

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 deactivated.

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

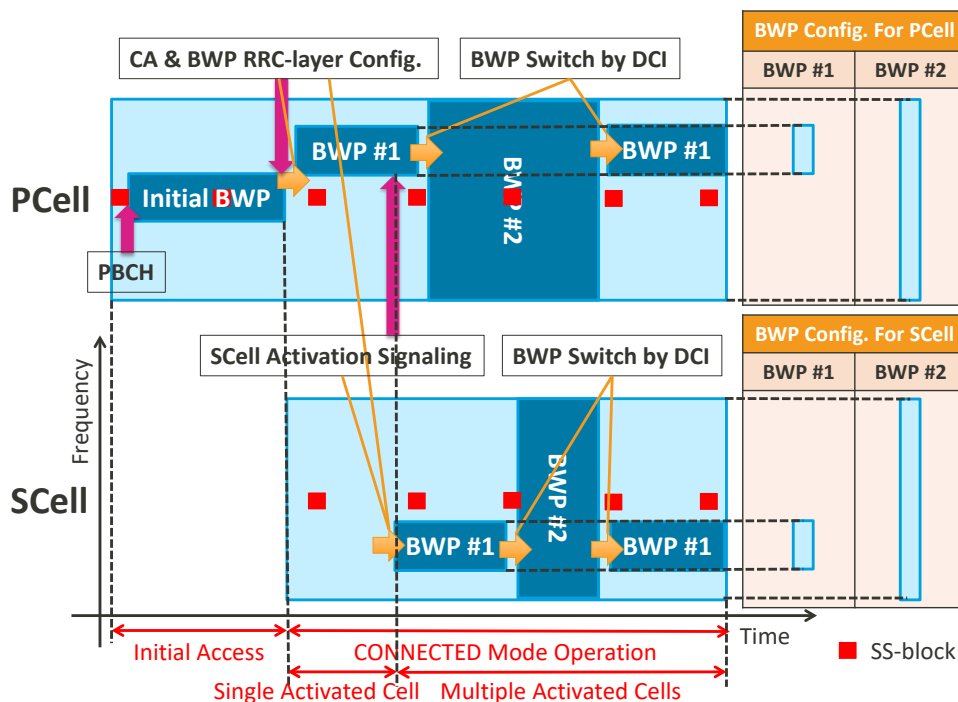


Figure 1. Illustration of indication in RRC signalling for Scell configuration/reconfiguration (Option #1)

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 $K1 \geq 1$ 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 $K2 \geq 1$ 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.

