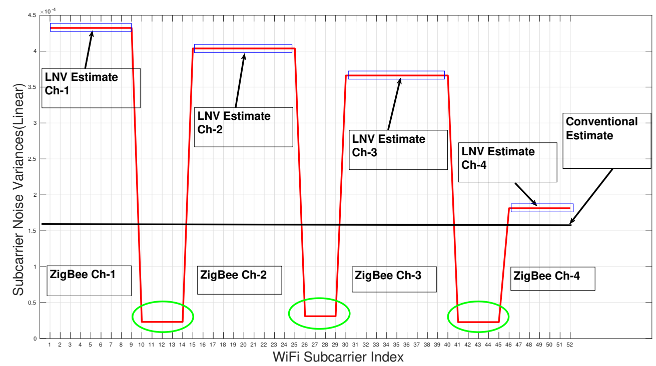

Fig. 3. Conventional vs LNV Estimates: Single WiFi Channel Interfered by 4 ZigBee Channels

2 DEMO DESCRIPTION

We divide our demo in two parts:

(1) Single Antenna Interference Mitigation
(2) Dual Antenna Interference Mitigation

2.1 Single Antenna Interference Mitigation

Single antenna based work was published in EuCNC 2018 [4]. An SDR implementation of the same with a single Zigbee interferer was demonstrated at SPAWC 2018, Kalamata, Greece. The implementation was done using Ettus USRP B210 and a combination of signal processing modules from GNU Radio [1] and Openairinterface [2]. A recording of the demo can be found in [3].

In our first demonstration, we run two parallel WiFi receivers: One conventional WiFi receiver and other based on [4]. We, then transmit a fixed number of frames from a dual-channel USRP transmitter (Fig. 5) which transmits single WiFi stream at 2.437GHz (ch-6) and 2 ZigBee streams at 2.435 GHz (ch-17) and 2.440 GHz (ch-18) without CSMA/CA, creating 100% chance of collision. Following that we display and measure the number of CRC passed frames by both the receivers for PER comparison.

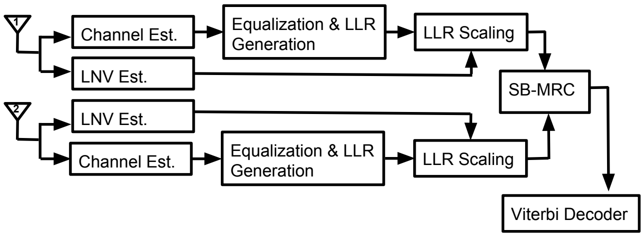

Fig. 4. Schematic of Section 2.2: Dual Antenna Solution

2.2 Dual Antenna Interference Mitigation

Dual antenna based work was published in [5]. SDR implementation of [5] is done using Ettus USRP B210 and a combination of GNU Radio and Openairinterface. In order to implement Maximal Ratio Combiner (MRC) for WiFi receiver in [5], we implemented Soft Bit Maximal Ratio Combiner (SB-MRC). SB-MRC combines LLRs obtained from different antenna branches instead of combining complex samples. SB-MRC is not only proven to be better than conventional MRC [6] but hardware implementation friendly too. To the best of author's knowledge, this is the first SDR based SB-MRC implementation working in real-time and capable of receiving packets from commercial WiFi transmitters. A brief schematic of SB-MRC supplemented by our proposed method [5] is illustrated in Fig. 4. SB-MRC developed by us is capable of performing diversity combining on any other wireless standard which uses SDVD.

The methodology of our second demonstration is same as the first demonstration.

3 DEMO SET-UP

Demo set-up is shown in Fig. 5. It consists of:

- Dual-channel SDR transmitter which generates standard compliant WiFi and ZigBee signals.
- SDR WiFi receiver(conventional method and our proposed method): Single and Dual antenna
- Faraday cage in order to avoid interference from other devices operating in 2.4GHz band during the demo.

4 DEMO REQUIREMENTS

We need a Desktop monitor (with HDMI connector) to display the results and power plugs for two laptops. Setup time is approximately 30 minutes.

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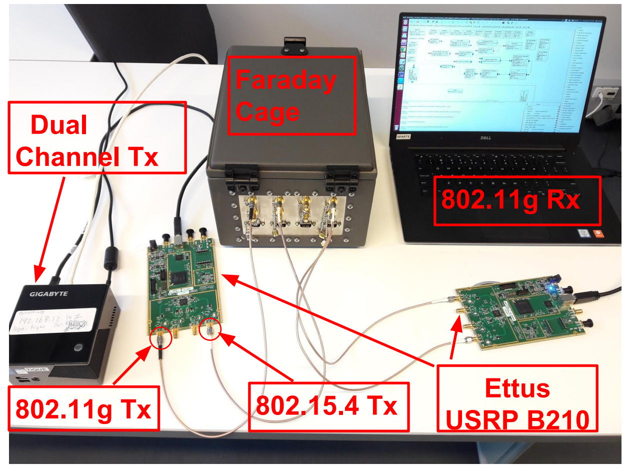

Fig. 5. Demo Set-Up

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