3GPP TSG RAN Meeting #102
Edinburgh, UK, December 11-15, 2023

RP-233687

Views on Rel-19 RAN4 RRM and Demodulation topics

Agenda Item:	9.1.4.3
Source:	Intel Corporation
Document for:	Discussion & Decision

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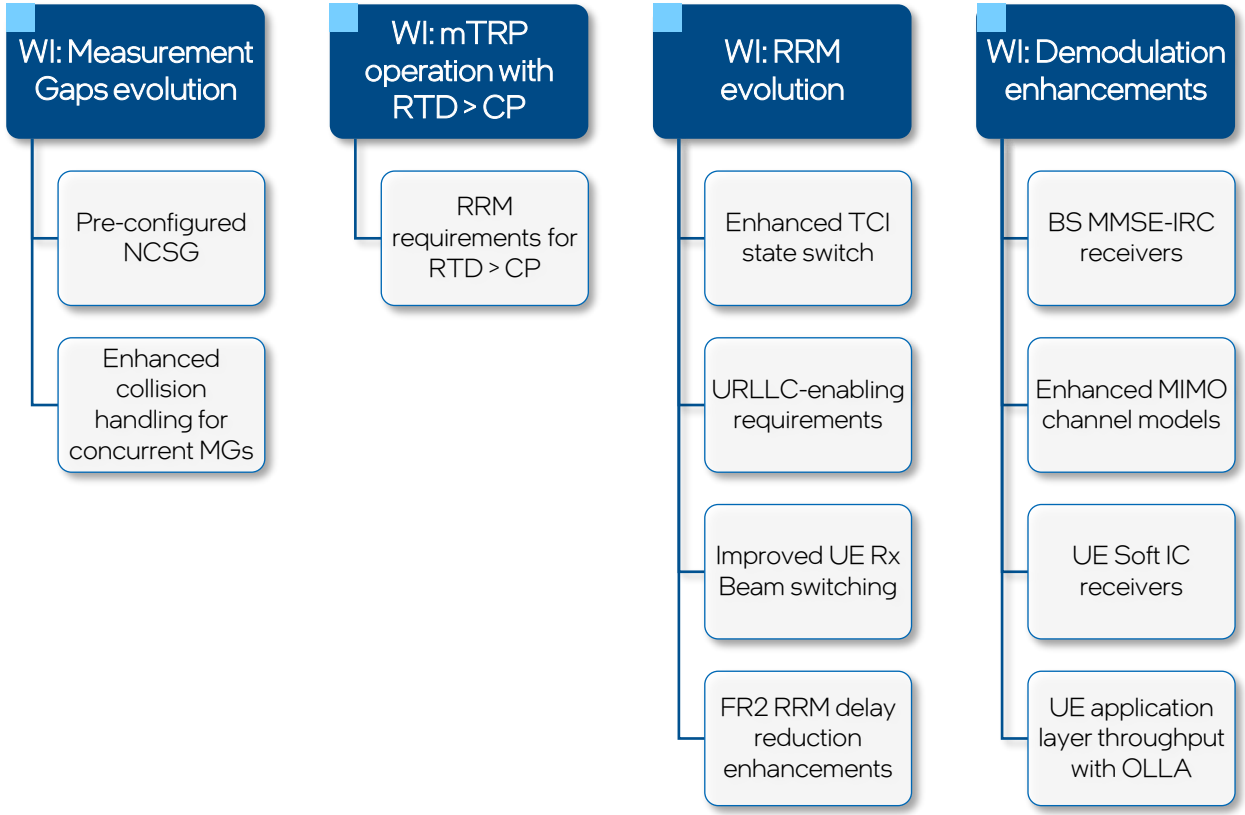
Introduction

The general views on RAN4 Rel-19 SI/WI package is provided in RP-233685

The following SI/WIs are recommended for RRM/Demod areas:

- WI: Measurement Gaps evolution
- WI: mTRP operation with RTD > CP
- WI: RRM requirements evolution
- WI: Demodulation enhancements