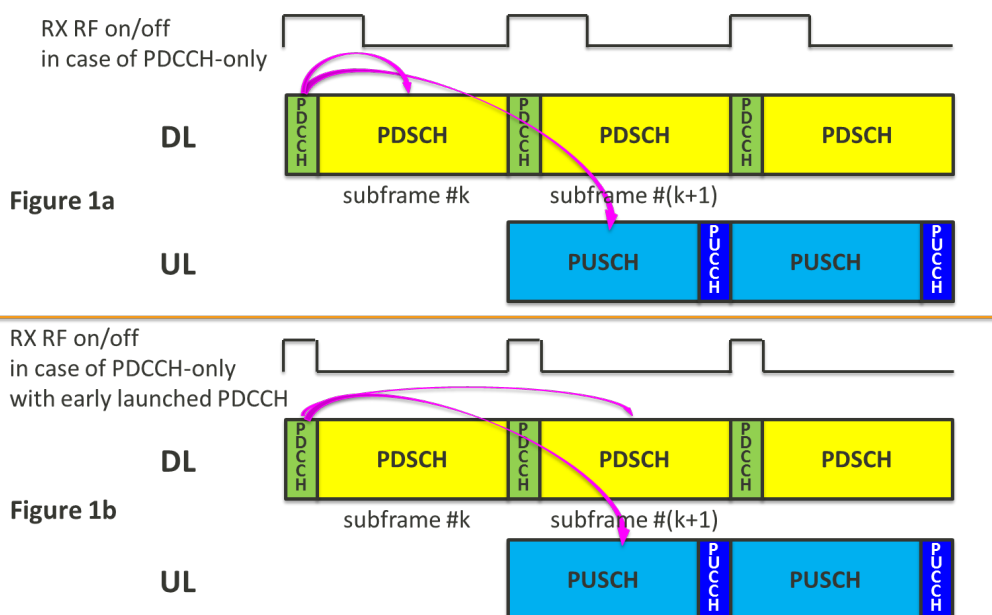


Figure 2. RX RF on duration comparison with/without cross-slot scheduling

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

Full BW Rx	100%	5.5/14	39.0%	0	0	0	0
Low BW Rx	50%	0	0	5.5/14	19.6%	1/14	3.6%
DCI Processing Only	33%	0	0	0	0	4.5/14	10.6%
Micro-sleep	5%	8.5/14	3.0%	8.5/14	3.0%	8.5/14	3.0%
TOTAL		14/14	42.3%	14/14	22.6%	14/14	17.2%

Therefore, if NR supports $K0 = 0$ and 1 and BWP configuration can further include the configuration of $K0$ value, it's helpful to further reduce UE power consumption. For high-BW BWP, multiple $K0$ values can be configured to a UE and a DCI field can be introduced to indicate to the UE which $K0$ value is applied for the DL scheduling. When there is no active BWP switching, $K0 = 0$ can be applied for PDSCH scheduling. When there is active BWP switching, $K0 = 1$ can be applied for PDSCH scheduling to allow sufficient transition time. For low-BW BWP, single $K0$ value (i.e. $K0 = 1$) can be configured to a UE for further power saving if latency is not an issue.

Observation #2: 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.

Proposal #4: NR supports $K0 = 0$ and 1 and BWP configuration further includes the configuration of one or multiple $K0$ values.

- If multiple $K0$ values are configured to a UE, a DCI field is used to indicate to the UE which value is applied for the DL scheduling

3.3 CSS support in BWP

In RAN1 NR AH#2, it was agreed as follows.

- 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

Though it was agreed that at least one of configured DL BWPs includes one CORESET with common search space (CSS) at least in primary component carrier, it doesn't resolve the issue on how a connected-mode UE monitors DCIs for system information (SI) update, RACH response (msg2), pre-emption indication and other group-based commands if there is no common search space in an active bandwidth part. Since SI update can be done by UE-specific signalling and no group-based commands except pre-emption indication agreed so far, CSS is only needed for RACH response (msg2) and pre-emption indication. There could be two alternatives to resolve the issue in bandwidth part operation.

- Option #1: No periodic gap for RACH response monitoring on Pcell
 - For Pcell, one of configured DL bandwidth parts includes one CORESET with the CSS type for RMSI & OSI
 - For Pcell, each configured DL bandwidth part includes one CORESET with the CSS type for RACH response & paging control for system information update
 - For each serving cell, each configured DL bandwidth part includes one CORESET with the CSS type for pre-emption indication and other group-based commands.
 - Pros: Periodic time gap for DCI monitoring for RMSI, OSI, RACH response & paging control is not required
 - Cons: Duplicated signalling overhead for DCI for RACH response & paging control on Pcell
- Option #2: Periodic gap for RACH response monitoring on Pcell
 - For Pcell, one of configured DL bandwidth parts includes one CORESET with CSS type for RMSI, OSI, RACH response & paging control for system information update
 - For each serving cell, each configured DL bandwidth part includes one CORESET with the CSS type for pre-emption indication and other group-based commands.
 - Pros: No duplicated signalling overhead for DCI for RACH response & paging control
 - Cons: Periodic time gap for CSS & GCSS monitoring is required

Figure 1 illustrates an example for Option #2. Since there could be many gaps for intra-frequency/inter-frequency RRM measurement, beam measurement, reception of SS-block which uses different numerology from PDCCH/PDSCH & SS-block based RLM according to RAN4's study, introducing additional gaps for common search space monitoring could result in large UE throughput loss. To minimize the gap number in DL, from our views, Option #1 is preferred.

