**3GPP TSG-RAN WG4 Meeting #** **100-e R4-2115000**

**Electronic Meeting, August 16-27, 2021**

**Source:** Huawei, HiSilicon

**Title:** TP on overlapping UE channel bandwidths (Overlapping CA)

**Agenda Item:** 10.2.3

**Document for:** Approval

# 1 Introduction

In last RAN meeting, a new SI has been approved on efficient utilization of licensed spectrum that is not aligned with existing NR channel bandwidths. One of the objective is to study the use of overlapping UE channel bandwidths.

Study the use of overlapping UE channel bandwidths (from both UE and network perspective) to cover operator’s license spectrum for both UL and DL, and if new gNB channel bandwidths are needed.

NOTE: For all considered solutions, new (dedicated) channel filters (e.g. non-integer-multiples of 5MHz) are not considered for the UE and not prioritized for the gNB.

The comparison of the two solutions were discussed in [2]. In the contribution, we provide further update on solution 2 overlapping CA in.

Solution 1: new channel bandwidth for gNB and legacy channel bandwidth for UE (Overlapping UE CBW in [4])

New channel bandwidth for gNB

UE1: legacy channel bandwidth

UE2: legacy channel bandwidth

Solution 2: Overlapping CA

Overlapping CA for gNB

Overlapping CA for UE3

UE1: legacy channel bandwidth

UE2: legacy channel bandwidth

In previous meetings, the evaluations on irregularBW approaches have been discussed. In this contribution, we provide further discussion and text proposal on overlapping UE channel bandwidths.

# 2 Discussion

## 2.1 New channel bandwidth

The flexible channel bandwidth has been discussed since Rel-15 NR study item. To trade-off the implementation complexity and efficient utilization of operators’ spectrum, 13 channel bandwidths has been introduce for FR1 in Rel-15/16, i.e. {5MHz, 10MHz, 15 MHz, 20 MHz, 25 MHz, 30 MHz, 40 MHz, 50 MHz, 60 MHz, 70 MHz, 80 MHz, 90 MHz, 100 MHz}, and two new channel bandwidths (35 MHz and 45 MHz) will be introduced in Rel-17.

**Observation 1**: for channel bandwidths less than 50 MHz, integer-multiples of 5MHz channel bandwidths are supported or will be supported in BS/UE specifications.

And from the SID, the new (dedicated) channel filter are not considered for the UE and not prioritized for the gNB.

“NOTE: For all considered solutions, new (dedicated) channel filters (e.g. non-integer-multiples of 5MHz) are not considered for the UE and not prioritized for the gNB.”

If the irregular channel bandwidths are explicitly defined in the specification, it will create huge technical specification work. For each channel bandwidth, the guard band size and the transmission bandwidth configuration need to be specified and used as a basis for defining transmitter and receiver requirements. The identified impact to BS core specification for a new channel BW is shown in following Table 2.1-1.

Table 2.1-1 Analysis on the impact to BS core specification for a new channel BW

|  |  |  |  |
| --- | --- | --- | --- |
| **Subject** | **Clause in 36.104/38.104** | **Requirement** | **Assessment for new channel BW** |
| General | 5.3.2 | Transmission bandwidth configuration | the Transmission bandwidth configuration NRB for the new CBW need to be defined |
| 5.3.3 | Minimum guardband and transmission bandwidth configuration | The minimum guardband for the new CBW need to be defined |
| 5.3.5 | BS channel bandwidth per operating band | new CBW need defined per band |
| Transmitter | 6.3.3 | Total power dynamic range | it is a NRB related requirement |
| 6.6.2 | Occupied bandwidth | BS channel bandwidth should be defined |
| 6.6.3 | ACLR | The filter are set using transmission bandwidth configuration (BWConfig). It need to be defined for testing |
| 6.7 | Transmitter intermodulation | the interfering is defined according to BS channel bandwidth |
| Receiver | 7.2 | Reference sensitivity level | for 15 KHz SCS, 25 RB and 106 RB FRC which can be reused |
| 7.3 | Dynamic range | interfering signal level is according to BS channel bandwidth |
| 7.4 | In-band selectivity and blocking | the position of interfering signal is defined according to BS channel bandwidth/transmission bandwidth configuration |
| 7.7 | Receiver intermodulation | the position of interfering signal is defined according to BS channel bandwidth/transmission bandwidth configuration |
| 7.8 | In-channel selectivity | it is defined according to BS channel bandwidth |

**Observation 2**: It will create huge technical specification work to define each irregular channel bandwidths explicitly in the specification.

