Agenda Item: 8.1.2.1
Source: National Taiwan University
Title: **Preliminary Evaluation of CPS-OFDM Waveform in Case 2, Case 3, and Case 4**
Document for: Discussion and Decision

1 Introduction

New radio (NR) waveform design is based on OFDM with potential support of non-orthogonal property and multiple access [1]. In our related work [2]-[3], CPS-OFDM waveform characterized by precoder flexibility with multiple access support is proposed to be one of 5G NR waveform candidates. In this document, we provide some preliminary evaluation results of CPS-OFDM waveform in Case 2, Case 3, and Case 4 according to the parameters given in [4]-[5]. We also show the corresponding performance comparisons with legacy OFDM and DFT-s-OFDM waveforms [6].

1.1 Contributions

Simulation results demonstrate that CPS-OFDM is much more robust to asynchronous transmissions and mixed numerologies than legacy OFDM and DFT-s-OFDM.

2 Simulation Setup

Simulation parameters are chosen according to the agreements in the 3GPP RAN1 meeting [4]-[5]. Basic system parameters are listed in Table 1. Radio frequency (RF) components and channel estimation are assumed to be ideal. The details of transceiver implementation can be found in [7]. The performance metric is uncoded bit-error rate (BER) measured by the target receiver.

Table 1: System parameters.

Parameter	**Value**
Carrier frequency	4 GHz
Sampling rate	15.36 MHz
Guard interval overhead	6.7%
Data transmission bandwidth per user	720 kHz
Number of users	2
Power offset of the interfering user	0 dB
Bandwidth of guard tones between the two users	60 kHz
Modulation scheme	16QAM
Coding scheme	None
Number of antennas	1T1R
Multipath channel model	TDL-C-300 for 3 km/hr
Channel equalization	MMSE-FDE

For the setting of CPS-OFDM, as stated in [7], we choose $K = 3$, $M = 16$, $[\mathbf{d}_k]_0 = 0, \ \forall k$, $Z = 3$, and $\beta = 0.5$. At this stage, for simplicity, raised-cosine coefficients with $\alpha = 0$ and zero padding (ZP) are used for subcarrier-wise shaping and guard interval, respectively. In the future, the shaping coefficients $(\gamma_0, \gamma_1, \cdots, \gamma_{S-1})$ and the intra-subband numerology (depending on the parameters K, M, β, and μ) can be further optimized up to different use cases and requirements. Note that CPS-OFDM is very insensitive to power amplifier (PA) nonlinearity with respect to the deterioration in lowering OOB/OOSB emission.

The parameters of the target user for evaluation are shown in Table 2.

Table 2: Target user parameters.

Parameter	**Notation**	**Value**
Subcarrier spacing		15 kHz
Number of allocated subcarriers	S	48
FFT size	N	1024
Number of timing offset samples	τ	0

Case 2 is a downlink scenario in which the target user equipment (UE) is interfered by the adjacent subband transmission using 30 kHz subcarrier spacing.

Here we simplify Case 3 to be a "two-user" asynchronous uplink scenario with the same numerology, in which the signal of the interfering UE arrived at the base station (BS) is delayed by $\{0, 128, 512\}$ timing offset samples.

Case 4 is also simplified to be a "two-user" uplink scenario with mixed numerologies, where the transmission of the target UE and the interfering UE are based on 15 kHz and $\{30, 15, 7.5\}$ kHz subcarrier spacing values, respectively.

3 BER Performance Evaluation

The uncoded BER evaluation results in Case 2, Case 3, and Case 4 are presented in this section.

