**3GPP TSG RAN WG1#106-e R1-210nnnn**

**e-Meeting, August 16th – 20th, 2021**

**Agenda Item: 8.2.2**

**Source: Moderator (Lenovo)**

**Title: Draft discussion [106-e-NR-52-71GHz-02] on PDCCH monitoring enhancements**

**Document for: Discussion, Decision**

# Introduction

Among other items, the WID "Extending current NR operation to 71 GHz" includes the following RAN1 objective:

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| --- |
| Support enhancement to PDCCH monitoring, including blind detection/CCE budget, and multi-slot span monitoring, potential limitation to UE PDCCH configuration and capability related to PDCCH monitoring. |

As stated by the chairman:

[106-e-NR-52-71GHz-02] Email discussion/approval on PDCCH monitoring enhancements with checkpoints for agreements on August 19, 24, 27 – Alex (Lenovo)

Depending on the progress, new questions or proposal may be added after the defined checkpoints.

# Discussion

FL NOTE: Excerpts from submitted documents are listed in Section 3.

## Topic A1: Blind Decoding Capability, Multi-slot monitoring

### Issue A1-1: Multi-slot capability implied by support of 480/960 kHz

**FL Suggestion: Please comment if the following proposal is agreeable.**

Proposal: A UE supporting 480 kHz or 960 kHz SCS supports multi-slot PDCCH monitoring.

|  |  |
| --- | --- |
| **Company** | **Comment** |
| Sharp | We support the proposal. |
| vivo | We support the proposal |
| Intel | We support the FL proposal.  |
| Nokia, NSB | Agree |
| Panasonic | Support the proposal. |
| Lenovo, Motorola Mobility | We support the proposal |
| LG Electronics | We support the proposal. In addition, it would be good to clearly modify the proposal so that multi-slot monitoring is limited to 480 kHz or 960 kHz, as shown belowProposal: A UE supporting 480 kHz or 960 kHz SCS supports multi-slot PDCCH monitoring for 480 kHz or 960 kHz SCS. |
| ZTE, Sanechips | Agree with the FL suggestion. |
| InterDigital | We think that what LGE pointed out makes sense, however, the updated proposal is a bit confusing. Thus, we propose following update:A UE supporting 480 kHz SCS supports multi-slot PDCCH monitoring for 480 kHz SCS.A UE supporting 960 kHz SCS supports multi-slot PDCCH monitoring for 960 kHz SCS. |
| CATT | we agree in principle , but prefer the wording from IDCC |

### Issue A1-2: Multi-slot PDCCH monitoring capability definition

During RAN1#104bis-e, the following refinement of the alternatives has been agreed:

|  |
| --- |
| * Alt 1: Use a fixed pattern of slot groups as the baseline to define the new capability.
	+ Each slot group consists of X slots
	+ Slot groups are consecutive and non-overlapping
	+ The capability indicates the BD/CCE budget within Y consecutive [symbols or slots] in each slot group separately
	+ FFS: Supported values/constraints of X and Y, e.g. Y<=X, Y=X
	+ FFS: Restrictions on location of the Y [symbols or slots] within a slot group, e.g. the Y [symbols or slots] always start at the first slot within a slot group
	+ FFS: Further definition of capabilities
* Alt 2: Use an (X, Y) span as the baseline to define the new capability
	+ X is the minimum time separation between the start of two consecutive spans
	+ The capability indicates the BD/CCE budget within a span of at most Y consecutive [symbols or slots]
	+ Y <= X
	+ FFS: Exact values of X and Y and units in which they are defined (e.g., symbols, slots), including cases where a span is longer than one slot or crosses a slot boundary.
	+ FFS: What is a span pattern, how it is defined and whether it is supported. If it is supported, whether number of slots within which the span pattern is repeated is needed, and if needed, the value of the number of slots.
	+ FFS: Further definition of capabilities
* Alt 3: Use a sliding window of X slots as the baseline to define the new capability.
	+ The capability indicates the BD/CCE budget within the sliding window
	+ The sliding unit of the sliding window is [1] slot.
	+ FFS: Further definition of capabilities
* Specific numbers for X, Y may depend on UE capability and gNB configuration
	+ Examples:
		- X = [4] slots for 480 kHz SCS and X = [8] slots for 960 kHz SCS
 |

**FL Summary:**

**Alt 1** supported by Huawei, HiSilicon, Interdigital, Sony, ZTE, Sanechips, Nokia, Nokia Shanghai Bell, Charter (2nd choice), LG, MediaTek, Apple, Sharp, Xiaomi

**Alt 2** supported by vivo, Lenovo, Motorola Mobility, Samsung, Futurewei, Qualcomm, Panasonic, Apple, NTT DOCOMO, Convida Wireless

**Alt 2 in addition to Alt 1** if necessary: Interdigital, Mediatek

**Alt 3** supported by Ericsson, Charter (1st choice)

**FL Suggestion:**

Select Alt1 for defining the multi-slot PDCCH monitoring capability.

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| --- | --- |
| **Company** | **Comment** |
| Sharp | We support the proposal.  |
| vivo | We don’t support the proposal. Actually, the capability definition implies the possible search space (SS) configurations. Possible SS configurations for Alt. 1 UEs is a subset of that for Alt. 2 UEs, which means more network configuration flexibility. For Alt. 2, it could achieve the same complexity as Alt. 1 but provide more network configuration flexibility. So Alt 2 is preferred by us. |
| Intel | As proposed in early meetings, our original preference is Alt 3. However, considering the progress, we are fine to compromise to Alt 1 or Alt 2 assuming the following concern can be addressed* Back-to-back configuration of USS/CSS sets. This could be avoided by having Y<=X/2 as discussed in last meeting
* Flexibility of CSS/USS time configuration. For this property, Y cannot be just 3 symbols. Y>=2 slots is preferred with Y=1 slot is fine for special case, e.g. X=2.

We don’t have strong opinion between Alt 1 and 2. Alt 1 can be slightly preferred due to its simplicity.  |
| Nokia, NSB | We support the FL proposal |
| Panasonic | Before agreeing on Alt 1, the second FFS point (restriction on location of Y) should be confirmed first. Otherwise, back-to-back monitoring issue could arise. If the restriction on location of Y cannot be agreed for Alt 1, we prefer Alt 2.  |
| Lenovo, Motorola Mobility | We cannot support Alt 1 as it could be quite restrictive in terms of monitoring occasions within a slot group.Otherwise, the issue of back-to-back PDCCH monitoring occasions across slot groups might arise if there is no restriction of where the monitoring occasions are within the groupIn our view, Alt 2 provides the most complete solution and is a straightforward extension of monitoring span concept specified in Rel-16 |
| LG Electronics | We support the proposal. |
| ZTE, Sanechips | Agree with the proposal. |
| InterDigital | We support the proposal.  |
| CATT | We are Ok with the proposal. alt 2 is indeed more flexible than alt1 (but configuration will be more complex), however we don't see there's too much gain from the added complexity. |

### Issue A1-3: Multi-slot PDCCH monitoring capability values (i.e. "X" in Alt 1/2/3)

**FL Suggestion:**

For reporting the multi-slot PDCCH monitoring capability, at least the following values are suppported:

* X=4 for SCS 480 kHz
* X=8 for SCS 960 kHz

**Please state whether/which additional values for X for the reported capability should be supported in addition to the above.**

|  |  |
| --- | --- |
| **Company** | **Comment** |
| Sharp | No additional values for X are needed. |
| vivo | Support the proposal |
| Intel | We prefer to progress a bit on additional X values to be supported. In our view, X=2 can be supported for SCS 480kHz. X=2,4 can be supported for SCS 960kHz. In any case, we prefer to avoid X=1 which essentially means per-slot PDCCH monitoring capability and is contradict to the main motivation for the enhancement of this feature.  |
| Nokia, NSB | We support the FL proposal |
| Panasonic | X=1, i.e. single slot capability can be considered (optionally) in addition. |
| Lenovo, Motorola Mobility | We support the FL suggestion/proposal and don’t see a need to have additional values |
| LG Electronics | Agree that “at least” suggested values above are supported. In order to flexibly support different service requirements, it may also be needed to have additional values (e.g., X=2 for 480 kHz, X=4 for 960 kHz) supported as UE capabilities. |
| ZTE, Sanechips | We suggest X={1, 2, 4} slots for 480 kHz SCS and X= {1, 2, 4, 8} slots for 960 kHz SCS. The values of X should be more flexible depending on UE’s capability. |
| InterDigital | As well as ZTE, we also propose to support X={1, 2, 4} slots for 480 kHz SCS and X= {1, 2, 4, 8} slots for 960 kHz SCS. X = 4 slots for 480 kHz and X = 8 slots could be mandatory capabilities, and other values can be used based on UE capability.  |
| CATT | we agree with the proposal. there's no need to support single slot monitoring capability for 480/960KHz |

### Issue A1-4: Limitations on the values of Y in Alt 1/2/3

Most companies seem to support rather small values for Y for any of the alternatives (e.g. Y=1, Y<=X/2), while one company opposes very small values (If X = 4, Y is no less than 2. If X = 8, Y is no less than 3.)

**FL Suggestion:**

Agree that Y is TBD but limited by Y<=X/2.

|  |  |
| --- | --- |
| **Company** | **Comment** |
| Sharp | agree |
| vivo | Support the proposal |
| Intel | We agree with the FL proposal.  |
| Nokia, NSB | We support the FL proposal |
| Panasonic | For Alt 2, per Rel-16 span definition, a span is a number of consecutive symbols in a slot where the UE is configured to monitor PDCCH. In order to guarantee the separation between two spans by X for UE power and complexity saving, Y should contain one single span with length up to [3] symbols.For Alt 1, if Y is defined in unit of slots (especially when Y is as large as X/2), it should be understood that some symbols of Y may not belong to any span. Therefore, it should be decided together the capability definition within Y in terms of duration of span, number of allowed spans, and minimum separation between two consecutive spans (if more than one span is allowed within Y).  |
| Lenovo, Motorola Mobility | We support the FL suggestion/proposal.  |
| LG Electronics | Agree the proposal. We prefer to continue the discussion after X is decided since the allowable range for Y value may vary depending on X. Also, it is necessary to set the upper bound to avoid overly frequent monitoring. For that value, X/2 seems reasonable as discussed from the last meeting. |
| ZTE, Sanechips | Agree with the proposal. |
| InterDigital | We are fine with the proposal.  |
| CATT | We are ok in principle. but we want to add: FFS further restriction to maintain scheduling flexibility. |

### Issue A1-5: Supported PDCCH multi-slot monitoring durations for 480/960 kHz (i.e. to what durations can a UE be configured)

**FL Summary:**

Most companies suggest to support the following multi-slot monitoring durations:

* 4 slots for SCS 480 kHz
* 8 slots for SCS 960 kHz

Some companies suggested one or more of the following additional durations:

* 1, 2 slots for SCS 480 kHz
* 1, 2, 4 slots for SCS 960 kHz

For operation with a multi-slot monitoring duration that doesn't correspond to the indicated capability, a scaling of the capability values may need to be discussed.

**FL Proposal:**

Supported number of slots for multi-slot PDCCH monitoring operation (i.e. configurable value(s))

* For 480 kHz: 4 slots
* For 960 kHz: 8 slots

**Please state whether/which additional values for the UE monitoring operation (by configuration) should be supported.**

|  |  |
| --- | --- |
| **Company** | **Comment** |
| Sharp | No additional values for X are needed. |
| vivo | Support the proposal |
| Intel | This proposal seems overlap with that in 2.1.3. it is better FL can clarify more on the intention. If it is for additional values of X. Our preference is to additionally support X=2 for SCS 480kHz and X=2,4 for SCS 960kHz.  |
| Nokia, NSB | In addition to X=4 slots for 480 kHz SCS and X=8 for 960 kHz SCS, we propose to support the following values:* X=[1, 2] for 480 kHz SCS
* X=[1, 2, 4] for 960 kHz SCS
 |
| Panasonic | It is not clear what the duration means in the above summary. Is it X or Y? From our understanding, as long as the configuration does not go beyond the UE capability represented by (X,Y), it should be supported. For example, if UE indicates (X=4 slots, Y=1 slots) in Alt 1, the periodicity of search space by configuration can be 4 slots, 8 slots, etc.  |
| Lenovo, Motorola Mobility | We support the FL proposal |
| LG Electronics | We are not sure if the specific values in this proposal mean X. If it is for additional values of X, we are fine with the proposal. In order to flexibly support different service requirements, it may also be needed to have additional values less than 4 slots for 480 kHz or 8 slots for 960 kHz. |
| ZTE, Sanechips | We are a little puzzled about this Proposal. In our opinion, the basic unit of multi-slot PDCCH monitoring duration should be equal to X in Alt 1-3, that can be discussed in Topic A2. |
| InterDigital | As mentioned in the above, we support X={1, 2, 4} slots for 480 kHz SCS and X= {1, 2, 4, 8} slots for 960 kHz SCS. The gNB can configure X based on gNB implementation and UE capability.  |
| CATT | support the proposal |

## Topic A2: Search Space Enhancement

### Issue A2-1: SS duration granularity

**FL Suggestions: To be discussed after progress on Topic A1 and N1 timeline.**

### Issue A2-2: Additional SS periodicities

**FL Suggestions: To be discussed after progress on Topic A1 and N1 timeline.**

### Issue A2-3: SS set group switching

**FL Summary:**

Many companies support SSSG switching for 480/960 kHz, which seems to be a natural extension of the Rel-16 functionality, so it may not need explicit agreement. However, without agreeing corresponding minimum switching times the switching feature would not be available for SCS greater than 60 kHz kHz.

An open item is whether SSSG switching can support switching between PDCCH multi-slot monitoring periodicities (and per-slot monitoing, if supported).

**FL Suggestions: To be discussed after progress on Topic A1 and N1 timeline.**

### Issue A2-4: CSS enhancements/modifications

**FL Summary:**

Companies point out that the current Type0 PDCCH CSS requires the UE to monitor PDCCH over two *consecutive* slots, which is not compliant with the multi-slot PDCCH monitoring capability. Another potential issue is pointed out for Type 0/0A/1/2 PDCCH CSS.

**Please provide your comments on the following proposals:**

**R1-2107331 (Qualcomm): New search space set #0 (Type0 CSS) design**

|  |  |
| --- | --- |
| **Company** | **Comment** |
| Sharp | We prefer the Alt 1 in R1-2107331 to change the monitoring slots (from n0 and n0+1 to n0 and n0+X). |
| vivo | Suggest to defer the discussion until there is clear conclusion on definition of multi-slot capability |
| Intel | The proposal of search space set #0 in slot n and n+X0 may be a problem (depending on how it is handled). For example, if slot n is not a valid slot following multi-slot PDCCH monitoring capability, slot n+X0 could be invalid as well. We believe design search space set #0 should taken into account how SS/PBCH in the initial access is addressed. With that said, in general, existing pattern is strongly preferred unless critical issue is identified.  |
| Nokia, NSB | We think that this is not necessary. The issue can be solved by proper setting of Y (see Issue A1-4) |
| Panasonic | This is related to the question whether single-slot or multi-slot monitoring can be assumed before the RRC connection. If single-slot is the “default” capability before RRC connection, no new SS set#0 design is needed. We should discuss whether to support single-slot monitoring and if supported what is the “default” capability first. |
| Lenovo, Motorola Mobility | We suggest coming back to this discussion once the issue A1-2 is resolved and we agree on the multi-slot PDCCH monitoring mechanism. We can then see if there would be an issue with Type 0 PDCCH CSS. |
| LG Electronics | Support the monitoring of Type0 CSS in two non-consecutive slots. |
| ZTE, Sanechips | Defer to discuss this issue until multi-slot PDCCH monitoring capability is concluded in 2.1. |
| InterDigital | We agree with Nokia that the issue can be handled by using a configuration of Y. |
| CATT | not necessary. if Y>=2slot then there's no problem. |

**R1-2107331 (Qualcomm): New CSS prioritization rule**

|  |  |
| --- | --- |
| **Company** | **Comment** |
| Intel | Our reading on the proposal is to drop all USS sets in a slot that is adjacent to CSS slot. This may impact scheduling flexibility much if too many USS sets are dropped. Further, it is questionable if CSS slot itself is a valid slot or not for multi-slot PDCCH monitoring capability.  |
| Nokia, NSB | We think that this is not necessary. The issue can be solved by proper setting of Y (see Issue A1-4) |
| Panasonic | Open to further discussion |
| ZTE, Sanechips | Defer to discuss this issue until multi-slot PDCCH monitoring capability is concluded in 2.1. In the R1-2107331, it says that two issues is brought by Proposal 6 and 1, that suggests to adopt Alt 2 definition of the multi-slot PDCCH monitoring.  |
| InterDigital | Fine to defer the discussion. |
| CATT | This is not necessary. This changed the monitoring behavior. if Y<=X then such problem does no exist. |

**R1-2107436 (LG): Multi-slot monitoring of Type0-PDCCH CSS for SSB/CORESET#0 multiplexing pattern 1 should be considered for 480 kHz or 960 kHz SCS.**

|  |  |
| --- | --- |
| **Company** | **Comment** |
| Sharp | support |
| Intel | Same comments as that for ‘R1-2107331 (Qualcomm): New search space set #0 (Type0 CSS) design’  |
| Nokia, NSB | We think this is a topic for AI 8.2.1 |
| Panasonic | Same comment to “R1-2107331 (Qualcomm): New search space set #0 (Type0 CSS) design” above. We are open to further discussion after the definition of multi-slot capability is finalized.  |
| LG Electronics | Type0 CSS monitoring in two non-consecutive slots (i.e., slot n0 and slot n0+M) should be considered in multi-slot monitoring framework. Regarding the Intel’s comment, we think that the first monitoring slot, i.e., slot n, should be determined as a valid slot in some way. The point of this proposal is that the monitored second slot is not contiguous with the first slot. More details can be discussed further depending on the results of other issues. |
| ZTE, Sanechips | Support |
| InterDigital | We prefer to defer the discussion until finalizing the details on initial access and multi-PDCCH.  |
| CATT | this can be considered , however currently we think this can be acheive with proper Y value |

**R1-2107578 (Intel): If Type0/0A/1/2 CSS sets are monitored in a slot, configured PDCCH monitoring occasions around the slot can temporarily violate the multi-slot PDCCH monitoring capability, with the limitation of maximum number of BDs/CCEs.**

|  |  |
| --- | --- |
| **Company** | **Comment** |
| Sharp | Not preferred, because it makes budget calculation more complex |
| Intel | This is our proposal. Since Type0/0A/1/2 CSS sets only occur with long cycle, i.e. 20ms, it only has limited impact on PDCCH monitoring. Therefore, certain special handling can be considered for Type0/0A/1/2 CSS sets.  |
| Nokia, NSB | We think the BD/CCE limits should always be followed. It should be possible to manage the issue by proper setting of Y (see Issue A1-4). If there are monitoring occasions outside Y slots/symbols, those should be considered as invalid. |
| Panasonic | We understand the proposal is to define exceptional rule for Type0/0A/1/2 CSS with respect to multi-slot monitoring capability. We are open to further discussion. As an alternative, the affected USS MO can be dropped to respect the multi-slot capability.  |
| ZTE, Sanechips | We think CSS sets should always be lower than or equal to multi-slot PDCCH monitoring capability. |
| InterDigital | We don’t prefer to adopt special handling for CSS sets.  |
| CATT | Even if this is a problem , it should be discussed in AI 8.2.1 |

**R1-2107790 (Sharp): When monitoring Type0-PDCCH CSS in two slots across a slot group, the number of available SSBs may be reduced.**

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| --- | --- |
| **Company** | **Comment** |
| Sharp | If we change the monitoring of Type0 CSS, the MO may overlap with the SSB. In other words, when redesigning CSS, the location of the SSB should be considered.  |
| Intel | The exact pattern of SS/PBCH and search space set #0 can be defined in the other agenda for initial access.  |
| Nokia, NSB | We think this is not necessary. The issue can be solved by proper setting of Y (see Issue A1-4) |
| Panasonic | It is not clear what is proposing here.  |
| LG Electronics | We have similar view as Intel. The location/pattern of the SSB and SS set #0 has not been decided yet. |
| ZTE, Sanechips | We believe that the above is only an observation based on some assumptions, NOT a proposal. Whether this observation is correct depends on the discussion of the above issues in 2.2.4. In addition, SSB should be discussed in A.I. 8.2.1. |
| InterDigital | We agree with Intel that the exact pattern of SS/PBCH and SS set #0 should be discussed in 8.2.1. |
| CATT |  |

## Topic A3: BD Budget/Dropping

**To be discussed after progress on Topic A1.**

## Topic A4: PDCCH Extensions

### Issue A4-1: CORESET duration longer than 3 symbols

**Please provide your comments on the following proposals:**

**R1-2106796 (Sony): PDCCH monitoring with a maximum duration of more than 3 OFDM symbols per PDCCH monitoring occasion is more suitable.**

**R1-2106832 (Lenovo, Motorola Mobility): For supporting NR between 52.6 GHz and 71 GHz with high subcarrier spacing values including 480kHz and 960kHz, CORESET duration longer than 3 symbols should be supported**

**R1-2107238 (OPPO): CORESET configuration with less RBs and more symbols for 480kHz and 960kHz SCS should be supported.**

|  |  |
| --- | --- |
| **Company** | **Comment** |
| Sharp | Not sure if this is in the scope of WID.  |
| vivo | We are open to discuss but could be deprioritized in this meeting |
| Intel |  We are open to discuss the number of symbols of a CORESET.  |
| Nokia, NSB | We think the basic functionality should be defined first. This could be considered if time allows. |
| Lenovo, Motorola Mobility  | We support increasing the number of symbols, but don’t see a reason to limit the number of RBs as proposed by Oppo |
| LG Electronics | Not sure if this is in the scope here. |
| ZTE, Sanechips | We think a duration of more than 3 OFDM symbols can be considered since it is beneficial for improving PDCCH coverage and PDCCH capability. |
| InterDigital | We prefer to hold the discussion. We can discuss this issue after finalizing details on multi-PDCCH monitoring if possible.  |
| CATT | We don't think it is necessary. |

**R1-2106832 (Lenovo, Motorola Mobility): For supporting NR between 52.6 GHz and 71 GHz with high subcarrier spacing values including 480kHz and 960kHz, CORESET structure with only TDM between the DM-RS symbols and control information should be supported**

|  |  |
| --- | --- |
| **Company** | **Comment** |
| Sharp | Not sure if this is in the scope of WID. |
| vivo | We are open to discuss but could be deprioritized in this meeting |
| Intel | We prefer to reuse the existing DMRS structure for a CORESET unless a problem can be identified, or a significant gain can be verified for other designs.  |
| Nokia, NSB | We think this is not within the scope of Rel-17 WID. |
| LG Electronics | Not sure if this is in the scope here. |
| ZTE, Sanechips | We do not think there is a need to make this enhancement.  |
| InterDigital | We prefer to reuse the existing DMRS for CORESETs. |
| CATT | We do not think there is a need to make this enhancement. |

## Topic B: Multiple PDSCH/PUSCH by a single DCI

### Issue B-1: DCI format monitoring restrictions

**R1-2106832 (Lenovo, Motorola Mobility): For supporting NR between 52.6 GHz and 71 GHz with high subcarrier spacing values including 480kHz and 960kHz, if a new DCI is agreed to schedule multiple PDSCH/PUSCH, then restrictions on monitoring of other DCI formats (such as DCI format 0\_1/1\_1) should be supported i.e., search space set configuration with restricted combination of DCI formats should be supported to not increase the number of blind decodes**

**FL Suggestion: Do not discuss this proposal in RAN1#106-e**

## Topic C: Multi-Beam Aspects

### Issue C-1: Beam-specific indication in DCI format 2\_0

**FL Summary: Contributions and discussion in earlier meetings show the following proposal has support by many companies; however a several companies prefer to decide on the proposal after progress on directional LBT in channel access AI is achieved.**

Proposal: In DCI format 2\_0, the following parameters can be indicated in a beam-specific manner

* Remaining CO duration
* Available RB set
* Search space group switching

**FL Suggestion: Potentially come back to this issue in RAN1#106-e, pending progress on directional LBT**

## Topic D: Multi-Cell Operation, Cross-carrier scheduling

### Issue D-1: *Npdsch* (Gap of PDCCH symbols between PDSCH and PDCCH)

**FL Summary: Contributions and discussion in earlier meetings show the following proposal has support by many companies; however a several companies prefer to decide on the proposal after progress on directional LBT in channel access AI is achieved.**

