

3GPP TSG RAN Rel-18 workshop  
Electronic Meeting, June 28 - July 2, 2021

RWS-210003

# eMBB PHY Enhancements

for Rel-18

AI: 4.1

Qualcomm



# Motivation

- A large number of projects is expected to be proposed for Rel-18 consideration
- 3GPP will have to **balance**:
  - Projects enhancing eMBB services tailored for smartphones with enhancements targeting verticals
  - Continuations of previous projects with projects for new areas
- In this contribution we list the eMBB enhancing PHY layer areas that we believe are important for Rel-18 consideration
- In general, we discuss features in the areas of MIMO, UE power savings, NR-U, and mobility
- A companion contribution in RWS-210004 lists the eMBB upper layer enhancements

# eMBB PHY Areas (1/2)

## General Areas

- **High capability UEs and CPEs**

- Enhanced support of 6/8 Rx UEs exploiting demod-architecture & antenna correlation (CSF, SRS, DMRS)
- Higher order modulation (DL): 4096-QAM (FR1) & 1024-QAM (FR2)
  - Consider looking into techniques enabling less stringent EVM requirements at Tx
- UL transmission with >4 ant/layers (codebook and non-codebook based)
- UL MIMO improvement via UL TPMI enh (higher resolution & sub-band)

- **UL improvements**

- Improved UL CA support via UL Power Control enhancements, i.e., “uplink dynamic power aggregation” (see next slide)
- UE panel/Tx specific operation (e.g. different FFT/TA/feedback/demod per panel/Tx) for transmission of PHY channels (see mTRP/mPanel/mTx)

- **mTRP & Multi-Panel/Multi-Tx UE**

- Simultaneous UL transmissions
  - Simultaneous PUCCH/PUSCH/SRS transmission to same/multiple TRPs
  - Simultaneous beams for one PUSCH: multi-panel TPMI enhancements for codebook based & necessary enhancements for non-codebook based
  - UL beam selection for multi-beam transmission
- Extension to UL-only mTRP operation (w/o corresponding DL mTRP op)
- Cross-carrier scheduling for mTRP, SPS for (mDCI based) mTRP

- **Mobility**

- CSI & CSI-RS enhancements for medium & high mobility scenarios
- L1/L2 based inter-cell mobility aiming at applying to a larger geographical area vs. Rel-17 (FR2)

- **NR-U**

- Improvements related to 6GHz band regulations (FCC & ETSI)
- FR2x specific enhancements (multi-TTI, beam switching gap, beam squinting for very WB Tx, etc.)
- SL-U discussed as part of Sidelink evolution

- **Multi-beam operation**

- Enhancements around UE initiated beam switch events
- Beam indication/training overhead & latency reduction (beyond Rel-17)

- **Overhead reduction by enhanced PHY adaptation**

- Adaptive DMRS, SRS

- **Other items not completed in previous Releases:**

- Link efficiency improvements for PUCCH
- SRS on dormant BWP

# eMBB PHY Areas (2/2)

## Uplink dynamic power aggregation

### • Background and Motivation

- 4G DL CA has a long history of successful expansion
- In contrast 4G UL CA is not successfully deployed
  - In the UL, the most sought-after resource is **UE transmit power**
  - In a large portion of a cell coverage area, the UE cannot efficiently use more than a fraction of the BW of a single carrier => it is perceived to be pointless to aggregate more UL CCs

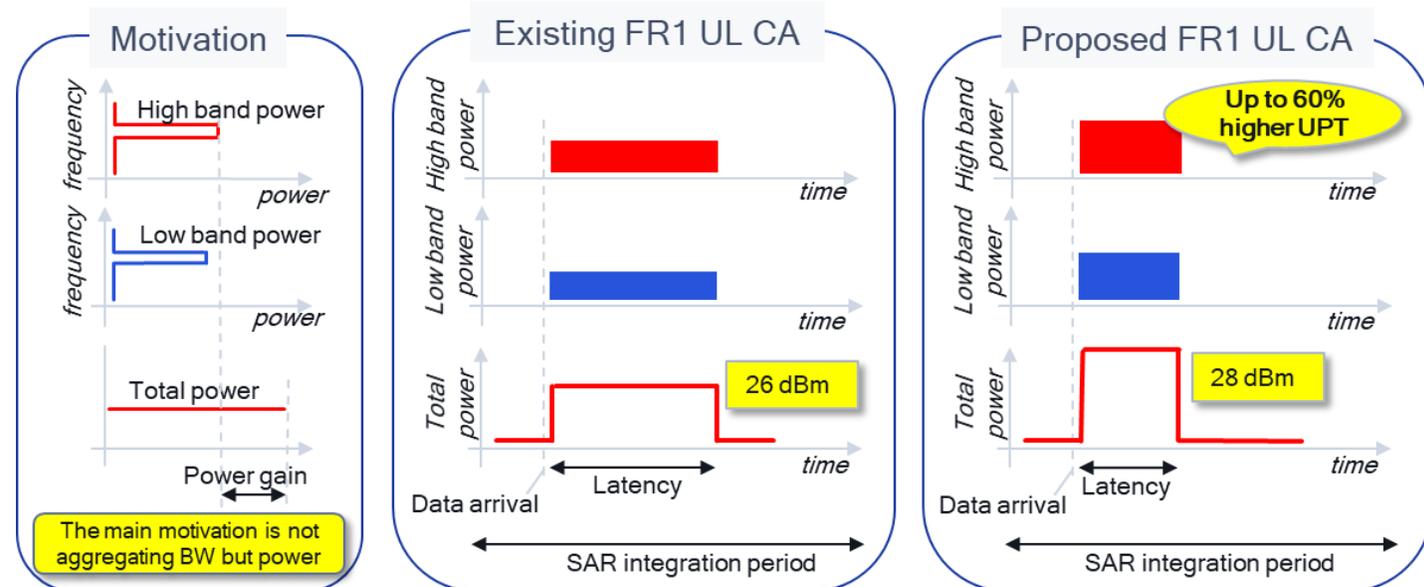
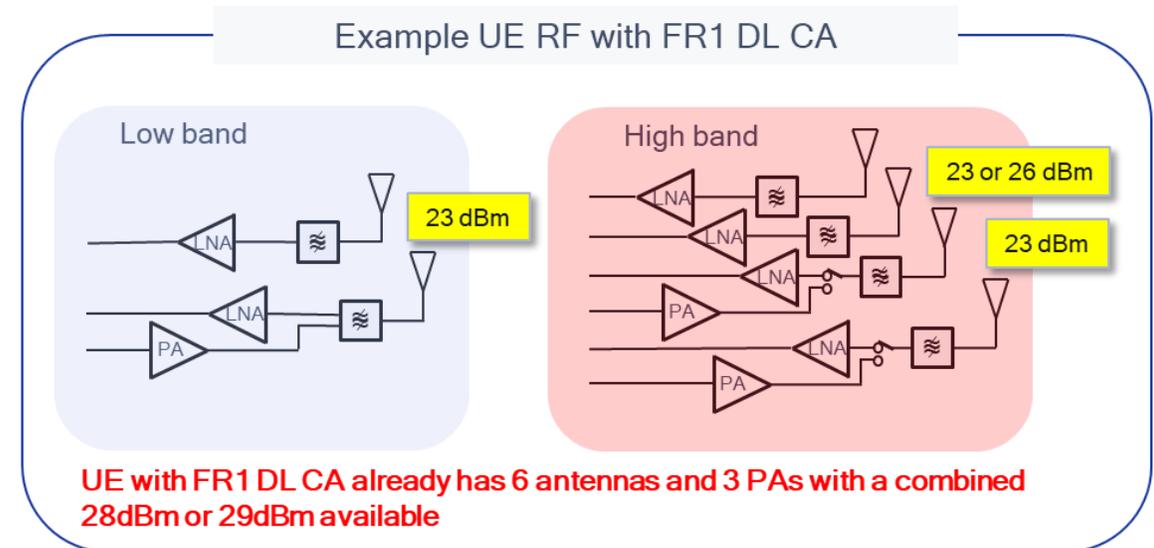
- **Every band that the UE supports represents more transmit power potential**

### • Proposal: Introduce UL dynamic power aggregation in order to tap into this resource

- Allow using to total available short term peak power
- Long term (30 second) duty cycle control by the UE to maintain SAR compliance

