NR MULTI-ANTENNA

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NR – DESIGNED FOR MULTI-ANTENNA

- Benefits of multi-antenna transmissions:
  - Increased signal strength, reduced interference, MU-MIMO
- In NR, all signals can be beamformed
  - PDSCH, PUSCH, PDCCH, PUCCH, PBCH, PSS/SSS, CSI-RS, SRS,…
- Transmissions are (to a large extent) self-contained
  - In-beam DM-RS for channel estimation – no reliance on broadcast pilots
- Procedures designed with beam-based transmission in mind:
  - Initial access
  - Mobility

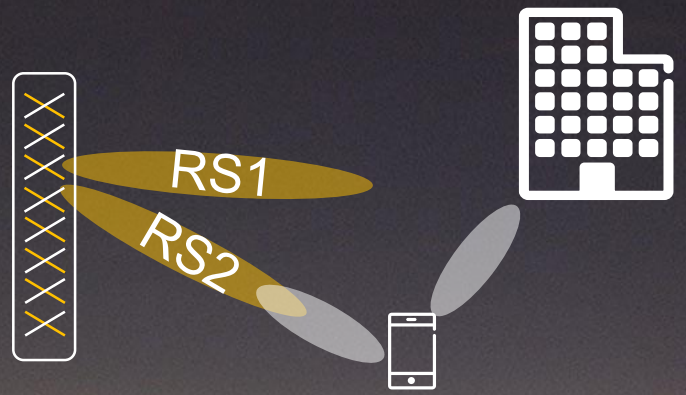
TWO CLASSES OF MIMO SOLUTIONS

Low band

- Fully digital antenna implementation is feasible
- Digital beamforming makes it feasible to estimate the entire channel by transmitting CSI-RS.
- Data can be transmitted with a narrow beam given the estimated channel.

High band

- Fully digital antenna implementation may not be feasible
- Analog beamforming implies that gNB and/or UE can only transmit/receive in one direction (beam) at any point in time
- Therefore only feasible to span selected directions of the channel → One will need to rely on a limited number of beams.



CODEWORD, LAYER, PORT, …

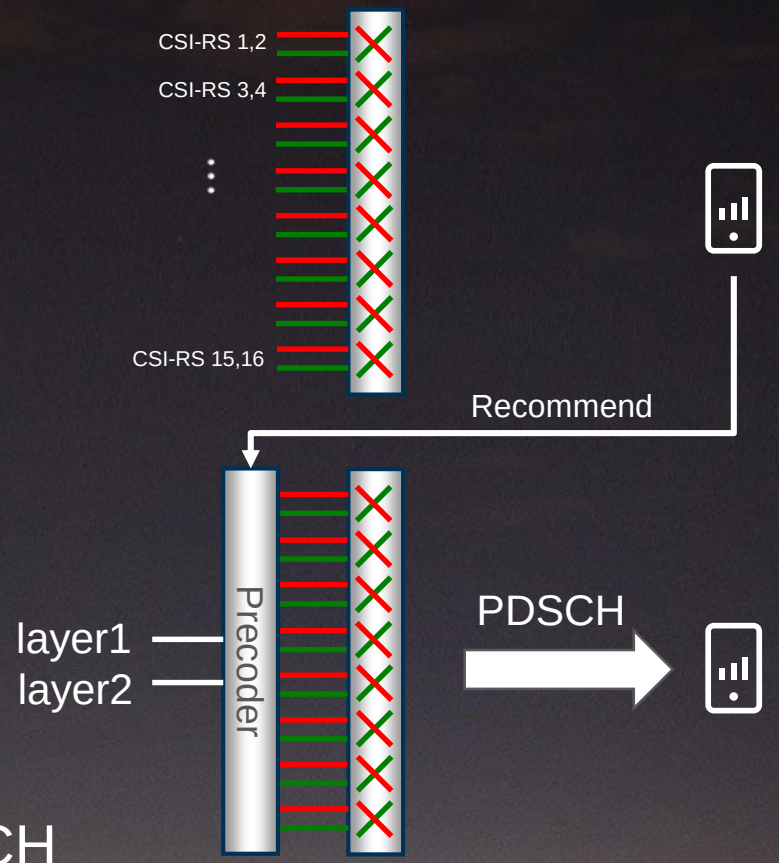
- Codeword:
  - The coded bits corresponding to one transport block
  - One codeword corresponds to one HARQ process
- Layer:
  - One codeword is split over *n* layers (*n*=rank)
  - One layer corresponds to one DM-RS port
- (Antenna) port:
  - Where a reference signal is transmitted

