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

RWS-210396

MIMO Enhancements

Agenda Item: 4.3
Source: Lenovo, Motorola Mobility
Document for: Discussion

Candidate MIMO Enhancements

(1) Prediction-based beam management

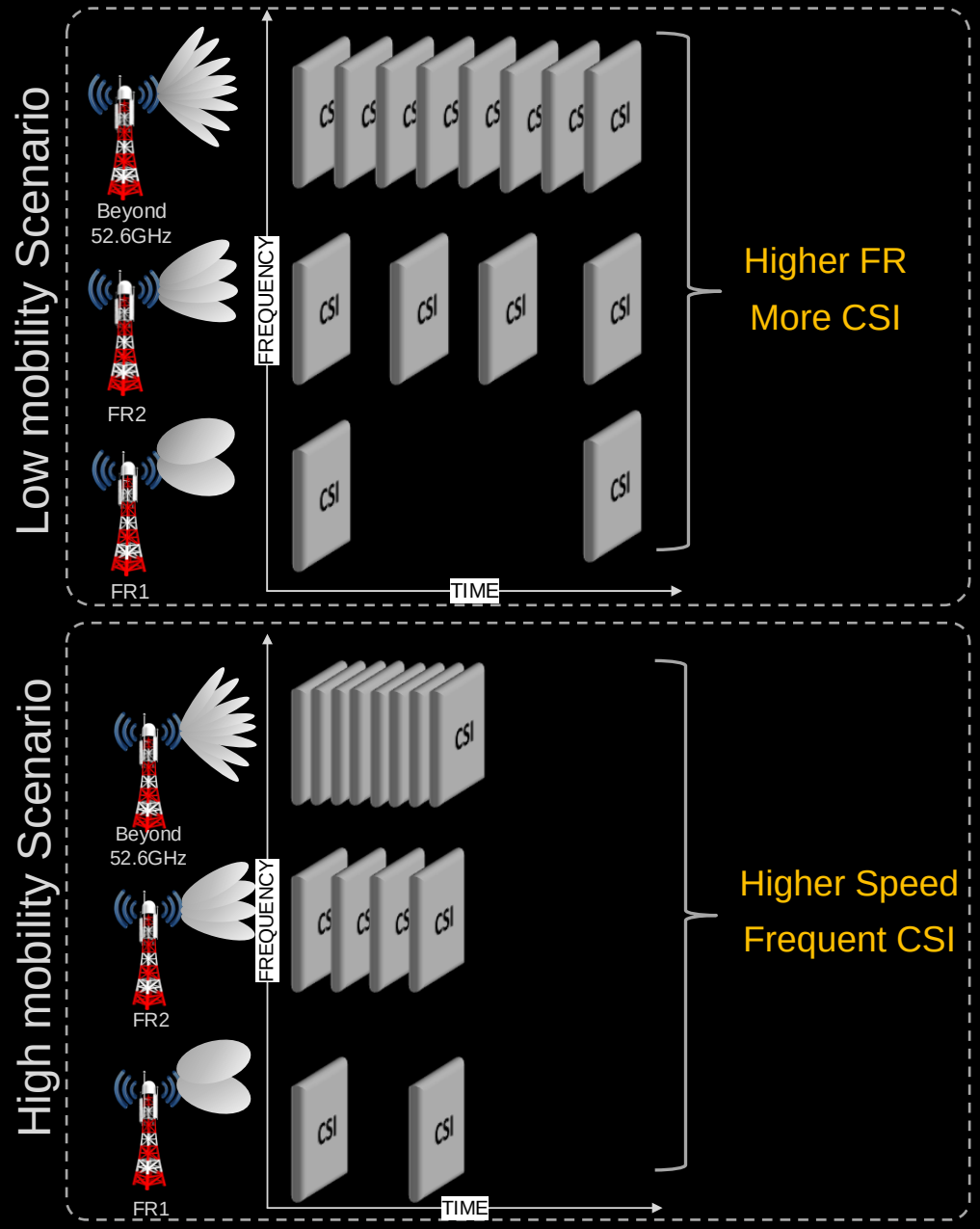
(2) CSI enhancements for high-speed deployment

