**3GPP TSG RAN WG1 Meeting #103-e R1-20XXXXX**

**e-Meeting, October 26th – November 13th, 2020**

**Source: Moderator (Lenovo)**

**Title: Feature lead summary#3 on multi-cell scheduling via a single DCI**

**Agenda item:** **8.13.2**

**Document for:** **Discussion and Decision**

# Introduction

This document summarizes the contributions submitted under the “**Multi-cell PDSCH scheduling via a single DCI**” agenda item of the Rel-17 work item on “Dynamic spectrum sharing (DSS)”.

The revised DSS WID [1] contains the following objective related to this agenda item:

|  |
| --- |
| This work item is limited to FR1, and includes the following objectives for NR Dynamic Spectrum Sharing (DSS):* PDCCH enhancements for cross-carrier scheduling including [RAN1, RAN2]
	+ PDCCH of SCell scheduling PDSCH or PUSCH on P(S)Cell
	+ Study, and if agreed specify PDCCH of P(S)Cell/SCell scheduling PDSCH on multiple cells using a single DCI
		- The number of cells can be scheduled at once is limited to 2
		- The increase in DCI size should be minimized
* Note: The total PDCCH blind decoding budget should not be changed as a result of this work
* Note: These enhancements are not specific to DSS and are generally applicable to cross-carrier scheduling in carrier aggregation
 |

In RAN1 #102-e meeting, the following agreements under the “Multi-cell PDSCH scheduling via a single DCI” agenda item of was reached:

|  |
| --- |
| Agreements:* For the study on single DCI scheduling PDSCH on two cells
	+ Consider the following scenarios as baseline for evaluation
		- UE configured with Inter-band CA with PCell and an SCell
			* PCell for the UE is operated on a DSS carrier (i.e., same carrier is also used for serving LTE users)
			* Case 1: Different SCS for PCell and SCell
			* Case 2: Same SCS for PCell and SCell
	+ Additional scenarios can also be evaluated, e.g. as below
		- Intra-band CA case with multiple serving cells having same SCS (all cells operated on non DSS carriers)
		- Inter-band CA case with PCell and more than one SCell (at least the SCells are operated on non DSS carriers)
		- Note: other combinations not precluded
* Note: Further details of evaluation framework (including carrier BW, slot format etc.) to be discussed in next stage
 |

In Section 2, candidate schemes for multi-cell PDSCH scheduling, evaluation assumptions as well as evaluation results are summarized. Companies’ views on whether to support this feature are also summarized at the end of Section 2. Based on majority companies’ views, some proposals are listed for discussion purpose.

In Section 3, the standard impacts on DCI format design and HARQ-ACK codebook determination are summarized. Several open questions are listed in this section and companies are encouraged to provide their inputs for each open question.

In Section 4, miscellaneous issues are listed which can be treated in low priority.

# Summary of contributions

The section summarises key proposals and observations from submitted contributions. A few proposals and questions to resolve based on the general leaning of the companies are captured below.

## Candidate schemes for multi-cell PDSCH scheduling

Regarding number of TBs carried by the multiple PDSCHs scheduled by a single DCI, many companies show their views in below contributions. Based on the summary, most companies think the scheduled multiple PDSCHs carrying a single TB will lead to significant standard impact on CA framework, HARQ and protocol layer design and propose the scheduled multiple PDSCHs carry different TBs.

For two PDSCHs on two carriers scheduled by a single DCI, companies’ views on same or different TBs are summarized below:

|  |  |
| --- | --- |
| Company | Key Proposals/Observations |
| Huawei, HiSilicon | *Scheme 1: one DCI schedules two PDSCHs over two cells* *Scheme 2: one DCI schedules one PDSCH over two cells* |
| vivo | *Proposal 2. The study focuses on the case that the two PDSCH jointly scheduled by a single DCI correspond to different TBs.* |
| CATT | *Proposal 2: Two TBs should be scheduled separately on different serving cells for multi-cell PDSCH scheduling via a single DCI.* |
| Spreadtrum | *Clarify which the scheme is in the scope.* |
| ETRI | *Observation 4: For multi-cell joint scheduling, the principle that one PDSCH does not span multiple cells can be kept to minimize the workload.* |
| Lenovo, Motorola Mobility | *Observation 5: Scheduling a single TB on two carriers is not in the scope of Rel-17 DSS.* |
| NTT DOCOMO | *Observation 11:* * *Whether the same TB and/or different TBs is/are scheduled on multiple cells can be considered.*
 |

Based on the majority companies’ views, below proposal can be discussed:

FL proposal#1:

For Rel-17 DSS, when multiple PDSCHs are scheduled by a single DCI, the multiple PDSCHs carry different TBs.

Companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **View** |
| Nokia | Support |
| Apple | Support, even though we do not see the need to even allow single DCI to schedule two PDSCH in different CCsIn the current CA, we do not have HARQ process sharing between two CCs, so different TB is a nature baseline. |
| InterDigital | Support |
| Charter Communications | We think both a single TB and two TBs can be scheduled. |
| Huawei, HiSi | Open to either with benefits. |
| Spreadtrum | Support |
| vivo | Agree.Support of the scheduling of a same TB on two cells will involve a lot of RAN2 spec change which is undesirable. |
| Qualcomm | Agree. It would be fair to say “when and if multiple PDSCHs are scheduled by a single DCI, …” |
| Lenovo, Motorola Mobility | Support |
| Moderator | @Qualcomm: updated proposal 1 as suggested. |
| CATT | Support |
| OPPO | Open to either. |

### Updated proposals

FL proposal#1:

For Rel-17 DSS, when and if multiple PDSCHs are scheduled by a single DCI, the multiple PDSCHs carry different TBs.

Companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **View** |
| ZTE | It seems that we may need to first determine whether to support one PDCCH schedules two PDCHs on two carriers or not. If supported, then we are fine with the above proposal. |
| NTT DOCOMO | OK to support. |
| CATT | Support |
| Intel | Support, maybe better to also emphasis that a TB carried by a PDSCH on a carrier is associated with a HARQ process of the carrier |
| vivo | Support |
| OPPO | Open to either. |
| Ericsson | We prefer below formulation given this is under study“For the study on using single DCI for scheduling multiple PDSCHs, it is assumed for the evaluations that the multiple PDSCHs carry different TBs.” |
| Samsung | Support the suggestion by Ericsson. |

## 1st round of discussion on evaluation

### Evaluation assumptions:

|  |  |
| --- | --- |
| **Parameters** | **Values** |
| Scenario | Inter-band CA Intra-band CA |
| Bandwidth  | PCell: 10/20MHzSCell: 10/20/100MHz |
| Simulation cases | Case 1: two DCIs with baseline payload size schedule two PDSCHs on two carriers, respectivelyCase 2: a single DCI with larger payload size schedules two PDSCHs on two carriers |
| DCI payload size (excluding CRC) | Single PDSCH scheduling: 60 bitsMulti-cell PDSCH scheduling: 72/84/96/108/120 bits |
| Evaluation metrics | PDCCH blocking probability, CCE saving ratio, PDSCH throughput improvement, UE power saving |

### PDCCH blocking probability

Since NR transmission can’t use REs occupied by LTE CRS and LTE PDCCH region on a carrier shared with LTE, NR PDCCH capacity on this shared carrier is limited especially when this shared carrier is configured as PCell for NR. The insufficient NR PDCCH capacity on the NR PCell will lead to system performance degradation especially when more NR devices are camped on the NR PCell.

Supporting cross-carrier scheduling from NR SCell to NR PCell results in requiring additional PDCCH capacity of the scheduling SCell due to the need for self-scheduling on the SCell as well cross-carrier scheduling on the (shared carrier) PCell. Thus, the PDCCH capacity on the SCell may be a potential issue when a large number of UEs are configured on the SCell or the SCell is not configured with a large enough bandwidth. This issue can be addressed by allowing a single DCI on one carrier to schedule PDSCHs on two carriers. In detail, two PDSCHs on two carriers are scheduled by a single DCI format, which saves PDCCH scheduling overhead compared to scheduling two PDSCHs on two carriers by two DCI formats. Since the number of required PDCCHs is reduced, many companies think the PDCCH blocking probability can be alleviated.

On the other hand, in inter-band CA, the payload size of the single DCI increases significantly when it schedules two PDSCHs on two carriers due to different channel conditions. Some companies think it may increase PDCCH blocking rate since a high AL is needed for this DCI. For intra-band CA, some companies think the payload size of the single DCI does not increase significantly by sharing many fields of the DCI.

Regarding PDCCH blocking probability, companies’ views are summarized as below:

|  |  |
| --- | --- |
| Company | Key Proposals/Observations |
| Huawei, HiSilicon | *Observation 1: For 700MHz + 800MHz scenario, one PDCCH scheduling PDSCH(s) on two cells can achieve up to 23%~50% average CCE saving ratio.**Observation 2: For 800MHz + 1800MHz scenario, one PDCCH scheduling PDSCH(s) on two cells can achieve up to 18.2%~50.4% average CCE saving ratio.**Observation 3: For 1800MHz + 3500MHz scenario, one PDCCH scheduling PDSCH(s) on two cells can achieve up to 12.8%~43% average CCE saving ratio.**Observation 4: Single DCI scheduling PDSCH(s) on two cells can reduce the PDCCH blocking probability obviously* |
| Vivo | *Observation 1. Compared with using single DCI, a joint DCI scheduling two PDSCHs on two cells brings around 44.87% and 44.51% CCE saving gain if the joint DCI size (excluding CRC) is less than 60% of the total size of two single DCI at 2.6GHz and 4GHz respectively, and the gain becomes less significant if the compression rate of joint DCI size increases.**Observation 3. Compared with using single DCI, a joint DCI scheduling two PDSCHs on two cells brings around 13.95% or 13.57% reduction in PDCCH blocking rate if the joint DCI size (excluding CRC) is less than 60% of the total size of two single DCI at 2.6GHz and 4GHz respectively, and the reduction rate becomes less significant if the compression rate of joint DCI size increases.**Observation 4. PDCCH blocking rate reduction by joint DCI scheduling can only bring a marginal <=3.31% throughput gain in practical scenarios at 4GHz.* |
| CATT | *Multi-cell scheduling via a single DCI can significantly reduce the possibility of PDCCH blocking. Consequently, the PDCCH capacity increase remarkably.**The benefits harvested from DSS-DCI in terms of PDCCH capacity is impacted on the DCI design, i.e. the smaller size the DSS-DCI has, the more significant benefit can be got.* |
| OPPO | *Observation 2: The smaller DCI size increases, the more UEs achieve gain from one-to-two scheduling.* |
| MediaTek | *Observation 2: Around 30% DCI overhead reduction is observed for Rel-17 DCI aggregation for x-carrier scheduling, assuming that the aggregated DCI size is scaled with the number of scheduled cells.* |
| Lenovo, Motorola Mobility | *Observation 1: Compared to a single DCI scheduling a single PDSCH, the payload size of a single DCI scheduling two PDSCHs on two carriers needs to be increased about 21~54%.* *Observation 2: Compared to two DCIs scheduling two PDSCHs, the payload size of a single DCI scheduling two PDSCHs on two carriers can save 23% ~ 39% overhead.* |
| Intel | *Observation 2: Based on the required SINR values and geometry curves obtained by LLS and SLS** *The ratio of CCE saving is about 20~40%;*
* *The reduced PDCCH blocking ratio is observed.*
 |
| Samsung | Observation 4: *Coverage and relative BLER comparisons for DCI format C2 further worsen for operation under less favorable conditions such as with some correlation or blockage of UE receiver antennas or for 2 UE receiver antennas.* Observation 5: *For DSS, a maximum gain in resources per slot from scheduling PDSCH on 2 cells using a single DCI format is ~0.35% for a BWP of 20 MHz and ~0.07% for a BWP of 100 MHz on the scheduling cell.* |
| Nokia, NSB | *Observation 1: Two-cell DCI format reduces overhead by at least 24 CRC bits, and if single DCI field applies to both cells (at least for HARQ-related parameters), further significant PDCCH overhead reduction is expected.**Observation 6:*1. *A 120 bits (>106bits) PDCCH payload does not fit anymore to 1CCE, this means that for 50-70% users, aggregation level must be doubled. For the AL>2, the 120bit PDCCH payload probability is not anymore significantly increased compared to 80 and 100bit, and could be also compensated by increasing PDCCH TX power.*
2. *When comparing 80bit and 100bits PDCCH payload, the AL probability is similar*
 |
| InterDigital | *Observation 2:**PDCCH blocking probability and CCE utilization can be reduced by using a single DCI scheduling PDSCH on two cells.* |
| DOCOMO | *Observation 1:** *PDCCH of P(S)Cell/SCell scheduling PDSCH on multiple cells using a single DCI can improve PDCCH resource efficiency.*
 |
| Ericsson | Initial evaluations indicate that DCI scheduling PDSCH on two cells (mc-DCI) provides no/marginal performance gains. |
| Qualcomm | *Observation 1: The gain from multi-cell PDSCH scheduling compared to single-cell PDSCH scheduling in inter-band CA for DSS scenario is mainly comes from the omission of 24-bit CRC. In intra-band CA scenario, higher gain would be achievable by compressing some DCI fields.* |

### PDSCH throughput improvement

Based on Rel-15 NR CORESET design principle, the unused control resource REs can be scheduled for PDSCH transmission, thus some companies observed PDSCH throughput improvement due to the reduction of PDCCH overhead.

However, some companies observed PDSCH throughput loss due to the inappropriate scheduling parameters that have to be shared between the two carriers even though PDCCH blocking probability is decreased.