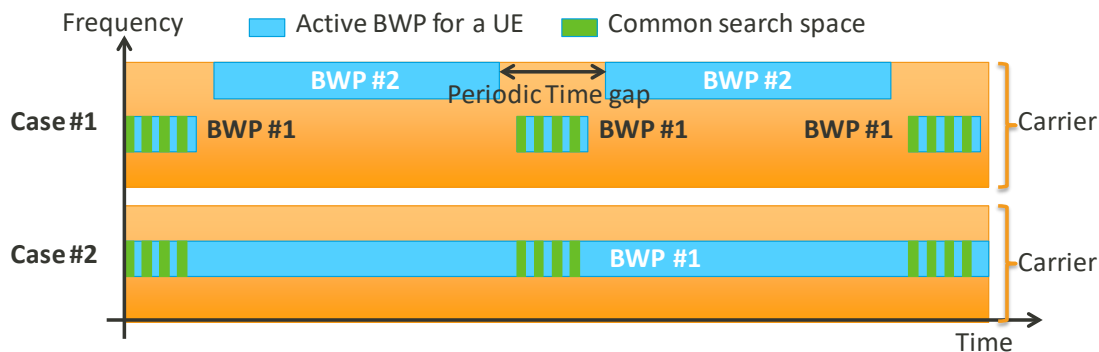


Figure 3. Example illustration of Option #2

Observation #3: There are many use cases (shown as follows) requiring gaps and too many gaps will degrade UE throughput performance so RAN1 should strive to minimize the number of gaps.

- Intra-frequency/inter-frequency RRM measurement
- Beam measurement
- Reception of SS-block using different numerology from PDCCH/PDSCH
- SS-block based RLM

Proposal #5: Support the following for CSS monitoring on Pcell.

- For Pcell, one of configured DL bandwidth parts includes one CORESET with the CSS type for RMSI & OSI
- For Pcell, each configured DL bandwidth part includes one CORESET with the CSS type at least for RACH response
 - FFS paging control for system information update
- For each serving cell, each configured DL bandwidth part includes one CORESET with the CSS type for pre-emption indication and other group-based commands.

3.4 Maximal number of configured BWPs

In RAN1 NR AH#2 (June 2017), the following use cases of BWP operation was concluded as observation.

1. Use case #1: Support reduced UE bandwidth within a wideband carrier
2. Use case #2: Support UE bandwidth adaptation for UE power saving
3. Use case #3: Support FDM of different numerology (i.e. CP type, subcarrier spacing)

To support above three use cases, from our views, the maximal number of configured BWP can be 8 with the following reasons though use case #3 is deprioritized due to the pre-requisite of multiple active BWPs.

1. To support use case #1, it requires at least 1 configured BWP but, considering load balancing within a wideband carrier, it would be better if 2 BWPs with different frequency locations can be configured to a UE. It means that the maximal number of configured BWPs can be 2.
2. To support use case #2, it requires at least 2 configured BWP but, considering load balancing within a wideband carrier, it would be better if 2 pairs of BWPs (2 BWPs for each pair) with different frequency locations can be configured to a UE. It means that the maximal number of configured BWPs can be 4.
3. To support use case #3, it requires at least 2 configured BWP with different numerology but, considering load balancing within a wideband carrier & use case #2, it would be better if 2 pairs of BWPs (2 BWPs for each pair) with different frequency locations for a given numerology. It means that the maximal number of configured BWPs can be 8 if up to two different numerology are considered.

Figure 1 illustrates an example on maximal number of configured BWPs to support different use cases.