**Proposal 1:** New dedicated channel bandwidths for irregular channel bandwidths are not defined explicitly in the specification for both BS and UE.

## 2.2 Scenarios

According to the SID, the following spectrum allocations have been requested so far:

Table 2.2-1: Summary of operators’ input for irregular channel bandwidth

|  |  |
| --- | --- |
| Band (s) | Channel Bandwidth(s) |
| n5 | 7, 11 MHz |
| n12 | 6, 12 MHz |
| n26 | 7 MHz |
| n28 | 13 MHz |
| n29 | 6, 11 MHz |

Per approved WF [3],

* Overlapping CBWs from UE perspective is an optional feature and only applicable in the DL
* Overlapping CBWs from network perspective is an optional feature in the DL and in the UL.

For current solutions to support overlapping CBWs from UE perspective, the basis assumption is that UE support intra-band non-contiguous CA for the band. The following table show the supported intra-band non-contiguous CA in latest TS 38.101-1.

Table 5.5A.2-1 in TS 38.101-1: NR CA configurations and bandwidth combination sets defined for intra-band non-contiguous CA

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| NR CA Configuration | Uplink Configurations | Channel bandwidths for carrier(MHz) | Channel bandwidths for carrier(MHz) | Channel bandwidths for carrier(MHz) | Channel bandwidths for carrier(MHz) | MaximumAggregated bandwidth(MHz) | Bandwidth combination set |
| CA\_n2(2A) | - | 5, 10, 15, 20 | 5, 10, 15, 20 |  |  | 40 | 0 |
| CA\_n3(2A) | - | 5, 10, 15, 20 | 5, 10, 15, 20 |  |  | 40 | 0 |
| CA\_n5(2A) | - | 5, 10, 15, 20 | 5, 10, 15, 20 |  |  | 25 | 0 |
| CA\_n7(2A) | - | 5, 10, 15, 20 | 5, 10, 15, 20 |  |  | 40 | 0 |
| CA\_n25(2A) | - | 5, 10, 15, 20 | 5, 10, 15, 20 |  |  | 40 | 0 |
| CA\_n41(2A) | CA\_n41(2A) | 40, 50, 60, 80, 100 | 40, 50, 60, 80, 100 |  |  | 180 | 0 |
|  | 10, 15, 20, 40, 50, 60, 80, 90, 100 | 10, 15, 20, 40, 50, 60, 80, 90, 100 |  |  | 190 | 1 |
| - | 10, 15, 20, 30, 40, 50, 60, 80, 90 | 15, 20, 30, 40, 50, 60, 80, 90, 100 |  |  | 190 | 2 |
| CA\_n48(2A) |  | 10, 15, 20, 40, 50, 60, 80, 90, 100 | 10, 15, 20, 40, 50, 60, 80, 90, 100 |  |  | 1402 | 0 |
|  | 10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 100 | 10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 100 |  |  | 1402 | 1 |
| CA\_n48(3A) | - | 10, 15, 20, 40,50, 60, 80, 90, 100 | 10, 15, 20, 40,50, 60, 80, 90, 100 | 10, 15, 20, 40,50, 60, 80, 90, 100 |  | 1402 | 0 |
|  | 10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 100 | 10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 100 | 10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 100 |  | 1402 | 1 |
| CA\_n48(4A) | - | 10, 15, 20, 40, 50, 60, 80, 90, 100 | 10, 15, 20, 40, 50, 60, 80, 90, 100 | 10, 15, 20, 40, 50, 60, 80, 90, 100 | 10, 15, 20, 40, 50, 60, 80, 90, 100 | 1352 | 0 |
|  | 10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 100 | 10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 100 | 10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 100 | 10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 100 | 1352 | 1 |
| CA\_n66(2A) | - | 5, 10, 15, 20, 40 | 5, 10, 15, 20, 40 |  |  | 60 | 0 |
| 5, 10, 15, 20, 25, 30, 40 | 5, 10, 15, 20, 25, 30, 40 |  |  | 80 | 1 |
| 5, 10, 15, 20, 40 | 5, 10, 15, 20, 40 |  |  | 80 | 2 |
| CA\_n66(3A) | - | 5, 10, 15, 20, 40 | 5, 10, 15, 20, 40 | 5, 10, 15, 20, 40 |  | 80 | 0 |
| CA\_n71(2A) | - | 5,10, 15, 20 | 5,10,15, 20 |  |  | 30 | 0 |
| CA\_n77(2A) | CA\_n77(2A) | 20, 40, 80, 100 | 20, 40, 80, 100 |  |  | 200 | 0 |
|  |  | 10, 15, 20, 25, 30, 40, 50, 60, 70, 80, 90, 100 | 10, 15, 20, 25, 30, 40, 50, 60, 70, 80, 90, 100 |  |  | 200 | 1 |
| CA\_n77(3A) | - | 20, 40, 80, 100 | 20, 40, 80, 100 | 20, 40, 80, 100 |  | 300 | 0 |
| 10, 15, 20, 25, 30, 40, 50, 60, 70, 80, 90, 100 | 10, 15, 20, 25, 30, 40, 50, 60, 70, 80, 90, 100 | 10, 15, 20, 25, 30, 40, 50, 60, 70, 80, 90, 100 |  | 300 | 1 |
| CA\_n78(2A) | CA\_n78(2A) | 10, 20, 40, 50, 60, 80, 90, 100 | 10, 20, 40, 50, 60, 80, 90, 100 |  |  | 200 | 0 |
|  |  | 10, 20, 25, 30, 40, 50, 60, 80, 90, 100 | 10, 20, 25, 30, 40, 50, 60, 80, 90, 100 |  |  | 200 | 1 |
|  |  | 10, 20, 25, 30, 40, 50, 60, 70, 80, 90, 100 | 10, 20, 25, 30, 40, 50, 60, 70, 80, 90, 100 |  |  | 200 | 2 |
| NOTE 1: Void.NOTE 2: Parameter value accounts for both, the maximum frequency range of band n48 (150 MHz), and the minimum frequency gaps in between NR non-contiguous component carriers. |

