3GPP TSG RAN WG1 NR Meeting# 90 **R1-1713654**
Prague, Czech Republic, 21st – 26th August 2017

Agenda item: 6.1.3.5

Source: Samsung

Title: Wider Bandwidth Operations

Document for: Discussion and decision

1 Introduction

RAN1 concluded from NR SI that maximum channel bandwidth per NR carrier is 400 MHz in Rel-15 and the maximum number of NR carriers for CA and DC is 16 from RAN1 specification perspective. In the context of NR wider bandwidth operation, two aspects are considered; 1) UE RF bandwidth adaptation, 2) Coexistence among narrow band UEs (NB UEs), CA UEs and wideband UEs (WB UEs) within a wideband NR carrier. The primary benefit for UE RF bandwidth adaptation is UE power saving [1]. Supporting multiple UE types/categories within a wideband NR carrier allows implementation flexibility. RAN1 introduced bandwidth part (BWP) to support NR wider bandwidth operation. A BWP consists of a group of contiguous PRBs and is associated with a specific numerology (sub-carrier spacing, CP type).

2 Default BWP

Default BWP (or anchor BWP) is the BWP whether the UE has detected the SS block and can be reconfigured after initial access. The default BWP would enable following operation:

– fallback operations if the indication of active DL/UL BW part is missed by a UE and/or DCI-based indications are missed by the UE

– DRX operation or IDLE mode operation, e.g. UE monitors PDCCH or paging messages over it

The size of the default BWP can be same as the minimum channel BW supported by all NR UEs. Default BWP can be UE specific such that load balancing can be achieved. For FDD, default DL and UL BWPs may be independent.

For the case of initial access, no indication of BWP is necessary. The CORESET location for the RMSI scheudling can be indicated by PBCH as an offset from the SS block center (in terms of RB's or absolute frequency location); the frequency resource for PDSCH conveying RMSI is scheduled by PDCCH mapped on the CORESET. The RACH configuration indicates the time/frequency resources where the UE can perform RACH and these can be indicated again as an offset from the RMSI location or from the SS block locations. For each step of the RACH procedure, the locations for RAR (can be same as RMSI CORESET), Msg4, etc can be indicated via previous steps in initial access. Hence, we believe that no special indications for the BWP is needed during the initial access stages.

Proposal 1: Support UE specific default/anchor BWP.

Proposal 2: No indication regarding BWP (or default BWP) is needed in PBCH and during initial access phase.

Proposal 3: The size of the default BWP can be same as the minimum channel BW supported by all NR UEs.

3 BWP Activation

Following options were identified for the indication of active DL/UL bandwidth part(s) apart from the RRC-based indication which is already agreed to be supported

- Option #1: DCI (explicitly and/or implicitly) or MAC CE
- Option #2: Timer-based
- Option #3: Time pattern (e.g. DRX like)

For Option#1, explicit DCI can indicate the center frequency or starting RB of the configured BWP to be activated. Implicit method can work when the UE falls back, e.g., by associating resource allocation filed in scheduling assignment. In order to avoid any potential misunderstanding between the UE and gNB, explicit DCI signaling is preferable.

For DCI based indication and MAC CE signaling, there is a tradeoff in terms of fast signaling and reliability. DCi based indication is fast and supports fast BW adaption. On the other hand, MAC CE signaling is slower but is more reliable. Hence to allow for dynamic BW adaption, to get full benefits of this flexible BW, to allow for forward compatibility, it is preferred to support DCI-based BWP activation for NR. When a UE misses the DCI indicating to switch to a wider BWP, after a timer expiry, the UE can monitor the previously monitored narrow BWP and after a second timer expiry it can move to the default BWP. Such mechanisms may be defined for the UE to allow for fallback modes of operations.

Proposal 4: Support DCI-based activation mechanisms for BWP along with timer-based mechanisms to allow for fallback mode operations.

