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Rel-19 Multi-carrier enhancements for NR

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Background/Motivation

- **Rel-18 Multi-carrier enhancements for NR**
  - To increase flexibility and spectral/power efficiency on scheduling data over multiple cells including intra-band cells and inter-band cells while reducing the control overhead
    - » Multi-cell PUSCH/PDSCH scheduling (one PDSCH/PUSCH per cell) with a single DCI
  - To achieve higher UL data rate, spectrum utilization and UL capacity even with practical limitation on number of Tx chains at UE
    - » UL Tx switching across up to 4 bands with restriction of up to 2 Tx simultaneous transmission for FR1 UEs
- **RAN Chair assessment/guidance on Rel-19 Multi-carrier enhancements in RWS-230488**
  - *The proposed areas for possible enhancements are quite diverging and wide*
  - *Careful examination is necessary in terms of real commercial needs*
- **Our general motivation for further enhancements on multi-carrier operation**
  - There have been quite high commercial demands for 1) efficient use/expansion of FR2 and 2) UL performance improvement
    - » Due to limited TUs for Rel-18 MCE, the Rel-18 solutions may not be able to address some of important use-cases and original motivations, including above 1) and 2)
    - » Further enhancements for Multi-carrier operation could lead to an optimized design for UE supporting multiple carriers/bands (which is quite typical e.g., for smartphones) and it can simplify the multi-carrier operation/configuration in practice

Proposals

- **Given the guidance in RWS-230488, Rel-19 MCE (if any) should have limited scope(s) e.g., within 0.5~1 TU for each WG**
- **Considering above and real commercial needs on the improvement of FR2 and UL, at least following enhancements should be considered in Rel-19**
  - Improving MPR for intra-band CA in FR2 [RAN4]
    - » Motivation: In current RAN4 specification, FR2 CA MPR is defined based on not only UL CBW but also DL CBW and hence even if there is only one UL carrier configured for a UE, MPR is very high when UE is configured with multiple DL carriers in FR2. So, in practice, UE needs to be re-configured with reduced number of DL carriers (e.g., single DL carrier) when UL power is not sufficient due to large MPR. Such a restriction makes multi-carrier operation in FR2 totally difficult. This item may be part of RAN4 RF enh in Rel-19 if exists.
    - » Proposed objective: Study and specify FR2 CA MPR improvement (e.g., based on UL CBW only)
  - Multi-cell scheduling + multi-slot scheduling via single DCI [RAN1]
    - » Motivation: Multi-cell scheduling from FR1 cell to FR2 cells is beneficial in terms of UE power consumption and reliability for PDCCH monitoring, and the combination with multi-slot scheduling can achieve efficient scheduling of multiple FR2 cells having higher SCS than that of FR1 scheduling cell.
    - » Proposed objective: Specify enhancements for multi-cell scheduling for supporting multi-cell + multi-slot scheduling via single DCI for the case of scheduling cell with lower SCS than that of scheduled cells

Other potential proposals

- **Views on other potential objectives based on RAN Rel-19 WS papers**
  - [MC-DCI and legacy DCI monitoring on different scheduling cells for a scheduled cell]
    - » Utilizing legacy DCI on self-carrier for scheduling retransmission is beneficial for offloading PDCCH transmissions from scheduling cell of MC-DCI and not requiring cross-carrier scheduling capabilities to UE. So, multi-cell scheduling via MC-DCI together with self-carrier scheduling via legacy DCI for each of co-scheduled cells, i.e., up to two scheduling cells (including own cell) for a scheduled cell can be considered.
  - [Flexible association between UL and DL carriers]
    - » It would be beneficial to study this concept which leads to more flexible use of each carrier assuming multiple carriers/bands available for a UE. It would also lead to more optimized UL/DL usage across carriers/bands according to traffic, bandwidth, Tx power, etc. For example, UL only carrier in lower frequency with sufficient bandwidth which is associated with DL carrier(s) in higher frequency would be beneficial in terms of UL performance such as coverage and capacity. However, there may be no such UL only carrier with sufficient bandwidth to be available soon, and hence new frequency band(s) may be required.
  - [Fast carrier switching for DL (configuring more DL carriers than DL CA capability)]
    - » It would be good for UE with limited DL CA capability (such as RedCap UE) to switch across carriers (e.g., between FDD and TDD carriers) to fully utilize its capability, while we are wondering whether there is any other realistic usage scenario than RedCap UE with DL switching between FDD and TDD carriers. In addition, even for RedCap UE, we should be careful to consider whether adding such switching functionality will not lose the benefits of RedCap in terms of cost/complexity/power consumption.

Other potential proposals

- **Views on other potential objectives based on RAN Rel-19 WS papers**
  - [Two-stage DCI for multi-cell scheduling]
    - » Having two different solutions/designs (R18 MC-DCI and R19 Two-stage DCI) for the same purpose should be avoided. Hence, it is necessary to carefully investigate whether/what is a realistic scenario where R18 MC-DCI is not applicable and R19 Two-stage DCI can meet “real commercial needs” if any.
  - [Different SCS/carrier type among co-scheduled cells for multi-cell scheduling]
    - » Generally, such scenario is difficult to use common indication across cells, and hence using single cell scheduling DCI may be enough. To achieve sufficient gain over such legacy operation (i.e., DCI size compression), some techniques (e.g., grouping of co-scheduled cells, Two-stage DCI, etc.) may be necessary if supported.
  - [Other enhancements for more efficient multi-carrier operation, e.g., cross-carrier HARQ retransmission, joint CSI measurement across carriers, etc.]
    - » Regarding cross-carrier HARQ retransmission, it was discussed several times but it has not been introduced concerning large specification impacts especially if it is cross-“cell” HARQ retransmission while the gain from the cross-carrier/cell HARQ may be limited to such as HARQ retransmission latency and reliability improvement in some special cases (e.g., complementary TDD configurations across carriers, unlicensed carriers, etc.).
    - » Regarding joint CSI measurement across multiple carriers, it may be possible for intra-band case, and utilizing max number of ports across all carriers for each carrier without increasing UE complexity would be attractive. It may be better to be handled as part of MIMO enhancements.

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