It is found that only CA\_n5(2A) is already supported among the request in Table 2.2-1. Hence in order to efficiently utilize the operators’ spectrum, single carrier using legacy channel bandwidth operation in both sides should be prioritized.

**Observation 3**: Intra-band non-continuous CA is not supported for most bands requested in the SID

**Proposal 2:** for UE, single carrier using legacy channel bandwidth operation in both sides should be prioritized.

## 2.3 Guardband and spectrum utilization

For overlapping CA solution, the legacy channel bandwidth should be supported, hence the minimum guardband should not be less than the minimum guardband of lower UE channel bandwidth than operator licensed bandwidth.

The second aspect is channel positions. In order to support legacy UEs, channel raster should be applied for each UE channels. In order to simplify the resource schedule and make the use of single SSB for CA operation, RB alignment is proposed. As a consequence, the channel spacing is an in integer multiple of 900 KHz for 15 KHz SCS.

With the channel spacing decided, the spectrum utilization can be calculated. Table 2.4-1 show the channel spacing and spectrum utilization for example channel bandwidth combinations.

**Table 2.3-1: channel spacing and spectrum utilization**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Channel Bandwidth(MHz) | SCS(kHz) | CA combos | Nominal channel spacing (MHz) | Transmission bandwidth configuration NRB  | Spectrum utilization (%) |
| 6 | 15 | 5+5 | 0.9 | 30 | 90 |
| 7 | 15 | 5+5 | 1.8 | 35 | 90 |
| 11 | 15 | 10+10 | 0.9 | 57 | 93.3 |
| 12 | 15 | 10+10 | 1.8 | 62 | 93 |
| 13 | 15 | 10+10 | 2.7 | 67 | 92.8 |

## 2.4 RF requirements for overlapping CA

BS RF requirements

The primary assessment on each BS RF requirement is shown in Table 2.5-1

**Table 2.4-1: analysis on the impact to BS core specification**

|  |  |  |  |
| --- | --- | --- | --- |
| **Subject** | **Clause in 36.104** | **Requirement** | **Assessment** |
| Transmitter | 6.1 | General | no change |
| 6.2 | Base station output power | no change  |
| 6.3.2 | RE Power control dynamic range  | no change  |
| 6.3.3 | Total power dynamic range | no impact, no limits defined for CA |
| 6.4 | Transmit ON/OFF power  | no change |
| 6.5 | Transmitted signal quality | no change |
| 6.6.1 | Occupied bandwidth | No change for the requirement |
| 6.6.2 | ACLR | no change, it is defined for the edge carrier |
| 6.6.3 | Operating band unwanted emissions | no change, one uniform emission mask is defined and can be reused. |
| 6.6.4 | Transmitter spurious emissions | no change |
| 6.7 | Transmitter intermodulation | no change, it is defined for the edge carrier |
| Receiver | 7.1 | General | no change |
| 7.2 | Reference sensitivity level | no change, reference sensitivity level including FRC can be re-used |
| 7.3 | Dynamic range | no change, the requirements is defined per channel BW. |
| 7.4 | In-band selectivity and blocking | no change, it is defined for the edge carrier |
| 7.5 | Out-of-band blocking | no change |
| 7.6 | Receiver spurious emissions | no change |
| 7.7 | Receiver intermodulation | no change, it is defined for the edge carrier |
| 7.8 | In-channel selectivity | no change, the requirements is defined per channel BW. |