Intel's priorities for RAN4 Rel-19 RRM/Demod

	Prioritized objectives/scope	Comments
Measurement Gaps evolution	• Pre-configured NCSG • Enhanced collision handling for concurrent MGs (parallel measurements)	An umbrella WI is recommended to continue the evolution of MG enhancements with [1.5] RD TU per meeting.
mTRP operation with RTD > CP	• RRM requirements to enable mTRP operation with RTD > CP incl. inter-cell beam management, TCI state activation, LTM – L2 triggered mobility, CSI-RS based L3 measurements (intra-frequency)	A standalone project with [1] RD TUs with an emphasis on enablement of UE operation in mTRP scenarios with RTD > CP operation. The scope can be also included in the generic RRM enhancements WI

RRM evolution	• Interruption and scheduling restriction optimization
	  • Enhanced TCI state switching requirements
	  • URLLC-enabling requirements
	  • Improved UE Rx Beam switching
	• FR2 RRM delay reduction enhancements
		A single umbrella WI is recommended to continue the evolution of RRM enhancements with [1.5] RD TU per meeting.
		The scope shall focus on improving the requirements rather than on addressing leftovers.

Demodulation enhancements	• BS MMSE-IRC for uplink inter-cell interference • Enhanced MIMO channel models with spatial components for UE and BS requirements • UE Soft IC receivers (study) • UE application layer throughput with OLLA	An umbrella WI is recommended to continue the evolution of Demodulation enhancements with [2] RD TU per meeting. The WI scope shall ensure a balance between BS and UE requirements.

Measurement Gaps Evolution

Measurement Gaps Evolution

Overview of R19 workshop proposals

NCSG enhancements

- Pre-configured NCSG
- Parallel measurements upon NCSG collisions
- L1 inter-frequency measurements in NCSG
- NCSG enhancements for deactivated SCell

Others

- Per CC gaps
- Gap overhead enhancements
- Independent gap configuration for DC
- Calculation of Kp enhancements
- L1 inter-frequency measurements by NeedForGap UE

Intel proposals

Down-selection of proposals taking into consideration commercial needs and deployment plans is required

