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 ($n=\text{rank}$)
  - 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
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:
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?

**Micro scenario, type I feedback**
- 16 ports: 0%
- 20 ports: 7%
- 24 ports: 12%
- 28 ports: 14%
- 32 ports: 18%

**Macro scenario, type I feedback**
- 16 ports: 0%
- 20 ports: 9%
- 24 ports: 16%
- 28 ports: 19%
- 32 ports: 21%

**Mean user throughput gain (%)**
- 16 ports: 0%
- 20 ports: 10%
- 24 ports: 20%
- 28 ports: 30%
- 32 ports: 40%

**Cell-edge user throughput gain (%)**
- 16 ports: 0%
- 20 ports: 10%
- 24 ports: 20%
- 28 ports: 30%
- 32 ports: 40%
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 supported for coverage extension
  - 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
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
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
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