### • Benefit

- Provides needed UL peak data rate boost and correspondingly increased UL User Perceived Throughput



# Annex

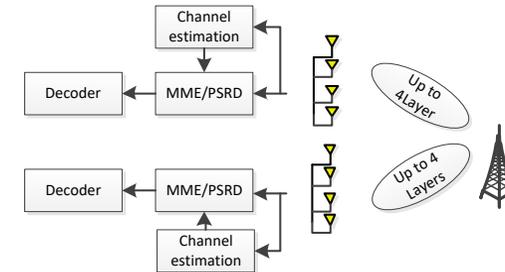
Further details on individual proposals

# MIMO Enhancement - DL 6/8Rx (1/2)

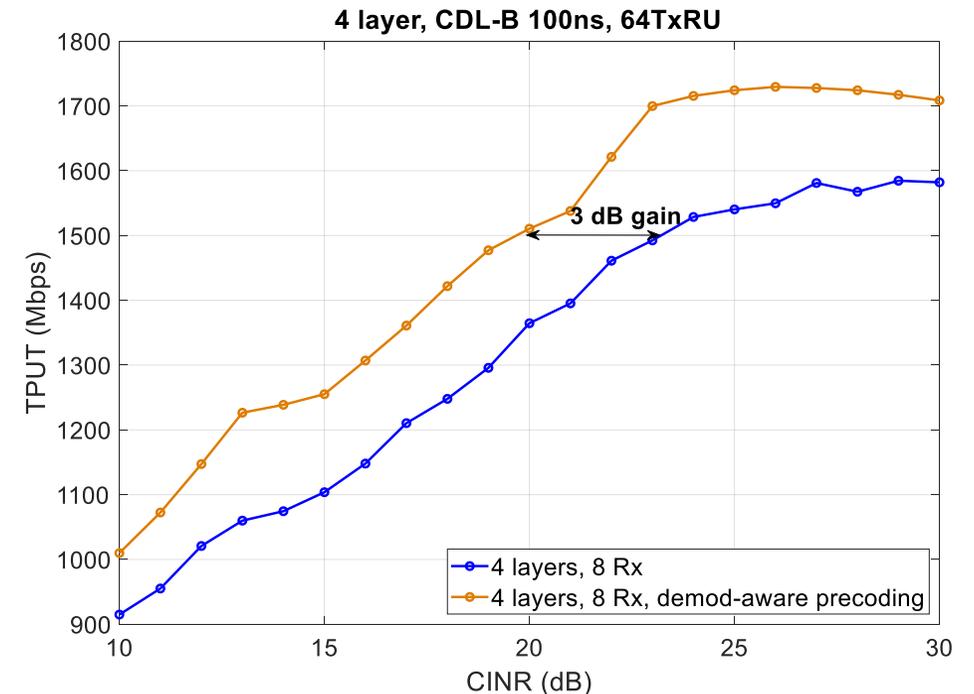
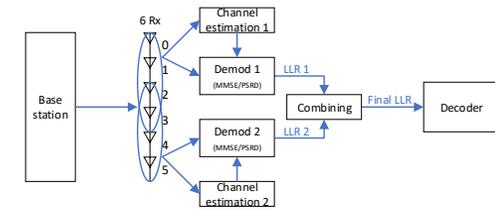
Enhancement for advanced UEs with large # Rx antenna (> 4 antennas)

- Motivation
  - Support various demod-architectures
  - Improve higher-order MIMO performance
  - Reduce sounding overhead
- Key aspects
  - Exploit demod-architecture (e.g., LLR-combining)
    - Optimize CSF for each 4 Rx group
    - Optimize codeword to layer mapping
  - Higher-order MIMO optimization
    - DMRS overhead reduction
    - Null-DMRS for better demod Rnn estimation
  - Exploit antenna correlation
    - Partial spatial sounding to reduce SRS overhead
    - UE-assisted full channel reconstruction

SDM-based demod



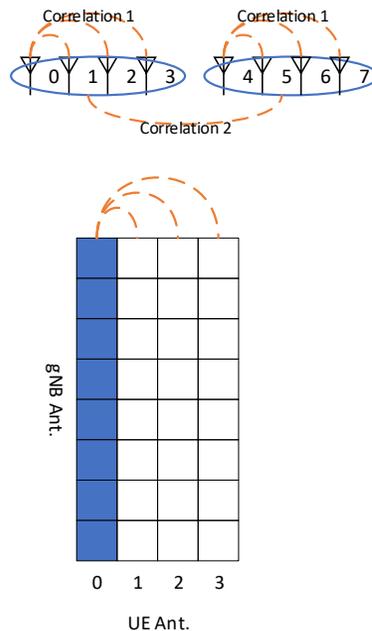
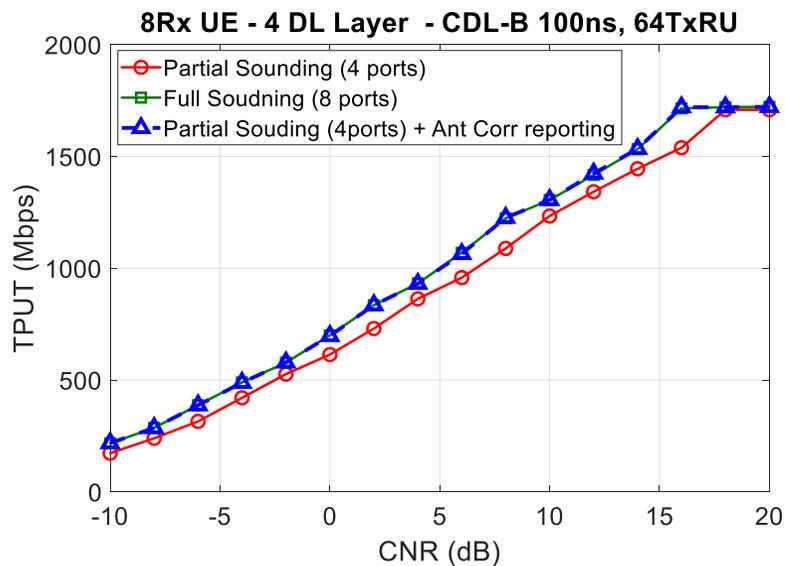
LLR-combining demod



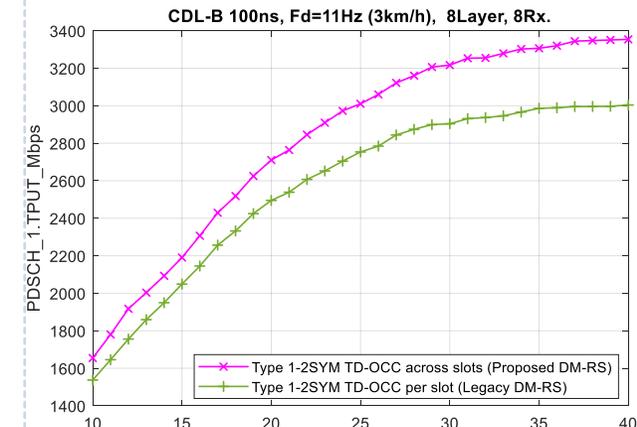
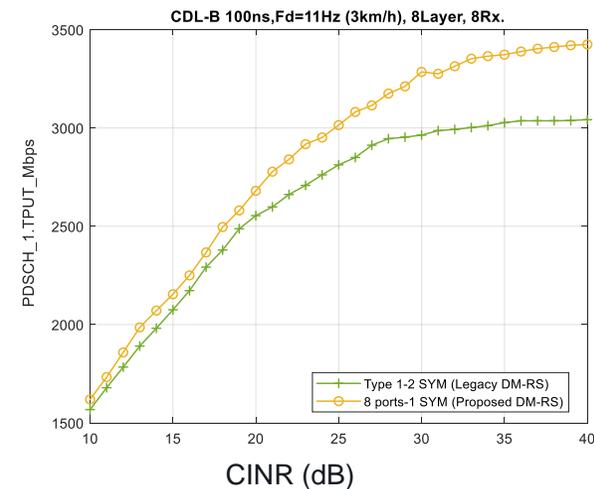
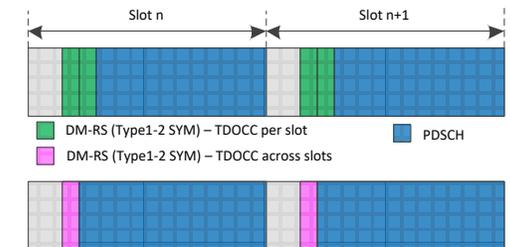
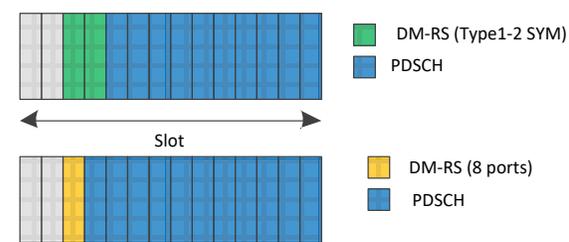
# MIMO Enhancement - DL 6/8Rx (2/2)