Time-pattern based mechanisms such as SPS-like or DRX-like may also be used. Such time-pattern mechanisms can ease the signaling overhead between gNB and UE. However, UE power consumption caused by un-necessary retuning of the wider BWP for a long time duration should be taken care of. Further, some UE behavior should be specified if the UE receives a DCI based activation while it is following the previously indicated timer-based mechanism.

Observation 1: UE behavior should be specified in case that a DCI based BWP related command is received when UE is following the timer.

Proposal 5: NR supports time pattern-based BWP activation.

Regardless of above options, upon gNB indication of active BWP(s), UE confirmation would be needed in order to avoid any potential misalignment between gNB and UE.

In order to accommodate the transition time for UE bandwidth adaptation/BWP activation, the timing gap between UE reception of the indication and its application should be wide enough. The minimum required timing gap would depend on specific operation scenario. For example, as RAN4 pointed out, the total transition time should include AGC settling time in case of multiple-carrier operation. Flexible timing control can be supported via timing indication in the DCI (both same-slot and cross-slot scheduling).

Further, slot format may impact the timing. For instance, when slot n contains both DL and UL part and UE receives the indication of bandwidth adaptation at slot n, the UE may need to suspend the bandwidth adaptation until the end of UL part for potential UL transmission.

3.1 DCI Design for dynamic BWP Activation

Regarding DCI design for dynamic BWP activation, following two ways can be considered.

Alt 1) Separate DCI design for switching

Alt 2) Joint DCI design for switching and scheduling

For Alt 1, a new DCI format should be introduced for dynamic BWP indication which is separately designed with scheduling DCI. A UE configured by multiple BWPs allowing dynamic BWP activation has to keep monitoring the DCI format corresponding to BWP switching. In order to minimize or maintain the number of blind decoding, several solutions can be considered. As Alt 1-1, a sequence-based DCI indicating BWP switching can be transmitted in the fixed or pre-configured time and frequency resources. The computational complexity is reduced for sequence-based DCI compared to channel coding-based DCI. Further, very tiny bits such as 1 or 2-bit will be enough to indicate BWP activation. For this small size bits, sequence-based DCI can outperform the channel coding-based DCI in terms of BLER performance. However, there is inherent problem of false alarm due to absence of CRC. As Alt 1-2, DCI for BWP switching can be transmitted in the fixed location within a given search space with a fixed aggregation level. Then, a UE does not need to blindly search a number of PDCCH candidates for detecting the DCI format corresponding to BWP switching. However, using fixed location can degrade the detection performance of the DCI. Also, too much overhead of CRC compared to payload size is expected (BWP switching indicator will just require only few bits and CRC length would be e.g., 16 bits.). As Alt 1-3, the size of DCI format for BWP switching can be designed to be the same with other scheduling DCI format. To distinguish between switching DCI and scheduling DCI, additional DCI field can be introduced for DCI format flag. Or, CRC bits can be scrambled with different RNTI. However, it is inefficient to fit the very small size of DCI for switching into relatively long size of DCI for scheduling i.e., to fit the small contents needed for switching purposes into some existing DCI format (for example due to overhead reasons as mentioned above).

For Alt 2, a DCI field indicating BWP switching can be added in the scheduling DCI. At a cost of increment in DCI size, the total number of blind decoding are not affected. There are two possible alternatives inserting BWP indicator field (BIF) considering relationship with carrier indicator field (CIF) as shown in Figure 1. As Alt 2-1, BIF can be inserted independently with CIF. The CIF may indicate one of the CCs where PDSCH is scheduled and the BIF indicates a BWP to be activated in that CC. As Alt 2-2, CIF and BIF can be jointly encoded and composed of a combined bit field like CBIF (carrier and BWP indicator field) as shown in Figure 1. CBIF can indicate a combination of carrier index and BWP index to be scheduled. Alt 2-2 is more flexible and efficient method compared to Alt 2-1 since in Alt 2-2, the contents of each bit field conveyed by CBIF can be configured by higher layer signaling reflecting current CA and BWP of each CC configuration.

