Demo Abstract: Cross-Technology Communication between LTE-U/LAA and WiFi

Piotr Gawłowicz*, Anatolij Zubow*, Suzan Bayhan†
* Technische Universität Berlin, Germany
†University of Twente, The Netherlands
{gawlowicz, zubow}@tkn.tu-berlin.de
s.bayhan@utwente.nl

***Abstract*—Although modern wireless technologies like LTE and 802.11 WiFi provide very high peak data rates they suffer from performance degradation in dense heterogeneous deployments as they rely on rather primitive coexistence schemes. Hence, for efficient usage of the shared unlicensed spectrum a cross-technology communication (CTC) between co-located LTE unlicensed and WiFi devices is beneficial as it enables direct coordination between the co-located heterogeneous technologies. We present OfdmFi, the first system that enables to set-up a bi-directional CTC channel between co-located LTE unlicensed and WiFi networks for the purpose of cross-technology collaboration. We demonstrate a running prototype of OfdmFi. First, we present the performance of a bi-directional CTC channel between LTE unlicensed and WiFi. Second, we show that partial channel state information of the CTC channel can be obtained. Third, we demonstrate the possibility to transmit a cross-technology broadcast packet which is received simultaneously by the two heterogeneous technologies, WiFi and LTE. During the demo, we display all the relevant performance metrics in real-time.**

***Index terms*—** CTC, WiFi, LTE-U/LAA, testbed

I. Introduction

In order to accommodate the constantly growing data traffic volume, the performance and the spectral efficiency of the wireless networks have to be constantly improved. However, further advancements in the physical layer of modern technologies are rather complex, while increasing the network capacity by moving to smaller and smaller transmission radius is usually costly. Fortunately, there are still gains to be obtained through the efficient spectrum (re)usage. This, however, requires to break with tradition of static separation of competing technologies in frequency via careful regulation (i.e. conservative bands assignment often leads to low utilization). The unchaining of frequency bands results in the increased spectrum occupancy, but at the same time poses the challenge of coexistence between heterogeneous technologies, i.e. managing cross-technology interference (CTI). As a remedy, recent research shows that an explicit and coordinated collaboration among co-located heterogeneous networks is needed to efficiently tackle CTI, ensure fair coexistence and bring performance breakthroughs in the spectrum sharing [1]–[4]. However, enabling such collaboration requires an information exchange that is hard to realize due to completely incompatible network protocol stacks. Specifically, even if a node detects CTI caused by a co-located heterogeneous neighbor, it has no clue whom it is interfering with.

II. OfdmFi Primer

OfdmFi is a CTC scheme that enables direct over-the-air communication between LTE-U/LAA base stations and WiFi nodes and hence empowers co-located wireless networks of both technologies to perform cross-technology neighbor discovery and identification, as well as establishing a control channel which can be used to implement coexistence strategies minimizing the impact of CTI. It imposes data-bearing patterns on top of OFDM transmission of underlying technologies, e.g. LTE, which can be cross-observed by an OFDM receiver of a different technology (i.e. different number/spacing of subcarriers and symbol duration), e.g. WiFi. Specifically, OfdmFi transmitter modulates the power level of the wireless resources in its OFDM grid in order to create the two-dimensional message-bearing power patterns. Note that our approach is best imagined as a punched card from the early days of computers where digital data is represented by the presence or absence of holes in predefined positions – Fig. 1.

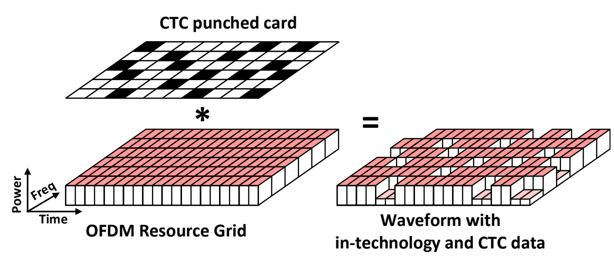

Fig. 1. OfdmFi creates CTC punched cards using OFDM resources.

As neither LTE-U/LAA nor WiFi support Tx power control at the level of sub-carriers, in OfdmFi, we have designed mechanisms that allow a OfdmFi transmitter to emulate power control at the required granularity level and hence enable successful CTC. Note that the mechanisms are implemented using standard-compliant features of both technologies and do not require any hardware modification. Specifically, we exploit the fact that an LTE scheduler can blacklist the usage of specific resource blocks in each time-slot. Whereas, in WiFi, we interleave payload bits with extra bits in the proper positions, i.e. *pattern generating bits*, hence, after passing the WiFi Tx chain the low power constellation points from the 64-QAM alphabet are used on proper subcarriers for multiple OFDM symbols to encode CTC-symbol. As normally the

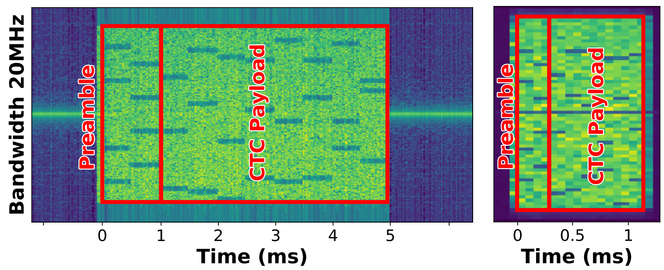

Fig. 2. Spectrograms of punched cards: LTE*→WiFi and WiFi→LTE*.

