Demo: Feasibility of Simultaneous Transmit and Receive in Wi-Fi 7 Multi-Link Devices

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ABSTRACT

Multi-link operation (MLO) is a key feature of Wi-Fi 7, which is currently under development. MLO improves throughput and latency by allowing two devices to establish multiple links between them. The maximal gains are achieved when the links do not interfere, and the devices can use them independently. Otherwise, inter-channel interference prevents successful frame reception. In this case, the Wi-Fi 7 standard forbids simultaneous transmission and reception on such links. This demo shows the effect of cross-link interference in Wi-Fi and discuss that even with notable cross-link interference, simultaneous transmission and reception are still possible in some cases.

CCS CONCEPTS

• **Networks** → **Network experimentation**; **Wireless local area networks**; **Programming interfaces**.

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1 INTRODUCTION

The key feature of the IEEE 802.11be standard (Wi-Fi 7) is the multi-link operation (MLO) [1]. IEEE 802.11be introduces a multi-link device (MLD) that has several radios and use several frequency channels simultaneously. A client MLD can establish multiple links with the access point (AP) MLD. Then they can exchange data using these links simultaneously. Thus, MLO improves throughput and latency, which are the main targets of Wi-Fi 7. The highest gains are achieved when an MLD can use the channels independently, e.g., transmitting data on one while receiving data on the other (so-called Simultaneous Transmit and Receive mode, STR). Unfortunately, radio filters are not ideal and some power may leak from the transmitting channel to the neighboring ones, which induces inter-channel interference (ICI).

The ICI level depends on the quality of radio filters. The standard spectral mask limits the power leakage in the neighboring channels by $-20 \ldots -40$ dB, which makes it negligible for the devices located far from the transmitter. That is why ICI is not typically considered in many papers evaluating the performance of Wi-Fi. However, for small distances between two radios within the same MLD, the ICI prevents the device from receiving data on one link while transmitting on the other. As small smartphones will hardly eliminate the ICI, the standard introduces a non-STR (NSTR) mode, where the MLD needs to synchronize the transmission and reception of the data on various links, at the cost of reduced throughput more complicated channel access procedure.

Previous studies on ICI for outdated devices produced more than ten years ago [2, 3] mainly conclude that there are the thresholds in the distance between the devices and in the spectral distance between the channels, which determine if the radios work independently or the transmission blocks the reception. These conclusions are supported by Draft 2.0 of IEEE 802.11be, which defines two modes of MLO: STR and NSTR. However, in [4], with software-defined radios (SDR), we found that the effect is not binary: in a large area the MLD can operate as STR but requires the receiving data to be transmitted with a lower Modulation and Coding Scheme (MCS). As the properties of SDR may differ from radios used in modern off-the-shelf devices, in this demo paper, we experimentally study this effect with off-the-shelf smartphones. As no Wi-Fi 7 devices are available on the market yet, we emulate MLO with modern smartphones and APs.

2 TESBED DESCRIPTION

To evaluate the conditions when STR MLO is possible, we create a testbed, shown in Fig. 1. A client MLD communicates to an STR AP MLD using two channels in the 5GHz band. The STR AP MLD is emulated with two distant Keenetic Giga APs,

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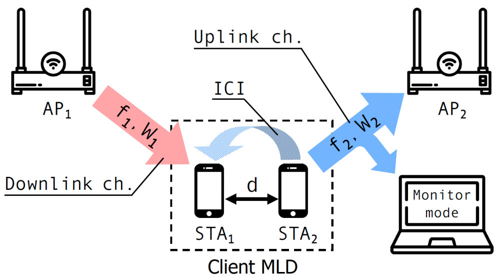

Figure 1: The designed testbed

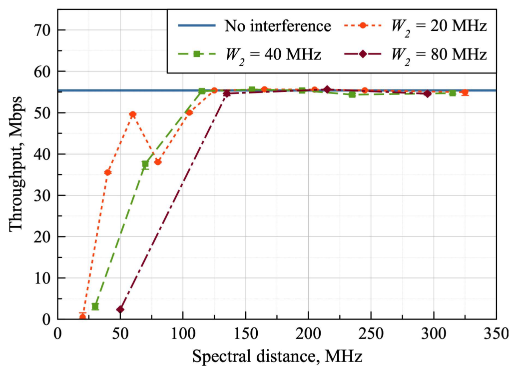

Figure 2: Downlink throughput for d = 30 cm.

denoted as AP_1 and AP_2. Two radios of the client MLD are emulated with two smartphones (Huawei P40 and OnePlus 6, denoted as STA_1 and STA_2). AP_1 transmit data to STA_1 in the first (downlink) channel of width W_1 and central frequency f_1. STA_2 transmits data to AP_2 in the second (uplink) channel of width W_2 and center frequency f_2. This transmission can prevent the successful reception of the frame in the first channel because of the ICI.

All devices support bandwidth up to 80 MHz. Beamforming and MIMO are switched off. We install additional software on the devices to generate saturated UDP traffic in both channels with frame payload of 1000 bytes. We use an additional laptop in monitor mode to control the saturation of traffic in the uplink channel, which generates the main ISI.

During the experiment, we vary W_2, but bandwidth W_1 = 20 MHz is fixed because preliminary tests have shown that otherwise AP_1 adaptively reduces it if the ICI is strong.

Let the STAs be located at d = 30 cm from each other, which corresponds to the typical size of a laptop. Figure 2 shows the dependence of downlink throughput on spectral distance $\Delta f = abs(f_1 - f_2)$ between the channels. The throughput completely restores to an interference-free level when the spectral distance exceeds 125 MHz. The results fully correspond to the previous studies and to the behavior

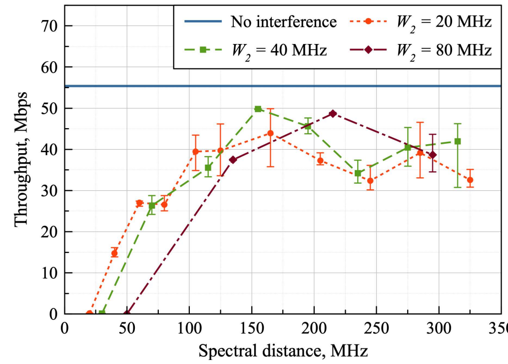

Figure 3: Downlink throughput for d = 13 cm.

assumed in the Wi-Fi 7 standard, i.e., low Δf, corresponds to the NSTR mode, and high Δf allows the STR mode.

This conclusion is not valid if the distance between STAs is d = 13 cm, which corresponds to the typical size of smartphones, see Fig. 3. Even when the spectral distance exceeds 300 MHz, the throughput reduction is about 30% because of severe near-field ICI. Though the client MLD can transmit and receive simultaneously, the AP MLD shall select a more robust MCS if the client MLD transmits some data in the uplink in the other channel. In our experiments, the ICI from STA_2 on STA_1 is stable, so the rate control algorithm selects an appropriate MCS automatically. However, in real life, the AP shall get some information from the STA about the required MCS reduction depending on the used bands.

3 DEMONSTRATION

During our demo, we will show the effects described above. Also, we are going to collect more results with other devices of participants. We kindly ask the organizer to provide us with a power supply and a table for the demo setup. We also need to deploy two APs 10–20m from the table.

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