Measurement Gaps Evolution

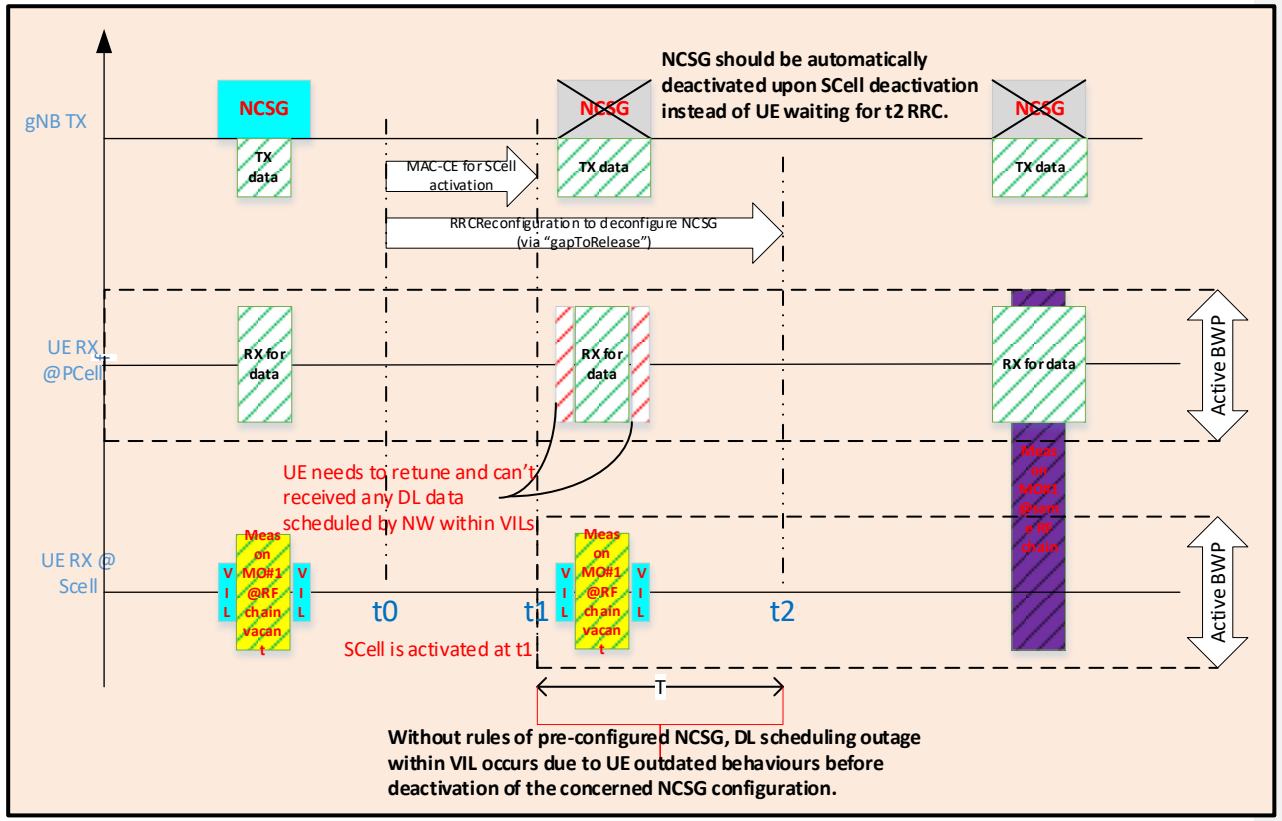
Pre-configured NCSG

Motivation

- The combination of pre-configured MG and NCSG features was de-prioritized in Rel-18 timeframe.
- Under CA operations, UE measures on SCell-s either within NCSG or outside of gap depending on SCell activation status (assuming SCell SSBs are within UE's active BWP). Problems are observed in the below cases without pre-configured NCSG:
  - Case 1: During SCell activation, DL scheduling could be lost due to RRC processing for releasing the associated NCSG.
  - Case 2: During SCell deactivation, UE does not perform measurements on the SSBs on the deactivated SCell until that the UE completes RRC processing for the new NCSG or MG. The measurement latency will be largely extended due to UE RRC processing time.

Candidate objectives

- *Pre-configured NCSG*
  - *Mechanism to configure the pre-configured NCSG*
  - *Activation/deactivation procedure*
  - *UE capability*



Preconfigured NCSG de-activation

Measurement Gaps Evolution

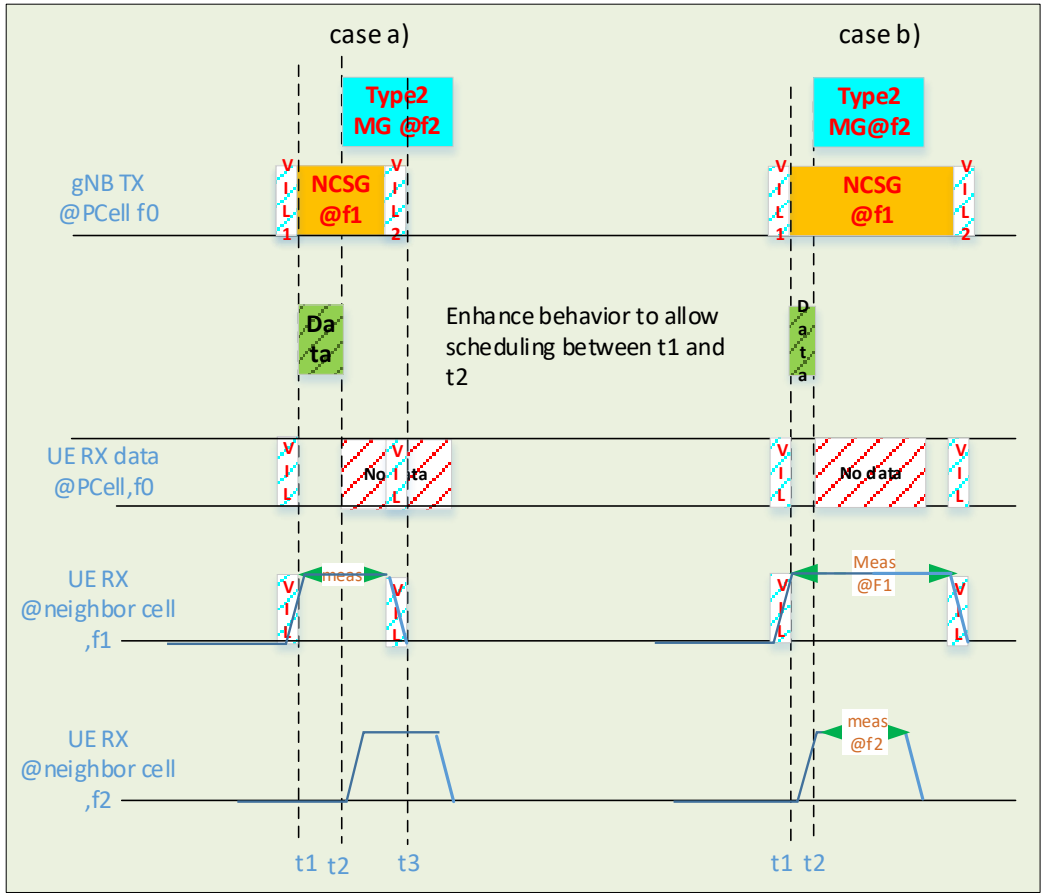
Enhanced collision handling for concurrent MGs