**R1-2106443 (Huawei, HiSilicon): Npdsch for 480 kHz and 960 kHz SCS are scaled from that of 120 kHz SCS by 4 times and 8 times assuming similar PDCCH processing capability as 120 kHz SCS.**

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| --- | --- |
| **Company** | **Comment** |
| vivo | Support |
| Intel | We are fine to leave the issue open for the moment and revisit the issue after more discussion on processing timeline is available.  |
| Nokia | We think that this is part of AI 8.2.5 (processing times). The topic should be discussed there (and not in this agenda item). |
| LG Electronics | It seems appropriate that this issue should be addressed in the timeline agenda. If necessary, we can revisit it here after the discussion on that agenda has progressed. |
| ZTE, Sanechips | In Table 5.5-1 in TS 38.214, there is no scaling applied for *Npdsch* value for $μ\_{PDCCH}=0,1,2,3$ (15,30,60,120 kHz). Scaling 4 times and 8 times from that of 120 kHz SCS seems too larger, that will impact on scheduling. Smaller values can be considered.TS 38.214 Table 5.5-1: *Npdsch* as a function of the subcarrier spacing of the scheduling PDCCH

|  |  |
| --- | --- |
| ***µPDCCH*** | ***Npdsch* [symbols]** |
| 0 | 4 |
| 1 | 5 |
| 2 | 10 |
| 3 | 14 |

 |
| CATT | This should be discussed in AI 8.2.5 |

### Issue D-2: Cross-carrier scheduling and multi-cell operation limitations

**Please provide your comments on the following proposal:**

**R1-2107331 (Qualcomm): Cross-carrier scheduling of a cell within 52.6-71 GHz from/to a cell outside 52.6-71 GHz is supported, at least for |*μPDCCH* − *μPDSCH* | ≤ 3.**

|  |  |
| --- | --- |
| **Company** | **Comment** |
| vivo | Support |
| Intel | We are in principle fine with having a limitation on the difference of SCS, i.e., |*μPDCCH* − *μPDSCH* | ≤ k. the exact value k can be FFS |
| Nokia, NSB | Support for cross-carrier scheduling for one SCS (esp. 120 kHz SCS) should have the highest priority. Other scenarios can be considered if time allows. |
| Lenovo, Motorola Mobility | We tend to agree and see that such cross carrier scheduling outside of 52.6-71GHz can be supported. |
| ZTE, Sanechips | We support the proposal as it can reduce the scheduling complexity via add some restrictions. |
| InterDigital | We are fine in principle, however, we don’t see the need to introduce special restriction such as |*μPDCCH* − *μPDSCH* | ≤ k.Given that, we propose following:Cross-carrier scheduling of a cell within 52.6-71 GHz from/to a cell outside 52.6-71 GHz is supported.FFS: Further restriction e.g., |*μPDCCH* − *μPDSCH* | ≤ k. |
| CATT | This should be discussed in AI 8.2.5 |

**R1-2107727 (Apple): For cross-carrier scheduling, the max number of CCs that can be scheduled from a single CC is reported as UE capability.**

|  |  |
| --- | --- |
| **Company** | **Comment** |
| vivo | Defer this to UE feature discussion |
| Intel | We don’t see the necessity of the proposal. The existing maximum number of CCs in CCS is not a UE capability.  |
| Nokia, NSB | Agree that cross-carrier scheduling feature is UE capability. The related details can be agreed at a later phase during the WI. |
| ZTE, Sanechips | Same as Rel-15/16 NR and no enhancement is needed. |
| CATT | This shoud be discussed in UE capability AI |

### Issue D-3: Carrier-group based GC-PDCCH configuration

**Please provide your comments on the following proposal:**

R1-2107436 (LG)**: Carrier-group based GC-PDCCH configuration for unlicensed FR2-2 band may be beneficial with respect to signalling efficiency.**

|  |  |
| --- | --- |
| **Company** | **Comment** |
| vivo | Not essential and suggest to be deprioritized. For multi-cell operation, we think handling of multiple serving cells for mixed capability should be discussed. |
| Intel | We are open for the discussion. The concept of carrier-group should be clarified first.  |
| Nokia, NSB | We see that discussion related to GC-PDCCH with per beam -operation is more urgent. Carrier-group based configuration can be considered as well. |
| LG Electronics | Considering a coexistence with Wi-Fi (2.16 GHz), UE may be configured with aggregated carriers to use the bandwidth corresponding to about 2 GHz (or 2.16 GHz) and some measurements such as LBT result for each carrier can be identical over those carriers. In such case, available RB sets and CO duration can be indicated per carrier-group instead of per each carrier, and the set of carriers within the carrier-group can share these information to reduce the amount of signaling. In this case, carrier-group can be determined as a set of consecutive carriers aligned to the Wi-Fi bandwidth (such as 2 GHz or 2.16 GHz). |
| ZTE, Sanechips | De-prioritize the discussion on this issue as it is also related to the progress in Section 8.2.6. |
| CATT | Agree to de-prioritize. |

# Contribution Details

The following sections show extracted discussion and proposals from the contributions submitted to this AI, by a pure subjective decision by the FL.

## Topic A1: Blind Decoding Capability, Multi-slot monitoring

List of issues, proposals, and suggestions for handling in the email discussion phase.

### R1-2106443 (Huawei, HiSilicon)

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| Three alternatives of PDCCH monitoring capability definition will be further discussed with pros and cons in this section.Based on different limitations on value and location of Y, there are several interpretations for Alt-1:1. Y=X slots: PDCCH monitoring capability indicates the BD/CCE budget within Y consecutive slots as shown in Figure 1. Under this definition, the BD/CCE budget can be allocated anywhere within the fixed pattern, which may leads to some problematic scenarios:
	1. The total BD/CCE budget is evenly distributed within X slots as shown in Figure 1 (a). It leads to more frequent PDCCH detection than that in FR2-1 if higher SCS is configured, which results in increased UE power consumption and restricted aggregation level per monitoring occasion;
	2. PDCCH candidates is randomly distributed within each X slots as shown in Figure 1 (b). Then, UE might suffer from instantaneous increasing of blind detection within a slide window across two consecutive X slots (illustrated by red dotted box) in which capability is defined. Thus, higher capability is required for UE to cater to the worst case.

Figure 1. Two scenarios when Y=X of Alt-1 for PDCCH monitoring capability definition1. Y<X slots, there are further two alternatives:
	1. Y is located at the first several [symbols or slots] of each X slots, as shown in Figure 2(a). The PDCCH candidates can only be located within the Y [symbols or slots]. Then the distance between two consecutive PDCCH monitoring occasions can be guaranteed. The only drawback is less flexibility on search space configuration. However, the less flexibility will not cause latency degradation considering the shorter slot duration of 480 kHz and 960 kHz SCS.
	2. Y can be located at anywhere within each X slots, as shown in Figure 2(b). Similar to the case illustrated in Figure 1 (b), it might lead to an uneven BD/CCE allocation in a unit period, due to a gap between two adjacent MOs less than X slots (as illustrated by the red dotted box).

Figure 2. Three scenarios when Y<X slots of Alt-1 for PDCCH monitoring capability definitionAlt-2 is based on the capability definition per span introduced in Rel-16 URLLC WI. In Rel-16, a span is defined as the number of consecutive symbols in a slot for UE to monitor PDCCH. The maximum value of a span is Y, and the minimum gap between two consecutive spans is X symbols either within a slot or across slot boundaries. To extend such concept to multi-slot PDCCH monitoring, a straightforward approach is to replace X symbols in Rel-16 with X slots. Then, the capability is defined as Y consecutive [symbols or slots], as demonstrated in Figure 3. It will require considerable standard efforts for specification of PDCCH monitoring capability for 120kHz, 480 kHz and 960 kHz SCS in FR2-2, considering that only capability for 15 kHz SCS and 30 kHz SCS in FR1 have been specified for URLLC. Figure 3. Alt-2 for PDCCH monitoring capability definitionTo avoid the scenarios demonstrated in Figure 1 (b) and Figure 2 (b) for Alt-1, Alt-3 with a floating window was proposed. In Alt-3, the PDCCH monitoring capability is defined as a window with a floating start point and a fixed length of X slots. Within a given window, the PDCCH monitoring candidates are dynamically configured according to the latency requirement. A drawback of Alt3 is that the number of PDCCH candidates allocated per monitoring occasion may be too small to achieve high aggregation level to ensure coverage, and it may increase UE power consumption compared to Alt1 since with Alt3 the UE would have to monitor PDCCH in every slot, which goes against the starting motivation of using multi-slot PDCCH monitoring for large SCS values. The PDCCH latency of Alt1 is already good enough in our view.Considering the tradeoff between flexibility and standard effort, we prefer Alt 1 with Y<X slots and Y located at the beginning of each X slots. Under this pattern, the location of CSS, USS per UE can be TDMed within Y symbols/slots, as shown in Figure 4. In addition, location of USS for a given UE is located at the same position within each X slots. Therefore, we can make sure the PDCCH candidates within any window of length X slots don’t exceed the PDCCH monitoring capability. Figure 4. Search spacing location based on Alt-1 with Y < XUsing the capability definition of 120 kHz as a baseline, the value of X can be 4 and 8 for 480 kHz and 960 kHz, respectively. For the value of Y [symbols or slots], we suggest using a smaller number. Because a large time duration of Y introduces at least two problems. One is that there will be too much opportunities to configure the monitoring occasion within Y [symbols or slots], leading to a small number of PDCCH candidates configured per monitoring occasion, and the highest aggregation level cannot be achieved. The other is that it increases complexity of UE due to the frequent blind PDCCH detection. Therefore, a maximum value of Y can be 1 slot for 480 kHz and 2 slots for 960 kHz as a start point.***Observation 1:***  *For multi-slot PDSCH scheduling with 480 kHz and 960 kHz SCS, it is sufficient to configure a search space within Y consecutive [symbols or slots], where the Y [symbols or slot] are located at the beginning of each X slots. It is therefore sufficient to define the UE multi-slot PDCCH monitoring capability based on the fixed pattern of Y [symbols or slots] within each X slots, with Y < X.*In FR2, slot-level PDCCH monitoring is supported in terms of the maximum number of monitored PDCCH candidates and the maximum number of non-overlapped CCEs as shown in Table 1 and Table 2, respectively [2]. Typically, up to three OFDM symbols in one slot can be configured for slot-level PDCCH monitoring. In those symbols, UE blindly decodes the PDCCH candidates at different CCE aggregation levels.Table 1. Maximum number $M\_{PDCCH}^{max,slot,μ}$ of monitored PDCCH candidates per slot for a DL BWP with SCS configuration $μ\in \left\{0, 1,2,3\right\}$ for a single serving cell

|  |  |
| --- | --- |
| $$μ$$ | Maximum number of monitored PDCCH candidates per slot and per serving cell $M\_{PDCCH}^{max,slot,μ}$ |
| 0 | 44 |
| 1 | 36 |
| 2 | 22 |
| 3 | 20 |

Table 2. Maximum number $C\_{PDCCH}^{max,slot,μ}$ of non-overlapped CCEs per slot for a DL BWP with SCS configuration $μ\in \left\{0, 1,2,3\right\}$ for a single serving cell

|  |  |
| --- | --- |
| $$μ$$ | Maximum number of non-overlapped CCEs per slot and per serving cell $C\_{PDCCH}^{max,slot,μ}$ |
| 0 | 56 |
| 1 | 56 |
| 2 | 48 |
| 3 | 32 |

It can be observed from the tables that the maximum numbers of monitored PDCCH candidates and non-overlapped CCEs are 20 and 32 per slot for 120 kHz SCS, respectively. For 480 kHz and 960 kHz, the number of slots for multi-slot PDCCH monitoring can be 4 and 8, to keep the same monitoring duration as that of a slot under 120 kHz. Hence, to keep the same complexity as slot-level PDCCH monitoring of 120 kHz, the same maximum number of PDCCH candidates and non-overlapped CCEs can be applied to multi-slot PDCCH monitoring of 480 kHz and 960 kHz, as shown in Table 3 and Table 4. In the tables, X equals to 1 for $μ\leq 3$, equals to 4 for $μ=5$, and equals to 8 for $μ=6$.Table 3. Maximum number $M\_{PDCCH}^{max,slot,μ}$ of monitored PDCCH candidates per X slot(s) for a DL BWP with SCS configuration $μ\in \left\{0, 1,2,3,5,6\right\}$ for a single serving cell. X=4 forμ=5, X=8 for μ=6. X=1 otherwise.

|  |  |
| --- | --- |
| $$μ$$ | Maximum number of monitored PDCCH candidates per X slot(s) and per serving cell $M\_{PDCCH}^{max,slot,μ}$ |
| 0 | 44 |
| 1 | 36 |
| 2 | 22 |
| 3 | 20 |
| 5 | 20 |
| 6 | 20 |

Table 4. Maximum number $C\_{PDCCH}^{max,slot,μ}$ of non-overlapped CCEs per X slot(s) for a DL BWP with SCS configuration $μ\in \left\{0, 1,2,3,5,6\right\}$ for a single serving cell. X=4 forμ=5, X=8 for μ=6. X=1 otherwise.

|  |  |
| --- | --- |
| $$μ$$ | Maximum number of non-overlapped CCEs per X slot(s) and per serving cell $C\_{PDCCH}^{max,slot,μ}$ |
| 0 | 56 |
| 1 | 56 |
| 2 | 48 |
| 3 | 32 |
| 5 | 32 |
| 6 | 32 |

***Proposal 1****: The BD/CCE budget for multi-slot PDCCH monitoring is defined within the first Y consecutive slots per fixed X consecutive slots, where the maximum number of PDCCH candidates and non-overlapped CCEs per X slots for 480 and 960 kHz SCS is the same as for 120 kHz with slot-level PDCCH monitoring:** + *for 480 kHz SCS: X is 4 slots, and Y = 1 slot*
	+ *for 960 kHz SCS: X is 8 slots, and Y = 2 slots*
 |

### R1-2106580 (vivo)

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| In RAN#90e [1], it is agreed that (120, 480, 960) KHz SCS are all supported for data/control. When PDCCH is configured in one DL BWP with 480/960KHz SCS, UE needs to monitor PDCCH every slot (i.e. ~15/30 us) if following the mandatory capability defined in existing NR operation as described in Section 2.1.1. This is quite challenging for UE implementation especially in such high frequency band. So, the mandatory capability on PDCCH monitoring in NR FR1&FR2 should be relaxed for NR operation from 52.6-71GHz, e.g. UE only needs to monitor in certain slot group instead of each slot within one subframe.**Proposal 1: For NR operation from 52.6-71GHz, PDCCH monitoring capability in FR1&FR2 should be relaxed from slot level to multi-slot level granularity.**For Alt. 1.2-1.4, there are the following two problems:* Problem 1: the BD/CCE budget can’t be guaranteed for any X consecutive slots which may exceed UE implementation capability.
* Problem 2: no enough gap between consecutive PDCCH monitoring occasions can be guaranteed for UE to go to sleep and thus save the power consumption.

Although Alt. 1.1 have no such problems, the configuration of PDCCH monitoring is limited in certain fixed slot and gNB has no enough flexibility to configure CSS and USSs for multiple UEs. For Alt. 3, problem 1 is solved but problem 2 is still existing since any slot could be configured as PDCCH monitoring occasion. Alt. 2 could solve the above-mentioned problems with more configuration flexibility.**Proposal 2: Support Alt. 2 to define multi-slot based PDCCH monitoring capability, i.e. use (X, Y) span as baseline to define the capability.**Comparing Alt. 2.1 and Alt. 2.2 in Alt. 2, Alt. 2.1 is more flexible than Alt. 2.2 since UE could be configured with PDCCH monitoring occasions for Y consecutive slots. For Alt. 2.2, Y consecutive symbols within only one slot is allowed to be configured with PDCCH monitoring occasions, i.e. Alt. 2.2 is a special case of Alt. 2.1 assuming Y=1. In this sense, Alt. 2.1 could provide more complexity for gNB in PDCCH monitoring configuration.**Proposal 3: Using slot-level (X, Y) span (i.e. Alt. 2.1) to define multi-slot PDCCH monitoring capability is preferred compared to symbol-level (X, Y) span (i.e. Alt. 2.2).**After determination of the allowed slots for PDCCH monitoring, the allowed symbols within the slot could be referring to Rel-15 capability, e.g. the first 3 symbols within the slot are allowed to be configured with PDCCH monitoring occasions.Another question is whether to support slot-based capability for BWP with 480K/960K. The complexity of slot-based capability is quite challenging to UE implementation and there seems no benefit for UE to support slot-based capability. Thus, there is no need to support slot-based capability for BWP with 480K and 960K. Besides, multi-slot level capability should be the mandatory capability for BWP with 480K/960K.Proposal 4: Multi-slot level capability is the mandatory capability for BWP with 480K and 960K SCS where slot-based capability is not supported.It is clearly that UE will report UE capability on whether to support 480/960KHz SCS, e.g.

| ***scs-480kHz***Indicates whether the UE supports 480kHz subcarrier spacing for data channel in FR2-2. | UE | No | No | FR2-2 only |
| --- | --- | --- | --- | --- |
| ***scs-960kHz***Indicates whether the UE supports 960kHz subcarrier spacing for data channel in FR2-2. | UE | No | No | FR2-2 only |

According to **Proposal 4**, there is no need to report UE capability on whether to support multi-slot-based capability explicitly, i.e. reporting support of 480K/960K SCS implies support of multi-slot-based capability.Proposal 5: Reporting support of 480K/960K in UE capability implies support of multi-slot-based capability at UE side.For NR Rel-16 UEs, there exists two types of PDCCH monitoring capability (i.e. slot-based and span-based) if it reports ***pdcch-Monitoring-r16***. In this case, gNB may configure the capability type for a serving cell. If not configured, Rel-15 slot-based capability if the default one to be used. Then the following two types of serving cell may exist for one UE:* Cell Type 1 (FR1/FR2): Serving cell with slot-based PDCCH monitoring capability;
* Cell Type 2 (FR1 only): Serving cell with span-based PDCCH monitoring capability.

Thus, the following cases may occur for one UE:* Case 1: All serving cells belongs to cell type 1;
* Case 2: All serving cells belongs to cell type 2;
* Case 3: At least one serving cell belongs to cell type 1 and at least one serving cell belongs to cell type 2.

In general, the following table summarizes the relation of UE reporting capability and allowed gNB configuration cases:

|  |  |  |
| --- | --- | --- |
| UE type | Reporting capability | Allowed Operation |
| Rel-16 UEs | - | Case 1 only |
| Rel-16 UEs | ***pdcch-Monitoring-r16*** | Case 1/Case 2 |
| Rel-16 UEs | ***pdcch-Monitoring-r16******pdcch-MonitoringMixed-r16*** | Case 1/Case 2/Case 3 |

Besides, NR Rel-16 UEs will report capability related parameters (e.g. $N\_{cells}^{cap}$) for each case respectively. If multi-slot-based capability is introduced for NR Rel-17 UEs, how to configure or determine the capability type needs to be considered. As long as multi-slot-based capability is the mandatory one for BWP with 480K/960K SCS according to **Proposal 4**, configuration of 480K/960K SCS for a BWP implies multi-slot-based capability for that BWP, which means PDCCH monitoring capability should be defined per BWP.Proposal 6: For NR Rel-17 UEs, PDCCH monitoring capability is defined per BWP and configuration of 480K/960K SCS for a BWP implies multi-slot-based capability for that BWP.After defining the PDCCH monitoring capability per BWP, the capability for one serving cell should also be determined for calculation of BD/CCE budget in multiple serving cell case. The straight forward way is to adopt the PDCCH monitoring capability for active BWP or configured first active BWP as the capability of the serving cell. Proposal 7: PDCCH monitoring capability for a serving cell is the capability for its active BWP or configured first active BWP when it is deactivated.Compared to NR Rel-16, one additional cell type occurs:* Cell Type 3 (FR2-2 only): Serving cell with multi-slot-based PDCCH monitoring capability.

In addition to the operation cases in NR Rel-16, there may be more cases as listed below:* Case 4: All serving cells belongs to cell type 3;
* Case 5: At least one serving cell belongs to cell type 1 and at least one serving cell belongs to cell type 3;
* Case 6: At least one serving cell belongs to cell type 2 and at least one serving cell belongs to cell type 3;
* Case 7: At least one serving cell belongs to cell type 1, at least one serving cell belongs to cell type 2 and at least one serving cell belongs to cell type 3.

Observation 1: More additional cases are brought by introduction of multi-slot-based PDCCH monitoring capability. |

### R1-2106767 (InterDigital)

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| ***Observation 1:*** *A fixed pattern of X slots (Alt-1) provides the simplest muti-slot PDCCH monitoring scheme which is similar to UE PDCCH monitoring of 120 kHz SCS.* ***Observation 2:*** *Span based monitoring (Alt-2) may provide different PDCCH monitoring patterns in every slot, however, requires more complex UE implementation.* ***Observation 3:*** *Given the short slot duration of 480 kHz and 960 kHz, benefits of distributing the monitoring/processing loads by supporting sliding windows (Alt 3) are doubted.* ***Proposal 1:*** *For 480 kHz SCS and 960 kHz SCS, support of Alt 1 is preferred for multi-slot PDCCH monitoring.****Proposal 2:*** *If needed, additionally consider span based monitoring (Alt-2) for 480 kHz and 960 kHz.****Proposal 3:*** *Sliding window based monitoring (Alt-3) is not supported in Rel-17.* ***Proposal 4:*** *At least, identical PDCCH monitoring operation with 120 kHz SCS should be supported for new SCSs.****Proposal 5:*** *For the values of X, at least X=4* *slots for 480 kHz SCS and X=8 slots for 960 kHz SCS should be a baseline for the values of X.****Proposal 6:*** *For the values of Y, following PDCCH monitoring occasions are supported:** For type 1 CSS with dedicated RRC configuration, type 3 CSS, and UE-SS, the monitoring occasion can be **1 slot for 480 kHz SCS** and **2 slots for 960 kHz SCS**, respectively.
* For type 1 CSS without dedicated RRC configuration and for type 0, 0A, and 2 CSS, the monitoring occasion can be **any OFDM symbol(s) of a slot group**, with the monitoring occasions for any of Type 1- CSS without dedicated RRC configuration, or Types 0, 0A, or 2 CSS configurations.
* Further study may be needed on how to change the condition ‘within a single span of three consecutive OFDM symbols within a slot’ to a slot group.
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### R1-2106796 (Sony)

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| In the last meeting, three possible multi-slot PDCCH monitoring schemes have been proposed [3]:* Alt 1: Use a fixed pattern in a slot group as the baseline to define the new capability.
* Alt 2: Use an (X, Y) span as the baseline to define the new capability
* Alt 3: Use a sliding window of X slots as the baseline to define the new capability.