UE RF requirements

The primary assessment on each UE RF requirement is shown in Table 2.4-2

**Table 2.4-2: analysis on the impact to UE core specification**

|  |  |  |  |
| --- | --- | --- | --- |
| **Subject** | **Clause in 38.101-1** | **Requirement** | **Initial assessment** |
| Transmitter requirements | 6.2A.1 | UE maximum output power for CA | N/A, overlapping CA from UE perspective is only used in the DL |
| 6.2A.2 | UE maximum output power reduction for CA | N/A, overlapping CA from UE perspective is only used in the DL |
| 6.2A.3 | UE additional maximum output power reduction for CA | N/A, overlapping CA from UE perspective is only used in the DL |
| 6.2A.4 | Configured output power for CA | N/A, overlapping CA from UE perspective is only used in the DL |
| 6.3A | Output power dynamics for CA | N/A, overlapping CA from UE perspective is only used in the DL |
| 6.3A.3 |  Transmit ON/OFF time mask for CA | N/A, overlapping CA from UE perspective is only used in the DL |
| 6.4A | Transmit signal quality for CA | N/A, overlapping CA from UE perspective is only used in the DL |
| 6.5A | Output RF spectrum emissions for CA | N/A, overlapping CA from UE perspective is only used in the DL |
| Receiver requirements | 7.3A.2 | Reference sensitivity power level for CA | the framework can be reused with that it is measured carrier by carrier. |
| 7.4A | Maximum input level for CA | the framework can be reused with that it is measured carrier by carrier. |
| 7.5A | Adjacent channel selectivity for CA | the framework can be reused with that it is measured carrier by carrier. |
| 7.6A | Blocking characteristics for CA | the framework can be reused with that it is measured carrier by carrier. |
| 7.7A | Spurious response for CA | No change  |
| 7.8A | Intermodulation characteristics for CA | the framework can be reused with that it is measured carrier by carrier. |
| 7.9A | Spurious emissions for CA | No change. |

**Observation 3**: The impact to RF core requirements is very limited to support overlapping CA.

## 2.5 Impact to other WG for overlapping CA

NR provides the flexibility to avoid any collisions of SSB, CORESET and reference signals between two overlapping CCs in frequency domain or time domain. The network can avoid the collision of PDSCHs between two CCs.

From procedure wise, the network can indicate UE the location and bandwidth of BWP by using RRC signaling on individual CC. The procedure applies to each CC (serving cell) for intra-band overlapping CA. Even two CCs are overlapped in frequency domain, BWP in each CC can be configured flexibly, and the overlapped resource can be scheduled flexibly by network without collision.

Regarding measurement, the normal RRM/RLM measurement and RAN2 procedures can be followed for intra-band overlapping CA from network perspective. For intra-band overlapping CA from UE perspective, the same RRM/RLM measurement and RAN2 procedure including SCell addition/release can apply. As mentioned above the network can make use of the flexibility provided by NR and the proper scheduling to avoid any collision of SSBs and other reference signals between two CCs. Thus there is no impact on RRM/RLM measurement.

In summary, there is no impact on RAN1 and RAN2 of intra-band overlapping CA to support the irregular channel bandwidth except for some capability signalling for the new UE.

**Observation 4:** there is no impact on RAN1 and RAN2 of intra-band overlapping CA to support the irregular channel bandwidth except for some capability signaling for the new UE.

# 3 Conclusions

In the contribution, we provide discussion on overlapping UE channel bandwidth (from both UE and network perspective). Based on the discussion in clause 2, the text proposal for TR 38.844 are proposed for approval.

# References

1. RP-202103, New SID: Study on Efficient utilization of licensed spectrum that is not aligned with existing NR channel bandwidths, T-Mobile USA, Ericsson
2. R4-2101507, Consideration for overlapping UE channel bandwidths, Huawei
3. R4-2103264, Way forward on overlapping CBW method, Nokia
4. R4-2105419, Way forward on Evaluation of IrregularBW Approaches,
5. R4-2110662, Evaluation for overlapping UE channel bandwidths

**<TP for TR 38.844>**

# 6 Result, Analysis outcome

## 6.1 Study of larger Channel BW than licenced BW

### 6.1.1 General Aspects

This clause describes, in general terms, how to utilize an irregular Channel Bandwidth by deploying the “larger channel Bandwidth” method.

