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Views on Multi-carrier Enhancements in Rel-19

Overview

- Multi-carrier operation is a key enabler for high data rate and low latency by aggregating and flexible use of the scatter spectrums from operators.
- Continued RAN1 evolution on multi-carrier operation till Rel-18. Further enhancements can be considered to satisfy the real market needs.
  - Rel-16 cross-carrier scheduling/unaligned frame boundary CA, Rel-17 DSS/MR-DC and Rel-18 MC etc.
  - A need to enhance complementary TDD CA scenario and UL-heavy scenario.

Complementary TDD CA, ZTE BS + MTK M80, Real field test in Hebei CMCC network.

- DL Real time UPT: > 2 Gbps
- UL Real time UPT: > 1 Gbps
- E2E latency: 3.48 ms，over 20% reduction

- Enhancements on top of existing multi-carrier framework can be prioritized for a late release of 5G-Advanced.

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Capability sharing among different carriers in multi-carrier scenarios (1/5)

- For Tx switching in Rel-16~18, 1/2 Tx antenna can be shared among up to 4 bands.
- It is worthwhile to study other potential capabilities that can be shared among different carriers.
  - E.g., UE baseband processing capabilities (HARQ entity, bandwidth size, PDCCH monitoring, number of active BWPs or FDMed PDSCHs/PUSCHs in one carrier etc.), or any RF components?

Fig.1, Scenario 1: A UE is configured with **complementary TDD CA**, where only one carrier has DL or UL at a given time.

Fig.2, Scenario 2: A UE reports support of a feature in BC A+B, while **only the cell in Band A is configured/activated**.

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Capability sharing among different carriers in multi-carrier scenarios (2/5)

Example #1: HARQ entity sharing

- In Rel-17, HARQ entity in MAC is shared among different cells in inter-cell M-TRP scenario.
- While in other more typical scenarios, HARQ re-transmission or PXSCH/PUCCH repetition across different carriers is not supported.
- Cross carrier HARQ transmission is beneficial for low latency.

Fig. 1, Cross carrier HARQ re-transmission in complementary TDD CA

Fig. 2, Cross carrier repetition transmission in complementary TDD CA

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Capability sharing among different carriers in multi-carrier scenarios (3/5)

Example #2: Bandwidth sharing between two carriers

- Channel bandwidth is reported per carrier/band in existing specification.
- Channel bandwidth is mainly restricted by baseband memory and RF filter, which may be able to shared among carriers, especially in some specific scenarios, e.g., complementary TDD CA scenario where there is no scheduling/transmission on one of the two carriers.
- Study bandwidth sharing utilization between two carriers in complementary TDD CA.

Fig. 1, Bandwidth sharing between two carriers in complementary TDD CA

- Operators may have 100 MHz BW in each of the two TDD bands, while some commercial UEs only supports 140 MHz across two bands, resulting in configuration of 70 MHz at each of the two bands.
- DL/UL BW boosting is possible at least in complementary TDD CA scenario.

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Capability sharing among different carriers in multi-carrier scenarios (4/5)

Example #3: FDMed PXSCH transmissions within one carrier

- In LTE R10, FDMed two-cluster PUSCH or PUSCH+PUCCH within one carrier is supported, due to similar UE baseband/RF capabilities as to CA introduced in R10.
- In NR, FDMed PDSCH is supported in some specific scenarios (Multi-TRP, MBS + Unicast with the same SCS).
- Extending to more general scenarios is desirable for supporting different services simultaneously and efficiently.
- Study UE behavior of FDMed reception/transmission in complementary TDD CA or only one cell is configured/activated.