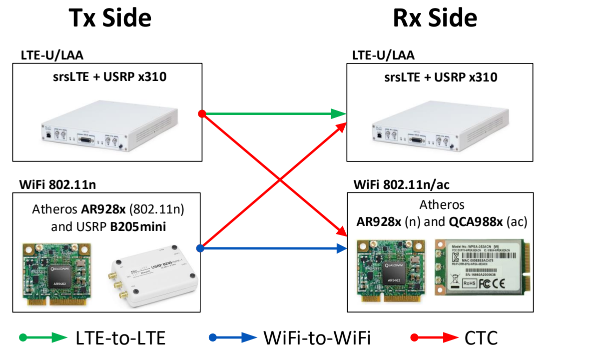

Fig. 3. Platforms used for LTE*-WiFi prototype.

QAM constellation points are used with equal probability, the power on unaffected subcarriers averaged during the CTC symbol duration is around 13 dB higher compared to the power of subcarrier forced to use only low-power constellation points. Therefore, the position of a low-power subcarrier can be easily determined, and hence CTC-symbol can be decoded. Fig. 2 presents example spectrograms of the CTC-frames. As shown, OfdmFi uses three low power CTC-symbols in each CTC-slot to encode CTC data and four symbols in the preamble to assure its uniqueness. Note that due to different physical layer parameters (i.e. sampling rate as well as subcarrier number and spacing) as well as available (emulated) Tx power control granularity level, the punched cards are different in both directions. Therefore, OfdmFi achieves data rate of 84 kbps from WiFi to LTE and 24 kbps in the reverse direction.

In order to receive a CTC-frame (punched card), the receiver performs per-subcarrier power measurements exploiting the spectrum sensing capabilities of modern wireless devices. OfdmFi introduces its own synchronization and frame detection mechanism based on CTC preamble detection. Moreover, a OfdmFi receiver follows a classical approach to overcome the channel frequency selectivity, i.e. it performs channel estimation and removes the effect of the channel from the received signal.

A detailed description of our approach can be found in [5].

III. Demonstrator Description

In our OfdmFi prototype, we use Ettus USRP SDR platforms together with modified *srsLTE* software [6] for LTE-U/LAA nodes, and COTS WiFi hardware from Atheros for the WiFi nodes. In addition, we can generate WiFi waveform using WLAN Toolbox [7] and send it using USRP SDR. The hardware setup used in our demo together with possible communication links is presented in Fig. 3. Note that we use Intel NUC mini-PCs running Linux OS as hosts for the *srsLTE* framework and WiFi cards.

Our demo consists of three following parts:

Part I: We demonstrate that OfdmFi enables cross-technology communication between unlicensed LTE and WiFi and can be easily implemented using the proposed power emulation mechanisms even on COTS hardware. Here we demonstrate the performance of a bi-directional CTC link for different transmission power values and communication distances. All relevant link statistics including data rate, goodput and frame error rate are displayed in real-time. Moreover, the payload of the CTC frame can be set.

Part II: Advanced cross-technology interference management schemes like interference nulling [1], [8] require channel state information (CSI) which is hard to obtain in case of incompatible and heterogeneous technologies. In this part of the demo, we show that partial CSI (i.e. amplitude) can be obtained from the CTC channel. Specifically, we will display the envelope (i.e. amplitude of each subcarrier of underlying technology) of the CTC channel as measured by a CTC node during the frame reception. Note that the OfdmFi receiver detects and synchronizes with the beginning of the CTC frame using a preamble detection mechanism and then measures the channel for equalization purposes. During the demo, we will change the position of the nodes to show how it affects the channel between LTE and WiFi nodes.

Part III: We showcase cross-technology broadcasting where the same data is transmitted to heterogeneous receivers. To this end, we set the same content in a WiFi frame and CTC frame imposed on top of it. Then, we trigger the single transmission of the WiFi frame and observe that both of the collocated WiFi and LTE nodes receive the message. This way, during a single transmission attempt, we jointly transmit CTC and in-technology data.

References

[1] A. Zubow, P. Gawłowicz, and S. Bayhan, "On Practical Coexistence Gaps in Space for LTE-U/WiFi Coexistence," in *European Wireless*, 2018.

[2] S. Sagari, S. Baysting, D. Saha, I. Seskar, W. Trappe, and D. Raychaudhuri, "Coordinated Dynamic Spectrum Management of LTE-U and Wi-Fi Networks," in *IEEE DySPAN*, 2015.

[3] Z. Yin, Z. Li, S. M. Kim, and T. He, "Explicit Channel Coordination via Cross-technology Communication," in *ACM MobiSys*, 2018.

[4] DARPA, "Spectrum Collaboration Challenge 2," *www.spectrumcollaborationchallenge.com*, 2017, accessed: 2020-01-18.

[5] P. Gawłowicz, A. Zubow, S. Bayhan, and A. Wolisz, "Punched Cards over the Air: Cross-Technology Communication Between LTE-U/LAA and WiFi," in *IEEE WoWMoM*, 2020.

[6] I. Gomez-Miguelez, A. Garcia-Saavedra, P. D. Sutton, P. Serrano, C. Cano, and D. J. Leith, "srsLTE: An Open-source Platform for LTE Evolution and Experimentation," in *ACM WiNTECH*, 2016.

[7] MATLAB, "MATLAB WLAN Toolbox," https://www.mathworks.com/products/wlan.html, accessed: 2020-01-18.

[8] P. Gawłowicz, A. Zubow, and S. Bayhan, "Cross-Technology Interference Nulling for Improved LTE-U/WiFi Coexistence," in *ACM MobiSys*, 2018.