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Views on study of in-band full duplex (IBFD) operation in Rel. 18

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- Benefits and challenges
- Simulations
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- Potential IBFD schemes for study
- Study Objective

Motivation

- In 5G, different verticals have showed requirement of very dynamic traffic handling in both DL and UL directions along with low latency for packet delivery.
  - E.g., V2X applications, XR devices etc.
- Existing semi-static and/or dynamic resource allocation has limitation w.r.t. the latency e.g., CSI acquisition delay, scheduling delay
- Spectrum at FR1
  - Bandwidth is limited in developing countries and most operators have the lowest per bit pricing in the world
    - Capacity enhancements are critical for low costs
  - The current cells operating at full capacity
    - Efficient spectrum utilization is required
- Massive MIMO
  - Enables CSI information at transmitter using reciprocity

➡ **Support In-Band Full-Duplex communications in 5G advance**

In-Band Full Duplex (IBFD) gNB

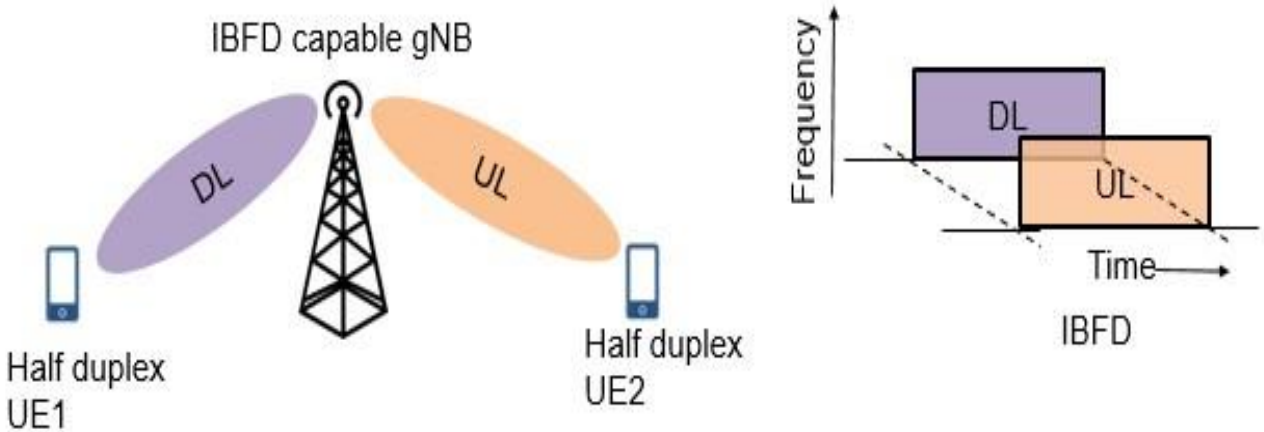


Fig. 1 In-band full duplex (IBFD) enabled gNB

Benefits and Challenges in IBFD

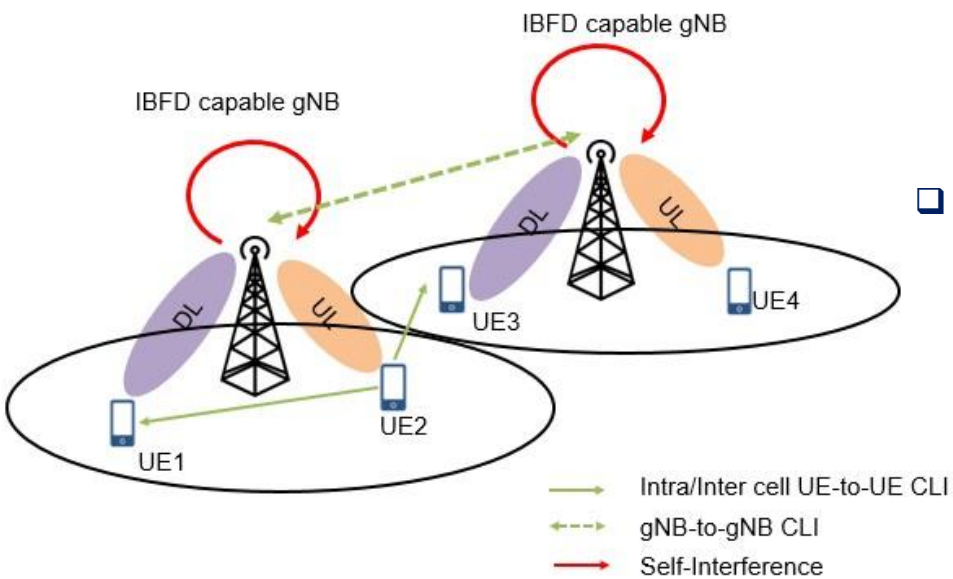
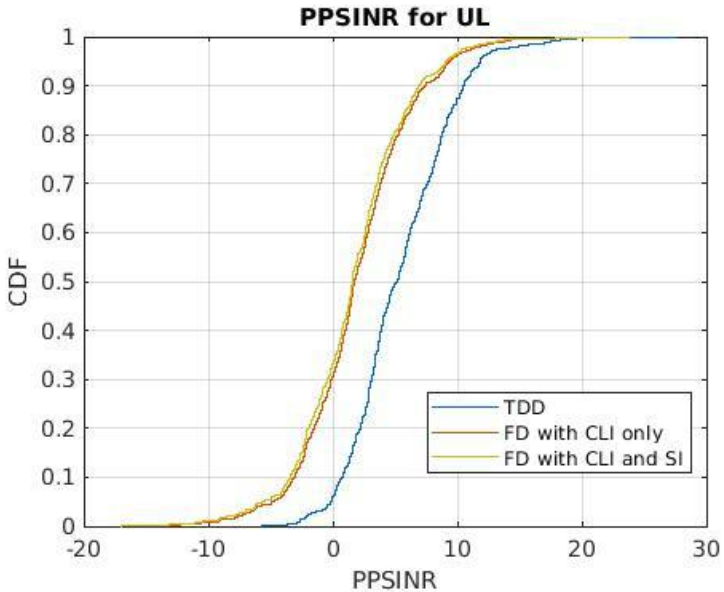
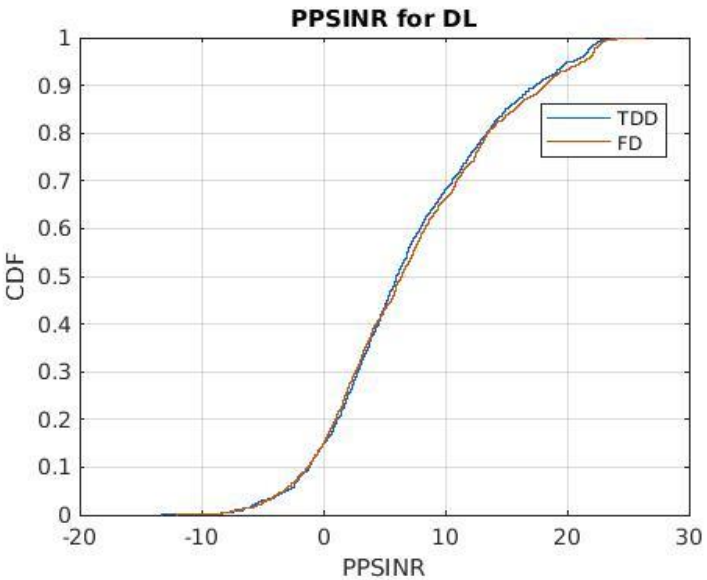


Fig. 2 Network with IBFD enabled gNBs

- Benefits
  - Increase in spectral efficiency
    - Up to 2x
  - Latency reduction
  - Efficient MIMO operation
- Challenges
  - Self-Interference cancellation (SIC) at gNB
  - Inter/intra cell cross link interference (CLI) e.g., UE-to - UE interference and gNB-to-gNB interference

IBFD simulations for Urban Micro scenario





- This shows a comparison of post processing SINR (PPSINR) FD systems w.r.t to TDD systems (Simulation parameters are in Appendix)
  - ◊ With proper CLI and SI mitigation in UL, S.E. in UL can be improved.
  - ◊ 1.9x improvement in DL spectral Efficiency (S.E.) as compared to half duplex TDD system can be achieved.