Regarding PDSCH throughput improvement, companies’ views are summarized as below:

|  |  |
| --- | --- |
| Company | Key Proposals/Observations |
| Huawei, HiSilicon | *Observation 5: For two carriers of 10MHz @ 700MHz&800MHz frequency with or without DSS, when the traffic load is high, one PDCCH scheduling PDSCH(s) on two carriers can achieve 7.2% to 15% throughput gain.*  |
| Vivo | *Observation 2. CCE saving by joint DCI scheduling can bring up to around 6.41% throughput gain if the PDSCH can rate match around PDCCH.* |
| OPPO | *Observation 1: One-to-two scheduling has 13.5% throughput gain due to PDCCH overhead reduction.* |
| ZTE | *Observation 2:* *For Case B (most of the DCI fields are separate indicated for two carriers), the cell throughput performance is almost the same as the baseline and the gain of PDCCH blocking rate is marginal.**For Case C (most of the DCI fields are shared between two carriers), the cell throughput performance is decreased by 13~16% compared with the baseline though the PDCCH blocking rate is decreased.* |
| Samsung | Observation 4: *Coverage and relative BLER comparisons for DCI format C2 further worsen for operation under less favorable conditions such as with some correlation or blockage of UE receiver antennas or for 2 UE receiver antennas.* Observation 5: *For DSS, a maximum gain in resources per slot from scheduling PDSCH on 2 cells using a single DCI format is ~0.35% for a BWP of 20 MHz and ~0.07% for a BWP of 100 MHz on the scheduling cell.* |

### UE blind detection reduction and power saving

Using a single DCI format scheduling two PDSCHs on two carriers can save UE’s power consumption since UE needs to monitor the DCI in the search space of only one carrier where the DCI format is transmitted. This is especially true when the scheduling cell is configured with small bandwidth and the scheduled cell has ultra-wide carrier.

Regarding UE power saving, companies’ views are summarized as below:

|  |  |
| --- | --- |
| Company | Key Proposals/Observations |
| Huawei, HiSilicon | *Observation 10: A single PDCCH scheduling PDSCH over two cells can save up to 6.67%~15% power consumption comparing with two separate PDCCHs for scheduling.* |
| MediaTek | *Observation 3: There is 50% and 15% reduction are observed for UE blind decoding complexity and power consumption, respectively.* |
| Charter Communications | *Observation 1: The ability to schedule PDSCH on multiple cells using a single DCI will help reduce UE power consumption when operating with ultra-wide carriers, for e.g., NR beyond 52.6 GHz.* |
| Lenovo, Motorola Mobility | *Observation 3: Using single DCI scheduling two PDSCHs on two carriers can save UE’s power consumption.*  |
| Nokia, NSB | *Observation 2: Two-cell DCI format may reduce UEs monitoring burden as UE needs to monitor search-space set(s) of only single scheduling cell compared to R16, given that design is based on DCI format 1\_1.* |

### Preliminary observations

Preliminary observations on PDCCH blocking probability using a single DCI to schedule multiple PDSCHs on multiple carriers are summarized below:

* 14 companies [Huawei, HiSilicon, vivo, CATT, OPPO, MediaTek, Lenovo, Motorola Mobility, Intel, Nokia, NSB, InterDigital, DOCOMO, Qualcomm] observed decreased PDCCH blocking probability or reduced CCE consumptions.
* 3 companies [ZTE, Samsung, Ericsson] observed marginal performance gain in PDCCH blocking.

Preliminary observations on PDSCH throughput improvement by scheduling unused control resource REs for PDSCH transmission are summarized below:

* 4 companies [Huawei, HiSilicon, vivo, OPPO] observed about 6~15% performance gain.
* 1 company [ZTE] observed 13~16% performance loss due to shared scheduling information for the two carriers.

Preliminary observations on UE blind decoding reduction and power saving are summarized below:

* 8 companies [Huawei, HiSilicon, MediaTek, Charter Communications, Lenovo, Motorola Mobility, Nokia, NSB] think multi-cell scheduling by a single DCI can save UE power.

### Whether to support multi-cell PDSCH scheduling by single DCI?

Regarding whether to support multi-cell PDSCH scheduling by a single DCI, below companies show clear views which are summarized in below table.

**Company views:**

|  |  |
| --- | --- |
| **Company** | **Key Proposals/Observations** |
| CATT | Proposal 1: Multi-cell PDSCH scheduling via a single DCI should be further studied considering it can bring significant benefits in terms of PDCCH capacity, PDSCH throughput and network flexibility. |
| Vivo | Observation 1. Compared with using single DCI, a joint DCI scheduling two PDSCHs on two cells brings around 44.87% and 44.51% CCE saving gain if the joint DCI size (excluding CRC) is less than 60% of the total size of two single DCI at 2.6GHz and 4GHz respectively, and the gain becomes less significant if the compression rate of joint DCI size increases. |
| Spreadtrum | Support multi-cell PDSCH scheduling via a single DCI. |
| ASUSTeK | Proposal 1: NR DSS supports PDCCH scheduling PDSCHs on two cells using a single DCI.  |
| Samsung | Proposal: A DCI format that schedules PDSCH receptions on two cells is not introduced. |
| Apple | Proposal 1: We do not observe enough justification and motivation to allow single DCI to schedule PDSCH on multiple cells.  |
| ZTE | Proposal 1: RAN1 further discusses the necessity, gain, open issues and possibility of timely completion of single DCI scheduling two PDSCHs on two carriers. |
| Charter Communications | Proposal 1: Consider enhanced multi-carrier operation where a single DCI can schedule PDSCH on two non-DSS cells with the same SCS, including SCells with a dormant BWP, for energy-efficient and low-latency NR performance. |
| Lenovo, Motorola Mobility | Proposal 1: Support using a single DCI to schedule two PDSCHs on two carriers. |
| MediaTek | Proposal 4: Support DCI aggregation for cross-carrier scheduling in Rel-17 DSS.* FFS whether DCI aggregation for cross-carrier scheduling is 1-stage or 2-stage
 |
| Nokia, NSB | Proposal 1: Support multi-cell DCI in R17, focus on multiple SCell (2 or more) with the same/similar carrier size and SCS first. Strive to keep DCI format 1\_1 payload <106bits (including CRC). |
| InterDigital | Proposal 1: Support a single DCI to schedule two PDSCH in different cells. |

So far, 10 companies [CATT, Spreadtrum, ASUSTeK, Charter Communications, MediaTek, Lenovo, Motorola Mobility, Nokia, NSB, InterDigital] clearly propose to support such multi-carrier scheduling. 2 companies [Samsung, Apple] suggests not to introduce this feature in Rel-17 DSS.

Based on majority companies’ views, below proposal is made:

FL Proposal#2:

* Support using a single DCI to schedule two PDSCHs on two carriers.

Companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **View** |
| Nokia | Support |
| Apple | We do not see the need.  |
| Samsung | Do not agree with the proposal.The WID mentions “Study, and if agreed specify PDCCH of P(S)Cell/SCell scheduling PDSCH on multiple cells using a single DCI”. A statement such as “X companies support, Y companies do not support, and X > Y” is not any sort of study or an analysis for benefits/drawbacks/trade-offs of the proposal. |
| InterDigital | Support |
| Charter Communications | Support |
| Huawei, HiSi | Support the proposal and Ok with continuing some discussion per SS comment. We think the FL proposal is naturally to collect companies view based on the presented study of contributions. |
| Spreadtrum | Support |
| vivo | Since this is a study objective, we think we should start with some discussions about the expected/achievable gain by this feature from different aspects, hopefully some observations can be drawn from RAN1 perspective.  |
| Qualcomm | OK to support, if we make sure that the design is forward looking for intra-band CA and for more than 2 carriers.  |
| Lenovo, Motorola Mobility | Support |
| ZTE | Discuss and summarize the potential gain first.Based on companies’ input, simulations under different assumptions have been performed and different observations have been made by companies. From our perspective, we believe it may be better to first have some discussion on the simulation results and try to make some observations. If the observation is obvious, then we can discuss whether to support this enhanced scheduling or not based on the observations. If the observation is diverging, then we may need to further align simulation assumptions. |
| CATT | Support. As summarized by FL, the benefits coming with multiple PDSCHs via single DCI have been studied from several aspects. We think it is fair enough to at least say the feature is studied. |
| LG | Similar view with Samsung. Negative to the proposal.Basically, we think this multi-CC scheduling is quite different from the multi-TTI scheduling (already introduced in Rel-16 NR-U for PUSCH and currently being discussed in Rel-17 SI for PDSCH), at least in terms of the benefit to save DCI overhead.The benefit expected to be obtained by the multi-CC scheduling is very limited compared to the multi-TTI scheduling due to basically uncorrelated MCS/RA and other HARQ parameters across multiple CCs.In addition, from the SI procedure perspective, we agree with ZTE that the evaluation results and relevant observations are to be summarized/discussed first before deciding whether to support this feature according to clear statements in the SID. |
| OPPO | Support |
| Ericsson | In our view, focus at this stage should be on evaluations and obtaining conclusions from the evaluations. Our initial evaluations indicate that DCI scheduling PDSCH on two cells (mc-DCI) provides no/marginal performance gains. |

### Updated proposals

Discussion points on simulation results:

Preliminary observations on CCE overhead saving by using a single DCI scheduling two carriers compared to using two legacy DCIs scheduling two carriers are summarized below:

* 2 companies [Huawei, HiSilicon] observed 12.8%~50.4% CCE saving ratio achieved.
* 1 company [vivo] observed 44.87% and 44.51% CCE saving gain if the joint DCI size (excluding CRC) is less than 60% of the total size of two single DCI at 2.6GHz and 4GHz respectively, and the gain becomes less significant if the compression rate of joint DCI size increases.
* 1 company [Intel] observed about 20~40% CCE saving.

Preliminary observations on PDCCH blocking probability by using a single DCI scheduling two carriers compared to using two legacy DCIs scheduling two carriers are summarized below:

* 13 companies [Huawei, HiSilicon, CATT, OPPO, MediaTek, Lenovo, Motorola Mobility, Intel, Nokia, NSB, InterDigital, DOCOMO, Qualcomm] observed decreased PDCCH blocking probability.
* 1 company [vivo] observed 13.95% or 13.57% reduction in PDCCH blocking rate if the joint DCI size (excluding CRC) is less than 60% of the total size of two single DCI at 2.6GHz and 4GHz respectively, and the reduction rate becomes less significant if the compression rate of joint DCI size increases.
* 3 companies [ZTE, Samsung, Ericsson] observed marginal performance gain in PDCCH blocking.

Preliminary observations on PDSCH throughput by scheduling unused control resource REs for PDSCH transmission are summarized below:

* 2 companies [Huawei, HiSilicon] observed 7.2% to 15% throughput gain.
* 1 company [OPPO] observed 13.5% throughput gain.
* 1 company [vivo] observed up to 3.31% throughput gain.
* 1 company [ZTE] observed 13~16% performance loss due to shared scheduling information for the two carriers.

Preliminary observations on UE blind decoding reduction and power saving are summarized below:

* 2 companies [Huawei, HiSilicon] observed 6.67%~15% UE power saving by using single DCI scheduling two carriers compared with two legacy DCIs.
* 6 companies [MediaTek, Charter Communications, Lenovo, Motorola Mobility, Nokia, NSB] think multi-cell scheduling by a single DCI can save UE power.

Companies’ views on whether to support multi-cell scheduling via a single DCI are summarized below:

* Support (14): Nokia, NSB, InterDigital, Charter Communications, Huawei, HiSilicon, Spreadtrum, Qualcomm, CATT, Lenovo, Motorola Mobility, OPPO, ASUSTeK, MediaTek
* Not support (3): Samsung, LG, Apple

Proposals:

Further study the multi-cell PDSCH scheduling via a single DCI with following evaluation assumptions and scenarios:

|  |  |
| --- | --- |
| **Parameters** | **Values** |
| Scenario | Inter-band CA (700MHz + 3.5GHz)Intra-band CA  |
| SCS | 15 kHz for 700MHz30 kHz for 3.5GHz |
| Bandwidth  | PCell: 10/20MHzSCell: 10/20/100MHz |
| Number of symbols for CORESET | 2 |
| CORESET BW (contiguous PRB allocation) | 24/48/96 RBs depending on SCell bandwidth and SCS |
| CCE-to-REG mapping | interleaved |
| REG bundle size | 6 |
| Interleaver size | 2 |
| DCI payload size (excluding CRC) | Single PDSCH scheduling: 60 bits as baseline payload sizeMulti-cell PDSCH scheduling: 72/84/96/108/120 bits |
| BLER target for multi-cell scheduling DCI | Option 1: 1%Option 2: 0.5% |
| Evaluation metrics | CCE saving ratioPDCCH blocking probabilityPDSCH throughput UE power consumption |

Note: PDCCH is transmitted on SCell for cross-carrier scheduling PCell.

Companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **View** |
| Intel | Some clarifications. Is PCell on the lower carrier frequency? Will PDCCH be transmitted on PCell or SCell?Since we are targeting DSS, it is better to have an assumption on number of CRS ports for LTE carrier.The number of PRBs in CORESET is impacted by the BW of a carrier. E.g. It only has about 50 PRB for 10MHz BW with SCS 15KHz.  |
| ZTE | First of all, regarding the evaluation metrics, as the key issue for DSS WI is to increase the PDCCH capability, it seems that “UE power saving” may not be a key metric here.Secondly, LLS and geometry are needed for “CCE saving ratio” and “PDCCH blocking probability” simulation. SLS is needed for “PDSCH throughput” simulation. Since companies’ views are diverging on whether to support one-to-two scheduling, it would be good for companies to align the simulation assumptions and compare simulation results to see whether there is any gain. We should at least try to align the simulation assumption for LLS and geometry. If possible, we would also like to align the SLS simulation assumption.Usually, 2GHz and 4GHz are typical carrier frequency for LLS and SLS, e.g, like what we did in Coverage WI. Thus, we prefer to add 2GHz and change 3.5GHz to 4GHz for inter-band CA. For intra-band CA, we would prefer to use 2GHz.Currently, the CORESET BW is 96 RBs. To support 96 RBs CORESET, we may need at least 20MHz bandwidth assuming 15KHz. Thus, the 10MHz can be deleted from our perspective.For DCI size, we prefer to align with what we discussed in last meeting, i.e., 72, 84, 85, 96 and 110 bits.Regarding the detailed SLS assumption, we have provided our assumptions in our tdoc x8831. |
| vivo | Share the same view with intel, whether the PDCCH is on Pcell and Scell should be clarified first. Given that the key issue is PDCCH capacity on DSS carrier and multi-cell scheduling is expected to reduce the PDCCH load of DSS carrier, it is typical to assume that the PDCCH is on the Pcell on the lower frequency and the Scell should be scheduled by PDCCH on Pcell. If CORESET BW=96 RB is assumed, it seems 10MHz for 15kHz case and 10/20MHz for 30kHz case can be removed from the table. Or, we need to provide more options for CORESET bandwidth, e.g., 24/48 RB. Moreover, we share the same view as ZTE that 2.6GHz and 4GHz are typical and should also be considered. So we would like to update the assumptions by following:

|  |  |
| --- | --- |
| Scenario | Inter-band CA (700MHz or 2.6GHz for Pcell + 3.5GHz or 4GHz for Scell)Intra-band CA  |
| SCS | 15 kHz for 700MHz or 2.6GHz30 kHz for 3.5GHz or 4GHz |