Motivation

- Based on current design for concurrent MGs with NCSG, UE needs to drop one of the gap instances when they are collided for intra-band measurements or inter-band measurements (e.g., both (f0+f1) and (f1+f2) band combinations).
- UEs with vacant RF chain(s) can utilize them for parallel measurements for the multiple gaps no matter they are collided or not. The enhanced dropping rule can be beneficial to increase overall both UE and NW efficiency.

Candidate objectives

- Define enhanced UE behavior upon gap collisions
  - Optimized dropping rules when NCSGs are within concurrent MGs



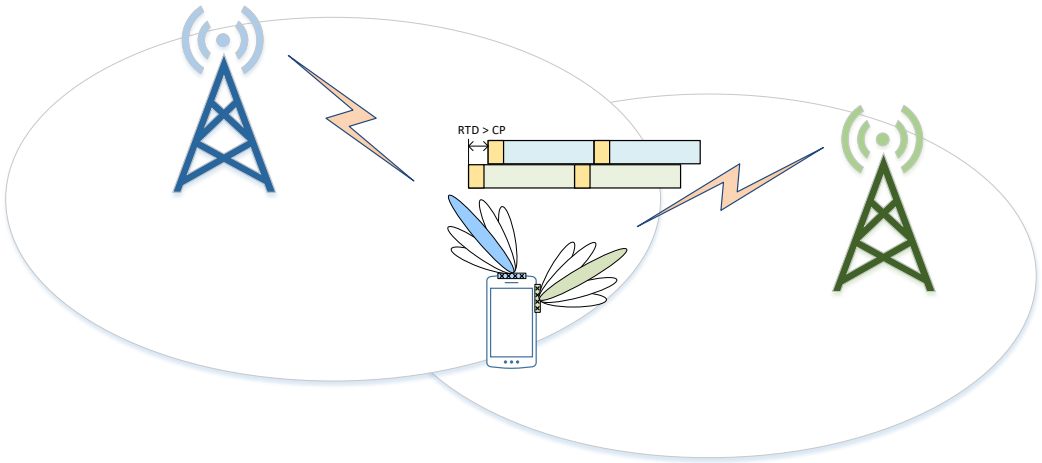
NCSG collision handling

Requirements to enable mTRP operation with RTD > CP

Requirements to enable mTRP operation with RTD > CP

Background

- In practical deployments it is challenging to guarantee that timing offsets between signals from different TRPs are within a CP, especially for FR2 operation with a high SCS, which limits the efficiency of mTRP operation
- Many existing baseline RRM/Demod requirements for mTRP scenarios are defined under an assumption that timing offsets between signals are less than CP



- Support of RTD > CP is being discussed under several Rel-18 work items, but a relatively limited support is expected to be introduced
  - **Rel-18 NR MIMO:** New UE capabilities are defined by RAN1 to enable Rx timing difference between the two DL reference timings > CP. A very limited set of RAN4 requirements is being introduced (MRTD/MTTD).
  - **Rel-18 NR FR2 HST:** RTD > CP is supported FR2 UE PC6. RRM requirements are limited to MRTD. Demod requirements are FFS.
  - **Rel-18 NR FR2 Multi-Rx Chain:** RTD > CP scenario is de-prioritized.
  - **Rel-18 NR MobEnh:** RTD > CP support depends on UE capability. Separate RRM requirements are discussed corresponding to different UE capabilities.