(3) Multi-cell / Multi-TRP enhancements

(4) Uplink MIMO enhancements

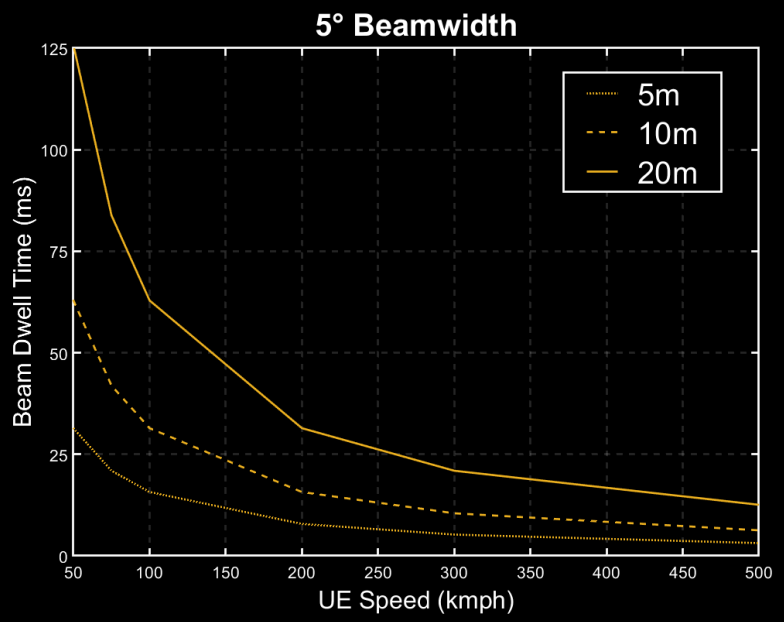
1. Prediction-based beam management: Motivation

- **In NR Rel-17, feMIMO WI is specifying beam enhancements**
  - **To support unified TCI framework for DL and UL**
  - **To reduce latency for beam updates**
- **However, latency and signaling overhead still expected to escalate with:**
  - **Narrower beam in higher frequency range**
  - **Medium-high speed UEs**
  - **Dense networks with larger number of UEs**



BM Issues: Example Analysis

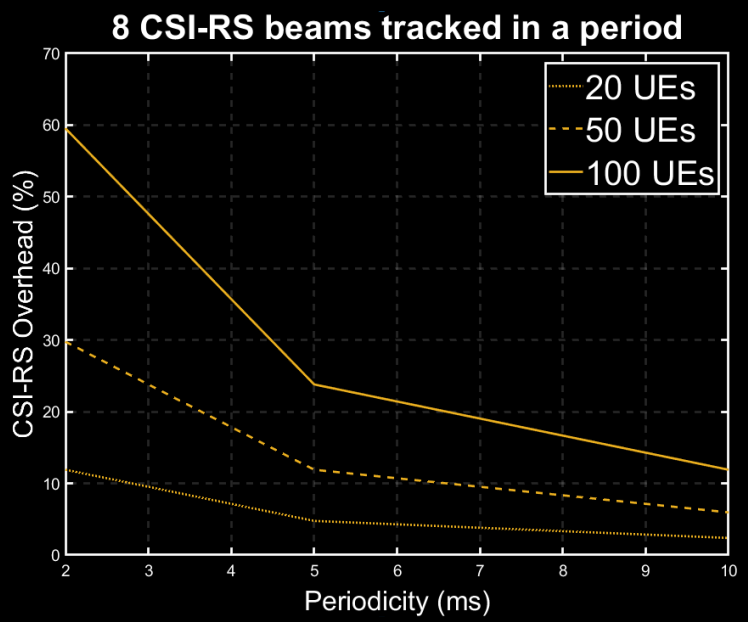
Beam Dwelling Time (ms)



