3GPP TSG RAN WG1 Meeting 90bis **R1-1718327**
Prague, CZ, 9th – 13th October 2017

Agenda Item: 7.3.4.1
Source: MediaTek Inc.
Title: Remaining Details on Bandwidth Part Operation in NR
Document for: Discussion

1 Introduction

Until 3GPP RAN1 AH#3 (September 2017), agreements on bandwidth part (BWP) operation can be summarized as follows.

- Usage scenarios of BWP operation includes the following
  - Enabling reduced UE bandwidth capability within a wideband carrier
  - Enabling reduced UE power energy consumption by bandwidth adaptation
- Relationship between CA & BWP
  - For each UE-specific serving cell, one or more DL BWPs and one or more UL BWPs can be configured by dedicated RRC for a UE
    - FFS association of DL BWP and UL BWP
    - FFS definition of an active cell in relation to DL BWP and UL BWP, whether or not there are cross-cell/cross-BWP interactions
  - In Rel-15, for a UE, there is at most one active DL BWP and at most one active UL BWP at a given time for a serving cell
- Initial active BWP
  - There is an initial active DL/UL bandwidth part pair to be valid for a UE until the UE is explicitly (re)configured with bandwidth part(s) during or after RRC connection is established
    - The initial active DL/UL bandwidth part is confined within the UE minimum bandwidth for the given frequency band
    - FFS: details of initial active DL/UL bandwidth part are discussed in initial access agenda
- BWP configuration
  - A bandwidth part consists of a group of contiguous PRBs
    - The bandwidth size ranges from the SS block bandwidth to the maximal bandwidth capability supported by a UE in a component carrier
    - The bandwidth part may or may not contain SS block
    - Reserved resources can be configured within the bandwidth part
  - For a connected-mode UE, one or multiple bandwidth part configurations for each component carrier can be semi-statically signaled to a UE and configuration parameters include
    - Numerology (i.e. CP type, subcarrier spacing)
    - Frequency location (the offset between BWP and a reference point is implicitly or explicitly indicated to UE) based on common PRB index for a give numerology
    - Bandwidth size (in terms of PRBs)
    - CORESET (required for each BWP configuration in case of single active DL bandwidth part for a given time instant)
  - Separate sets of bandwidth part configurations for DL & UL per component carrier
    - For TDD, a UE is not expected to retune the center frequency of channel BW between DL and UL if different active DL and UL BWPs are configured for the UE
  - Search space type in CORESET
    - At least one of configured DL BWPs includes one CORESET with common search space in Pcell
    - Each configured DL BWP includes at least one CORESET with UE-specific search space for the case of single active BWP at a given time per component carrier
- Active BWP operation
  - A UE is only assumed to receive/transmit within active DL/UL bandwidth part(s) using the associated numerology
    - At least PDSCH and/or PDCCH for DL and PUCCH and/or PUSCH for UL

- UE expects at least one DL bandwidth part and one UL bandwidth part being active among the set of configured bandwidth parts for a given time instant
  - Primary focus is to complete the single DL/UL active bandwidth part case
  - If time is available later after completing the single active bandwidth part case, multiple active bandwidth parts with different numerologies for a UE should be considered
- In case of single active DL BWP for a given time instant in a component carrier
  - A UE can assume that PDSCH and corresponding PDCCH (PDCCH carrying scheduling assignment for the PDSCH) are transmitted within the same BWP if PDSCH transmission starts no later than K symbols after the end of the PDCCH transmission.
  - In case of PDSCH transmission starting more than K symbols after the end of the corresponding PDCCH, PDCCH and PDSCH may be transmitted in different BWPs

- BWP activation/deactivation
  - Activation by dedicated RRC signaling
  - Activation/deactivation by scheduling DCI with explicit indication
  - Activation/deactivation by a timer for a UE to switch its active DL bandwidth part to a default DL bandwidth part
    - The default DL bandwidth part can be the initial active DL bandwidth part defined above
  - Specify necessary mechanism to enable UE RF retuning for active bandwidth part switching

However, there are still some remaining issues as follows and this paper provides our views on the highlighted ones.

- Relationship between CA & BWP
  - When an Scell is activated, which DL BWP and which UL BWP are active?
  - When an Scell is deactivated, what happen to active DL/UL BWP?

