**3GPP TSG RAN WG1#104-e R1-2103689**

**e-Meeting, April 12th – 20th, 2021**

**Agenda Item: 8.2.2**

**Source: Moderator (Lenovo)**

**Title: Draft discussion [104-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:

[104b-e-NR-52-71GHz-02] Email discussion/approval on PDCCH monitoring enhancements with checkpoints for agreements on Apr-15, Apr-20 – 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 monitoring for 120 kHz

At the end of RAN1#104e, it seemed agreeable to conclude that no multi-slot monitoring for an SCS of 120 kHz is needed. However due to lack of time, a corresponding agreement has not been reached.

**FL Proposal:**

Conclude that for 120 kHz SCS, no multi-slot monitoring for PDCCH is needed.

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| **Company** | **Comment** |
| Panasonic | Support the FL proposal |
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### Issue A1-2: Supported PDCCH monitoring durations for 480/960 kHz

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

**FL Proposal:**

Supported number of slots for multi-slot PDCCH monitoring

* For 480 kHz: 4 slots
* For 960 kHz: 8 slots
* Additional values smaller than 4/8 slots for 480/960 kHz are not precluded
* Larger values than 4/8 slots for 480/960 kHz are not supported

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| **Company** | **Comment** |
| Panasonic | Support the FL proposal. |
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### Issue A1-3: PDCCH monitoring capability definition

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

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| * 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
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**FL Summary based on submitted documents:**

Alt 1 supported by Huawei, HiSilicon, Nokia, Nokia Shanghai Bell, CATT, MediaTek, Apple, LG, Interdigital, ZTE, Sanechips

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

Alt 3 supported by Ericsson, Intel

New Alternative (allowing different MSM PDCCH monitoring capabilities for different PDCCH types e.g. CSS and USS) supported by Apple

Few companies support a capability definition according to Alt 3, while several companies pointed out that the concerns resolved by Alt 3 may be taken into account by proper X,Y parameter choices and/or additional restrictions.

**FL Suggestion: Check if the concerns solved by Alt 3 can be taken into account by further refining Alt1/Alt2, and preferences by companies not shown above. Discuss if one of the alternatives requires less specification effort or offers more flexibility.**

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| **Company** | **Comment** |
| Panasonic | The back-to-back monitoring concerns targeted by Alt 3 does not exist in Alt 2, and for Alt 1, such concern can be solved by restricting the location of Y within slot groups. Therefore, we propose to remove Alt 3 for further consideration due to the majority view. For further down-selection, we slightly prefer Alt 2 due to the flexibility of locating the span (X,Y) in time domain.  |
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### Issue A1-4: BD/CCE budget for SCS 120 kHz

**Is the following agreeable:**

For 120 kHz SCS in 52.6-71GHz, the BD/CCE budget is the same as that for 120 kHz in FR2.

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| **Company** | **Comment** |
| Panasonic | Yes. |
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## Topic A2: Search Space Enhancement

### Issue A2-1: SS duration granularity

**Do you agree to the following proposal:**

The search space set configuration should be enhanced for multi-slot PDCCH monitoring by changing the unit of duration to multi-slot.

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| **Company** | **Comment** |
| Panasonic | This can be decided later after Issue A1-3 is resolved. If Y in A1-3 is defined in number of consecutive symbols (instead of slots) and does not cross slot boundary, the above proposal may not be needed.  |
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### Issue A2-2: Additional SS periodicities

**Do you have any suggestions (e.g. which additional periodicities to add) based on the following proposal:**

The search space set configuration should be enhanced for multi-slot PDCCH monitoring by adding new periodicities.



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| **Company** | **Comment** |
| Panasonic | Can be discussed later after Issue A1-3 is resolved. |
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### Issue A2-3: SS set group switching

Do you agree to the following proposal:

Is SSSG switching supported for the new SCS (480/960 kHz)? Any suggestions for the corresponding switching time ?

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| **Company** | **Comment** |
| Panasonic | SSSG switching is also useful for new SCS 480/960 kHz. The switching time defined for 120kHz can be reused for the new SCS. |
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## Topic A3: BD Dropping

### Issue A3-1: Extending the Rel-15 principles to multi-slot monitoring scenario

In NR Rel-15, according 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.

**Do you agree to extend these rules to multi-slot PDCCH monitoring in the following way?**

* 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.

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| **Company** | **Comment** |
| Panasonic | Yes |
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### Issue A3-2: Extending the Rel-15 principles to multi-slot monitoring scenario

**Do you agree to the following proposal?**

In case of PDCCH overbooking for a USS

* The USS set with the largest SS set index is dropped
* If the PDCCH MOs of a USS set are configured in multiple slots, the USS set in those multiple slots is dropped slot by slot (see Intel R1-2103022)

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| **Company** | **Comment** |
| Panasonic | This can be further studied. As an simpler alternative to the above proposal, if PDCCH MOs of a USS set are configured in multiple slots, in case of overbooking, the USS set can be dropped in the multiple slots as a whole. Pros and Cons should be carefully studied before making decision. |
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## Topic A4: PDCCH Extensions

TBD

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

TBD

## Topic C: Multi-Beam Aspects

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

**Please provide your comments on the following 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

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| **Company** | **Comment** |
| Panasonic | Rel-15/16 DCI format 2\_0 can be used for beam-specific indication, as it is intended for a group of UEs. gNB can send different DCI format 2\_0 to different groups of UEs located in different spatial domains. |
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### Issue C-2: Other multi-beam enhancements

**Do you see the need for any other multi-beam-related enhancements? Please provide corresponding motivation and solution, where applicable.**

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| **Company** | **Comment** |
| Panasonic | In order to consider TDM transmission of beam-specific DCI format 2\_0, UE should know which symbols to monitor DCI format 2\_0 for which beam. Currently, DCI format 2\_0 is only monitored at the beginning of a slot and it is beam agnostic. Some mechanism similar to SSB beam sweeping can be considered for transmitting beam-specific DCI 2\_0.  |
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## Topic D: Multi-Cell Operation, Cross-carrier scheduling

### Issue D-1: Aspects to be resolved to support cross-carrier scheduling and multi-cell operation

**Companies have provided the following aspects that require further study and/or definitions to support cross-carrier scheduling and multi-cell operation**

* *Npdsch* (PDCCH symbols between PDSCH and PDCCH) is associated with the SCS of PDCCH. This needs to be defined for the new SCSs should be defined too. (Huawei R1-2102328, Apple R1-2103097)
* How to determine the number of monitored PDCCH candidates and non-overlapping CCE for different cells in the CA scenario, e.g. different cells with/without multi-slot PDCCH monitoring. (Spreadtrum R1-2102449, vivo R1-2102515)
* The minimum PDSCH scheduling delay and the minimum A-CSI RS triggering offset applicable to SCS 480kHz and 960kHz (Intel R1-2103022)
* Potential limitations on the applicable SCS(s) of the scheduling and scheduled cells/BWPs (Apple R1-2103097)
* The maximum number of carriers that can be simultaneously scheduled from a single carrier should be defined as a UE capability (Apple R1-2103097)

Please provide any comments on the above, or additional items.

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| **Company** | **Comment** |
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# 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.

### R1-2102328 (Huawei, HiSilicon)

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| In the last meetings, multi-slot PDCCH monitoring is agreed for new SCSs with three alternatives for monitoring capability definition. There are several interpretations for Alt-1, one interpretation is that capability indicates the BD/CCE budget within N slots, or Y consecutive slots per X slots with Y=X, as shown in Figure 1 Alt-1 (a). In comparison, per slot capability defined in Rel-15 allows that the BD/CCE budget can be allocated anywhere within the fixed pattern. During the discussion, there were proposals to further restrict the PDCCH monitoring capability within Y [symbols or slots] in the fixed pattern of [N or X] slots. The Y [symbols or slots] can be located either at the beginning of fixed pattern X or N slots as plotted in Alt-1(b), or can be flexibly located at any slot of the fixed pattern as plotted in Alt-1 (c). Alt-1c will lead to uneven BD/CCE allocation in a unit period considering a gap between two adjacent MOs less than X slots or N slots, just as the red box illustrates, which increases the dropping rate of PDCCH candidates. Therefore, an additional restriction should be defined for search space (SS) configuration to ensure detected BD/CCEs not exceed the capability defined. To avoid the scenario demonstrated by Figure 1 Alt-1 (c) for a fixed pattern, Alt-3 was proposed, which define the capability within a window with a floating start point, while the length of the window is X slots or N slots. If the X-slot window slides in the unit of slot, this is equivalent to defining UE capability per slot as in Rel-15, which either results in increased BD/CCE budgets or reduced aggregation level for each monitoring occasion in a slot.Figure 1. PDCCH monitoring capability definition alternativesAlt-2 is modified from the capability definition per span introduced in Rel-16 URLLC WI. In Rel-16, a span is defined as a number of consecutive symbols in a slot where the UE is configured to monitor PDCCH, whose maximum value is up to Y, and the minimum gap between two consecutive spans is X symbols within and across slot boundaries. If extending such concept for multi-slot PDCCH monitoring, one way is to replace X symbols in Rel-16 with X slots, and the capability is defined within Y consecutive symbols or X slots, as demonstrated in Figure 1 Alt-2. It will require considerable standard efforts for 480 kHz and 960 kHz SCS considering only capability for 15 kHz SCS and 30 kHz SCS have been specified for URLLC usage. By considering the tradeoff of flexibility and standard effort, we prefer defining multi-slot PDCCH monitoring capability as Alt 1-b, i.e. a fixed pattern of Y consecutive symbols or slots located at the first several symbols or slots within X slots.***Observation 1:***  *For multi-slot PDSCH scheduling with 480 kHz and 960 kHz SCS, it is sufficient to configure a search space in a fixed pattern of Y consecutive [symbols or slots] located at the first several [symbols or slots] within X (N) slots. It is therefore sufficient to define the UE multi-slot PDCCH monitoring capability based on either the fixed pattern of X (N) slots or based on the fixed pattern of Y [symbols or slots].*For 480 kHz and 960 kHz, on one hand, taking both complexity of blind detection and PDCCH coverage into consideration, we can define a maximum number of non-overlapped CCEs no less than 16 per N slots, or within Y [symbols or slots] per X slots, where Y means the number of symbols or slots for PDCCH monitoring within X slots to ensure the highest aggregation level. For example, the capability can be same with that of 120 kHz per X slots for new SCSs, to keep the same capability within a time unit, with proper consideration of Y. On the other hand, shorter symbol duration for 480 kHz and 960 kHz require less BD/CCE budget to make sure the PDCCH can be detected successfully in time. For example, the maximum number of non-overlapped CCEs can be 24 for 480 kHz, and 16 for 960 kHz. ***Proposal 1****: For multi-slot PDCCH monitoring, support the BD/CCE budget defined within first Y consecutive [symbols or slots] per fixed X consecutive slots:** + *for 480 kHz SCS: N or X is 4 slots, Y = 12 symbols (or 1 slot if Y is in the unit of slot)*
	+ *for 960 kHz SCS: N or X is 8 slots, Y = 24 symbols (or 2 slots if Y is in the unit of slot)*
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### R1-2102386 (OPPO)