The premise idea is that the system is configured with the larger channel bandwidth (indicated in System Information broadcasts well as gNB filter configurations), but the actual number of scheduled RBs is restricted so that it matches actual spectrum allocation ensuring sufficiently large guard bands.



**Figure 6.1.1-1: Using the next larger channel bandwidth (example for 7MHz).**

One of the first critical aspects for this approach is the size of guard bands and the anticipated number of schedulable RBs. As for the standard channel bandwidths, both values are captured in the corresponding specification to avoid any misinterpretation on how many RBs can be configured and scheduled. Following the same principle for every irregular channel bandwidth is feasible, but that will create same amount of technical specification work as if the corresponding irregular channel bandwidth were explicitly added to the specifications. Thus, the number of "available" RBs can be calculated based on certain assumptions. [For instance, the number of available RBs can be calculated by taking the actual spectrum allocation size and guard bands from the next lager standard channel. Since the channel filter which is too wide cannot be expected to provide the usual stop-band attenuation at the edges of the irregular channel bandwidth and since the (i)FFT's filtering effect is limited, simulations will be needed to assess the performance degradation and the gap to the RF performance requirements where the margin in dB becomes negative. Using the next lower channel guard bands is in principle possible, but it will most likely result in violated requirements for legacy implementations].

Editor’s note: The section within brackets above is to be further analysed and possibly moved to a clause containing more details in later updates of the TR

## 6.2 Study of overlapping UE channel bandwidths

### 6.2.1 Overlapping UE CBW

#### 6.2.1.1 General

One way to utilise the whole chunk of irregular spectrum of a particular size is to combine several overlapping channels of next lower standard channel bandwidth. As an example, Figure X-1 shows a case when two overlapping 10MHz carriers cover 13MHz channel bandwidth. From an individual UE perspective, each UE is configured with existing immediately lower channel bandwidth following legacy procedures and signalling: one UE can use the first 10MHz carrier, while another UE can use another carrier. In fact, both UEs can use overlapping part of the spectrum provided that the BS takes care that the overlapping region is allocated to one particular carrier at a time. It should be also noted that from the UE perspective, an existing immediately lower channel bandwidth will be always used, either for initial access (as the channel bandwidth advertised by the network) or as a dedicated channel bandwidth configured by RRC. From the network perspective, the BS will/can use the whole irregular channel bandwidth.



**Figure 6.2.1.1-1: Using overlapping carriers (example for 13MHz).**

It is worth noting that overall capacity of the cell will be according to the irregular channel bandwidth because the BS can use the full bandwidth. However, since a particular UE will use only one carrier of a smaller bandwidth within the irregular channel bandwidth, the maximum throughput for a single UE will be less than the theoretically possible within the spectrum in case there is only a single UE in the cell. Nevertheless, since there will be multiple UEs in the cell the overall system throughput will not decrease.

#### 6.2.1.2 Detailed description

One of the challenges associated with configuring overlapping carriers for the same spectrum is that both carriers should have aligned grid so that the BS can perform same FFT and schedule resources in the overlapping region. Moreover for alignment the initial BWP would be beneficial from BS coordination efforts to keep aligned between the UE dedicated channel bandwidth.



**Figure 6.2.1.2-1: Using overlapping carriers with single overlapping SSB (example for 13MHz).**

Another challenge while aligning RB grids is not an issue for bands above 3GHz that have the SCS based raster, it becomes more challenging for the sub-3GHz band that have 100kHz raster. As a result, carriers can be configured on raster points that correspond to the least common multiple of the channel raster and the RB size. As an example, the least common multiple will be 900kHz in case of the 15kHz SCS, which corresponds to 5RBs. It effectively means that overlapping carriers will not be able to address efficiently any irregular spectrum size and in some case maybe will not be applicable at all. Of course one way to improve spectrum utilisation is to allow shifting carriers in multiples of 1RB, but that will require introduction of new raster points, which will not be supported by legacy UEs.

Figure 6.2.1.2-2 presents an example for the 6MHz channel comprising two 5MHz channels. As can be seen from the figure, centre frequency distance between carriers is 900kHz, which is a multiple of 100kHz channel raster and 180kHz RB size. From an individual UE perspective, it is just a normal 5MHz carrier comprising 25RBs and having the 5MHz channel guard bands. From the BS perspective, it is a 6MHz channel with 30RBs. Figure 6.2.1.2-3 exemplifies how this approach can be used to support the 7MHz irregular channel bandwidth, in which the distance between the carriers is 2RBs i.e. 1800kHz. Finally, Figure 6.2.1.2-4 shows the 11MHz channel that is supported with two 10MHz channels.Referring to Figure 6.2.1.2-2, 6.2.1.2-3 and 6.2.1.2-4, it should be noted that guard bands will not necessarily be symmetrical and the exact guard band size will depend on a particular spectrum allocation, its size, and how the overlapping channels are placed.