PDSCH TRANSMISSION

- NR has only a single transmission scheme for PDSCH
  - One DMRS port per layer
- Any precoding can be used
  - The UE only has to know how many layers are transmitted
- A UE can receive 1-8 layers
  - For 1-4 layers PDSCH: One codeword
  - For 5-8 layers PDSCH: Two codewords

CODEBOOK-BASED TRANSMISSION

- One method to determine the precoder
- gNB transmits CSI-RSs from multiple antenna ports
- UE evaluates several possible precoders, e.g., beams
  - Precoders are chosen from a standardized *codebook*
- UE sends a recommended precoder to the gNB
- gNB applies the recommended precoder to transmit PDSCH

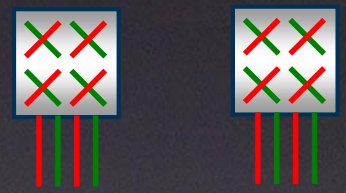


DL CODEBOOKS IN NR

- Type I single-panel:
  - Similar to LTE FD-MIMO codebooks, up to rank 8, based on single DFT grid-of-beams
- Type I multi-panel:
  - Rank 1-4: Extension of Type I single-panel by adding inter-panel co-phasing, either wideband or subband
  - Supports 2 and 4 panels
- Type II single-panel:
  - “Explicit”-like channel eigenvector feedback based on linear combination of DFT beams. High overhead. Only for rank 1-2.