- Initial active BWP → To be addressed by initial access agenda
  - Whether the configuration of initial active DL BWP is the same as that for RMSI and its corresponding CORESET
  - Where to signal the configuration of initial active UL BWP

- BWP configuration
  - Association or pairing of DL BWP and UL BWP?
  - Cross-slot scheduling in BWP?
  - Common search space support
  - PUCCH resource configuration across BWP
  - Max number of BWP configurations per carrier

- Active DL/UL BWP switching
  - Timer-based active DL BWP switching
    - Whether default DL BWP is configurable or not
    - New timer or reuse DRX timer
    - Triggering conditions of the timer
  - Other remaining details of DCI-based DL/UL BWP switching?
  - Transition time of active BWP switching

- Active BWP operation
  - AGC & synchronization tracking within active DL BWP, especially for that containing no SS-block
  - Whether DCI size is dependent on the bandwidth of the active DL/UL BWP
  - Whether support cross-BWP retransmission or not
  - Whether support overlap BWP configuration from network and UE side or not
  - BWP operation in DRX mode

- RRM/CSI measurement & SRS transmission
  - Whether to support CSI measurement outside active BWP
  - Reuse BWP configuration or separate configuration for RRM measurement

2 Relationship between CA & BWP

Until RAN1 AH#3, related agreements are shown as follows.

Agreements: ***(RAN1 #88)***

- *Resource allocation for data transmission for a UE not capable of supporting the carrier bandwidth can be derived based on a two-step frequency-domain assignment process*

- 1st step: indication of a bandwidth part
- 2nd step: indication of the PRBs within the bandwidth part
- FFS definitions of bandwidth part
- FFS signaling details

- *FFS the case of a UE capable of supporting the carrier bandwidth*

***Agreements:* (RAN1 2017 AH#3)**

- *For each UE-specific serving cell, one or more DL BWPs and one or more UL BWPs can be configured by dedicated RRC for a UE*
  - *FFS association of DL BWP and UL BWP*
  - *FFS definition of an active cell in relation to DL BWP and UL BWP, whether or not there are cross-cell/cross-BWP interactions*

***Agreements:* (RAN1 2017 AH#3)**

- *In Rel-15, for a UE, there is at most one active DL BWP and at most one active UL BWP at a given time for a serving cell*

There was one FFS on definition of an active cell in relation to DL BWP and UL BWP in the agreements. From our views, there is no need to discuss the definition of an active cell as long as a clear mechanism to indicate active BWP when an Scell is activated and what happen to active BWP when an Scell is deactived.

Q1: When an Scell is activated, which DL BWP and/or which UL BWP are active?

There could be two options to indicate which DL BWP and which UL BWP are active.

- Option #1: Indication in RRC signalling for Scell configuration/reconfiguration (shown in Figure 1)
  - RRC signalling for Scell configuration/reconfiguration is used for indicating which DL BWP and/or which UL BWP are initially activated when the Scell is activated
  - It allows to decouple the discussion of CA and BWP operations no matter which signalling (either DCI or MAC CE) is used for Scell activation

- Option #2: Indication in Scell activation signalling
  - Scell activation signaling is used for indicating which DL BWP and/or which UL BWP are initially activated when the Scell is activated
  - Joint design for CA activation and BWP activation needs to be considered and it may relate to cross-carrier scheduling if DCI is used for Scell activation