Note: PDCCH is located on Pcell and the Scell is scheduled by Pcell@ModeratorThanks for reply.I am not sure why moderator think that a typical for DSS is Scell scheduling Pcell. In R15 and R16, Pcell cannot be scheduled by other cell, and to ensure the coverage of DCI, PDCCH are usually located at the Pcell which is typically deployed on DSS carriers. Scell scheduling Pcell is a new feature that is still under discussion (i.e., it is neither yet supported by the specification nor can it be deployed in reality), so we are not convinced that it is a typical especially as we are at the stage of evaluation. Besides, the note updated by moderator implies that Scell scheduling Pcell and multi-cell scheduling are coupled but it will be difficult toidentify whether the gain is due to Scell scheduling Pcell or to multi-cell scheduling. We suggest changing the note back to the version we suggest. |
| OPPO | Support |
| Huawei, HiSi | We think the discussion should be:* Draw initial observations/conclusions based on the common part of presented simulations
* Further discuss additional simulations that are needed – this should have a clear necessity on top of the above presented results

For LLS results, we are not comparing different schemes to down-select one, rather, (almost) all link-level results have justified the benefits of using single PDCCH scheduling multiple carriers in same/different scenarios.Therefore, we should be able to draw some conclusions already, based on the presented simulation results where as summarized below there are large proportion of commonality in the link-level simulation assumptions. For the parameters having different values, it could be understood that there will not be obvious impact on the possible conclusion/observation, e.g. frequency carrier, frequency distributed or not, Rx combining.  |
| Moderator | @Intel: yes, PCell is transmitted on low frequency. PDCCH is transmitted on SCell for cross-carrier scheduling PCell. Regarding number of RBs for CORESET, 48 RBs are added.@ZTE: (1) UE power saving can be an optional metric. I see some companies have such results. (2) I agree with you. That is also my intention. (3) I think 2.6GHz or 4GHz will not impact on simulation results compared with 700MHz or 3.5GHz. (4) 48 RBs are added. (5) 72/84/96/108/120 bits are evenly increased which seem more reasonable. @vivo: For DSS, I think the typical case is PDCCH is transmitted on SCell and cross-carrier schedules PCell. I added one note below the table. Meanwhile, I added 24/48 RBs for CORESET bandwidth. Regarding the carrier frequency, I think 2.6GHz or 4GHz will not impact on simulation results compared with 700MHz or 3.5GHz.  |
| Ericsson | Suggest following updates for the evaluation assumptions to be consistent across different BWs chosenBandwidth – 40MHz should be included at least for SCell (10/20/40/100MHz)CORESET Size – 273RBs should be included as 100MHz is considered (24/48/96/273 RBs)Number of symbols for CORESET – 1 or 2On evaluation metrics – suggest replacing “CCE saving ratio” with “Control channel overhead” as what we need to measure is to what extent the control channel overhead can be reduced.  |
| Moderator | @vivo: I think using SCell to cross-carrier scheduling PCell is agreed as highlighted in WID. The current standardization work in 8.13.1 is focused on detailed standard which has no impact on the principle of SCell scheduling PCell. Moreover, for DSS scenario, PCell is located in low frequency band shared with LTE and cross-carrier scheduled by SCell due to limited PDCCH capacity in PCell. That’s my intention to capture the note below the table.@ Ericsson: Fine to add the 1 symbol CORESET in the simulation assumption. 273 RBs are not integer multiple of 6 RBs. Can you elaborate a bit more? |
| Samsung | Initial comments on simulations1. The SCS and the carrier frequency do not matter much. One value can be selected to simplify matters – we’re fine with either 15 kHz/2.6 GHz or 30 kHz/4 GHz
2. For the bandwidth, 10 MHz is meaningful for the scheduling/NR cell. Can keep 20 MHz and 100 MHz.
3. CORESET BW should not matter (there can also be multiple CORESETs) and can be removed from consideration. Can determine size based on 20 MHz and agreed SCS.
4. DCI sizes are arbitrary – cannot just say the DCI size for joint scheduling is 72 bits.

Should identify what fields can remain with single value and then determine DCI size for joint scheduling. If the fields do not affect scheduling (e.g. do not include FDRA, MCS, …), LLS is enough. Otherwise, we need to discuss implications and possibly agree to SLS to evaluate throughput loss due to restrictions.1. A reference geometry distribution is needed to interpret results from LLS – e.g. UMa with 500m ISD.
2. For UE power consumption evaluations, a model needs to be agreed. Can discuss the model used in Rel-16 for UE PS. However, we do not see how there can be any impact/relevance.

General comments1. Companies should provide explanation/reasoning for observed results
2. Companies should provide full details for the results. For example, when evaluating blocking probability, several companies did not mention whether the same CCE distribution was considered regardless of the DCI size, while others assumed the same CCE distribution which is of course incorrect.
3. Analytical results are also possible to obtain and would be good to be part of the study. A major benefit is that simulation ‘black-box’ for errors/misalignment/etc. (especially for system simulations) are avoided and trade-offs/potential gains are very clear.
4. Consideration that the CORESET size is fixed and a non-full utilization of all CCEs in the CORESET would not result in any additional resources for PDSCH should be considered in the analysis of the results.
5. Percentage of UEs that can use certain CCE aggregation level for a target BLER should be mapped according to the geometry distribution. Possible PDCCH overhead savings and relative blocking probability should be evaluated accordingly. Any impact on throughput can be directly derived from overhead savings, if any, and a probability that CCEs in a CORESET are fully used. Similar for an impact on blocking probability.
 |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 　 | MTK (R1-2008963) | CATT(R1-2007840) | Ericsson(R1-2009207) | Huawei(R1-2007580) | Intel(R1-2009004) | Interdigital(R1-2009086) | Nokia(R1-2009047) | OPPO(R1-2008285) | Samsung(R1-2008196) | vivo(R1-2007696) | ZTE(R1-2008831) | Observations | Huawei comments |
| Freq. Carrier | 2.1GHz/4.4GHz | 700/800MHz | 4GHz | 700/800/1800/3500 MHz | 2.6GHz | 2 GHz | 　 | 4 GHz | 2.6 GHz | 2.6GHz4GHz | 700MHz/2 GHz | 700MHz: 3 companies800MHz: 2 companies1.8GHz: 1 company2/2.1GHz: 3 companies2.6GHz: 3 companies3.5GHz: 1 company4/4.4 GHz: 4 companies | The parameter difference will have no obvious impact on the results for F+F and F+T respectively. Almost aligned. |
| System bandwidth | 20MHz for 2.1GHz100MHz for 4.4GHz | 　 | 100MHz | 　 | 　 | 10 MHz | 　 | 　 | 20 MHz | 2.6GHz:20MHz/106 RB4GHz:100MHz/273RB | 20 MHz | 10/20 MHz for FDD+FDD20/100MHz for FDD+TDD | The parameter difference will have no obvious impact on the results for F+F and F+T respectively. Almost aligned. |
| SCS | 15 kHz for 2.1GHz30 kHz for 4.4GHz | 15kHz | 30kHz | 15 kHz for 700/800/1800 MHz30 kHz for 3500 MHz | 15kHz | 15kHz | 　 | 15kHz | 　 | 2.6GHz:15kHz4GHz:30kHz | 15 KHz | 15 kHz for FDD, 30 kHz for TDD | Common for FDD+FDD and FDD+TDD. Aligned. |
| CORESET RBs | 　 | 96 | 　 | 96 | 48 | 　 | 48 | 　 | 20 MHz | 96 | 48 | 48/96 | For certain CORESET no obvious difference. Aligned. |
| CORESET symbol | 3 | 3 | 　 | 3 | 2 | 3 | 2 | 3 | 2 | 2 | 2 | 3: 5 companies2: 5 companies | No obvious impact on LLS results. 2 and/or 3 CORESET symbol can be based for conclusion.  |
| Channel model | TDL\_C DS=100,300ns | TDL\_C DS=300ns | TDL-A, medium correlationDS=300ns | TDL\_A DS=30ns | TDL\_C DS=300ns | TDL-B (delay spread: 100ns)  |  AWGN | TDL-B DS=100ns | TDL\_A DS=30ns | TDL\_C, Low correlation,DS=300ns | TDL\_C DS=300ns | TDL\_C: 5 companiesTDL\_A: 3 companiesTDL\_B: 2 companiesAWGN: 1 company | TDL-A DS=30ns and TDL-C DS=300ns are used in most cases. Results based on TDL-B also demonstrates performance gain. |
| Tx number | 4 | 4 | 　 | 4 | 4 | 　 | 　 | 2 | 2 | 2 | 　 | 4: 4 companies2: 2 companies | The difference on Tx will have no obvious impact on LLS results |
| Rx number | 4 | 2 | 　 | 2Rx for 700/800/1800 MHz4Rx for 3500 MHz | 2 | 2 | 　 | 2 | 4 | 2 | 2 | 2 for FDD, 4 for TDD (vivo and OPPO use 2 for 2.6/4GHz) | Mostly aligned with 2 for FDD, 4 for TDD |
| Target BLER | 0.01 | 　 | 　 | 0.01 | 0.01 | 1% for 2 DCI scheme0.5% for single DCI schemes | 　 | 　 | 1% for 2 DCI scheme0.5% for single DCI schemes | 0.01 | 　 | 1% in most sourcing companies; two sourcing companies uses 0.5% for single DCI | Discussion point |
| Tx type | Interleaved | Interleaved | 　 | Interleaved | 　 | Interleaved | Non-interleaved | Interleaved | Interleaved | Interleaved | Interleaved | Almost the same | No impact on the possible conclusion |
| Interleaver size | 　 | 2 | 　 | 2 | 　 |  R=3 for 3OS | 　 | 　 | 2 | 2 | R=3 for 3OS,others,R=2 | 2: 5 companies3 for 3OS: 2 companies | No impact on the possible conclusion |
| Bundle size | 6 | 6 | 　 | 6 | 　 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | Aligned |
| Modulation | QPSK | 　 | 　 | QPSK | 　 | QPSK | 　 | QPSK | QPSK | 　 | QPSK | QPSK | Aligned |
| UE Speed | 3km/h | 3km/h | 3km/h | 3km/h | 3km/h | 3km/h | 3km/h | 3km/h | 3km/h | 3km/h | 3km/h | 3km/h | Aligned |
| Tx Diversity | 　 | one port precoder cycling | 　 | One port precoder cycling | Precoder cycling every 6 REGs | One port precoder cycling | 　 | 　 | Precoder cycling | One port precoder cycling | 1-port precoder cycling | 1-port precoder cycling | Aligned |
| DCI size (excluding CRC) bits | 60/84 | 60/72/82/85/96/110/120 | 　 | 60/72/82/85/96/110/120  | 60/72/84/96/108/120 | 60 bits for 2 DCI scheme76/86/96/106 bits for single DCI scheme | 36/56/76/96 | 58/68/82/92/106bits | 60 bits for legacy DCI104 bits for Single DCI | Legacy DCI: 60 bits, One-to-two scheduling DCI: 72/ 84/96/110 | Legacy DCI: 60 bits, One-to-two scheduling DCI: 72/84/ 85/96/110 | 60/72/84/96/110/120 | A large proportion of common DCI sizes are assumed: 60bits for baseline72/84/96/110 for single DCI. |
| Receiver type | 　 | 　 | 　 | 　 | 　 | MMSE | 　 | 　 | 　 | 　 | MMSE | MMSE | Aligned |
| Channel estimation | 　 | 　 | 　 | 　 | 　 | Realistic | 　 | 　 | 　 | 　 | Practical | Practical | Aligned |

## 2nd round of discussion on simulation assumptions

As per Chairman’s guidance, let’s further discuss the simulation assumptions:

### Link level simulation

Table 1: Link level simulation assumptions

|  |  |
| --- | --- |
| **Parameters** | **Values** |
| Scenario | Inter-band CA (700MHz + 3.5GHz)Intra-band CA  |
| SCS | 15 kHz for 700MHz30 kHz for 3.5GHz |
| Bandwidth  | PCell: 10/20MHzSCell: 10/20/100MHz |
| Channel model | TDL-A |
| Delay spread | 30 ns |
| Number of symbols for CORESET | 1 or 2 |
| CORESET BW (contiguous PRB allocation) | 24/48/96 RBs depending on SCell bandwidth and SCS |
| CCE-to-REG mapping | interleaved |
| REG bundle size | 6 |
| Interleaver size | 2 |
| DCI payload size (excluding CRC) | Single PDSCH scheduling: 60 bits as baseline payload sizeMulti-cell PDSCH scheduling: 72/84/96/108/120 bits |
| BLER target for multi-cell scheduling DCI | Option 1: 1%Option 2: 0.5% |
| Number of BS antennas | 4Tx |
| Number of UE antennas | 2Rx  |
| Modulation | QPSK |
| Channel coding | Polar code |
| UE speed | 3km/h |
| Aggregation level | 1/2/4/8/16 |
| Tx Diversity | One port precoder cycling |

Note: PDCCH is transmitted on SCell for cross-carrier scheduling PCell.

