# Novel Cross-Link Interference-Aware Scheduling for In-Band Full-Duplex 6G Wireless Networks

Janghyuk Youn
*Dept. of AI Convergence Network*
*Ajou University*
Suwon-si, Republic of Korea
jhyoun@ajou.ac.kr

Choul-Young Kim
*Dept. of EE*
*Chungnam National University*
Daejeon-si, Republic of Korea
cykim@cnu.ac.kr

Bang Chul Jung
*Dept. of ECE*
*Ajou University*
Suwon-si, Republic of Korea
bcjung@ajou.ac.kr

***Abstract*—This paper proposes a user scheduling algorithm to mitigate the critical cross-link interference (CLI) problem in in-band full duplex (IBFD) systems. In the proposed scheme, downlink (DL) user equipments (UEs) acquire effective CLI channel information from the beamformed pilot signals of scheduled uplink (UL) UEs. This allows the DL UEs to design receive beamformers that actively suppress CLI before the base station performs DL scheduling based on the mitigated interference. Simulation results demonstrate that our algorithm significantly improves the DL sum rate compared to conventional CLI measurement based schemes.**

***Index Terms*—Advanced duplexing, In-band full duplex, Cross-link interference, User scheduling**

## I. INTRODUCTION

Full duplex (FD) technology, particularly in-band full duplex (IBFD), has been continuously investigated as a promising solution to enhance the spectral efficiency of future wireless communication systems [1]. However, the practical implementation of IBFD systems faces significant challenges. One major obstacle is the severe self-interference (SI) at the base station (BS), which occurs when the transmitter's signal leaks into its own receiver. In addition, cross-link interference (CLI) arises between uplink (UL) user equipments (UEs) and downlink (DL) UEs. Mitigating these interferences is crucial for realizing the potential performance gains of IBFD.

For SI, substantial progress has been made in recent years. Advanced self-interference cancellation (SIC) techniques, spanning across RF, analog, and digital domains, have been developed, reducing SI to a manageable level and making IBFD increasingly feasible [2]. In contrast, managing CLI between UL and DL UEs presents a more complex problem. Unlike SI, which can be handled at the transceiver, CLI requires additional protocol-level procedures for effective interference control, involving multiple users.

Reflecting this importance, CLI measurement methods for CLI management have been discussed in the recent 3GPP TR 38.858, with initial proposals based on RSSI and RSRP [4]. However, methods that rely solely on signal strength measurements, such as RSSI and RSRP, are insufficient for effective CLI mitigation. Therefore, in this paper, we propose a novel user scheduling algorithm based on effective CLI channel information through pilot signals transmitted with UE-specific beamforming. Based on this information, it performs interference-aware beamforming and scheduling to enhance the overall system performance.

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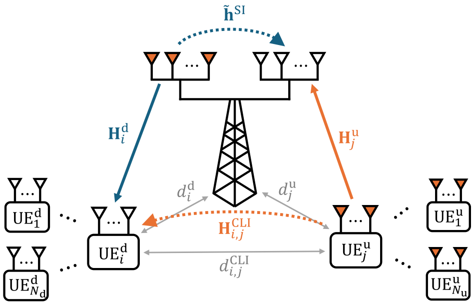

Fig. 1. System model of in-band full duplex network

## II. SYSTEM MODEL

In this section, we elaborate the system model. As shown in Fig. 1, the system consists of a single IBFD BS, $N_{\mathrm{d}}$ DL UEs, $N_{\mathrm{u}}$ UL UEs. Each number of DL and UL antennas in the BS is $M$, and the number of DL UE and UL UE antennas is $L$. Moreover, $d_i^{\mathrm{d}} \leq d_{\max}$, $d_j^{\mathrm{u}} \leq d_{\max}$, and $d_{i,j}^{\mathrm{CLI}}$ represent the distance between the BS and the $i$-th DL UE, between the $j$-th UL UE and the BS, and between the $j$-th UL UE and the $i$-th DL UE, respectively.