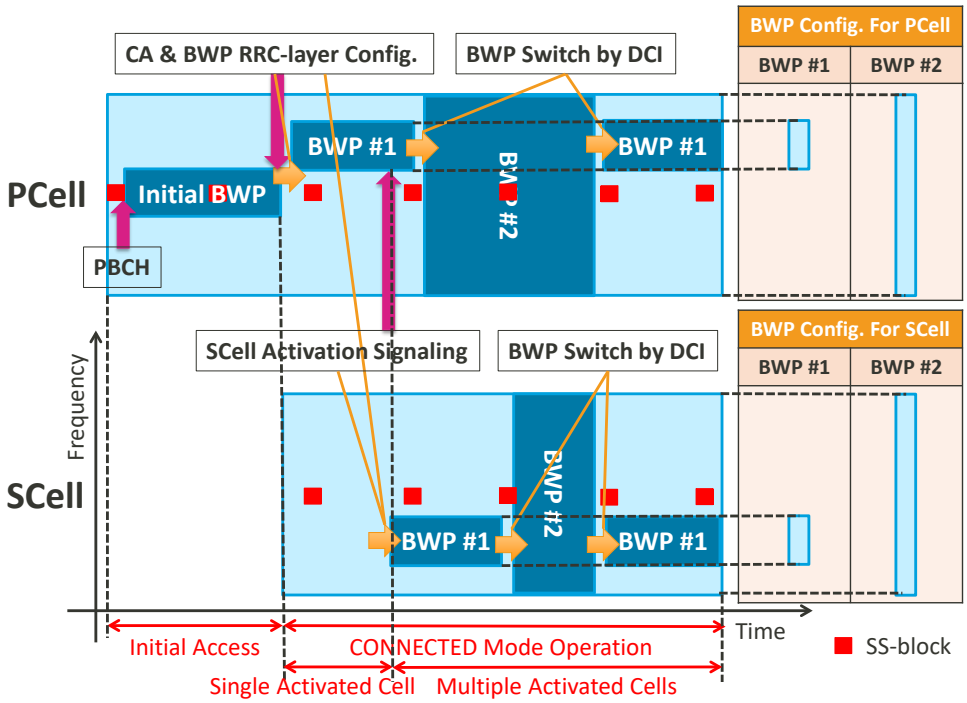

Figure 1. Illustration of indication in RRC signalling for Scell configuration/reconfiguration (Option #1)

Due to limited time, our preference is Option #1 because it allows to decouple the discussion of CA and BWP operations. Further optimization on CA operation can be considered in future releases.

Q2: When an Scell is deactivated, what happens to active DL BWP and/or active UL BWP?

From our views, all active BWP(s) with a Scell should be deactivated autonomously without any explicit indication when the Scell is deactivated.

Proposal #1: For an Scell, RRC signaling for Scell configuration/reconfiguration is used for indicating which DL BWP and/or which UL BWP are initially activated when the Scell is activated.

Proposal #2: For an Scell, active DL BWP and/or active UL BWP are deactivated autonomously when the Scell is deactivated.

3 BWP Configuration

3.1 Association between DL BWP and UL BWP

In RAN1 AH#3, the following is agreed and there is one FFS on the association between DL BWP and UL BWP.

***Agreements:* (RAN1 2017 AH#3)**

- *For each UE-specific serving cell, one or more DL BWPs and one or more UL BWPs can be configured by dedicated RRC for a UE*
  - *FFS association of DL BWP and UL BWP*
  - *FFS definition of an active cell in relation to DL BWP and UL BWP, whether or not there are cross-cell/cross-BWP interactions*

In RAN1 AH#2, the following is agreed so separate sets of BWP configurations for DL & UL per serving cell are supported in R15.

***Agreement:* (RAN1 2017 AH#2)**

- *For FDD, separate sets of bandwidth part (BWP) configurations for DL & UL per component carrier*
  - *The numerology of DL BWP configuration is applied to at least PDCCH, PDSCH & corresponding DMRS*
  - *The numerology of UL BWP configuration is applied to at least PUCCH, PUSCH & corresponding DMRS*
- *For TDD, separate sets of BWP configurations for DL & UL per component carrier*
  - *The numerology of DL BWP configuration is applied to at least PDCCH, PDSCH & corresponding DMRS*
  - *The numerology of UL BWP configuration is applied to at least PUCCH, PUSCH & corresponding DMRS*
  - *For UE, if different active DL and UL BWPs are configured, UE is not expected to retune the center frequency of channel BW between DL and UL*

From our views, there is no use case to support the association between DL BWP and UL BWP within a FDD serving cell. The association between DL carrier and UL carrier within a serving cell can be done by carrier association. However, there is one use case for TDD system, i.e. UE is not expected to retune the center frequency of channel BW between DL and UL. To achieve it, certain association between DL BWP and UL BWP may be needed. One way to associate them is to group DL BWP configurations with same center frequency as one set of DL BWPs and group UL BWP configurations with same center frequency as one set of UL BWPs. Then, the set of DL BWPs can be associated with the set of UL BWPs sharing the same center frequency. However, the question is whether to autonomously switch active UL BWP when UE's active DL BWP is switched to another one with different center frequency. Therefore, we have the following proposal.

Observation #1: For FDD system, the association between DL carrier and UL carrier within a serving cell can be done by carrier association, which is signaled in RMSI.

Proposal #3: For an FDD serving cell, no association between DL BWP and UL BWP is supported in R15.

- **FFS TDD case**

3.2 Cross-slot scheduling in BWP

Until RAN1 2017 AH#3, agreements related to DL scheduling timing are shown as follows.