Shorter beam dwelling time

- Higher speed
- Shorter TRP-UE distance
- Narrower beamwidth

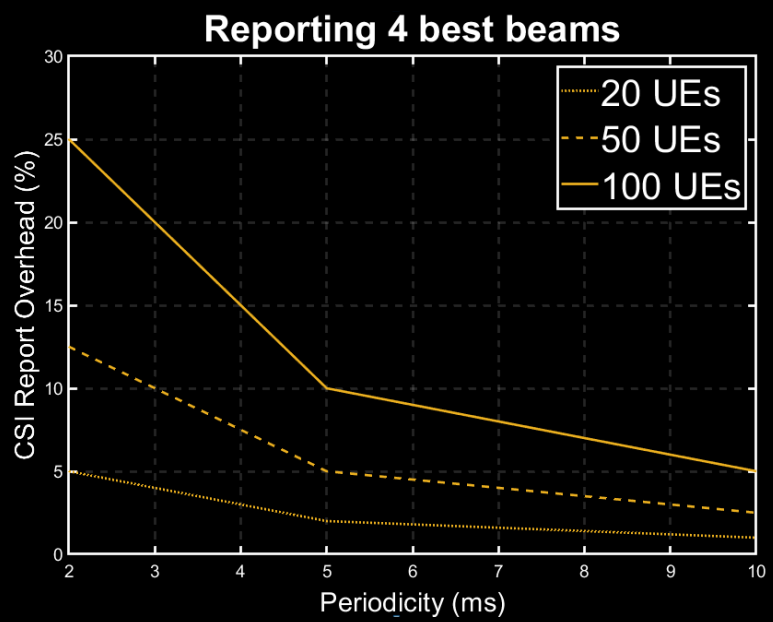
CSI-RS Overhead (%)



Frequent beam measurements

- Shorter beam dwelling time

CSI Reporting Overhead (%)