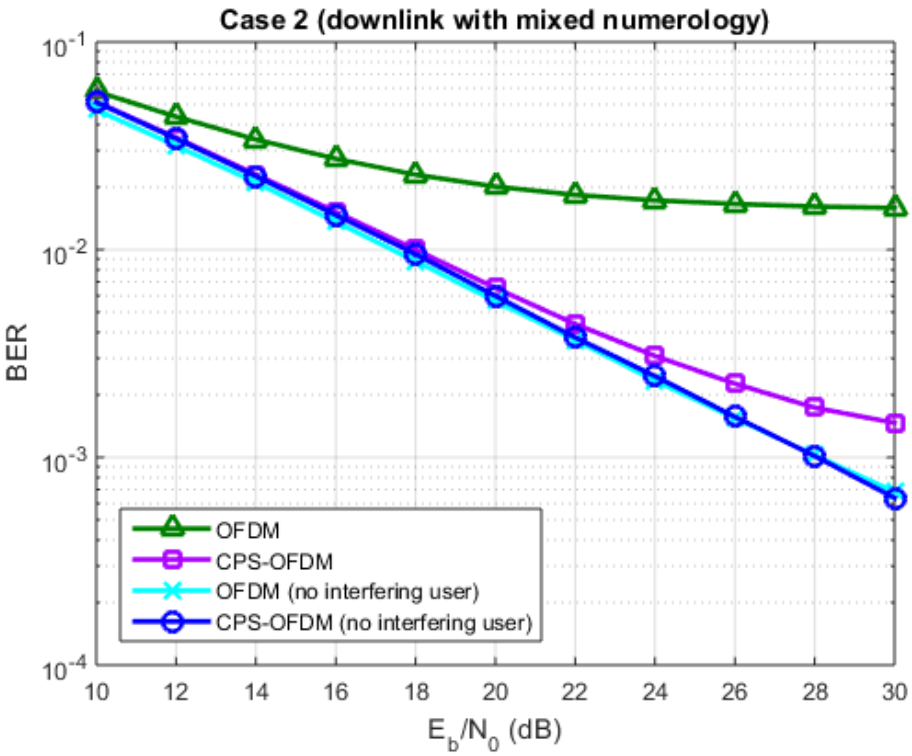

Figure 1: Robustness of CPS-OFDM to multiuser downlink with mixed numerologies

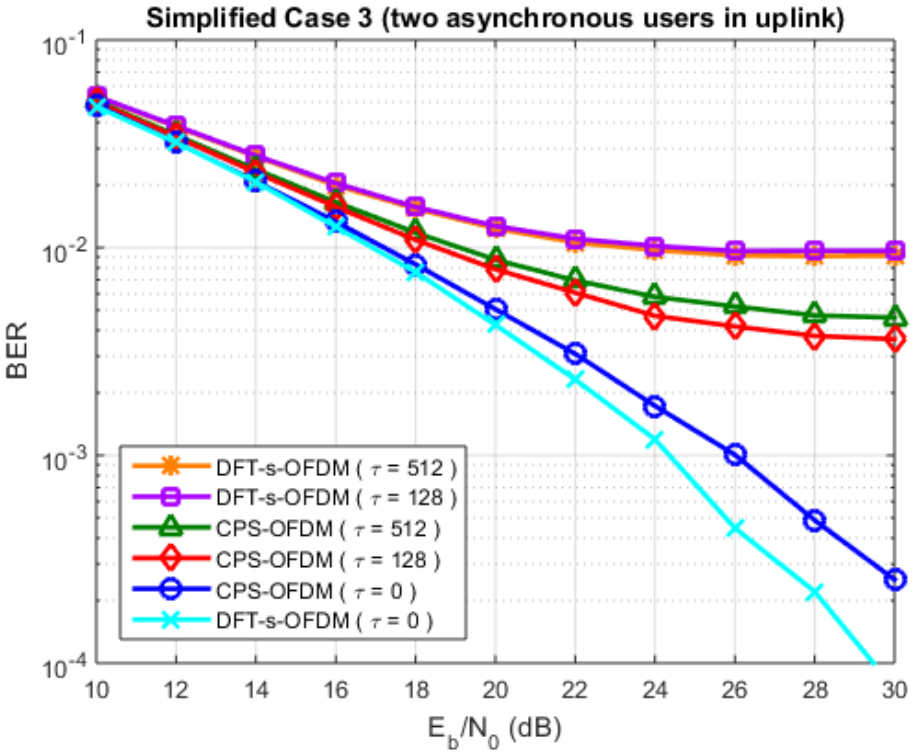

Figure 2: Robustness of CPS-OFDM to multiuser uplink with timing offset

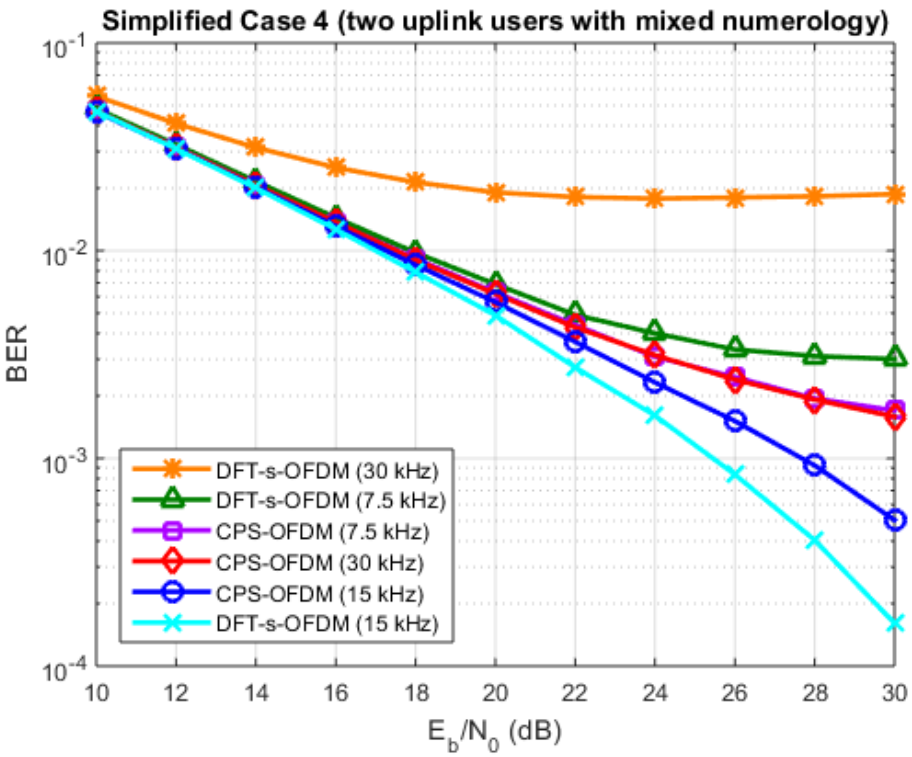

Figure 3: Robustness of CPS-OFDM to multiuser uplink with mixed numerologies

4 Summary

CPS-OFDM waveform characterized by precoder flexibility with multiple access support is designed to facilitate 5G fragmented spectrum usage. Based on the preliminary evaluation results in Case 2, Case 3, and Case 4, we summarize the observation as follows:

Observation 1: *CPS-OFDM is much more robust to asynchronous transmissions and mixed numerologies than legacy OFDM and DFT-s-OFDM.*

References

[1] NTT DOCOMO, "New SID proposal: study on new radio access technology," 3GPP RAN #71 Meeting, Technical Document RP-160351, Gothenburg, Sweden, March 7-10, 2016.