Agreements: (RAN86bis)

- *NR supports at least same-slot and cross-slot scheduling for DL.*
  - *Note: it is already agreed that NR supports same-slot and cross-slot scheduling for UL.*
- *For slot-based scheduling, NR specification should support the following*
  - *DL data reception in slot N and corresponding acknowledgment in slot N+K1*
    - *All UEs should support K1≥1 with exact values for K1 FFS*
    - *Some UEs may support K1=0 (FFS conditions)*
  - *UL assignment in slot N and corresponding uplink data transmission in slot N+K2*
    - *All UEs should support K2≥1 with exact values for K2 FFS*
    - *Some UEs may support K2=0 (FFS conditions)*

Agreements: (RAN89)

- *All Rel. 15 UE supports minimum value of K0 equal to 0, i.e., DL assignment and the scheduled DL data are in the same slot.*

Cross-slot scheduling in the downlink with nonzero K0 presents significant opportunities for further power saving in the UE when it operates in low-BW BWP. The typical PDSCH/PUSCH reception procedure is shown in the below Figure 2a. In existing LTE, PDCCH of subframe #k schedules PDSCH of subframe #k. Since UE does not know if there is its own PDSCH until UE finishes PDCCH decoding, UE needs to keep RX RF on and buffer PDSCH region for a while even there is no its own PDSCH. In case of PDCCH-only, this is waste of current consumption. If cross-slot scheduling concept is introduced, as shown in Figure 2b, current consumption can be reduced. PDCCH of subframe #k schedules PDSCH of subframe #(k+1). After receiving PDCCH part, RX RF can be turned off and baseband continues to decode PDCCH. If there is desired DCI, UE receives PDSCH in subframe #(k+1). In this way, there is no waste of RX RF due to uncertain PDSCH reception.

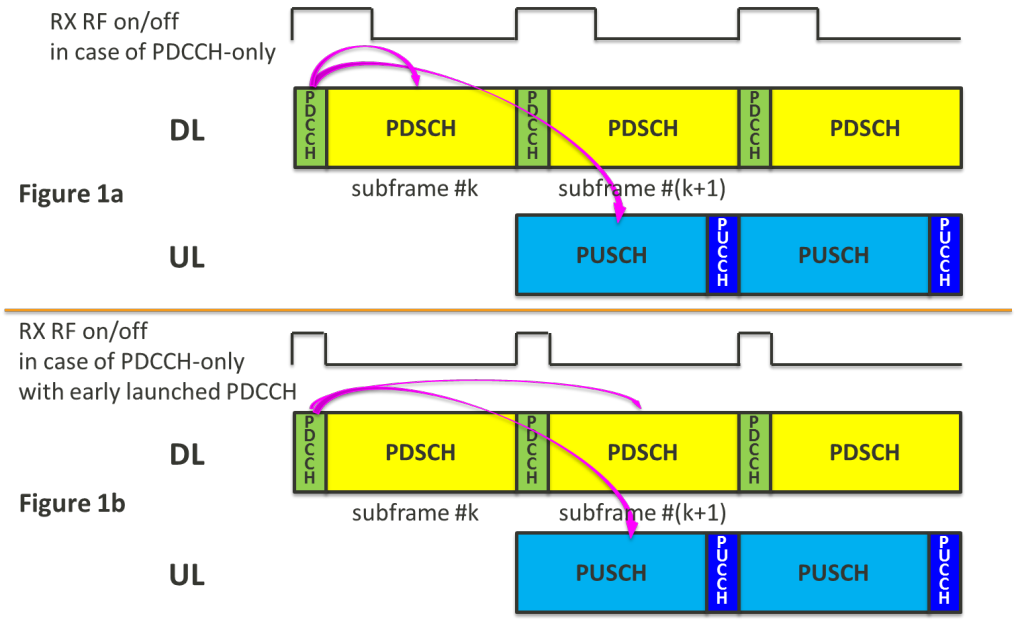

Figure 2. RX RF on duration comparison with/without cross-slot scheduling

According to Table 1, support cross-slot scheduling (i.e. K0 = 1) in low-BW BWP can save 59.3% and 23.9% UE power consumption, respectively, compared to same-slot scheduling with full BW and low BW.

Table 1. Power consumption comparison for K0 = 0 with full/low BW & K0 = 1 with low BW for no data case

No Data for UE		**K0 = 0 with Full BW**		**K0 = 0 with Low BW**		**K0 = 1 with Low BW**	
Power State	Relative Power	Symbol Duration	Power Contribution	Symbol Duration	Power Contribution	Symbol Duration	Power Contribution

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