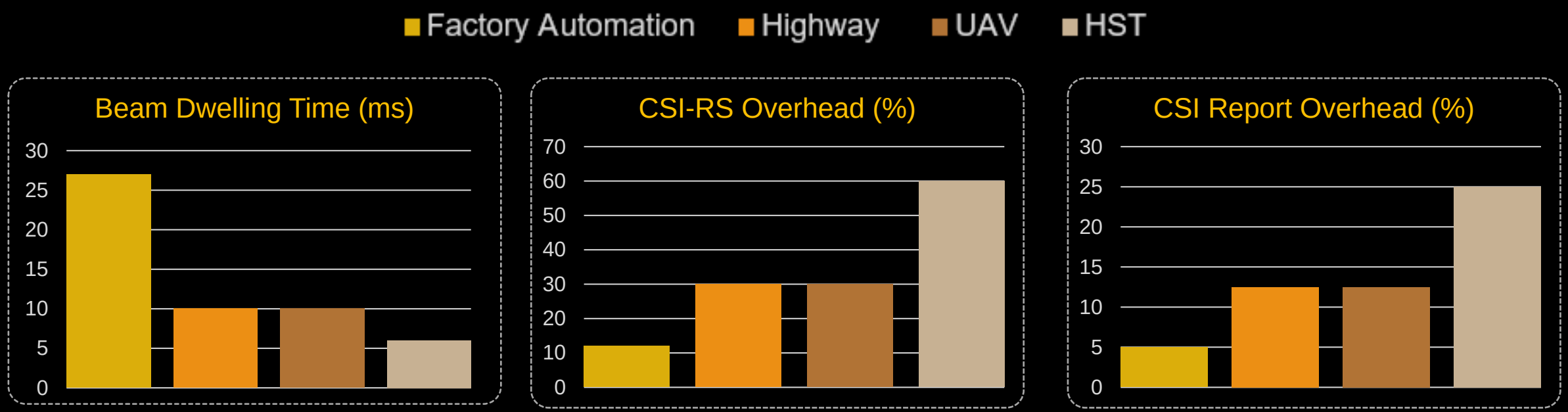


Frequent beam reporting

- Frequent beam measurements
- Frequent beam updates

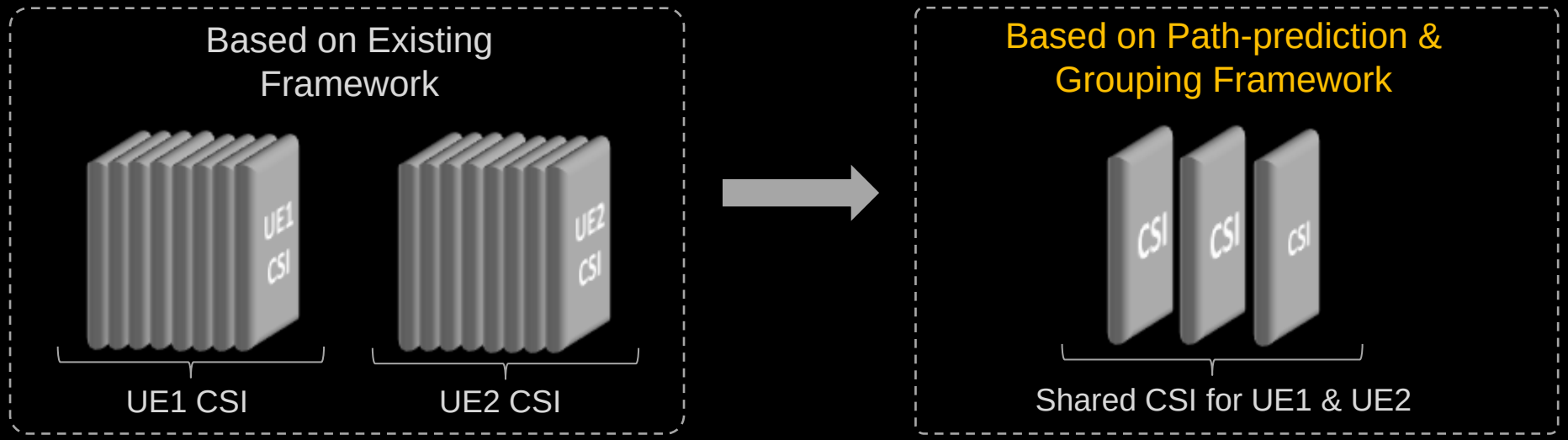
BM: Use-Case Analysis

Use Cases	Movement Pattern	Assumptions for Analysis					
		Speed (Kmph)	User Density	Beamwidth	# of Tracked Beams	TRP-UE Distance (m)	CSI Periodicity (ms)
Factory Automation	Restricted/periodic movement	75	50	5°	8	6.5	5
Highways	Deterministic movement (multiple lanes)	300	50	5°	8	10	2
UAV	Deterministic/monitored movement	300	50	5°	8	10	2
High Speed Trains	Restricted movement	500	50	5°	8	10	1



BM: Enhancement Candidates

- For Rel-18, existing beam-management & CSI framework can be enhanced by exploiting path prediction
- Path prediction-based beam-management and CSI framework
  - **To update/refine Tx-Rx beam pair(s) based on the position and/or orientation and/or mobility of the UE**
  - **To leverage grouping of UEs with similar motion and enhance CSI-RS measurement/reporting (UE1, UE2 below)**



For use cases where UE's path can be easily pre-determined or predicted, prediction-based beam management is expected to provide much benefits

BM: Enhancements Proposal

- **Study item for Prediction-based beam-management and CSI enhancements with following objectives:**
  - **Study and identify enhancements to reduce CSI measurements/reporting for beam-management procedures by**
    - **Applying path-predication based on UE's movement and/or location characteristics, such as deterministic/predicted/periodic/ movement**
    - **Applying grouping based on movement of multiple UEs with similar mobility pattern, for example, moving as a group or following same path**
  - **Study latency and CSI signaling overhead reduction with prediction-based beam-management**

2. CSI Enhancements for High-Speed – Motivation

- Current CSI framework in NR Rel-15/16 and Rel-17 WI is not optimized to handle fast channel variations with high-speed deployment scenarios
  - Scenarios including high-speed train, UEs in highways, Mobile IAB, vehicle mounted relay, V2X, UAV
  - Frequent CSI-RS transmission may capture the fast channel variation, at the expense of substantial CSI-RS transmission overhead and increased UE power consumption due to frequent CSI measurement
  - Frequent CSI reporting may enable high-resolution characterization of the channel, at the expense of draining uplink resources due to increased CSI feedback overhead