To our understanding, the motivation of Alt 3 (sliding window) is to avoid the back-to-back monitoring occasion while ensuring enough flexibility for network scheduling. However, those concerns can be well addressed by Alt 1 or Alt 2 by carefully selecting the value of multiple slots monitoring span according to the email discussion in RAN1#104bis-e meeting [3]. Therefore, we focus on Alt 1 and Alt 2 in the discussion below: Both Alt. 1 and Alt. 2 cover the aspect of defining X, Y, and they are feasible solutions. Illustrations of the slot group structure of a fixed slot group pattern and a flexible (X, Y) span are shown in Fig. 2, where it is assumed that X = 8 slots and Y = 3 slots for the fixed pattern. Considering the simplicity of the fixed slot group pattern in Alt. 1, it can be taken as a baseline for Rel-17 multi-slot PDCCH monitoring. Different combinations of (X, Y) may still be specified, which can be up to UE capabilities, e.g. (8,3), (4,3), (4,2), so that the network can benefit from advanced UE designs. Moreover, the back-to-back monitoring occasion can be simply avoided by setting Y to be smaller than X, and consecutive Y units can always start from the beginning of each slot group X to further reduce the complexity of the system. Though the proposed method may lack flexibility compared to other alternatives, it may predict that the limited number of unexpected MOs can eventually contribute to a better power efficiency on UE operations. On the other hand, for the span-based monitoring, after UE reporting span capability, the Y consecutive units' start position can be flexibly configured by the network as long as the gap between the first symbol of two continuous spans is no less than X, which improves the scheduling flexibility. However, as stated above, the lack of a fixed pattern could result in a large increase in UE processing complexity as the UE may have to plan for its processing highly dynamic, and the micro-sleep opportunity decreased for devices. 1. **: Using a fixed pattern (Alt.1) in a slot group provides the simplest scheme, while Use an (X, Y) span (Alt.2) can provide higher flexibility of scheduling.**

Overall, considering the short symbol duration of 480kHz and 960 kHz SCS, a fixed pattern according to Alt 1 may provide a better trade-off between flexibility and system complexity than the flexible multiple slot span pattern described in Alt. 2. **Proposal 1: Adopting Alt. 1 as a baseline for PDCCH multi-slot span for 480 kHz and 960 kHz with the additional constraints below:** * **X=4 slots for 480 kHz, and X=8 slots for 960 kHz**
* **1<=Y< X, while Y always starts from the first slot of each X slot group.**
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### R1-2106832 (Lenovo, Motorola Mobility)

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| ***Observation 1: For supporting NR between 52.6 GHz and 71 GHz for high subcarrier spacing values including 480kHz and 960kHz with multi-slot PDCCH monitoring, slot group configuration (Alt 1) with PDCCH monitoring occasion only at the beginning of slot group is beneficial to avoid back-to-back issue of PDCCH monitoring across two consecutive slot groups, but not preferable in terms of PDCCH monitoring flexibility******Observation 2: For supporting NR between 52.6 GHz and 71 GHz for high subcarrier spacing values including 480kHz and 960kHz with multi-slot PDCCH monitoring, slot group configuration (Alt 1) with the possibility to have PDCCH monitoring occasion in any slot within a slot group is beneficial from PDCCH monitoring flexibility point of view but could result in back-to-back issue of PDCCH monitoring across two consecutive slot groups******Observation 3: For supporting NR between 52.6 GHz and 71 GHz for high subcarrier spacing values including 480kHz and 960kHz with multi-slot PDCCH monitoring, if Rel-16 like mechanism with span is extended across multiple slots, then the PDCCH monitoring flexibility can be achieved, while also avoiding the issue of back-to-back PDCCH monitoring across continuous multi-slot groups*** Another alternative that has been discussed in RAN1#104-e is Alt 3 where a new principle is introduced to have a sliding window of X slots such that the PDCCH monitoring capability is maintained within that window according to the reported UE capability. The main motivation is to avoid back-to-back PDCCH monitoring. However, as described above in Figure 2 (b), Rel-16 like span based PDCCH monitoring mechanism can be simply extended across multiple slots and the issue of back-to-back PDCCH monitoring is avoided. In our view, Alt 2 and Alt 3 can basically achieve the same thing and therefore Alt 2 should be agreed as it is a simple extension of exiting mechanism and would be easier to specify.***Proposal 1: For supporting NR between 52.6 GHz and 71 GHz with high subcarrier spacing values including 480kHz and 960kHz, support Alt 2 i.e., extension of (X, Y) PDCCH monitoring span for multi-slot PDCCH monitoring***Furthermore, exact duration of the multi-slot PDCCH monitoring span can be configurable with different values in terms of number of slots depending upon the SCS values. In our view, with 480kHz SCS value, multi-slot PDCCH monitoring span should be 4 slots and with 960kHz SCS value, multi-slot PDCCH monitoring span should be 8 slots. For supporting lower values for either of the SCS value, it can be further considered if there is a strong motivation to do so.***Proposal 2: For supporting NR between 52.6 GHz and 71 GHz with high subcarrier spacing values including 480kHz and 960kHz, support 4-slot duration for 480 kHz and 8-slot duration for 960 kHz:**** ***These durations should be the basis for reporting the UE capabilities***
* ***Any lower values should be considered only if there is strong motivation/benefit to do so***
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### R1-2106874 (Samsung)

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| Slot-based PDCCH monitoring could be considered as a baseline at high SCS (480 KHz and 960 KHz), e.g. for the case UE capability is not available, wherein the maximum number of monitored PDCCH candidates and maximum number of non-overlapping CCEs in a slot can be estimated by extrapolating Rel-16 numbers for other SCSs. Table 1 suggests corresponding numbers as reference for discussion and whether to keep the minimum maximum number of CCEs as 16 for 960 kHz SCS can be further discussed.**Proposal 1: Support slot-based PDCCH monitoring for 480 KHz and 960 KHz, and use Table 1 as a reference for the maximum number of monitored PDCCH candidates and non-overlapped CCEs per slot.**Table 1: Maximum number  of monitored PDCCH candidates and non-overlapped CCEs per slot for a DL BWP with SCS configuration $μ\in \{5,6\}$ for a single serving cell

|  |  |  |
| --- | --- | --- |
|  | Maximum number of monitored PDCCH candidates per slot and per serving cell  | Maximum number of non-overlapped CCEs per slot and per serving cell  |
| 5 | [10-12] | [18-20] |
| 6 | [8-9] | [14-16] |

**Observation 3**: Alt 2 supports a gap between consecutive PDCCH monitoring spans, which can avoid increasing PDCCH blocking due to reduced PDCCH monitoring capability.**Observation 4:** Alt 2 supports flexible PDCCH monitoring pattern and provides flexibility to a gNB in the configuration of search space sets.The minimum PDCCH monitoring gap X should be more than one slot so that a UE can distribute PDCCH processing/monitoring requirements over multiple slots. For a maximum PDCCH monitoring span duration, Y, applicable values for Y can be same as Rel-15 slot-based PDCCH monitoring (i.e. one slot, or first 3 symbols of a slot). Alternatively, Y can also be multiple slots to provide more PDCCH monitoring occasions and higher scheduling flexibility to the NW. As a UE may expect much narrower beam direction from 52.6 GHz to 71 GHz compared to FR1 or FR2, the additional occasions when Y is larger than one slot can be used to for PDCCH receptions associated with different beam directions.**Proposal 2: Support multi-slot span based PDCCH monitoring capability according to combination (X, Y), where*** **X > 1 slots (e.g. X = 4 for 480 KHz and X = 8 for 960 KHz)**
* **Y = 2/3 symbols or Y>= 1 slots (e.g. 1<=Y<=X/2)**

**Proposal 3: Support UE reporting of multiple combinations (X, Y), and support adaptation among combinations and UE assistance information on the selection of combination.**For multi-slot span based PDCCH monitoring, the limits for PDCCH candidates/non-overlapping CCEs can be defined per combination of (X, Y). Similar to multi-symbol span based PDCCH monitoring in NR Rel-16, $M\_{PDCCH}^{max,(X,Y), μ} $and $C\_{PDCCH}^{max,(X,Y), μ}$ are determined according to the selection of multi-slot span gap, X, and multi-slot span duration, Y. The larger the X or Y a UE supports, the larger the values of $M\_{PDCCH}^{max,(X,Y), μ} $and $C\_{PDCCH}^{max,(X,Y), μ}$ can be. As $M\_{PDCCH}^{max,slot, μ}$ and $C\_{PDCCH}^{max,slot, μ}$ are small for SCS of 120 KHz, further reduction is not practically possible for higher SCS as PDCCH blocking may become an issue particularly when considering support of CSS sets, support of PDCCH candidates for multiple CCE aggregation levels, and application of the PDCCH overbooking procedure per search space set.. Therefore, $M\_{PDCCH}^{max,(X,Y), μ} $and $C\_{PDCCH}^{max,(X,Y), μ}$ need to be defined per multi-slot span for high SCS, such as $μ=5, or 6$.**Proposal 4: Support maximum number** $M\_{PDCCH}^{max,(X,Y), μ}$ **of PDCCH candidates, and maximum number** $C\_{PDCCH}^{max,(X,Y),μ} $**of non-overlapped CCEs, per multi-slot span for combination (X, Y), where X >1 slots, Y>=1 slots, and** $μ=5, or 6$**.** |

### R1-2106957 (CATT)

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| **Alt 1: Use a fixed pattern of slot groups as the baseline to define the new capability.** For Alt 1, a fixed pattern of slot group consists of X slots where the PDCCH monitoring occasions can be configured within Y consecutive slots/symbols of slot group. The capability indicates the maximum number of BD/CCE within a fixed pattern of slot groups for a UE for operation with a single serving cell. During the previous discussion, it has been observed that Y=X may cause the number of back-to-back MOs in adjacent slot groups exceeds maximum number of BD/CCE budget and can’t be check by UE. Thus, it is reasonable to assume the value of Y is no more than the value of X. Furthermore, the location of the Y consecutive slots/symbols within the slot group should be further clarified and there are two alternatives as follows.* Alt 1-1: the Y [symbols or slots] always start at the first slot within a slot group
* Alt 1-2: the Y [symbols or slots] can start at the any symbol within a slot group

Figure 1：The location of the Y within the slot groupIt has been known that each slot groups are consecutive and non-overlapping. When Alt 1-1 is supported, the minimum time separation of two MOs configured within Y [symbols or slots] in adjacent slot groups is fixed as shown in Figure 1. While, the minimum time separation of two MOs configured within Y [symbols or slots] in adjacent slot groups in Alt 1-2 is variable, which is complex for RAN1 to determine the BD/CCE budget. Therefore, it’s recommend that the Y [symbols or slots] always start at the first slot within a slot group**Proposal 1: For the fixed pattern of slot groups, the Y [symbols or slots] should always start at the first slot within a slot group.**When the Y [symbols or slots] start at the first slot within a slot group, as long as the valued of Y is no more than half of the value of X, the issue about back-to-back MOs in adjacent slot groups can be avoided. At the same time, to ensure as much scheduling flexibility as possible, larger value needs to be assigned to Y. This will put less limitation on the flexibility of the network configuration. To ensure the flexibility of network for scheduling PDCCH, it is recommended that Y be equal to half of the X.**Proposal 2: For the fixed pattern of slot groups, it is recommended to define the value of Y as half of the value of the X.** **Alt 2: Use (X, Y) span as baseline to define the new capability.** Figure 2: Use span to define the new capabilityThe main difference between Alt 1 and Alt 2 is that the span does not need to start at the boundary of the slot, as shown in Figure 2. The span can start from any symbol within a slot where PDCCH monitoring occasion starts. The X is minimum time separation between two consecutive spans. Y is the number of consecutive symbols configured for CORESET in a span where UE is configured for PDCCH monitoring. In Rel-16, combinations (2, 2), (4, 3) and (7, 3) of span with 15 kHz SCS and 30 kHz SCS was supported for URLLC mini-slot scheduling. Regarding the value of Y, 2 symbols and 3 symbols are supported in Rel-16 where the value of X is always smaller than 1 slot. The UE for operation in 52.6GHz-71GHz should at least support X=4 slots for 480 kHz SCS and X=8 slots for 960 kHz SCS. There shall be some limitation for the scheduling flexibility of the network, especially when Y is small comparing with X. To ensure the flexibility of network for scheduling PDCCH and avoid the issue about back-to-back MOs, Y equal to half of X is the best choice. We noticed this is true for both Alt 1 and Alt 2.**Proposal 3: For the (X, Y) span, it is recommended to define the value of Y as half of the value of the X.** **Alt 3: Use a sliding window of N slot to define the new capability.**Figure 3: Using sliding window to define the new capabilityThe length of the sliding window could be 4 slots and 8 slots for 480 kHz SCS and 960 kHz SCS respectively, and the sliding unit of sliding window is 1 slot, as shown in Figure 3. The sliding window can define UE PDCCH monitoring capability within any consecutive N slots. If overbooking of PDCCH candidates is allowed, UE requires to iterative accounting of the number of PDCCH blind decoding within the sliding window and some search space may be discarded because the manimum number of monitored PDCCH candidate is exceeded. There is no distinct advantage of sliding window for PDCCH monitoring but apparent drawback in UE complexity in iterative calculating the total number of PDCCH monitoring within the window. **Observation 1: PDCCH monitoring capability by sliding window of N-slot has no distinct advantage of increasing the number of monitored PDCCH candidate or scheduling flexibility. When overbooking calculation is involved, the sliding window of N-slot for PDCCH monitoring has the apparent drawback of extra complexity associated with each sliding window.**  |

### R1-2107001 (ZTE, Sanechips)

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| **Proposal 1: Alt 1 using a fixed pattern of slot groups is preferred as the baseline to define the new capability for PDCCH monitoring with the new SCSs 480/960 kHz:*** **Each slot group consists of X slots**
* **X={1, 2, 4} slots for 480 kHz SCS**
* **X= {1, 2, 4, 8} slots for 960 kHz SCS**
* **The capability indicates the BD/CCE budget within Y consecutive slots in each slot group**
* **For multi-slot PDCCH monitoring, Y ≦ X/2 and is always the first Y slot(s) within each slot group**
* **The locations of the PDCCH monitoring symbols should not be restricted**
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### R1-2107051 (Ericsson)

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| For the three UE multi-slot PDCCH processing capability definitions to be discussed below, there is a need to clearly define the locations of the monitoring windows. In the TDD UL/DL configuration, if only one pattern is configured, the periodicity of pattern1 shall divide 20 ms evenly. If two patterns are configured, the sum of the periodicities of both patterns shall divide 20 ms evenly. As a result, the first symbol of every $20/P$ period when only one pattern is configured or every $20/(P+P\_{2})$ period when two patterns are configured is a first symbol in an even frame. Therefore, this first symbol in an even frame can be used as the start of the first PDCCH processing capability window. All subsequent monitoring windows are defined with the specific window advancing offsets in the three respective UE multi-slot PDCCH processing capability definitions. For Alt 1, the window advancing offset is fixed for a cell. If X=4 for a 480 kHz SCS cell or if X=8 for a 960 kHz SCS cell, the multi-slot PDCCH processing capability windows for Alt 1 are aligned with the slots of a 120 kHz SCS cell.1. The PDCCH processing capability window starts from the first symbol in an even frame to align with the TDD UL/DL configuration.

In designing the Rel-17 multi-slot PDCCH monitoring solutions, both aspects shall hence be addressed jointly:* In which slot(s) of a multi-slot span shall PDCCH be monitored?
* In which OFDM symbols of a monitored slot shall PDCCH be monitored?

It should be emphasized these two aspects need to be addressed jointly for a prospective solution. For example, if a solution is adopted whereby all monitoring is concentrated within a single slot of an N-slot bundle (not our preference), then there needs to be flexibility to configure USS and CSS in different spans within the slot. For such a solution Case 1-1 would be far too restrictive. On the other hand, if there is network flexibility to configure a UE to monitor in different slots of an N-slot bundle (e.g., CSS and USS in different slots), then case 1-1 and/or 1-2 would probably be sufficient.1. In defining a solution for Rel-17 multi-slot PDCCH monitoring, both intra- and inter-slot monitoring aspects shall be addressed jointly:
	1. In which slot(s) of a multi-slot span shall PDCCH be monitored?
	2. In which OFDM symbols of a monitored slot shall PDCCH be monitored?
2. Solutions to support multi-slot PDCCH monitoring for Rel-17 NR should consider the benefits and impacts to both UEs and gNBs. The solutions shall allow the network to distribute the multi-slot PDCCH monitoring/processing loads for different types of UEs flexibly across the multiple slots.

Note further that monitoring two consecutive slots is already a required behavior in existing NR specifications. More specifically, PDCCH monitoring of Type0-PDCCH CSS set for each SSB index locates in two consecutive slots. To avoid complicated specifications changes to fundamental initial access protocols, such required behaviors should be supported for 480 kHz SCS.1. To avoid complicated specifications changes to fundamental initial access protocols, PDCCH monitoring of more than one consecutive slots within a multi-slot monitoring window is supported.
2. Alt 1A (Y≤1 slot) where PDCCH monitoring is restricted to the first slot of an X-slot group is less flexible for the network operations. To remedy the restriction, intra-slot PDCCH monitoring capability 2 support is needed.
3. Alt 1B (Y=X) where PDCCH monitoring can be configured in any slot of an X-slot group becomes operationally identical to Alt 3 when all restrictions against local PDCCH processing load violations are put in place.
4. Alt 1C (Y≅X/2) where PDCCH monitoring can be configured over the first few slots of an X-slot group support network operation flexibility managing UEs not requiring low latency.
5. For Alt 1, selecting Y≅X/2 (PDCCH monitoring can be configured over the first few slots of an X-slot group) provides a balance between UE PDCCH monitoring complexity and network operation flexibility.
	1. If X = 4, Y is no less than 2.
	2. If X = 8, Y is no less than 3.
6. Alt 2A (Y ≤ 1 slot) requires the UE to support intra-slot monitoring capability of Y≫3 OS.
7. Alt 2B (Y≅X/2) where PDCCH monitoring can be configured over the first few slots of an X-slot group support network operation flexibility managing UEs not requiring low latency.
8. Compared to Alt 1, the float monitoring capability spans of Alt 2 introduce additional monitoring capability misalignment/overburden issues when multiple serving cells are active. As a result, additional PDCCH processing load restriction/checking will need to be defined for Alt 2 to handles these cases.
9. There are multiple possible “first monitoring occasions” of groups of monitoring occasions or, equivalently, multiple delineations of monitoring occasion groups that can give opposite answers to whether a particular PDCCH monitoring configuration is allowed or not. It is necessary to check several different delineations of monitoring occasion groups under Alt 2 which brings about complexity and similarity to Alt 3. The multiple possible delineations also raise issues on how exactly to handle PDCCH overbooking/dropping under Alt 2.

With Rel-17 work approaching closing, RAN1 should strive to progress in the multi-slot PDCCH processing capabilities for 480/960 kHz SCS. Toward this end, we propose the following starting exemplary lower and upper bounds as the starting point for RAN1 discussion:* 480 kHz SCS with bundle size of B=4
	+ $N\_{BD, 5}^{4-slot}=\left[20-48\right]$
	+ $N\_{CCE, 5}^{4-slot}=[32-80]$
* 960 kHz SCS with bundle size of B=8
	+ $N\_{BD, 6}^{8-slot}=\left[20-72\right]$
	+ $N\_{CCE, 6}^{8-slot}=[32-128]$

Note that the capabilities of a UE supporting 960 kHz SCS can be higher than those for supporting only 480 kHz SCS since the former is equipped with higher processing powers to address larger bandwidths with shorter OFDM symbol and slot times.1. RAN1 agrees to the following multi-slot PDCCH processing capability ranges for 480/960 kHz SCS as the starting point to progress the Rel-17 specification effort:
	1. 480 kHz SCS with bundle size of B=4: $N\_{BD, 5}^{4-slot}=\left[20-48\right]$ and $N\_{CCE, 5}^{4-slot}=[32-80]$
	2. 960 kHz SCS with bundle size of B=8: $N\_{BD, 6}^{8-slot}=\left[20-72\right]$ and $N\_{CCE, 6}^{8-slot}=[32-128]$

One question that is not addressed in the above, is whether or not bundling sizes other than B = 4/8 are supported for 480/960 kHz SCS, and RAN1 should further discuss this. In our view, it would lead to quite large spec impact if completely arbitrary bundle size is supported, hence we think that some form of quantization would be needed for the scaling of BD/CCE capabilities with the bundle size B. The first level decision to take is the PDCCH processing capability ranges as in Proposal 6. After that, a 2nd level decision can be taken on whether or not other vales of B = 4/8 are supported, and how the capability scaling should work.1. RAN1 should further discuss whether bundle sizes other than 4/8 for 480/960 kHz are supported, and if so, how to appropriately scale the UE capabilities while minimizing spec complexity.
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### R1-2107098 (Futurewei)

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| For Alt1 and Alt 2 when UEs have different X and Y spans and different monitoring capabilities it may be difficult for gNB to schedule the CSS to be monitored by all UEs. However, with CSS located at the beginning of each span gNB may accommodate UEs with different capabilities. **Proposal 1: Use the Rel-16 capability (*pdcch-Monitoring-r16*, (X, Y) span) as the baseline to define the new capability, where Y is the multi-slot span length, and X represents the minimum duration between consecutive multi-slot spans (Alt 2).**In RAN1 #104-e discussions most companies supported the PDCCH monitoring enhancements only for SCS larger than 120 kHz. In other words, some RAN1 companies including us, did not see reasons to have multi-slot PDCCH monitoring capability for 120kHz SCS, which is the only SCS mandated so far for beyond 52.6GHz to 71 GHz spectrum. **Proposal 3: For 120 kHz SCS, no UE multi-slot capability for monitoring for PDCCH is needed.** The Proposal 3 implies that the maximum span duration for SCS 120kHz is one slot, which is equal to the duration of 4 slots for SCS 480kHz and 8 slots for SCS 480kHz. Thus, to be consistent with the maximum monitoring span duration at 120 kHz SCS, the maximum span durations for 480 kHz SCS and 960 kHz SCS may be 4 slots and respectively 8 slots i.e., 125 us. **Proposal 4: The maximum multi-slot PDCCH monitoring span durations supported for 480 kHz SCS and 960 kHz are 4 slots and respectively 8 slots.**We note that the maximum duration of multi-slot span does not preclude shorter duration spans such as 1 or 2 slots, which may be necessary for low latency application (URLLC/IIoT). |

### R1-2107105 (Nokia, Nokia Shanghai Bell)

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| In the following we compare functionalities between Alt 1 and Al 2. We think that Alt 3 (sliding window) should not be considered any further. First of all, it’s quite unclear how it works. Secondly, we think that floating/sliding window complicates the monitoring operation considerably (e.g. when compared to Alt 1), and without clear benefits. Thirdly, we think that it’s possible to define the sufficient flexibility elements also via Alt 1 or Alt 2.***Proposal 1*:** *Down select Alt 3 from the list alternatives for defining the multi-slot PDCCH monitoring capability* **Comparision between Alt 1 and Alt 2:**It can be noted that the Alt1 and Alt2 can provide almost the same functionalities. * Both can be used to support multi-slot PxSCH scheduling
* Both can be defined according to similar UE capabilities defined in terms of the maximum number of PDCCH candidates and non-overlapping CCEs.
* Both can operate according to the same principle: BD/CCE caps are defined as sum within a span (Y) separated by multi-slot gap (X).

The main difference between two alternatives seems to be the following:* Alt 1: span is always in a predefined (periodical) location.
* Alt 2: span can start anywhere.

 Based on that, Alt1 provides opportunites for UE/gNB to calculate BD/CCE dropping in advance while Alt2 requires support for dynamic operation. This creates considerable burden for both UE and gNB. From gNB point of view, presence of multiple UEs (and constraints due to RF beamforming) needs to be considered as well. Based on the complexity issues, we make the following proposals. ***Proposal 3*:** *Select Alt 1 for multi-slot PDCCH monitoring***Parameter values for X and Y:**We think that it makes sense to define X and Y in terms of symbols. However, we see this more as a signaling aspect and if the group later decides that a raster of 14 symbols is sufficient, we can revise the decision accordingly. ***Proposal 4*:** *Define X and Y in terms of symbols. It can be dedided later if a raster of 14 symbols is sufficient (for X)*Table 1 shows the number of slots and OFDM symbols w.r.t. a slot with 120 kHz SCS. Based on Note2 [2]“*UEs supporting a band in the range of 52.6GHz-71GHz are not required to support 480kHz SCS and 960kHz SCS*”. This means that 120 kHz SCS is supported by all UEs and all 60GHz deployments. * We think that the maximum number of PDCCH candidates and non-overlapping CCEs could be defined in terms of 120 kHz slots. This corresponds to 4 slots with 480 kHz SCS and 8 slots with 960 kHz SCS, respectively.
* Additionally, we think that span of [2] slots should be supported for 480 kHz SCS, and span of [2, 4] slots should be supported for 960 kHz SCS, respectively.

