大唐无线移动创新中心
Datang Wireless Mobile Innovation Center

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Motivation for the new work item proposal: Rel.14 Enhanced MIMO Beamforming for LTE

CATT, Huawei, HiSilicon

LTE status quo

- MIMO started from CRS-based mode in Rel.8
  - Closed-loop (CL-MIMO): targets users with static channel (e.g. low speed)
  - Open-loop (OL-MIMO): targets users with non-static channels
    - Applicable to different speed scenarios (e.g. low, medium, and high)
      - Better performance at mid-to-high speed, due to superior signal robustness, diversity and link quality
      - Lower feedback overhead and UE complexity
      - Widely used in currently networks

- MIMO is shifting to DMRS-based , but current LTE has only closed-loop mode
  - Rel.9: dual-layer beamforming
  - Rel.10: 8 layer beamforming
  - Rel.11: CoMP multi-point processing
  - Rel.12: 4Tx codebook enhancements
  - Rel.13: massive MIMO, 1/2/4/8 port beamformed CSI-RS, and 12/16 port non-precoded CSI-RS

General View

- Enhancement for MIMO configurations (2/4/8Tx) is critical
  - 2/4/8 Tx is essential to operators
  - important in future networks for many years, even after massive MIMO becomes available
  - important for low-frequency band coverage
  - both closed-loop and open-loop schemes are important

- Massive MIMO is attractive for future LTE evolution
  - Beamformed CSI-RS (standardized in Rel.13) is a promising evolution path
    - Number of antenna ports (e.g. 2/4/8) can be much lower than no. of physical antennas → future proofness
  - Enhancement should focus on practical use case, avoid "paper design"
  - Beam tracking, estimation and feedback for beamformed CSI-RS should be the focus

DMRS-Based MIMO Enhancement : Robustness with Open loop MIMO and Tx Diversity

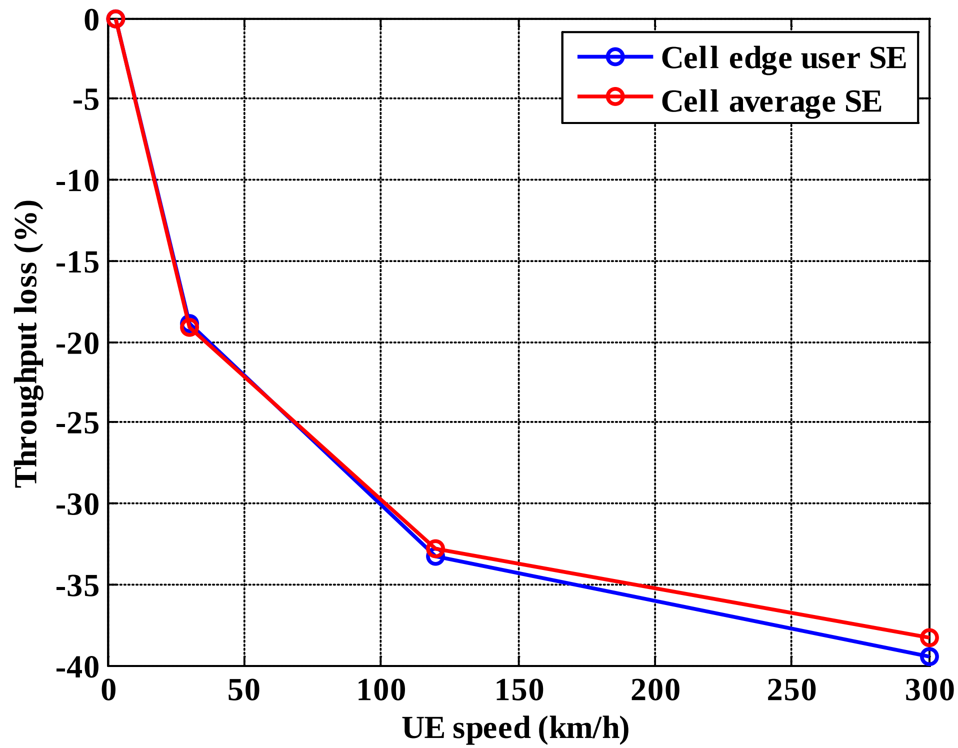
- LTE CRS-based MIMO supports CL and OL-MIMO modes
- LTE DMRS-based MIMO supports CL-MIMO mode only
  - Significant performance loss at mid-to-high speed
- DMRS-based enhancement: OL-MIMO and TxD
  - Extending MIMO technologies to all deployment scenarios
    - DMRS-based Tx diversity as the fall back mode of CL-MMO
    - DMRS-based OL-MIMO used for non-static MIMO channels
      - ❖ Important for mid-to-high speed, but <u>equally beneficial</u> for low-speed
  - Open-loop operation to attain performance robustness against non-static channel in real deployment
  - Performance enhancement of non-UE-specific DL physical channels
    - DL control, broadcast, and multi-cast channels
  - Robust/reliable CSI methods and PDSCH transmission scheme