Enhancement for advanced UEs with large # Rx antenna (> 4 antennas)

- SRS grouping
  - Partial spatial sounding (less ports are sounded)
  - UE reports correlation between antennas and gNB can reconstruct the full channel
  - **Benefits:** Reduced sounding overhead (Less SRS resources) and improved UE power efficiency while achieving performance similar to full sounding

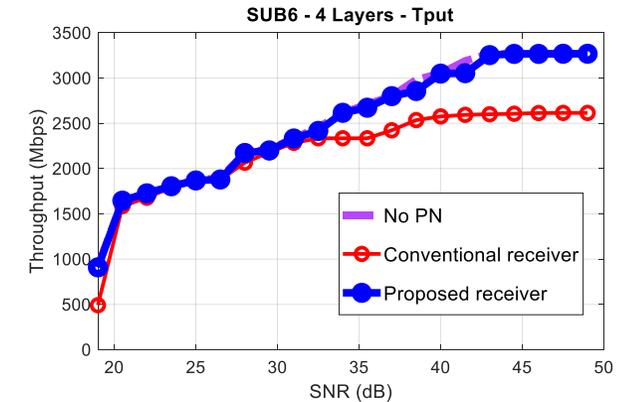


- DM-RS overhead reduction
  - For CPE/UEs with > 4Rx and > 4 DL layers
  - Increase # orthogonal ports per symbol (e.g., 8 ports)
  - DM-RS time-bundling for low Doppler channels



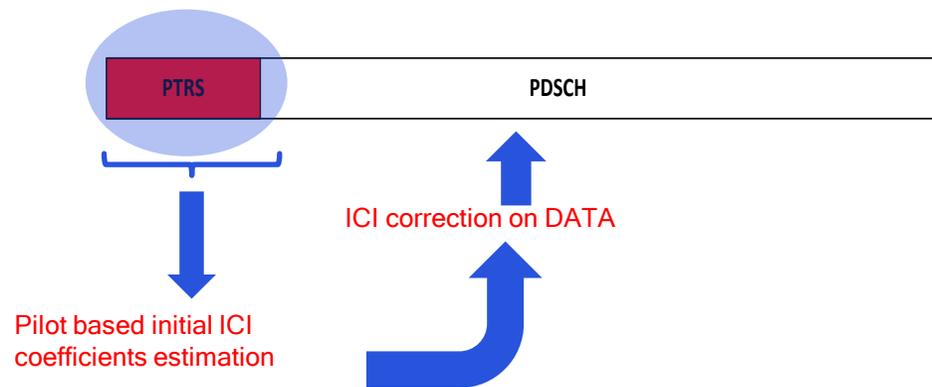
# Super-QAM Modulation

1. Enhanced receiver to enable super-QAM modulations (1024-QAM for FR2 and 4096-QAM for FR1)
2. RF RAN4 requirements applicable for 256-QAM could apply to higher order mod
3. No gNB/UE RF impact or requirements (same phase noise and linearity requirements)

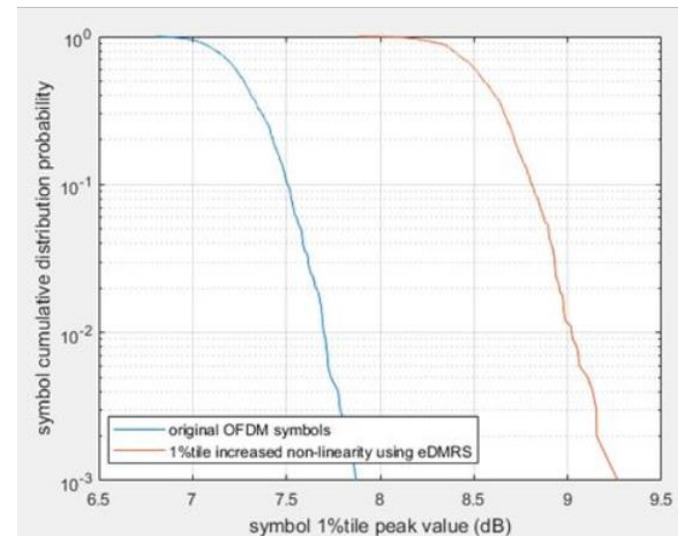


## Key Spec Modifications

### Enhance PTRS for ICI mitigation

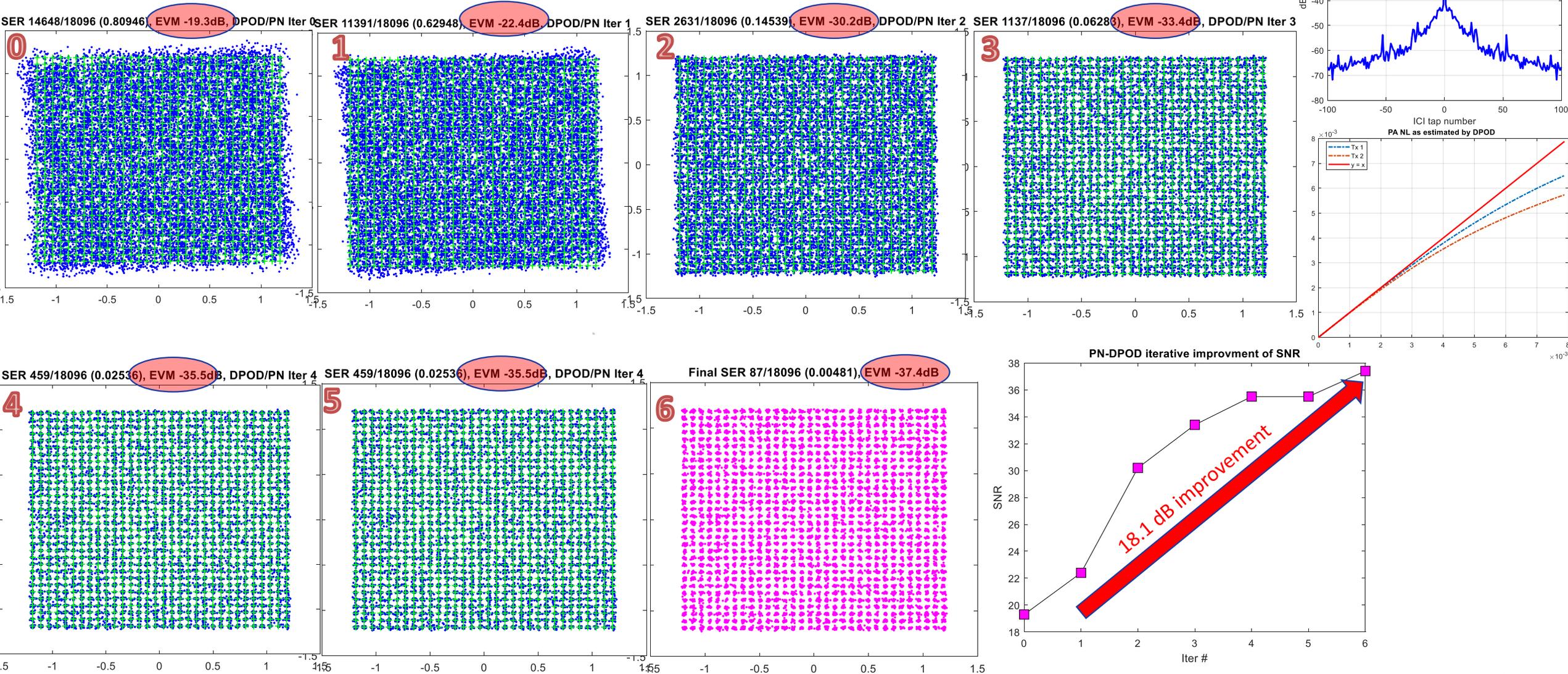


### Enhance DMRS for PA non-linearity estimation



# mmW Lab Validation Results

- 1KQAM  $r=0.92$ , 2layers, 2T x 2R, 38 PTRS, full allocation (66RBs @120KHz, BW=100MHz), TinTon GS = 40