**Figure 6.2.1.2-2: Detailed overview of overlapping carriers (6MHz channel with 5MHz carriers).**



**Figure 6.2.1.2-3: Detailed overview of overlapping carriers (7MHz channel with 5MHz carriers).**

**Figure 6.2.1.2-4: Detailed overview of overlapping carriers (11MHz channel with 10MHz carriers).**

Table 6.2.1.2-1 below summarises potential number of schedulable RBs for a scenario when the next smaller overlapping channels are used. To calculate them, it is assumed that distance between individual carriers is a multiple of 900kHz and that the resulting guard bands must meet at least next smaller channel requirements. So, "Channel Nrb", "Channel guard bands", and "Utilisation" represent the network view, while from the UE perspective all the parameters are the same as for the next smaller channel.

**Table 6.2.1.2-1: Exemplary number of RBs based on the next smaller overlapping channel (15kHz SCS).**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Channel (MHz)** | **Next smaller channel (MHz)** | **Next smaller channel guard band (kHz)** | **Next smaller channel Nrb** | **Channel Nrb** | **Utilisation (%)** |
| 6 | 5 | 242,5 | 25 | 30 | 90 |
| 7 | 5 | 242,5 | 25 | 35 | 90 |
| 11 | 10 | 312,5 | 52 | 57 | 93,3 |
| 12 | 10 | 312,5 | 52 | 62 | 93 |
| 13 | 10 | 312,5 | 52 | 67 | 92,8 |

Table 6.2.1.2-2 presents similar calculations for the number of available RBs with overlapping carriers, but for the 30kHz SCS. As can be seen from the table, a solution based on the 30kHz SCS overlapping carriers does not provide a good spectral utilisation for certain non-standard channel bandwidths due to the reason that the "distance" between carriers must be a multiple of 1800kHz. Because of that, channel bandwidths such as 7 and 12MHz have more or less good utilisation, whereas 6 and 11MHz do not provide any benefit at all.

**Table 6.2.1.2-2: Exemplary number of RBs based on the next smaller overlapping channel (30kHz SCS).**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Channel (MHz)** | **Next smaller channel (MHz)** | **Next smaller channel guard band (kHz)** | **Next smaller channel Nrb** | **Channel Nrb** | **Utilisation (%)** |
| 6 | 5 | 505 | 11 | 11 | 66 |
| 7 | 5 | 505 | 11 | 16 | 82,3 |
| 11 | 10 | 665 | 24 | 24 | 78,5 |
| 12 | 10 | 665 | 24 | 29 | 87 |
| 13 | 10 | 665 | 24 | 29 | 80,3 |

To suppport two overlapping carriers, at least for irregular channel bandwidths <10MHz the network broadcasts two separate SSBs, one for each overlapping regular carrier. In case of irregular channels of a small size, e.g. less than 10MHz, it may create the challenge of aligning SSBs in the time and frequency domain so that they do not overlap thus complicating the gNB scheduling. To be more precise, the overlapping CORESET#0 (4.32 MHz) means that this approach complexity increases to coordinate the overlapping SSB for different UEs. As an example, if a particular irregular channel bandwidth does not allow for placing two SSBs in the same time slots, then the network will have two ensure that they are "multiplexed" accordingly in the time domain.

*Editor’s note: To be clarified further whether we need two SSBs for large irregular channel bandwidths or a single/common SSB suffices.*

This approach works with all the legacy UEs. As mentioned earlier, from an individual UE perspective, this is just a standard Rel-15 channel and no special UE side enhancements are needed. Thus an operator can use this solution with the whole ecosystem of available devices.

### 6.2.2 Combined UE CBW (one cell)

#### 6.2.2.1 General Aspects

- Studied spectrum blocks covered by “main RF carrier” and “additional RF carrier”

- The “main RF carrier” is Rel-15 compatible and contains the SSB as well as all necessary broadcast information, legacy UEs and UEs which do not support this solution are able to camp on it and be connected without being aware of the “additional RF carrier”

- The “additional RF carrier” aligned to the “main RF carrier” PRB grid, UEs which support this solution would be reconfigured (once UE capabilities are known) in RRC\_CONNECTED to use widera BWP. “additional RF carrier” can be used partially (with up to 2 PRBs not available) by legacy UEs which are on the channel raster.