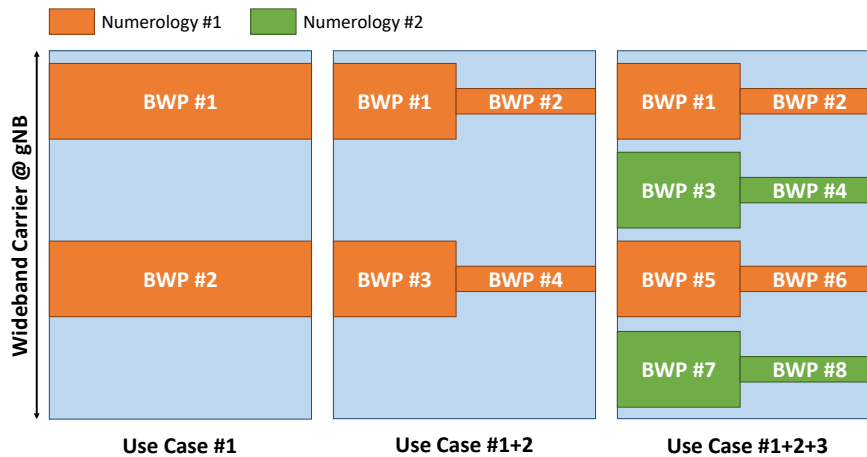


Figure 4. Maximal number of configured BWPs, considering different use cases with load balancing

Proposal #6: The maximal number of configured BWPs is 4 or 8 in NR R15.

4 Active DL/UL BWP Switching

4.1 Timer-based active DL BWP switching

Until RAN1 2017 AH#3, agreements related to active DL/UL BWP switching are shown as follows.

Agreements: (RAN1 2017 AH#2)

- Activation/deactivation of DL and UL bandwidth parts can be
 - by means of dedicated RRC signaling
 - Possibility to activate in the bandwidth part configuration
 - by means of DCI (explicitly and/or implicitly) or MAC CE [one to be selected]
 - by means of DCI could mean
 - Explicit: Indication in DCI (FFS: scheduling assignment/grant or a separate DCI) triggers activation/deactivation
 - Separate DCI means DCI not carrying scheduling assignment/grant
 - Implicit: Presence of DCI (scheduling assignment/grant) in itself triggers activation/deactivation
 - This does not imply that all these alternatives are to be supported.
 - FFS: by means of timer
 - FFS: according to configured time pattern

Agreements: (RAN1#90)

- Support activation/deactivation of DL and UL bandwidth part by explicit indication at least in (FFS: scheduling) DCI
 - FFS: In addition, MAC CE based approach is supported
- Support activation/deactivation of DL bandwidth part by means of 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
 - FFS: The default DL bandwidth part can be reconfigured by the network
 - FFS: detailed mechanism of timer-based solution (e.g. introducing a new timer or reusing DRX timer)
 - FFS: other conditions to switch to default DL bandwidth part

Agreements: (RAN1 2017 AH#3)

- NR supports the case that a single scheduling DCI can switch the UE's active BWP from one to another (of the same link direction) within a given serving cell
 - FFS whether & how for active BWP switching only without scheduling (including the case of UL scheduling without UL-SCH)

The discussion of this section focuses on the following two issues.

Q1: New timer or reuse DRX timer**Q2: Triggering/resetting conditions of the timer**

For Q1, our preference is new timer due to the following reasons.

- The considerations of DRX inactivity timer configuration and the timer configuration for timer-based active DL BWP switching are very different
 - DRX inactivity timer usually requires larger value to reduce the latency of potential DL data packet transmission
 - The timer for timer-based active DL BWP switching requires smaller value to maximize UE power saving gain
- Enforcing two different schemes to share the same timer may defeat their own design purpose and will complicate the designs
- From UE perspective, the introduced complexity of one new timer is negligible

For Q2, the triggering & resetting conditions of the timer for timer-based active DL BWP switching are shown as follows. An example is illustrated in Figure 5.

- Timer-triggering condition: The timer is triggered when UE receives a DCI to switch its active DL BWP from the default BWP to another
- Timer-resetting condition: The timer is reset when a UE receives a DCI to schedule PDSCH(s) in the BWP other than the default BWP