Single panel

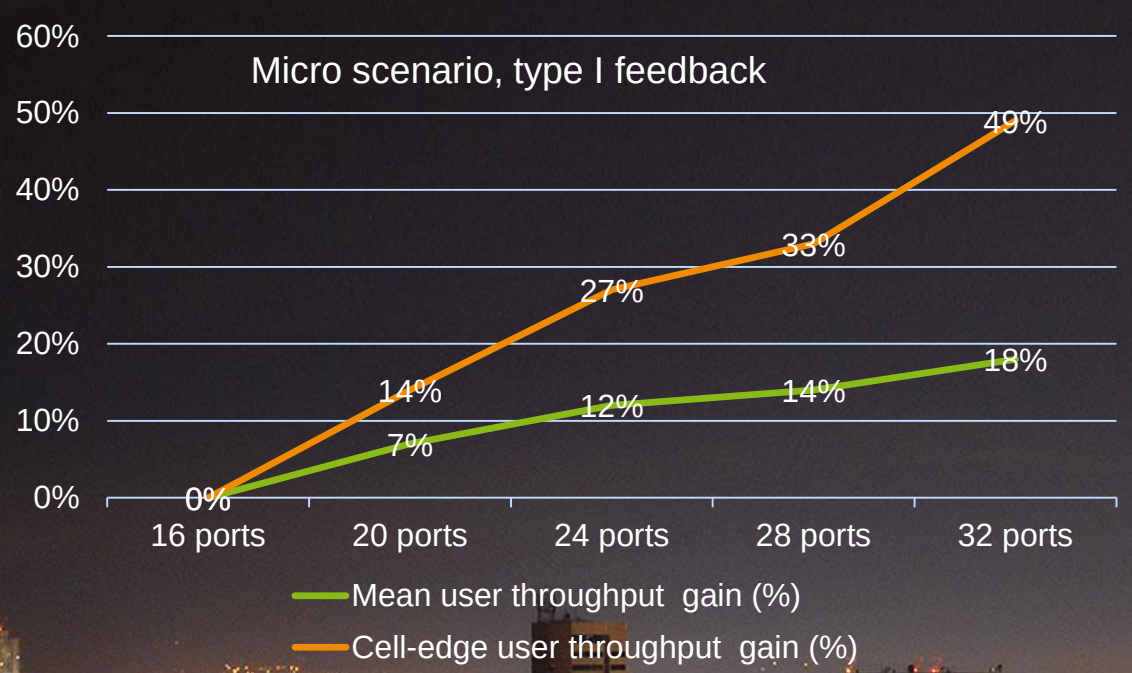
Multi panel

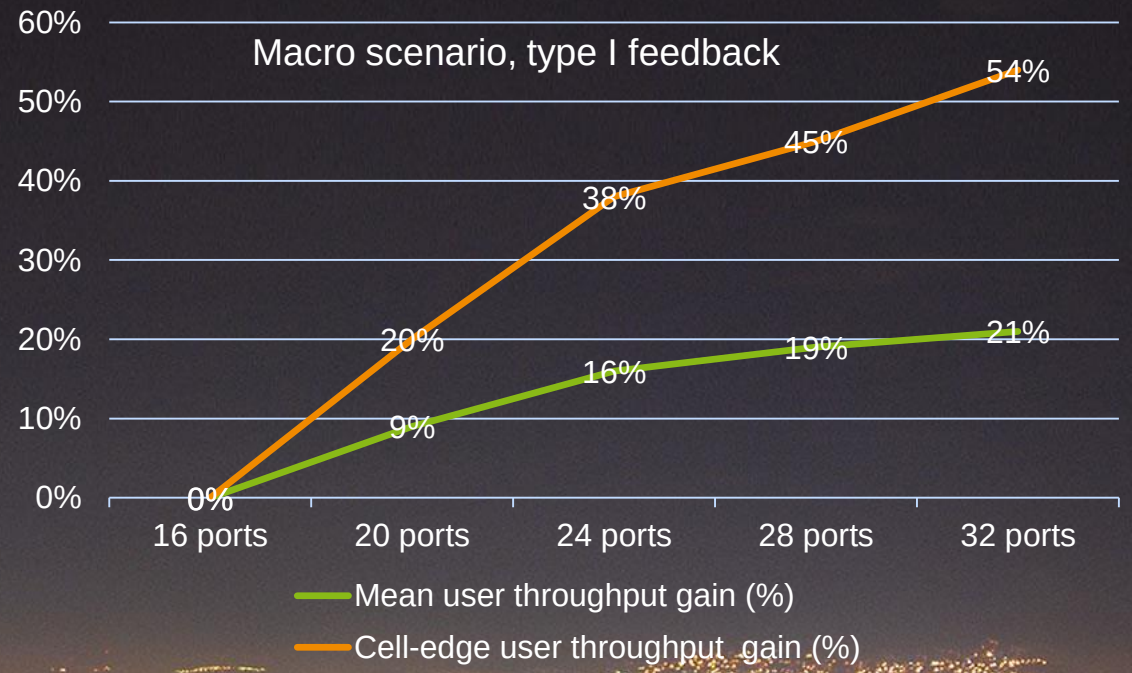


RECIPROCITY BASED PDSCH TRANSMISSION

- With reciprocity-based precoding, DL CSI is acquired based on UL SRS transmission
  - Full channel information available, enabling more advanced precoding for MU-MIMO
- It is mainly a proprietary feature; it can be implemented by using components in the standard.
  - Therefore not that visible in the standard.
- Reciprocity based and codebook based PDSCH both have their strengths, even for TDD

DO WE SEE ANY GAINS FROM LARGER ANTENNAS?