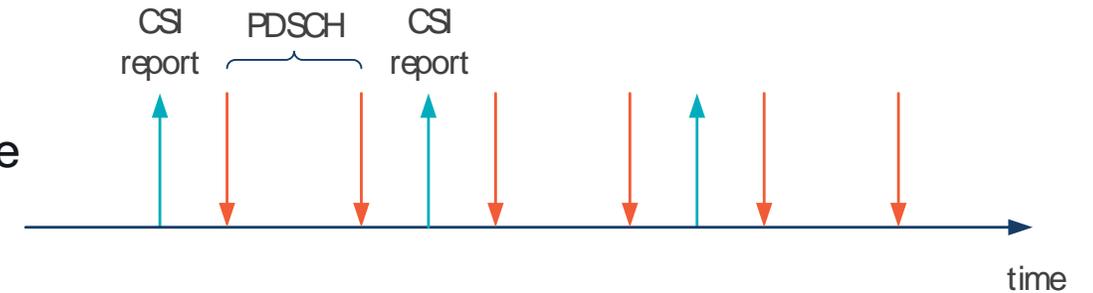
# High Mobility Enhancements (1/3)

Exploiting channel time correlation...

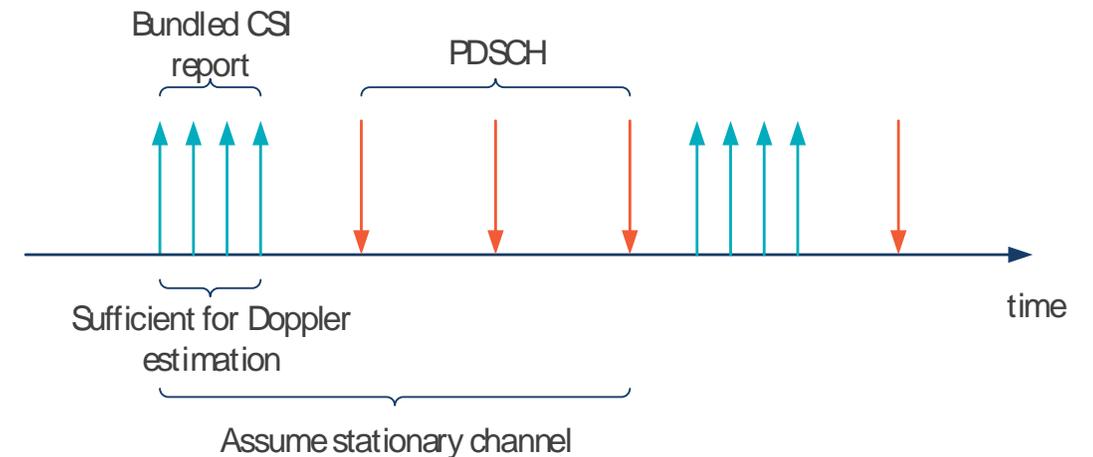
- via CSI extrapolation
  - UE reports a bundle of multiple CSI reports to capture the Doppler information
  - gNB extrapolates the CSI for forthcoming PDSCH transmission

- Specification impact
  - Bundled CSI-RS transmission
    - Sufficient time-domain density for Doppler estimation
  - Bundled CSI reporting
    - Efficient time-domain CSI compression

Conventional (inefficient) reporting:



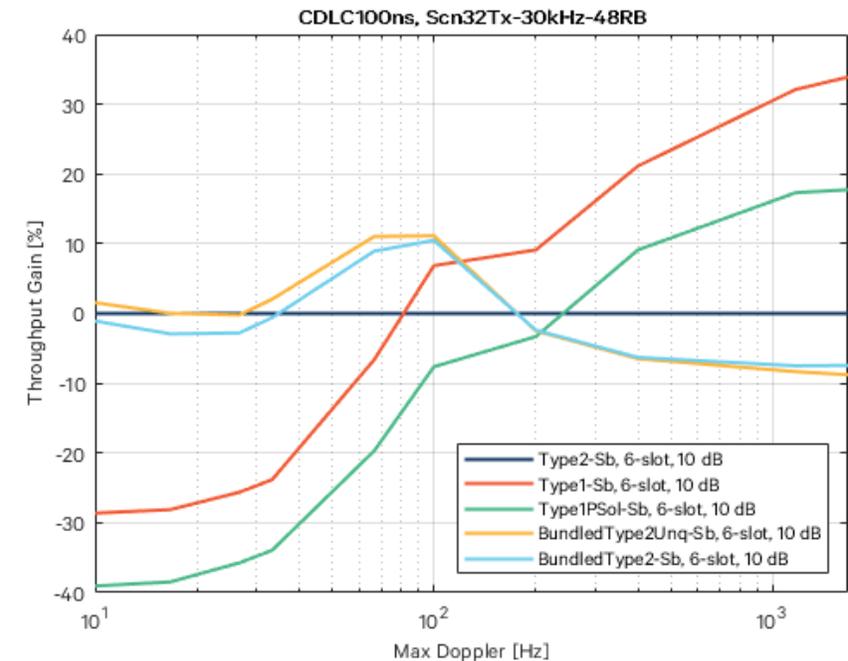
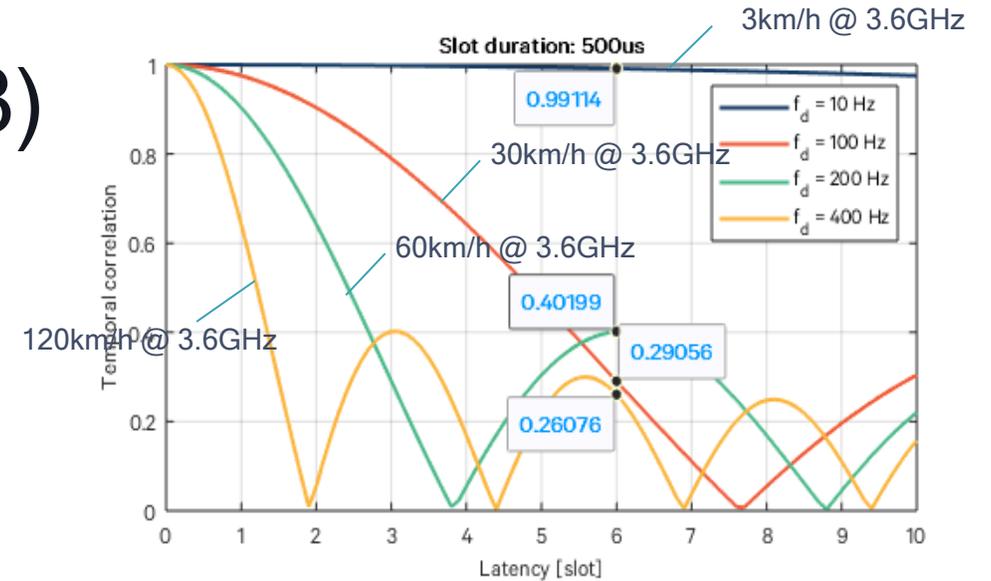
Replaced by:



# High Mobility Enhancements (2/3)

## Doppler Aware CSI Type Selection

- Background:
  - For a given UE mobility, some CSI type is preferred
    - Low mobility: Type II CSI is preferred
    - Medium mobility: Bundled CSI is preferred
    - High mobility: Type I CSI or semi-open-loop CSI is preferred
  - gNB may not have enough information to decide which type of CSI is suitable for the UE
- Proposal:
  - Network configures multiple CSI types in one CSI report config
  - UE provides CSI type recommendation



