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MIMO Enhancements for Rel-18

RAN Rel-18 Workshop

28th June – 2nd July 2021

RWS-210075

Nokia, Nokia Shanghai Bell

MIMO Enhancements: Motivation

Release 16 added important steps to make Type II codebook and MU-MIMO operation reality with low overhead feedback

Release 17 to finalize especially multi-TRP operation beyond PDSCH to cover PUSCH and also PDCCH/PUCCH

In Release 18 important to focus on clear improvements, not just extending existing functionality

- Keep concise structure in the WID, with minimum number of Feature Leads

In particular the following areas are relevant for Rel-18 enhancements:

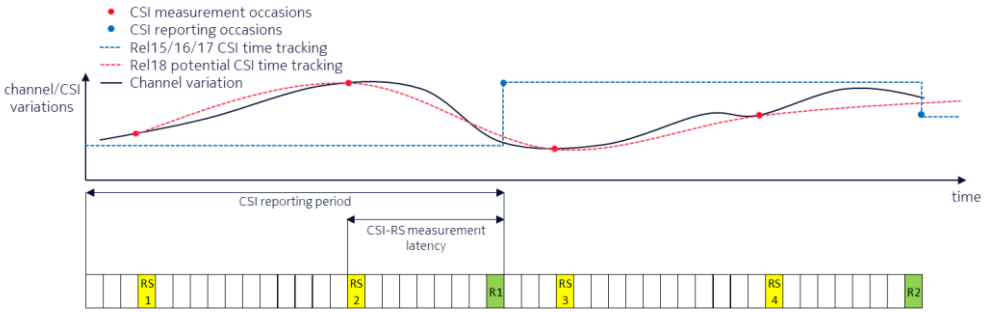
- **CSI acquisition enhancements**: performance drops significantly at moderate-to-high speeds already (see slides 5&6)
- **UL MIMO enhancements**: in Rel-16 and Rel-17 the focus has been on DL MIMO enhancements, reducing the gap between DL and UL performance, motivated by the desire to equalize the UL and DL capabilities/performance given the emergence of UL-heavy applications and advanced UEs/CPEs/IAB nodes/Industrial devices
- **Multi-TRP operation**: only DL is supported with mTRP in Rel-16 and Rel-17, UL performance can be enhanced by mTRP operation in UL, e.g. taking into account UEs with multiple panels
- **Multi-beam enhancements**: some topics are not expected to fully conclude in Rel-17 due to lack of time, in particular related to beam enhancements, e.g. L1/L2 mobility

MIMO Enhancements: Objectives

- **CSI acquisition enhancements (FR1 & FR2)**
  - CSI acquisition enhancements for higher mobility UEs / High Speed Trains
  - Lower the latency of initial acquisition and improve the CSI processing timeline
- **UL enhancements (FR1 & FR2)**
  - Support higher rank on UL, frequency selective precoding for >4TX precoders (FR1)
  - Support multi layer PUSCH transmission with DFT-S-OFDM
- **Other topics pending on Rel-17 WI progress**
  - MPE leftovers (if any) (FR2)
  - MPUE with different panel capabilities (FR2)
- **Multi-TRP operation (FR1 & FR2)**
  - Support more realistic assumptions (e.g., different TA, beam switching gap) for Multi-TRP operation
  - Support UL transmission from a multi-panel UE to two TRPs (simultaneous transmission from two UE panels)
  - Multi-codeword encoding for Multi-TRP transmission with single-DCI
- **Multi-beam enhancements (FR1 & FR2)**
  - Enhanced TCI framework: enablers for dynamic configuration of separate TCIs
  - Improvements to L1/L2-centric mobility (RAN1/RAN2) (FR1&FR2)
  - Latency and overhead reduction, including
    - Support of P3 narrow beam alignment procedures
    - Enhanced UE-assisted UL beam switching
  - Enhanced interference indication

CSI acquisition enhancements: Background

- **Enhancing CSI reporting for medium and high mobility (FR1 & FR2)**
  - Current CSI framework does not consider time variations; each report is an independent snapshot of the channel
    - Introduce mechanisms to track CSI variations in time for higher mobility UEs
    - In fast varying channels, achieve higher CSI accuracy and lower overhead compared to reducing the CSI reporting period