- A generalized CSI framework is needed for high-speed deployment scenarios that exploits temporal channel correlation to achieve a reasonable tradeoff between performance, complexity, and CSI feedback overhead

CSI - Temporal channel correlation

- **The channel coherence time varies significantly with the UE speed (Table 1)**

- **Channel correlation at 60 Km/h (Figure 1)**
  - **If the CSI is fully measured/reported every 8 slots, resources are not utilized efficiently since the channel correlation is not exploited**
  - **If the CSI is fully measured/reported every 16 slots, the performance would be degraded since the CSI becomes weakly correlated after the 10th slot**

UE speed (Km/h)	Tc (slots)
3	360
10	108
30	36
60	18
120	9
360	3

Table 1: Channel coherence time (in slots) at F_c= 4GHz, SCS= 60kHz

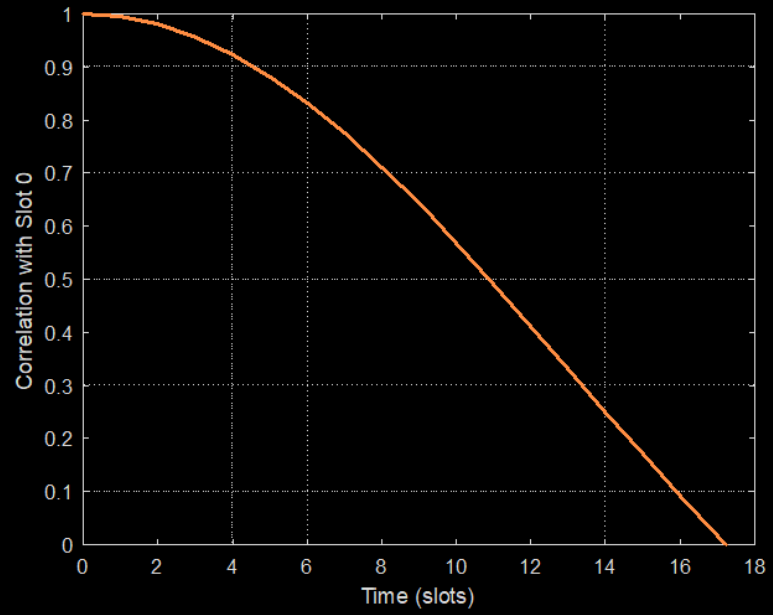


Figure 1: Temporal correlation (Jake's model) of channel at slot 0 with channel at slot n at F_c= 4GHz, SCS= 60kHz

CSI - Mixed channel behavior

- **Example:** Different intervals of channel quality
  - **Interval 1:** Minor channel variation
  - **Interval 2:** Moderate/Fast channel variation
  - **Interval 3:** Abrupt channel variation, e.g., blockage
  - **Interval 4:** Large/Slow channel variation