Fig. 1, More scenarios requiring the support of FDMed PXSCH transmissions

Fig. 2, Performance comparison between FDMed transmission and legacy TDMed transmission

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Capability sharing among different carriers in multi-carrier scenarios (5/5)

- **Example #4: PDCCH monitoring capability sharing**
  - The maximum number of BD/CCE for PDCCH monitoring is defined per slot/span per cell.
  - Even a cell is deactivated or in dormancy, it is still counted in the total number of cells $N_{\text{cells}}^{\text{DL},\mu}$ for determining the upper limit of PDCCH monitoring capability.
  - Study increased PDCCH monitoring capability in case a Scell is deactivated or in dormancy or has a complementary TDD configuration with other cells.

Fig. 1, Scenario for PDCCH monitoring capability sharing in complementary TDD CA

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Cross-carrier scheduling enhancements

Cross-carrier scheduling enhancements

- Each carrier of the two carriers is allowed to schedule PDSCH/PUSCH on itself or on the other carrier.
  - To fully utilize the PDCCH resources on each carrier and reduce the scheduling latency.
  - The two carriers are with the same SCS.
  - The BD/CCE budget and DCI size budget are kept.
  - UE only needs to monitor PDCCH in one of the two carriers in each slot.

Fig. 1, Legacy PDCCH scheduling

Fig. 2, Enhanced PDCCH scheduling in complementary TDD CA, with additionally support ② + ④, and support ② + ③

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Flexible DL and UL carrier association

- **Motivation#1:** More flexible association of DL and UL physical carrier is desirable for satisfying different requirements.
  - Cell#1+Cell#2 ➔ Support more UL physical carriers than DL physical carrier.
  - Cell#2 ➔ Handle special carrier requirements in one band due to regulation or spectrum sharing.
    - E.g., only UL allowed or DL power should be minimized.
  - Cell#3 ➔ Satisfy different requirements in downlink and uplink more flexibly.
    - E.g. higher throughput req. in DL & larger coverage req. in UL.

Fig.1, Flexible association of DL and UL physical carrier, where each cell is a normal cell and can work independently.

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Flexible DL and UL carrier association —— Scell with UL only

Motivation#2: Scell with UL only

- Better spectrum utilization e.g. due to re-farming / spectrum restriction
  - Some spectrum may only be used for UL transmission due to regulations, e.g., 2.3 GHz in China, 3.5 GHz/C bands in area near the airport in India and US.
- Benefit for UL-heavy traffic
  - More and more use cases requiring UL-heavy transmission in verticals, e.g., remote control and machine vision etc.
- Benefit for network energy saving and cost reduction
  - Scenario 2a is prioritized in Rel-18 NES discussion in RAN4.
    - *'Scenario 2a: No DL transmission but with UL reception at the NW side on the SSB -less SCell .'*
- Avoid interference of UL band of one cell to the DL band of another cell.
  - n5 DL and n8 UL frequency ranges partially overlap. Non-simultaneous n5 DL and n8 UL operation for UL CA of CA_n5-n8 by a state of (UL, DL) = (n5+n8, n8) is under discussion in Rel-18 in RAN2 and RAN4 (Details in R4-2306465).

Mechanism

- Can be achieved via reusing current CA framework with minimum RAN1/RAN2/RAN4 spec impact
- Enable flexible configuration of DL and UL physical carrier frequency for one cell, e.g. not limited to the same band, and one DL physical carrier can be shared by multiple cells.
- Introduce UL only Scell.

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Objectives

- Study and specify capability sharing among different carriers in multi-carrier scenarios, including at least capability sharing for HARQ entity, bandwidth size, number of FDMed PDSCHs/PUSCHs in one carrier and PDCCH monitoring.
- Cross-carrier scheduling enhancements to allow each carrier of the multiple carriers to schedule PDSCH/PUSCH on itself or on the other carriers.
- Specify flexible association of DL and UL physical carrier for CA.
  - Enable flexible configuration of DL and UL physical carrier frequency for one cell, e.g. not limited to the same band, and one DL physical carrier can be shared by multiple cells, on top of current CA framework with minimum RAN1/RAN2/RAN4 spec impacts.
  - Specify UL only Scell.

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Thanks