Use Cases of DMRS based MIMO Enhancement

- Existing MBB w/ mobile handsets
- Connected car – performance improvement for automotive application with LTE MIMO connectivity
  - Strong business interests from auto makers (e.g. GM, Mercedes)
  - New revenue opportunities for operators
- Benefits for scenarios with discontinuous or unreliable CSI feedback – e.g., LAA
- Support of DL Control Channels channel Enhancement with OL-MIMO
- Support of eMBMS enhancement with OL-MIMO

High-Speed Performance of Current DMRS CL Mode (TM9)

Parameter	Value
Antenna configuration	eNB: 8Tx cross-polarized (+/-45), 0.5λ space UE: 2Rx cross-polarized
Scenario	3D-UMa with 500m ISD
Down-tilt	3D-UMa 500m: 100 degree
System bandwidth	10MHz (50RBs)
Carrier frequency	2GHz
UE distribution	Follows 36.873
UE speed	3km/h, 30km/h, 120km/h, 300km/h
Model of cross polarization	36.814
Traffic model	Full buffer
Rank adaptive	SU with rank adaptation
Scheduling algorithm	PF
Receiver	Realistic channel estimation
	Realistic interference estimation
	MMSE-IRC receiver
HARQ	Max 4 transmissions
CSI feedback	PUSCH 3-2
	CQI, PMI reporting triggered per 10ms
	RI triggered per 120ms
Wrapping method	Geographical distance based
Handover margin	3 dB



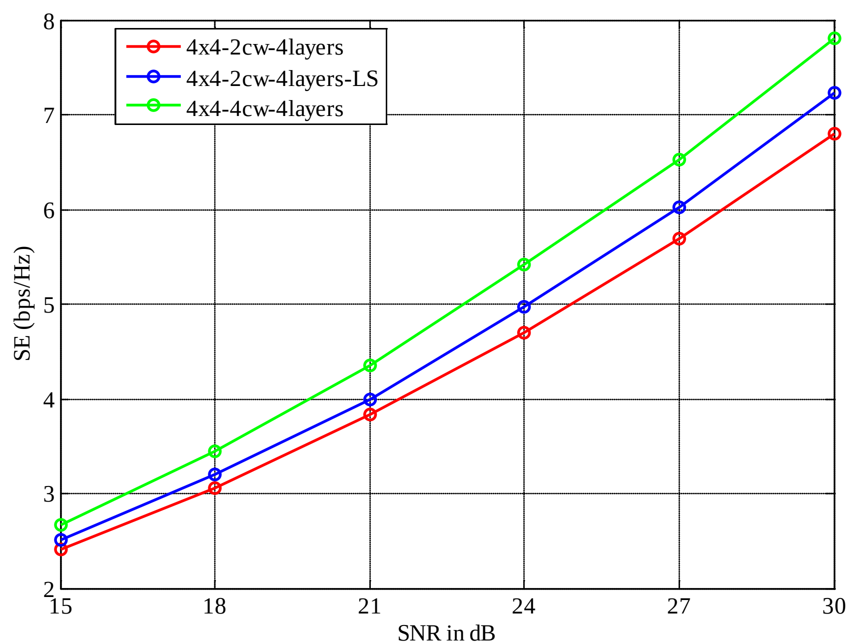
DMRS-based MIMO Enhancement – CSI Accuracy Enhancement

- CSI accuracy enhancements, targeting high-order MU-MIMO, *e.g.*
  - Spatial layer processing enhancement for increasing the CSI granularity and improving the CSI accuracy (e.g. layer-specific CQI, precoder layer permutation)
  - Advanced interference measurement / prediction mechanism (e.g. MU interference estimation)
  - CSI measurement and feedback mechanism enhancements (e.g. overhead reduction)
  - Feedback latency reduction
  - Enhancement may consider both PDSCH data channel and other DMRS-related transmission (e.g. EPDCCH)