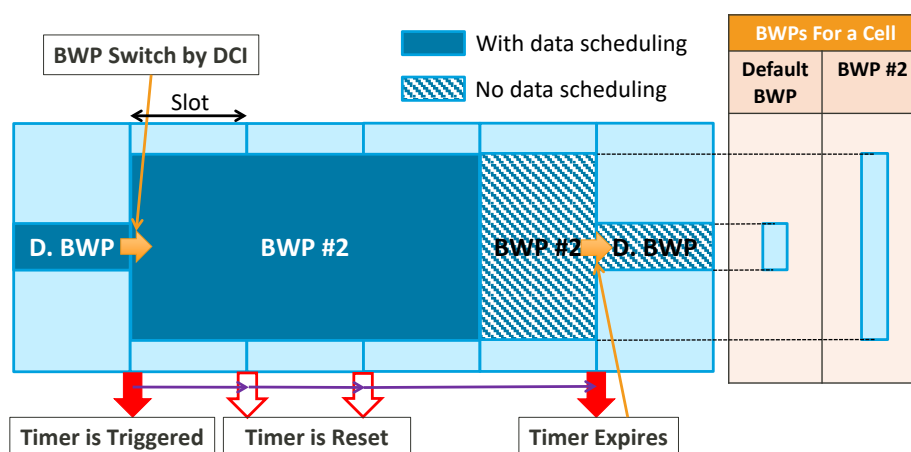


Figure 5. Example illustration of timer-based active DL BWP switching

Observation #4: Technical reasons for a new timer at least include the following.

- The considerations of DRX inactivity timer configuration and the timer configuration for timer-based active DL BWP switching are very different
- Enforcing two different schemes to share the same timer may defeat their own design purpose and will complicate the designs
- From UE perspective, the introduced complexity of one new timer is negligible

Proposal #7: Support a new timer for timer-based active DL BWP switching.

Proposal #8: Support the timer-triggering & timer-resetting conditions for the new timer as follows.

- A UE triggers the timer when it successfully decodes a DCI to switch its active DL BWP from the default DL BWP to another
- A UE reset the timer when it successfully decodes a DCI to schedule PDSCH(s) in the BWP other than the default DL BWP

5 Active BWP Operation

5.1 AGC & synchronization tracking

According to the reply LS from RAN4, AGC is not required for the bandwidth part switch in single-carrier operation due to the assumption of the same cell (i.e. same carrier and same gNB). However, time/frequency synchronization tracking could be another critical issue because wider bandwidth part (e.g. 275 PRBs) requires finer timing resolution for better data channel decoding performance and it can't be achieved by PSS/SSS which occupy 127 REs only. In addition, bandwidth part may not contain PSS/SSS. Therefore, wideband reference signals are beneficial for a UE to fine-tune its time/frequency synchronization accuracy & obtain accurate AGC level to allow data scheduling with high MCS level immediately after bandwidth part configuration switch. Potential options for the wideband reference signals could be as follows. Our preference is Option #1 and FFS the necessity of Option #2.

- Option #1: Periodic wideband time/frequency tracking reference signal (TRS) if it exists
- Option #2: Aperiodic wideband time/frequency tracking reference signal (TRS) triggered by the bandwidth part configuration switch signalling

Observation #5: *There may be AGC & time/frequency tracking issues due to the following.*

- Active bandwidth part may not contain SS-block
- Active bandwidth part is switched from bandwidth part configuration with narrow bandwidth to that with wide bandwidth

Proposal #9: DL bandwidth part configuration further includes periodic TRS configuration for time/frequency tracking & AGC settling.

- FFS the necessity of aperiodic TRS triggered by DCI-based activation/deactivation signalling

5.2 BWP operation in DRX mode

There is another issue regarding to active BWP operation during UE's DRX mode. It involves at least two questions.

Q1: Which DL BWP should be assumed for a UE as the active DL BWP by default during DRX on duration?

Q2: Whether it's necessary to support active DL/UL BWP switching for a UE in DRX mode and how?

For Q1, for better power saving gain, it's reasonable for a UE to assume the default DL BWP as the active DL BWP by default for DCI monitoring during DRX-ON duration. However, it's also beneficial to allow the network to switch a UE's active DL BWP from the default DL BWP to the one with wider bandwidth to shorten the time for DL data scheduling. For active UL BWP indication/switching, it can be indicated by UL scheduling DCI. It's also beneficial to support timer-based active DL BWP switching to allow UE's faster fall-back to the default BWP when there is no DL data scheduling. Therefore, for Q2, we think both scheduling DCI-based active DL/UL BWP switching and timer-based active DL BWP switching should be supported in DRX mode. Figure 6 illustrates an example of BWP operation in DRX mode.