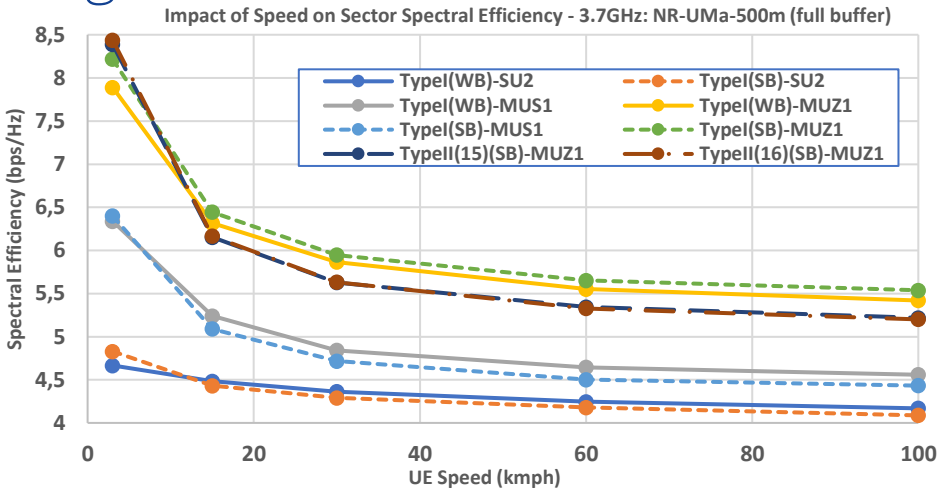


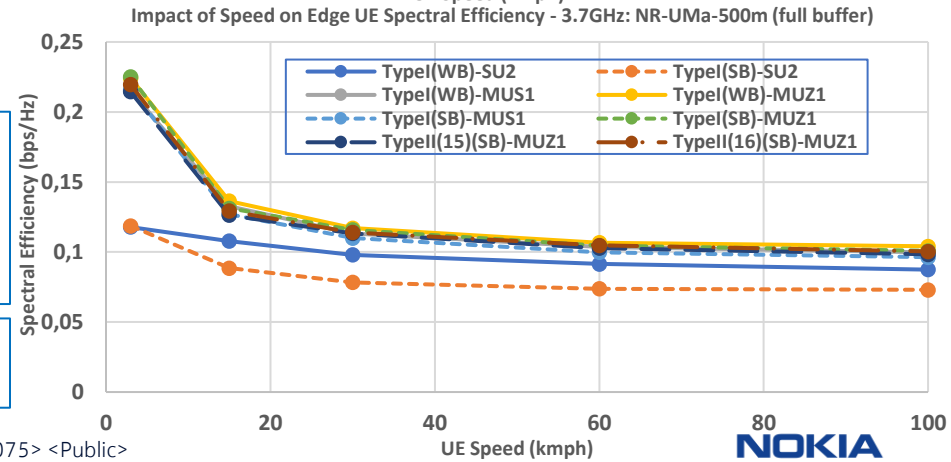
- **Potential means for improving the CSI processing timeline**
  - Faster initial CSI acquisition after (re)configuration
  - Currently, 'low latency' is possible only with Type-I SP, only 'high latency' is available for Type-II/eType-II
    - Study the use of DMRS for CSI acquisition, to reduce the measurement delay, CSI calculation delay (e.g., fewer ports to measure)
    - Improve timeline for certain CSI quantities
  - Currently, outdated CSI measurements may be reported, e.g., when DRX is configured or in case of CPU overbooking
    - Reduce maximum latency between a CSI-RS measurement and CSI reporting

CSI acquisition enhancements: Background

Impact of speed on CSI reporting

- **Both Type I and Type II/eType II suffer significant degradation already at 15 km/h, with Type II/eType II degrading more rapidly**
  - 30% SE loss at 15 km/h for Type II/eType II relative to 3 km/h; 40% loss at 60 km/h
  - 20% SE loss at 15 km/h for Type I relative to 3km/h; 30% loss at 60 km/h
- **Subband CSI impacted more that wideband CSI in SU-MIMO operation**
  - WB Type I performance overtakes SB already at 15 km/h
  - SB reporting degrades more at cell edge