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| 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-2: R16 span frameworkA baseline of the span pattern can be the slot-based PDCCH monitoring for 120 kHz SCS. Then the X value can be scaled up for 480 kHz and 940 kHz. In this case, the X value is 4 slots for 480 kHz and 8 slots for 960 kHz. For the value of span length Y, at least a length of 3 symbols should be supported. In addition, for having more scheduling flexibility, a longer span length can also be considered, e.g. Y= 1 slot. **Proposal 1: for reusing span framework, consider a baseline corresponding to slot-based PDCCH monitoring capability with 120 kHz.** * **X value of 4 slots for 480 kHz and 8 slots for 960 kHz.**
* **Y value of 3 symbols should be supported.**
* **Additional Y value of 1 slot can be considered.**

Alt-1 plus Alt-3: Enhancement to a fixed slot-group pattern In R15, the PDCCH monitoring capability is defined per slot with the maximum number of PDCCH symbols for search space monitoring is 3. For 480 kHz and 940 kHz, the slot can be extended to slot-group. Also take 120kHz SCS as reference, the sizes of slot-group pattern for 480 kHz and 940 kHz are 4 slots and 8 slots respectively. For each UE, a UE-specific PDCCH monitoring slot-group pattern with UE-specific offset configuration can be considered at least for a USS. So different UE can be configured in different time locations for USS monitoring, hence to achieve more scheduling flexibility. **Proposal 2: for reusing slot-based capability, consider a baseline corresponding to slot-group-based PDCCH monitoring capability with 120 kHz.** * **One slot group comprises 4 slots for 480 kHz and 8 slots for 960 kHz.**
* **UE can be configured with a UE-specific starting position for each slot group.**

Regarding the PDCCH monitoring capability for 480 kHz and 960 kHz with span combinations, we can have the following baseline capability.

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

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### R1-2102449 (Spreadtrum)

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| In last meeting, it is agreed that relax per-slot PDCCH monitoring to multi-slot PDCCH monitoring for high SCS. The points for further study how to define the multi-slot PDCCH monitoring capability. In other company’s draft [3], it was proposed that the number of BD/CCE in multi-slot span should be limited. If a large number of BDs and CCEs are forced per slot, the total number of BD and CCE in a multi-slot span could be significantly high because the total number of slots is 4x or 8x of SCS 120kHz. As shown in Figure 1, the numbers of BDs and CCEs are distributed in 4 consecutive slots, and there is no limit to configuration in each slot within the 4 slots. In special cases, gNB can respectively configure most/all of the BDS/CCE slots in slot A and consecutive slot B, which belong to different multi-slots span. However, this configuration causes a larger PDCCH detection capability, as the number of PDCCH detection for one UE is nearly double. Therefore, there is a need to restrict the number of BD/CCE of adjacent/consecutive slots belonging to different multi-slot spans. One easy way to put an upper limit of the number of the BDs/CCEs in two adjacent/consecutive slots belonging to different multi-slot spans. Figure 1: Illustration of multi-slot span***Proposal 1: It is necessary to limit the number of the BDs/CCEs in two adjacent/consecutive slots belonging to different multi-slot spans.***On the one hand, many of the UE capabilities are already numerology dependent and the “slot” is commonly used as a reference time grid to confine the capabilities. On the other hand, if the UE is expected to monitor PDCCH in every slot, the micro-sleep opportunities decrease due to the short slot length for the high SCS and the power efficiency during the connected mode would be degraded. Therefore, for the high SCSs, multi-slot can be considered to confine the UE capabilities. In conclusion, it is desirable to support both per-slot and multi-slot span PDCCH monitoring capabilities for different SCSs. However, it needs further discussion how to switch between single-slot and multi-slot span or multi-slot of different lengths.***Proposal 5: Support both single-slot and multi-slot based PDCCH monitoring capabilities for above 52.6GHz.*** |

### R1-2102515 (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.slot level capability should be only limited to 480K and 960K SCS. For other SCSs such as 120K, the PDCCH monitoring capability is the same as NR Rel-15&16. **Proposal 4: Multi-slot-based capability applies to BWP with 480K and 960K SCS only.**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.**Proposal 5: Slot-based capability is not supported for BWP with 480K and 960K.**In RAN#90e, it is agreed that (120, 480, 960) KHz SCS are all supported for data/control, i.e. PDCCH SCS could be one of (120, 480, 960) KHz SCS depending on the BWP numerology configuration. Therefore, there is need to define the BD/CCE budget for each of the above agreed numerology for NR operation from 52.6-71GHz.First, 120KHz SCS is also the supported numerology for NR FR2 operation. The difference on the range of center frequency doesn’t bring any difference on PDCCH monitoring complexity. Therefore, the BD/CCE budget value for 120KHz (i.e. =3) in FR2 could be reused for that for NR operation from 52.6-71GHz**Proposal 6: For a DL BWP with 120KHz SCS in 52.6-71GHz, UE derives the BD/CCE budget as the same as that for 120KHz in FR2 including the budget value.**Second, 480KHz and 960KHz are new supported numerologies in 52.6-71GHz. **T**he time domain granularity of current BD/CCE budget definition is per slot as observed from Section 2.2.1. However, PDCCH monitoring capability will be based on multi-slot level as proposed in 2.1.2. Naturally, BD/CCE budget per multi-slot span per serving cell should be defined, e.g. proportional to the value per slot per serving cell by the number of slots within a multi-slot span. Besides, the value should be adapted to different (X, Y) similar with the span-based BD/CCE budget in NR Rel-16. **Proposal 7: For a DL BWP with 480KHz and 960KHz SCS in 52.6-71GHz, the BD/CCE budget value per multi-slot span per serving cell should be defined for each (X, Y) value.**In NR operation from 52.6-71GHz, BD/CCE budget will be defined for multiple slot as proposed by **Proposal 3** and **Proposal 7**. 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 9: In multi-slot-based PDCCH monitoring capability case, PDCCH candidates could be allocated to multiple slots in granularity of SS and slot.** |

### R1-2102559 (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* One of the questions related to Alt 1 is how it relates to parallel search space sets, which may be associated also with different numerologies. There are two approaches: * The simplest approach is to have common slot group definition for each search space set.
* Another approach is to allow search space -specific configuration for (X) and (Y). An example of this is shown in Figure 2.

When comparing Figure 1 and Figure 2, it can be noted that search space -specific configuration allows for more flexible distribution of BD/CCEs in time, and enables more efficient utilization of the UE PDCCH monitoring capabilities. Furthermore, it allows more flexible configuration options for the mixture of different search spaces such as CSS and USS.***Proposal 2*:** *Consider search spece -specific configuration for the slot group(s).***Alt2: Multi-slot span monitoring:**NR Rel-16 supports PDCCH monitoring restriction according to span -based monitoring. It’s defined according to two parameters, X and Y:* X (symbols) is the minimum time separation between the first symbols of two consecutive spans
* Y (symbols) is the maximum duration of the span.
* The capability indicates the BD/CCE budget within a span of at most Y consecutive symbols

The span -based monitoring defined in Rel-16 supports only scenarios with X≤7. This corresponds to span-based monitoring within a slot. However, the Rel-16 solution scales to multi-slot scenario as well, and it is possible to define monitoring restriction for 60GHz scenario based on the same operation logic. ***Observation 1*:** *Rel-16 span-based solution scales to different multi-slot scenarios.***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 monitoring
* 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:**One of the open points is how to define 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.*Table 1. Number of slots and symbols / 120 kHz slot (~0.125ms)

|  |  |  |
| --- | --- | --- |
| SCS (kHz) | # of slots / 0.125ms | #of symbols / 0.125ms |
| 120 | 1 | 14 |
| 480 | 4 | 56 |
| 960 | 8 | 112 |

Table 2 shows an example for defining PDCCH monitoring capabilities. When considering numerical values for the maximum number of PDCCH candidates per span, and the maximum number of non-overlapping CCEs per span, we think that the existing capabilities defined for 120 kHz SCS could be used as a baseline.* 20 PDCCH candidates per 120 kHz slot duration
* 32 non-overlapped CCEs per (120 kHz) slot duration.

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

|  |  |  |
| --- | --- | --- |
|  | 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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### R1-2102622 (CATT)

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| Alt 1: Use a fixed pattern of N slots as the baseline to define the new capability.* Alt 1-1: MOs can only be distributed in the first few symbols of the pattern.
* Alt 1-2: MOs can be distributed at any symbols within the pattern.