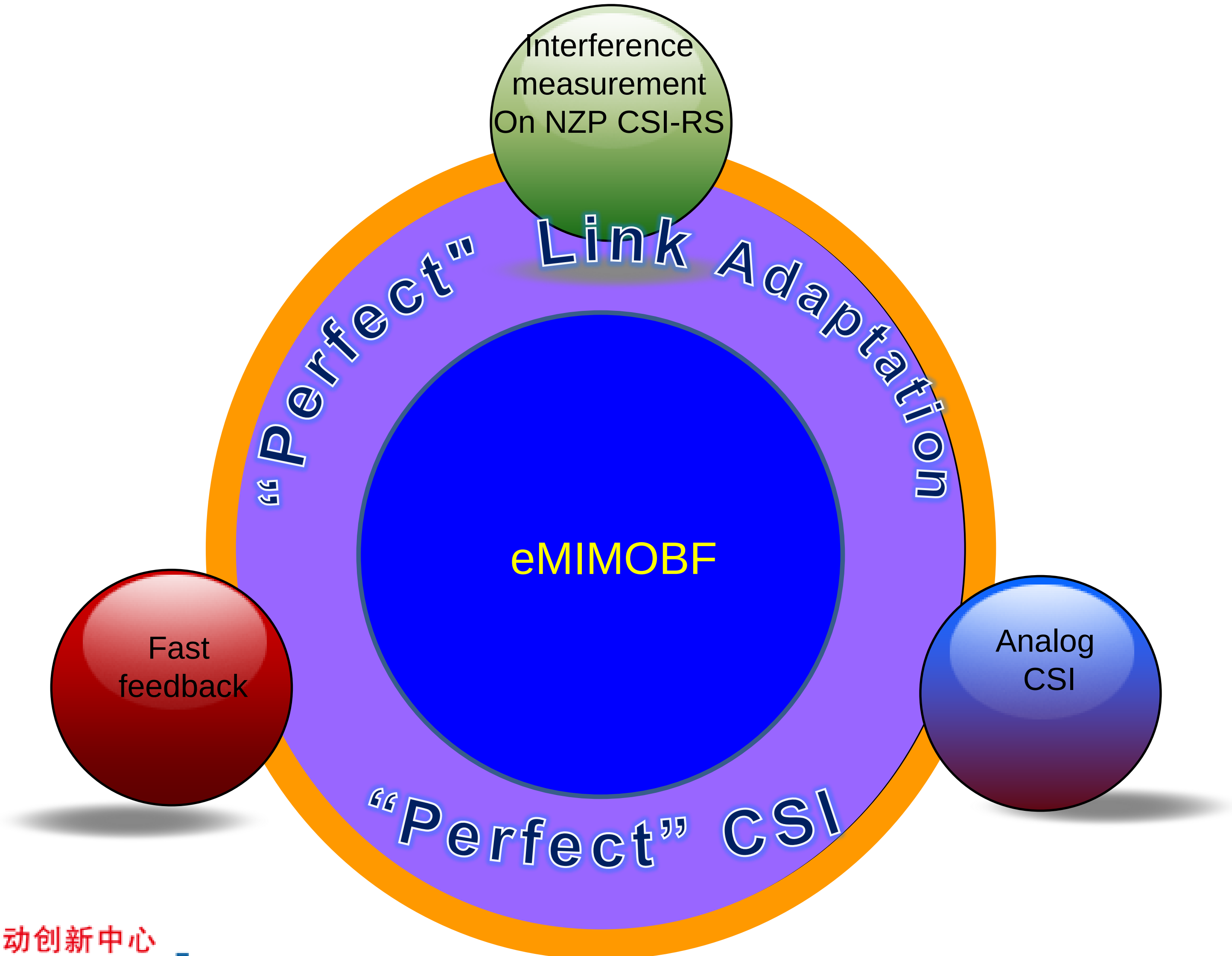
Example: CSI spatial resolution

- Spatial resolution of CSI is limited by 2CW
  - If Rank >2, layer-specific CQI is averaged to CW-specific CQI
  - Higher resolution may be achieved with increased CQI number in uplink feedback
- Layer-to-CW mapping is fixed in LTE, so are the columns in feedback precoder
  - Large CQI quantization loss if a high-SNR layer CQI and a low-SNR layer CQI is combined into one codeword
  - CQI quantization loss can be reduced by allowing column re-arrangement in feedback precoder