- The “main RF carrier” and the “additional RF carrier” treated as single cell (one carrier from baseband perspective) to a llow for a single BWP to cover studied spectrum block in RRC\_CONNECTED

- Both the “main RF carrier” and the “additional RF carrier” would clearly define the size and position of the guard band which allows for an unambiguous placement of the overlapping channel filters and thus prevents problems with OBUE, ACS or in-band blocking

- From UE perspective, supported in downlink only

### 6.2.3 Overlapping CA (two cells)

#### 6.2.3.1 General Aspects

Using overlapping CA to support irregular spectrum is one of the method without the need of introduction of new dedicated channel bandwidths for both UE and BS. Figure 6.2.3-1 shows overlapping CA from network perspective, in which BS supports the intra-band overlapping CA, while UEs only supports the single CC with the existing channel bandwidth. And figure 6.2.3-2 shows overlapping CA from UE perspective, in which both BS and UE support the intra-band overlapping CA to use all RBs.

Even two CCs are overlapped in frequency domain, the network can configure different CCs with non-overlapping BWP to avoid the conflict of physical signals or channels.

UE1: legacy channel bandwidth

UE2: legacy channel bandwidth

Overlapping CA for gNB

**Figure 6.2.3-1**: Overlapping CA from network perspective

Overlapping CA for gNB

UE3: overlapping CA of CC1 and CC2

CC1: BWP#1

CC2: BWP#2

**Figure 6.2.3-2**: Overlapping CA from UE perspective

In summary,

* No new gNB channel bandwidth is required
* Legacy UE using existing lowerregular NR channel bandwidth can operate in either carrier
* Overlapping CA approach needs to have PRB grid alignment between overlapping CCs
* UE perspective, overlapping CA is optional supported in DL only

## 6.3 Complexity and efficiency study

#### 6.3.1 Combined UE CBW (one cell)

- Does not require new channel filters for UE and gNB to be designed and tested

- Requires support of two RF carriers phase aligned on the Tx side to ensure phase continuity on the Rx side

- Requires UE support of intra-band non-contiguous CA, increased complexity due to combining two RF carriers into one baseband carrier

- For scenarios with less than 10 MHz, second SSB is not excluded but not recommended due to significant additional overhead (duplicated SSB transmission as well as other radio resources such as PDCCH, CSI-RS, PDSCH (for SIB), CSI for Tracking, etc.). However, second SSB could enable or improve the legacy UEs' use of the further PRBs provided by the additional RF carrier in spectrum scenarios with less than 10 MHz.

- “Additional RF carrier” not to be on the channel raster to increase spectrum utilization (up to 2 PRBs), it should be noted “additional RF carrier” is used only by UEs which support this solution

- Proposed BWPs size of the irregular spectrum chunk may have an impact on performance requirements and additional testing

- High spectrum utilization due to lower internal guard band as well as no additional CA overhead (duplicated common channels and signals such as SSB, PDCCH and CSI-RS configured both in Pcell and Scell, in addition of the MAC processes associated with CA) due to single baseband carrier usage:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Spectrum block [MHz]** | **Number of PRBs****(15kHz SCS without 100kHz raster alignment)** | **Spectrum utilization (without 100kHz raster alignment) [%]** | **Number of PRBs****(15kHz SCS with 100kHz raster alignment)** | **Spectrum utilization (with 100kHz raster alignment) [%]** |
| 6 | 30 | 90 | 30 | 90 |
| 7 | 36 | 92.6 | 35 | 90 |
| 11 | 58 | 94.9 | 57 | 93.3 |
| 12 | 63 | 94.5 | 62 | 93 |
| 13 | 69 | 95.5 | 67 | 92.8 |

#### 6.3.x Overlapping CA (two cells)

From network perspective:

For gNB, no new filter for RF channel is needed. The CA implementation can be reused. The only update is to allow the configuration that the two carriers can be partially overlapped by adjusting the channel spacing. The network can prevent collisions between the two component carriers.

For UE, there is no impact and fully backwards compatible.

From UE perspective:

For gNB, there is no further requirements compared to the above description for overlapping CA from network perspective.

For UE, it is optional support in DL only. For the UE supports DL intra-band non-contiguous CA with corresponding channel bandwidth(s), overlapping CA can be considered by support the configuration with partially overlapping carriers. And in the case no new channel filter for UE is needed.