Figure 1: MOs distribution limitation within the fixed patternAs shown in Figure 1, the main difference between Alt 1-1 and Alt 1-2 is the configured CORESET resource allocation as PDCCH MOs. When Alt 1-1 is supported, gNB can only schedule the UE in the first 3 symbols of slots with the fixed pattern of CORESET allocation within the multi-slot interval. The number of CCEs would be distributed to those slots configured with CORESETs. UE will search the PDCCH candidates from the distributed CCE allocation among slots configured with CORESETs. Alt 1-2 can allocate the CORESET at any symbols within the multi-slot interval without the limitation on the first 3 symbols of slot. The CCEs could be distributed to any symbols within the multi-slot interval. This would give the gNB full flexibility in scheduling any PDSCH/PUSCH at any symbol within the multi-slot interval. However, this would also require large signaling overhead in the pattern of search space configuration within the multi-slot interval. Since the slot interval is very short for 480 kHz and 960 kHz SCS, the latency and flexibility of gNB scheduling with limiting the CORESET at the first 3 symbols of the slot would not be significant. Alt 1-2 does not provide much benefit in latency and scheduling flexibility over that of Alt 1-1. **Proposal 1: The CORESET can be limited to first 3 symbols of first slot within the multi-slot interval for a fixed pattern.** Alt 2: Use (X, Y) span as baseline to define the new capability. A span is the time interval for the gNB scheduling. The span starts with the first symbol 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, NR supports (2, 2), (4, 3) or (7, 3) span for 15 kHz and 30 kHz SCS for URLLC mini-slot scheduling. The X value of 2, 4, 7 symbols are the supported mini-slot structure in NR. For 480 kHz and 960 kHz SCS, the value of X could be extended to support 14 symbols/1 slot, 28 symbols/2 slots, 56symbols/ 4 slots and 112 symbols/8 slots as the scheduling interval for UE multi-slot PDCCH monitoring capability. Since the maximum system bandwidth increases in proportion to the increase for larger SCS, e.g., 1600 MHz for 480 kHz SCS, the number of CCEs in the first 3 symbols of slot would be the similar to that of lower SCS based on 275 PRBs constraint of the system BW. In order to make a trade-off between schedule flexibility and UE capability, X value should be defined with different granularity (56, 28, 14) or (112, 56, 28) symbols which could be defined for 480kHz and 960kHz SCS respectively. 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 and X=8 slots for 960 kHz. When the value of X is extended to a value greater than 1 slot, the scheduling interval is increased and the scheduling flexibility is decreased. In order to enhance the scheduling flexibility, the value of Y greater than 3 symbols should be further studied.**Proposal 2: The value of X can be defined with different granularity (112, 56, 28, 14) symbols for (X, Y) span.****Proposal 3: The value of Y greater than 3 symbols should be further studied for (X, Y) span.**Alt 3: Use a sliding window of N slot to define the new capability.Figure 2: Example for sliding windowThe length of the sliding window could be 4 slots and 8 slots for 480 kHz and 960 kHz respectively, and the sliding unit of sliding window is 1 slot, as shown in Figure 2. The sliding window can define UE PDCCH monitoring capability within any consecutive slots of N. If PDCCH monitored capability is defined within multi-slot window, the number of PDCCH candidates for UE to monitor should remain the same under the maximum number of monitored PDCCH candidate. For example, the total number of PDCCH candidates in sliding windows 1 and 2 should be the same since the number of PDCCH candidates in slot 5 should be the same as that in slot 1 regardless this is 4-slot fixed pattern (Alt 1) or time span (Alt 2). If overbooking of PDCCH candidates is allowed, UE requires to iterative accounting of the number of PDCCH blind decoding within the sliding window and may have the results of discarding decoding of some PDCCH candidates due to over the limit of maximum number of monitored PDCCH candidate. 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 2: 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.** **Proposal 4: Alt1 fixed pattern of N slot or Alt 2 (X, Y) span can be used to define the new UE capability for multi-slot PDCCH monitoring candidate.** |

### R1-2102704 (MediaTek)

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| For 120 kHz, in RAN1 #104e meeting, there was a discussion on whether the multi-slot monitoring enhancement can be configured to UE operating in 120kHz. In our view, it is beneficial to apply existing FR2 design as much as possible for operation in the spectrum of 52.6GHz to 71 GHz in order to reduce spec impact and implementation burden. In our understanding, no issue has been identified for PDCCH monitoring under SCS=120 kHz in SI phase and it is desirable to reuse existing PDCCH monitoring design and UE capability without further enhancements for configuration of 120 kHz SCS in the targeted spectrum. Proposal 1: For 120 kHz SCS, no PDCCH monitoring enhancement is needed. The existing FR2 designs and capabilities for PDCCH monitoring of 120 kHz SCS are reused.During the discussion in RAN1 #104e 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 M symbols or first M slots within each N 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 and N 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 and with further details on the monitoring symbols in the slots. Proposal 2: To achieve scheduling flexibility in multi-slot monitoring, the monitoring pattern should adopt slot as the basic unit for both 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. The monitoring symbols within the slots can be further studied. 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 slot within every N=4 slots is for PDCCH monitoring, then the resulting monitoring pattern satisfies the (X=4, Y=1) monitoring constraint in Alt2, which is illustrated in . 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.**Proposal 3: For Alt2, if supported, the multi-cell monitoring capability for non-aligned spans across CCs need to be further studied.**  |

### R1-2102773 (Futurewei)

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| A visualization of the proposed solutions is presented in the following Figure 1. The Alt 2 is an extension of the existing solution where the span duration and the span repetitions are larger than a slot duration. The Alt 3 basically is the same as Alt 2, where the sliding window step increment is equivalent to the slot span repetition. Alt2 and Alt3 are reduced to Alt 1 when the span duration (sliding window duration) and the span repetition (sliding window increment step) are equal to N. Therefore, Alt 2 and Alt 1 are more flexible solutions. Figure 1**Proposal 1: Use the Rel-16 capability (*pdcch-Monitoring-r16*, (X, Y) span) as the baseline to define the new capability.**In RAN1 #104-e discussions most companies supported the PDCCH monitoring enhancements only for SCS larger than 120 kHz. In other words, RAN1 companies 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 2: For 120 kHz SCS, no UE multi-slot capability for monitoring for PDCCH is needed.** The Proposal 2 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 should be 4 slots and respectively 8 slots i.e. 125 us.**Proposal 3: The maximum multi-slot PDCCH monitoring span durations supported for 480 kHz SCS and 960 kHz are 4 slots and respectively 8 slots.**The RAN1 discussions were not conclusive on the minimum durations for multi-slot PDCCH monitoring at higher SCS. At this time, we do not see reasons to support a shorter PDCCH monitoring span durations at higher SCS than those already allowed. 3GPP supports (2, 2), (4, 3) and (7, 3) as the monitoring span for SCS of 15 kHz and 30 kHz. A 2-symbol span duration at 30 kHz corresponds to 32 symbols at 480 kHz and 64 symbols at 960 kHz SCS, which implies that the shortest monitoring span durations should be 2 slots at 480 SCS, and 4 slots at 960 kHz SCS.**Proposal 4: Consider the following values for PDCCH monitoring span durations for 480 kHz {2,4} slots, and for 960 kHz {4,8} slots.**We note that the above proposal excludes the single slot monitoring for higher SCS. |

### R1-2102789 (Ericsson)

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
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| Based on the discussion on PDCCH monitoring capability enhancements, three alternative solutions were selected for further study in RAN1 #104-e:* Alt 1: A fixed pattern of N-slot groups.
* Alt 2: Use the Rel-16 capability (*pdcch-Monitoring-r16*, (X, Y) span) as the baseline to define the new capability
* Alt 3: A sliding window of N slots for defining multi-slot PDCCH monitoring capability.

In the following, we analyze the three alternatives based on the principles discussed in the last section and how each alternative address the above two aspects. We found that, while the three alternatives start from different starting perspectives, they all end up utilizing or requiring certain sliding window check on the PDCCH processing loads.1. While the three alternatives for defining UE multi-slot PDCCH processing capabilities are constructed from different starting perspectives, they all end up utilizing or requiring certain sliding window check on the PDCCH processing loads.
2. Alt 1A where PDCCH monitoring is restricted to the beginning of an N-slot group is less flexible than Alt 2 but has the same operational flaws as Alt 2 from a network perspective.
3. Alt 1B where PDCCH monitoring can be configured in any slot of an N-slot group becomes operationally identical to Alt 3 when all restrictions against local PDCCH processing load violations are put in place.
4. Alt 2 (and Alt 1A) requires the UE to support intra-slot monitoring capability of Y≫3 OS.
5. Alt 1A or Alt 2 with small Y values places stringent limitations on how the network can configure PDCCH monitoring occasions: forcing USS to be aligned closely with the CSS. It substantially suppresses the network’s potential to optimize the various requirements from different UEs and the network in terms of capabilities, latency requirements and PDCCH resource capacities.
6. 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.
7. Alt 2 may also require additional PDCCH processing load restriction/checking as Alt 1B. Further clarification from the proponent companies are needed.
8. Alt 3 allow the network to flexibly spread the UEs’ N-slot PDCCH processing capabilities, , over the N-slot span (for example, all in one slot or over several slots) to optimize the various requirements from different UEs and network in terms of capabilities, latency requirements, PDCCH resource capacities and power savings.
9. For Rel-17 UE with multi-slot PDCCH processing capabilities, overbooking and PDCCH dropping rules similar to those for Rel-15 can be considered:
	* Overbooking is not allowed for CSS.
	* Overbooking is not allowed for SCells.
	* For the PCell, a window of N slots sliding forward in time is checked one sliding position at a time (indexed by the slot number of its first slot).
		+ For a sliding window at a given position, the USS are considered one at a time based on their ID.
			- **If the UE processing capabilities are exceeded in the window, monitoring occasions of the USS are dropped from the window. All subsequent USS are also dropped from the window.**
		+ Furthermore, if a monitoring occasion in a later position of the sliding window overlaps the same dropped monitoring occasion from an earlier position of the window, the monitoring occasion remains as dropped.