We define the channel between the BS and the $i$-th DL UE as $\mathbf{H}_i^{\mathrm{d}}$, that between the $j$-th UL UE and the BS as $\mathbf{H}_j^{\mathrm{u}}$. In addition, the CLI channel between the $j$-th UL UE and the $i$-th DL UE is defined by $\mathbf{H}_{i,j}^{\mathrm{CLI}}$. We assume that each element of $\mathbf{H}_i^{\mathrm{d}}$, $\mathbf{H}_j^{\mathrm{u}}$, and $\mathbf{H}_{i,j}^{\mathrm{CLI}}$ follows the complex normal Gaussian distribution with zero mean and variance of ${\sigma_i^{\mathrm{d}}}^2 = p\left(f_{\mathrm{c}}, d_i^{\mathrm{d}}\right)$, ${\sigma_j^{\mathrm{u}}}^2 = p\left(f_{\mathrm{c}}, d_j^{\mathrm{u}}\right)$, and ${\sigma_{i,j}^{\mathrm{CLI}}}^2 = p\left(f_{\mathrm{c}}, d_{i,j}^{\mathrm{CLI}}\right)$, respectively. All variances represent path-loss of each channel, where the path-loss is defined as follows:

$$p\left(f, d\right) = \gamma_{\mathrm{b}} + \gamma_{\mathrm{f}} \log f + \gamma_{\mathrm{d}} \log d \qquad [\mathrm{dB}]. \tag{1}$$

$\gamma_{\mathrm{b}}$, $\gamma_{\mathrm{f}}$, and $\gamma_{\mathrm{d}}$ illustrate the base loss parameter, the frequency loss parameter, and the distance loss parameter, respectively.

Finally, the residual SI at the BS after SIC, denoted as $\tilde{\mathbf{h}}^{\mathrm{SI}}$, is modeled as complex normal Gaussian noise with a variance of $P_{\mathrm{BS}}\gamma_{\mathrm{SIC}}$, where $P_{\mathrm{BS}}$ is the BS transmit power and $\gamma_{\mathrm{SIC}}$ is



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TABLE I
SIMULATION PARAMETERS

| Parameter | Value | Parameter | Value | Parameter | Value |
|---|---|---|---|---|---|
| $N_{\mathrm{d}}$ | 40 | $N_{\mathrm{u}}$ | 40 | $M$ | 8 |
| $L$ | 4 | $d_{\max}$ [m] | 200 | $f_{\mathrm{c}}$ [GHz] | 3.5 |
| $\gamma_{\mathrm{b}}$ [dB] | 20 | $\gamma_{\mathrm{f}}$ [dB] | 20 | $\gamma_{\mathrm{d}}$ [dB] | 35 |
| $\gamma_{\mathrm{SIC}}$ [dB] | -100 | | | | |

the SIC attenuation factor. Additionally, the transmit power of the UEs is defined as $P_{\mathrm{UE}}$.

## III. Effective CLI Channel based User Scheduling

In this section, we describe the procedure of our proposed algorithm. Here, all UEs are assumed to know their local channel by receiving the pilot signal from the BS.

### A. UL UE BF design & feedback

First of all, each $j$-th UL UE designs their own transmit BF $\left(\mathbf{v}_j \in \mathbb{C}^{L\times 1}\right)$ to maximize their communication channel gain, where the optimal BF can be easily found by singular value decomposition (SVD).

After designing BF, all UL UEs transmit the pilot signal through $\mathbf{v}_j$ to the BS. Consequently, BS can acquire the effective communication channel as

$$\mathbf{g}_j = \mathbf{H}_j^{\mathrm{u}}\mathbf{v}_j \qquad \forall j \in \{1,\cdots,N_{\mathrm{u}}\}. \tag{2}$$

Furthermore, $i$-th DL UE also acquire the effective CLI channel between them and UL UEs as follows:

$$\mathbf{g}_{i,j}^{\mathrm{CLI}} = \mathbf{H}_{i,j}^{\mathrm{CLI}}\mathbf{v}_j \qquad \forall j \in \{1,\cdots,N_{\mathrm{u}}\}. \tag{3}$$