Parameters:
- 3.7GHz US C-Band, ISD=500m, NR-Uma
- All UEs are outdoors and at the same speed
- 10MHz BW, 15kHz SCS,
- Minimum feedback delay = 5msec
- CSI feedback periodicity = 40msec

SU2 = SU-MIMO with max rank 2
MUS1 = MU with SU-MIMO weights (i.e., no ZF) with max rank 1 per UE
MUZ1 = MU with regularized ZF and max rank of 1 per UE

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CSI acquisition enhancements: Background

Impact of speed on CSI reporting

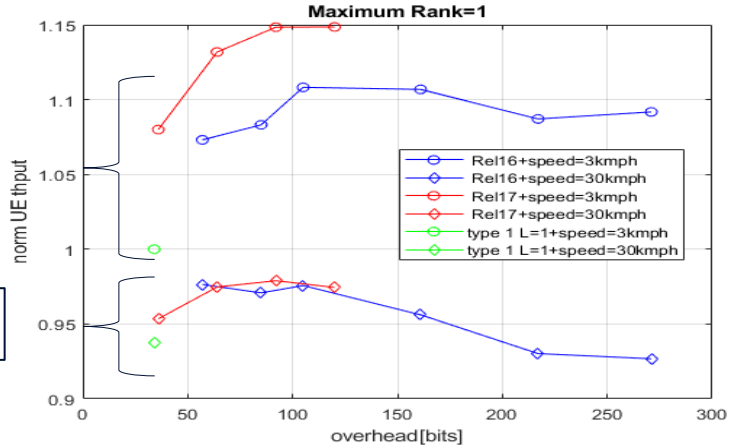
- **All feedback schemes suffer significant degradation at 30 km/h, with eType II and fePS Rel17 degrading more rapidly**
  - Relative UE thput gain of fePS Rel17 ,eType II over Type 1 vanishes at 30kmph
  - Relative UE thput gain of fePS Rel17 over eType II is significantly reduced at higher speeds
  - Up to 20% loss in UE thput at MR2 for fePS Rel17 at 30kmph relative to fePS Rel17 at 3kmph
  - In a high LOS scenario, weaker beams/weaker FD components age more quickly, i.e. results in a worse performance.

Parameters:

- 32 APs, 2GHz, ISD=200m, NR-Duma
- Bursty traffic, RU ~65%, MU-MIMO
- All UEs are outdoors and at the same speed
- 20MHz BW, 15kHz SCS,
- Minimum feedback delay = 5msec
- CSI feedback periodicity = 5msec
- Rel.16 regular (configs 1-6)/ Rel.17 fePS ($K_1 = 16, \mathrm{P} = 32, \beta = 0.25,0.5,0.75,1$)
- UE thput normalized w.r.t Type I @3kmph

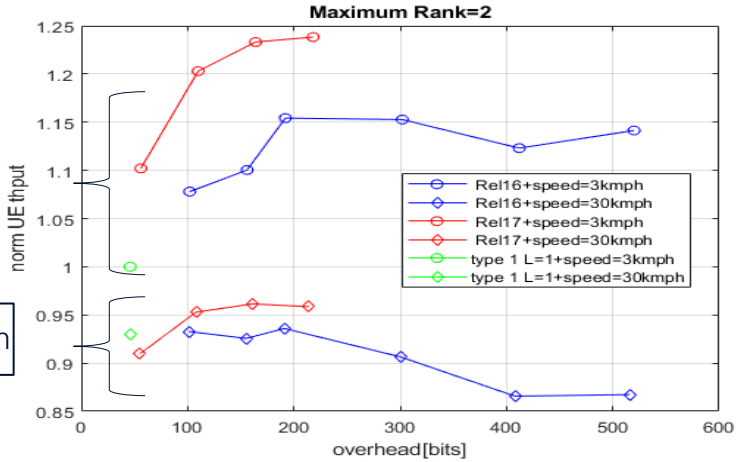
3kmph

30kmph



3kmph

30kmph



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Uplink enhancements: Background