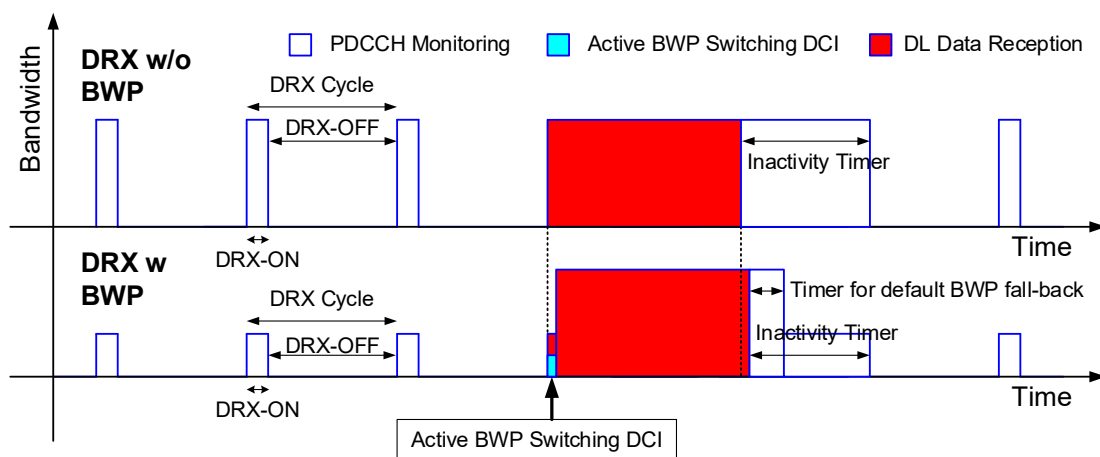


Figure 6. Example illustration of BWP operation in DRX mode

Proposal #10: In DRX mode, a UE should assume that the default DL BWP is the active DL BWP by default during DRX-ON duration.

Proposal #11: Support scheduling DCI-based active DL/UL BWP switching in DRX mode.

Proposal #12: Support timer-based active DL BWP switching in DRX mode.

6 RRM/CSI Measurement & SRS Transmission

In RAN1 #90, the following agreements is achieved for measurement and SRS transmission.

Agreements: (RAN1#90)

- *When a UE performs measurement or transmit SRS outside of its active BWP, it is considered as a measurement gap*
 - *FFS: details of measurement gap configuration*
 - *During the measurement gap, UE is not expected to monitor CORESET*

However, it's not clear whether to support both RRM measurement and CSI measurement outside active/configured DL BWPs or just RRM measurement outside active/configured DL BWPs. Since CSI measurement requires higher UE complexity and CSI reporting is mainly for MIMO scheduling, it should be limited in active DL BWP, not all configured BWPs. Regarding how to assign MCS for 1st several DL data packets after active DL BWP switching, it can be resolved by the following.

1. The network assigns robust MCS to a UE for 1st several DL data packets based on RRM measurement reporting
2. The network signals to a UE by active DL BWP switching DCI to trigger aperiodic CSI measurement/reporting to speed up CQI convergence

In addition, allowing periodic CSI measurement outside active DL BWP may introduce new gap in addition to the following cases and thus degrade UE throughput performance. However, aperiodic CSI measurement outside active DL BWP can be considered.

- Intra-frequency/inter-frequency RRM measurement
- Beam measurement
- Reception of SS-block which uses different numerology from PDCCH/PDSCH
- SS-block based RLM

For radio resource management (e.g. BWP switch or BWP reconfiguration), RRM measurement is more suitable. For beam management, at least CSI-RS RRM measurement/reporting in active BWP is necessary. However, CSI-RS RRM measurement/reporting in other configured BWP is also beneficial for the network to know which BWP has better channel condition and able to switch a UE from one BWP to another. Regarding whether to reuse BWP configurations for CSI-RS RRM measurement, it's related to RRC signalling design and should be up to RAN2's decision. Since not all configured BWPs include SS-block, SS-block RRM measurement/reporting can't be done in all configured BWPs. In addition, there may be some SS-blocks in frequency domain outside the configured BWPs for a UE. Therefore, SS-block RRM measurement configuration should be based on the SS-block frequency location(s) of serving cell or neighbouring cells, instead of binding with BWP configuration.