For parameter Y, the natural starting point is Y=[1, 2, 3] (i.e. the size options currently available for CORESET duration). ***Proposal 5:*** *Support the following parameters for X** *X=[28, 56] for 480 kHz SCS*
* *X=[28, 56, 112] for 960 kHz SCS.*

***Proposal 6****: Support at least Y=[1, 2, 3] for multi-slot -based monitoring.*In addition to multi-slot span -based monitoring, UEs with 480 kHz and 960 kHz SCSs should support slot-based monitoring. In order to support slot-based operation with reasonable coverage, one should support at least 8 non-overlapped CCEs (preferably 16), and at least 4 PDCCH candidateds also for slot-based operation. There are number of TBDs in Table 2. The numerical values for these should be decided during the WI.***Proposal 7****: Consdier PDCCH monitoring capabilities defined for 120 kHz SCS as a baseline for multi-slot -span based monitoring** *support at least 20 PDCCH candidates per 120 kHz slot duration*
* *support 32 non-overlapped CCEs per 120 kHz slot duration.*
* *support at least 8 non-overlapped CCEs also for slot-based operation.*

Table 2. Example table demonstrating UE capabilities for multi-slot span -monitoring

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|  | Max. # of monitored PDCCH candidates per slot/span per combination (X,Y) and per serving cell | Max. # of non-overlapped CCEs per slot/span for per combination (X,Y) and per serving cell |
| *μ* | Slot-based | (28, Y) | (56, Y) | (112, Y) | Slot based | (28, Y) | (56, Y) | (112, Y) |
| 3 | 20 | - | - | - | 32 | - | - | - |
| 5 | ≥4 | TBD | ≥20 | - | ≥8 | TBD | ≥32 | - |
| 6 | ≥4 | TBD | TBD | ≥20 | ≥8 | TBD | TBD | ≥32 |

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### R1-2107113 (Charter Communications)

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| In comparison of Alt. 1 and Alt. 2, the latter alternative is less strict and potentially satisfies more diverse use cases with different latency requirements. However, Alt.1 can provide the same flexibility using the configuration of *SearchSpace.* In the configuration of *SearchSpace*, the monitoring periodicity and the offset within the periodicity can be configured using the following parameter which allows the periodicity to be configured as 1, 2, 4, 5, 8, 10, … slots up to a maximum of 12560 slots.monitoringSlotPeriodicityAndOffset CHOICE { sl1 NULL, sl2 INTEGER (0..1), sl4 INTEGER (0..3), sl5 INTEGER (0..4), sl8 INTEGER (0..7), sl10 INTEGER (0..9), sl16 INTEGER (0..15), sl20 INTEGER (0..19), sl40 INTEGER (0..39), sl80 INTEGER (0..79), sl160 INTEGER (0..159), sl320 INTEGER (0..319), sl640 INTEGER (0..639), sl1280 INTEGER (0..1279), sl2560 INTEGER (0..2559) }Higher monitoring slot periodicity provides more opportunities for micro sleep and is suitable for UEs that require lower data rate and more relaxed latency requirements. On the other hand, lower monitoring slot periodicity is suitable for UEs requiring higher data rate and lower latency requirements. Therefore, Alt. 1 together with the configuration of *SearchSpaces* can provide the flexibility of Alt. 2 and satisfy conditions (2), mentioned in the previous section.It has been emphasized by some companies that in Alt 2 the X is the minimum separation between the start of two consecutive spans which can create an ambiguity about the “first monitoring occasion”. This ambiguity requires gNB to perform processing load checking according to different delineations of monitoring occasions which adds extra complexity. Since Alt.1 can provide the advantages of Alt.2 without causing extra complexity, Alt.1 is preferable in our view.**Observation 1: In our view, alternative 1 is preferable compared with Alt. 2 for defining the multi-slot PDCCH monitoring capability. It provides straightforward implementation while it can offer advantages of Alt. 2.****Observation 2: In our view, alternative 3 is preferable compared with Alt. 2 and Alt.1 for defining the multi-slot monitoring since it satisfies conditions (1-2), while it provides scheduling flexibility.** **Proposal 1: In our view, alternative 3 is preferable compared with Alt. 1 and Alt. 2 for defining the multi-slot PDCCH monitoring capability.**Since in RAN1#104b-e, it was agreed that for 120 kHz SCS, the BD/CCE budget is the same as that in FR2, these budgets can be used to determine the processing capabilities for 480/960 kHz SCS. The 480/960 kHz SCSs have 4x and 8x shorter slot durations compared with 120 kHz SCS, thus, to have the same average processing complexity per time, X = [4] slots for 480 kHz SCS and X = [8] slots for 960 kHz SCS can be defined. **Proposal 2: As a baseline, X = [4] slots for 480 kHz SCS and X = [8] slots for 960 kHz SCS can be chosen for alternative 1.** |

### R1-2107153 (NEC)

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| For 480 kHz and 960 kHz SCS adopted beyond 52.6GHz, In the WID [3], PDCCH monitoring enhancement with multi-slot span is supported, it can maintain scheduling framework same as for smaller SCS (e.g. 120 kHz) when the UE is configured to monitor the PDCCH every multiple slots, and specific number of the multiple slots is in discussion, e.g. 4 slots for 480 kHz SCS and 8 slots for 960 kHz SCS. But for some use cases such as low-latency services which require more frequent PDCCH monitoring, the flexibility will be reduced with the multi-slot based monitoring. To handle those use cases with low-latency, denser PDCCH monitoring occasion should be considered to support, such as per-slot, per 2-slots based monitoring for 480 kHz SCS and per 2-slots, per 4-slots based monitoring for 960 kHz SCS, and accordingly the associated BD/CCEs limit number needs to further study. **Proposal 1: Additional PDCCH monitoring group sizes should be supported: 1 or 2 for 480 kHz SCS, 2 or 4 for 960 kHz SCS, and further study the associated BD/CCEs limit number.** |

### R1-2107238 (OPPO)

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| In the past two meetings, three alternatives were discussed for the PDCCH monitoring per slot group. Among these three alternatives, Alt3 intended to avoid a case where burst monitoring happens and with the sliding window it ensures that the capacity is maintained within a window of any location. Although we empathy this solution, we think that the claimed issue is not new to the slot-group monitoring but already exists in legacy system. For example, in R16 span-based capability (Fig. 1), the monitoring capability is defined within a span, but it might still happen that an aggregated burst monitoring see the example of {7,3}. In this case, it seems that there has been already a situation of such kind and the legacy UE can already handle it quite well. Moreover, if the span length and span interval are well design, there won’t be additional requirement for R17 UE for the PDCCH monitoring. For this reason, we think Alt-3 is not needed. **Observation 1: the issue to be addressed by Alt-3 seems already exists in legacy system and the legacy UE can already handle this issue.** **Proposal 1: Alt-3 is not necessary and focus on Alt-1 and Alt- 2.** From our understanding, the main difference between Alt-1 and Alt-3 is that the Alt-3 does not define a fixed starting slot of the slot group, which can be shifted according to the configured PDCCH monitoring occasions. In fact, there is no fundamental difference between Alt-3 and Alt-2, both can achieve a similar goal. The advantage of Alt-2 is that R16 span framework can be reused. However, the definition of X and Y may need revision to make it tailored to high subcarrier spacing cases. Alt-1 design detailsThe slot group is similar to span interval and it controls the distance between two spans. The slot group value should at least be equal to a slot duration of 120kHz SCS, that is slot group value = 4 for 480kHz SCS and 8 for 960kHz SCS. **Proposal 2: for Alt-1, support a slot group containing 4 slots for 480kHz SCS and 8 slots for 960kHz SCS.** Since the slot group is fixed, e.g. bounded with slot index, therefore, the span within a slot group should not be in fixed location. Otherwise, this would very much limit the scheduling flexibility. For this reason, we suggest that the span location within the slot group is not fixed from the first slot. It can be determined according to the configured search space. However, the span location within the slot group across different slot group should be fixed. **Proposal 3: for Alt-1, support a non-fixed location of a span in a slot group. But the relative span location in the slot group is fixed across different slot groups.** Regarding the span length, we suggest that the length should be limited to 3 symbols up to 1 slot. With this limitation, the UE will be allowed to benefit from the micro sleeping. **Proposal 4: For Alt-1, the span length is limited to 3 symbols up to 1 slot.** Alt-2 design detailsFor Alt-2, we think reusing the R16 span framework can work nicely. The span interval should be designed at least to support 1 slot duration of 120kHz. In this case it has a similar span interval as Alt-1, i.e. 4 slots for 480kHz SCS and 8 slots for 960kHz SCS. The span length can be in the range of 3 symbols up to 1 slot. **Proposal 5: for Alt-2,** * **supporting span interval X=4 for 480kHz SCS and 8 for 960kHz SCS.**
* **Supporting span length Y in the range of 3 symbols to 1 slot**

Regarding the monitoring capacity within a span, we suggest that the following to be supported.

|  |  |  |  |
| --- | --- | --- | --- |
| SCS | Value of X | #PDCCH candidate | #CCE |
| 480 kHz | 4 slots | 20 | 32 |
| 960 kHz | 8 slots | 20 | 32 |

**Proposal 6: Support the maximum PDCCH candidates to be monitored as 20 and maximum CCE as 32 within a span.**  |

### R1-2107331 (Qualcomm)

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| For high SCSs, it would be necessary to support both per-slot and multi-slot PDCCH monitoring capabilities; although the maximum number of BD/CCE is limited, per-slot PDCCH monitoring may be useful in some use cases, e.g., for serving a low-latency traffic or for channel monitoring outside a COT. As pointed out in earlier meetings, per-slot PDCCH monitoring is a special case of multi-slot PDCCH monitoring and can be handled in the same framework. If both per-slot and multi-slot capabilities are supported, the default capability, which is assumed when there is no dedicated RRC configuration, should be determined, e.g., when 480 kHz SCS is used for initial access. Noting that per-slot PDCCH monitoring would be more demanding for the high SCSs, having multi-slot PDCCH monitoring as the default capability is desirable.**Proposal 1: For 480 kHz and 960 kHz SCSs, multi-slot PDCCH monitoring is the default capability, and assumed during the idle/inactive mode operation (e.g., for ANR detection) and initial access procedure.****Proposal 2: For 480 kHz and 960 kHz SCSs, per-slot PDCCH monitoring (i.e., X = 1 slot) is supported as an optional UE capability during a connected mode operation.**If a UE supports both per-slot and multi-slot PDCCH monitoring (i.e., supporting more than one X values), switching between the two different PDCCH monitoring behaviors may be required. For instance, for the operation in FR2-2 unlicensed band, more frequent PDCCH occasions (e.g., every slot) would be necessary so that the gNB can start transmitting PDCCH as early as possible after LBT success. On the other hand, for data transmission and reception during a COT, per-multi-slot PDCCH monitoring may be assumed at least for the power efficient operation. In Rel-16, for FR1, each BWP can be configured with either per-slot or per-span PDCCH monitoring (i.e., by configuration of *monitoringCapabilityConfig-r16*) and, thus, the switching between two different PDCCH monitoring behaviors is through BWP switching. Thus, if the per-span PDCCH monitoring capability is extended for high SCSs as will be discussed in Section 2.1.3, the same BWP-based mechanism would directly be applied.As an alternative switching mechanism, particularly for the unlicensed band operation, search space set group switching can be considered. In this case, each search space set group may be configured for either per-slot or multi-slot PDCCH monitoring. For example, search space set group 0 (i.e., the default group) can be configured with per-slot PDCCH monitoring and used when the UE is outside the channel occupancy time. On the other hand, search space set group 1 can be configured with multi-slot PDCCH monitoring and used during a COT. Although search space set group switching has dedicatedly been used for NR-U operation in Rel-16, the discussion on the extension for licensed band operation is in progress in Rel-17 UE power saving WI. Therefore, if supported for the licensed band operation, search space set group switching will provide more dynamic transition between per-slot and multi-slot PDCCH monitoring, both for unlicensed and licensed band operation.**Proposal 3: For UEs supporting both per-slot and multi-slot PDCCH monitoring capabilities, support a dynamic switching mechanism between per-slot and multi-slot PDCCH monitoring capabilities.****Observation 1: Bandwidth part switching and search space set group switching mechanisms can be considered as candidate switching mechanism between per-slot and multi-slot PDCCH monitoring.**In determining the value(s) of X, the existing per-slot PDCCH monitoring capability for 120 kHz can be the baseline. The new capability should achieve at least a similar extent of scheduling flexibility and power consumption as the 120 kHz SCS. Therefore, as stated in the FL’s proposal A1-2 in RAN1 #104bis-e, X = 4 slots for 480 kHz SCS and X = 8 slots for 960 kHz SCS should be the considered as default values that are supported by all UEs. Larger values of X than those may adversely affect the performance compared to that of 120 kHz SCS and should not be supported. On the other hand, based on the UE capability, additional values smaller than X = 4 slots for 480 kHz SCS and X = 8 slots for 960 kHz SCS, e.g., {1, 2} for 480 kHz and {1, 4} for 960 kHz, may optionally be supported. In particular, X = 1 corresponds to the per-slot PDCCH monitoring capability.**Proposal 4: For the value of X in the multi-slot PDCCH monitoring capability, the following sets are considered:** * **480 kHz SCS: X = {1, 2, 4} slots, where 4 is the default value (supported by all UEs), while X=1 and X=2 are per UE capability,**
* **960 kHz SCS: X = {1, 4, 8} slots, where 8 is the default value (supported by all UEs), while X=1 and X=4 are per UE capability.**

In the same vein, not to harm the performance compared to that of 120 kHz SCS, the same number of BD/CCE limit should be considered as the starting point with X = 4 slots for 480 kHz SCS and X = 8 slots for 960 kHz SCS.**Proposal 5: For the multi-slot PDCCH monitoring capability with X = 4 slots for 480 kHz SCS and X = 8 slots for 960 kHz SCS, at least the same maximum numbers of PDCCH candidates and non-overlapped CCEs as 120 kHz SCS are supported (i.e., 20 BDs and 32 CCEs).****Observation 2: More than one PDCCH monitoring occasion or span dispersed within a X-slot duration may adversely impact the power efficiency.**Among different alternatives agreed in RAN1 #104bis-e, Alt 1 and Alt 3 do not restrict the position and number of MOs within a X-slot window, particularly when Y is large, and the gain of multi-slot scheduling is diluted. Thus, to improve power efficiency, one can pose additional restriction on the position and number of MO within the window, and they boil down to Alt 2. As such, due to the clear advantage in power efficiency, it is desirable to support Alt 2.For further details of Alt 2, the first up to 3 symbols within a slot can be used for MOs, at least for UE-specific search space sets, Type 1 common search space set with dedicated RRC configuration, and Type 3 common search space set; unlike the cases of SCSs smaller than or equal to 120 kHz, the motivation and benefit of sub-slot-level PDCCH monitoring is not clear. Furthermore, in the agreement for Alt 2, it is FFS whether the repetition of the same span pattern over a number of slots is needed. The FFS is based on the view that Alt 2 is an extension of Rel-15 PDCCH monitoring capability, i.e., FG 3-5b (*pdcch-MonitoringAnyOccasionsWithSpanGap*). However, in our view, Alt 2 should be regarded as an extension of Rel-16 per-span PDCCH monitoring capability, i.e., FG 11-2 (*pdcch-Monitoring-r16*), and the notion of the repeated span pattern is not relevant. To clarify, the same definition of span in Rel-16 should be used (Section 10 in TS 38.213):* A span is a number of consecutive symbols in a slot where the UE is configured to monitor PDCCH.
* A span starts at a first symbol where a PDCCH MO starts and ends at a last symbol where a PDCCH MO ends, where the number of symbols of the span is up to Y.

**Proposal 6: For the definition of multi-slot PDCCH monitoring capability, Alt 2 is supported with the following modification:*** **Alt 2: Use an (X, Y) span as the baseline to define the new capability**
	+ **X is the minimum time separation *in symbols* between the start of two consecutive spans**
	+ **The capability indicates the BD/CCE budget within a span of at most Y consecutive *symbols***
		- **A span is placed within the first 3 OFDM symbols of a slot for USS and CSS with dedicated RRC configuration**
	+ **The following combinations of (X, Y) are supported:**
		- **480 kHz SCS: (14, 3), (28, 3), (56, 3)**
		- **960 kHz SCS: (14, 3), (56, 3), (112, 3)**
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### R1-2107432 (Panasonic)

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| For Alt 1, to ensure the separation between two spans, besides the condition that Y contains one single span, the position of Y should be fixed with respect to X, e.g. at the beginning of the X-slot group. Then Alt 1 becomes similar to Alt 2, with the only difference that in Alt 1 the locations of the X-slot groups have fixed pattern with respect to SFN but in Alt 2 the locations of the X-slot groups are more flexible. Then the selection between Alt 1 and Alt 2 would depend on whether such flexibility is needed or not. From our point of view, the flexible location of X-slot group is useful to avoid TDD UL slots if semi-static TDD DL/UL slots are supported in above 52.6GHz operation. **Proposal 1: For defining multi-slot PDCCH monitoring capability, select Alt 2 with X in slots and Y in symbols and Y containing one short span (up to a few symbols).**If the above discussed restriction that Y contains one single short span is agreed by RAN1, there is no need for further capability definition discussion within Y. On the other hand, some companies seem to prefer to use Y representing the number of consecutive slots that could potentially contain MOs (in both Alt 1 and Alt 2), where the underlined assumption is that some symbols of Y may not belong to any span. As a result, it is to be discussed the further capability definition within Y. From our point of view, the discussion points include the maximum allowed duration of a MO span and maximum number of allowed MO spans. It also should discuss the minimum time separation between two consecutive MO spans to order to avoid local PDCCH processing overloading issue. **Proposal 2: For both Alt 1 and Alt 2, if more than one short span can be configured within Y, further discuss capability definition within Y in terms of duration of span, number of spans, and minimum separation between two consecutive spans.** |

### R1-2107436 (LG)

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| For both Alt-1 and Alt-2, SS set configurations and dropping rules can be determined simply since basic principles for them are already well established to a single slot or a single span in rel-15/16. However, Alt-2 does not allow multiple discontinuous Y slots/symbols within X slots/symbols by the definition of span in rel-16. In addition, if the duration of Y is much smaller than X, all MOs for both CSS and USS should be in small number of slots/symbols. This may reduce the gNB’s flexibility and restrict the SS set configuration especially for CSS. Therefore, we suggest that Alt-1 should be the baseline to define the BD/CCE capability for multi-slot PDCCH monitoring. One possible issue for Alt-1 has also been raised in the previous meeting, i.e., UE may have higher requirement than expectation on PDCCH monitoring in two consecutive slots across slot-group boundary. However, it may not be the problem if additional constraints for Y on PDCCH monitoring in back-to-back slots. We propose some restrictions to Y to resolve the possible issues for Alt-1.**Proposal #1: Adopt Alt-1, with the following restrictions for configurations of Y*** + **Y should be multiple slots (including single slot) with slot-level granularity**
	+ **The size of Y should be determined with respect to the size of X**
	+ **Minimum gap between the last symbol of the previous Y and the first symbol of the next Y over two consecutive X slot group should be guaranteed**
	+ **The position of Y in each X slot group should start from a fixed slot in each X slot group, i.e., the first slot position for each X slot group should be the same**
	+ **FFS: The number of Y in each X slot group**
	+ **FFS: The possibility of different positions of Y for CSS and USS**

There can be simple ways to determine X which is the length of a slot-group. One way is to set the slot-group as the fixed length aligned to the slot length corresponding to 120 kHz SCS since it is the smallest SCS that could be configured in FR2-2. Since it is already possible to monitor PDCCH in units of 120 kHz slot length, there is no need to set the slot-group length to a value larger than the 120 kHz slot length. Therefore, the consecutive 4 slots could be used as slot-group for 480 kHz SCS, and consecutive 8 slots for 960 kHz SCS. Need for the values smaller than them may require further discussion. Another way is to use a new PDCCH monitoring time unit, i.e., X and Y, with capability signalling. A preferred combinations of X and Y can be signalled for each UE, and these can be used as a basic time unit for PDCCH monitoring. This could provide more flexibility for multi-slot PDCCH monitoring operation.**Proposal #2: Determine the number of slots for slot-group as 4 for 480 kHz and 8 for 960 kHz. Consider to configure X and Y based on UE capability if multiple values for X and Y are supported.** |

### R1-2107510 (MediaTek)

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| Alt1 provides a simple monitoring behavior within each X slots/symbols and achieves multi-slot monitoring by conducting the PDCCH monitoring in a fixed and small portion of the X slots/symbols. Furthermore, Alt1 limits the monitoring pattern in predetermined locations. On the other hand, monitoring pattern can be more flexible in Alt2 where Alt2 regulates the duration of each PDCCH monitoring to be within Y unit of time and achieves multi-slot monitoring by configuring no PDCCH monitoring in the rest of X-Y units of time. In fact, Alt2 extends the span notion defined in Rel-16 URLLC. As for the Alt3, it is motivated by providing scheduling flexibility for gNB based on the UE capability of BD/CCE limit within a moving window of time, which can resolve the back-to-back PDCCH monitoring at UE side from the gNB configuration. However, during the discussion in RAN1 #104bis-e meeting, it has been identified that the benefit of Alt3 on avoiding back-to-back PDCCH monitoring can be achieved by restricting the monitoring pattern at the beginning of each slot group and by properly designing (X,Y) values in Alt1 and Alt2. It has also been identified that Alt3 can lead to dynamic PDCCH monitoring dropping at UE side due to the moving window of checking BD/CCE limit. Therefore, we suggest to remove Alt3 from discussion and focus on the selection from Alt1 and Alt2 for the multi-slot PDCCH monitoring framework **Proposal 1: For multi-slot PDCCH monitoring capability, remove Alt3 from the discussion.** During the discussion in RAN1 #104bis-e meeting, the unit of monitoring pattern within each alternatives was discussed without any conclusions. For Alt1, the unit of the fixed pattern can be either symbol or slot, e.g., UE PDCCH monitoring is confined within the first Y symbols or first Y slots within each X slots. For Alt2, the unit of (X,Y) can also be either symbol, which follows the legacy span definition in Rel-16, or slots. If the unit of symbol is adopted in Alt1 and Alt2, then PDCCH monitoring might concentrate in consecutive symbols within and even across slots. In this case, the associated scheduling delay can be impacted depending on the ratio of fixed pattern duration Y and X slots in Alt1 and the ratio of X and Y in Alt2. On the other hand, if the unit of slot is adopted in Alt1 and Alt2, i.e., the fixed pattern in Alt 1 indicates the slots for PDCCH monitoring and the unit of (X,Y) in Alt2 is slot, PDCCH monitoring can be distributed into consecutive slots and the monitoring symbols within each slot can be further specified, which can provide more flexibility on scheduling. In fact, a monitoring pattern specified with the unit of symbol can also be described by a monitoring pattern specified with the unit of slot with further details on the monitoring symbols in the slots. **Proposal 2: To achieve scheduling flexibility in multi-slot PDCCH monitoring, the monitoring pattern should adopt slot as the basic unit for (X,Y) in both Alt1 and Alt2. The monitoring symbols within the slots can be further studied.** Regarding the candidate values of (X,Y) in Alt1 and Alt2, there was a discussion in RAN1 #104bis-e meeting on the range of X. In particular, {1, 2, 4} were discussed for 480kHz and {1, 2, 4, 8} were discussed for 960kHz. In our view, at least X=4 slots and X=8 slots should be supported for multi-slot PDCCH monitoring in 480 kHz and 960kHz, respectively, to achieve PDCCH monitoring power saving. For supporting X=8 slots in 480kHz multi-slot PDCCH monitoring, the decision should acknowledge the discussion outcome on the maximum number of scheduled PDSCHs in a single DCI under 480kHz. For the same reason of UE power saving, at least Y=1 should be supported. For other values of (X,Y), we prefer to have an UE capability to address the trade-off between UE implementation complexity and gNB scheduling flexibility.**Proposal 3: To achieve UE power saving in multi-slot monitoring, at least (X=4 slots, Y=1 slot) and (X=8 slots, Y=1 slot) should be supported for multi-slot PDCCH monitoring in 480 kHz and 960kHz, respectively, in both Alt1 and Alt2. For other pairs of (X,Y), if needed, optional UE capability should be introduced.** Although many details are not specified yet in those alternatives, there can be some shared design concepts between Alt1 and Alt2 when the fixed pattern in Alt 1 indicates the slots for PDCCH monitoring and the unit of (X,Y) in Alt2 is slot. For example, if the fixed pattern in Alt1 indicates the first Y=1 slot within every X=4 slots is configured for PDCCH monitoring, then the resulting monitoring pattern satisfies the (X=4, Y=1) monitoring constraint in Alt2, which is illustrated in Figure 1. Therefore, Alt1 can be considered as a basic configuration for multi-slot monitoring framework. Compared with Alt1, Alt2 provides an additional degree of freedom on indicating the locations of slots for PDCCH monitoring under the (X,Y) constraint, which is illustrated in Figure 2. However, such flexibility comes with a cost of complicating the BD/CCE limit distribution when multi-cell operation is considered. For example, it is possible that the spans in the same cell follow the (X,Y) constraint but the spans from different cells might be close to each other and violate the (X,Y) constraint in time domain, which is illustrated in Figure 3. In this example, both CCs follow (X=4,Y=1) constraint and the BD/CCE limit assigned to Span1\_2 in CC#1 and Span2\_1 in CC#2 need to acknowledge UE monitoring capability on monitoring the back to back spans of slots. Therefore, to complete Alt2 design, the multi-cell monitoring capability need to be carefully specified. The same issue can also occur in Alt1 if the fixed multi-slot monitoring patterns among CCs are not aligned. Therefore, some restriction on the search space set configuration may be necessary to realize either Alt1 or Alt2, e.g., the supported PDCCH monitoring periodicity of $k\_{s}$ slots and PDCCH monitoring offset of $o\_{s}$ slots should be limited to ($k\_{s},o\_{s} $)=($m×X, n×X$) when a UE supports (X,Y) multi-slot PDCCH monitoring capability where ($m, n$) are non-negative integers. **Proposal 4: Adopt Alt1 as the basic multi-slot PDCCH capability with the following aspects.** * **Each slot group consists of X slots**
* **Slot groups are consecutive and non-overlapping**
* **The capability indicates the BD/CCE budget within Y consecutive slots in each slot group separately**
* **Support at least (X=4 slots, Y=1 slot) and (X=8 slots, Y=1 slot) for multi-slot PDCCH monitoring in 480 kHz and 960kHz, respectively**
	+ **FFS other (X,Y) values as optional UE capability**
	+ **FFS the monitoring occasion restriction within the Y=1 slot**
* **Support PDCCH monitoring periodicity of** $k\_{s}$ **slots and PDCCH monitoring offset of** $o\_{s}$ **slots to be limited to (**$k\_{s},o\_{s} $**)=(**$m×X, n×X$**) when a UE supports (X,Y) multi-slot PDCCH monitoring capability where (**$m, n$**) are non-negative integers**
* **Restrictions on location of the Y slots within a slot group to be the first Y slots within a slot group**
* **FFS: whether to support Alt2 as optional capability. If supported, the multi-cell monitoring capability for non-aligned spans across CCs need to be further studied.**
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### R1-2107578 (Intel)

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| **Proposal 1:** * X can be 2 and 4 for SCS 480kHz, 2, 4 and 8 for SCS 960kHz
	+ Per-slot PDCCH monitoring capability is not supported for SCS 480/960kHz
* The maximum value Y is X/2.
* The minimum value of Y is 2, except the case that X equals to 2 and Y equals to 1 for SCS 480kHz.