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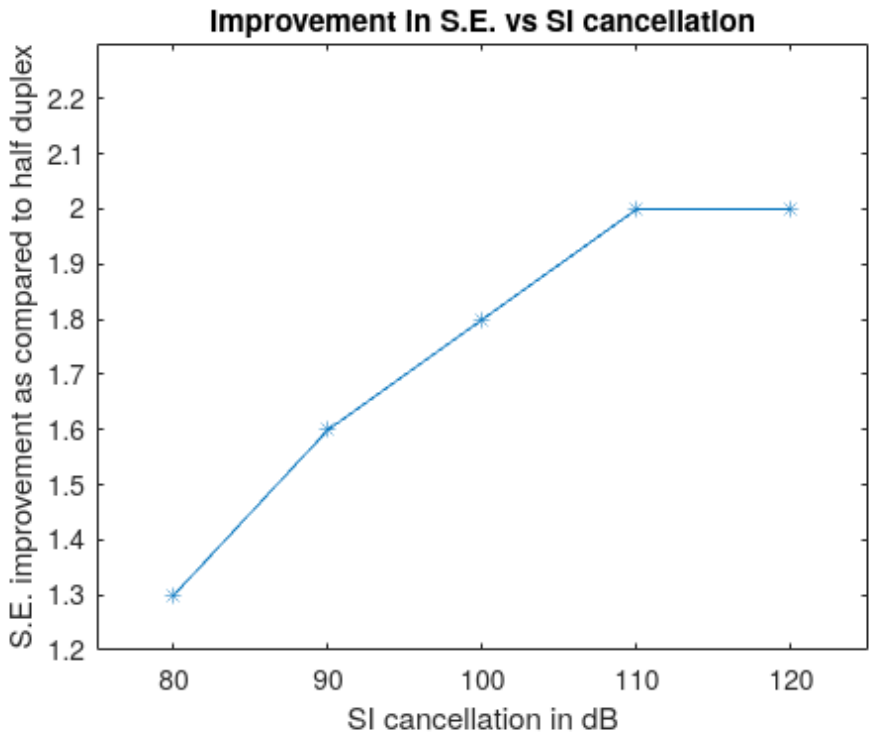

- This shows impact of SI cancellation on spectral efficiency improvement
  - To achieve up to 2x SE improvement certain limit of SI cancellation (in this case around 110dB) is necessary.
- Note: Effect of CLI in UL not considered.

IBFD Use cases

- Latency Reduction in eMBB and URLLC along with spectral efficiency improvement
- IAB system performance improvement
- Transmission and reception using multiple TRPs

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Latency in eMBB and URLLC

- legacy TDD systems drawback: Delay between scheduling grant and UL transmission will depend upon the slot structure
  - This will increase the delay which becomes more critical in URLLC operations

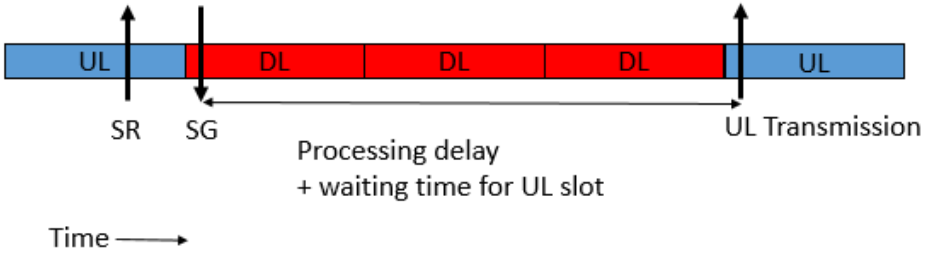


Fig. 3 Delay between SG and UL transmission in legacy TDD systems

SR : Scheduling request
SG : Scheduling grant

Latency reduction Using IBFD

- In IBFD system: Delay between scheduling grant and UL transmission only depends upon the processing delay