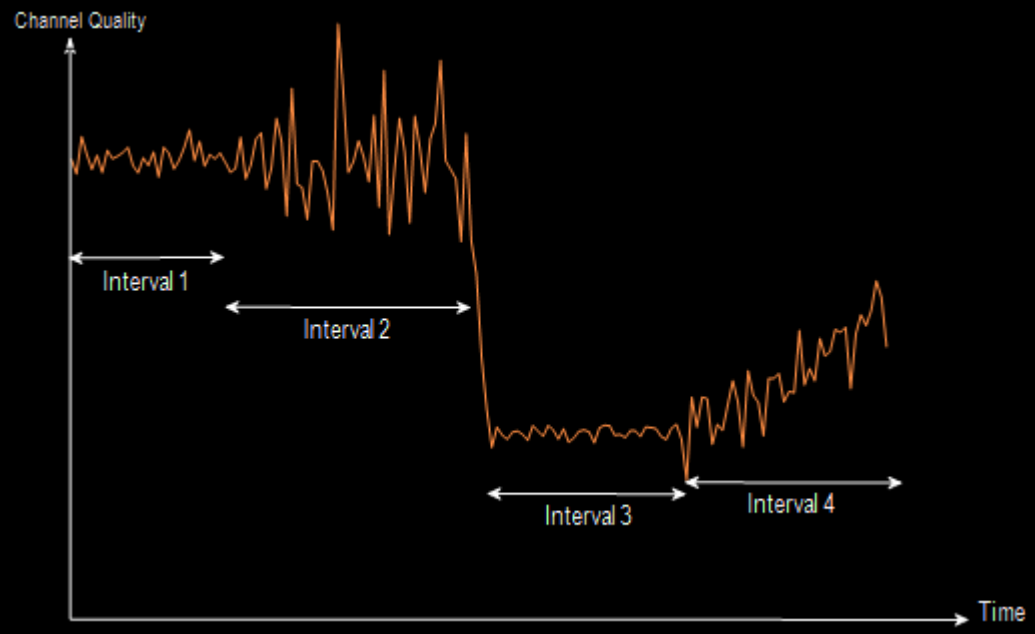


Figure 2: Variations of channel quality across time

- **Channel behavior may vary over time for the same device, e.g., drones, requiring different CSI periodicity and resolution**
- **Current framework with multiple CSI Reporting Settings may not be efficient due to large CSI-RS transmission overhead and redundancy across Reporting Settings**
- A more flexible CSI framework that seamlessly handles mixed channel behavior is needed

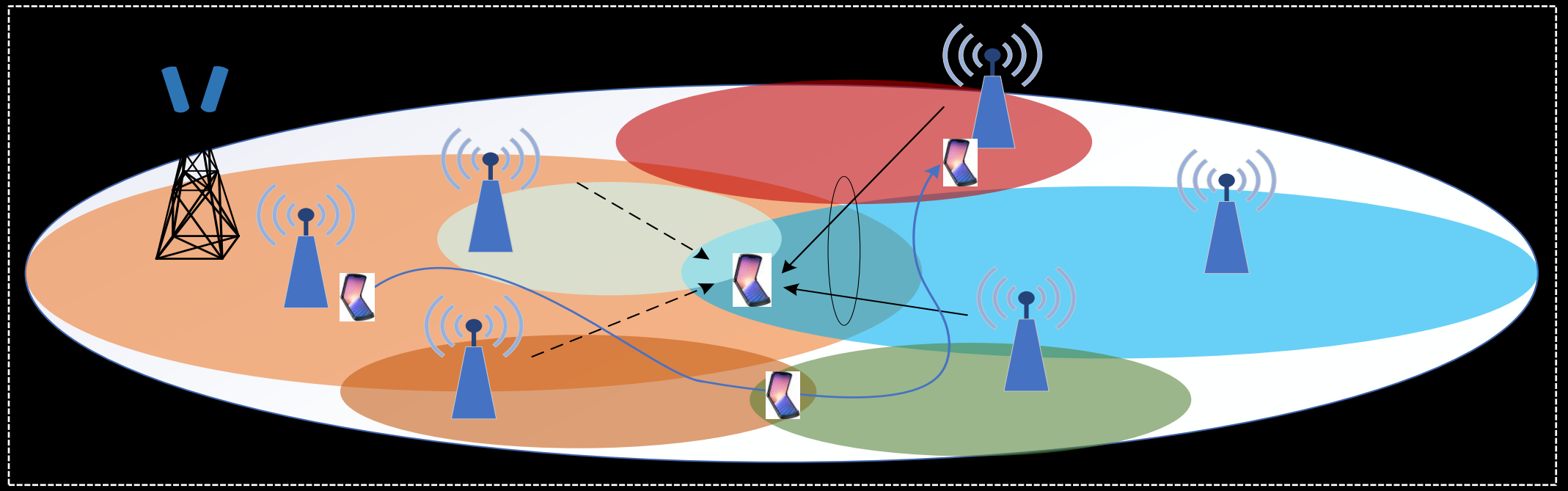
Proposal on CSI enhancements for high-speed deployments