### Assumptions

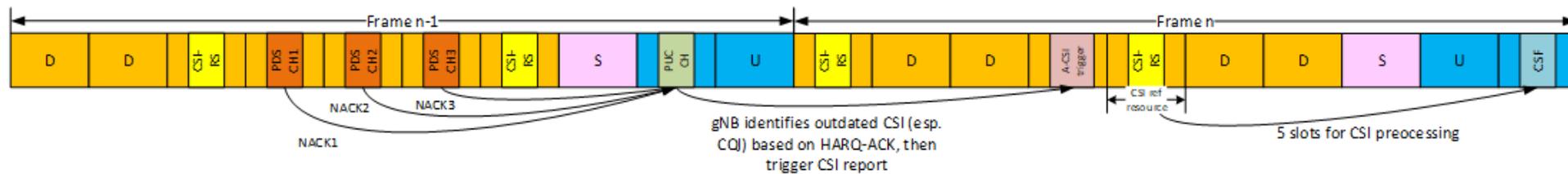
- 30kHz SCS,  $n_3 - n_2 = 6$  slots, DL SINR = 10dB

# High Mobility Enhancements (3/3)

## UE initiated CSI feedback

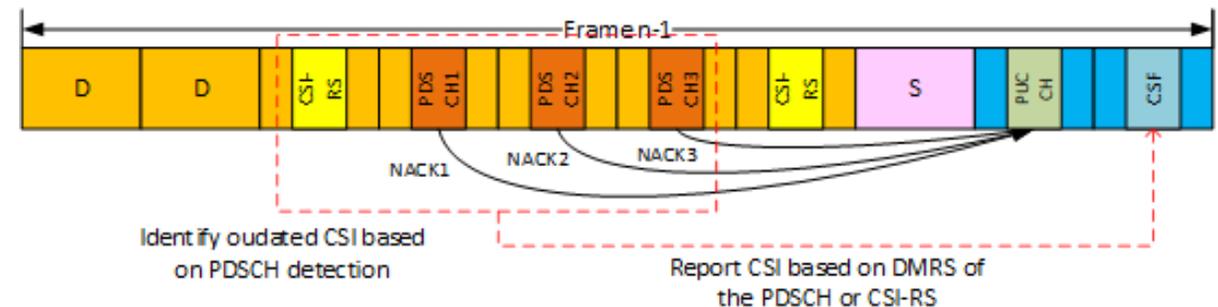
- Issue

- In R15/16, A-CSI is per network request. Network will trigger new CSI reporting upon identifying outdated CSI based on HARQ-ACK. This procedure consumes large latency between the failed PDSCH and updated CSI, thus causing inefficient rate-control in high doppler scenario (or in URLLC scenario)



- Key ideas: UE initiated CSI feedback to enable more efficient rate-adaptation

- Triggering mechanism
- CSI measurement resource
- Reserved UL channel to carry CSI
- Processing criteria:
  - CPU, reference resource, timeline, priority rules



# UL TPMI enhancements (1/2)

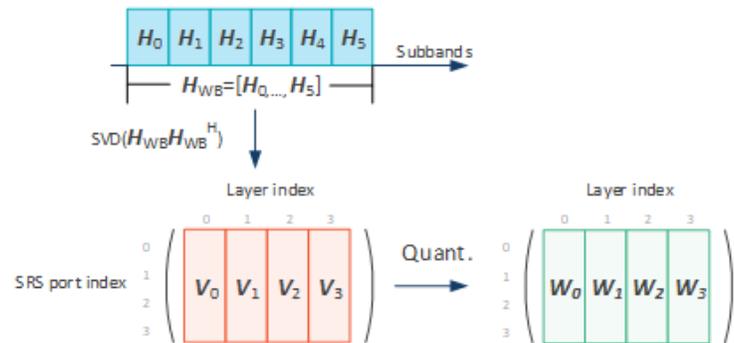
## High resolution TPMI and/or subband TPMI

- Motivation
  - Current NCB based UL exploits SVD of the channel, but relying on full reciprocity
  - Current CB based UL is worse than NCB based UL due to low-resolution quantization of the SVD precoder
- Candidate schemes

### Scheme 1: WB precoder w/ high resolution TPMI

$$W = [W_0, \dots, W_{v-1}] = \begin{bmatrix} c_{0,0} & \dots & c_{0,v-1} \\ \vdots & \ddots & \vdots \\ c_{N_{tx}-1,0} & \dots & c_{N_{tx}-1,v-1} \end{bmatrix}$$

- $c_{i,l}$  is indicated via (amp/phase) quantization

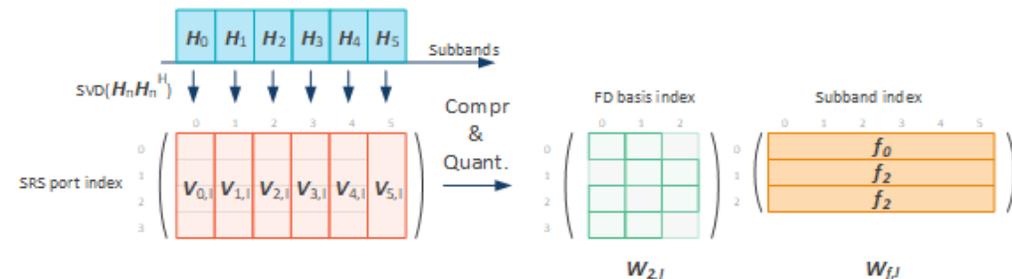


- **Benefit: High-resolution TPMI with constant modulus**

### Scheme 2: SB precoding w/ high resolution TPMI based on FD compression

$W_l = W_{2,l} \times W_{f,l}$  of size  $N_{tx} \times N_{SB}$  is the precoder for layer  $l$  across  $N_{SB}$  UL subbands

- $W_{2,l}$  is the  $N_{tx} \times M$  sparse coefficients matrix
  - Each coeff is indicated via (amp/phase) quantization
- $W_{f,l}$  of size  $M \times N_{SB}$  contains  $M$  FD bases



- **Benefit: Balance in the trade-off btw overhead vs. SB precoding**

# UL TPMI enhancements (2/2)

## High resolution TPMI and/or subband TPMI

- Observations (setup)

- (WB/SB) high-res precoding vs. Rel-15:
  - Significant gain compared to Rel-15 CB
  - Slightly better performance compared to Rel-15 WB NCB (5% w/ WB high-res, 12% w/ SB high-res)
- SB high-res vs. WB high-res: 3%~6% benefit

### HighRes WB, 2/3-bit

- 2/3-bit amp and 2/3-bit phase quantization for each coeff

### HighRes SB, 2/3-bit:

- 8 NZC indicated for each layer
- 2/3-bit amp + 2/3-bit phase quantization for each NZC

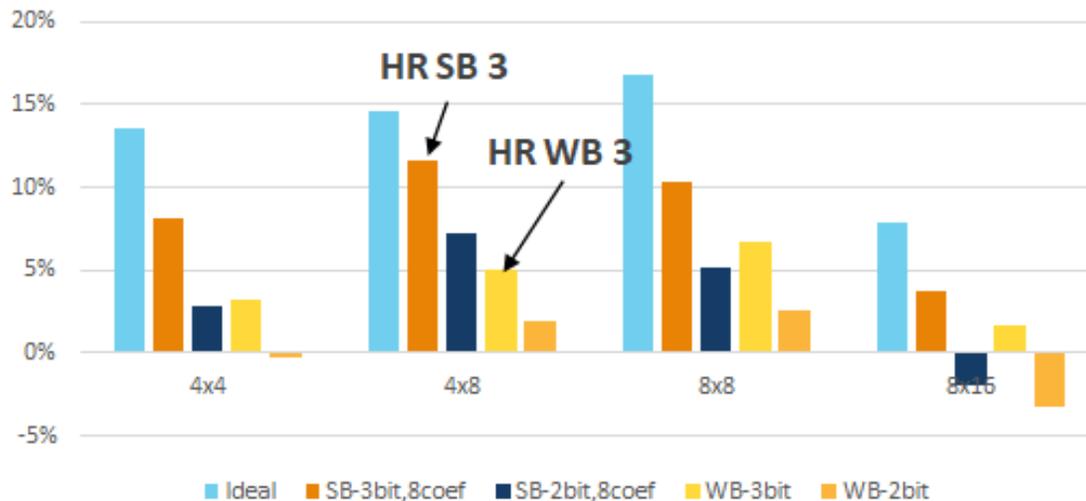
### WB/SB NCB:

- UE uses SVD precoder on the hypothesis of SU transmission

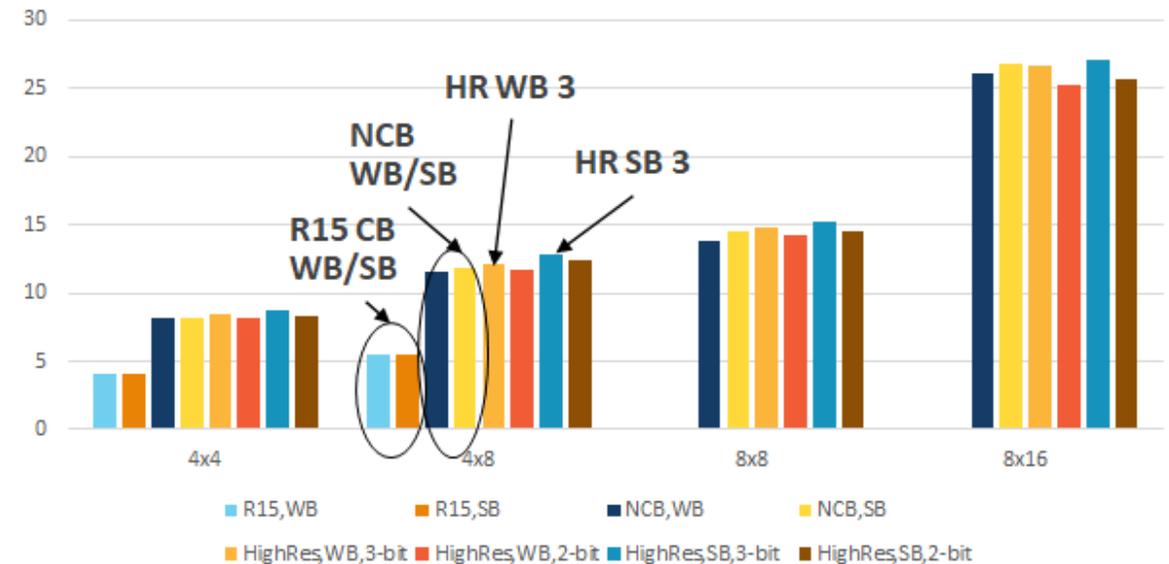
### R15 WB/SB:

- CB based transmission with WB/SB R15 TPMI

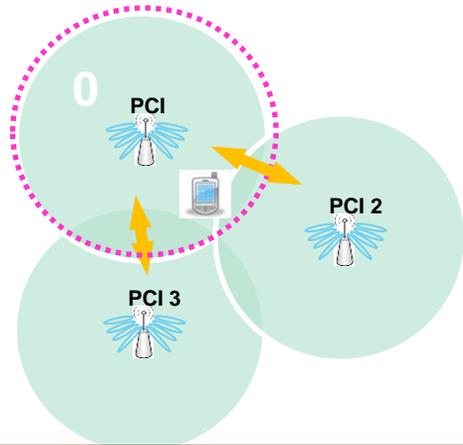
SLR precoder gain w/ high resolution TPMI vs. NCB WB



MU-MIMO, With SLR precoding (for high resolution TPMI)



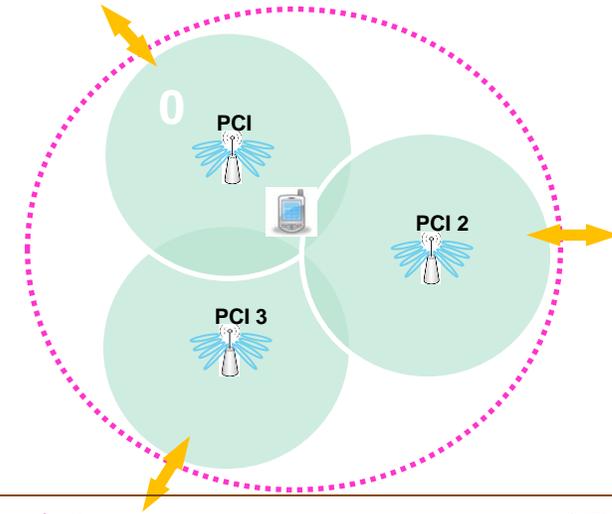
# L1/L2-based Inter-cell Mobility



L1/L2 mobility range within serving cell PCI 1

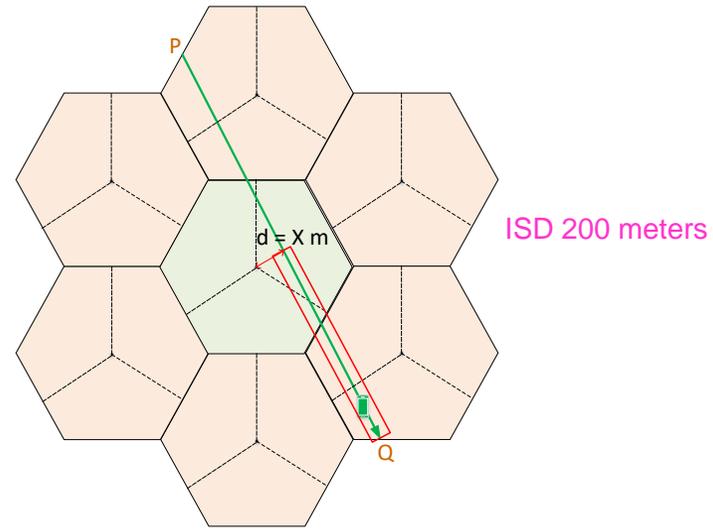


Mobility outside  is L3 based mobility

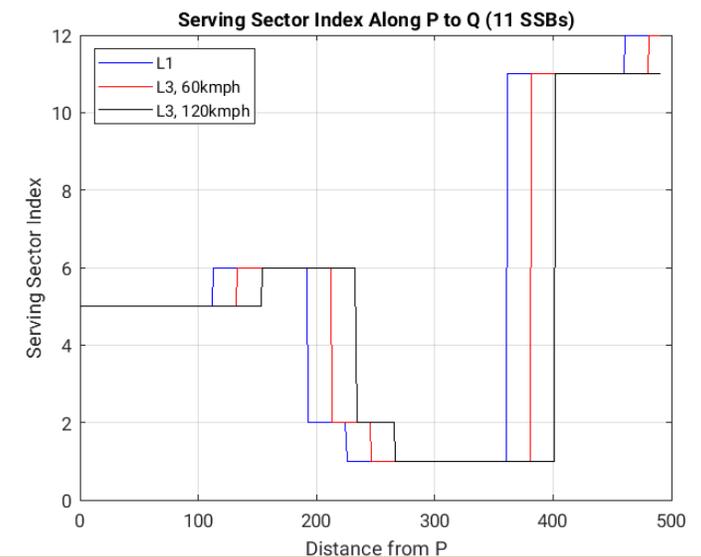


L1/L2 mobility range within union of PCI1, PCI2, PCI3

Lower latency for switching to better beam



UE travels from P to Q at different speeds; +3dB handover hysteresis

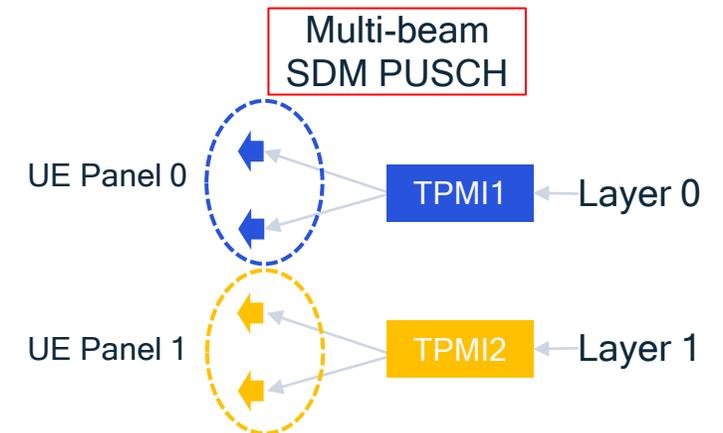
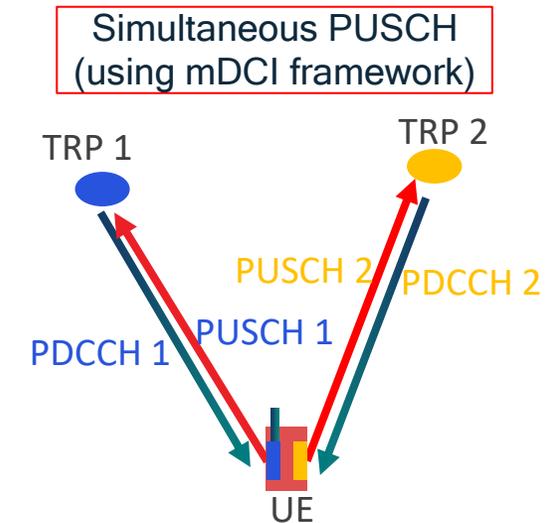