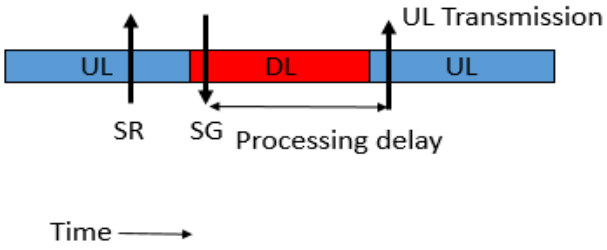


Fig. 4 Delay between SG and UL transmission in IBFD systems w.r.t. UE

SR : Scheduling request
SG : Scheduling grant

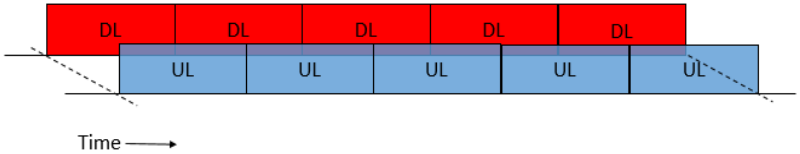


Fig. 5 Effective slot structure at IBFD gNB

- The UL transmission can consist of control information like HARQ

IAB enhancement using IBFD

- Backhaul link is mostly LOS link
  - Therefore, the rank will be limited to 2
    - This limits MIMO capability in backhaul
- IAB with 2x2 MIMO is a potential scenario for IBFD application
  - Self interference cancellation is less complex
- Basic support of full duplex with limited scope in Rel. 17
- Signaling enhancement specific to full duplex specifically for self interference measurement/mitigation

Fig. 6 IBFD capable IAB node

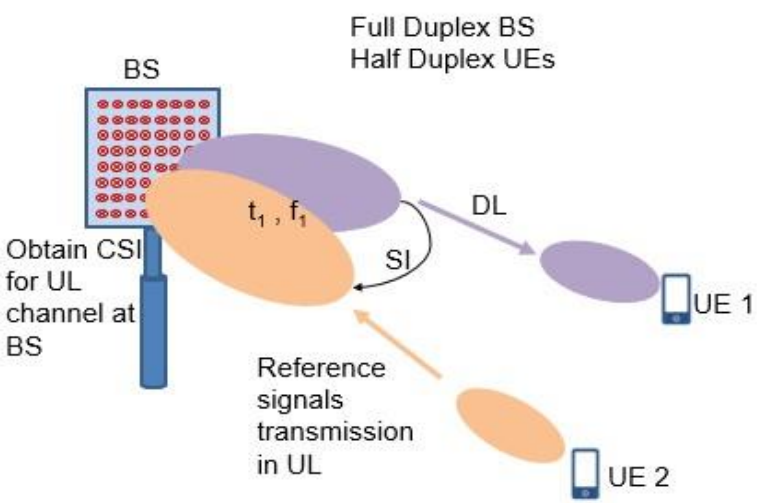
Potential IBFD schemes for study

- IBFD at gNB for data transmission (e.g., over PDSCH, PUSCH, PSSCH etc)

- Obtain Full CSI Using Reciprocity (e.g., reference signal transmission like CSI-RS, SRS etc.)
  - Using the additional resources available due to IBFD for reference signal transmission with reduced power
- Feedback Full CSI (e.g., interference profile along with CQI,PMI Rank)
  - Using the additional resources available due to IBFD for reporting CSI information
- Control Overhead Reduction by using the additional available resources due to IBFD for control channel transmission.

Obtain Full CSI Using Reciprocity

- Benefits
  - Reference signal and CSI overhead reduction
  - Reduced feedback delay error
  - Support high speed mobility
  - Better channel estimation as a greater number of reference signal resources available
- Challenges
  - Effective management of co-channel BS-BS and UE-UE interference
  - Efficient reference signal design to utilize full benefit