- Study, and, if needed, specify CSI enhancements for high-speed deployment scenarios with the following objectives:
  - Identify methods for a unified CSI framework (configuration / measurement / reporting) that exploits temporal channel correlation and provides robustness against time-varying characteristic of the channel with large Doppler spread
    - Achieve reasonable tradeoff between performance and CSI reporting feedback overhead
    - Reduce CSI measurement/reporting complexity at the UE
    - Enable fast, seamless handling of instantaneous variations in channel quality, e.g., due to blockage or abrupt changes in UE orientation

3. Multi-cell / Multi-TRP enhancements: Motivation

- Basic functionality for multi-TRP operations specified in Rel-16 and being further improved in Rel-17
  - Multi-TRP based PDSCH and PDCCH repetition with higher reliability
  - Multi-TRP based PUCCH and PUCCH repetition with higher reliability
  - Beam management and CSI enhancement to support multi-TRP operation
- Basic multi-cell operation functions are also being discussed in Rel-17
  - L1 beam report for non-serving cells to support inter-cell mobility in FR2
  - QCL enhancement to support inter-cell multi-TRP operation
- However, following limitations are assumed
  - Multi-TRP/panel support in Rel-17 is limited to only synchronous inter-TRP
  - Only up to 2 TRPs are supported for multi-TRP operation for DL as well as UL

Multi-cell / Multi-TRP enhancements – New scenarios



- Scenario 1
  - UE moves across the coverage of multiple TRPs with different PCIs
  - Considering inter-DU and inter-frequency cases

- Scenario 2
  - UE is in coverage of more than 2 TRPs
  - Any two or more of those TRPs can be selected for NCJT transmission

Proposal for multi-cell / multi-TRP Enhancements

L1/L2-centric inter-cell mobility

- Identify and specify features to support higher efficient and lower latency L1/L2-centric inter-cell mobility
  - Event-based beam reporting with multiple candidate cells
  - UE-initiated serving cell change for high mobility
  - Support of inter-DU inter-cell mobility
  - Support of inter-frequency inter-cell mobility

Multi-TRP/panel operation

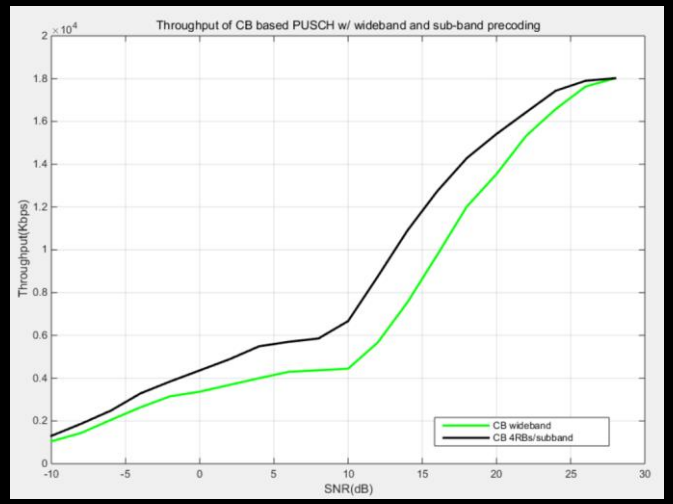
- Identify and specify features to support advanced multi-TRP operation
  - Support of asynchronous scenarios, e.g., DL signals received beyond CP and UL signals transmitted to different TRPs with different TA values
  - Support of different numerologies for different TRPs in multi-TRP mode
  - Support of more than 2 TRPs operations in a cell
    - Dynamic TRP-group selection for NCJT
    - Enhancements on beam management and CSI measurement/reporting for flexible TRP grouping for NCJT