Regarding link level simulation assumptions, companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **View** |
| ZTE | **Baseline (comments for the Note)**: First of all, we would like to align the simulation baseline with companies. Basically, there are three kinds of baselines here (1) PCell/SCell self-scheduling (2) PCell self-scheduling + PCell cross-carrier schedules SCell (3) SCell self-scheduling + SCell cross-carrier schedules PCell. From our understanding, it may be not good to simulation SCell-schedule-PCell and one-to-two scheduling together because the detailed design of SCell-schedule-PCell is not ready and it is not clear whether the gain is from SCell-schedule-PCell or one-to-two scheduling. Furthermore, this WI is trying to address the PDCCH capability issue when PCell is used as DSS carrier in CA scenario and the justification of this WI said it is important that sufficient scheduling capacity for NR UEs on the shared carriers. Thus, our understanding is that (2) PCell self-scheduling + PCell cross-carrier schedules SCell should be the baseline.**Carrier frequency**: As we can see the summary from Huawei, more companies simulate 700MHz/2GHz/2.6GHz/4GHz. Since simulation of 2GHz and 2.6GHz may be similar, we may only need to pick one of them. Thus, our preference is 700MHz/2GHz+4GHz for inter-band CA and 2GHz for intra-band CA.**SCS**: 15KHz for 700MHz/2GHz, 30KHz for 4GHz.**Channel model**: TDL-C with delay spread 300ns is commonly used in the FR1 simulation. Based on the observations in the summary table above, most of companies use this channel model. Thus, we propose to use TDL-C with delay spread 300ns.**Number of BS antennas**: 2Tx for 700M/2GHz, 4Tx for 4GHz**Number of UE antennas**: 2Rx for 700M/2GHz, 4Rx for 4GHz**Ratio of UEs supporting CA**: In the practical scenario, only a part of UEs support CA. The ratio of UEs supporting CA may have big impact on the simulation results. Thus, we propose to add a parameter of UEs supporting CA. |
| vivo | *Regarding the Note and PDCCH location:*We share the same view as ZTE that PCell self-scheduling + PCell cross-carrier schedules SCell is the baseline. According to the online discussion, while both features in the WID are expected to alleviate the problem of insufficient PDCCH capacity for DSS carriers, we don't see the need to introduce a dependency between the two features, and hence the evaluation of multi-cell scheduling should be decoupled from Scell scheduling Pcell. Please note that we should first reach a consensus on the gain of multi-cell scheduling before moving on to discuss its relationship with scell scheduling Pcell. However, it would be more difficult for the companies to converge if the evaluation is done on top of Scell scheduling Pcell, as it will be unclear how much gain would be achieved by multi-cell scheduling. Perhaps the proposal could be modified as below.* CORESET BW (contiguous PRB allocation): 24/48/96 RBs depending on ~~S~~PCell bandwidth and SCS
* Note: PDCCH is transmitted on Pcell.

*Regarding channel frequency*We are fine with ZTE’s proposal to add 2/4GHz*Regarding the channel model:*According to the table above (Thanks Huawei for the nice table), it seems that most companies used TDL-C 300ns in their simulations, we prefer to consider TDL-C 300ns.*Regarding the number of BS antennas* 2TX and 4TX*Regarding the BLER target for multi-cell scheduling DCI*Prefer option1. |
| Huawei | **Regarding the baseline,** we think two cases can be considered:Baseline 1: this should be the most basic case that NR supported, i.e. self-scheduling + self-scheduling. Cross-carrier scheduling is an advanced feature on top and even in LTE many UE supporting CA does not support cross-carrier scheduling. Especially, for DSS, it is strange that a DSS carrier would be used for X-carrier scheduling another carrier.Baseline 2: this could be one advanced baseline envisioned from Rel-17 with Scell scheduling Pcell motivated by Rel-17 DSS, which was proposed by all other companies last meeting in order to demonstrate the potential of both Rel-17 DSS features.**Ratio of UEs supporting CA**It is not needed. The simulation concerns throughput which is assuming the network is heavy load therefore the users number are already assumed as CA users. There is no point even to do DSS if the load is light. **Other comments**

|  |  |  |
| --- | --- | --- |
| Parameters | Suggested values |  Huawei comments |
| Scenario | Inter-band CA: at least include 700MHz + 800MHz/2GHz;Inter-band CA: at least include2GHz | We have operators interest who have scattering FDD spectrum @ sub3G. It can also include the scenario of NR + NR, DSS+NR and DSS+DSS. |
| SCS | 15 kHz for FDD30 kHz for TDD |  |
| Bandwidth  | PCell: 10/20MHzSCell: 10/20/100MHz |  OK with FL suggestion. If to minimize the combinations we prefer simply:10 MHz + 10MHz10 MHz + 20 MHz10 MHz + 100 MHz |
| Channel model | TDL-A | ok |
| Delay spread | 30 ns | ok |
| Number of symbols for CORESET | 2 or 3 | It is not proper to assume 1 symbol CORESET for PDCCH capacity evaluation, which mean no PDCCH capacity concern for such gNB. |
| CORESET BW (contiguous PRB allocation) | 48/96 RBs depending on bandwidth and SCS | It is not proper to assume less CORESET resource for PDCCH capacity evaluation, which mean no PDCCH capacity concern for such gNB. |
| CCE-to-REG mapping | interleaved | ok |
| REG bundle size | 6 | Ok |
| Interleaver size | 2 | ok |
| DCI payload size (excluding CRC) | Single PDSCH scheduling: 60 bits as baseline payload sizeMulti-cell PDSCH scheduling: 72/84/96/108/120 bits | Ok with FL suggestions but perhaps remove the middle value of 96 can save some workload. |
| BLER target for multi-cell scheduling DCI | 1% | Not reasonable to use 0.5% target BLER. |
| Number of BS antennas | 4Tx |  OK |
| Number of UE antennas | 2Rx for FDD, 4Rx for TDD |  |
| Modulation | QPSK | OK |
| Channel coding | Polar code | OK |
| UE speed | 3km/h | OK |
| Aggregation level | 1/2/4/8/16 | OK |
| Tx Diversity | One port precoder cycling | OK |

 |
| CATT | 1. We are fine with the proposed values from above companies. We agree with that scenario is the critical issue for DSS when we discuss the possible solutions and benefits. But it is not the case for discussing LLS parameters. What we need to determine is the frequency carrier, e.g. 700 MHz, 2 GHz or 4 GHz. The illustration of scenario is better to be moved to ‘note’ below the table. The first row of parameters is suggested to be updated as below:

|  |  |
| --- | --- |
| Carrier frequency | 700MHz /2 GHz… |

1. For channel model and delay spread, share the same views as ZTE and Vivo, TDL-C and 300ns delay spread may be more reasonable considering it has most supporters.
2. For number of CORESET duration, agree with HW that 1 symbol is not a convincing valve. Furthermore, if 1 symbols is supported, the combination of CORESET duration and RBs should be clarified as 24/48 RB cannot support a aggregation larger than 8.
3. For BLER target, we support 1%.
 |
| Moderator | **According to current companies’ input, the updated link level simulation assumptions are listed below:**Table 1: Link level simulation assumptions

|  |  |
| --- | --- |
| **Parameters** | **Values** |
| Carrier frequency | Inter-band CA (700MHz + 4GHz)Intra-band CA (2GHz) |
| SCS | 15 kHz for 700MHz/2GHz30 kHz for 4GHz |
| Bandwidth  | Baseline: PCell 10MHz + SCell 10MHzOptional: PCell 20MHz + SCell 20/40/100MHz |
| Channel model | TDL-C |
| Delay spread | 300 ns |
| Number of symbols for CORESET | 2 |
| CORESET BW (contiguous PRB allocation) | 24/48/96 RBs depending on the bandwidth and SCS |
| CCE-to-REG mapping | interleaved |
| REG bundle size | 6 |
| Interleaver size | 2 |
| DCI payload size (excluding CRC) | Single PDSCH scheduling: 60 bits as baseline payload sizeMulti-cell PDSCH scheduling: 72/84/108/120 bits |
| BLER target for multi-cell scheduling DCI | 1% |
| Number of BS antennas | 2Tx for 700MHz/2GHz carrier frequency 4Tx for 4GHz |
| Number of UE antennas | 2Rx  |
| Modulation | QPSK |
| Channel coding | Polar code |
| UE speed | 3km/h |
| Aggregation level | 1/2/4/8/16 |
| Tx Diversity | One port precoder cycling |

Note: PDCCH is transmitted on SCell for cross-carrier scheduling PCell.**@ZTE @vivo @Huawei:** regarding the problem which cell the PDCCH is transmitted,as highlighted in WID, the most important feature for Rel-17 DSS is allowing SCell to cross carrier schedule PCell. The motivation is PCell may be located in low frequency band, as you proposed, 700MHz or 2.6GHz, where the carrier is shared with LTE. NR PDCCH capacity on NR PCell is limited so that we allow using Scell to cross carrier schedule PCell. Based on this, I think the baseline scenario is NR PDCCH is transmitted on NR Scell which can schedule PDSCH on NR SCell by self-scheduling and schedule PDSCH on NR PCell by cross-carrier scheduling. This baseline scenario is aligned with the framework of Rel-17 NR DSS. Regarding the standardization of such cross-carrier scheduling, I think the standardization work is focused on details which has no impact on such simulation scenario. For the case where PDCCH is transmitted on NR PCell and schedule PDSCH on NR SCell and PDSCH on NR PCell, I think this feature can be seen as extension of Rel-17 DSS.Regarding ratio of UEs supporting CA, I agree with Huawei that this assumption is not needed. The motivation of supporting cross-carrier scheduling from SCell to PCell is based on the assumption that many UEs are operated so that the PDCCH capacity is not sufficient. If the load is light, the DSS features is not adopted. Regarding other simulation assumptions, I captured your proposed in the above updated table. Please kindly check whether it is fine with you.Regarding DCI payload size, the option of 96 bits is removed.**@all:** regarding target BLER, only 1% is kept since the latest input from companies prefer 1%. |
| Moderator2 | **According to current companies’ input, the updated link level simulation assumptions are listed below:**Table 1: Link level simulation assumptions

|  |  |
| --- | --- |
| **Parameters** | **Values** |
| Carrier frequency | Option 1: Inter-band CA (700MHz + 4GHz)Intra-band CA (2GHz)Option 2:Only 4GHz is considered |
| SCS | 15 kHz for 700MHz/2GHz30 kHz for 4GHz |
| Bandwidth  | Option 1:Baseline: PCell 10MHz + SCell 10MHzOptional: PCell 20MHz + SCell 20/40/100MHzOption 2:Baseline: Scheduling cell 100 MHzOptional: Scheduling cell 20 MHz |
| Channel model | TDL-C |
| Delay spread | 300 ns |
| Number of symbols for CORESET | 2 or 3 |
| CORESET BW (contiguous PRB allocation) | 48/96 RBs depending on the bandwidth  |
| CCE-to-REG mapping | interleaved |
| REG bundle size | 6 |
| Interleaver size | 2 |
| DCI payload size (excluding CRC) | Single PDSCH scheduling: 60 bits as baseline payload sizeMulti-cell PDSCH scheduling: 72/84/104 bits |
| BLER target for multi-cell scheduling DCI | Option 1: 1%Option 2: 0.5% |
| Number of BS antennas | 2 Tx for 700MHz/2GHz carrier frequency 4 Tx for 4GHz |
| Number of UE antennas | 2 Rx for 700MHz/2GHz carrier frequency4 Rx for 4GHz carrier frequency |
| Modulation | QPSK |
| Channel coding | Polar code |
| UE speed | 3km/h |
| Aggregation level | 1/2/4/8/16 |
| Tx Diversity | One port precoder cycling |

Note: PDCCH is transmitted on SCell for cross-carrier scheduling PCell. |
| ZTE | **For Baseline and target simulation case:** Our preference of baseline is PCell self-scheduling + PCell cross-carrier scheduling SCell. However, if companies are fine with the FL proposed baseline (SCell self-scheduling + SCell cross-carrier scheduling PCell), we can also live with it if this is the majority view. The difference between our preference and FL proposed case is which cell is used to evaluate PDCCH blocking issue. Our understanding is that one-to-two scheduling is used to reduce the PDCCH overhead in DSS carrier, thus we propose to use (PCell self-scheduling + PCell cross-carrier scheduling SCell) as baseline. Anyway, we can live with the FL proposed baseline if this is the majority view.However, we didn’t see the need to make PCell self-scheduling + SCell self-scheduling as the baseline for the following reasons.1. If PCell self-scheduling + SCell self-scheduling is adopted as the baseline, it is not clear how to set the target simulation case. If one-to-two scheduling on PCell is the target case, the PDCCH overhead on PCell is increased, which is opposed to the objective of this WID. If one-to-two scheduling on SCell is the target case, as we simulate SCell-scheduling-PCell and one-to-two scheduling at the same time, it is not clear whether the potential gain comes from SCell-scheduling-PCell or one-to-two scheduling.2. If PCell self-scheduling + SCell self-scheduling is adopted as the baseline, it is not clear how to calculate the baseline of the PDCCH blocking rate. If one-to-two scheduling on PCell is the target case, the PDCCH blocking rate is increased in PCell while the PDCCH blocking rate is 0 in SCell (similar results if the one-to-two scheduling on sSCell is the target case). How to calculate the potential gain of PDCCH blocking rate in this case?If we choose either (PCell self-scheduling + PCell cross-carrier scheduling SCell.) or (SCell self-scheduling + SCell cross-carrier scheduling PCell) as the baseline, the target simulation case is clear, i.e., the DCI for one-to-two scheduling is on the same scheduling cell as baseline.**For Bandwidth**: We are not sure why we end up with 10M bandwidth for SCell. The bandwidth for 4GHz is often as large as 40MHz and 100MHz. We would propose to set 40MHz or 100MHz as the baseline.**For DCI size**: We didn’t see the need to delete 96bit. We propose to add it back. |
| Moderator | **@ZTE: I added two notes below the table for clarifying the simulation scenarios. Please kindly check them. 40MHz bandwidth is added for SCell. 96 bit DCI payload size is added back.****According to current companies’ input, the updated link level simulation assumptions are listed below:**Table 1: Link level simulation assumptions

|  |  |
| --- | --- |
| **Parameters** | **Values** |
| Carrier frequency | Option 1: Inter-band CA (700MHz + 4GHz)Intra-band CA (2GHz)Option 2:Only 4GHz is considered |
| SCS | 15 kHz for 700MHz/2GHz30 kHz for 4GHz |
| Bandwidth  | Option 1:Baseline: PCell 10MHz + SCell 10/40MHzOptional: PCell 20MHz + SCell 20/40/100MHzOption 2:Baseline: Scheduling cell 100 MHzOptional: Scheduling cell 20 MHz |
| Channel model | TDL-C |
| Delay spread | 300 ns |
| Number of symbols for CORESET | 2 or 3 |
| CORESET BW (contiguous PRB allocation) | 48/96 RBs depending on the bandwidth  |
| CCE-to-REG mapping | interleaved |
| REG bundle size | 6 |
| Interleaver size | 2 |
| DCI payload size (excluding CRC) | Single PDSCH scheduling: 60 bits as baseline payload sizeMulti-cell PDSCH scheduling: 72/84/96/104 bits |
| BLER target for multi-cell scheduling DCI | Option 1: 1%Option 2: 0.5% |
| Number of BS antennas | 2 Tx for 700MHz/2GHz carrier frequency 4 Tx for 4GHz |
| Number of UE antennas | 2 Rx for 700MHz/2GHz carrier frequency4 Rx for 4GHz carrier frequency |
| Modulation | QPSK |
| Channel coding | Polar code |
| UE speed | 3km/h |
| Aggregation level | 1/2/4/8/16 |
| Tx Diversity | One port precoder cycling |