Figure 1. Example of DCI design for dynamic BWP activation

To decide DCI design for dynamic BWP activation, we need to consider the PDSCH scheduling for BWP operation. When multiple BWPs are configured, a PDCCH and the associated PDSCH can be transmitted in the same BWP (corresponds to self-BWP scheduling) or different BWP (corresponds to cross-BWP scheduling). Actually, self-BWP scheduling is the baseline operation, and whether or not to support cross-BWP scheduling is still open. In addition, single BWP activation is now supported and multiple BWP activation is FFS so far.

Especially for single BWP activation scenario, there are several motivations to support cross-BWP scheduling. First, BWP switching is generally triggered when there is a data traffic which should be transmitted via other BWP not the current BWP. By using cross-BWP scheduling, fastest data reception is possible since there is no need to monitor the PDCCH in the changed BWP. Second, interference of PDCCH can be managed by using cross-BWP scheduling as in CA scenario. Third, considering combined operation BWP with CA, cross-BWP scheduling should be naturally supported when a UE is configured by cross-carrier scheduling. Lastly, more efficient DCI design can be applied when cross-BWP scheduling is supported.

If only self-BWP scheduling is supported, there is no way to evade use of separate DCI design corresponding to Alt 1 since independent DCI signaling is necessarily required. For example, a UE should detect a switching DCI in BWP-1 at first and then the scheduling DCI have to be obtained in BWP-2 if only self-BWP scheduling is supported. Then the UE power consumption will increase due to the additional blind decoding for additional DCI format as describe above. On the other hand, if cross-BWP scheduling is supported, joint DCI design for switching and scheduling of Alt 2 can be used. Then a scheduling DCI for BWP-2 including BWP indicator can be transmitted and detected in the activated BWP-1. Without any impacts on UE complexity, dynamic BWP switching can be supported.

Proposal 6: Cross-BWP scheduling is supported.

Proposal 7: BWP indication field is added in the DCI if cross-BWP scheduling is supported and BWP indication field is configurable.

3.2 CORESET configurations across BWP

The following agreements were made in the last RAN1 meeting –

- *At least one of configured DL BWPs includes one CORESET with common search space at least in primary component carrier*
- *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*
    - *In case of single active BWP at a given time, if active DL BWP does not include common search space, then UE is not required to monitor the common search space*

Issue 1: CORESET configuration

In these cases, one open question is whether the CORESET configurations i.e., CORESET parameters such as CORESET duration, REG bundling size, REG interleaving, number of blind decoding operations, REG bundle size, transmission type, across BWPs are same or not. At least for the sake of simplicity and to reduce RRC signaling which configures the USS and its CORESET in every configured BWP for the UE, a UE can assume that the same parameters are valid across different BWPs, at least on the ones which have same numerology.

Proposal 8: A UE can assume same CORESET configuration parameters, at least for user specific search, across different configured BWPs with same numerology.

For the case of group common control and the common control channels, since they are configured for all UE's or for a group of UEs, this CORESET may be configured in the BW region which may be common across the various BWPs of different UEs. It is not clear how this will be handled if different UE's have BWP with different numerology and this CSS is present in the overlapping region as shown in figure below –

Figure 2. Example of CSS CORESET configuration

Hence, it is preferred that the UE be explicitly signaled via RRC about the CSS and group-common control signaling parameters.

Proposal 9: NR UE will be UE specifically signaled about the CSS and group common control parameters per BWP.

Issue 2: Receiving common DCI

Based on the agreement, at least one of the configured BWPs should have a CORESET for CSS. However, the BWP having a CORESET for CSS can be deactivated and instead, the other BWP having a CORESET configured by only USS can be activated. In this case, the UE is not required to monitor the CSS. Then the issue is how to receive common DCI for the UE. In LTE, CSS is always monitored by the UE to receive various common DCIs for receiving/updating system information, RACH and paging procedure, transmit power control, etc. Therefore, it should be ensured to receive the common DCI by the UE even for the case that there is no CSS CORESET within the activated BWP. Several alternatives can be considered as follows:

Alt 1) The gNB transmits the common DCI through the USS in the activated BWP to the UE if the currently active BWP does not include CSS and there is a common DCI which should be received by the UE at a given time. The UE performs additionally blind decoding for the expected common DCI format for the USS. Alt 1 corresponds to common DCI transmission in the UE-specific manner. The common DCI can be freely transmitted in any of PDCCH candidates in the given USS. Or fixed/pre-configured a set of PDCCH candidates such as specific aggregation levels in the USS can be used for common DCI transmission.