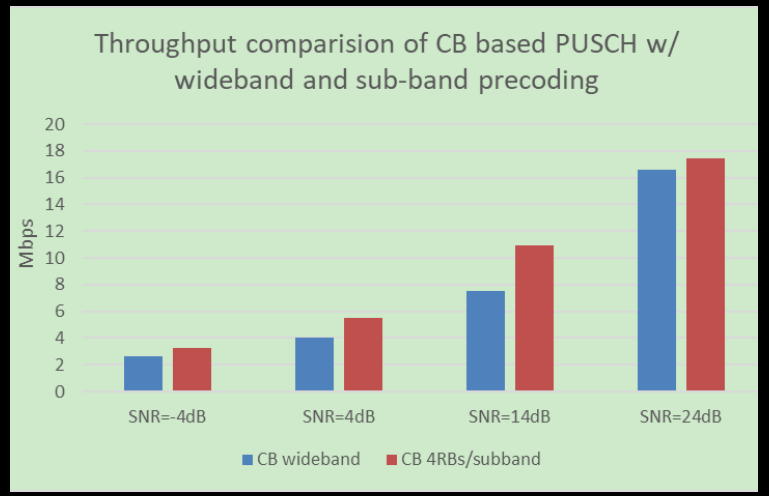
4. Uplink MIMO Enhancements: Motivation

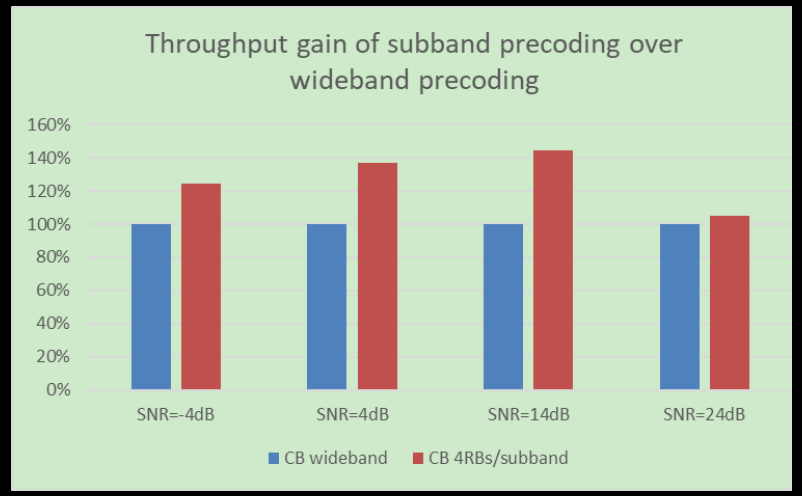
- Rel-16/17 enhancements on UL MIMO focused on improve of coverage as well as reliability
  - Full power UL Tx for coverage enhancements
  - PUSCH/PUCCH repetition in multi-TRP scenario for higher reliable transmission
- More and more UL-heavy traffic will emerge with the deployment of 5G
  - Real-time video surveillance in industrial and healthcare application
  - Vehicular application and VR/XR applications
- Need further improvements in UL performance for eMBB traffic as well as URLLC applications
  - UL data rate need to be further improved for eMBB traffic

Uplink Frequency-selective Precoding - Initial evaluation

Parameters	Value	Parameters	Value
Carrier frequency, SCS, System BW	4GHz, 30kHz, 100MHz	**Precoding granularity**	For sub-band, 4RB per RBG
Channel model	CDL-C in TR 38.901 with 300ns delay spread	**Configuration of UE antennas**	4T4R with (M, N, P) = (1,2,2), (dH, dV) = (0.5, 0.5) λ,
UE speed	30km/h	**Configuration of gNB antennas**	4T4R with (M, N, P) = (1,2,2), (dH, dV) = (0.5, 0.5) λ,
Rank, precoders and MCS	Fixed rank-1, TPMI and MCS are adaptive	**DMRS configuration**	Additional DMRS symbol=2







Proposal for UL MIMO Enhancements

- **Work item for UL MIMO enhancements with the following objectives:**
  - **Identify and specify features for frequency-selective UL precoding at least for FR1**
  - **Identify and specify features for UL transmission for UE with more than 4 antennas**
    - **High resolution codebook and corresponding TPMI indication for UE with 6 or 8 antennas**
    - **Support of higher rank UL transmission**
  - **Identify and specify features for simultaneous multi-panel UL transmission in FR2, including the following aspects:**
    - **UL beam management to enable simultaneous multi-beam transmission for UL transmission**

thanks.

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Lenovo