According to the revised WID [1], initial access is supported for SCS 480kHz with support of Type0-PDCCH CSS set. Further, for ANR and PCI confusion detection, Type0-PDCCH SCS set is supported for SCS 480kHz and 960kHz. Therefore, for SS/PBCH block and CORESET multiplexing pattern 1 in NR, UE needs to monitor Type 0/0A/1/2 CSS sets with search space set 0 in two consecutive slots. The time position of the two slots depends on the position of the associated with a SS/PBCH block. On the other hand, other CSS/USS sets are configured by high layer parameters *monitoringSlotPeriodicityAndOffset* and *duration*. The combined pattern of slots configured with Type 0/0A/1/2 CSS sets and other CSS/USS sets may satisfy the pattern of the multi-slot PDCCH monitoring capability for a SS/PBCH block of the UE. However, when the SS/PBCH block of the UE changes, the combined pattern of slots may become invalid for the multi-slot PDCCH monitoring capability. Instead of reconfiguration of all CSS/USS sets when the SS/PBCH block changes, dropping the PDCCH MOs in a slot can be considered to make the combined pattern valid. However, dropping Type 0/0A/1/2 CSS sets has negative impact on the scheduling of broadcast information. On the other hand, dropping other CSS/USS sets is not desirable for PDSCH/PUSCH scheduling. Since Type 0/0A/1/2 CSS sets only occurs in long cycle, i.e., 20ms, it can be considered to temporarily allow the violation of slot pattern of the multi-slot PDCCH monitoring capability near to a slot carrying Type 0/0A/1/2 CSS sets. **Proposal 2:** * If Type0/0A/1/2 CSS sets are monitored in a slot, configured PDCCH monitoring occasions around the slot can temporarily violate the multi-slot PDCCH monitoring capability, with the limitation of maximum number of BDs/CCEs.
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### R1-2107727 (Apple)

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| ***Proposal 1:*** *The MSM PDCCH monitoring capability should be based on Alt 1 or Alt 2. Alt. 3 should not be supported.****Proposal 2:*** *The corresponding values of X and Y are set to allow flexibility in the placement of the CSS and UE-SS without undue burden on UE power consumption e.g. Y ≤1.****Proposal 3:*** *The values of X for Alt-1 and Alt-2 are as follows:** *For 480 kHz: X = 4 slots, for 960 kHz, X = 8 slots.*
	+ *Additional values smaller than 4/8 slots for 480/960 kHz can be supported based on UE capability.*
	+ *Larger values than 4/8 slots for 480/960 kHz are not supported.*
* *Single-slot PDCCH monitoring for 480 kHz and 960 kHz are not supported.*

***Proposal 4:*** *For Alt-1, the value Y should be defined based on slots.** *the SS sets are within the first Y slots of the slot group and Y < X i.e., no back-to-back monitoring of PDCCH between slot groups is supported. With Y = 1*
* *PDCCH monitoring of all SS sets monitored in the Y slots occurs within N consecutive symbols of Y:*
	+ *Case 1: PDCCH monitoring limited to within the first N consecutive symbols of Y*
	+ *Case 2: PDCCH monitoring is on any span of up to N consecutive symbols of Y*

***Proposal 5:*** *For Alt-1, the positions of CSS and UE-SS in Y should be clarified based on both network flexibility and UE power consumption.* ***Proposal 7:*** *For Alt-2, the value Y should be defined based on symbols* * *The duration of Y < X with Y ≤ 3 symbols*

***Proposal 6:*** *For Alt-1, the Max # of monitored PDCCH candidate per (multi-)slot per CC (BD) can and the Max # of non-overlapped CCEs per (multi-)slot per CC can be set as in Table 1.*

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| *μ* | Maximum number of monitored PDCCH candidates | Maximum number of non-overlapping CCEs |
| X=1 | X=2 | X=4 | X=8 | X=1 | X=2 | X=4 | X=8 |
| 3 | 20 | - | - | - | 32 | - | - | - |
| 5 | N/A | 10 | 20 | - | N/A | 18 | 32 | - |
| 6 | N/A | 8 | 10 | 20 | N/A | 14 | 18 | 32 |

***Proposal 8:*** *The Max # of monitored PDCCH candidate per slot/span per CC (BD) and the Max # of non-overlapped CCEs per slot/span per CC can be set as in Table 2.*

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|  | Max. # of monitored PDCCH candidates per slot/span per combination (X,Y) and per serving cell | Max. # of non-overlapped CCEs per slot/span for per combination (X,Y) and per serving cell |
| *μ* | Slot-based | (28, Y) | (56, Y) | (112, Y) | Slot based | (28, Y) | (56, Y) | (112, Y) |
| 3 | 20 | - | - | - | 32 | - | - | - |
| 5 | N/A | 10 | 20 | - | N/A | 18 | 32 | - |
| 6 | N/A | 8 | 10 | 20 | N/A | 14 | 18 | 32 |

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### R1-2107790 (Sharp)

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| Since multi-slot monitoring is considered to be an extension of single-slot monitoring, Alt.1 can simplify the enhancement of SearchSpace and reduce the impact on the specification by using a slot as the unit. On the other hand, several companies have pointed out that Alt.2 is more flexible than Alt.1 because the span interval can be freely determined. However, the necessity of flexibility by monitoring based on the (X, Y) span in Alt.2 has not been shown, and Alt.1 also allows flexible MO distribution by considering search space configuration for 480 kHz and 960 kHz SCS with short slot. In addition, Alt.2 requires a discussion on the rules that determine the BD/CCE limits for aligned and non-aligned spans between CCs. We don't know if the rules in Rel-16 are applicable to Alt.2, and defining new rules will take multiple meetings. Therefore, we support Alt1 where the unit is a slot, which has less impact on the specification.**Proposal 1: We support the fixed pattern of slot groups where the unit is a slot.**For multi-slot monitoring, one X-slot group with a heavy PDCCH processing load at the end of the group may be followed by another X-slot group with a high PDCCH processing load at the beginning. Each X-slot group complies individually with the PDCCH processing capacity of the UE, but the capacity limit is locally exceeded at the boundary between the two groups. As discussed in the #104b e-meeting, such back-to-back problems need to be considered when determining the multi-slot monitoring span. In order to resolve the problem and consider monitoring CSS, Y should be less than X/2 starting at beginning of slot group and at least 3 symbols. Then, multiple slots for Y can increase the flexibility of MO distribution and one slot for Y is useful in terms of power efficiency by providing opportunities for microsleeps. Therefore, Y should be less than X/2 and always start at beginning of slot group as a limitation. **Proposal 2:** **Y should be less than X/2 and always start at beginning of slot group.**As several companies have pointed out, multi-slot monitoring should correspond to the same processing performance on a time basis as single-slot monitoring at 120 kHz. Therefore, the value of X can be 4 slots for 480 kHz SCS, and 8 slots for 960 kHz SCS. Since the value of Y is equal to or less than X/2, corresponding to the UE capability to consider resolving the back-to-back problem, we can consider Y=1 as the simplest Y while ensuring flexibility in MO distribution. Whether to support values greater than 1 remains to be studied.**Proposal 3: The following values should be used as basic settings. The value of Y greater than 1 deserves further study.****・for 480 kHz SCS : X = 4, at least Y = 1****・for 960 kHz SCS : X = 8, at least Y = 1** |

### R1-2107846 (NTT DOCOMO)

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| At the previous meetings, RAN1 discussed down-selection among the three alternatives above.To define the multi-slot PDCCH monitoring capability, the followings need to be addressed in our view: 1. The number of BD/CCE should not exceed the specified budget in any slot group.
2. CSS and USS can be configured in different symbols/slots in a slot group.

For the first requirement, it can be realized by Alt.3 obviously since Alt.3 checks the number of BD/CCE with sliding the window of X slots. This is the motivation why Alt.3 is proposed and it requires no restrictions on SS location. However, such flexibility on SS configuration may cause the UE complexity such as dynamic SS dropping which need to be discussed carefully if Alt.3 is supported. Furthermore, if SSs are distributed to multiple slots in a slot group, UE blind decoding burden can increase for 480/960 kHz SCS. This requirement/concern can be solved by Alt.1 and Alt.2 with restriction on the SS location, e.g., Y should be no larger than 2 slot when X is 4 slot.For the second requirement, it needs to be considered for Alt.1/2 to avoid the case Y value is so small that there is no room to configure CSS and USS in different symbols/slots in a slot group according to the first requirement. This requirement can be achieved depending on the configuration of Y value, e.g., Y should be more than 1 slot when X is 8 slot.In addition to the definition of multi-slot PDCCH monitoring capability, the exact values of X and Y for Alt.1/2 have been discussed.For X value(s), to ensure the same duration of 1 slot for 120 kHz SCS, 4/8 slots for 480/960 kHz SCS should be supported as X for multi-slot PDCCH monitoring capability. In addition, to support the same framework of single slot PDCCH monitoring capability which can be supported depending on the UE capability even in 52.6 – 71 GHz, a value 1 should also be supported for both 480 and 960 kHz SCS.For Y value(s) of Alt.1/2, as discussed above, SS configuration flexibility and UE BD burden are trade-off and it depends on which Y value can be supported with the UE capability, e.g., if the combination of X=4 slot and Y=1 slot is applied, it can provide the same PDCCH monitoring as the case when the first 3 symbols in a slot are the monitoring occasion with 120 kHz SCS which can be supported by a UE FG3-1, however, SS configuration is limited in the one slot. Thus, to take a balance of SS configuration flexibility and UE BD burden, multiple Y values should be defined for each X value respectively. In addition, if Y is defined in unit of slot, which symbols can be MO should be discussed and the symbols in the slot(s) can be different between CSS and USS.***Proposal 1:*** *For the multi-slot PDCCH monitoring capability, X and Y should be defined as follows:** *X = 1, 4 for 480 kHz SCS and X = 1, 8 for 960 kHz SCS should be supported.*
* *Multiple Y values can be defined for each X value respectively.*
	+ *E.g., For 480 kHz SCS: (X, Y) = (1, 1), (4, 1), (4, 2).*
	+ *E.g., For 960 kHz SCS: (X, Y) = (1, 1), (8, 2), (8, 3), (8, 4).*
* *If Y is defined in unit of slot, which symbols can be MO should be discussed.*

Based on the discussion above, the requirements for multi-slot PDCCH monitoring capability can be fulfilled by all of Alt.1/2/3, and we should focus on the discussion on how to define multi-slot PDCCH monitoring capability with Alt.1 and Alt.2 to avoid the possible UE complexity or standardization efforts for Alt.3.***Proposal 2****: For defining the multi-slot PDCCH monitoring capability for 480 and 960 kHz SCS, down-selection from Alt.1 and Alt.2 should discussed further.*One difference between Alt.1 and Alt.2 is the definition of X. For Alt.1, X is defined as the number of slots which composes a slot group and the time separation between the start of two Y symbols/slots should be fixed as X. On the other hand, for Alt.2, X is defined as the minimum time separation between the start of two consecutive spans and this means that the time separation between the start of two Y symbols/slots can be larger than X. Accordingly, Alt.2 can provide better scheduling flexibility than Alt.1.Therefore, for further down-selection between Alt.1 and Alt.2, Alt.2 which can provide better scheduling flexibility than Alt.1 and can be achieved by extending Rel-16 span PDCCH monitoring definition is preferable.***Proposal 3****: For defining the multi-slot PDCCH monitoring capability for 480 and 960 kHz SCS, Alt.2 should be supported as the baseline.*If Alt.2 is supported for defining the multi-slot monitoring capability, there would be some follow-up issues. One is the span pattern, which defines the monitoring occasion in a slot, and the pattern is repeated among all the slots in Rel-15/16 NR. Since the span length would be larger than the one in Rel-15/16 (i.e., more than 1 slot), whether to repeat the span pattern among all the slot groups may need to be discussed to have more flexibility on span pattern configuration. For example, if the span pattern is not repeated and UE supports multiple combinations of (X, Y), UE needs to check which (X, Y) combination(s) is/are applicable for every slot group then UE burden may increase. On the other hand, in such case, UE can adopt different (X, Y) value for each slot group, which can enable to increase the total number of monitored CCEs since UE can apply maximum number of BDs/CCEs more flexible.***Proposal 4****: At least the following aspects should be considered to discuss whether to specify the span pattern and repeat the pattern for all the slot groups if Alt.2 is supported as multi-slot PDCCH monitoring capability definition.** *UE burden for checking which (X, Y) combination is applicable.*
* *Whether applying different (X, Y) values for each slot group is beneficial.*
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### R1-2107913 (Xiaomi)

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| It is agreed that for the SCS 120 kHz, no multi-slot UE capability for PDCCH monitoring is needed. However, for SCS 480 kHz and 960 kHz, multi-slot PDCCH monitoring should be supported to avoid hurting the flexibility. The supported number of slots for multi-slot PDCCH monitoring for SCS 480 kHz and 960 kHz should be 4 and 8 respectively as the baseline. ***Proposal 1:*** ***The supported number of slots for multi-slot PDCCH monitoring for SCS 480 kHz and 960 kHz should be 4 and 8 respectively as the baseline.***From our opinion, in essence Alt2 is very similar to Alt1, except the span separation X is a minimum value instead of a fixed value. But considering search space set is periodical, we don’t think there is a need to change the span separation X.Alt 3 is to use a sliding window of N slots for defining multi-slot PDCCH monitoring capability, and increments in which sliding occurs can be further studied. Some companies think a sliding window can provide more flexibility to gNB/UE. But our opinion is, PDCCH monitoring capability is a capability that related to UE hardware, and is supposed to be fixed, at least semi-static. Currently we don’t see the justification to have a flexible multi-slot PDCCH monitoring capability definition.***Proposal 2: Support Alt1,*** ***a fixed pattern of N slots to define multi-slot PDCCH monitoring capability. And within the N slots, M (M<=N) slot(s) can be configured with PDCCH monitoring.*** |

### R1-2108015 (Convida Wireless)

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| Like Rel-16 URLLC PDCCH monitoring span (X, Y) definition, it can be extended to the mobile broadband (EMBB) service for NR from 52.6 GHz and above with few modifications. Like Alt-2, the PDCCH monitoring span (X, Y) for higher SCS/numerology (e.g., SCS 480KHz, 960 kHz) where the first number X is the number of slots between the beginning of two consecutive monitoring occasions, the second number Y is the number of slots or symbols needs to be monitored in a monitoring occasion. Rel-16 PDCCH/DCI span, it supports limited span like (X, Y) = (2, 2), (4, 3), and (7, 3). Note in Rel-16, the value of X and Y is based on units of symbols. Therefore, the X and Y supported in Rel-16 may not be suitable for NR from 52.6 GHz and above. For NR from 52.6 GHz and above, the duration per span may be across several slots to meet the scheduling requirement due to the number of PDCCH candidate and nonoverlapping CCEs being reduced per slot. The UE can be configured by gNB to monitor PDCCH with the maximum number of PDCCH candidates and nonoverlapping CCEs defined per slot as in NR Rel-15/16 or defined per span for the maximum number of PDCCH candidates and non-overlapping CCEs defined per span. An example of a PDCCH monitoring span shown in Figure 1. In Figure 1, we assume a configuration of PDCCH monitoring span for SCS = 960 KHz. For this example, let a span (X=8, Y=4) is configured, note the unit for X and Y can be either based on number of slots or symbols. it means there are PDCCHs need to be monitored in Y=4 slots and each PDCCH monitoring occasion are separated by X= 8 slots.**Figure 1**: An exemplary PDCCH monitoring span for NR from 52.6 GHz to 71 GHz.***Proposal 1. PDCCH monitoring can be either based on per slot as in Rel-15/16 for lower SCS (e.g., 120 KHz), or per span (multi slots as Alt-2) for NR from 52.6 to 71 GHz.*** The UE can be configured by the gNB to monitor PDCCH for the maximum number of PDCCH candidates ($M\_{PDCCH}^{max,span,μ}$) and nonoverlapping CCEs ($C\_{PDCCH}^{max,span,μ}$) defined per span like in Rel-16. In each PDCCH monitoring span, the number of PDCCH candidates and nonoverlapping CCE cannot exceed the UE capability. Therefore, UE behavior can be similar to legacy NR specification even when there is a overbooking. For example, the UE and gNB can map PDCCH candidates in each PDCCH monitoring span as the following mapping rules in legacy NR specification: (1) CSS sets are mapped before USS sets; (2) USS sets are mapped in ascending order of the SS set indices, and if the number of PDCCH candidates/CCEs exceeds either of the UE processing limits, etc.Alt-3 proposes the multi-slot span with the concept of the "sliding window”. The motivation is to limit the PDCCH processing loads on the UE over any sliding window of, say, $B$ slots. The maximum BD/CCEs can be distributed by gNB configuration to (1) all in one slot or (2) over several slots while respecting the maximum capability constraints over any sliding window of $B$ slots. One of the advantages is that the loading can be evenly distributed from gNB perspective. The sliding window can be treated as a time offset (number of slots) configuration for USS from the beginning of span. Also, the multi-slot span with the concept of the "sliding window” can be implemented by the PDCCH monitoring span pattern (X, Y) when the following two conditions are satisfied, i.e., X and Y are defined in terms of slots, and X = Y. Therefore, Alt-3 can be treated as a special case of Alt-2. In addition, the “sliding window” (e.g., the USS stating time-offset) for each UE is configured by gNB and UE just follows the configuration to perform PDCCH monitoring in each PDCCH monitoring span. ***Proposal 2. PDCCH monitoring per span with sliding window (i.e., Alt-3) can be up to gNB configuration for NR from 52.6 to 71 GHz.***  |

## Topic A2: Search Space Enhancement

### R1-2106443 (Huawei, HiSilicon)

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| The time domain parameters include periodicity, offset, duration, and monitoring symbols within slot as shown in following table.Table 5. Search space set configurationSearchSpace ::= SEQUENCE {searchSpaceId SearchSpaceId,controlResourceSetId ControlResourceSetId monitoringSlotPeriodicityAndOffset CHOICE { sl1 NULL, sl2 INTEGER (0..1), sl4 INTEGER (0..3), sl5 INTEGER (0..4), sl8 INTEGER (0..7), sl10 INTEGER (0..9), sl16 INTEGER (0..15), sl20 INTEGER (0..19), sl40 INTEGER (0..39), sl80 INTEGER (0..79), sl160 INTEGER (0..159), sl320 INTEGER (0..319), sl640 INTEGER (0..639), sl1280 INTEGER (0..1279), sl2560 INTEGER (0..2559)} duration INTEGER (2..2559) monitoringSymbolsWithinSlot BIT STRING (SIZE (14)) …**Periodicity and offset**: Assuming multi-slot PDCCH monitoring capability for 480 kHz and 960 kHz SCS is defined within the first Y [slots or symbols] per X-slot pattern as Alt 1(a) in section 2.1, a UE is usually configured with monitoring periodicity with integer multiple of X slots in order to ensure its monitoring occasion locates within the Y [slots or symbols]. Meanwhile, the number of slots will increase by 4 times and 8 times respectively for 480kHz SCS and 960kHz SCS if similar absolute monitoring periodicity as 120kHz SCS is maintained. In order not to increase the number of choices in *monitoringSlotPeriodicityAndOffset* too much, the unit of the periodicity could be X-slots corresponding to the multiple slot PDCCH monitoring capability, instead of one single slot. The offset values should also be scaled by X-slots considering the monitoring occasion should be located at Y [slots or symbols] from the beginning of X slots pattern. For example, “sl4” in Table 4 represents for the periodicity of 16 slots with 480 kHz SCS and 32 slots with 960 kHz SCS. The integers values of (0,1,2,3) for “sl4” correspond to slot#0, slot#3, slot#7, slot#11 in a 16-slot periodicity with 480kHz SCS and slot#0, slot#7, slot#15, slot#23 in a 32-slot periodicity with 960kHz SCS. If monitoring occasions are restricted within the first Y>1 slots in an X-slot pattern, additional slot-level offset should be added to the slot index derived from *monitoringSlotPeriodicityAndOffset.* Alternatively, the number of bits of *monitoringSymbolsWithinSlot* can be increased to cover Y slots, e.g. 28 bits for Y=2 slots. Or the number of bits of *monitoringSymbolsWithinSlot* could be extended to 56 bits or 112 bits as a simplest way to indicate the offset within X slots.**Duration**: In Rel-15, the duration field in SearchSpace configuration denotes the number of consecutive slots that a SearchSpace lasts upon every period. The value of duration should be smaller than the periodicity indicated by *monitoringSlotPeriodicityAndOffset*. In order to reuse the field and the value range defined in Rel-15 for 480 kHz and 960 kHz, a new interpretation should be defined. If the PDCCH monitoring capability for 480 kHz and 960 kHz is the same as that of 120 kHz in a fixed time duration, the duration for 480 kHz and 960 kHz can be defined as a number of consecutive X-slots where SearchSpace can be located. Within each X-slots, the monitoring occasion can only be located in the first Y [symbols or slots] configured by *monitoringSymbolsWithinSlot*. An example is shown between 120 kHz and 480 kHz in Figure 5, wherein, Ts denotes the duration configured for SearchSpace (yellow box), ks denotes the period. Figure 5. TDM-ed search space for different UEs within a monitoring span***Proposal 2:*** *The time domain parameters of search space set configuration should be revised for multi-slot PDCCH monitoring for 480 kHz and 960 kHz, as follows:** + *The unit of monitoringSlotPeriodicityAndOffset is changed to X-slots, with X=4 for 480 kHz and X=8 for 960 kHz.*
	+ *The unit of “duration” is changed to X-slots, with X=4 for 480 kHz and X=8 for 960 kHz.*
	+ *Additional slot level offset or extension of monitoringSymbolsWithinSlot* *is required if monitoring occasions are within the first Y>1 slots in an X-slots pattern.*

In NRU Rel-16, search space set group switching is introduced to balance the UE power consumption on PDCCH monitoring and channel access flexibility from gNB side. The gNB can initiate DL transmission in the middle of slot after LBT by configuring mini slot PDCCH monitoring(SSSG#0) to UE. After detecting a scheduling PDCCH or DCI format 2-0 with SSSG switching trigger, UE may switch to SSSG#1 with longer monitoring period within a COT. UE switch back to SSSG#0 after end of COT. It takes $P\_{switch}$symbols as listed in Table 8 for UE to accomplish the SSSG switch procedure. **Table 7. Minimum value of** $P\_{switch}$ **[symbols]**

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| $$μ$$ | Minimum $P\_{switch}$ value for UE processing capability 1 [symbols] | Minimum $P\_{switch}$ value for UE processing capability 2 [symbols] |
| 0 | 25 | 10 |
| 1 | 25 | 12 |
| 2 | 25 | 22 |

In FR2-2, a slot with 120 kHz SCS has similar time duration as 3 OFDM symbol mini-slot with 30 kHz SCS in FR1, which bring sufficient flexibility in channel access. Moreover, if slot-based PDCCH monitoring is supported for 480 kHz and 960 kHz SCS, the PDCCH monitoring periodicity is as small as about 15 us, which is very close to the CCA sensing slot duration. So it is not necessary to introduce SSSG switch between mini-slot monitoring and slot-based monitoring, and between slot-based monitoring and multi-slot monitoring. However, for 480 kHz and 960 kHz, SSSG switching can still bring benefit of UE power saving when SSSG switching occurs between multi-slot-based monitoring with a lower periodicity and a higher periodicity. ***Proposal 4:*** *SSSG* *switching can be supported between two different periodicities of multi-slot-based monitoring in order to save UE power consumption on PDCCH monitoring.* |

### R1-2106580 (vivo)

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| In NR Rel-15&16, the allowed SS period configuration is from 1 slot to 2560 slots as shown below [7]. When PDCCH uses 480/960K SCS, there are the following two issues to be considered:* Smaller SS period (e.g. 1 or 2 slots) is not needed for 480/960K SCS with multi-slot-based capability;
* The largest configurable SS period, i.e. 2560 slots=80/40ms for 480/960K SCS respectively, is not enough for SS configuration.