Chart, line chart  Description automatically generatedFigure 14: Extrapolated and values per slotThe extrapolated UE PDCCH processing capabilities in Figure 14 are tabulated in Table 1 as a function of SCS. The numbers indicate there may be doubts on whether the UE operating with a SCS such as 960 kHz SCS can support even one AL-16 PDCCH considering the need to configure a number of common and UE specific search spaces with various aggregation levels. Table 1: Extrapolated and values per slot

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| SCS [kHz] | 15 | 30 | 60 | 120 | 480 | 960 |
|  | **44** | **36** | **22** | **20** |  |  |
| BD Estimate | 44 | 34 | 26 | 20 | 12 | 9 |
|  |  |  |  |  |  |  |
| SCS [kHz] | 15\*20.5 (Nominal, used for fitting) | 60 | 120 | 480 | 960 |
|  | **56** | **48** | **32** |  |  |
| CCE Estimate | 56 | 40 | 32 | 20 | 16 |

The potential reduction of UE PDCCH processing capabilities per slot shown previously presents difficulties to maintain the same scheduling framework and flexibility as Rel-15 NR. It would impose substantial negative impacts to Rel-17 NR operation in 52.6 – 71 GHz if the UE PDCCH processing capabilities per multi-slot monitoring period remain as restrictive when the UE is configured to monitor the PDCCH every slots. Therefore, it will be beneficial for NR operation in 52.6 – 71 GHz to scale UE PDCCH processing capabilities per -slots with the bundle size B:1. A first approach to define the UE PDCCH processing capabilities when PDCCH monitoring per multiple slots is deployed for larger SCS is to scale the UE PDCCH processing capabilities per slots with the bundle size B. That is, the bundled UE PDCCH processing capabilities are and .
2. A second approach to define the bundled UE PDCCH processing capabilities when PDCCH monitoring per multiple slots is deployed for larger SCS with a PDCCH monitoring frequency equal to that of 120 kHz SCS is to maintain the same UE processing capabilities per-slot as in a 120 kHz SCS system. That is, the bundled UE PDCCH processing capabilities are , and .
3. If arbitrary monitoring bundle size of is supported for UE capability scaling Option 2, i.e., for 480 kHz SCS or for 960 kHz SCS are supported, the bundled UE PDCCH processing capabilities are scaled relative to those for the 120 kHz SCS by a factor of .
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### R1-2102809 (Panasonic)

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| Based on the above analysis, we have the following proposal**Proposal 1: Select Alt 2 for defining the multi-slot PDCCH monitoring capability.**  |

### R1-2102978 (Xiaomi)

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| With three SCSs, 120 kHz and 480/960 kHz are all specified, it may be not necessary to support all the three SCSs for NR 52.6-71GHz especially considering the complexity for high speed processing for 480/960 kHz. Since 120 kHz is already supported in FR1/2, it is backward compatible to support 120 kHz as a default/ mandatory SCS and 480/960 kHz as optional. The PDCCH monitoring capability for 120 kHz per slot can still reuse the one defined in current spec as a mandatory capability. And the PDCCH monitoring capability for 480/960 kHz per slot can be defined as optional capability. And even for the PDCCH monitoring capability for 480/960 kHz, different UE capabilities can also be considered, for example UE cap1 supports relatively lower PDCCH candidate numbers and non-overlapped CCE numbers than UE cap2, which allows more flexible UE implementation and gNB scheduling for NR 52.6-71GHz. ***Proposal 1: The PDCCH monitoring capability for 120 kHz per slot can still reuse the one defined in current spec as a mandatory capability. And the PDCCH monitoring capability for 480/960 kHz per slot can be defined as optional capability.******Proposal 2:*** ***For PDCCH monitoring capability for 480/960 kHz, different UE capabilities can be considered*** ***to allow more flexible UE implementation and gNB scheduling for NR 52.6-71GHz.***Three alternatives for defining the multi-slot PDCCH monitoring capability are proposed in R1 #104 meeting. Alt1 is a fixed pattern of N slots. From our understanding, Alt1 also implies that within the N slots, M(M<=N) slot(s) that can be configured with PDCCH. And the relative location of the M slot(s) is fixed within the N slots. Alt1 is a very simple and concise design since it is a fixed pattern. And meanwhile, for a certain N value, by configuring a proper M value, gNB can easily control the PDCCH resource overhead.Alt2 is to use the Rel-16 capability (pdcch-Monitoring-r16, (X, Y) span) as the baseline. In R16 URLLC, PDCCH monitoring span (X,Y) is defined as number of consecutive symbols in a slot where the UE is configured to monitor PDCCH. Each PDCCH monitoring occasion is within one span. If a UE monitors PDCCH on a cell according to combination (X,Y), the UE supports PDCCH monitoring occasions in any symbol of a slot with minimum time separation of X symbols between the first symbol of two consecutive spans, including across slots. A span starts at a first symbol where a PDCCH monitoring occasion starts and ends at a last symbol where a PDCCH monitoring occasion ends, where the number of symbols of the span is up to Y.With some little modification, for example, change the unit of X/Y from symbol to slot, a multi-slot PDCCH monitoring span can be defined based on pdcch-Monitoring-r16, (X, Y) span. That is a span contains at least X slots and the PDCCH monitoring occasion are located in the first Y slots within the at least X slots. 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 3: 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) that can be configured with PDCCH.***Compared with defining PDCCH monitoring capability per single slot, defining PDCCH monitoring capability per multi-slot span would allow gNB scheduling DCI in a bursty way. And it may cause the UE to spend more time on decoding all the DCIs scheduled in a DCIs burst, which will increase the total processing time for the scheduled PDSCH/PUSCH since UE has to decoding the DCI first. For example, with maximum number of B1/C1 of BDs/CCEs for PDCCH monitoring per single slot, UE is able to decode the all the DCIs in PDCCH in 1 symbol from the end of the PDCCH. But with maximum number of 4\*B1/4\*C1 of BDs/CCEs for PDCCH monitoring per 4-slot PDCCH monitoring group and gNB scheduling DCI in a single slot, UE may need extra 2 symbols to guarantee to decode the all the DCIs in PDCCH, thus cause the decoding time of PDSCH (N1) and preparation time of PUSCH (N2) may need to be extended as well.***Proposal 4: Impacts on PDSCH/PUSCH processing time (N1/N2) may need be considered if defining maximum number of BDs/CCEs for multi-slot group PDCCH monitoring.*** |

### R1-2102997 (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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### R1-2103022 (Intel)

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| From the discussions in last meeting, there is no common understanding on PDCCH monitoring capability in a group of slots, the applicable symbol positions of PDCCH MOs in a slot, and the RRC signalling for search space set configuration. Therefore, it is preferred to clarify above issues in the discussions. Otherwise, different understandings may exist for the same question. **Proposal 1: The PDCCH monitoring can be defined from 3 aspects*** **Definition of multi-slot PDCCH monitoring capability on maximum numbers of BD/CCE**
	+ **Meaning of X and Y (Y may be always equal to X)**
	+ **Which slots in the Y slots can carry PDCCH monitoring occasions**
* **Restriction on symbol position(s) for PDCCH monitoring occasion(s) in a slot**
* **Search space set configuration**

The search space set group (SSSG) switching in 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 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**The two SSSGs have different requirements on the PDCCH monitoring capability. With high SCS and short slot length, the mini-slot level PDCCH monitoring is not necessary for the first SSSG since there is marginal gain from latency point of view. On the other hand, even per-slot PDCCH monitoring capability may not be needed. In fact, per-slot PDCCH monitoring results in strict limitation on the search space set configuration, which is the reason to introduce multi-slot PDCCH monitoring in this WI. If Alt 1-1 or Alt 2 is used, 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. Therefore, if Alt 1-1 or Alt 2 is used, a larger X and a smaller Y is desired. Based on the above analysis, if Alt 1-1 or Alt 2 is adopted, it is much likely that UE needs to dynamically change its PDCCH monitoring capability together with SSSG switching. It complicates the PDCCH monitoring in the unlicensed operation. It is desired that a single PDCCH monitoring capability is used by UE and up to gNB to configure the search space sets in the two SSSG under same assumption of maximum numbers of BD/CCE. **Proposal 2: It is desired that the same PDCCH monitoring capability can be applied to both two SSSG configurations, to avoid frequency switching PDCCH monitoring capabilities.** **Figure 3: Sliding window based PDCCH monitoring capability****Proposal 3: It is preferred to define multi-slot PDCCH monitoring capability based on Alt 3*** **The step size for sliding can be X/2 slots for complexity reduction**
* **Up to gNB to configure SS sets in any one or more slots within the X slots, subject to the maximum numbers of BD/CCE**
* **There is no further limitation on maximum numbers of BDs/CCEs in a slot**

Regarding the size of multi-slot group, i.e. X, we prefer to have a size to align the slot length of SCS 120kHz. Further, additional X values can be considered for the flexibility of gNB configuration. Therefore, we prefer to allow the configurability of 2 or 4 for SCS 480kHz and 4 or 8 for SCS 960kHz. Another discussion point is the applicability of multi-slot PDCCH monitoring capability for SCS 120kHz. We think it is not necessary since per-slot PDCCH monitoring capability is already supported in NR Rel-15/16. It can be just reused for high frequency. **Proposal 4:** * **X can be 2 or 4 for SCS 480kHz, 4 or 8 for SCS 960kHz**
* **Multi-slot PDCCH monitoring capability is not supported for SCS 120kHz**

In NR, a search space (SS) set could be configured for the UE to monitor PDCCH. Up to 10 SS sets can be configured for each DL BWP in a serving cell. The time domain pattern of a SS set is configured by the following RRC parameters- a PDCCH monitoring periodicity of slots and a PDCCH monitoring offset of slots, by *monitoringSlotPeriodicityAndOffset*- a PDCCH monitoring pattern within a slot, indicating first symbol(s) of the CORESET within a slot for PDCCH monitoring, by *monitoringSymbolsWithinSlot* - a duration of slots indicating a number of slots that the search space set exists by *duration*Specifically, 3 cases for SS set configuration within a slot are supported by parameter *monitoringSymbolsWithinSlot*,* 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

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 7: 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**
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### R1-2103097 (Apple)

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| As a **new Alternative,** to enable some of the flexibility provided by Alternative 3, RAN1 should support allowing different MSM PDCCH monitoring capabilities for different PDCCH types e.g. CSS and USS. This is illustrated in Figure 1 where for both UEs, the CSS is based on a 2 slot slot-group, while UE1 uses an 8 slot USS slot-group and UE2 uses a 4-slot USS slot group. Alternatively, in scenarios with multiple component carriers, the CSS can be limited to the carriers with lower SCS while the CCs with 480 kHz and 960 kHz SCS are limited to USS only.Figure 1: CSS and USS MSM PDCCH MonitoringProcedures on overbooking and dropping may be discussed once the MSM methodology is finalized.***Proposal 1:*** *The MSS PDCCH monitoring capability should be based on a fixed pattern i.e. Alt 1 or Alt 2.** *The value Y should be defined based on symbols with Y ≤ 3 and Y < X.*

***Proposal 2:*** *For Alt 1, RAN1 can further consider the following cases:* * *Case MSM-1-1: PDCCH monitoring limited to within first M symbols of a MSM span*
* *Case MSM-1-2: PDCCH monitoring on any fixed position span of up to M consecutive symbols of a MSM span*

***Proposal 3:*** *The duration of a multi-slot monitoring span is as follows:** *For 480 kHz: 4 slots, for 960 kHz: 8 slots. Additional durations should be a UE capability.*
* *The use-case for single slot monitoring with X equal to a slot needs to be justified with the BD/CCE budget carefully selected.*