Faster beam switching to better beam with L1/L2 based mobility

# Simultaneous UL

Across multiple channels or within one channel

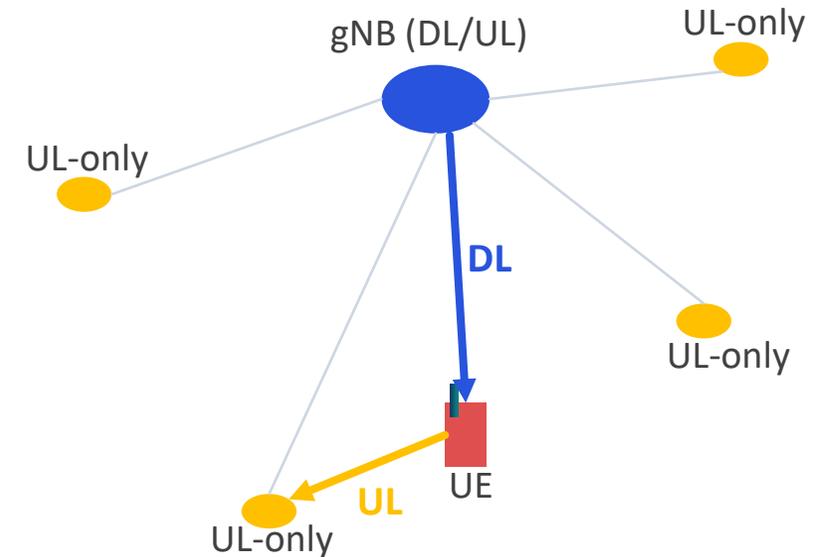
- Background:
  - Rel. 16 allows for simultaneous DL transmission
    - Two PDSCHs associated with different CORESETPoolIndex
    - One PDSCH with two TCI states in SDM/FDM manner
  - Rel. 17 PUSCH/PUCCH only focuses on TDM case
- Proposal:
  - Support simultaneous PUSCH transmission in one CC
    - CORESETPoolIndex framework is a natural starting point
    - UCI multiplexing rules for simultaneous PUSCH+PUCCH
    - PHR impact
  - Support multi-beam PUSCH in FDM/SDM manner
    - Build on top of Rel. 17 TDM enhancement
    - Multi-panel UL TPMI enhancements for codebook based PUSCH



# UL-only M-TRP operation

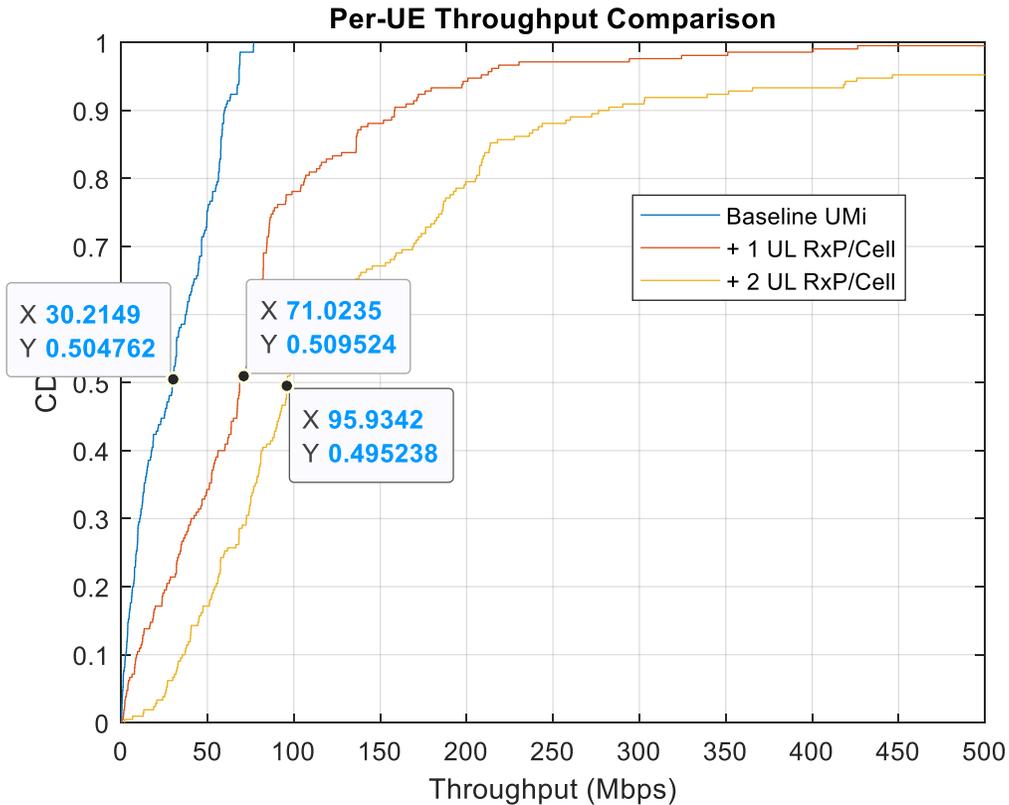
## Asymmetric DL / UL Densification

- Enabling new mTRP deployment models
  - Densification for UL-only nodes connected to gNB via backhaul
  - Reception-only capability of additional nodes: Cheaper deployment
- Benefit: UL coverage and capacity improvements
- Proposal:
  - Enhancement on UL beam management
    - SRS-based: For connected mode
    - Initial access: Coverage extension
  - UL power control enhancements
    - PL compensation w/o PL-RS measurement

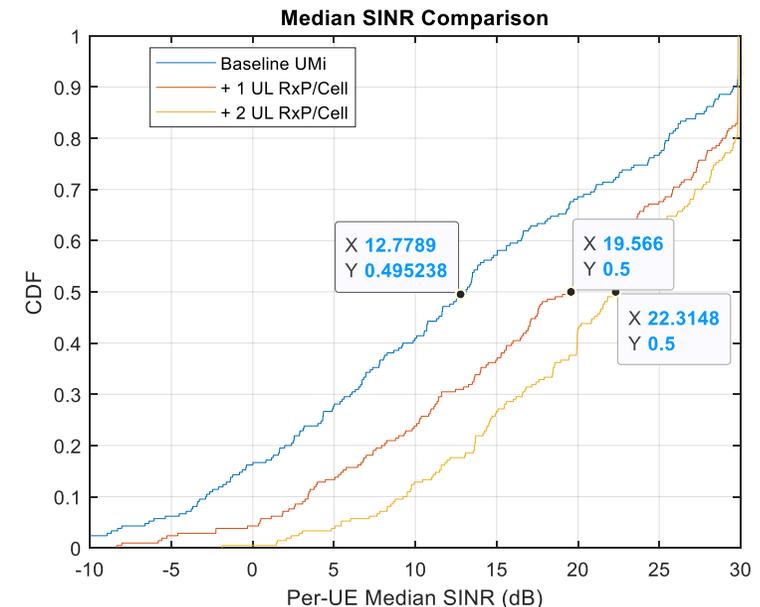


# UL-only M-TRP operation - Performance

## Asymmetric DL / UL Densification



Parameters	
Carrier freq.	28 GHz
BW, UE EIRP	100 MHz, 25 dBm
gNB ant array	gNB: 256 ant. elem. per pol {32x8 array}
UE ant array	UE: 2 panels, select best panel at association - 4 elem. per pol (FR2)
# UEs per gNB	10 UE per cell
Traffic	UL only, Full buffer traffic
Frequency reuse	Full frequency reuse. No orthogonalization
Association	PL + BF based
UE location	All outdoors