For overlapping CA solution, the legacy channel bandwidth should be supported, hence the minimum guardband should not be less than the minimum guardband of lower UE channel bandwidth than operator licensed bandwidth. To support legacy UEs, channel raster should be applied for each UE channels. And in order to simplify the resource schedule and make the use of single SSB for CA operation, RB alignment is required. Table 2.4-1 show the channel spacing and spectrum utilization for the example channel bandwidths.

**Table 6.3.x-1: channel spacing and spectrum utilization**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Channel Bandwidth(MHz) | SCS(kHz) | CA combos | Nominal channel spacing (MHz) | Transmission bandwidth configuration NRB  | Spectrum utilization (%) |
| 6 | 15 | 5+5 | 0.9 | 30 | 90 |
| 7 | 15 | 5+5 | 1.8 | 35 | 90 |
| 11 | 15 | 10+10 | 0.9 | 57 | 93.3 |
| 12 | 15 | 10+10 | 1.8 | 62 | 93 |
| 13 | 15 | 10+10 | 2.7 | 67 | 92.8 |

## 6.4 Generic solutions guidance

NOTE: The 6th objective is not an analysis/study but a guidance on solutions. A comparison of the proposed solutions with respect to the criteria in the 6th objective should be included in this clause.

#### 6.4.1 Combined UE CBW (one cell)

- Generic and future proof solution, the channel bandwidth can be tailored with the resolution of 1PRB

- Ensured co-existence with very limited specification impact since both the “main RF carrier” and the “additional RF carrier” would conform to existing 3GPP requirements

- Does not require new channel filters for UE and gNB to be designed and tested

## 6.5 RAN1 and RAN2 impact

Placeholder for 7th objective study

## 6.6 Legacy UE impact

NOTE: The 8th objective is not an analysis/study but a guidance on solutions

#### 6.6.1 Combined UE CBW (one cell)

- No impact to legacy UEs. UEs which support this solution would be reconfigured in RRC\_CONNECTED, there is no change to UE behaviour in IDLE mode which could create potential issue with legacy UE compatibility

## 6.7 RAN4 standard impact identification

#### 6.7.1 Combined UE CBW (one cell)

- Very limited since both the “main RF carrier” and the “additional RF carrier” would conform to existing 3GPP requirements, to guarantee co-existence

#### 6.7.x Overlapping CA (two cells)

The CA framework defines the transmitter emission and receiver blocking at the edge of carriers. The requirements can be reused for overlapping CA. Overlapping CA channel spacing need to be updated to consider channel raster, minimum guard band and RB alignment.

For 15 KHz SCS and 100 KHz channel raster,

For NR *operating bands* with 15 kHz channel raster,

with

#### 6.7.y Overlapping UE CBW

If the irregular channel bandwidths are explicitly defined in the specification, it will create huge technical specification work. For each channel bandwidth, the guard band size and the transmission bandwidth configuration need to be specified and used as a basis for defining transmitter and receiver requirements. The identified impact to BS core specification for a new channel BW is shown in following Table 2.1-1.

Table 2.1-1 Analysis on the impact to BS core specification for a new channel BW

|  |  |  |  |
| --- | --- | --- | --- |
| **Subject** | **Clause in 36.104/38.104** | **Requirement** | **Assessment for new channel BW** |
| General | 5.3.2 | Transmission bandwidth configuration | the Transmission bandwidth configuration NRB for the new CBW need to be defined |
| 5.3.3 | Minimum guardband and transmission bandwidth configuration | The minimum guardband for the new CBW need to be defined |
| 5.3.5 | BS channel bandwidth per operating band | new CBW need defined per band |
| Transmitter | 6.3.3 | Total power dynamic range | it is a NRB related requirement |
| 6.6.2 | Occupied bandwidth | BS channel bandwidth should be defined |
| 6.6.3 | ACLR | The filter are set using transmission bandwidth configuration (BWConfig). It need to be defined for testing |
| 6.7 | Transmitter intermodulation | the interfering is defined according to BS channel bandwidth |
| Receiver | 7.2 | Reference sensitivity level | for 15 KHz SCS, 25 RB and 106 RB FRC which can be reused |
| 7.3 | Dynamic range | interfering signal level is according to BS channel bandwidth |
| 7.4 | In-band selectivity and blocking | the position of interfering signal is defined according to BS channel bandwidth/transmission bandwidth configuration |
| 7.7 | Receiver intermodulation | the position of interfering signal is defined according to BS channel bandwidth/transmission bandwidth configuration |
| 7.8 | In-channel selectivity | it is defined according to BS channel bandwidth |

It is concluded that new dedicated BS channel bandwidths for irregular channel bandwidths are not defined explicitly in the specification.

# 7 Conclusion

TBD

**< The end of TP >**