Note: For two-cell scheduling via a single DCI, PDCCH transmitted on SCell schedules one PDSCH on the SCell and another PDSCH on PCell.Note: For single-cell scheduling, one PDCCH transmitted on SCell schedules one PDSCH on the SCell via self-scheduling and another PDCCH transmitted on the SCell schedules another PDSCH on PCell via cross-carrier scheduling. |
| Intel | We agree with FL that the baseline could be ‘SCell self-scheduling + SCell cross-carrier scheduling PCell’. In fact, since the first objective of DSS WI, i.e. ‘Scell scheduling PCell’ must be specified, it is reasonable to check if/how large the additional benefit could be provided by adopting 2-cell scheduling.For bandwidth, it is OK to simulate 20MHz and 100MHz. 10MHz is also OK if a deployment scenario is identified. For DCI size, agree with ZTE to have 96 bits. If keeping 3 DCI sizes is preferred, the alternative way could be to simulate 72/88/104 bits |
| Huawei | For baseline and target assumption, we share the same view with Qualcomm, cross-carrier scheduling is an optional features for UE. It is further an advanced feature with cross carrier scheduling with different SCS, which is introduced in Rel-16. So it is possible that a UE support CA without support cross-carrier scheduling, but support joint scheduling which include the function of self-scheduling and cross-carrier scheduling. Thus, we view SCell scheduling PCell could be one advanced baseline if deemed necessary. We think the most ‘basic’ baseline should be included. We can discuss if the advanced baseline as currently noted in FL proposal is ok or not. But we want to point out that it precludes some flexibility of UE implementation and network to gain from a feature without implementing another feature.For the ZTE’s concern on the gain reasoning and PDCCH blocking, it should be clear that only using Scell scheduling Pcell won’t provide any DCI overhead reduction, so the gain is naturally from joint DCI scheduling. Whether same CORESET resource is assumed for self-carrier scheduling and single DCI scheduling is the key point. With NR flexible configuration, the CORESET resource can be easily aligned based on the CORESET symbols and CORESET BW across two carriers. We can also consider mini-slot based CORESET configuration which is already supported by Rel-15 configurations. Thus on the Pcell there can be more PDCCH resources, for both baseline and joint-DCI case. We have the following modifications for LLS. I understand companies may have different preference which we can check.* Adding 700MHz+2GHz for the case 10+10 BW. Option 2 can be additionally considered, however Option 2 only is not Ok, as we already agreed last meeting to consider same SCS and one on Pcell/DSS carrier. Option2 is precluding such scenario - a typical scenario for DSS. Also, as for ZTE comment, 10MHz is a reasonable assumption for intra-band (2GHz) and inter-band with 700MHz/2GHz.
* Removing 40Mhz BW from the baseline of Option1. There is already case of 20+20/40/100Mhz, there won’t be much difference from those.
* Removing 24 RB corset, or this can be optional
* Removing 0.5% BLER
* We don’t have strong view on exact payload size e.g. 88bits as Intel added. We think this can be left to gNB configuration.
 |

### System level simulation

Table 2: System level simulation assumptions

|  |  |
| --- | --- |
| **Parameters** | **Values** |
| Carrier frequency | 700/3.5GHz |
| SCS | 15 kHz for 700MHz30 kHz for 3.5GHz |
| Simulation bandwidth  | 10MHz  |
| BS antenna height | 25 m |
| UE height | 1.5m  |
| TRP transmit power | 46 dBm for 10MHz |
| Scenario | Urban Macro |
| ISD | 500m |
| TRP antenna configuration |  (M,N,P,Mg,Ng;Mp,Np)= (1,2,2,1,1;1,1) for 700MHz(M,N,P,Mg,Ng;Mp,Np)= (4,8,2,1,1;1,1) for 3.5GHz |
| UE antenna configuration |  (M,N,P,Mg,Ng;Mp,Np)= (1,1,2,1,1;1,1) for 700MHz(M,N,P,Mg,Ng;Mp,Np)= (1,2,2,1,1;1,1) for 3.5GHz |
| Device deployment | 80% indoor, 20% outdoor  |
| UE speeds of interest | Indoor users: 3km/h |
| Outdoor users (in-car): 30 km/h |
| BS noise figure | 5 dB |
| BS antenna element gain | 8 dBi |
| UE noise figure | 7 dB |
| Thermal noise level | -174 dBm/Hz |
| Traffic | Full Buffer |
| Macro sites | 19 |
| Number of UEs per cell | 10 UEs  |
| Downtilt | 102° |
| Minimum BS to UE distance | 35m |

Note: PDCCH is transmitted on SCell for cross-carrier scheduling PCell.

Regarding system level simulation assumptions, companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **View** |
| ZTE | **Baseline**: Similarly, our understanding is that (2) PCell self-schedules PCell + PCell cross-carrier schedules SCell should be the baseline.**Geometry CDF**: It would be good if companies could align the Geometry CDF, which has a big impact on the PDCCH blocking rate simulation also.**Carrier frequency**: as commented in the LLS, we prefer to use 700MHz/2GHz/4GHz**SCS**: 15KHz for 700MHz/2GHz, 30KHz for 4GHz.**Bandwidth**: It should be the same as LLS.**TRP antenna configuration**700MHz: 2Tx antenna ports (M, N, P, Mg, Ng; Mp, Np) = (1, 2, 2, 1, 1; 1, 1)2GHz: 2Tx antenna ports (M, N, P, Mg, Ng; Mp, Np) = (8, 4, 2, 1, 1; 1, 1)4GHz: 8Tx antenna ports (M, N, P, Mg, Ng; Mp, Np) = (8,4,2,1,1;1:4)**UE antenna configuration**700MHz: 2Tx antenna ports (M, N, P, Mg, Ng; Mp, Np) = (1, 1, 2, 1, 1; 1, 1)2GHz: 2Tx antenna ports (M, N, P, Mg, Ng; Mp, Np) = (1, 1, 2, 1, 1; 1, 1)4GHz: 8Tx antenna ports (M, N, P, Mg, Ng; Mp, Np) = (1,1,2,1,1;1:1)**UE noise figure**: 9 dB**Ratio of UEs supporting CA**: In the practical scenario, only a part of UEs support CA. The ratio of UEs supporting CA may have big impact on the simulation results. Thus, we propose to add a parameter of UEs supporting CA. |
| vivo | *Regarding the Note and PDCCH location*Please check our comments to LLS*Regarding channel frequency*Please check our comments to LLS*Regarding bandwidth*It seems the system bandwidth provided in the table for SLS is not aligned with LLS, 20/100MHz should be added.*Regarding UE noise figure*9db (Follow TR38.901 and TR 38.802) |
| Huawei | **Similar comments** as in LLS for baseline, carrier frequency, SCS and simulation bandwidth.**Additionally**, for SLS baseline, also consider one DSS scenario with LTE overhead.**Other comments:**

|  |  |
| --- | --- |
| **Parameters** | **Values** |
| UE height | 3(*nfl* – 1) + 1.5 mFor outdoor UEs , *nfl* =1For indoor UEs, *nfl* ~ uniform(1,*Nfl*) where *Nfl* ~ uniform(4,8) Refer to TR38.901 |
| TRP antenna configuration |  (M,N,P,Mg,Ng;Mp,Np)= (1,2,2,1,1;1,1) for 700MHz/800MHz(M,N,P,Mg,Ng;Mp,Np)= (2,8,2,1,1;1,1) for 2GHz |
| UE antenna configuration |  (M,N,P,Mg,Ng;Mp,Np)= (1,1,2,1,1;1,1) for 700MHz/800MHz(M,N,P,Mg,Ng;Mp,Np)= (1,1,2,1,1;1,1) for 2GHz |
| UE noise figure | Ok with vivo suggestion |
| Number of UEs per cell | 10, 15, 20  |
| CORESET symbols | 3 |
| Scheduling algorithm | PF |
| DSS scenario | LTE control in DSS carrier | 1 |
| CRS port in DSS carrier | 2/4 |
| LTE PDSCH load in DSS carrier | 50% |

 |
| Qualcomm | Regarding the assumptions on PDCCH monitoring:A UE supporting CA supports self-scheduling on each CC. Cross-carrier scheduling from PCell to SCell with the same SCS and different SCSs are optional features in Rel.15 and in Rel.16, respectively. Cross-carrier scheduling from SCell to PCell will be another optional feature to be supported in Rel.17. Therefore, the baseline should be self-scheduling on both PCell and SCell.The current note “PDCCH is transmitted on SCell for cross-carrier scheduling PCell” should be fine. For inter-band CA with the PCell as a DSS carrier, it does not make sense to transmit the DCI for multi-cell PDSCH scheduling, which has larger payload than the DCI for single-cell PDSCH scheduling for self-scheduling, on the DSS carrier (=PCell). For intra-band CA, either mapping on the PCell or on the SCell does not have a difference.Scenario, SCS, BandwidthAt least two scenarios should be considered: (scenario 1) inter-band CA between a DSS carrier using 15kHz FDD having BW of 10/20MHz and a non-DSS carrier using 30kHz TDD having BW of 20/100MHz, and (scenario 2) intra-band CA between non-DSS carriers using 30k TDD having BW of 20/100MHz. Then, for scenario 1, it would be good to align companies understanding how to address the impact of different SCSs between the PCell and the SCell. That is, during one slot duration of the PCell, there are two slots on the SCell. Suppose a DCI for multi-cell PDSCH scheduling is supported for scenario 1. As illustrated in the right figure below, there is one slot on the SCell that cannot be scheduled PDSCH by the DCI for multi-cell PDSCH scheduling unless the DCI supports multi-slot PDSCH scheduling on the SCell. Scheduling PDSCH on the second slot of the SCell requires one more DCI format. Note that in the figure below, PDSCH preparation time necessary when the scheduling cell and the scheduled cell use different SCSs is not illustrated. However, this is necessary in reality.  |
| CATT | Similar comments as LLS.Regarding to noise figure, agree with vivo. |
| Moderator | **According to current companies’ input, the updated link level simulation assumptions are listed below:**Table 2: System level simulation assumptions

|  |  |
| --- | --- |
| **Parameters** | **Values** |
| Carrier frequency | Inter-band CA (700MHz + 4GHz)Intra-band CA (2GHz) |
| SCS | 15 kHz for 700MHz/2GHz30 kHz for 4GHz |
| Simulation bandwidth  | Baseline: PCell 10MHz + SCell 10MHzOptional: PCell 20MHz + SCell 20/40/100MHz |
| BS antenna height | 25 m |
| UE height | 1.5m  |
| TRP transmit power | 46 dBm for 10MHz |
| Scenario | Urban Macro |
| ISD | 500m |
| TRP antenna configuration | (M,N,P,Mg,Ng;Mp,Np)= (1,2,2,1,1;1,1) for 700MHz(M,N,P,Mg,Ng;Mp,Np)= (2,8,2,1,1;1,1) for 2GHz(M,N,P,Mg,Ng;Mp,Np)= (8,4,2,1,1;1,4) for 4GHz |
| UE antenna configuration | (M,N,P,Mg,Ng;Mp,Np)= (1,1,2,1,1;1,1) for 700MHz(M,N,P,Mg,Ng;Mp,Np)= (1,1,2,1,1;1,1) for 2GHz/4GHz |
| Device deployment | 80% indoor, 20% outdoor  |
| UE speeds of interest | Indoor users: 3km/h |
| Outdoor users (in-car): 30 km/h |
| BS noise figure | 5 dB |
| BS antenna element gain | 8 dBi |
| UE noise figure | 9 dB |
| Thermal noise level | -174 dBm/Hz |
| Traffic | Full Buffer |
| Macro sites | 19 |
| Number of UEs per cell | 10 UEs  |
| Downtilt | 102° |
| Minimum BS to UE distance | 35m |

@ZTE @vivo: Regarding the simulation scenario, please kindly check the explanation below link level simulation table.@ZTE: Regarding ratio of UEs supporting CA, please kindly check the explanation below link level simulation table.Regarding UE noise figure, I changed it to 9dB.@ZTE @Huawei: I made a compromise on BS antenna configuration for 2GHz and 4GHz. Please kindly check whether it is fine with you.@Huawei: Regarding LTE control overhead, I tend to think it can be reported by company. |
| ZTE | In addition to the comments for LLS, we have some other comments specific to SLS.It seems that TRP antenna configuration (8, 4, 2, 1, 1; 1, 4) is commonly used for 2GHz also. We would prefer to use (8, 4, 2, 1, 1; 1, 4) for 2GHz too. |
| Moderator | @ZTE: regarding TRP antenna configuration, due to few inputs, I tend to keep it open and expect more inputs from companies.**According to current companies’ input, the updated system level simulation assumptions are listed below:**Table 2: System level simulation assumptions

|  |  |
| --- | --- |
| **Parameters** | **Values** |
| Carrier frequency | Inter-band CA (700MHz + 4GHz)Intra-band CA (2GHz) |
| SCS | 15 kHz for 700MHz/2GHz30 kHz for 4GHz |
| Simulation bandwidth  | Baseline: PCell 10MHz + SCell 10MHzOptional: PCell 20MHz + SCell 20/40/100MHz |
| BS antenna height | 25 m |
| UE height | 1.5m  |
| TRP transmit power | 46 dBm for 10MHz |
| Scenario | Urban Macro |
| ISD | 500m |
| TRP antenna configuration | (M,N,P,Mg,Ng;Mp,Np)= (1,2,2,1,1;1,1) for 700MHz(M,N,P,Mg,Ng;Mp,Np)= (2,8,2,1,1;1,1) for 2GHz(M,N,P,Mg,Ng;Mp,Np)= (8,4,2,1,1;1,4) for 4GHz |
| UE antenna configuration | (M,N,P,Mg,Ng;Mp,Np)= (1,1,2,1,1;1,1) for 700MHz(M,N,P,Mg,Ng;Mp,Np)= (1,1,2,1,1;1,1) for 2GHz/4GHz |
| Device deployment | 80% indoor, 20% outdoor  |
| UE speeds of interest | Indoor users: 3km/h |
| Outdoor users (in-car): 30 km/h |
| BS noise figure | 5 dB |
| BS antenna element gain | 8 dBi |
| UE noise figure | 9 dB |
| Thermal noise level | -174 dBm/Hz |
| Traffic | Full Buffer |
| Macro sites | 19 |
| Number of UEs per cell | 10 UEs  |
| Downtilt | 102° |
| Minimum BS to UE distance | 35m |