Requirements to enable mTRP operation with RTD > CP

Motivation

- A systematic and generic approach is desirable to introduce the support of mTRP operation with time offsets larger than CP including RRM and Demodulation requirements to facilitate feature adoption for different device types
- At least the following RAN4 requirements are defined under an assumption of RTD < CP and limit mTRP operation
  - RRM
    - Inter-cell beam management
    - TCI state activation
    - LTM – L2 triggered mobility
    - CSI-RS based L3 measurements (intra-frequency)
  - Demodulation
    - Simultaneous demodulation of mTRP DL signals

Candidate objectives/scope

- Study and introduce UE requirements to enable mTRP operation with RTD > CP incl. DL/UL operation
- FR1 & FR2 scenarios
- Handheld, CPE/FWA and HST devices
- Consider both single carrier and CA scenarios
- UEs with and without simultaneous data reception capabilities
- RRM requirements to enable RTD > CP
- 2nd priority: UE demodulation requirements for RTD > CP

RRM Evolution

RRM Evolution

Overview of R19 workshop proposals

Measurement reporting enhancements

FR2 delay reduction
- CSSF w/o MG enh-s
- RLM and BFD reduction
- General L3 delay reduction

Further enhanced EMR
- Selection of a reduced set of carriers
- Improved reporting during connected mode

CSI-RS enhancements
- CMTC
- Collisions between L3 and L1
- Inter-cell L1 measurements based on CSI-RS

Interruptions and scheduling restrictions optimizations

- Enhanced TCI state switch
- URLLC enabling requirements
- Improved UE Rx beam switching
- BWP switching enhancements
- HO interruption reduction

Missing requirements

- SRS antenna port switching during whole slot
- HO with PSCell enhancements
- Missing requirements for RedCap UE
- NR RACH-less HO requirements
- Second RLM BLER pair requirements
- BFD reconfiguration requirements

Mobility and procedure enhancements

- Further SCell activation enhancements based on R18 solutions
- Unified TCI extension to multi-TRP
- Dynamic RTD/TTD update

Others

Relaxed RRM requirements and UE power saving
- To apply RedCap requirements to non-RedCap UE
- 1Rx NTN UE requirements
- eDRX requirements
- Relaxed RLM/BFD requirements

AI/ML based Rx beam sweeping
- Reduced delay requirements
- RSRP map, deep learning and image super-resolution

Intel proposals

Down-selection of proposals taking into consideration commercial needs and deployment plans is required