Observation #6: *The following can be used to resolve MCS assignment issue for 1st several DL data packets after active DL BWP switching.*

- *The network assigns robust MCS to a UE for 1st several DL data packets based on RRM measurement reporting*
- *The network signals to a UE by active DL BWP switching DCI to trigger aperiodic CSI measurement/reporting to speed up link adaptation convergence*

Proposal #13: For a UE, periodic CSI measurement outside the active BWP in a serving cell is not supported in R15.

Proposal #14: For a UE, support RRM measurement outside active BWP in a serving cell.

Proposal #15: For a UE, support RRM measurement outside configured BWPs in a serving cell.

7 Conclusion

Observations are summarized as follows.

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.

Observation #2: Support cross-slot scheduling (i.e. $K_0 = 1$) 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.

Observation #3: There are many use cases (shown as follows) requiring gaps and too many gaps will degrade UE throughput performance so RAN1 should strive to minimize the number of gaps.

- Intra-frequency/inter-frequency RRM measurement
- Beam measurement
- Reception of SS-block using different numerology from PDCCH/PDSCH
- SS-block based RLM

Observation #4: Technical reasons for a new timer at least include the following.

- The considerations of DRX inactivity timer configuration and the timer configuration for timer-based active DL BWP switching are very different
- Enforcing two different schemes to share the same timer may defeat their own design purpose and will complicate the designs
- From UE perspective, the introduced complexity of one new timer is negligible

Observation #5: There may be AGC & time/frequency tracking issues due to the following.

- Active bandwidth part may not contain SS-block
- Active bandwidth part is switched from bandwidth part configuration with narrow bandwidth to that with wide bandwidth

Observation #6: The following can be used to resolve MCS assignment issue for 1st several DL data packets after active DL BWP switching.

- The network assigns robust MCS to a UE for 1st several DL data packets based on RRM measurement reporting
- The network signals to a UE by active DL BWP switching DCI to trigger aperiodic CSI measurement/reporting to speed up link adaptation convergence

Proposals are summarized as follows.

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.

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

- FFS TDD case

Proposal #4: NR supports $K_0 = 0$ and 1 and BWP configuration further includes the configuration of one or multiple K_0 values.

- If multiple K_0 values are configured to a UE, a DCI field is used to indicate to the UE which value is applied for the DL scheduling

Proposal #5: Support the following for CSS monitoring on Pcell.

- For Pcell, one of configured DL bandwidth parts includes one CORESET with the CSS type for RMSI & OSI
- For Pcell, each configured DL bandwidth part includes one CORESET with the CSS type at least for RACH response
 - FFS paging control for system information update
- For each serving cell, each configured DL bandwidth part includes one CORESET with the CSS type for pre-emption indication and other group-based commands.

Proposal #6: The maximal number of configured BWPs is 4 or 8 in NR R15.

Proposal #7: Support a new timer for timer-based active DL BWP switching.

Proposal #8: Support the timer-triggering & timer-resetting conditions for the new timer as follows.

- A UE triggers the timer when it successfully decodes a DCI to switch its active DL BWP from the default DL BWP to another
- A UE reset the timer when it successfully decodes a DCI to schedule PDSCH(s) in the BWP other than the default DL BWP

Proposal #9: DL bandwidth part configuration further includes periodic TRS configuration for time/frequency tracking & AGC settling.

- FFS the necessity of aperiodic TRS triggered by DCI-based activation/deactivation signalling

Proposal #10: In DRX mode, a UE should assume that the default DL BWP is the active DL BWP by default during DRX-ON duration.

Proposal #11: Support scheduling DCI-based active DL/UL BWP switching in DRX mode.

Proposal #12: Support timer-based active DL BWP switching in DRX mode.

Proposal #13: For a UE, periodic CSI measurement outside the active BWP in a serving cell is not supported in R15.

Proposal #14: For a UE, support RRM measurement outside active BWP in a serving cell.

Proposal #15: For a UE, support RRM measurement outside configured BWPs in a serving cell.