Parameter	Value
Antenna configuration	eNB: 4Tx cross-polarized (+/-45), 0.5λ space UE: 4Rx cross-polarized (+/-45), 0.5λ space
System bandwidth	10MHz (50RBs)
Carrier frequency	2GHz
Channel model	ITU UMi NLOS
UE speed	3km/h
Receiver	Realistic channel estimation
	MMSE receiver
HARQ	Max 4 transmissions
CSI feedback	Periodic feedback with periodicity of 10ms and subband of 6 PRB

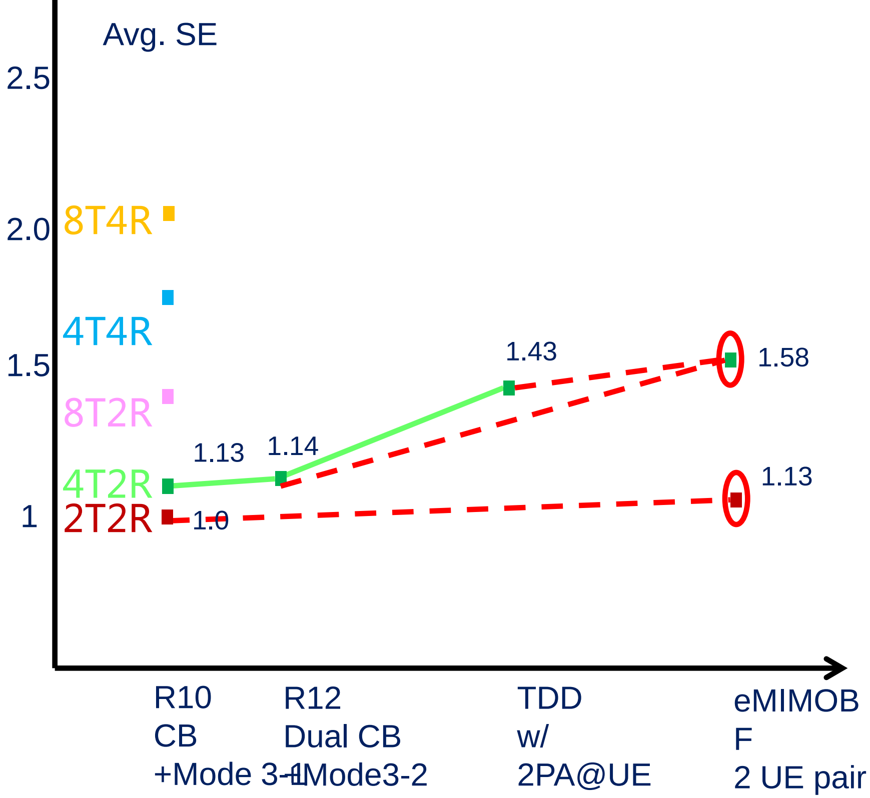


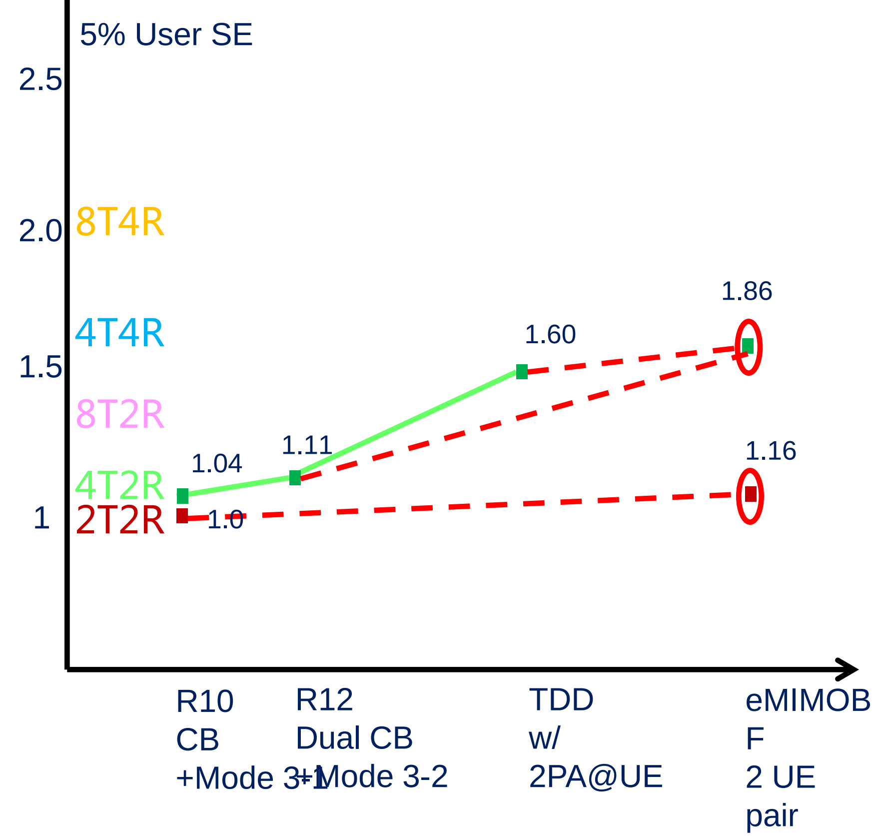
Example: CSI Accuracy Enhancement



Example: CSI accuracy enhancement

- 4T eMIMOBF enhance 60%+ Avg. SE over 2T2R, around 40% over 4T
  - 10 UE assumed in a cell; demodulation error modeled; 80% indoor UE;
  - TM9 used for more than 2 antennas evaluation: 2CRS ports, 12 RE DMRS, 6MBSFN
  - TM4 used for 2T2R evaluation : 2CRS ports