RRM Evolution

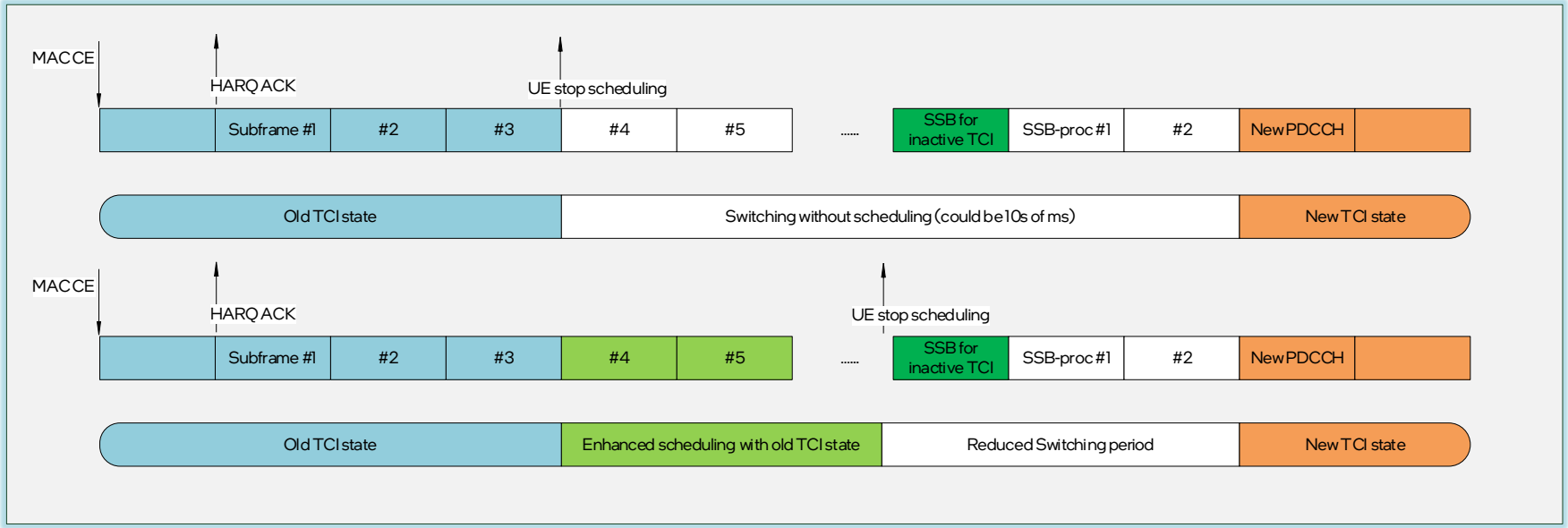
Enhanced TCI state switch requirements

Background

- In TCI state switching requirements, there is a time gap where UE is not required to receive or transmit data.
- The gap has an impact on the throughput performance in case the first SSB arrives relatively late for DL TCI state switching and in case the first PL-RS arrives late for UL TCI state switching.
- UE behavior can be enhanced to receive and transmit data during the time gap of $T_{first\text{-}SSB}$ for DL TCI state switching or during the $T_{first_target\text{-}PL\text{-}RS}$.

Candidate objectives

- Enhancements to maintain the UE reception and transmission during the period (or part of period) of DL, UL and joint DL/UL active TCI state switching



Current MAC CE based TCI state switch timeline

Enhanced MAC CE based TCI state switch timeline

Example of MAC-CE based downlink TCI state switch

RRM Evolution
URLLC-enabling requirements

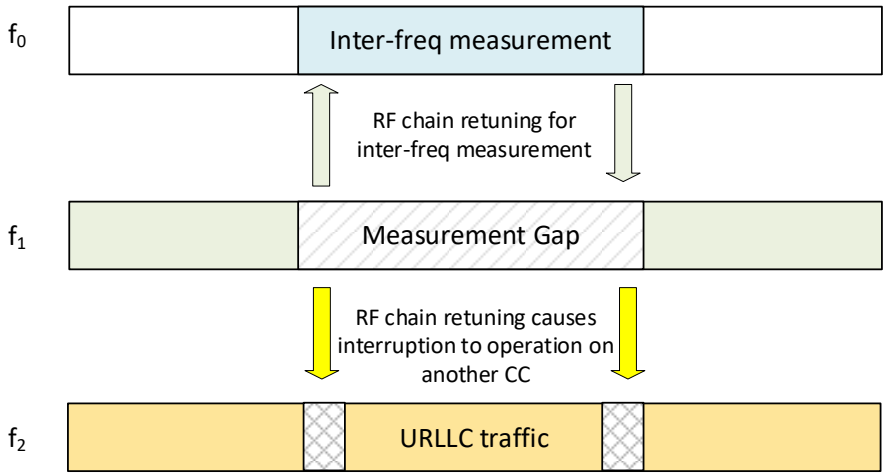
Background

- URLLC is one of key applications for 5G/5G-A.
- From RRM requirements perspective URLLC data is no different to eMBB in terms of allowed disruptions in data, which is not well fulfilling URLLC service requirements regarding mission criticality. RRM procedures such as measurements, interruptions due to RF retuning, SCell activation, etc. may affect URLLC traffic.
- Further enhancements to RRM requirements and UE capabilities can be considered to minimize disruptions on URLLC traffic.

Candidate objectives

- Study and specify enhancements for protection of carriers with URLLC traffic from RRM-related disruptions
  - Identify the cases, where disruptions on carriers with URLLC traffic may occur
  - Enhancement to reduce the allowed interruption length on carriers with URLLC traffic
  - Mechanisms for interruption protection on carriers with URLLC traffic
  - Additional UE capabilities for interruption free RF chains dedicated for carriers with URLLC traffic

Note: The same set of enhancements can be applied to other time-sensitive or reliability-sensitive types of services incl. XR. The work can be a part of RRM or MG evolution.