***Proposal 4:*** *RAN1 should enable signaling of different MSM PDCCH monitoring capabilities for different PDCCH types e.g. CSS and USS.* |

### R1-2103158 (Qualcomm)

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| As identified during the SI phase, one of the key motivations of multi-slot PDCCH monitoring is to avoid a loss of scheduling flexibility and performance, which is caused by having to excessively reduce the number of PDCCH candidates and non-overlapped CCEs due to the short slot length associated with high SCSs, i.e., 480 and 960 kHz. However, for 120 kHz SCS, the motivation for the new PDCCH monitoring capability is weak, since the per-slot PDCCH monitoring capability has already been defined for 120kHz SCS in Rel-15. Therefore, it is preferred to maintain the legacy (Rel-15) per-slot PDCCH monitoring capability for 120kHz and confirm the FL’s proposal A1-1.Proposal 1: For 120kHz SCS, a new multi-slot PDCCH monitoring capability is not supported.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 some companies pointed out in RAN1 #104-e, 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, particularly when 480kHz and 960kHz SCSs are considered 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 2: For 480kHz and 960kHz SCSs, multi-slot PDCCH monitoring is the default capability, and assumed during the idle/inactive mode operation and initial access procedure, if supported.Proposal 3: For 480kHz and 960kHz SCS, 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 60GHz 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 SCS as will be discussed later, 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 4: 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, X = 4 slots for 480 kHz SCS and X = 8 slots for 960 kHz SCS should be the default values. 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 5: 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 6: For the multi-slot PDCCH monitoring capability with X = 4 slots for 480 kHz SCS and X = 8 slots for 960 kHz SCS, the same maximum numbers of PDCCH candidates and non-overlapped CCEs as 120 kHz SCS are supported (i.e., 20 BDs and 32 CCEs).Among different alternatives summarized in FL’s proposal A1-5, Alt 1 and Alt 3 do not restrict the position and number of MOs within a X-slot window, 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 FL’s proposal 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 7: 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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### R1-2103230 (Samsung)

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| Slot-based PDCCH monitoring could be considered as a baseline at high SCS (480KHz and 960KHz), e.g. for the case UE capability is available, wherein the maximum number of monitored PDCCH candidate and maximum number of CCEs in a slot can be estimated by extrapolating currently supported numbers for other SCSs. In Table 1, we suggest the numbers as reference for discussion, and whether to keep the minimum maximum number of CCE as 16 for 960 kHz SCS can be further discussed.**Proposal 1: Support slot-based PDCCH monitoring for 480KHz and 960KHz, and use Table 1 as a reference to design 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 for a single serving cell

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|  | 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 1 with Y = N and Alt 3 cannot guarantee a gap between neighboring sets of PDCCH MOs.**Observation 4:** Alt 1 with Y < N has restriction on allocating the PDCCH MOs within the N slots. Therefore, we support Alt2. **Proposal 2: Support multi-slot span based PDCCH monitoring based on combination (X, Y), where the minimum PDCCH monitoring gap X is at least one slot, and the maximum PDCCH monitoring span Y can be one or more slots, for SCS of 480KHz and 960KHz.****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 BD/CCE limit can be defined per combinations of (X, Y). Similar as multi-symbol span based PDCCH monitoring in NR Rel-16, the maximum number of monitored PDCCH candidates and maximum number of non-overlapped CCEs are determined according to the selection of multi-slot span gap, X, and multi-slot span duration, Y. The larger X or Y a UE supports, the larger values of BD/CCE limits the UE may expect. As and are quite small for SCS of 120KHz, there is no much room to reduce the BD/CCE limit for higher SCS. PDCCH blocking may become an issue when the BD/CCE limit is too small. Therefore, it’s better to consider BD/CCE limits per multi-slot span for high SCS, such as .**Proposal 4: Support maximum number of PDCCH candidates per multi-slot span for combination (X, Y), where X >1 slots, Y>=1 slots, and .****Proposal 5: Support maximum number of non-overlapped CCEs per multi-slot span for combination (X, Y), where X >1 slots, Y>=1 slots, and .** |

### R1-2103295 (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, both Alt. 1 and Alt. 2 covers 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. However, the lack of scheduling flexibility is the main drawback of the fixed pattern scheme. On the other hand, a more flexible scheme based on (X, Y) scheme in Alt. 2 can alleviate this issue. The Y consecutive slots' start position can be flexibly configured by the network as long as the gap between the first two symbols is larger than X, which can improve the scheduling flexibility. 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.**

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 benefits evaluation of flexible scheduling further.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. 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 1: PDCCH monitoring with a maximum duration of more than 3 OFDM symbols per PDCCH monitoring occasion is more suitable.** |

### R1-2103340 (LG)

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| There are two simple ways to determine the length of a slot-group. The first way is to set the reference length regardless of actual SCS configuration. For instance, the slot length corresponding to 120 kHz SCS can be used as a reference length since 120 kHz is the smallest SCS that could be configured in FR-X. In this case, if one slot length corresponding to 120 kHz SCS is set to the reference length, then the consecutive four slots are used as slot-group for 480 kHz SCS, and consecutive eight slots are used as slot-group for 960 kHz SCS. Another way is to use a new PDCCH monitoring time unit with capability signalling. A preferred reference length can be signalled for each UE, and this length can be used as a basic time unit for PDCCH monitoring. 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 #1: Considering simplified UE implementation and potential power consumption reduction, support slot-group based PDCCH monitoring where the maximum number of PDCCH candidates and non-overlapping CCEs are defined per slot-group and the number of slots for slot-group can be determined based on reference SCS (e.g., 120 kHz) or UE capability.**In addition, 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, SS set configurations such as periodicity (and offset) can be configured to a value larger than M (or a multiple of M) slots. Accordingly, duration may be limited to be configured with less than M (or a multiple of M) slots. Moreover, it can be discussed how to handle the case where the slot-group boundary does not exactly match the periodicity and duration configurations. Therefore, through slot-group based PDCCH monitoring configuration and associated SS set configurations, it can be further expected to reduce the UE implementation burden or power consumption. **Proposal #2: Consider to configure PDCCH monitoring occasions to be confined within the slot-group (or multiple of slot-groups), by using search space set configuration parameters (e.g., periodicity, offset, and duration).** Three different alternatives were captured in [1] and/or [2] as the baseline to define the new capability. Various aspects for each alternative must be investigated before down-selection. We discuss some pros and cons for each alternative here. For both Alt-1 and Alt-2, SS set configurations and dropping rules can be determined simply since basic principles for them are already established to a single slot or a single span in rel-15/16. Scaling with multi-slot monitoring instead of single slot or span may be straightforward. This would be a quite important advantage to complete the whole feature of multi-slot monitoring in time. However, Alt-2 does not allow multiple discontinuous Y slots/symbols within X slots/symbols. 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. For Alt-3, the gNB can have improved flexibility since any slot within a sliding window can be a monitoring occasion. However, this can make SS set configuration complicated because the gNB should consider all sliding windows including the slot in which MO is configured before deciding MOs in the slot. Moreover, MOs in every slot can reduce the power saving effect (and may also increase the monitoring burden by UE) which is the main advantages of multi-slot monitoring. In addition, the overbooking/dropping rules may be complicated. For example, there is an issue raised in previous meeting that the MO dropped in n-th sliding window may be dropped again in (n+1)-th window, which would intensify the ambiguity of the dropping operation. Therefore, we propose Alt-1 as the baseline to define the BD/CCE capability for multi-slot PDCCH monitoring. However, in previous meeting, one possible issue for Alt-1 has also been raised, i.e., UE may have higher requirement than expectation on PDCCH monitoring in two consecutive slots across slot-group boundary. However, it may not 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 #3: Adopt Alt-1, with the following restrictions for configurations of Y*** + **Y should be multiple slots with slot-level granularity**
	+ **The size of Y should be configurable with a minimum gap between the last symbol of the previous Y and the first symbol of the next Y over two consecutive X slot group**
	+ **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**

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. To avoid PDCCH monitoring over two shortened consecutive slots, PDCCH monitoring over two consecutive slot-groups can be considered for high SCS. For example, for a given slot index for Type0-PDCCH CSS set monitoring, the next MO can be located in slot index 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). 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 #4: Consider slot-group based multi-slot monitoring for Type0-PDCCH CSS when SSB and CORESET#0 are multiplexed by pattern 1, if 480 kHz and/or 960 kHz SCS is supported for SSB.** |

### R1-2103412 (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. The PDCCH monitoring span (X, Y) for higher SCS/numerology (e.g., SCS 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, or per span (multi slots) for NR from 52.6 to 71 GHz.***In [2], Ericsson 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, 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 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. As indicated by Ericssion [2], 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, Ericsson’s proposal can be treated as a special case of PDCCH monitoring span (X, Y). In addition, the “sliding window” (e.g., the USS stating time-offset) for each UE is totally 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 can be up to gNB configuration for NR from 52.6 to 71 GHz.***  |