- **Uplink enhancements (FR1 & FR2)**
  - **Support higher rank on UL, frequency selective precoding for >4TX precoders (FR1)**
    - Introduction of IAB and new vertical applications (video camera, robots, drone etc) are requiring for UL enhancement
      - Support for 8 TX codebook and SRS enhancement
      - 8TX with frequency selective precoding did show decent throughput gain.
  - **Support multi layer PUSCH transmission with DFT-S-OFDM**
    - DFT-s-OFDM has advantage of coverage gain over CP-OFDM, however it has a limitation of supporting rank-1 only. Especially for FR2, PAPR gain has more potential to improve UL coverage even when higher rank is supported.

Multi-beam enhancements: Background

- **Support further overhead and latency reduction enhancements**
  - Enable dynamic TCI state switching for periodic RSs
    - In Rel15/16/17 TCI state for periodic RS can be switched only with RRC
  - Reduce activation latency of TCI states
    - In general, MAC based activation used for beam switching assumes always UE's panel switch-on latency (3 ms) which is not needed in all cases (beams under the same panel or panels that are active simultaneously)
  - Support standalone A-TRS
    - Currently P-TRS needs to be configured, A-TRS can only be associated to P-TRS
    - Use cases: A-TRS upon P2 CSI-RS TX beam, NR-U
  - Support dynamic operation of joint and separate TCIs
    - Rel17 expected to configure already in RRC the TCI state being either joint between DL and UL or separate
    - Consider pool of TCI states in RRC and MAC to construct both joint and separate DL/UL TCI states (activation step)
- **Support interference handling enhancements**
  - In Rel-15/16 DCI based interference indication (DMRS CDM group and ports) supported but no explicit interference regarding to other interference
  - Assist dynamically UE to determine its RX according to indicated interference situation
- **UE-assisted UL beam switching**
  - In Rel15/16/17 the gNB explicitly configures/activates/indicates spatial source/TCI state for the UE in uplink, based on L1-RSRP reporting of best DL RS(s)
  - Facilitate UE-assisted UL TX beam selection while keeping control at gNB to account e.g. MPE and beam switching overhead
    - E.g. for dynamic grant and configured grant PUSCH

Multi-TRP enhancements: Background

- Support more realistic assumptions for Multi-TRP operation
  - In both Rel-16 and 17, multi-TRP framework assume unrealistic assumptions (e.g. same TA, no switching gaps)
    - E.g. : In realistic network deployment scenarios, multi-TRP transmissions may not be received within a CP duration.
  - RAN1 shall **identify the realistic assumptions** for supported M-TRP modes (including multi-DCI multi-TRP, PDCCH/PUCCH/PUSCH repetition, and inter-cell multi-TRP operation), and further **consider the required enhancements and changes** to support them.
- Support simultaneous UL transmission from two UE panels
  - All multi-TRP UL schemes (or operation) defined in Rel-16/17 are TDM schemes.
    - E.g. multi-DCI based multi-TRP operation has to guarantee non-overlapping PUSCH scheduling towards multiple TRPs, Rel-17 PUCCH/PUSCH schemes are only TDM.
  - RAN1 shall consider simultaneous UL transmission towards multiple TRPs, including,
    - PUSCH/PUCCH with **fully/partially overlapping in time and frequency** for multi-DCI multi-TRP.
    - **SDM and FDM repetition schemes** for Rel-17 PUCCH/PUSCH schemes
- Multi-codeword encoding for Multi-TRP transmission with single-DCI
  - In Rel-16, single-DCI multi-TRP operation was restricted to use legacy codeword layer mapping.
  - With a simple **extension on codeword layer mapping**, s-DCI based M-TRP operation can be extended to transmission of two codewords where link adaptation can be done per CW basis (optimized per TRP).
- Extending unified TCI framework to Multi-TRP operation.
  - Unified TCI framework is a redundant signalling framework, which is not necessary for multi-TRP operation.

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