[2] National Taiwan University, "Fundamentals of CPS-OFDM waveform for 5G new radio," 3GPP RAN1 #86 Meeting, Technical Document R1-167820, Gothenburg, Sweden, Aug. 22-26, 2016.

[3] National Taiwan University, "OFDM-based waveform with precoding techniques," 3GPP RAN1 #85 Meeting, Technical Document R1-165113, Nanjing, China, May 23-27, 2016.

[4] Huawei and HiSilicon, "Way forward on assumptions for waveform evaluation," 3GPP RAN1 #84bis Meeting, Technical Document R1-163558, Busan, Korea, Apr. 11-15, 2016.

[5] Huawei, HiSilicon, NTT DOCOMO, and Nokia, "Way forward on calibration assumptions for NR waveform," 3GPP RAN1 #85 Meeting, Technical Document R1-165989, Nanjing, China, May 23-27, 2016.

[6] 3GPP, "RAN1 chairman's notes," New Radio (NR) in RAN1#85 meeting, Nanjing, China, May 23-27, 2016.

[7] National Taiwan University, "Evaluation Results of OFDM-Based Waveforms in Case 1a and Case 1b," 3GPP RAN1 #86 Meeting, Technical Document R1-167874, Gothenburg, Sweden, Aug. 22-26, 2016.