### R1-2103449 (InterDigital)

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| During RAN study item on requirements for NR beyond 52.6 GHz [2], various benefits of 52.6 – 71 GHz such as high speed data rate, low latency and high capacity have been identified based on the enormous amount of available contiguous bandwidth. Based on the identified benefits, various use cases for 52.6 – 71 GHz are also envisioned and most of the use cases such as short-range high-data rate D2D, vertical industry factory application, IAB, Factory automation/IIoT, AR/VR, ITS/V2X and critical medical communication require low latency as a key requirement. However, if NR only supports multi-slot based PDCCH monitoring for efficient signaling, benefits from low latency possible use cases will be significantly reduced. ***Observation 1:*** *For NR in 52.6 – 71 GHz, most of identified use cases require low latency as a key requirement, however, benefits from low latency and possible use cases significantly reduce if only multi-slot based PDCCH monitoring is supported.* ***Proposal 1:*** *Support both per-slot level monitoring and multi-slot level monitoring for transmission and reception.*In contrast to the existing SCS, per-slot level monitoring may lead to a more complex UE implementation considering reduced slot durations and UE processing time. Given that, it is desirable to have multi-slot level monitoring for general UE operations e.g., high data rate eMBB and per-slot level monitoring for UEs which require low latency. ***Observation 2:*** *Per-slot level monitoring requires a more complex UE implementation due to reduced slot durations of additional SCSs and possibly UE processing time.* ***Proposal 2:*** *It is preferred to support multi-slot level monitoring for general UE operations and per-slot level monitoring for low latency operations.*While multi-slot based PDCCH monitoring for additional SCS enables efficient signaling, multi-slot based PDCCH monitoring also reduces PDCCH scheduling flexibility and benefits from low latency. In addition, based on FR2 NR with 120 kHz SCS, single slot based PDCCH monitoring has been already proven feasible in various practical implementations. ***Observation 3:*** *Single slot based PDCCH monitoring has been already proven feasible in various practical implementations.* ***Proposal 3:*** *Multi-slot PDCCH monitoring is not supported for the existing SCS of 120 kHz.*In this section, we provide our views on the alternatives discussed for multi-PDCCH monitoring in RAN1#104-e [1]. * Alt-1: A fixed pattern of X slots.
	+ In this alternative, UE considers multiple consecutive X slots as a slot group and monitors PDCCH within first Y slots. This alternative may not be relatively efficient than Alt-2 and Alt-3, however, actual implementation of UE PDCCH monitoring will be similar to UE PDCCH monitoring with 120 kHz SCS, if X=4 for 480 kHz SCS and X=8 960 kHz and Alt-1 leads to simplest enhancements to support multi-slot PDCCH monitoring.
* Alt-2: Use a span (X,Y) similar to the Rel-16 capability (*pdcch-Monitoring-r16*, (X,Y) span) as the baseline to define the new capability
	+ In this alternative, UE monitors PDCCH by using a span with (X,Y) similar to Rel-16 capability. Rel-16 span based monitoring supports based on a span (X,Y) with X symbols of the minimum time separation between the two consecutive spans and Y symbols of the maximum duration of the span. Possible enhancement to support multi-PDCCH monitoring would be introduction of X and/or Y as slots to apply the span concept for multi-slot PDCCH monitoring. The specification impact may be relatively smaller, however, UE implementation may be relatively complex if the UE needs to support multiple applicable values for combination (X,Y) and dynamic adaptation on (X,Y) to efficiently utilize the span concept for multi-slot PDCCH monitoring (e.g., switching between small Y and large Y).
* Alt-3: A sliding window of X=Y slots for defining multi-slot PDCCH monitoring capability
	+ In this alternative, UE monitors PDCCH by using X-slot sliding window. The sliding window based PDCCH monitoring may distribute PDCCH processing loads over multiple slots. However, if UE-specific slot offsets are applied to Alt-1, degree of distribution on PDCCH processing load is doubted in network’s point of view.

***Observation 4:*** *A fixed pattern of X slots (Alt-1) provides simplest PDCCH monitoring similar to UE PDCCH monitoring with 120 kHz SCS while span based monitoring (Alt-2) and sliding window based monitoring (Alt-3) may achieve more efficient PDCCH monitoring with more complex UE implementation.****Proposal 4:*** *It is preferred to support a fixed pattern of X slots (Alt-1).****Proposal 5:*** *If needed, additionally consider one of span based monitoring or sliding window based monitoring for 480 kHz and 960 kHz.* |

### R1-2103488 (ZTE, Sanechips)

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| **Proposal 1: In the following options for enhancing PDCCH monitoring with the new SCSs 480/960 kHz, Alt 1 is preferred as the baseline to define the new capability:*** **Alt 1: Use a fixed pattern of slot groups**
* **Alt 2: Use an (X, Y) span**
* **Alt 3: Use a sliding window of X slots**

**Proposal 2: For Alt 1 using a fixed pattern of slot groups 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**
* **Y equals to 1 slot and is always the first slot within each slot group**
* **The locations of the PDCCH monitoring symbols should not be restricted**
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### R1-2103512 (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 such as per-slot, per 2-slots based monitoring should consider to be supported, and accordingly the associated BD/CCEs limit number needs to further study. **Proposal 1: For 480 and 960 kHz SCS, per-slot or per 2-slots PDCCH monitoring should be supported and further study the associated BD/CCEs limit number.**For 480 kHz and 960 kHz SCS, the maximum number of BD/CCEs per multi-slot (including 2 slots, 4 slots or 8 slots) should be defined in additional tables, it’s a new monitoring capability.**Proposal 2: For 480 and 960 kHz SCS, the maximum number BD/CCEs per-slot can be added in existing tables, and per multi-slot monitoring capability (including 2 slots, 4 slots or 8 slots) should be defined in new additional tables.** |

### R1-2103568 (NTT DOCOMO)

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| The motivation for specifying the multi-slot monitoring capability is to avoid excessive reduction of the values of PDCCH processing limits (max number of BDs/CCEs) with the time unit of slot for larger SCSs (i.e., 480 and 960 kHz). For 120 kHz SCS, we don’t see any issue for the exiting per-slot and per-span PDCCH monitoring capability. Hence, we think the new capability is not necessary for 120 kHz SCS.***Proposal 1****: The multi-slot PDCCH monitoring capability should be specified only for 480 and 960 kHz SCS and is not necessary to be specified for 120 kHz SCS.****Proposal 2****: For defining the multi-slot PDCCH monitoring capability for 480 and 960 kHz SCS, Alt.2 should be supported as the baseline.*The exact values of (X, Y) were also discussed at the last meeting and FL proposal was suggested as follows:

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| **Modified Feature Lead Proposal A1-2:**Supported value(s) X in multi-slot UE capability for PDCCH monitoring* For 480 kHz: 4 slots, for 960 kHz: 8 slots.
* FFS: if supported, additional smaller values (including 1 slot)
* Additional larger values are not supported
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We support the proposal that at least 4 slots for 480 kHz SCS and 8 slots for 960 kHz should be supported for X to achieve the same time duration as one slot of 120 kHz SCS. In addition, it should be possible to support smaller value(s) X, e.g., 1 slot, depending on the UE capability since it enables per-slot PDCCH monitoring supported in Rel-15/16 already.For Y values and its unit, we think that at most 3 symbols are sufficient unless there is any clear motivation to support larger values. If Y is defined in a unit of slot, how to define the monitoring occasion symbols in Y slots should be discussed.***Proposal 3****: At least X = [1, 4] for 480 kHz SCS and X = [1, 8] for 960 kHz SCS, and Y up to 3 symbols for both 480 and 960 kHz SCS should be supported for multi-slot monitoring capability.*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 multi-slot PDCCH monitoring is supported.** *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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## Topic A2: Search Space Enhancement

### R1-2102328 (Huawei, HiSilicon)

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| Within each slot group composed of X slots or N slots, search space should be configured at the first several slots or symbols, to make sure the allocated BD/CCEs matches the capability definition. Moreover, considering the unchanged maximum PRBs for new SCSs and number of slots scheduled by one DCI is increased, the number of UEs co-scheduled by the single DCI will be far more than that of single slot scheduling of 120 kHz, if same requirement on throughput is assumed, leading to a large requirement on PDCCH capacity. It is difficult to accommodate all PDCCHs in a single CORESET. Thus, search space of different UEs could be TDM-ed within the first several slots or symbols, as demonstrated in Figure 2 with 480 kHz as an example. Each UE is configured with a search space associated with a CORESET of two symbols (can be replaced by M symbols). The starting symbol of a search space for different UEs can be configured through *monitoringSymbolsWithinSlot* in *SearchSpace*. For example, the start symbol of PDCCH monitoring for UE i(i=0,1,2,3) is M\*mod(i,4).Figure 2. TDM-ed search space for different UE within a monitoring span***Proposal 2:*** *The time domain parameters of search space set configuration should be enhanced to adapt to the multi-slot PDCCH monitoring by** + *changing the unit of duration to multi-slot, where search space is located at the first several slots or symbols of each multi-slot within the duration*
	+ *adding new periodicities to increase the flexibility of search space set configuration*
	+ *search space of different UE are TDM-ed within the first several S slots or symbols*
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### R1-2102449 (Spreadtrum)

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| Each search space set group may be configured for either per-slot or per-span PDCCH monitoring. In order to access the unlicensed spectrum as soon as possible when the gNB passes the LBT. It is better to transmit the PDCCH frequently in the time domain. However, when the unlicensed spectrum is occupied, a sparse PDCCH monitoring occasion is beneficial to the power consumption of UE. Therefore, search space set group switching will provide more dynamic transition between per-slot and per-span PDCCH monitoring.***Proposal 6: Support a dynamic switching between single-slot and multi-slot based PDCCH monitoring capabilities for the high SCSs.*** |

### R1-2102515 (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 10: Search space configuration should be improved for 480K/960K SCS.** |

### R1-2102622 (CATT)

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| In NR, a UE monitors a set of PDCCH candidate in one or more CORESET according to corresponding search space configuration. The monitoring occasion can be configured by the following RRC parameters*.** *monitoringSlotPeriodicityAndOffset:* Used to configure the periodicity and offset for PDCCH monitoring, the unit of configuration is slot
* *duration*: Used to configure the number of consecutive slots that a *SearchSpace* lasts in every occasion.
* *monitoringSymbolsWithinSlot*: Used to configure the first symbol for each PDCCH MO within the slot. The size of this parameter is 14 bit and each bit represents a symbol in a slot. If the value of one bit is 1, the OFDM symbol corresponding to this bit is a PDCCH monitoring occasion.

For Rel-15/16, the unit of search space configuration is one slot. The parameter duration indicates the number of consecutive slots where MOs are located. The parameter *monitoringSymbolsWithinSlot* indicates the distribution of MOs within one slot. When the schedule interval is extended to multi-slot, it will be problematic to configure MOs for UE with parameter of *searchspace* defined in Rel-16. For example, the periodicity of search space configuration is 12 slots, the MOs is configured at slot #1, slot#5 and slot#9 with the 4 slots schedule interval as shown in Figure 3. The parameter of *searchspace* defined in Rel-16 cannot indicate the distribution case of MO#1 and MO#2 for UE. Thus, the parameter of *searchspace* should be redefine based on the new UE capability.Figure 3: Example for MO configuration (T\_periodicity=12 slots, k\_offset=0)When the scheduling interval is N slots, the parameter of *searchspace* can be redefined as following:* *duration*: The duration represents the number of consecutive multi-slots where MOs are located.
* *monitoringSymbolsWithinSlot*: The bitmap represents the MOs distribution within the multi-slots.