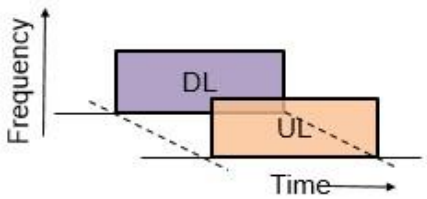


Fig. 7 Reference signal transmission in UL to obtain CSI

Feedback
Full CSI

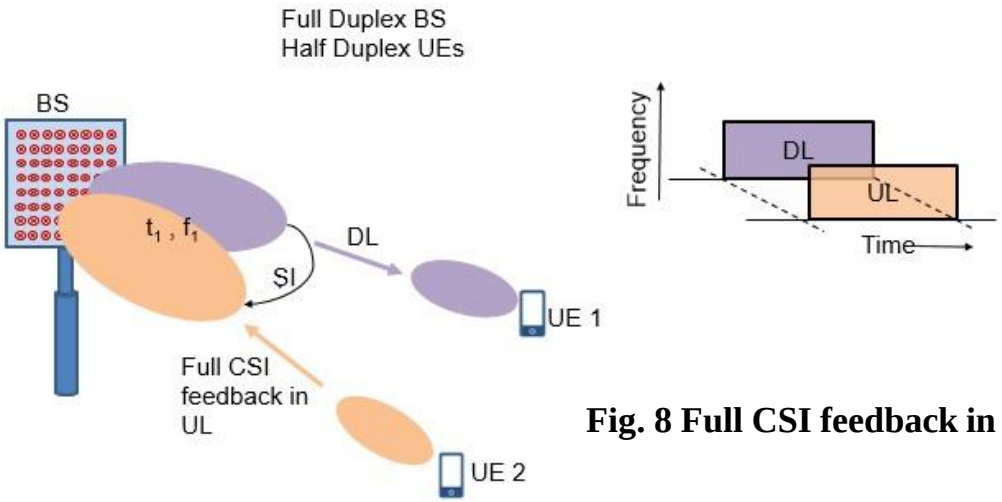
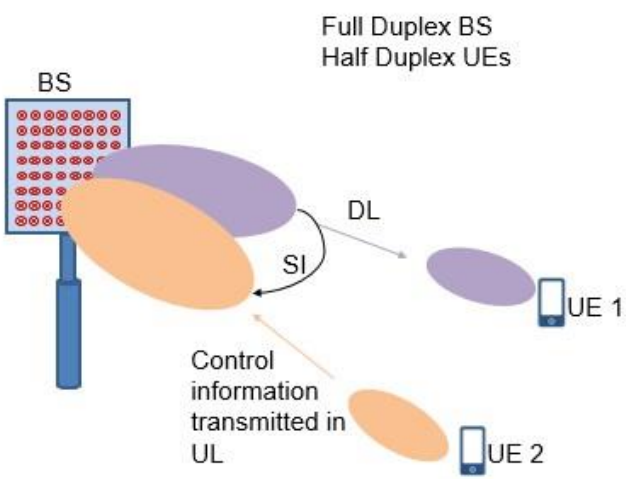


Fig. 8 Full CSI feedback in UL

- Benefits
  - CSI overhead reduction
  - Reduced feedback delay error
  - Reduced CSI quantization error
  - Reduced latency
  - Can be used in eMBB and URLLC applications

- Challenges
  - Effective management of co-channel BS-BS and UE-UE interference
  - CSI framework modification to get full benefit

Control Overhead Reduction



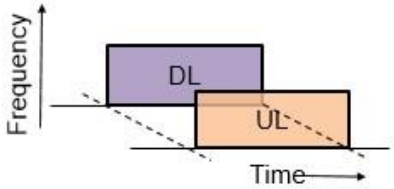


Fig. 9 Control information transmission in UL

- Benefits
  - Control signal overhead reduction
  - Low latency HARQ feedback
    - Applicable in URLLC like latency critical operations
- Challenges
  - Effective management of co-channel BS-BS and UE-UE interference
  - Efficient control channel design to utilize full benefit

Study Objective

- Study feasibility of full Duplex operation
  - Define/prioritize scenarios for Full Duplex operation in terms of some aspects such as:
    - Full duplex operation in gNB and/or UE
    - Frequency resource utilization (e.g., separated frequency resource in a carrier is used for DL and UL, same frequency resource in a carrier is used for simultaneous operation of both DL and UL), etc.
    - Frequency range (e.g., FR1, FR2, FR-X)
    - Deployment scenario (e.g., Rural, Urban, Indoor, Isolated)
    - Antenna configuration (e.g., Single-/multi-panel, Co-located/distributed antenna),
- Study standardization impacts and potential enhancements for the selected scenarios for full Duplex operation in unpaired spectrum such as: [RAN1]
  - Resource allocation (e.g., BWP)
  - Interference handling (i.e., self-interference, UE-UE interference, gNB-gNB interference)
  - MIMO operation (e.g., Beam management, Reference signal, CSI measurement/report, Multi-TRP/Cell)
  - Duplex adaptation
  - Flexibility of IBFD for different NR channels e.g., data channel , control channel and RS signals

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Appendix (Simulation parameters)

Cell ISD	200m
BS Tx power	30dBm
Max. UE Tx power	23 dBm
UE antenna	1
BS antenna	2
BW	10 MHz
SCS	15 KHz
UEs Per sector	10
SI cancellation	118dB (including Passive, analog, digital)
Channel Model	Based on 38.901
Carrier frequency	2.5 GHz

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