Alt 2) The gNB can configure a monitoring periodicity for CSS to the UE. The UE is forced to follow the configuration for the CSS monitoring regardless of which BWP is activated at a given time. For example, let assume that BWP-1 has CSS (also USS) and BWP-2 has USS only. If BWP-2 is now activated and the next slot is configured to monitor CSS in BWP-1, then the BWP-1 is automatically activated in the next slot and the UE can monitor CSS in BWP-1 according to pre-configured monitoring periodicity.

Alt 3) The gNB can transmit an indicator to activate the BWP having CSS to the UE if the currently activated BWP does not include CSS and there is a common DCI which should be received by the UE. If the UE receives the indication to activate the BWP having CSS, the UE changes the BWP and monitors the CSS. In Alt 3, the BWP switching can be occurred only for the purpose of receiving common DCI without data reception. Therefore, there need some additional mechanism to distinguish whether this BWP switching is for common DCI reception or for data reception or for both to efficiently control the UE blind decoding.

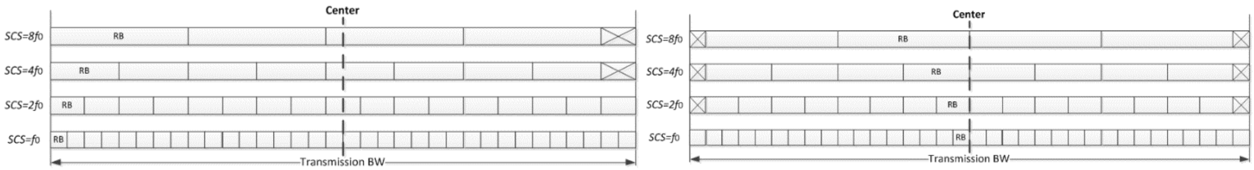
Among above alternatives, Alt 2 and Alt 3 can cause frequent BWP switching for CSS monitoring according to circumstances. This is not desirable to the UE in terms of power consumption. Therefore, Alt 1 is slightly preferred for the solution of common DCI reception.

Observation 2: A mechanism how to receive common DCI when active DL BWP does not include common search space should be further studied.

4 PRB grid alignment within a wideband NR carrier

As per RAN1#89, same PRB grid structure for a given numerology is assumed for NB UEs, CA UEs and WB UEs within a wideband NR carrier. This is crucial for WB and NB UEs co-existence with multiplexing efficiency, for instance to support MU-MIMO. The issue becomes more prominent for multiple numerologies used by WB and NB UEs. However it is not clear if any more new issues arise due to wideband operation as compared to the normal PRB grid alignment issue being discussed in NR. Figure 1 illustrates two potential alternatives and can be used for wideband as well. Since a NB UE may not know the WB UE operations and the system BW, it seems more flexible to support Alt.2 for PRB grid alignment.

Proposal 10: Support Alt 2 for PRB grid alignment in wideband system design.



Alt 1: Aligned at end of frequency

Alt 2: Aligned at center of frequency

Figure 3: Alternatives for PRB grid alignment

5 Other issues

Retransmission across BWPs

The following agreements was made in last RAN1 meeting:

Agreements:

- One TB is mapped to one DL/UL carrier.
- Re-transmission of a TB cannot take place on different carrier than the initial transmission.
- **Working assumption:**
  - Re-transmission of a TB cannot take place on different numerology than the initial transmission in Rel. 15.

Agreements:

- For HARQ,
  - The retransmissions can occupy a different frequency allocation than the initial transmission (Note, this is supported in LTE)
  - For downlink, the transmission durations for a given TB may not be the same in some cases.
    - Among initial transmission and retransmissions for a data having fixed DMRS position relative to the start of the slot

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