**Proposal 5：The parameter of *searchspace* should be redefine based on the new UE capability.** |

### R1-2102978 (Xiaomi)

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| Search space set group switching is introduced in R16 NR-U for power saving propose and group switching time is defined for SCS 15-60 kHz. To facilitate unlicensed band operation for NR 52.6-71GHz, group switching time should also be defined for 120/480/960kHz ***Proposal 6: Search space set group switching time***  ***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 7:*** ***New search space periodicity parameters, as well as the search space offset/duration parameters, may need to be introduced for the new SCSs.*** |

### R1-2102997 (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)*** |

### R1-2103022 (Intel)

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| 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 .**Proposal 8: 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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### R1-2103097 (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 USS 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 2.*A picture containing chart  Description automatically generated*Figure 2: Example of SSSG switching with multi-slot monitoring limitations***Proposal 8:*** *Consider the effect of the change in SCS and of MSS PDCCH monitoring on SSSG switching.* |

### R1-2103158 (Qualcomm)

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| In Proposal 2, it is proposed to assume multi-slot PDCCH monitoring as the default capability. This implies that, while the UE is monitoring common search spaces during idle/inactive mode operation or initial access procedure, multi-slot PDCCH monitoring should be applied. Further, in Proposal 7, 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 during the discussion in RAN1 #104-e, 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, two cases may be considered.**Case 1) 480 kHz and 960 kHz SCSs are only for SCells and not used for initial access related signals/channels**A candidate outcome of the on-going discussion in AI 8.2.1 is supporting 480kHz and 960kHz only for SCells. In this case, there is no need for UE to monitor CSSs on a cell with 480kHz or 960kHz SCS and the two issues are not quite relevant. Some CSSs, such as Type1 and Type3 CSS, can still be dedicatedly configured per UE, to align with USS.**Case 2) 480 kHz and 960 kHz SCSs are also for PCell**This case is relevant to the two issues raised above, and different approach 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 and slot , 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 and slot , where is the default value of X, i.e., for 480 kHz and for 960 kHz. 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 , , …, and . 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, the repetition of CSS may have additional benefit of cell coverage enhancement.**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. 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 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, or
* Active TCI states of the active BWP, which includes CSI-RSs quasi-co-located with SSBs.

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 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 8: If 480 kHz or 960 kHz is supported for initial access in the SPCell, common search space set design should be enhanced to address multi-slot-based CSS monitoring and multiplexing with USS. |

### R1-2103230 (Samsung)

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| 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, it’s obvious that the PDCCH monitoring periodicity of slots should be limited by the multi-slot span gap X, while PDCCH monitoring duration of slots should be limited by multi-slot span, Y. Therefore, a limitation on search space set configuration should be supported, such that PDCCH monitoring periodicity is not smaller than multi-slot span gap, i.e. , while PDCCH monitoring duration is not larger than multi-slot span, i.e. 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 , where and 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 . 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), introduce limitations on search space set configurations, including*** **PDCCH monitoring periodicity, e.g. and**
* **PDCCH monitoring duration,**
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### R1-2103488 (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 , the duration *TS* is a integral multiple of X slots (X slots consists a slot group), or is a integral multiple of slot groups, i.e. 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 two configuration types in a slot group. In configuration 2, PDCCH MO is configured in the first slot within the slot group.(a) Configuration 1(b) Configuration 2**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 3: PDCCH monitoring periodicity 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.** |

### R1-2103512 (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 the monitoring capability before and after the switch is the same, both are per-slot based. While for 480 kHz and 960 kHz SCS, 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, need to consider if current SSSG switching is suitable for the PDCCH monitoring based on per multi-slot. **Proposal 3: For operation in unlicensed band with 480 kHz and 960 kHz SCS, should discuss if current SSSG switching is suitable for per multi-slot based monitoring.** Currently,, which means the SSSG switching time, is defined for SCS configuration = 0,1,2. For new SCSs adopted beyond 52.6GHz, to operate in unlicensed band, SSSG switching time should be defined and added in the table 10.4-1 of TS 38.213[2]. **Proposal 4: Search space set group switching time 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, which monitoring capability is the reference, per slot or per multi-slot? It should be discussed.**Proposal 5: For 480 kHz and 960 kHz SCS, which monitoring capability is the reference to estimate the search space set group switching time should be discussed.** |

## Topic A3: BD Dropping

### R1-2102449 (Spreadtrum)

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| When multi-slot PDCCH monitoring is introduced, there will be a related problem of PDCCH overbooking. In NR Rel-15, the maximum number of BDS/CCE in a slot is determined based on the capability of the UE. 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 number. However, for a SCell, the gNB should guarantee that numbers of monitored PDCCH candidates and non-overlapped CCEs per slot or per span that do not exceed the corresponding maximum numbers per slot or per span, respectively.The similar rules could be extended to multi-slot span. For PCell or PSCell, it is allowed that the numbers of monitored PDCCH candidates and non-overlapped CCEs in a multi-slot span by the configuration of SS set(s) that exceed the corresponding maximum numbers. Define certain dropping rules, so that the actual number in the multi-slots span does not exceed the corresponding maximum number.***Proposal 2: PDCCH overbooking per-slot in NR Rel-15 can reused in multi-slot span for beyond 52.6GHz.***In Rel-15, there is no dropping method applied to the CSS set for PCell/PSCell. Therefore, the similar rule can be reused in multi-slot spans. When handling USS sets, if the total number of BDs/CCEs exceeds the corresponding maximum number, the same principle as Rel-15 can be reused, namely dropping USS sets with high index of SS sets. In addition, the PDCCH MOs of the USS set may be configured in multiple slots in the multi-slot span, the USS set in all the multiple slots is dropped slot by slot. Considering the different number of USS in each slot, there are certain rules for dropping one slot, such as dropping slot from back to front or dropping slot with the largest number of USS sets. In addition, dropping USS set should be based on the set ID. Small ID preferentially perform PDCCH monitoring, and larger ID perform dropping.***Proposal 3: It is expected there is no dropping for CSS sets for PCell/PSCell in PDCCH overbooking.******Proposal 4: To handling USS dropping in PDCCH overbooking in the multi-slot span**** ***If the PDCCH MOs of a USS set are configured in multiple slots in the multi-slot span, the USS set in all the multiple slots is dropped based on the certain order of the slots.***
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### R1-2103022 (Intel)

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| In NR Rel-15, according 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 5: In each group of X slots,*** **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 6: 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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### R1-2103230 (Samsung)

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| Currently, NR supports PDCCH candidates allocation/dropping per slot or span in a slot as specified in TS38.213 [2]. Given the PDCCH allocation/dropping rule, a UE determines PDCCH candidates to monitor based on the configuration of search space set for each PDCCH monitoring slot or span within a slot. When configured PDCCH candidates or non-overlapped CCEs exceeds BD or CCE limit, UE will drop remaining search space set with higher index. **Figure 2: Illustrating of PDCCH candidates allocation with combination (X = 4, Y =2).**For multi-slot span based PDCCH monitoring as illustrated in Figure 2, a span for PDCCH monitoring can be over multiple slots based on combination (X, Y). The PDCCH candidates allocation/dropping rule from Rel-16 should be extended to support PDCCH monitoring in a multi-slot span. Also, the PDCCH candidates allocation/dropping rule per multi-slot should be applicable to a CA mode at the high carrier frequency. **Proposal 7: Support PDCCH candidates allocation/dropping per a span over multiple slots for a single serving cell and CA.** |

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

### R1-2102386 (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 3: CORESET configuration with less RBs and more symbols for 480kHz and 960kHz SCS should be supported.**  |

### R1-2102559 (Nokia, Nokia Shanghai Bell)

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| There are two basic solutions shown in Figure 2 to balance the PDCCH coverage with the repeated PDSCH: * Option 1: Mixed numerology between PDCCH and PDSCH: use a lower SCS, such as 120 kHz, for PDCCH. This is feasible from phase noise point of view and would minimize changes to PDCCH. On the other hand, this is not allowed in Rel. 15/16 NR.
* Option 2: Increased number of symbols available for PDCCH: This can be done either by defining a CORESET with increased length, or by means of CORESET repetition (of existing length).

We think that these two solutions need to be studied, and at least one solution for improved PDCCH coverage needs to be supported.   ***Proposal 8:****Support improved PDCCH coverage for the cases of high SCS* (i.e. Y>3)Figure 2. Candidate options to improve PDCCH coverage. |

### R1-2102773 (Futurewei)

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| The maximum number of symbols available for a PDCCH occasion (CORESET) supported in NR is 3 symbols [3], TS 38.211, Clause 7.3.2.2. Moreover, in Beyond 52 WID [1] was explicitly mentioned that the increased UL coverage is not part of WID scope. Therefore, we have the following proposals:**Proposal 5: For Beyond 52.6 GHz band, Rel-17 does not need to improve coverage or reliability of PDCCH compared to Rel-15/16 solutions.** |

### R1-2102978 (Xiaomi)

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| Similarly, with CORESET duration larger than 3 symbols, as proposed by some companies in last meeting, PDSCH/PUSCH processing timeline will also be impacted, since potentially UE has to spend more time on PDCCH decoding. ***Proposal 5: Impacts on PDSCH/PUSCH processing time (N1/N2) may need be considered if defining CORESET duration larger than 3 symbols.*** |

### R1-2102997 (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.*** |

### R1-2103295 (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 benefits evaluation of flexible scheduling further.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. 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 1: PDCCH monitoring with a maximum duration of more than 3 OFDM symbols per PDCCH monitoring occasion is more suitable.** |

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

### R1-2102997 (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*** |

### R1-2103412 (Convida Wireless)

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| Single DCI can schedule multiple PDSCHs as shown in Figure 2. In Figure 2, a DCI schedule multiple (e.g., two) PDSCHs. In this example shown in Figure 2, the PDCCH monitoring frequency is reduced, thus it can reduce PDCCH decoding efforts for a UE. However, some DCI field like HARQ process number, TB indication, New data indicator and Redundancy version, etc. may not be shared for each scheduled PDSCH. If the single-to-multiple scheduling DCI format (e.g., DCI format 1\_1) with the DCI size is large (e.g., DCI > 120 bits) which it requires a larger CCE aggregation level, then PDCCH blockage may become higher thus degrading the scheduling performance. Therefore, PDCCH blockage needs to be avoided for single-to-multiple scheduling PDSCHs scenario.  **Figure 2**: Single DCI schedule multiple (e.g., two) PDSCHs.***Proposal 3. To avoid PDCCH blockage issue when single DCI scheduling multiple PDSCHs, the size of DCI format should be studied.***  |