### B. UL UE scheduling

At the BS, UL UEs are scheduled based on $\mathbf{g}_j$ using a zero-forcing with selection (ZFS) scheme [3], resulting in the scheduled set $\mathcal{S}_{\mathrm{u}} = \left\{s_1^{\mathrm{u}},\cdots,s_{S_{\mathrm{u}}}^{\mathrm{u}}\right\}$. The BS broadcasts this decision. This allows each DL UE to identify the scheduled UL UEs in $\mathcal{S}_{\mathrm{u}}$ as its actual interference sources and construct the corresponding interference channel matrix as:

$$\mathbf{G}_i^{\mathrm{CLI}} = \left[\mathbf{g}_{i,s_1^{\mathrm{u}}}^{\mathrm{CLI}},\cdots,\mathbf{g}_{i,s_{S_{\mathrm{u}}}^{\mathrm{u}}}^{\mathrm{CLI}}\right]. \tag{4}$$

### C. DL UE BF design & feedback

Each $i$-th DL UE designs a receive beamformer $\mathbf{u}_i$ to minimize interference from $\mathbf{G}_i^{\mathrm{CLI}}$ by using the left singular vector corresponding to its smallest singular value from SVD. The DL UEs then transmit pilots with their designed beamformers and feed back the resulting CLI power. Consequently, the BS acquires the effective channel $(\mathbf{f}_i)$ and CLI power $\left(g_i^{\mathrm{CLI}}\right)$ for each DL UE as:

$$\mathbf{f}_i = \mathbf{u}_i^H\mathbf{H}_i^{\mathrm{d}}, g_i^{\mathrm{CLI}} = \left\|\mathbf{u}_i^H\mathbf{G}_i^{\mathrm{CLI}}\right\|^2 \quad \forall i \in \{1,\cdots,N_{\mathrm{d}}\}. \tag{5}$$

### D. DL UE scheduling

Finally, the BS schedules the DL UEs using the ZFS scheme based on $\mathbf{f}_i$. Unlike UL scheduling, the sum rate is calculated based on an SINR that incorporates the reported CLI power $g_i^{\mathrm{CLI}}$.

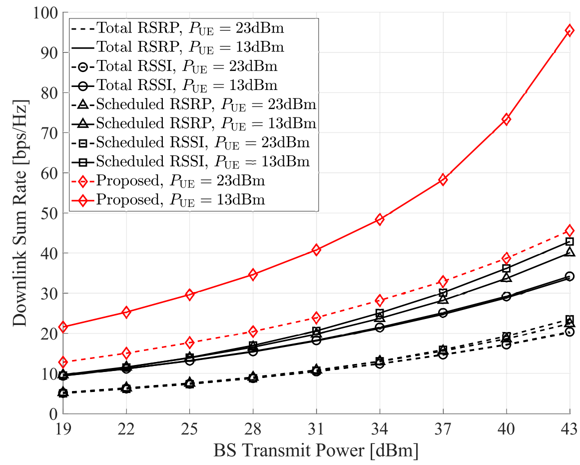


Fig. 2. Downlink sum rate according to BS transmit power

## IV. Simulation Results

For performance comparison, we implement baseline algorithms based on the RSSI and RSRP measurement methods discussed in 3GPP TR 38.858 [4]. These baselines are divided into two scenarios: 'Total', where a DL UE considers interference from all UL UEs, and 'Scheduled', where it only considers interference from scheduled UL UEs. Critically, in all baseline schemes, UEs design beamformers to maximize their own channel gain without actively mitigating CLI. The UL sum rate is excluded from the comparison for clarity, as it is identical for all algorithms.

The simulation parameters for the result of Fig.2 are described as Table.I. Fig.2 confirms that the proposed algorithm achieves a significantly higher DL sum rate compared to the baseline algorithms. This superior performance is attributed to the additional effect of DL UEs designing their beamformers based on the effective CLI channel, which actively suppresses the inter-UE CLI.

## V. Conclusion

In this paper, we proposed a user scheduling algorithm that jointly considers beamforming and scheduling to mitigate CLI in IBFD systems. The key idea is that DL UEs actively suppress interference by designing receive beamformers based on the effective CLI channel information acquired from scheduled UL UEs. Simulation results demonstrated that this proactive interference suppression leads to a significant DL sum rate improvement over conventional schemes. Future work could analyze the signaling overhead and evaluate performance with more complex scheduling criteria.

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