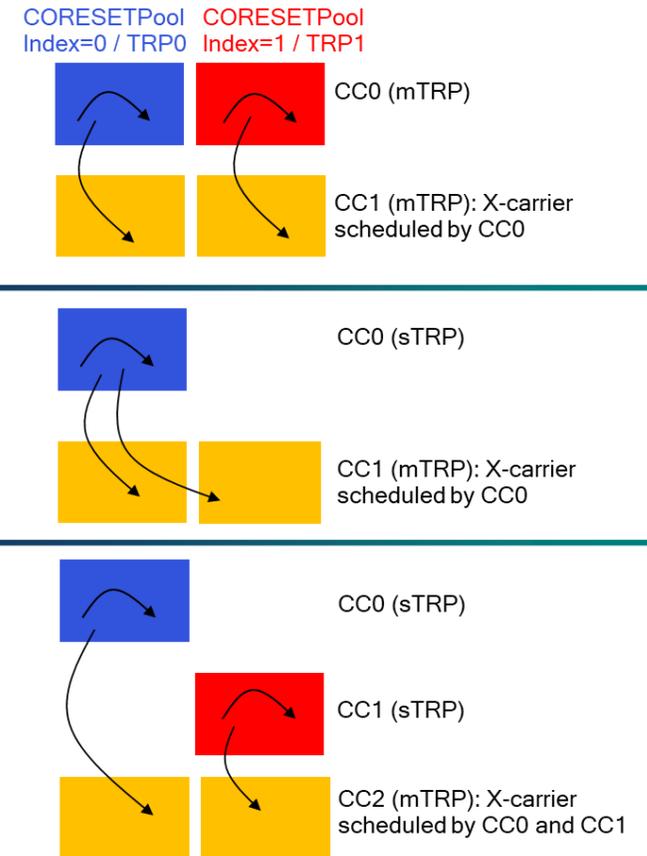
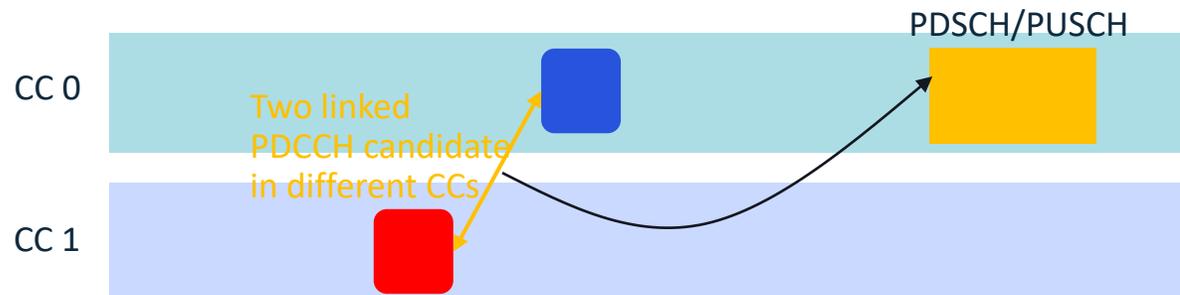


- Two main sources of gain
  - Load splitting: Decrease in number of UE per cell
  - SINR improvement: {6.8 dB, 9.5 dB} improvement with 1 and 2 additional UL RxP per cell

# Cross-Carrier Scheduling for mTRP

## Integration of mTRP with X-carrier scheduling features

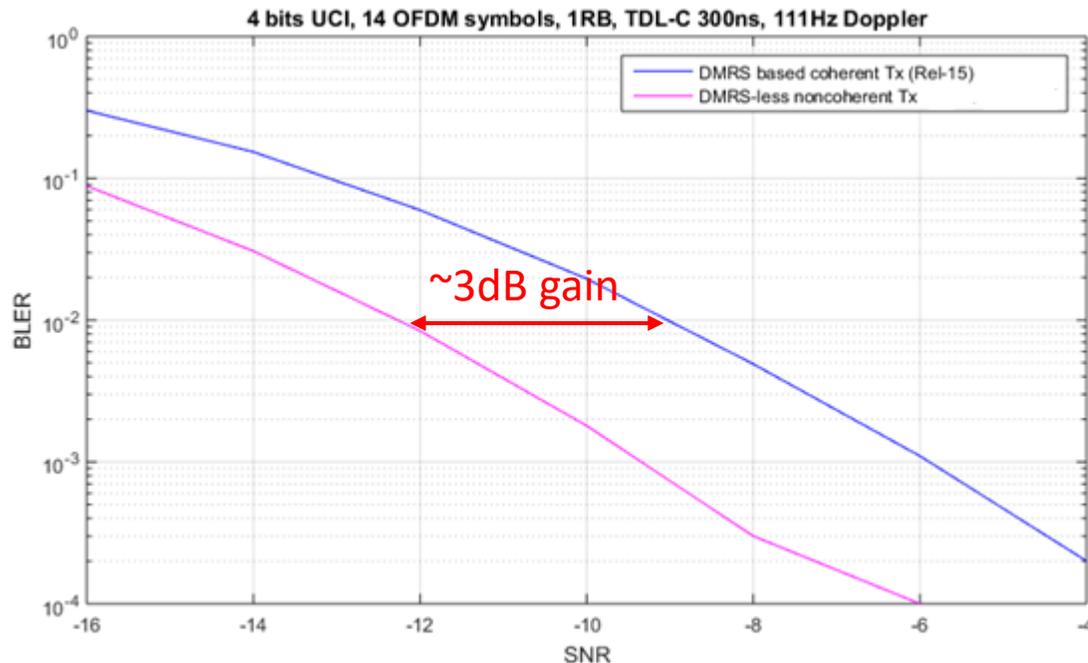
- Motivation: Integration of features related to X-carrier scheduling in Rel. 15/16/17 with mTRP features in Rel. 16/17
- Main areas:
  - X-carrier scheduling support for mDCI based mTRP
    - Enables FR1 CC scheduling FR2 mTRP PDSCH
      - FR1 CC can be mTRP or sTRP
      - Impact on two default beams
  - PDCCH repetition in different CCs
    - Enable not only more freq. diversity but also spatial diversity even with one active TCI state per CC
      - Note: Rel. 17 DSS already allows two CCs to schedule one CC



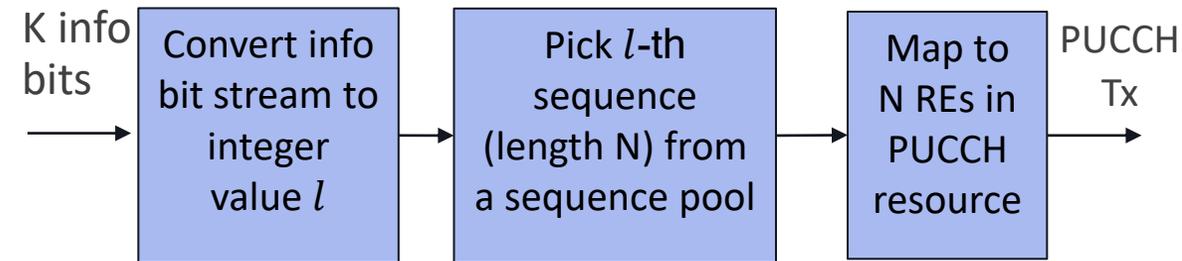
# Link efficiency improvement for PUCCH

## Extend sequence based PUCCH beyond 2 bits UCI (up to 11 bits)

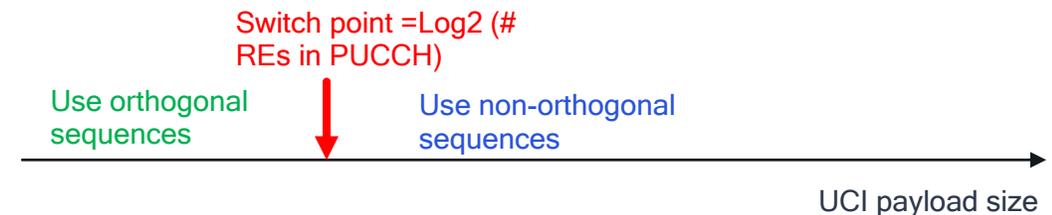
- In low SNR regime, DMRS-based coherent communication performs worse than DMRS-less noncoherent transmission, due to:
  - DMRS overhead
  - Bad channel estimation quality at low SNR
  - Existing PUCCH channel code (e.g., RM code for  $\leq 11$  bits) is not optimized at low code rate



### Sequence based PUCCH



- **Proposal:** Support sequence-based DMRS-less noncoherent transmission for PUCCH (beyond format 0) to improve its link efficiency.
  - Orthogonal sequences for small payload size
  - Non-orthogonal sequences for medium payload size





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