### R1-2103568 (NTT DOCOMO)

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| In 8.2.5. sub-agenda item, multi-PDSCH/PUSCH scheduling with single DCI is now discussed. If several DCI fields, such as HARQ process number, new data indicator or redundancy version, are indicated for each scheduled PDSCH/PUSCH separately, the DCI size may increase and only higher aggregation level (e.g., 4, 8, 16) can be valid to ensure the reliability. If aggregation level is limited, UE may reduce the BD burden. Thus if the DCI size is increased and /or new DCI format is introduced for multi-PDSCH/PUSCH scheduling, it might be beneficial to make aggregation level for the DCI formats which schedule multi-PDSCH/PUSCH and other DCI formats configurable separately.***Proposal 5****: The DCI format for multi-PDSCH/PUSCH scheduling specific restriction on aggregation level might be beneficial if the size of DCI increases for multi-PDSCH/PUSCH scheduling.* |

## Topic C: Multi-Beam Aspects

### R1-2102559 (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 9:****Changes to DCI format 2\_0 may be beneficial for at least unlicensed 60GHz NR operation.*  |

### R1-2102997 (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 signalling 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. That is to say, 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.*** |

### R1-2103097 (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 9:*** *Consider enhancement of DCI 2-0 transmission to signal COT duration and SS adaptation at the beginning of the COT.* |

### R1-2103230 (Samsung)

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| Moreover, for 60 GHz unlicensed band, the 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, it is natural to support the feature of indicating COT, available RB set, and search space group switching to 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. We believe generalizing the feature to a beam-specific manner is beneficial to address different interference situation along beam directions, and compatible with the intention to introduce directional LBT. **Proposal 8: Support indicating COT, available RB set, and search space group switching in a beam-specific manner for 60 GHz licensed band.** |

### R1-2103340 (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 FR-X 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 #5: Consider per beam indication of available RB set, CO duration, and/or SS set switching by using DCI format 2\_0.** |

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

### R1-2102328 (Huawei, HiSilicon)

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| For cross-carrier scheduling, a gap in unit of PDCCH symbols between PDSCH and PDCCH are defined in FR2 for PDSCH resource allocation, which is associated with the SCS of PDCCH as shown in Table 5. All of them have close relation with PDCCH processing time and time duration of a PDCCH symbol. So the detailed values of these parameters for new SCSs should be defined too. And scaled values for *Npdsch* when the SCSs of PDCCH and PDSCH are different can be applied for the new SCSs as a start point, which are 56 and 112 for 480 kHz and 960 kHz respectively. **Table 5. *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:*** *Scaled value based on the ratio of PDCCH SCS to 120 kHz can be defined for the gap between PDSCH and PDCCH as a start point, when the SCSs of PDSCH and PDCCH are different.* |

### R1-2102449 (Spreadtrum)

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| Cross-carrier scheduling is useful for NR. Therefore, it is expected that cross-carrier scheduling between serving cells using SCS 120/480/960kHz can be supported. In the CA case, due to different SCS, some cells are based on per-slot PDCCH monitoring, some ones are based on multi-slot PDCCH monitoring, and some are based on per-span PDCCH monitoring, even the number of slot in the multi-slot is not same in different cells. One discussion point is how to determine the number of monitored PDCCH candidates and non-overlapping CCE for different cells combine in the CA scenario. In addition, another point of discussion is carrier aggregation (CA) between cells with frequencies of 52.6-71GHz and FR2 or even FR1 cells. Such CA scenario could be supported, especially considering PCells below 52.6-71GHz are more appropriate for coverage/robustness.***Proposal 7: The allocation of BDs/CCEs need further study in different cells for CA case.******Proposal 8: Carrier aggregation between a cell with a frequency of 52.6-71GHz and a cell in FR2 or even FR1 could be supported.*** |

### R1-2102515 (vivo)

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| Third, for multi-cell operation scenario, the situation becomes more complex by introducing such multi-slot span-based BD/CCE budget definition. For Case B in NR FR1&FR2 operation, the scheduling cells with the same SCS are categorized together to meet a total limit. However, for one UE operation in both FR1&FR2 and 52.6-71GHz (e.g. CA deployment), BD/CCE budget is applied per slot level in some scheduling cells while per multi-slot span in other scheduling cells. How to category the scheduling cells to be restricted with a total BD/CCE limit needs to be considered taking into account the above hybrid scenario. Particularly, although the SCS and BD/CCE limit granularity in terms of slot number are different for different scheduling cells, the absolute time domain granularity may be the same, e.g. cell A with 120KHz SCS and slot level BD/CCE budget and cell B with 480KHz SCS and BD/CCE budget per 4 slots. **Proposal 8: For multi-cell operation, the categorization of scheduling cells to be applied with a total BD/CCE limit should consider PDCCH SCS and BD/CCE limit granularity jointly.** |

### R1-2103022 (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 9: 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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### R1-2103097 (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 5****: 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 6:*** *RAN1 should study the effect of a large differential between the SCSs of the carriers involved in the cross carrier scheduling procedure.****Proposal 7:*** *for cross carrier scheduling, the max number of CCs that can be scheduled from a single CC is reported as UE capability.* |

### R1-2103158 (Qualcomm)

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| 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 9: 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. |

### R1-2103340 (LG)

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| Considering the efficient coexistence with Wi-Fi operating with nominal channel bandwidth of 2.16 GHz, NR in unlicensed FR-X 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 FR-X band.**Proposal #6: Carrier-group based GC-PDCCH configuration for unlicensed FR-X band may be beneficial with respect to signalling efficiency.** |

### R1-2103488 (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

|  |  |
| --- | --- |
| ***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.** |

## Topic E: Other

### R1-2103158 (Qualcomm)

|  |
| --- |
| The discussion on the new PDCCH monitoring capability in Section 2.1 is focused on reducing the density of PDCCH MOs. Although this alleviates the overhead of PDCCH processing for high SCSs with short slot lengths, the flexibility and latency of scheduling would be adversely affected by the sparsity of the MOs. For example, if a new traffic arrives at a time instance between two PDCCH MOs, actual scheduling for the traffic is delayed to the next MO. Although multi-PDSCH/PUSCH scheduling, if it is jointly be supported with the multi-slot PDCCH monitoring capability, can partially compensate the scheduling flexibility issue, it cannot fully address the latency issue.As an alternative, DCI transmission on PDSCH may be considered. In principle, this corresponds to the DL counterpart of UCI reporting on PUSCH. In other words, DCI(s) may be piggybacked on a PDSCH, which is either dynamically or semi-persistently scheduled. At a glance, it also seems to have some similarities with the two-stage sidelink control information design. However, while the 2nd stage SCI delivers supplementary information for the PSSCH scheduled by the 1st stage SCI, the piggybacked DCI(s) can deliver DL/UL scheduling grants for later slots. Thus, along with a very sparse PDCCH MO configuration, it can provide additional opportunities for DCI transmission, addressing both the scheduling flexibility and latency issues. The piggybacked DCI(s) may share the same beam, precoding, and DMRS with the DL-SCH data on the same PDSCH. Further, the payload size (or format) and mapping of the piggybacked DCI(s) should be indicated by the scheduling DCI (transmitted either on a PDCCH or on another PDSCH) of the PDSCH, so that the DL-SCH data can perform rate matching, and no blind decoding for the DCI format would be required. In Figure 3, PDSCH scheduling by a piggybacked DCI is conceptually illustrated.Observation 3: Along with the multi-slot PDCCH monitoring capability, DCI piggyback, as well as multi-PDSCH/PUSCH scheduling, may be considered to compensate the loss of scheduling flexibility and latency.Figure 3: Sparse PDCCH monitoring occasions with DCI transmission on PDSCH. |

# List of submitted TDocs

The following TDocs have been used to compile above summary:

**R1-2102328 Enhancement on PDCCH monitoring Huawei, HiSilicon**

**R1-2102386 Discussion on PDCCH monitoring OPPO**

**R1-2102449 Discussion on PDCCH monitoring enhancement for NR beyond 52.6 GHz Spreadtrum Communications**

**R1-2102515 Discussions on PDCCH monitoring enhancements for NR operation from 52.6GHz to 71GHz vivo**

**R1-2102559 PDCCH monitoring enhancements Nokia, Nokia Shanghai Bell**

**R1-2102622 PDCCH monitoring enhancements for up to 71GHz operation CATT**

**R1-2102704 PDCCH monitoring enhancement for 52.6-71 GHz NR operation MediaTek Inc.**

**R1-2102773 Further considerations on PDCCH monitoring enhancements FUTUREWEI**

**R1-2102789 PDCCH Monitoring Enhancements Ericsson**

**R1-2102809 PDCCH monitoring enhancement for NR from 52.6GHz to 71GHz Panasonic**

**R1-2102978 PDCCH monitoring enhancement for NR 52.6-71GHz Xiaomi**

**R1-2102997 PDCCH monitoring enhancements for NR from 52.6 GHz to 71GHz Lenovo, Motorola Mobility**

**R1-2103022 Discussion on PDCCH monitoring enhancements for extending NR up to 71 GHz Intel Corporation**

**R1-2103097 Discussion on PDCCH Enhancements for above 52.6 GHz Apple**

**R1-2103158 PDCCH monitoring enhancements for NR in 52.6 to 71GHz band Qualcomm Incorporated**

**R1-2103230 PDCCH monitoring enhancements for NR from 52.6 GHz to 71 GHz Samsung**

**R1-2103295 PDCCH enhancement for NR from 52.6GHz to 71GHz Sony**

**R1-2103340 PDCCH monitoring enhancements to support NR above 52.6 GHz LG Electronics**

**R1-2103412 PDCCH Monitoring Considerations for Supporting NR from 52.6 GHz to 71 GHz Convida Wireless**

**R1-2103449 Discussions on PDCCH monitoring enhancements InterDigital, Inc.**

**R1-2103488 Discussion on the PDCCH monitoring enhancements for 52.6 to 71GHz ZTE, Sanechips**

**R1-2103512 Discussion on PDCCH monitoring enhancements supporting NR from 52.6GHz to 71 GHz NEC**

**R1-2103568 PDCCH monitoring enhancements for NR from 52.6 to 71 GHz NTT DOCOMO, INC.**