**Proposal 11: Search space configuration should be improved for 480K/960K SCS.** |

### R1-2106832 (Lenovo, Motorola Mobility)

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| In addition to the mechanism for multi-slot PDCCH monitoring, also enhancements will be needed for the search space configuration to better facilitate any of the above alternatives. Currently, three main configuration parameters associated with SS configuration includes PDCCH monitoring periodicity, PDCCH monitoring duration within a period and a bitmap to indicate symbols for PDCCH monitoring within a slot. For any of the above three alternatives, one main criterion is that PDCCH monitoring will be configured across multiple slots (group of slots). Therefore, it would make sense to define periodicity only in multiple of these slot groups. Therefore, minimum periodicity should not be less than the multi-slot duration, for example 4 slots for 480 kHz SCS value and higher values of periodicity should be in multiples of 4 slots. Similarly, the duration should be defined in multiples of slot groups. ***Proposal 3: For supporting NR between 52.6 GHz and 71 GHz with high subcarrier spacing values including 480kHz and 960kHz, search space configuration should be enhanced to support (or restrict) the PDCCH monitoring periodicity and corresponding duration in multiples of slot groups rather than multiples of slots***Furthermore, in order to facilitate the flexibility for configuring any slot (including more than one slot) within a multi-slot duration for PDCCH monitoring occasion, the existing bitmap for symbols in the SS configuration is not efficient. For example, for 8 slots, the bitmap will be 14\*8 bits long. Therefore, it would make sense to support additional slot-level bitmap for indicating PDCCH monitoring slots within the multi-slot duration. Then the symbol-level bitmap can be applied only to those slots that are indicated to be monitored. For example, if there is a 4-slot monitoring duration, then a slot-level bitmap “1010” would indicate that monitoring occasion is in slot 1 and slot 3. And if symbol-level bitmap is “ 11100000000000” is indicated, then that means for slot 1 and slot 3, PDCCH monitoring occasion is in the first 3 symbols, respectively.***Proposal 4: For supporting NR between 52.6 GHz and 71 GHz with high subcarrier spacing values including 480kHz and 960kHz, search space configuration should be enhanced to support slot-level bitmap to indicate the slots where PDCCH monitoring is configured for a multi-slot PDCCH monitoring (for example, if there is a 4-slot monitoring duration, then a slot-level bitmap “1010” would indicate that monitoring occasion is in slot 1 and slot 3)*** |

### R1-2106874 (Samsung)

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| An issue was raised in RAN1#104bis-e regarding switching PDCCH monitoring capability based on SSSG switching. However, that issue is not valid. Based on Rel-15/16 configuration of PDCCH monitoring capability, a UE does not switch PDCCH monitoring capability based on SSSG switching. SSSG switching is performed within an active DL BWP while PDCCH monitoring capability is configured per DL BWP and applies to all search space sets configurations within the DL BWP. Also, it is possible to extend SSSG switching to support switching of UE PDCCH monitoring capability, if necessary. NR supports switching PDCCH monitoring capabilities based on BWP switching and the same principle can apply for switching PDCCH monitoring capabilities based on SSSG switching. However, the motivation for supporting PDCCH monitoring capability switching without BWP switching needs to be justified first before considering any enhancement on Rel-16 SSSG switching to support PDCCH monitoring capability switching.**Observation 5:** PDCCH monitoring capability switching is supported in NR Rel-16 based on BWP switching. **Proposal 5: Further study motivation for enhancement of Rel-16 SSSG switching scheme to support PDCCH monitoring capability switching.** To support multi-slot span based PDCCH monitoring, a UE would expect that a time gap between any two consecutive PDCCH monitoring spans is not smaller than the multi-slot span gap X, while any PDCCH monitoring span duration is up to Y slots. PDCCH monitoring occasions are determined according to configured search space sets, where PDCCH monitoring periodicity $k\_{s},$ and duration $T\_{s}, $are configured in number of slots for a search space set *s*. Two consecutive PDCCH monitoring spans can either be PDCCH monitoring occasions from the same search space set or PDCCH monitoring occasions from different search space sets. Therefore, both intra search space set span gap and inter search space set span gap should be considered – i.e. the span gap should be considered across all search space sets as in Rel-16. Figure 1 illustrates an example of multi-slot span based PDCCH monitoring with combination of (X = 4, Y =2), the configuration of search space set 3 is invalid because the two consecutive PDCCH monitoring occasions from search space set 1 and search space set 3 is smaller than X, but is not smaller than Y. **Figure 1: Illustration of search space set configurations limited by combination of (X = 4, Y =2).**For intra search space set span gap, the PDCCH monitoring periodicity of $k\_{s}$ slots should be limited by the multi-slot span gap X, while the PDCCH monitoring duration of $T\_{s}$ slots should be limited by the multi-slot span Y. Therefore, a PDCCH monitoring periodicity should not be smaller than the multi-slot span gap, i.e. $k\_{s}\geq X$, while PDCCH monitoring duration is not larger than multi-slot span, i.e. $T\_{s}\leq Y if a PDCCH monitoring span is extended to be Y slots$.For inter search space set span gap, two consecutive PDCCH monitoring occasions from different search space sets may belong to different PDCCH monitoring spans. In this case, the gap between the two consecutive PDCCH monitoring occasions from search space set *i*  and search space set *j* is limited by multi-slot span gap, X, such that $|(k\_{i}-O\_{i})-(k\_{j}-O\_{j})|\geq X$, where $O\_{i}$ and $O\_{j}$ are offsets for search space set *i*  and search space set *j*. In another case, the two consecutive PDCCH monitoring occasions from different search space sets can belong to the same PDCCH monitoring span. In the latter case, the gap between the two consecutive PDCCH monitoring occasions from search space set *i* and search space set *j* should be limited by multi-slot span duration, Y, such that $|(k\_{i}-O\_{i})-(k\_{j}-O\_{j})|<Y$. For the benefit of simple scheduling and configuration, it’s better to consider applicable values for PDCCH monitoring periodicity to be integer of X. **Proposal 6: For multi-slot span based PDCCH monitoring based on combination (X, Y), the PDCCH monitoring periodicity is** $k\_{s}=k⋅X$**,** $k=1, 2, …$**, and the PDCCH monitoring duration is** $T\_{s}\leq Y if Y >1 slot$Another PDCCH candidate configuration related aspect impacted by multi-slot based PDCCH monitoring is the determination of CCE locations for a PDCCH candidate. The determination of CCE indexes for a PDCCH candidate is based on a parameter, $Y\_{p,n\_{s,f}^{μ}}$, where $n\_{s,f}^{μ}$ is the slot index of the PDCCH monitoring occasion. For multi-slot based PDCCH monitoring and a PDCCH monitoring duration of X>1 slots, the index of the first slot from the X slots is used to determine $Y\_{p,n\_{s,f}^{μ}}$ i.e. $Y\_{p,n\_{s,f}^{μ}}$ is replaced by $Y\_{p,X⋅n\_{s,f}^{μ}}$*,* for each PDCCH monitoring occasion within the X slots; otherwise, with $Y\_{p,n\_{s,f}^{μ}}$ updated per slot and considering the time-first mapping for PDCCH and that Y can be more than 1 slot, the Rel-16 CCE-based structure for PDCCH transmissions cannot be maintained. **Proposal 8: For multi-slot PDCCH monitoring according to configuration (X, Y),** $Y\_{p,n\_{s,f}^{μ}}$ **is replaced by** $Y\_{p,X⋅n\_{s,f}^{μ}}$ **in the search space equation in [2].**  |

### R1-2106957 (CATT)

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| **Proposal 4：For 480 kHz SCS and 960 kHz SCS, the search space configuration can be enhanced as follows.*** **Extending the unit of duration from slot to X-slot indicating a number of consecutive multi-slot that the search space exists.**
* **Adding a new bitmap *monitoringSlotWithinMulti-slot* indicating the slot that the search space exists within the multi-slot.**

The search space group set switching was introduced in Rel-16 NR-U with 15 kHz SCS, 30 kHz SCS and 30 kHz SCS for dynamic switching between different search spaces. Before the gNB obtains the COT, the frequent monitoring enable the gNB to transmit DCI as soon as possible if gNB’s LBT is successful. However, frequent monitoring is not conducive to power saving of the UE during the COT. When the search space group set switching is configured, the gNB can indicate to UE switching between a search space with long periodicity and a search space with short periodicity to meet different scheduling requirements. Therefore, we suggest the legacy SSSG switching mechanism should be reused for the 120 kHz SCS, 480 kHz SCS and 960 kHz SCS in 60GHz NR-U, as shown in Figure 6.**Proposal 5: The Legacy SSSG switching mechanism should be reused for the 120 kHz SCS, 480 kHz SCS and 960 kHz SCS in 60 GHz NR-U.**It has been agreed that the BD/CCE budget for 120 kHz SCS in 52.6-71 GHz is the same as that for 120 kHz in FR2. Thus, we believe 120 kHz SCS in 52.6-71 GHz doesn’t support the monitoring capability of the span defined in Rel-16 just like 120 kHz in FR2. The PDCCH monitoring capability for 120 kHz SCS is the baseline for study of the PDCCH monitoring capability for 480 kHz SCS and 960 kHz SCS. The motivation to support single slot PDCCH monitoring capability for 480 kHz SCS and 960 kHz SCS out of the COT is not clear. It is not necessary to enhance the SSSG switching to support dynamic switching between single slot PDCCH capability and multi-slot PDCCH capability for 480 kHz SCS and 960 kHz SCS.**Proposal 6: SSSG switching is not required to be enhanced to support the switching between single slot PDCCH capability and multi-slot PDCCH capability 480 kHz SCS and 960 kHz SCS.** |

### R1-2107001 (ZTE, Sanechips)

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| If a fixed pattern of slot groups to define the new capability for PDCCH monitoring is adopted, when configuring the search space set by higher layer parameter *monitoringSlotPeriodicityAndOffset*, the gNB needs to ensure that PDCCH monitoring periodicity $k\_{s}$, the duration *TS* is an integral multiple of X slots (X slots consists a slot group), or is an integral multiple of slot groups, i.e. $k\_{s}$ and *TS* are in the units of slot group. For example, if a slot group includes four slots (X=4), the duration *TS* can be configured as 4, 8, 12, 16, ... of slots. Alternatively, the duration *TS* can be configured as 1, 2, 3, 4, ... of slot groups, i.e. the basic granularity of the duration *TS* should be defined as a slot group. Figure 3 gives one configuration type in a slot group, e.g., PDCCH MO is configured in the first slot within the slot group.**Figure 3: Configurations if a fixed pattern of slot groups is supported**Multiple PDSCH/PUSCH scheduling with a single DCI being discussed in agenda item 8.2.5 can not only save DCI overhead, but also reduce PDCCH monitoring frequency without sacrificing scheduling flexibility. Therefore, the design of the new UE capability for PDCCH monitoring, search space set configuration can be considered in combination with multiple PDSCH/PUSCH scheduling by a single DCI.**Proposal 2: PDCCH monitoring periodicity** $k\_{s}$ **and the duration *TS* of the search space sets should be configured as an integral multiple of a slot group, if a fixed pattern of slot groups to define the new capability for PDCCH monitoring is supported.**Search Space Set Group (SSSG) Switching was introduced in Rel-16 NR-U. In order to reduce access delay and save power, the SSSG monitoring periodicity/granularity is increased or decreased according to the channel access procedure. UE has to support frequent PDCCH monitoring outside gNB-COT and infrequent PDCCH monitoring inside COT. The existing SSSG switching is applied for SCS 15/30/60 kHz For SSSG switching on large SCS values like 120, 480 and 960 kHz, UE needs to dynamically change between two PDCCH monitoring periodicity/granularity. SSS switching operation is also related to whether per slot PDCCH monitoring is supported. Besides, the switching time $P\_{switch}$ with all SCSs supported in above 52.6 GHz needs to be defined if SSSG switching is agreed to be supported. **Proposal 3: Support SSSG switching for SCS 120/480/960 kHz, and the following points can be further studied:*** **SSSG switching between multi-slot and per-slot monitoring if per-slot monitoring is supported for 480/960 kHz**
* **The switching time** $P\_{switch}$ **with all SCSs supported in above 52.6 GHz**
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### R1-2107153 (NEC)

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| In TS 38.213 [2], search space set group switching is introduced for NR-U in Rel-16, and it’s used for UE to save power by switching from more frequent PDCCH monitoring to less frequent in a COT. There are 2 search space set groups for switching, one is dense monitoring periodicity and the other is sparse. Switching is in an active BWP and based on explicit or implicit switching indication, and the monitoring capability keeps the same before and after the switch. For operation in unlicensed band beyond 52.6GHz, in our understanding, the current SSSG switching can be reused for 120 kHz SCS, since in last meeting [1], it has been concluded: for 120 kHz SCS, no multi-slot UE capability for PDCCH monitoring is needed. So the monitoring capability before and after the switch is the same, both are per-slot based. While for 480 kHz and 960 kHz SCS, PDCCH monitoring capability is changed along with SSSG switching, e.g. there are 2 configured SSSG, the first search space set defines PDCCH is monitored per 2-slots, and the second set defines PDCCH is monitored per 4-slots, the monitoring time unit and capability is different before and after the switching. If this scenario is supported, how to adapt it to R16 SSSG switching needs to be discussed.**Proposal 2: For operation in unlicensed band with 480 kHz and 960 kHz SCS, consider whether/how to support SSSG switching along with changing different PDCCH monitoring capability**As mentioned in [4], in R16, the switching boundary is the first slot that is at least $P\_{switch}$ symbols after some switch indication and the timer decrement value is counted by slot. For 480 kHz and 960 kHz SCS, PDCCH monitoring capability is multi-slot based, e.g. 4 slots for 480 kHz SCS and 8 slots for 960 kHz SCS, the switching boundary and the timer counter should be modified to multi-slot based accordingly.**Proposal 3: For operation in unlicensed band with 480 kHz and 960 kHz SCS, the switching boundary and the timer counter should be modified to slot group based**Currently,$ P\_{switch}$, which means the SSSG switching time, is defined for SCS configuration $μ$ = 0,1,2. For new SCSs adopted beyond 52.6GHz, to operate in unlicensed band, SSSG switching time $ P\_{switch}$ should be defined and added in the table 10.4-1 of TS 38.213[2]. **Proposal 4: Search space set group switching time** $P\_{switch}$ **should be defined for new SCSs.**For 480 kHz and 960 kHz SCS, if PDCCH monitoring capability is based on per multi-slot, the UE will decode more DCI than per slot monitoring, the processing time will last longer, and it will have an influence in SSSG switching time estimation. So when we estimate minimum value of$ P\_{switch}$, which monitoring capability is the reference, per slot or per multi-slot? It should be determined.**Proposal 5: For 480 kHz and 960 kHz SCS, which monitoring capability is the reference to estimate the search space set group switching time** $P\_{switch}$ **should be determined.** |

### R1-2107331 (Qualcomm)

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| In Proposal 1, it is proposed to assume multi-slot PDCCH monitoring as the default capability for 480kHz and 960kHz SCSs. This implies that, while the UE is monitoring common search spaces during idle/inactive mode operation (e.g., for ANR detection) or initial access procedure, multi-slot PDCCH monitoring should be applied. Further, in Proposal 6, it is proposed to adopt Alt 2 definition of the multi-slot PDCCH monitoring. These two proposals may lead to the following potential issues:**Issue 1:** The current design of search space set #0 (i.e., Type0 PDCCH CSS) for SSB-CORESET multiplexing pattern 1 requires the UE to monitor PDCCH over two *consecutive* slots. This requirement is not compliant with the default multi-slot PDCCH monitoring capability and a new design is needed.**Issue 2:** When the UE monitors CSSs (e.g., Type0/0A/1/2 PDCCH CSSs) during the connected mode operation, Alt 2 definition requires that the MOs for CSS and USS should either be aligned in the same Y-symbol span, or be separated by at least X symbols. As identified in earlier meetings, this would be too restrictive in some cases. For example, the network may prefer to stagger different UEs’ USS MOs over X slots as shown in Figure 1 to distribute the control channel overhead. However, since the CSS MO is common for all UEs, it may not be possible to align the CSS MO with all UEs’ span. In the example in Figure 1, where the USS MOs are configured per (X, Y) = (56, 3), UE1’s CSS and USS MOs coincide in the same span and it can monitor both the CSS and USS. However, UE2, UE3, and UE4 cannot monitor both CSS and USS MOs since the minimum separation of X = 56 symbols is not satisfied between CSS and USS MOs.Figure 1: Configuration example of USS and CSS MOs.To address the issues, some enhancement and modification for the CSS design is necessary. The enhancement should be applied to Type0/0A PDCCH CSSs, as well as Type1/2 PDCCH CSSs with or without dedicated configuration. Different candidate approaches would be considered to address the issues.**Alt 1: New search space set #0 (Type0 CSS) design**As discussed in Issue 1 above, for SSB-CORESET multiplexing pattern 1, the existing Type0 CSS requires the UE to monitor two consecutive slots, slot $n\_{0}$ and slot $n\_{0}+1$, which is not compliant with multi-slot PDCCH monitoring. Thus, to address the issue, a new design of Type0 CSS may require the UE to monitor two non-consecutive slots, i.e., slot $n\_{0}$ and slot $n\_{0}+X\_{0}$, where $X\_{0}$ satisfies the default UE capability, e.g., $X\_{0}=4$ for 480 kHz and $X\_{0}=8$ for 960 kHz, as discussed in Proposal 4. Similar design enhancement can further be discussed for other SSB-CORESET multiplexing pattens.To address Issue 2, the PDCCH transmission in a CSS MO would be repeated over multiple consecutive slots. For example, in addition to the enhancement discussed above, the same or equivalent PDCCH (and the associated PDSCH) may be repeated over slots $n\_{0}$, $n\_{0}+1$, …, and $n\_{0}+X\_{0}-1$. It should be noted that the repetition assumes the same QCL-TypeD property, and different from the existing beam sweeping transmission of CSS. Thus, the network can configure different UE’s USS so that at least one occasion of the CSS repetition overlaps with the USS MO, and the UE only monitors CSS MO that overlap with its USS MO. Furthermore, once the baseline design of the CSS repetition is introduced, it may be enhanced to support extended coverage for FR2-2 in later NR releases.**Alt 2: New CSS prioritization rule**In Rel-15, when the MOs of different CORESETs overlap in time, a prioritization rule is applied. For example, when a CSS MO overlaps with a USS MO with a different QCL-TypeD property, monitoring of the CSS MO is prioritized. To address Issue 2, the CSS prioritization can be extended so that the UE prioritize CSS over USS, not only when they overlap, but also when they are non-overlapping but closely located. For instance, the prioritization rule may be augmented with a notion of CSS zone. As illustrated in Figure 2, windows of X1 and X2 slots (or symbols) may be placed before and after the CSS MO, respectively, to define a CSS zone, where the values of X1 and X2 may be up to UE capability. If a USS MO falls within the CSS zone, the UE may be expected to prioritize CSS MO and drop the USS MO. From UE’s perspective, among the multiple CSS MOs with different QCL-TypeD properties (i.e., up to $L\_{max}=64$ different beams), only one or a few of them are actually monitored and associated with CSS zones. The UE and network may agree on the CSS MOs that are actually monitored based on another rule or signaling, which may include:* A MAC CE activation command indicating a TCI state for the CORESET associated with the CSS (i.e., CORESET #0),
* An SSB identified by a recent random access procedure by the UE, which is not initiated by a PDCCH order,
* Active TCI states of the active BWP, which includes CSI-RSs quasi-co-located with SSBs, or
* Dedicated configuration of Type1/2 PDCCH CSS.

During the connected mode operation, monitoring of CSS is relatively infrequent and thus the actual blockage event of PDCCH transmission in USS would be rare. Also, even though the USS is cancelled by the aforementioned CSS prioritization, the UE can still receive a scheduling grant with C-RNTI within the CSS MO via DCI format 0\_0/1\_0. Therefore, the impact of the extended CSS prioritization rule can be kept marginal.Since there could be many different alternatives than the two discussed above, it would be desirable to extend the discussion in RAN1 and specify any enhancement of the common search space design.Proposal 7: If 480 kHz or 960 kHz SCS is used for ANR detection or initial access in the SPCell, common search space set design should be enhanced to address multi-slot-based CSS monitoring and multiplexing with USS; Enhancement of search space set #0 (i.e., Type0 PDCCH CSS) for SSB-CORESET multiplexing pattern 1 is prioritized.Figure 2: CSS prioritization with CSS zone. |

### R1-2107436 (LG)

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| SS set configuration can also be set appropriately for the slot-group. Through SS set configuration based on slot-group, PDCCH monitoring occasion could be adjusted properly (e.g., restricted), and then, additional power saving effects would be expected. For slot-group based PDCCH monitoring, specifically, *periodicity* could be configured to a value larger than X (or a multiple of X) slots and *duration* could be configured with respect to X (or Y) slots. Moreover, it can be discussed how to handle the case where the configured slot-group boundary does not exactly match to the union of PDCCH MOs based on SS set configurations. In this case, USS dropping could be enhanced with the unaligned region to reduce the number of blind detection effectively. **Proposal #4: Consider to configure PDCCH monitoring occasions to be compliant with the slot-group (or multiple of slot-groups), by using search space set configuration parameters (e.g., periodicity, offset, and duration).** Regarding SSSG switching, in Rel-15/16 NR, one SSSG could be switched to another SSSG at the slot boundary after at least P\_switch symbols from the switching triggering. However, if SSSG switching is introduced for multi-slot monitoring in Rel-17, SSSG switching should be performed at the slot-group boundary in order to be compliant with the slot-group. In addition, it may be necessary to discuss the appropriate P\_switch values for 480 kHz and 960 kHz.**Proposal #5: For 480 kHz or 960 kHz multi-slot monitoring, SSSG switching should be performed at the slot-group boundary, if supported.** For SSB/CORESET#0 multiplexing with pattern 1, PDCCH monitoring of Type0-PDCCH CSS set for each SSB index is achieved in two consecutive slots, slot $n\_{0}$ and slot $n\_{0}+1$. To avoid PDCCH monitoring over two shortened consecutive slots, PDCCH monitoring over two consecutive slot-groups can be considered for 480kHz and 960kHz. For a given slot index $n\_{0}$ for Type0-PDCCH CSS set monitoring, the next MO can be located in slot index $n\_{0}+M$ where M corresponds to the size of slot-group. The slot-group for this case can be determined differently than the slot-group for other types of SS set (e.g., USS). In addition, the size of slot-group can be configured by MIB/SIB1 or be predefined for each SCS, e.g., *M*=4 for 480 kHz, *M*=8 for 960 kHz.**Proposal #6: Multi-slot monitoring of Type0-PDCCH CSS for SSB/CORESET#0 multiplexing pattern 1 should be considered for 480 kHz or 960 kHz SCS.** |

### R1-2107578 (Intel)

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| According to the revised WID [1], initial access is supported for SCS 480kHz with support of Type0-PDCCH CSS set. Further, for ANR and PCI confusion detection, Type0-PDCCH SCS set is supported for SCS 480kHz and 960kHz. Therefore, for SS/PBCH block and CORESET multiplexing pattern 1 in NR, UE needs to monitor Type 0/0A/1/2 CSS sets with search space set 0 in two consecutive slots. The time position of the two slots depends on the position of the associated with a SS/PBCH block. On the other hand, other CSS/USS sets are configured by high layer parameters *monitoringSlotPeriodicityAndOffset* and *duration*. The combined pattern of slots configured with Type 0/0A/1/2 CSS sets and other CSS/USS sets may satisfy the pattern of the multi-slot PDCCH monitoring capability for a SS/PBCH block of the UE. However, when the SS/PBCH block of the UE changes, the combined pattern of slots may become invalid for the multi-slot PDCCH monitoring capability. Instead of reconfiguration of all CSS/USS sets when the SS/PBCH block changes, dropping the PDCCH MOs in a slot can be considered to make the combined pattern valid. However, dropping Type 0/0A/1/2 CSS sets has negative impact on the scheduling of broadcast information. On the other hand, dropping other CSS/USS sets is not desirable for PDSCH/PUSCH scheduling. Since Type 0/0A/1/2 CSS sets only occurs in long cycle, i.e., 20ms, it can be considered to temporarily allow the violation of slot pattern of the multi-slot PDCCH monitoring capability near to a slot carrying Type 0/0A/1/2 CSS sets. **Proposal 2:** * If Type0/0A/1/2 CSS sets are monitored in a slot, configured PDCCH monitoring occasions around the slot can temporarily violate the multi-slot PDCCH monitoring capability, with the limitation of maximum number of BDs/CCEs.