Note 1: For two-cell scheduling via a single DCI, PDCCH transmitted on SCell schedules one PDSCH on the SCell and another PDSCH on PCell.Note 2: For single-cell scheduling, one PDCCH transmitted on SCell schedules one PDSCH on the SCell via self-scheduling and another PDCCH transmitted on the SCell schedules another PDSCH on PCell via cross-carrier scheduling.Note 3: Companies are encouraged to report whether separate or shared fields for FDRA/TDRA/MCS are assumed in simulation. |
| Huawei | For SLS, more UE number is proposed, i.e. 15/20. 10UE was used in LTE CA while this is NR DSS with PDCCH capacity pressure. More number of users is needed to reflect the traffic load especially in DSS carrier (which would serve users from two RATs). |

### Proposals for further evaluation

Proposal 1:

Further study multi-cell PDSCH scheduling via a single DCI with below simulation assumptions:

Table 1: Link level simulation assumptions

|  |  |
| --- | --- |
| **Parameters** | **Values** |
| Carrier frequency | Option 1: Inter-band CA (700MHz + 4GHz)Intra-band CA (2GHz)Option 2:Only 4GHz is considered |
| SCS | 15 kHz for 700MHz/2GHz30 kHz for 4GHz |
| Bandwidth  | Option 1:Baseline: PCell 10MHz + SCell 10/40MHzOptional: PCell 20MHz + SCell 20/40/100MHzOption 2:Baseline: Scheduling cell 100 MHzOptional: Scheduling cell 20 MHz |
| Channel model | TDL-C |
| Delay spread | 300 ns |
| Number of symbols for CORESET | 2 or 3 |
| CORESET BW (contiguous PRB allocation) | 24/48/96 RBs depending on the bandwidth  |
| CCE-to-REG mapping | interleaved |
| REG bundle size | 6 |
| Interleaver size | 2 |
| DCI payload size (excluding CRC) | Single PDSCH scheduling: 60 bits as baseline payload sizeMulti-cell PDSCH scheduling: 72/84/96/104 bits |
| BLER target for multi-cell scheduling DCI | Option 1: 1%Option 2: 0.5% |
| Number of BS antennas | 2 Tx for 700MHz/2GHz carrier frequency 4 Tx for 4GHz |
| Number of UE antennas | 2 Rx for 700MHz/2GHz carrier frequency4 Rx for 4GHz carrier frequency |
| Modulation | QPSK |
| Channel coding | Polar code |
| UE speed | 3km/h |
| Aggregation level | 1/2/4/8/16 |
| Tx Diversity | One port precoder cycling |

Note 1: For two-cell scheduling via a single DCI, PDCCH transmitted on SCell schedules one PDSCH on the SCell and another PDSCH on PCell.

Note 2: For comparison, for single-cell scheduling, one PDCCH transmitted on SCell schedules one PDSCH on the SCell via self-scheduling and another PDCCH transmitted on the SCell schedules another PDSCH on PCell via cross-carrier scheduling.

Proposal 2:

Further study multi-cell PDSCH scheduling via a single DCI with below simulation assumptions:

Table 2: System level simulation assumptions

|  |  |
| --- | --- |
| **Parameters** | **Values** |
| Carrier frequency | Inter-band CA (700MHz + 4GHz)Intra-band CA (2GHz) |
| SCS | 15 kHz for 700MHz/2GHz30 kHz for 4GHz |
| Simulation bandwidth  | Baseline: PCell 10MHz + SCell 10/40MHzOptional: PCell 20MHz + SCell 20/40/100MHz |
| BS antenna height | 25 m |
| UE height | 1.5m  |
| TRP transmit power | 46 dBm for 10MHz |
| Scenario | Urban Macro |
| ISD | 500m |
| TRP antenna configuration | (M,N,P,Mg,Ng;Mp,Np)= (1,2,2,1,1;1,1) for 700MHz(M,N,P,Mg,Ng;Mp,Np)= (2,8,2,1,1;1,1) for 2GHz(M,N,P,Mg,Ng;Mp,Np)= (8,4,2,1,1;1,4) for 4GHz |
| UE antenna configuration | (M,N,P,Mg,Ng;Mp,Np)= (1,1,2,1,1;1,1) for 700MHz(M,N,P,Mg,Ng;Mp,Np)= (1,1,2,1,1;1,1) for 2GHz/4GHz |
| Device deployment | 80% indoor, 20% outdoor  |
| UE speeds of interest | Indoor users: 3km/h |
| Outdoor users (in-car): 30 km/h |
| BS noise figure | 5 dB |
| BS antenna element gain | 8 dBi |
| UE noise figure | 9 dB |
| Thermal noise level | -174 dBm/Hz |
| Traffic | Full Buffer |
| Macro sites | 19 |
| Number of UEs per cell | 10 UEs  |
| Downtilt | 102° |
| Minimum BS to UE distance | 35m |

Note 1: For two-cell scheduling via a single DCI, PDCCH transmitted on SCell schedules one PDSCH on the SCell and another PDSCH on PCell.

Note 2: For comparison, for single-cell scheduling, one PDCCH transmitted on SCell schedules one PDSCH on the SCell via self-scheduling and another PDCCH transmitted on the SCell schedules another PDSCH on PCell via cross-carrier scheduling.

Note 3: Companies are encouraged to report whether separate or shared fields for FDRA/TDRA/MCS… are assumed in simulation when evaluating two-cell scheduling via a single DCI.

## 3rd round of discussion

Per Chairman’s guidance, let’s discuss further on the highlighted issues:

In previous RAN1 meeting, we have made below agreements:

|  |
| --- |
| Agreements:For the study on single DCI scheduling PDSCH on two cells * 1. Consider the following scenarios as baseline for evaluation
		1. UE configured with Inter-band CA with PCell and an SCell
			1. PCell for the UE is operated on a DSS carrier (i.e., same carrier is also used for serving LTE users)
			2. Case 1: Different SCS for PCell and SCell
			3. Case 2: Same SCS for PCell and SCell
	2. Additional scenarios can also be evaluated, e.g. as below
		1. Intra-band CA case with multiple serving cells having same SCS (all cells operated on non DSS carriers)
		2. Inter-band CA case with PCell and more than one SCell (at least the SCells are operated on non DSS carriers)
		3. Note: other combinations not precluded

Note: Further details of evaluation framework (including carrier BW, slot format etc.) to be discussed in next stage |

### Simulation scenarios

For inter-band CA case, there are several options for two-cell scheduling:

* Option 1: PDCCH transmitted on SCell schedules one PDSCH on the SCell and another PDSCH on PCell.
* Option 2: PDCCH transmitted on PCell schedules one PDSCH on the SCell and another PDSCH on PCell.

Regarding the above issue, companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **View** |
| Samsung | Option 1 or Option 2 shouldn’t matter. The purpose is to schedule from a cell with large BW (e.g. 2 GHz or 4 GHz carrier freq.) to a cell with small BW (e.g. 700 MHz carrier freq.). |
| OPPO | Both Option 1 and option 2 should be considered. For option1, the logic is “If PCell scheduling SCell is supported to improve PDCCH coverage/reliability/efficiency due to low frequency band of PCell , then PDCCH capacity on PCell is limited🡪Allow multi-cell scheduling to avoid PDCCH capacity increase pressure” For option2, the logic has been mentioned by FL in email.Logic for option1 and 2 are different but both of them are meaningful. We should leave flexibility to implementation. For study, various scenario may be helpful to understand multi-cell scheduling. Especially for LLS, increased evaluation work load is limited. |
| vivo | We prefer option2. |
| Intel | Prefer Option 1, but Option 2 is also fine |
| Nokia | The generic option would be that “a PDCCH transmitted on the scheduling schedules one PDSCH on that cell, and another PDSCH on another cell”. There is no need to take any stand on whether the scheduling cell is a PCell or an SCell, and if it is an SCell, if it scheduled a PCell. |
| Qualcomm | Option 1. The important assumption is, if there are two cells for PDSCH and if one of the cells is selected to transmit a DCI format for multi-cell PDSCH scheduling, the DCI format should be transmitted on a cell having enough PDCCH capacity. For inter-band CA, it should be the SCell.  |
| CATT | Similar views as Nokia. Both options are valid. Each scenario can benefit from two-cell scheduling. But they should only be captured outside the table of simulation parameters. |
| Moderator | To avoid any debate on PCell or SCell, can we just use the first cell and the second cell? My updated proposal is listed below:For two-cell scheduling:* PDCCH transmitted on a first cell schedules one PDSCH on the first cell and another PDSCH on a second cell.
 |
| LG | Fine with FL’s latest proposal. |
| Ericsson | Agree with Samsung comment.  |
| Huawei | OK with FL’s latest proposal.  |

For inter-band CA case, there are several options for single-cell scheduling (baseline):

* Option 1: One PDCCH transmitted on SCell schedules one PDSCH on the SCell via self-scheduling and another PDCCH transmitted on the SCell schedules another PDSCH on PCell via cross-carrier scheduling.
* Option 2: One PDCCH transmitted on SCell schedules one PDSCH on the SCell via self-scheduling and another PDCCH transmitted on the PCell schedules another PDSCH on PCell via self-scheduling.
* Option 3: One PDCCH transmitted on PCell schedules one PDSCH on the PCell via self-scheduling and another PDCCH transmitted on the PCell schedules another PDSCH on SCell via cross-carrier scheduling.

Regarding the above issue, companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **View** |
| Samsung | Option 1 – no need for option 2 for the objectives of the study. |
| OPPO | Option 3 is preferred.For option 1, SCell scheduling PCell, has not supported before R17, it is not reasonable to regard an emerging technical as baseline.  |
| vivo | We can support option1 with the following modifications(please see our reply in the e-mail). We are also fine with option3 proposed by OPPO.Option 1: One PDCCH transmitted on a first cell ~~SCell~~ schedules one PDSCH on the first cell ~~SCell~~ via self-scheduling and another PDCCH transmitted on the first cell ~~SCell~~ schedules another PDSCH on a second cell ~~PCell~~ via cross-carrier scheduling, where the first cell is on DSS carrier. |
| ZTE | There are multiple Option1/Option2 here. Based on our understanding, the first question is about target simulation scenario for one-to-two scheduling and the second question is about the baseline. Thus, we mark the Option1/Option2 in the first question as **Target Option1/Option2** and the Option1/Option2/Option3 as **Baseline Option1/Option2/Option3**. Thus, the two questions are related. Our preference is as below.1st preference: **Target Option2** + **Baseline Option3**2nd preference: **Target Option1** + **Baseline Option1**We don’t understand how **Baseline Option2** can work due to the following reasons.1. It is not clear how to calculate the PDCCH blocking rate for this baseline scenario. There are one PDCCH blocking rate for PCell and another PDCCH blocking rate for SCell, we may need to clarify how to combine these two PDCCH blocking rate.2. It will impact the throughput analysis. If PCell self-scheduling and SCell self-scheduling is adopted as the baseline, moving PDCCH from PCell to SCell will increase the system throughput as the PDCCH symbols on PCell can be reduced. This gain is not from one-to-two scheduling, but from SCell-schduling PCell. |
| Intel | Option as first preference, Option3 second |
| Nokia | This seems secondary for the phase of determining whether or not to specify a DCI that can schedule multiple cells. Suggest deferring the discussion. |
| Qualcomm | As a matter of fact, the baseline should be Option 2. ZTE’s argument is just because of evaluation limitation. If we need to pick-up either Option 1 or Option 3, then Option 1 should be selected for inter-band CA scenario, assuming that the SCell is non-DSS carrier and has less PDCCH resource restriction. |
| CATT | Option 3. |
| Moderator | To avoid any debate on PCell or SCell, can we just use the first cell and the second cell? My updated proposal is listed below:For single-cell scheduling (baseline):* One PDCCH transmitted on a first cell schedules one PDSCH on the first cell via self-scheduling and another PDCCH transmitted on the first cell schedules another PDSCH on a second cell via cross-carrier scheduling.
 |
| LG | Fine with FL’s latest proposal. |
| Ericsson | OK with latest moderator proposal. |
| Huawei | OK with FL’s latest proposal. Additionally, we propose to optionally compare the results with self-scheduling on each carrier. We should not use an advanced feature as baseline but since companies want to, we need this option as well. |

### Carrier frequency

For inter-band CA, there are several options:

* Option 1a: Inter-band CA (700MHz + 4GHz)
* Option 1b: Inter-band CA (700MHz + 2GHz)
* Option 2: Only 4GHz is considered

Regarding the above issue, companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **View** |
| Samsung | Option 2.This is for PDCCH LLS on a scheduling cell. Inter/intra-band CA is irrelevant. Prefer 4 GHz, instead of 2 GHz, for the scheduling cell as 4 GHz was considered by all study items in NR. Can have 2 GHz as optional.  |
| OPPO | Either option 1a or option 1bSimilar as discussion on simulation scenarios, both 700MHz and 2/4GHz can be considered as a scheduling cell. |
| Vivo | We are fine with option1a/1b. |
| ZTE | For LLS, it seems one carrier frequency for PDCCH transmission is sufficient. However, for SLS, two carrier frequencies are needed.We prefer Option 1a or Option2 (for LLS). |
| Intel | Option 1a/1b |
| Nokia | We would see FDD+FDD (option 1b) as the more natural DSS scenario than TDD+FDD (1a). |
| Qualcomm | Option 1a. By the way, carrier frequency, SCS, and simulation bandwidth, are tied together and should be jointly considered. |
| CATT | As we mentioned on the GTW session, this parameter is for LLS and what really matters is the carrier frequency for the scheduling cell on which PDCCH is transmitted. Of course the scenarios such as inter-band CA or intra-band CA is important as commented by the other companies. The explanation or description on scenarios should be captured in the note below the table instead of in the row.We propose to capture the intended carrier frequency directly in the table, i.e.:Carrier frequency: 2 GHz, 4 GHz |
| Moderator | To avoid any debate on Pcell or Scell and better align with DSS scenario, one compromise may be using 700MHz/4GHz as baseline and 2GHz optional for carrier frequency of scheduling cell. |
| LG | Option 2.Sufficient with one frequency. |
| Ericsson | We are not OK with latest moderator proposal. Discussion should be on carrier frequency for scheduling cell for which we prefer 4 GHz for baseline case. For link simulations, there is no need to agree on carrier frequency of scheduled cell. |
| Huawei | * Clarify this is LLS assumption such that carrier frequency for scheduled cell is to be discussed for SLS (added in 2.4.11)
* Suggest using 2GHz/4GHz as baseline and 700MHz optional for carrier frequency of scheduling cell
 |