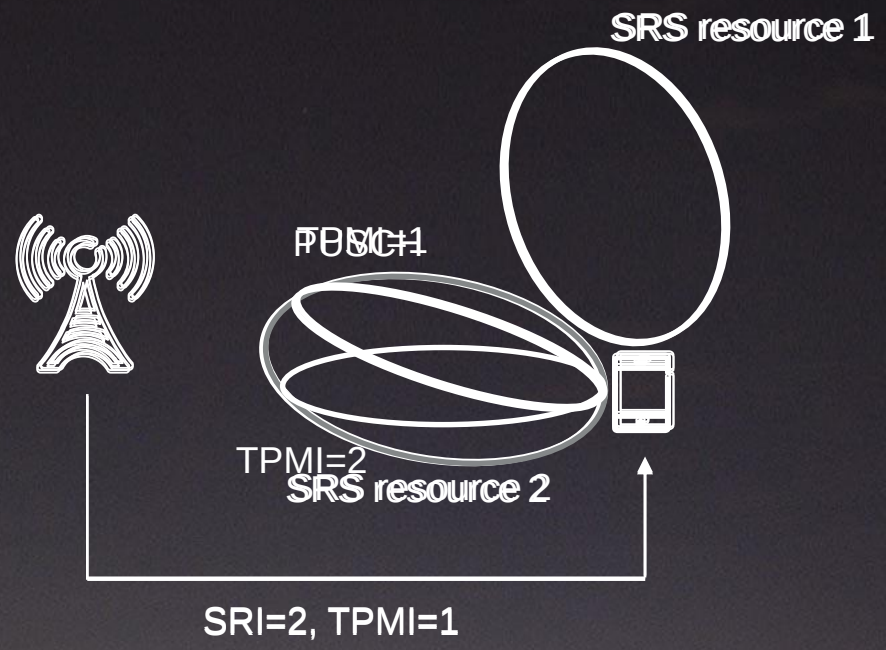
MULTI ANTENNA - PUSCH

- A UE can transmit 1-4 layer PUSCH and use up to 4 Tx chains
  - A single codeword is used
- CP-OFDM waveform is used
  - DFT-S-OFDM additionally supproted for coverage extenstion
    - Only for single layer
- Codebook-based precoding and non-codebook based precoding (~reciprocity) PUSCH is supported

CODEBOOK BASED PUSCH TRANSMISSION

A typical use case would be

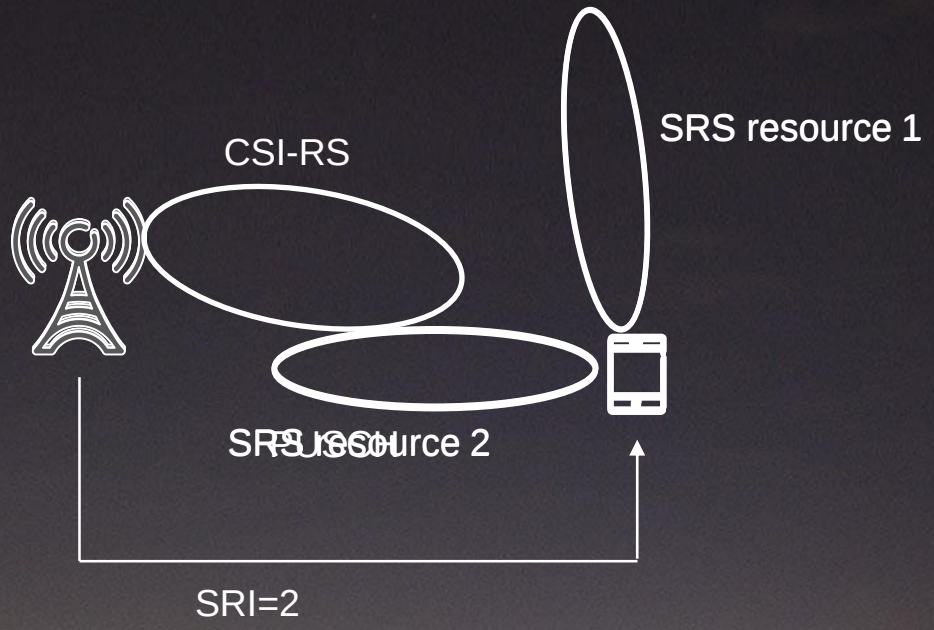
1. A UE transmits one or two SRS resources
   - An SRS resource has 1,2 or 4 ports
2. gNB indicates
   - SRS resource indicator (SRI), and
   - TPMI and TRI (UE precoder matrix from a precoder codebook and rank)
3. The UE performs PUSCH transmission