Interruption impact on carriers with URLLC traffic

RRM Evolution

Improved UE Rx Beam switching requirements

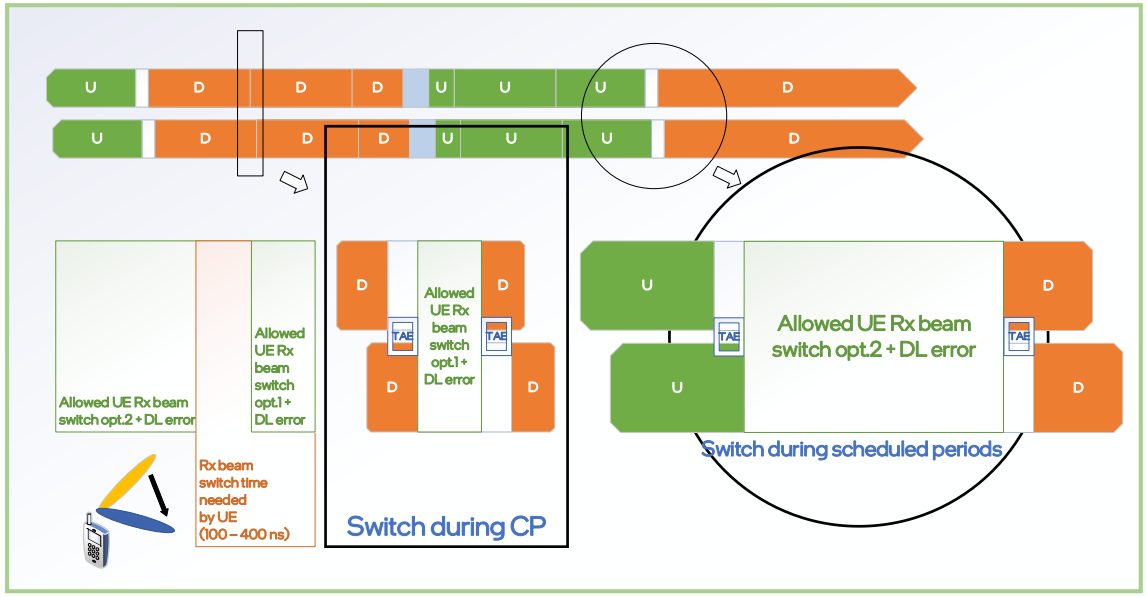
Background

- In FR2, there are cases where the CP length cannot accommodate the switching time of UE Rx beam switching properly, therefore causing interruptions on scheduling every time the UE switches its Rx beam.
- Performance degradation is expected on the serving cell for both single carrier and CA scenarios with CBM.
- Dedicated scheduled time periods or guard periods between UL and DL symbols for beam switching can be used to avoid performance loss.

Candidate objectives

- Enhancement to schedule time periods for FR2 UE Rx beam switching

SCS	CP length	TAE for Contiguous CA	DL timing error
120kHz	580ns	130ns	~33ns
480kHz	146ns	32.5ns	~8ns
960kHz	73ns	32.5ns	~4ns
Note: UE Rx beam switching time ranges from 100 to 400 ns.			



Comparison between switching during CP and during scheduled periods

Demodulation Evolution

BS Demodulation
MMSE-IRC for inter-cell interference

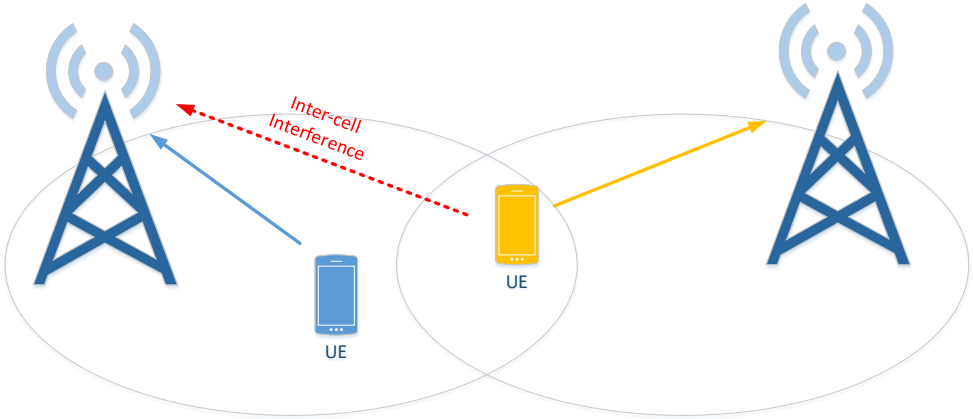
Motivation

- Existing BS requirements are defined for noise limited conditions and do not allow verification of BS interference rejection capabilities under practical conditions.
- Interference-limited conditions are quite typical for 5G deployments and support of MMSE-IRC processing is important to guarantee good performance in the field (see typical LTE profiles on the right).