For intra-band CA, there are several options:

* Option 1: Intra-band CA (2GHz)
* Option 2: Intra-band CA (FR2)

Regarding the above issue, companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **View** |
| Samsung | Not relevant for LLS – scheduling cell is at FR1 |
| vivo | WID clearly states that the study is limited to FR1 CA. so option2 is not supportedThis work item is limited to FR1, and includes the following objectives for NR Dynamic Spectrum Sharing (DSS): |
| ZTE | Option2 is not supported by this WI. |
| Nokia | FR2 would seem like the natural use case here, reducing the PDCCH load. That said, the FR1 2 GHz case could be used as a validation scenario just as well. We would expect the overall findings to be the same. |
| Qualcomm | Agree with Nokia |
| CATT | Similar comments as above, the intended carrier frequency can be captured directly. Further explanation or descriptions can be included in the note below the table. |
| Moderator | @Nokia: As companies mentioned, FR2 is not in the scope of Rel-17 DSS. I propose to focus on 2GHz intra-band CA case at this stage and may extend to FR2 in next phase. |
| Ericsson | Since this is not part of baseline scenario agreed in RAN1#102-e, the assumptions can be left to individual companies. Our preference is 4 GHz for evaluations.  |
| Huawei | * Suggest 700MHz baseline for carrier frequency of scheduling cell (there is already 2GHz in the inter-band case)
 |

### SCS

SCS is related to carrier frequency. For inter-band CA, there are several options:

* Option 1: 15 kHz for 700MHz/2GHz carrier frequency
* Option 2: 30 kHz for 4GHz carrier frequency

Regarding the above issue, companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **View** |
| Samsung | Option 2 – 30 kHz is typical for NR (FR1), it is also the assumption in other SIs. Can have 15 kHz as optional. |
| OPPO | Both option 1 and 2 are considered to support different scenarios. |
| vivo | This issue is depended on the outcome of 2.4.2.If option1b in 2.4.2 is agreed, 15/30kHz should be supported.If only option1a in 2.4.2 is agreed, we are fine with opiton1. |
| Nokia | Agree with the options. The selection should follow with what is agreed as simulation carrier frequencies. |
| Qualcomm | Both option 1 and option 2:15 kHz for 700MHz/2GHz carrier frequency and 30 kHz for 4GHz carrier frequency. |
| CATT | As comment in the previous section, both 15 kHz and 30 kHz should be included. |
| Moderator | Based on current comments, the updated proposals are listed below:Both 15kHz and 30kHz are supported based on the carrier frequency.  |
| LG | Option 2.Option 1 as optional. |
| Ericsson | Regarding moderator latest proposal, the assumption should be clarified whether it is for scheduled cell or scheduling cell. Our proposal for baseline, scheduling cell can be 30 kHz SCS, scheduled cell can be 15 kHz or 30 kHz.  |
| Huawei | Ok with the original proposals, i.e. both options |

For intra-band CA, companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **View** |
| Samsung | Not relevant |
| Nokia | If 2 GHz (FDD) is adopted, use 15 kHz.If FR2 is adopted, use 120 kHz. |
| Qualcomm | Option 2 if the carrier frequency for intra-band CA is 4GHz. |
| CATT | Similar comments as before, not relevant to LLS. Can be included in the note following the table for more information. |
| Huawei | For 700Mhz (FDD), use 15 kHz. |

### Simulation bandwidth

For inter-band CA case, there are several options for bandwidth assumptions:

* Option 1a: PCell 10MHz + Scell 10MHz.
* Option 1b: Pcell 10MHz + Scell 20MHz.
* Option 1c: Pcell 10MHz + Scell 40MHz.
* Option 1d: Pcell 10MHz + Scell 100MHz.
* Option 2a: Scheduling cell 100 MHz.
* Option 2b: Scheduling cell 20 MHz.

Regarding the above issue, companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **View** |
| Samsung | Option 2a – no need/justification to change assumptions compared to other Sis.Option 2b can be optional. Options 1x are not relevant for LLS – option 1a can’t even support a single PDCCH with 16 CCEs.  |
| OPPO | Option 1a/1b/1d are preferred. |
| ZTE | Option 1b/1c/1d or Option 2a/2b  |
| Intel | Option 1b/1d |
| Nokia | 700 MHz: 10 MHz2 GHz: 20 MHz4 GHz: 40 MHz or 100 MHz (40 MHz as simulation BW, results could be scaled to 100 MHz)30 GHz: 100 MHzThe combinations follow from chosen carrier frequencies |
| Qualcomm | Option 1b/1c/1d for inter-band CA and Option 2a/2b for intra-band CA. |
| CATT | The bandwidth of scheduling cell should be explicitly addressed. While the combinations of Pcell and Scell can be reflected in the notes following the table for information. |
| Moderator | To avoid any debate on Pcell or Scell and better align with DSS scenario, one compromise may be using 20MHz/40MHz as baseline and 10MHz/100MHz optional for bandwidth of scheduling cell. |
| LG | Option 2a.Option 2b as optional. |
| Ericsson | For the baseline case agreed in RAN1#102-e : for scheduling cell, 40 MHz or 100 MHz should be assumed, and for scheduled cell, 10 MHz or 20 MHz BW. |
| Huawei | Agree with Nokia with some modifications (we already tend to avoid to use Pcell/Scell as in the proposal in section 2.4.1): 700 MHz: 10 MHz2 GHz: 10/20 MHz4 GHz: 40/100 MHzThe combinations follow from chosen carrier frequencies |

### CORESET symbol

Regarding number of CORESET symbols, there are several options for simulation assumptions:

* Option 1: 1 symbol.
* Option 2: 2 symbols.
* Option 3: 3 symbols.

Regarding the above issue, companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **View** |
| Samsung | Option 2 (2 symbols) baseline.Can have Option 1 (1 symbol) and Option 3 (3 symbols) as optional. |
| OPPO | Option 2 is baseline. Option 1 and 3 are optional |
| vivo | Option2 as baseline. |
| ZTE | Option2 as baseline. |
| Intel | Option2 as baseline. |
| Nokia | 1 or 2 symbols. Fine with 2 as the baseline |
| Qualcomm | For non-DSS carrier, any value is possible. For DSS carrier, 1 or 2 symbols would make sense. |
| CATT | We prefer option 3, but can also live with option 2 if it is majority view. |
| Moderator | Based on current comments, the updated proposals are listed below:2 symbols are baseline. |
| LG | Fine with FL’s latest proposal. |
| Ericsson | For 40 MHz carrier BW, 2 symbol coreset with 96 PRBs coreset BWFor 100 MHz carrier BW, 1 symbol coreset with 270 PRBs coreset BW |
| Huawei | Option 3 is baseline, Option 2 can be optional (e.g. for DSS carrier) |

### CORESET bandwidth

Regarding CORESET BW (contiguous PRB allocation), there are several options for simulation assumptions:

* Option 1: 24 RBs.
* Option 2: 48 RBs.
* Option 3: 96 RBs.

Regarding the above issue, companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **View** |
| Samsung | Option 3 – Option 1 doesn’t work (1 CCE = 6 RBs), Option 2 is not much better |
| OPPO | Option 2 and 3 are preferred.  |
| vivo | Option3 is preferred, we are also open to option2 |
| ZTE | Depends on the bandwidth |
| Intel | Option 2/3 |
| Nokia | Options 2 and 3 preferred |
| Qualcomm | Option 2 for a DSS carrier with BW 10MHz using SCS 15kHz. Option 3 for all other cases. By the way, CORESET symbol and bandwidth should be jointly discussed.  |
| CATT | Option 3. Option 2 can be optional. |
| Moderator | Based on current comments, the updated proposals are listed below:48 or 96 RBs for CORESET bandwidth |
| LG | Option 3. |
| Ericsson | For 40 MHz carrier BW, 2 symbol coreset with 96 PRBs coreset BWFor 100 MHz carrier BW, 1 symbol coreset with 270 PRBs coreset BW |
| Huawei | Suggestions for alignment:48 (for 700MHz/2GHz) or 96 RBs (for 4GHz) for CORESET bandwidth |

### DCI payload size (excluding CRC)

Regarding DCI payload size (excluding CRC) for two-cell scheduling DCI, there are several options for simulation assumptions:

* Option 1: 72 bits.
* Option 2: 84 bits.
* Option 3: 96 bits.
* Option 4: 104 bits.

Regarding the above issue, companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **View** |
| Samsung | Option 4 - 104 bits as baseline as it is the only value without scheduling impact (assuming 60 bits for single-cell scheduling DCI, excluding CRC). Note that 104 bits for a 2-cell scheduling DCI (and 60 bits for 1-cell DCI) is already optimistic (e.g. only 1 TB scheduling, 100 RBs BW, no CBGs, all optional fields set to 0 bits, …).Proponents of other values should (a) describe how those values are obtained, (b) provide SLS to evaluate throughout loss if fields having scheduler impact are merged/reduced (e.g. FDRA/TDRA/MCS/…), and (c) describe the operation with different SCS for the two cells. Another set of more realistic values for single/dual PDCCH DCI are 70/124 bits (e.g. to support scheduling for 2 TBs that is likely for UEs in CA). |
| OPPO | All of options can be considered. New DCI size is not fixed now, and the evaluation for various DCI size is meaningful to define target DCI size. |
| vivo | Option1/2/3/4We should evaluate different size assumptions to identify the target size range of two-cell scheduling DCI |
| ZTE | All the DCI sizes can be considered.However, we also share similar view with Samsung. Companies may be better to clarify how to get these different DCI sizes. If possible, system throughput analysis for each DCI size can also be considered. |
| Intel | Option 1/2/3/4 |
| Nokia | Given that we can’t first agree on the DCI design before simulating, we fully support the generic approach of trying out with a number of different DCI size options and seeing what we need to aim at in the DCI size to expect to have the benefits. Thus in our view a number of hypotheses would need to be tried out, and the above set is a decent one. The 104 bit DCI size is fairly large and 72 bit would probably not represent the lower bound though.  |
| Qualcomm | We have not discussed anything about contents of the DCI format for multi-cell PDSCH scheduling. Therefore, all the options should be kept on the table.  |
| CATT | We support option1-option 4. The final payload size highly depends on the detail design of DSS-DCI. All the four options should be simulated to show the potential benefits coming with different payload size. It would be a good guidance for the following study on designing the DSS-DCI.  |
| Moderator | At this stage, we can’t go into detailed DCI design to get the possible DCI payload size. However, for evaluation purpose, we have to assume a set of values in order to match the possible payload size as much as possible. So I propose to make 72/84/96/104 as baseline and other values are optional. As suggested by Samsung, companies are encouraged to report how the values are obtained, e.g., via separate or shared fields in DCI format. |
| LG | Option 4 with highest priority in terms of evaluation and observation.Other options as optional. |
| Ericsson | Option 4 should be baseline. Other options can be simulated, but companies should provide detailed explanation of the DCI field assumptions and associated scheduling/performance impact. |
| Huawei  | Agree with Moderator. This is just different assumptions that we need to look into. No need to fix into one single baseline as that restricts the potential optimization. |

### Target BLER for two-cell scheduling DCI

Regarding the target BLER for two-cell scheduling DCI, there are several options for simulation assumptions:

* Option 1: 1%.
* Option 2: 0.5%.

Regarding the above issue, companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **View** |
| Samsung | Option 2 for fair, ‘apples-to-apples’ comparison. Proponents for option 1 should explain why it is OK for a UE to miss a DCI scheduling 2 PDSCHs with same probability as for a DCI scheduling 1 PDSCH (or why the BLER target is lower for PDCCH than for PDSCH). |
| OPPO | Option 1. Taking PDCCH reliability and PDSCH reliability into account, the throughput is formulated by : if PDSCH A (TB size=a) and PDSCH B (TB size=b) is scheduled by one DCI, then Throughput\_1 = PDCCH\_reliability\_1 \*PDSCH\_reliability\*(a+b);if PDSCH A (TB size=a) and PDSCH B (TB size=b) are scheduled by two DCIs independently, then Throughput\_2= PDCCH\_reliability\_2 \* PDSCH\_reliability\*a+ PDCCH\_reliability\_2 \* PDSCH\_reliability\*b= PDCCH\_reliability\_2\* PDSCH\_reliability\* (a+b);To achieve same throughput, **PDCCH\_reliability\_1= PDCCH\_reliability\_2.**Moreover, the same target BLER is assumed for two code-word PDSCH transmission and one code-word PDSCH transmission. So Option 1 is preferred. |
| vivo | Option1 |
| Intel | Option2 |
| Nokia | Option 1 |
| Qualcomm | Option 1 |
| CATT | Option 1.It doesn’t relevant whether the DCI schedules single PDSCH or two PDSCHs. What matters is the reliability of PDCCH reception, no matter the DCI is scheduling one PDSCH or two PDSCHs. One example is LAA, a DCI can schedule multiple PUSCH wherein 1% target BLER is maintained for PDCCH reception. |
| Moderator | We have discussed this issue several rounds. Maybe it is better to leave the two options for online discussion and make decision by chairman.  |
| LG | Option 2.Same reason with Samsung. |
| Ericsson | 1% can be assumed for PDCCH BLER. Companies should report statistics for below cases:* At least one PDSCH can be scheduled for a UE (i.e. DCI for one PDSCH is blocked).
* No PDSCH can be scheduled for a UE (i.e. DCI for both PDSCHs are blocked).
 |
| Huawei | Option 1. |

### CCE-to-REG mapping

Regarding the CCE-to-REG mapping, based on the agreed interleaved CCE-to-REG mapping, whether to support non-interleaved CCE-to-REG mapping:

* Option 1: support non-interleaved CCE-to-REG mapping.
* Option 2: not support non-interleaved CCE-to-REG mapping.