The search space set group (SSSG) switching as defined NR-U is shown in Figure 1. The frequent PDCCH monitoring is assumed before gNB gets the channel occupation. For example, search space set with mini-slot level or slot-level PDCCH monitoring can be configured, which is the first search space set group (SSSG). The frequent PDCCH monitoring reduces the delay for gNB to start DL transmission immediately after the LBT is successful. On the other hand, after gNB starts a COT, a second SSSG is configured, which may contain infrequent PDCCH monitoring for power saving. The DL performance for the second SSSG is guaranteed by the configuration of more PDCCH candidates with same or different DCI format in each MO of the second SSSG. **Figure 1: SSSG switching in NR-U**Dynamic SSSG switching provides a means to balance the fast channel access right after LBT is successful and effective scheduling and power saving after the COT is obtained. The feature is useful for high frequency too. The configured search space configuration in the two SSSGs has different requirements on the PDCCH monitoring capability. In general, two options can be considered. * Option 1: switching between per-slot PDCCH monitoring capability and multi-slot PDCCH monitoring capabilities
* Option 2: switching between two multi-slot PDCCH monitoring capabilities

As discussed in Proposal 1, per-slot PDCCH monitoring capability is not preferred due to the limitation of PDCCH monitoring or UE complexity for high SCSs. Therefore, the search space set configuration of the two SSSGs can be configured based on Option 2. It is expected that both X and Y are small values to still allow frequent MOs in the first SSSG. On the other hand, the second SSSG relies on a large gap between MOs for the power saving. Based on the above analysis, UE needs to dynamically change its PDCCH monitoring capability together with SSSG switching. **Proposal 5:*** Dynamic SSSG switching is supported for all SCSs 120, 240 and 960kHz.
* The search space set configurations of the two SSSG can correspond to two different combinations (X, Y) of the multi-slot PDCCH monitoring capabilities

Case 1-1 is the basic PDCCH monitoring occasion(s) in the beginning of a slot, which should be supported for high SCS. Case 2 is to configure more frequent PDCCH MOs within a slot, which is targeted to reduce scheduling latency. This is important especially for low SCS, e.g. 15kHz or 30kHz. On the other hand, it is not necessary for a high SCS, e.g. 480kHz or 960kHz, given that the slot length is quite short, i.e. 1/32ms or 1/64ms. In this case, there is no clear motivation to allow full flexibility on the positions of PDCCH MO(s) in a slot, i.e. Case 2. Therefore, restriction on PDCCH MOs in a slot can simplify UE implementation without performance degradation. **Proposal 6:** * On the PDCCH monitoring occasion in a slot
	+ Case 1-1 is supported for all SCS 120kHz, 480kHz and 960kHz
	+ Case 2 is supported for SCS 120kHz
	+ Case 2 is not supported for SCS 480/960kHz

With the existing SS set configuration, up to 40 SS sets need to be configured to achieve the MO pattern in Figure 1. On the other hand, considering different DCI formats (fallback DCI or normal DCI) and different type of SS set (USS, CSS type0/0A/1/2, CSS type3 with different DCI formats), the required number of SS sets must be much higher than 40. The main drawback of the current SS set configuration comes from the parameter ‘*duration*’which is defined as a number of consecutive slots.To support the MO pattern for SCS 960kHz in Figure 1, a simple extension is to allocate a MO in every N slot, instead of consecutive slot allocation. The parameter ‘*duration*’ is still needed but can be reinterpreted as the window that MOs may be allocated, e.g. the DL period in a TDD period. Denote the number of slots that are configured with MOs of the USS set as M, then $duration=N∙M$.**Proposal 7:** * Within a period of a SS set configuration
	+ The parameter ‘duration’ is reinterpreted as a window on which MOs may be configured.
	+ One slot in every N slots within the window is configured with PDCCH MOs
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### R1-2107727 (Apple)

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| Search Space Set Group Switching was introduced in Rel-16 NR-U for power saving. It operates on CSS Type 3 and UE-SS and allows the UE to switch between two groups of search space sets to either increase or decrease the UE search space set monitoring to save power as needed e.g. within and outside a COT in unlicensed access. With the introduction of the new SCSs, there may be a need to modify timeline parameters such as the searchSpaceSwitchDelay and searchSpaceSwitchTimer. This may be set in units of slots or multi-slots based on the UE capability and the SCS.In Rel-16, the switching boundary and the timer decrement value are on the order of slots. In the case of MSM PDCCH monitoring, as the PDCCH may be on the order of multiple slots, both the switching boundary and the timer decrements can be modified to be on the order of multi-slots as needed. The effect of MSM on the transition boundary and the time unit of multiple slots (4 slot) is illustrated in Figure 1.*A picture containing chart  Description automatically generated*Figure 1: Example of SSSG switching with multi-slot monitoring limitations***Proposal 12:*** *Consider the effect of the change in SCS and of MSS PDCCH monitoring on SSSG switching.* |

### R1-2107790 (Sharp)

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| In AI 8.2.1, it was agreed to support Type0-PDCCH CSS of 480 kHz and 960 kHz SCS for ANR. Further proposed for initial access in addition to 120 kHz SCS in the frequency band above 52.6 GHz. For Type0-PDCCH CSS with SSB-CORESET multiplexing pattern 1, a UE needs to monitor two consecutive slots (n0 and n0+1 slots) in the current specification. Since the proposed multi-slot monitoring cannot support monitoring of two consecutive slots, the Type0-PDCCH CSS should be redesigned. For example, the slot indices for monitoring the Type0-PDCCH CSS could be n0 and n0+X instead of n0 and n0+1. However, SSBs transmitted between n0 and n0+X slots will not be available since SSBs of 480 kHz and 960 kHz SCS are discussed to be transmitted on a slot-by-slot basis.**Observation 1: If 480 kHz and 960 kHz SCS would be used for initial access, Type0-PDCCH CSS should be redesigned.****Observation 2: When monitoring Type0-PDCCH CSS in two slots across a slot group, the number of available SSBs may be reduced.** |

### R1-2107846 (NTT DOCOMO)

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| In Rel-16 NR-U, SSSG switching was introduced to change the PDCCH monitoring periodicity between inside and outside the COT for the sake of energy saving. For the same reason as NR-U, SSSG switching is beneficial for operation with shared spectrum of 60 GHz band. Accordingly, SSSG switching should be supported for 52.6-71 GHz frequency band operation considering the operation with shared spectrum in 60 GHz band.In the current specification, the SSSG switching time $P\_{switch}$ is specified for 15/30/60 kHz SCS. To support the SSSG switching, at least $P\_{switch}$ should be discussed for 120/480/960 kHz SCS.In addition, some companies proposed at the previous meeting that single-slot PDCCH monitoring capability and multi-slot PDCCH monitoring capability can be switched associated with SSSG configuration. This function can be supported, however, the SSSG switching for high SCS and single-slot and multi-slot capability switching associated with SSSG configuration should be discussed separately.***Proposal 7:****SSSG switching should be supported for 120/480/960 kHz SCS.**At least search space set group switching time*  $P\_{switch}$ *should be defined.* |

### R1-2107913 (Xiaomi)

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| Search space set group switching is introduced in R16 NR-U for power saving propose and group switching time $P\_{switch}$ is defined for SCS 15-60 kHz. To facilitate unlicensed band operation for NR 52.6-71GHz, group switching time $P\_{switch}$ should also be defined for 120/480/960kHz ***Proposal 3: Search space set group switching time*** $P\_{switch}$ ***should be defined for 120/480/960kHz.***The maximum search space periodicity in current spec is 2560 slots, and with SCS increased to 960kHz, the absolute time of the maximum search space periodicity will be decreased by 8 times. So new periodicity parameters may need to be introduced for the new SCSs, as well as the search space offset/duration parameters.***Proposal 4:*** ***New search space periodicity parameters, as well as the search space offset/duration parameters, may need to be introduced for the new SCSs.*** |

## Topic A3: BD Budget/Dropping

### R1-2106580 (vivo)

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| For Alt. 1/Alt. 3 in Section 2.1.2, the BD/CCE budget is defined per fixed or sliding slot group, i.e. PDCCH candidates and non-overlapped CCEs among the Y slots within the slot group should be less than $M\_{PDCCH}^{max,multi-slot,μ} $ $and C\_{PDCCH}^{max,multi-slot,μ}$.For Alt. 2 in Section 2.1.2, the BD/CCE budget is defined per Y-slot/symbol span, i.e. PDCCH candidates and non-overlapped CCEs among the Y slots within the slot group should be less than $M\_{PDCCH}^{max,multi-slot,μ} $ $and C\_{PDCCH}^{max,multi-slot,μ}$.The following alternatives are the candidate method to determine the value of $M\_{PDCCH}^{max,multi-slot,μ} $ $and C\_{PDCCH}^{max,multi-slot,μ}$:* Alt. 1: $M\_{PDCCH}^{max,multi-slot,μ}$=X\*$M\_{PDCCH}^{max,slot,μ}$, $C\_{PDCCH}^{max,multi-slot,μ}=$ X\*$C\_{PDCCH}^{max,slot,μ}$, where per slot limit $M\_{PDCCH}^{max,slot,μ}$ and $C\_{PDCCH}^{max,slot,μ}$ should be defined first;
* Alt. 2: Use the value in 120K as the reference, $M\_{PDCCH}^{max,multi-slot (X, Y),μ}$=$\left⌈\frac{X}{2^{μ-3}}\right⌉∙M\_{PDCCH}^{max,slot,3}$ and $C\_{PDCCH}^{max,multi-slot (X, Y),μ}$=$\left⌈\frac{X}{2^{μ-3}}\right⌉∙C\_{PDCCH}^{max,slot,3}$
* Alt. 3: Determine each value for supported (X, Y) using the following table:

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|  | Maximum number $C\_{PDCCH}^{max,multi-slot \left(X,Y\right),μ}$ of non-overlapped CCEs per slot group for combination $\left(X,Y\right)$ and per serving cell  |
| $$μ$$ | (4, 1) | (4, 2) | (8, 1) | (8, 2) | (8, 4) |
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Among the above alternatives, Alt. 3 is a similar way with that for span-based capability, which clearly provides the BD/CCE budget value as well as supported (X, Y) value.**Proposal 8: For NR Rel-17 UEs, supported (X, Y) value should be determined first and then decide corresponding BD/CCE budget value for each (X, Y) case by case.**In NR operation from 52.6-71GHz, BD/CCE budget will be defined for multiple slot as proposed by **Proposal 3**. In this case, PDCCH candidates should be allocated for multiple slot Hs in overbooking case. In existing NR operation, PDCCH candidates are allocated per slot in granularity of SS. However, in multi-slot-based PDCCH monitoring capability case, PDCCH candidates could be allocated to multiple slots in granularity of SS and slot. How to allocate the PDCCH candidates in two dimensions should be considered.**Proposal 10: In multi-slot-based PDCCH monitoring capability case, PDCCH candidates could be allocated to multiple slots in granularity of SS and slot.** |

### R1-2107098 (Futurewei)

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| In Rel 15 the monitoring capability is defined per slot, in Rel 16 the monitoring capability per span is added. The monitoring capability is defined by *monitoringCapabilityConfig* for a serving cell.For multi-slot PDCCH monitoring it is expected that UE maps the PDCCH candidates using the above rules, where the span may be larger than one slot.**Proposal 2: Reuse the Rel-15/16 overbooking rules when PDCCH candidates/CCEs exceeds either of the UE processing limits per span.** |

### R1-2107331 (Qualcomm)

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| If a UE is configured with multiple downlink cells of 480 kHz or 960 kHz SCSs, and each of the multiple cells is configured with multi-slot PDCCH monitoring, the distribution of the number of monitored PDCCH candidates and non-overlapped CCEs across the carriers should be considered. A clear benefit of adopting Alt 2 definition of the multi-slot PDCCH monitoring in Proposal 6 is that the existing rules associated with Rel-16 per-span PDCCH monitoring capability (*pdcch-MonitoringCA-r16*) can directly be applied (Section 10.1 in TS 38.213). That is, the distribution rules depend on the SCSs of active BWPs of the active cells, and on whether the spans of Y symbols are aligned or not aligned across cells.**Observation 3: For multi-slot PDCCH monitoring capability Alt 2, the existing rules for Rel-16 per-span PDCCH monitoring can directly be applied to determine multi-carrier PDCCH monitoring capability.**Similarly, for PDCCH overbooking, the existing rules associated with Rel-16 per-span PDCCH monitoring capability can directly be applied. That is, the overbooking is allowed only on a primary cell, and dropping of PDCCH candidates and non-overlapped CCEs is performed on a span-basis.**Observation 4: For multi-slot PDCCH monitoring capability Alt 2, the existing rules for Rel-16 per-span PDCCH monitoring can directly be applied for PDCCH overbooking and dropping.** |

### R1-2107432 (Panasonic)

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| The existing dropping rules for overbooking are applicable for individual slot or individual span within one slot. In the context of multi-slot monitoring capability, there is a need to extend the dropping rules for overbooking to across-slots or across-spans. In particular, for a X-slot group, gNB is allowed to configure USS in a way that the sum of all configured CSSs and USSs exceed UE multi-slot capability in terms of BD/CCE limits, and/or maximum number of spans, and/or minimum time separation between two spans. This is referred to overbooking for multi-slot capability. When UE and gNB map the PDCCH candidates to monitoring occasions, CSS are mapping first before USS (no overbooking for CSS, as the legacy). USSs are then mapped considering the BD/CCE requirements, the maximum allowed number of spans, and the minimum time separation between the two spans jointly. For example, when USSs are mapped in ascending order of the USS indices, if a USS MO cannot satisfy the minimum time separation from already mapped spans of MOs, the USS will be dropped. The details of enhancement can be further discussed when the multi-slot capability definition as discussed in previous two sections is finalized.**Proposal 3: Dropping rules for overbooking need to be extended to across-slots or across-spans for multi-slot monitoring capability. Details are FFS after multi-slot monitoring capability definition is clear.**  |

### R1-2107436 (LG)

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| Regarding the PDCCH monitoring per slot-group, associated procedures such as overbooking and dropping may also be enhanced. For example, if consecutive M slots for 960 kHz SCS is set to a slot-group for PDCCH monitoring, then SS set dropping due to overbooking would be performed in unit of slot-group. With this, additional restriction on PDCCH monitoring may be considered, e.g., by applying overbooking/dropping rules for some part of slots within a slot-group.**Proposal #3: How to perform SS set dropping due to overbooking should be further discussed for multi-slot monitoring.** |

### R1-2107578 (Intel)

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| In NR Rel-15, according to the UE capability on the maximum number of BDs/CCEs in a slot, * For PCell or PSCell, it is allowed that the configured number of BDs/CCEs in a slot by the configuration of SS set(s) is larger than the corresponding maximum numbers. Certain dropping rule is defined so that the actual number in the slot doesn’t exceed the corresponding maximum numbers.
* For a SCell, the gNB should guarantee that the configured numbers of BDs/CCEs in a slot by the configuration of SS set(s) do not exceed the corresponding maximum numbers.

The similar rules could be extended to multi-slot PDCCH monitoring capability, * For PCell or PSCell, it is allowed that the configured number of BDs/CCEs in a X-slot group by the configuration of SS set(s) is larger than the corresponding maximum numbers. Certain dropping rule is defined so that the actual number in the X-slot group doesn’t exceed the corresponding maximum numbers.
* For a SCell, the gNB should guarantee that the configured numbers of BDs/CCEs in a X-slot group by the configuration of SS set(s) do not exceed the corresponding maximum numbers.

**Proposal 3:** * When multi-slot PDCCH monitoring capability is supported,
	+ PDCCH overbooking is supported for PCell or PSCell
	+ For a SCell, the configured BDs/CCEs do not exceed the corresponding maximum numbers.

As in Rel-15, it is desired there is no dropping for CSS sets even for PCell/PSCell. Therefore, it is up to gNB to guarantee that CSS sets are properly configured. One thing to note is that multiple slots in a X-slot group may contain MOs for a CSS set subject to gNB configuration. In this case, the total numbers of BDs/CCEs in the multiple slots for the USS set are multiple times of that configured in single slot. Consequently, the numbers of available BDs/CCEs for USS sets are reduced. The UE capability on maximum numbers of BDs/CCEs needs to consider the increase of BDs/CCEs in the X-slot group for a CSS set. Regarding handling USS sets if total number of BDs/CCEs exceed the corresponding maximum numbers, a same principle as in Rel-15 can be reused, i.e. a USS set with high SS set index is dropped. Further, since the PDCCH MOs of the USS set may be configured in multiple slots in the X-slot group, a discussion point is whether the USS set in all the multiple slots is dropped as a whole or dropped slot by slot. The latter option is preferred since it allows more capacity for PDCCH monitoring without exceeding UE capability. **Proposal 4:** * To handling USS dropping in PDCCH overbooking
	+ A USS set with largest SS set index is dropped
	+ If the PDCCH MOs of a USS set are configured in multiple slots in the X slots, the USS set in the multiple slots is dropped slot by slot.
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### R1-2107790 (Sharp)

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| For 120 kHz SCS, the BD/CCE budget is set to (M, C) = (20, 32). Since the value of X is determined to maintain the same monitoring Capability as 120 kHz SCS, the BD/CCE budget should be (M, C) = (20, 32) for 480 kHz and 960 kHz SCS. The first three symbols are set as the minimum requirement for CSS monitoring at 480 kHz and 960 kHz SCS, because the maximum duration of CORESET follows 3. Even though the symbol length is shorter than 120 kHz, ensuring the same budget may affect the processing time of PDSCH/PUSCH (N1/N2). **Proposal 4: For 480 kHz and 960 kHz SCS, the BD/CCE budget is set to (M, C) = (20, 32).** **Observation 3: Ensuring the budget may affect the processing time of PDSCH/PUSCH (N1/N2).** |

### R1-2107846 (NTT DOCOMO)

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| In Rel-15/16, the SS set is allowed to be overbooked and the SS set dropping rules not to exceed the BD/CCE budget for slot/span are specified. To provide the details of the SS set overbooking in the current specification, it is allowed that PDCCH candidates or non-overlapped CCEs exceeds BD/CCE limit only for USS in PCell and PSCell, i.e., UE expects no overbooking for CSS and CSS/USS in SCell. These PDCCH overbooking rules can be reused for multi-slot PDCCH monitoring capability.For USS, SS dropping rule is specified that a UE drops remaining search space set(s) with higher index if SS set(s) are overbooked. If the SS dropping rule is extended for multi-slot PDCCH monitoring capability, at least the rule for the case when a SS set is configured across multiple slots in a slot group needs to be discussed. If SS set(s) is checked and dropped slot by slot, haw many SS set(s) in which slot in a multi-slot is dropped should be discussed. Therefore, to avoid the complexity of the dropping rule or standardization effort, the USS set in multiple slots should be checked and dropped as a whole.***Proposal 5:*** *The SS set overbooking can be allowed with multi-slot PDCCH monitoring capability same as the current specification, i.e., SS set overbooking is allowed for USS in PCell and PSCell and UE expects no overbooking for CSS and CSS/USS in SCell.****Proposal 6:*** *The dropping rule for multi-slot PDCCH monitoring capability can be the same as the current specification, i.e., a UE drops UE specific search space set(s) with higher index when SS sets are overbooked and expects there is no overbooking for CSS sets. In addition, if USS set is configured across multiple slots in a slot group, USS set should be checked and dropped as a whole.* |

## Topic A4: PDCCH Extensions for e.g. Coverage, Reliability

### R1-2106796 (Sony)

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| For multi-slot monitoring, there also had been some discussions from RAN1#104 on monitoring location and duration of OFDM symbols:

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| Further discussion on multi-slot span capabilities, monitoring periodicities, corresponding number and location of OFDM symbols for Cases 1-1 and 1-2.* Case 1: PDCCH monitoring of all SS sets monitored in a slot occurs within 3 consecutive OFDM symbols that have fixed positions in each slot
	+ Case 1-1: PDCCH monitoring limited to within first three OFDM symbols of a slot
	+ Case 1-2: PDCCH monitoring on any span of up to 3 consecutive OFDM symbols of a slot
		- For a given UE, all search space configurations are within the same span of 3 consecutive OFDM symbols in the slot
* Case 2: PDCCH monitoring cases other than Case 1
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With a limited location of PDCCH monitoring, Case 1-1 is simple for realization, while Case 1-2 is more flexible for gNB scheduling. Thus, we suggest Case 1-1 can be the baseline, and Case 1-2 can be discussed with further benefits evaluation of flexible scheduling.1. **: PDCCH monitoring limited to within the first several OFDM symbols of a slot can be supported as the baseline.**

As aforementioned, large SCSs with 480kHz and 960kHz cause a relatively short time duration of a symbol. Therefore, if CORESET duration remains up to 3 symbols as in R16, the real-time duration for PDCCH monitoring is quite small, which also puts extra time limitation of UE blind decoding. Therefore, we suggest a large CORESET duration with more than 3 symbols for SCS 480kHz and 960kHz alleviate UE processing capability for PDCCH decoding. Thus, we suggest PDCCH monitoring with a maximum duration of more than 3 OFDM symbols per PDCCH monitoring occasion. 1. **: If CORESET duration remains up to 3 symbols as in R16, the real-time duration for PDCCH monitoring is quite small due to the short symbol duration with large SCS.**

**Proposal 2: PDCCH monitoring with a maximum duration of more than 3 OFDM symbols per PDCCH monitoring occasion is more suitable.** |

### R1-2106832 (Lenovo, Motorola Mobility)

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| Furthermore, with high SCS values, the absolute duration of the slot is greatly reduced and moreover, when single DCI can schedule multi-PDSCH/PUSCH over multiple slots, it might be beneficial to consider longer duration than 3 symbols for CORESETs. Multiple benefits can be associated with longer duration:* Better support for higher aggregation levels for better reliability
* More resources available for CORESET, but with same or even reduced duration in absolute time
* More symbols available to allow TDM multiplexing between DM-RS and control information
	+ Benefit of a DM-RS symbol with continuous frequency resources will account for better channel estimation with higher SCS values.