Candidate objectives

- Study NR UL inter-cell interference profiles
- Define **BS MMSE-IRC demodulation requirements** for inter-cell interference scenarios for SU-MIMO cases

UL inter-cell interference



Typical UL DIP/INR values
for 85% DIP CDF based on TR 36.884

	HomoNet		HetNet	
	DIP	INR	DIP	INR
Interf UE1	-1.11	7.29	-0.43	12.38
Interf UE2	-10.91	-2.51	-13.78	-0.97

Enhanced MIMO Channel Models

Motivation

- RP-231711 (Nokia): *The commonly used TDL-low MIMO fading channel model does not have a spatial component. Hence, MIMO SDMA/precoding gains are not observable in performance requirements, due to lack of rank deficiency in the channel*

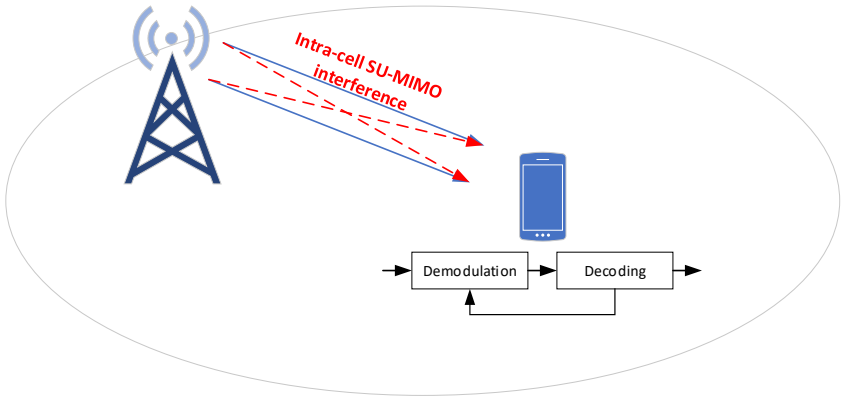
Candidate objectives

- (1st priority) Study and specify enhanced MIMO channel models for UE and BS performance characterization with realistic modeling of spatial characteristics
  - CDL channel models can be considered as a starting point
  - Study test feasibility of new channel models
  - Consider both FR1 and FR2 scenarios
- (2nd priority) Define UE and BS performance requirements with enhanced MIMO channel models

UE Demodulation

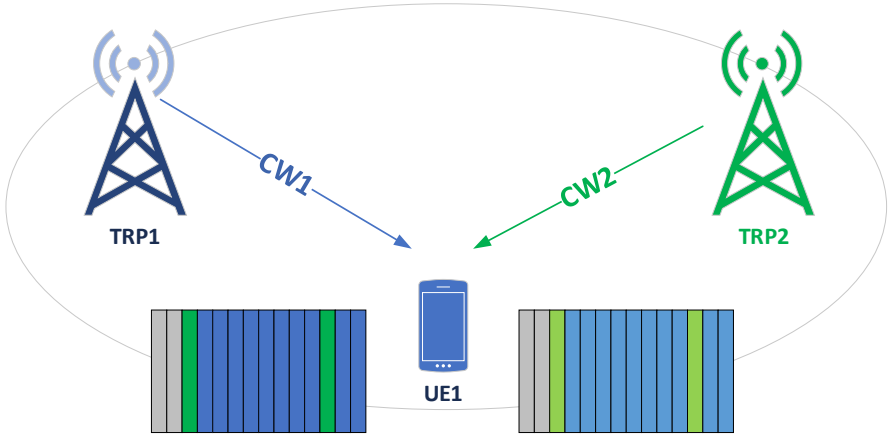
Soft IC receivers for DL SU-MIMO and multi-TRP

- Motivation: DL SU-MIMO requirements are defined for MMSE-IRC and R-ML receivers. Rel-16 eMIMO requirements for multi-DCI multi TRP scenario are defined for scenarios with non-overlapping PDSCH allocation and MMSE-IRC receiver. Soft IC receivers can be used to improve PDSCH performance for both scenarios.
- Candidate objectives: Study performance benefits and specify UE requirements for **Soft IC receiver for DL SU-MIMO and** for multi-DCI multi TRP scenarios



Application layer throughput requirements with OLLA

- Motivation: Misalignment of UE CSI feedback algorithms with network-controlled OLLA algorithms may potentially cause reduced performance in the field.
- Candidate objectives: Study and introduce **ATP requirements with OLLA** to ensure robust performance under realistic field conditions



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