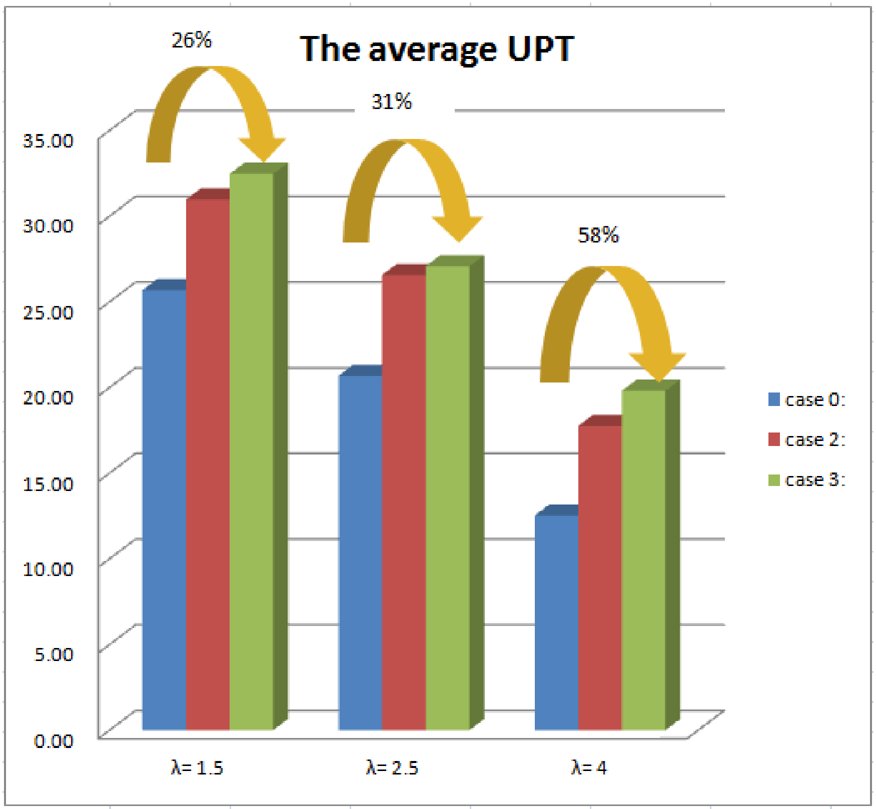


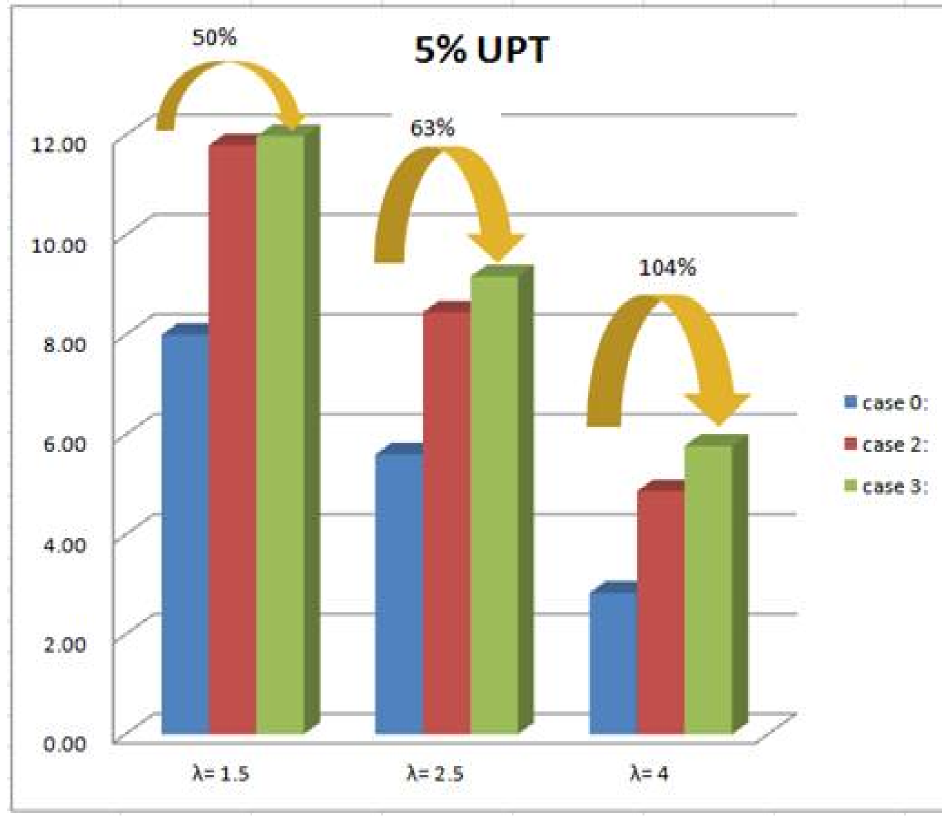
Full Buffer Traffic

Example: CSI accuracy enhancements

- 4T eMIMOBF provides remarkable UPT gain over legacy 4T, the gain increases with load

−Case 0	PUSCH mode 3-1	R8_codebook/FDD	FTP Model 1
−Case 2	Subband CQI	TDD	FTP Model 1
−Case 3	Subband analog CSI+CQI	eMIMO BF for FDD/TDD	FTP Model 1





Additional Enhancement: Beamformed CSI-RS

- BF-CSI-RS based on Rel.13 antenna port configuration (max 16 port) is simple, flexible and future proof
  - No. of physical antennas may keep growing, but antenna port number is upper bounded in the specification
- Rel.14 enhancement should consider beamformed CSI-RS
  - Maximum 16 ports per CSI-RS resource (same as in Rel.13, no new CSI-RS design)
  - Potentially large number of UE-specific beams, as number of physical antennas keep increasing (e.g. 64 and beyond)
- Potential enhancement areas
  - Beam measurement mechanism (e.g. beam accuracy, beam number, complexity reduction)
  - UE-specific beam tracking in general deployment scenario (e.g. high-speed, small-cell)
  - UE-specific beamformed CSI-RS codebook enhancement
  - Measurement mechanism for advanced interference coordination (e.g. intra-cell MU-MIMO)

Conclusions

- Rel.14 MIMO enhancement: Target legacy eNB configuration (2/4/8 Tx), while the mechanism may be applicable to massive MIMO as well (due to beamformed CSI-RS)
  - DMRS-based open-loop MIMO and Tx diversity
  - Both low-speed and mid-to-high scenarios to be considered
  - CSI spatial resolution and enhanced spatial layer processing techniques for advanced MIMO and non-co-located network operation
  - CSI accuracy and robustness enhancement
- Further enhancement of BF-CSI-RS
  - Support UE-specific beams as the number of physical antennas increases
  - Beam adaptation / tracking / feedback enhancement
  - Advanced interference coordination for MU/CoMP

– Max number of antenna ports remain 16 as in Rel.13