NON-CODEBOOK BASED PUSCH TRANSMISSION

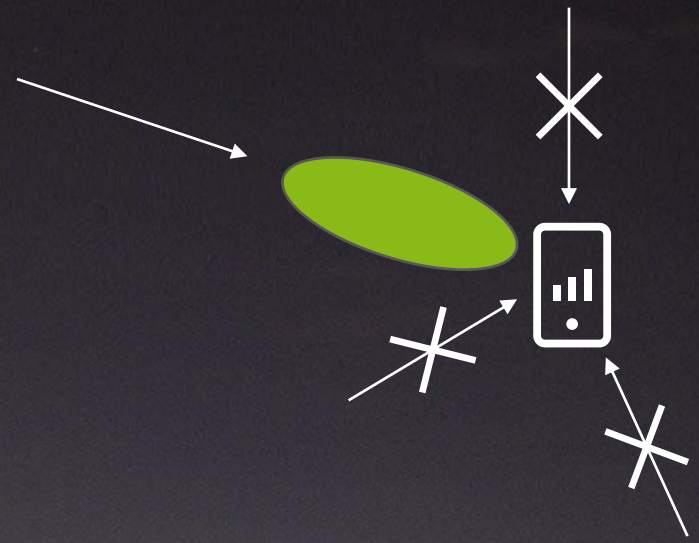
A typical use case would be

1. A CSI-RS can be indicated to UE for assisting calculating UL precoder (using DL-UL reciprocity)
2. A UE transmits up to four SRS resources
   - Each SRS resource is one port and corresponds to a PUSCH layer
3. gNB indicates
   - Multiple SRS resource indicators (SRIs)
   - Number of SRIs = rank
4. The UE performs PUSCH transmission