In fact, for very high SCS value such as 960kHz, even an entire slot for PDCCH can be considered to allow for only single PDCCH monitoring occasion within a slot.***Proposal 6:*** ***For supporting NR between 52.6 GHz and 71 GHz with high subcarrier spacing values including 480kHz and 960kHz, CORESET duration longer than 3 symbols should be supported:**** ***FFS: Maximum duration up to 14 symbols in a slot***

***Proposal 7: For supporting NR between 52.6 GHz and 71 GHz with high subcarrier spacing values including 480kHz and 960kHz, CORESET structure with only TDM between the DM-RS symbols and control information should be supported*** |

### R1-2107238 (OPPO)

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| With the introduction of 480 kHz and 960 kHz for data and control transmission in the high frequency range, compared to existing SCS, the symbols become much shorter and the frequency range will be much larger for a given CORESET configuration. Figure 1 compares the CORESET configuration of {12RBs, 2symbols} for 120kHz and 480kHz respectively. **Figure 1: CORESET configuration of {12RBs, 2symbols} for 120kHz and 480kHz**From Figure 1, it can be observed that to keep same CORESET configurations and same PDCCH candidates being monitored, compared to 120kHz SCS, the coverage of PDCCH transmission would be impacted due to the reduced transmission duration, and UE is required to estimate much higher frequency range with the SCS of 480kHz. While the maximum number of non-overlapped CCEs would be smaller for 480kHz SCS than 120kHz SCS. The difference would be much larger if 120kHz and 960kHz SCSs are compared. Therefore, enhancements to CORESET configuration, i.e., reducing CORESET RBs and increasing CORESET symbols for a given higher SCS, seem beneficial. **Proposal 7: CORESET configuration with less RBs and more symbols for 480kHz and 960kHz SCS should be supported.**  |

## Topic B: Multiple PDSCH/PUSCH by a single DCI

### R1-2106832 (Lenovo, Motorola Mobility)

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| In our view, if new DCI format can be agreed to be supported for high SCS values such as 480kHz and 960kHz, then PDCCH monitoring can be further reduced by restricting the need for UE to monitor other DCI formats for scheduling DL/UL such as DCI format 0\_1 and format 1\_1. If such restriction is supported, then the number of blind detections for a UE can be significantly reduced or at least not expected to increase from the current UE capabilities. ***Proposal 5: For supporting NR between 52.6 GHz and 71 GHz with high subcarrier spacing values including 480kHz and 960kHz, if a new DCI is agreed to schedule multiple PDSCH/PUSCH, then restrictions on monitoring of other DCI formats (such as DCI format 0\_1/1\_1) should be supported i.e., search space set configuration with restricted combination of DCI formats should be supported to not increase the number of blind decodes*** |

## Topic C: Multi-Beam Aspects

### R1-2106796 (Sony)

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| As haven been mentioned by multiple companies in the last meeting [5]-[7]: In Rel-16 NR-U, several fields such as CO duration, SS-group switching trigger, RB-sets, etc., were introduced to DCI format 2\_0. In the frequency range above 52.6 GHz, that information can be beam-dependent due to the utilization of beamforming. Therefore, there is a need to consider per beam indication of DCI format 2\_0. **Proposal 3: Support per beam indication of DCI format 2\_0 for above 52 GHz unlicensed operation.**  |

### R1-2106832 (Lenovo, Motorola Mobility)

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| Another important aspect for PDCCH monitoring is related to directional LBT. Directional LBT may cause some issues in comparison with omni-directional LBT. For example, different Tx beams used by gNB may correspond to different COTs, thus different CORESETs which are configured with different Tx beams by higher layer signaling may also correspond to different COTs. From power saving perspective, during a COT initiated by a gNB, a UE can stop monitoring the PDCCH occasions in the CORESET corresponding to a different COT, which can reduce the power consumption cause by blind decoding. After transmitting a PDCCH to a UE within a COT, the gNB will not transmit PDCCH to this UE in the CORESET corresponding to another COT until the current COT ends.***Proposal 8: For NR unlicensed bands between 52.6 GHz and 71 GHz with directional LBT based channel access mechanism, within a COT, PDCCH monitoring is not supported in the CORESETs corresponding to other COTs (PDCCH monitoring restricted to monitoring corresponding to only one COT at a time)***Furthermore, additional issue that can happen with multi-slot PDCCH monitoring is the QCL assumption (beam) associated with the CORESETs configured for a UE. For FR beyond 52.6, it is expected that narrow beams might be deployed and depending upon UE mobility, the beams can change quite fast. Therefore, if only a single beam is associated with a CORESET and if the multi-slot duration is longer such as 8 slots, then the single configured beam may not be valid for the entire duration of monitoring. Therefore, it should be considered to associate multiple QCL assumptions with a CORESET and also the duration for which each of the associated QCL assumption is valid. For example, if 8-slot PDCCH monitoring is configured to a UE, then the CORESET can be configured with 4 QCL assumptions (beams), where first beam is used to monitor CORESET in first 2 slots, second beam is used to monitor CORESET in second 2 slots and so on. Further details related to beam management for PDCCH CORESET are also discussed in our accompanying contribution [3].***Proposal 9: For supporting NR between 52.6 GHz and 71 GHz with high subcarrier spacing values including 480kHz and 960kHz, it should be supported to configure UE with multiple QCL assumptions (beams) associated with a CORESET and corresponding duration for the validity of each of the beams to monitor a CORESET within a multi-slot PDCCH monitoring*** |

### R1-2106874 (Samsung)

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| For 60 GHz unlicensed band, transmissions are expected to be highly directional. To address the channel access efficiency, a transmitter can choose an intended beam direction to perform the channel access procedure, and the sensed result is exclusively applicable to that intended beam direction only. Hence, indicating COT, available RB set, and search space group switching should be associated with the beam direction, wherein such feature was introduced in Rel-16 NR-U by using DCI format 2\_0 and in a cell-specific manner. Generalizing the feature to a beam-specific manner is beneficial to address different interference situations along beam directions, and is compatible with the intention to introduce directional LBT. **Proposal 9: Support indicating COT, available RB set, and search space group switching in a beam-specific manner for 60 GHz licensed band.** |

### R1-2106957 (CATT)

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| In Rel-16, the DCI format 2\_0 is used for indicating the slot format, COT duration, available RB set and search space group switching to a group of UEs. The UEs within the group should monitor the Type-3 PDCCH CSS on the indicated beam direction according to the TCI state of the associated CORESET. There are proposals to enhance DCI format 2\_0 to indicate COT duration, available RB set and search space group switching in a beam specific manner. In our opinion, the beam management related enhancement of DCI format 2\_0 can be further studied in the Rel-18 to ensure a unified solution with all other related issues.**Proposal 7：The enhancement of DCI format 2\_0 can be further studied in the Rel-18 to ensure a unified solution with all beam management issues.** |

### R1-2107098 (Futurewei)

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| In 60 GHz bands due to higher pathloss corresponding to high frequency it is expected that the transmitters use directional beams. Therefore, the PDCCH transmission and monitoring may be associated with beam directions (spatial filters). In TS 38.213 Clause 10.1, the *ControlResourceSet* variables are defined. The antenna port quasi co-location is provided by *TCI-State* indicating the quasi co-location of the DM-RS antenna port for PDCCH reception in the respective CORESET.If the UE is not provided with a configuration of TCI state(s)the UE assumes that the DM-RS antenna port associated with PDCCH receptions is quasi co-located with SS/PBCH the UE identified during the initial access procedure.We note that a UE may be provided with more than once TCI state for a CORESET. For the TCI state to be used it needs to be activated by a MAC CE activation command otherwise the UE assumes that the DM-RS antenna port associated with PDCCH receptions is quasi co-located with the SS/PBCH block or the CSI-RS resource the UE identified during the random-access procedure initiated by the Reconfiguration with sync procedure.We do not see any motivation to change the beam configuration and activation for multi-slot PDCCH monitoring behavior.**Proposal 5: Use the existing mechanism for beam configuration and activation for multi-slot PDCCH monitoring.** |

### R1-2107105 (Nokia, Nokia Shanghai Bell)

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| One more issue related to DL control seems to be operation of DCI format 2\_0 in a beam based system. In Rel. 15, DCI format 2\_0 contained only SFI, and from SFI point of view, UL and DL direction is clearly beam agnostic due to strong self-coupling between different panels. On the other hand, in R16 DCI format 2\_0 contains also other information, such as COT or SS-group switching trigger, RB-sets. Any of these pieces of information could become beam dependent. However, support for beam-dependent configurations of DCI format 2\_0 is not possible in FR2 currently. Although a UE can be indicated a change of active-TCI, DCI format 2\_0 PDCCH candidates and, payload location remains the same and thus cannot be beam specific.   ***Observation 2:*** *GC-PDCCH is an essential part of unlicensed band system, and there seems to be a need to support beam-dependent information, particularly if some form of directional LBT is chosen as coexistence mechanism.* ***Proposal 8:****Changes to DCI format 2\_0 may be beneficial for at least unlicensed 60GHz NR operation.*  |

### R1-2107436 (LG)

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| In Rel-16 NR-U, several fields such as RB set indicator, CO duration and SS set group switching trigger were introduced to DCI format 2\_0, in addition to SFI. However, for FR2-2 in Rel-17 where the use of directional beams may be essential, it can be worth considering the beam dependent GC-PDCCH configuration. In other words, it may be beneficial to give a spatial relation for a beam to which information of DCI format 2\_0 is applied. One simple conceivable method is to define some fields in DCI format 2\_0 separately for each beam. For example, RB set indicator and CO duration could be configured separately for each beam, but SFI could be configured as beam agnostic. Alternatively, a new field can be additionally introduced in DCI format 2\_0 to indicate the availability of each beam. In this method, UE receiving DCI format 2\_0 may determine the channel availability for each beam through a combination of the new field and existing fields (i.e., RB set indicator and CO duration). **Proposal #7: Consider per beam indication of available RB set, CO duration, and/or SS set switching by using DCI format 2\_0.** |

### R1-2107727 (Apple)

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| In R16 NR-U, DCI format 2-0 is enhanced to carry channel access related information: RB allocation, COT duration and search space set switching indication. While RB allocation information may not be needed depending on LBT bandwidth discussion, the COT duration and SSSG switching should be supported. COT duration and SSSG switching information should be sent at the beginning of the COT as shown in Fig.1. However, current design of DCI format 2-0 transmission limit to one beam per slot. Therefore, it takes multiple slots to finish the beam sweeping transmission of DCI format 2-0. For example, with 120KHz SCS and 32 beams, it takes 4ms to finish beam sweeping. Considering maximum COT duration is 5ms defined by EN 302 567, more efficient transmission scheme of DCI format 2-0 is needed. ***Proposal 13:*** *Consider enhancement of DCI 2-0 transmission to signal COT duration and SS adaptation at the beginning of the COT.* |

## Topic D: Multi-Cell Operation, Cross-carrier scheduling

### R1-2106443 (Huawei, HiSilicon)

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| For cross-carrier scheduling, a gap in unit of PDCCH symbols between PDSCH and PDCCH are defined in Rel-16 for PDSCH resource allocation, which is associated with the SCS of PDCCH as shown in Table 6. All of them have a close relation with the PDCCH processing time and the time duration of a PDCCH symbol. For the newly introduced SCS of 480 kHz and 960 kHz SCS, it is not expected to have significant processing timeline reduction than 120 kHz SCS. The scaled values of *Npdsch*, from that for 120 kHz SCS can be applied as a start point, i.e., 56 and 112 for 480 kHz and 960 kHz, respectively. **Table 6. *Npdsch* as a function of the subcarrier spacing of the scheduling PDCCH**

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| ***µPDCCH*** | ***Npdsch* [symbols]** |
| 0 | 4 |
| 1 | 5 |
| 2 | 10 |
| 3 | 14 |

***Proposal 3:*** *Npdsch for 480 kHz and 960 kHz SCS are scaled from that of 120 kHz SCS by 4 times and 8 times assuming similar PDCCH processing capability as 120 kHz SCS.* |

### R1-2106580 (vivo)

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| In multi-cell operation scenario, BD/CCE budget calculation becomes more complex by introducing such multi-slot-based BD/CCE budget definition, i.e. more additional cases as described in 2.1.4. As one straightforward way, the BD/CCE budget calculation adopts the same way for NR Rel-16, i.e. serving cells with the same PDCCH monitoring type are grouped together for further handling. Particularly, the follows steps apply:* Determination of $N\_{cells}^{Cap}$: UE needs to report respective $N\_{cells}^{Cap}$ for different cases, i.e. Case 1-7 as described in 2.1.4. For the case with mixed capability, *L* $N\_{cells}^{Cap}$values need to be reported where *L* is the number of capability types in that case (e.g. 3 in case 7);
* Determination of total limit for each group of serving cells:
	+ If the group adopts slot-based or span-based capability, legacy way is used;
	+ If the group adopts multi-slot-based capability, further divide the cell group into different parts depending on SCS and/or value of X/Y. Then BD/CCE budget for the serving cells will follow one total limit. Note that there may have certain limits in the group or part of serving cells.

As another alternative, the serving cell with SCS µ and multi-slot-based capability can be transformed to an equivalent virtual serving cell with SCS µ’ and slot-based capability, e.g. e.g. cell A with 480KHz SCS and BD/CCE budget per 4 slots is equivalent to a virtual cell A’ with 120KHz and BD/CCE budget per slot.**Proposal 9: For multi-cell operation, the following alternatives could be considered:****Alt. 1: Serving cells with the same PDCCH monitoring type including multi-slot-based capability are grouped together for further BD/CCE budget calculation;****Alt. 2: Transfer the serving cell with multi-slot-based capability to equivalent serving cell with slot-based capability for further BD/CCE budget calculation.** |

### R1-2107001 (ZTE, Sanechips)

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| The cross-carrier scheduling here mainly refers to cross-carrier scheduling of a cell within 52.6-71GHz band from/to a cell within FR1/FR2. Although a cell within 52.6-71GHz band cross-carrier schedules other cells within FR1/FR2 is less likely, it should not be ruled out unless we find enough proof. Similarly, we do not think that we can rule out the case of a cell with low SCS (e.g. 15kHz) cross-carrier schedules other cells with high SCS (e.g. 480kHz) in this phase before sufficient research.Another problems related to cross-carrier scheduling are minimum PDSCH scheduling delay and minimum A-CSI- RS trigger delay. In Rel-15/16 NR, cross-carrier scheduling only supports four cases of PDCCH with u = 0, 1, 2 and 3, as given in Table 5.5-1 and Table 5.2.1.5.1a in TS 38.214. The 120kHz SCS in above 52.6GHz band can reuse the value of u = 3. But the values of *µPDCCH* with 480/960kHz SCS needs to be determined. The same values of *µPDCCH* for minimum PDSCH scheduling delay and minimum A-CSI- RS trigger delay can be used for 480/960kHz SCS.TS 38.214 Table 5.5-1: *Npdsch* as a function of the subcarrier spacing of the scheduling PDCCH

|  |  |
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| ***µPDCCH*** | ***Npdsch* [symbols]** |
| 0 | 4 |
| 1 | 5 |
| 2 | 10 |
| 3 | 14 |

TS 38.214 Table 5.2.1.5.1a: *Ncsirs* as a function of the subcarrier spacing of the triggering PDCCH

|  |  |
| --- | --- |
| ***µPDCCH*** | ***Ncsirs* [symbols]** |
| 0 | 4 |
| 1 | 5 |
| 2 | 10 |
| 3 | [14] |

**Proposal 4: The values of *µPDCCH* with 480/960kHz SCS for minimum PDSCH scheduling delay and minimum A-CSI- RS trigger delay should be determined.**For carrier aggregation in rel-15/16, if a UE is configured with DL cells greater than the number of BD capable cells (reported by *pdcch-BlindDetectionCA*), the total number of PDCCH candidates or non-overlapped CCEs per slot or per span should be recalculated according to the following specifications in 38.213 clause 10.1.These operation can be reused (or with simple modification) for 480 kHz and 960 kHz when multi-slot PDCCH monitoring is applied and X(or Y) for each cell or each SCS are (timely) aligned. However, if X(or Y) value is the same but its location is not aligned for each numerology or for each cell (or if X,Y values are different across serving cells), it may be uncertain whether above operation could be reused as it is. To figure out the uncertainty, it should be investigated how to handle BD/CCE capabilities of multi-slot monitoring for carrier aggregation.**Proposal #9: It is necessary to study how to handle BD/CCE capability when the number of configured DL cells is greater than** $N\_{cells}^{cap}$**.** |

### R1-2107331 (Qualcomm)

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| In RAN1 #104-e, the following draft proposal has been captured in the FL’s summary for further discussion [3]:

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| **Modified Feature Lead Proposal A1-4:*** Cross-carrier scheduling of a cell within 52.6-71 GHz from/[to] a cell outside 52.6-71 GHz is supported.
* FFS: potential limitations on the applicable SCS(s) of the scheduling and scheduled cells/BWPs.
 |

To support both SA and NSA operations efficiently for cells in 52.6-71 GHz, extending the use of cross-carrier scheduling seems necessary. However, when the SCS difference between the scheduling and scheduled cells are very large (e.g., scheduling from 15 kHz SCS to 960 kHz SCS, and vice versa), the gain of cross-carrier scheduling may be harmed, while the design (e.g., timeline design) would be complicated. Therefore, it would be fair to put some restriction on the selection of SCSs. Since Rel-15 already supports cross-carrier scheduling between 15 kHz and 120 kHz SCSs as the extreme case, the same ratio of SCSs may be assumed for 51.6-71 GHz.**Proposal 8: Cross-carrier scheduling of a cell within 52.6-71 GHz from/to a cell outside 52.6-71 GHz is supported, at least for |*μPDCCH* − *μPDSCH* | ≤ 3.** |

### R1-2107436 (LG)

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| Considering the efficient coexistence with Wi-Fi operating with nominal channel bandwidth of 2.16 GHz, NR in unlicensed FR2-2 band may need to be operated with carrier bandwidth comparable to Wi-Fi. However, since some UEs may not support carrier bandwidth up to 2.16 GHz, it should be considered multi-carrier based operation where each carrier has bandwidth narrower than 2.16 GHz (e.g. 400 MHz) but aggregated bandwidth through multiple carriers can reach to around 2.16 GHz. In such case, some measurements for the channel availability such as LBT result for each carrier can be identical over multiple carriers which overlap to the occupied channel bandwidth of Wi-Fi. To indicate these information to group of carriers efficiently, carrier-group based GC-PDCCH configuration can be considered. For instance, GC-PDCCH indicating available RB sets and CO duration can be configured per carrier-group instead of per each carrier, and the set of carriers within the carrier-group can share these information. For another instance, DL/UL data scheduling can be configured per carrier-group to reduce the amount of GC-PDCCH transmission instead of indicating to each carrier. With carrier-group based configuration, it can be beneficial with respect to the controllability of channel access or data channel scheduling in unlicensed FR2-2 band.**Proposal #8: Carrier-group based GC-PDCCH configuration for unlicensed FR2-2 band may be beneficial with respect to signalling efficiency.** |

### R1-2107578 (Intel)

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| Cross-carrier scheduling is a quite useful feature for NR. Therefore, it is expected that cross-carrier scheduling between serving cells using SCS 120/480/960kHz can be supported. On the other hand, one more discussion point is the carrier aggregation (CA) between a cell with 52.6-71GHz frequency and a cell in FR2 or even FR1. From specification completeness point of view, such CA scenario could be supported, especially considering a PCell in lower frequency than 52.6-71GHz is more appropriate for coverage/robustness. As discussed in MR-DC in Rel-16, the minimum PDSCH scheduling delay and minimum A-CSI RS triggering offset applicable to SCS 480kHz and 960kHz should be discussed. On the other hand, if such kind of CA is supported and cross-carrier scheduling is considered, an extreme case could be that, a slot with SCS 15kHz is used to schedule up to 64 slots with SCS 960kHz. Without a clear motivation, we prefer to avoid unnecessary optimization. **Proposal 8:** * Cross-carrier scheduling of cell with 52.6-71GHz frequency from/to a cell of FR1 and FR2 is allowed by specification
	+ The minimum PDSCH scheduling delay and the minimum A-CSI RS triggering offset applicable to SCS 480kHz and 960kHz needs to be discussed.
	+ Additional enhancements are deprioritized unless a clear motivation is identified.
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### R1-2107727 (Apple)

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| In RAN1 #104-e, the following discussion was started but was not concluded: * Cross-carrier scheduling of a cell within 52.6-71 GHz from/[to] a cell outside 52.6-71 GHz is supported.
* FFS: potential limitations on the applicable SCS(s) of the scheduling and scheduled cells/BWPs.

For cross carrier scheduling the following issues should be studied: 1. *RAN1 should modify the parameter Npdsch to account for the new SCSs:* The parameter *Npdsch,* i.e., the # of PDCCH symbols after the end of the PDCCH scheduling the PDSCH needs to be modified for the new SCSs.
2. *RAN1 should study the effect of a large differential between the SCSs of the carriers involved in the cross carrier scheduling procedure.* In a scenario with different numerologies between PDSCH and PUCCH, a large differential between the SCSs may result in a large gap between a transmitted PDSCH(s) and its corresponding PUCCH. In one simple example, assume that the transmission occurs such that the HARQ is on FR1 with the SCS set to 15 kHz which is equivalent to 32 480 kHz slots. A frame structure of DDDSU would require an aggregation of up to 96 slots. The maximum differential changes from 8 (120 kHz to 15 kHz) to 64 (960 kHz to 15 kHz).
3. *The maximum number of carriers that can be simultaneously scheduled from a single carrier should be defined as a UE capability.* This may be necessary given the possible increase in the bandwidth of the different transmissions, and the increase in data rate for the new SCSs.

***Proposal 9****: RAN1 should modify the parameter Npdsch, i.e. the # of PDCCH symbols after the end of the PDCCH scheduling the PDSCH, to account for the new SCSs.****Proposal 10:*** *RAN1 should study the effect of a large differential between the SCSs of the carriers involved in the cross-carrier scheduling procedure.****Proposal 11:*** *for cross-carrier scheduling, the max number of CCs that can be scheduled from a single CC is reported as UE capability.* |

## Topic E: Other

# List of submitted TDocs

The following TDocs have been used to compile above summary:

**R1-2106443 Enhancement on PDCCH monitoring Huawei, HiSilicon**

**R1-2106580 Discussions on PDCCH monitoring enhancements for NR operation from 52.6GHz to 71GHz vivo**

**R1-2106767 Discussions on PDCCH monitoring enhancements InterDigital, Inc.**

**R1-2106796 PDCCH enhancement for 52.6 to 71 GHz Sony**

**R1-2106832 PDCCH monitoring enhancements for NR from 52.6 GHz to 71GHz Lenovo, Motorola Mobility**

**R1-2106874 PDCCH monitoring enhancements for NR from 52.6 GHz to 71 GHz Samsung**

**R1-2106957 PDCCH monitoring enhancements for up to 71GHz operation CATT**

**R1-2107001 Discussion on the PDCCH monitoring enhancements for 52.6 to 71GHz ZTE, Sanechips**

**R1-2107051 PDCCH Monitoring Enhancements Ericsson**

**R1-2107098 PDCCH and HARQ support for multi-PDSCH/PUSCH scheduling FUTUREWEI**

**R1-2107105 PDCCH monitoring enhancements Nokia, Nokia Shanghai Bell**

**R1-2107113 PDCCH monitoring enhancements Charter Communications**

**R1-2107153 Discussion on PDCCH monitoring enhancements supporting NR from 52.6GHz to 71 GHz NEC**

**R1-2107238 Discussion on PDCCH monitoring enhancement OPPO**

**R1-2107331 PDCCH monitoring enhancements for NR in 52.6 to 71GHz band Qualcomm Incorporated**

**R1-2107432 PDCCH monitoring for NR operation from 52.6 to 71 GHz Panasonic**

**R1-2107436 PDCCH monitoring enhancements to support NR above 52.6 GHz LG Electronics**

**R1-2107510 PDCCH monitoring enhancement for 52.6-71 GHz NR operation MediaTek Inc.**

**R1-2107578 Discussion on PDCCH monitoring enhancements for extending NR up to 71 GHz Intel Corporation**

**R1-2107727 PDCCH Enhancements for above 52.6 GHz Apple**

**R1-2107790 PDCCH monitoring enhancements Sharp**

**R1-2107846 PDCCH monitoring enhancements for NR from 52.6 to 71 GHz NTT DOCOMO, INC.**

**R1-2107913 Discussion on PDCCH monitoring enhancement for NR 52.6-71GHz Xiaomi**

**R1-2108015 PDCCH Monitoring for NR from 52.6 GHz to 71 GHz Convida Wireless**