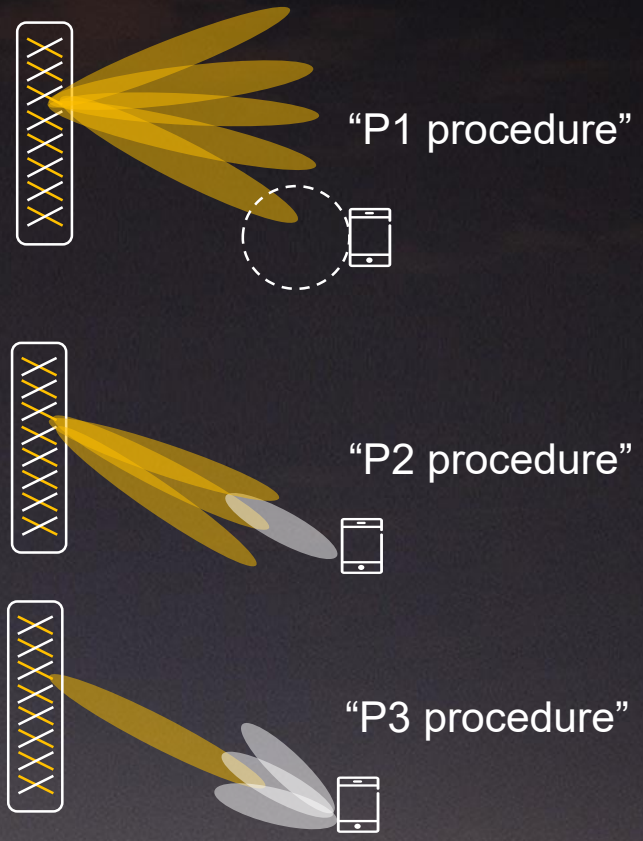
BEAM MANAGEMENT

- In mmW, analog antenna architectures will be common
- The gNB/UE will transmit/receive all signals in beams
  - Omni-directional transmission/reception will not be possible
- In particular, the UE can only receive signals from one direction at a time
  - Need to prepare to receive from another direction



BEAM MANAGEMENT PROCEDURES

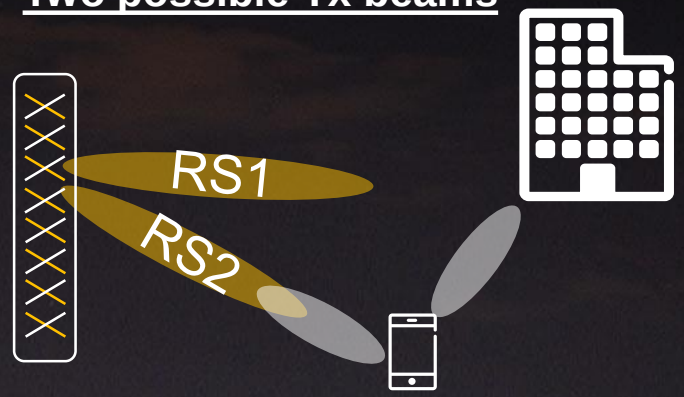
- The system ensures that the beams in the gNB and the UE are aligned
- Procedures for updating beams at the gNB/UE are supported
- Primarily based on UE measurements on DL reference signals
  - Either CSI-RS or SSB
  - UE uses the same beam for transmission as for reception, the gNB uses the same beam for reception as for transmission – *beam correspondence*
- P1 procedure: beam finding
  P2 procedure: Tx beam refinement
  P3 procedure: Rx beam refinement



BEAM INDICATION

- Before the network changes its Tx beam, it (sometimes) sends a beam indication to the UE
  - To support the update of the UEs RX beams
- Points to a *previously received* reference signal
- For the reception of all DL signals:
  - PDCCH
  - PDSCH
  - CSI-RS
- Signaled to the UE in different ways for different signals:
  - DCI, MAC CE, RRC

Two possible Tx beams



PDSCH in beam 1 (RS1)

BEAM MANAGEMENT: TYPICAL USE CASE

A typical use case would be

1. The network communicates with the UE using a certain Tx beam, and the UE uses a certain Rx beam
2. The network transmits CSI-RS in a set of candidate beams – UE reports the best
3. Network starts transmitting PDSCH in new beam
4. The network repeats CSI-RS in one beam
5. The UE varies its Rx beam
6. The UE chooses the best Rx beam

UL BEAM MANAGEMENT

- Needed only if UE does not have *beam correspondence*
  - When a UE has beam correspondence, it may derive the UL TX beam from the DL RX beam
- UL beam management is based on SRS beam sweeps
- U1,U2,U3 procedures analogous to P1,P3,P2 procedures
- The framework for UL beam management is in general similar to DL beam management framework

SUMMARY

- NR designed for multi-antenna transmissions
  - All procedures adapted
  - All channels can be beam-formed
  - All transmissions are self-contained
- For determination of PDSCH precoders, NR supports
  - Codebook-based transmission with up to 32 ports
  - Type I and type II codebooks
  - Reciprocity-based transmission – based on SRS
- NR supports codebook based and non codebook based PUSCH transmission
- Beam management procedures have been introduced targeting high band operation