Regarding the above issue, companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **View** |
| Samsung | Option 2 – mainly to contain and have converged results. It is also more realistic in FR1. |
| OPPO | Option 2 is optional. |
| Vivo | Option2 |
| Intel | Option2 |
| Nokia | Leave the usage of the interleaver up to the proponent |
| Qualcomm | As long as the same CCE-to-REG mapping is used for different solutions in a simulation results, either option is OK. |
| CATT | Option 2 is sufficient. |
| Moderator | Based on companies’ views, one way forward may be whether to adopt non-interleaved CCE-to-REG mapping is up to the proponent. |
| LG | Fine with FL’s latest proposal. |
| Ericsson | OK with latest moderator proposal. |
| Huawei | Suggest to make one as baseline, can take majority view. The other option is optional. |

### Antenna configuration

Regarding the antenna configuration for BS and UE, there are several options for simulation assumptions:

* Option 1: support 2Tx/2Rx for 700MHz/2GHz carrier frequency and 4Tx/4Rx for 4GHz carrier frequency.
* Option 2: only support 4Tx/4Rx for 4GHz carrier frequency.

Regarding the above issue, companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **View** |
| Samsung | Option 2 – same as for all other NR Sis (except for RedCap Ues for which CA is not applicable). Can have 2Tx/2Rx as optional. |
| OPPO | Option 1 is baseline. |
| Vivo | Option1, as we are discussing DSS, evaluation for DSS carrier should be prioritized. |
| Intel | Option1 |
| Nokia | Perhaps only need to discuss number of Rx antennas. The current requirement is 2Rx for 700/2 GHz and 4Rx for 4GHz, and deviating from that would require very good motivation that we don’t currently see. The UE Rx antenna setup should directly follow from the chosen bands. |
| Qualcomm | Option 1. RAN4 does not mandate 4Rx for 700MHz/2GHz carrier frequencies.TS38.101-1 Section 7.2: The UE is required to be equipped with a minimum of two Rx antenna ports in all operating bands except for the bands n7, n38, n41, n77, n78, n79 where the UE is required to be equipped with a minimum of four Rx antenna ports. |
| CATT | Option 1 to reflect more realistic scenarios. |
| Moderator | Considering the simulation assumptions that we are discussing are targeted for DSS scenario, concrete antenna configuration is dependent on the carrier frequency. So let’s take Option 1 as baseline. |
| LG | Option 2.Option 1 as optional. |
| Ericsson | Option 2 – only 4 GHz assumption is enough for scheduling cell.  |
| Huawei | Fine with FL’s latest proposal. |

### UE geometry

LLS will require AL distribution depending on UE geometry.

|  |  |
| --- | --- |
| **Parameters** | **Values** |
| Carrier frequency |  Depending on the LLS assumptions |
| SCS |
| Simulation bandwidth  |
| BS antenna height | 25 m |
| UE height | 1.5m  |
| TRP transmit power | 46 dBm for 10MHz |
| Scenario | Urban Macro |
| ISD | 500m |
| TRP antenna configuration | (M,N,P,Mg,Ng;Mp,Np)= (1,2,2,1,1;1,1) for 700MHz(M,N,P,Mg,Ng;Mp,Np)= (2,8,2,1,1;1,1) for 2GHz(M,N,P,Mg,Ng;Mp,Np)= (8,4,2,1,1;1,4) for 4GHz |
| UE antenna configuration | (M,N,P,Mg,Ng;Mp,Np)= (1,1,2,1,1;1,1) for 700MHz(M,N,P,Mg,Ng;Mp,Np)= (1,1,2,1,1;1,1) for 2GHz/4GHz |
| Device deployment | 80% indoor, 20% outdoor  |
| UE speeds of interest | Indoor users: 3km/h |
| Outdoor users (in-car): 30 km/h |
| BS noise figure | 5 dB |
| BS antenna element gain | 8 dBi |
| UE noise figure | 9 dB |
| Thermal noise level | -174 dBm/Hz |
| Traffic | Full Buffer |
| Macro sites | 19 |
| Number of UEs per cell | 10, 20 UEs  |
| Downtilt | 102° |
| Minimum BS to UE distance | 35m |

Shall SLS for throughput be provided?

|  |  |
| --- | --- |
| **Company** | **View** |
| Huawei | At least can be optionally provided. |
|  |  |

If so, what additional parameters are needed?

|  |  |
| --- | --- |
| **Company** | **View** |
| Huawei | Carrier frequency (/thus BW) for scheduled cells.* 700MHz/2GHz with 10MHz BW
	+ LTE overhead on DSS carrier can be optionally provided, up to proponent
 |
|  |  |

### Updated proposals

Proposal:

Further study with below simulation assumptions:

Simulation scenarios:

* For two-cell scheduling via a single DCI, PDCCH transmitted on a first cell schedules one PDSCH on the first cell and another PDSCH on a second cell.
* For single-cell scheduling (baseline), one PDCCH transmitted on a first cell schedules one PDSCH on the first cell via self-scheduling and another PDCCH transmitted on the first cell schedules another PDSCH on a second cell via cross-carrier scheduling.

Simulation assumption combinations for carrier frequency, SCS, antenna configuration and bandwidth of the first cell (scheduling cell):

* Combination 1(baseline): 2 GHz, 15 kHz SCS, 2 Tx, 2 Rx, 20 MHz BW
* Combination 2(baseline): 4 GHz, 30 kHz SCS, 4 Tx, 4 Rx, 100 MHz BW
* Combination 3(optional): 700MHz, 15 kHz SCS, 2 Tx, 2 Rx, 10 MHz BW

Simulation assumptions on CORESET configuration on the first cell (scheduling cell):

* Combination 1: 2 symbols, 48 RBs
* Combination 2: 2 symbols, 96 RBs

Payload size of two-cell scheduling DCI (excluding CRC):

* 60 for single-cell scheduling DCI (baseline).
* 72/84/96/104 for two-cell scheduling DCI.
* Companies are encouraged to report how the values are obtained, e.g., via separate or shared fields in DCI format.

Target BLER for two-cell scheduling DCI:

* Option 1: 1%.
* Supported by OPPO, vivo, Nokia, Qualcomm, CATT, Ericsson, Huawei, Lenovo
* Option 2: 0.5%.
* Supported by Samsung, Intel, LG

Regarding the CCE-to-REG mapping, based on the agreed interleaved CCE-to-REG mapping, whether to adopt non-interleaved CCE-to-REG mapping is up to the proponent.

Proposal:

* Further study with below simulation assumptions:

Table 2: System level simulation assumptions

|  |  |
| --- | --- |
| **Parameters** | **Values** |
| Carrier frequency | For scheduling cell, follow agreed link level simulation assumptions For scheduled cell, consider 700MHz/2GHz with 10/20MHz BW (LTE overhead on DSS carrier can be optionally provided, up to proponent) |
| SCS |
| Simulation bandwidth  |
| BS antenna height | 25 m |
| UE height | 1.5m  |
| TRP transmit power | 46 dBm for 10MHz |
| Scenario | Urban Macro |
| ISD | 500m |
| TRP antenna configuration | (M,N,P,Mg,Ng;Mp,Np)= (1,2,2,1,1;1,1) for 700MHz(M,N,P,Mg,Ng;Mp,Np)= (2,8,2,1,1;1,1) for 2GHz(M,N,P,Mg,Ng;Mp,Np)= (8,4,2,1,1;1,4) for 4GHz |
| UE antenna configuration | (M,N,P,Mg,Ng;Mp,Np)= (1,1,2,1,1;1,1) for 700MHz(M,N,P,Mg,Ng;Mp,Np)= (1,1,2,1,1;1,1) for 2GHz/4GHz |
| Device deployment | 80% indoor, 20% outdoor  |
| UE speeds of interest | Indoor users: 3km/h |
| Outdoor users (in-car): 30 km/h |
| BS noise figure | 5 dB |
| BS antenna element gain | 8 dBi |
| UE noise figure | 9 dB |
| Thermal noise level | -174 dBm/Hz |
| Traffic | Full Buffer |
| Macro sites | 19 |
| Number of UEs per cell | 10/15/20 UEs  |
| Downtilt | 102° |
| Minimum BS to UE distance | 35m |

# Standard impact

## DCI format design

If scheduling multiple PDSCHs on multiple carriers via a single DCI is supported, one important thing is to design the DCI format. Based on the simulation results, for reducing PDCCH blocking probability, the DCI payload should be further compressed. So many fields in the DCI need to be shared for the PDSCHs scheduled on two carriers. However, this scheduling inflexibility may lead to throughput loss for inter-band CA case. Due to the large frequency separation between the scheduled carriers in inter-band CA, the channel conditions are less correlated. It is difficult to assume same link adaptation property on the scheduled carriers and use single fields for indicating same MCS, frequency domain resource allocation as well as time domain resource allocation. For full flexibility scheduling two PDSCHs on two carriers by a single DCI, almost all the related fields in the scheduling DCI need to be doubled except DAI, HARQ timing, PRI, TPC and 24-bit CRC. However, the larger the DCI payload size, the lower the transmission reliability and less coverage. As a result, further overhead reduction is required for the two-carrier scheduling DCI at the cost of potential reduction in scheduling flexibility.

In addition, in order not to increase UE’s PDCCH blind decoding budget as one target of Rel-17 DSS, another open issues is whether the multi-carrier scheduling DCI needs to schedule not only a single PDSCH but also two PDSCHs on two carriers when the UE is configured with such feature.

Regarding DCI format design, companies’ views are summarized as below:

|  |  |
| --- | --- |
| Company | Key Proposals/Observations |
| Huawei, HiSilicon | Observation 7: For the DCI scheduling multi-carrier scheduling, some DCI fields can be predefined to be independent for separate PDSCHs, some fields can be predefined to be common for 2 PDSCHs, and the other fields can be configurable to be independent or common based on network decisions.Observation 8: It is possible to reduce the DCI payload around 18% when using single DCI joint scheduling two carriers instead of two separate DCIs, still with significant performance improvement without losing network scheduling flexibility. |
| vivo | Proposal 4. For joint DCI with DCI payload compression, study the trade-off between system capacity improvement due to CCE saving/PDCCH blocking rate reduction and the spectrum efficiency loss due to degraded scheduling flexibility.Proposal 5. The fields type (shared or cell-specific) in joint DCI needs to be investigated. |
| CATT | Proposal 3: The DCI content for multi-cell PDSCH scheduling and HARQ feedback procedure need to be further studied. |
| LG | Proposal #2: At least following issues would need to be addressed, and relevant specification impacts (and standardization workload for them) are expected, if the single DCI based multi-cell PDSCH scheduling is introduced.* How to indicate the multiple cells with PDSCH transmission by single scheduling DCI
* How to compose (and signal) the DCI fields in the multi-cell PDSCH scheduling DCI
* How to construct PDCCH search space for the multi-cell scheduling DCI transmission
* How to allocate (and handle) PDCCH BD candidates for the multi-cell scheduling DCI
 |
| Spreadtrum: | 1. The DCI fields should be discussed and study whether or not the scheduling information should be same or different for the multiple PDSCHs.
 |
| Samsung | Observation 1: Consideration of a DCI format scheduling PDSCH receptions on two cells should avoid any throughput degradation over using two DCI formats and any new design requirements on the gNB scheduler.Observation 2: For TDD operation and no scheduling restrictions, a DCI format scheduling 2 cells can avoid duplication for only the CRC bits.Observation 3: DCI format size 1\_1 is preferable to DCI format C2 across the geometry CDF, particularly for UEs above the 30% point of the geometry CDF which are more likely to operate with CA.Observation 4: Coverage and relative BLER comparisons for DCI format C2 further worsen for operation under less favorable conditions such as with some correlation or blockage of UE receiver antennas or for 2 UE receiver antennas. Observation 5: For DSS, a maximum gain in resources per slot from scheduling PDSCH on 2 cells using a single DCI format is ~0.35% for a BWP of 20 MHz and ~0.07% for a BWP of 100 MHz on the scheduling cell.Observation 6: The size matching of DCI format 0\_1 with DCI format 1\_1 that is required when using DCI format C2 reduces overhead savings from using DCI format C2.Observation 7: Introduction of a DCI format scheduling PDSCH on two cells by parallelizing use of field for scheduling on a single cell does not provide any material benefit over a DCI format scheduling PDSCH on a single cell.  |
| OPPO | Observation 2: The smaller DCI size increases, the more UEs achieve gain from one-to-two scheduling. |
| APPLE | Observation 2: Rel-16 Single-DCI Multi-TRP solutions significantly restrict PDSCH scheduling flexibility, and, is only designed for PDSCH repetition, i.e. single TB case |
| ASUSTeK | Proposal 2-1: DCI fields about reporting HARQ-ACK information are shared between the multiple PDSCHs scheduled by a single DCI. Proposal 2-2: DCI fields about resource assignment and transmission parameters are separate between the multiple PDSCHs scheduled by a single DCI. Proposal 3: Constrain one of the two cells scheduled by a single DCI to be the scheduling cell.  |
| ZTE | Observation 3: If single DCI scheduling two PDSCHs on two carriers is supported, to guarantee at least the moderate flexibility, the minimum size of this enhanced DCI for one-to-two scheduling is 93bits compared with 60 bits for legacy scheduling.Observation 4: If single DCI scheduling two PDSCHs on two carriers is supported, RAN1 needs to further study how to handle the Rel-16 newly introduced DCI fields in DCI format 1\_1. Observation 5: If single DCI scheduling two PDSCHs on two carriers is supported, RAN1 needs to further study whether to apply DCI format 1\_1/1\_2 or introduce a new DCI format for one-to-two scheduling. Observation 6: If single DCI scheduling two PDSCHs on two carriers is supported, RAN1 needs to further study how to indicate the two scheduled carriers.Observation 7: If single DCI scheduling two PDSCHs on two carriers is supported, RAN1 needs to further study how to guarantee the current BD/CCE budget.Observation 8: If single DCI scheduling two PDSCHs on two carriers is supported, RAN1 needs to further study how to perform the corresponding HARQ-ACK feedback. |
| Charter Communications | Proposal 1: Consider enhanced multi-carrier operation where a single DCI can schedule PDSCH on two non-DSS cells with the same SCS, including SCells with a dormant BWP, for energy-efficient and low-latency NR performance. |
| Lenovo, Motorola Mobility | Observation 4: Only non-fallback DCI can be configured to schedule one PDSCH on one carrier or two PDSCHs on two carriers. |
| MediaTek | Proposal 3: Both 1-stage DCI aggregation and 2-stage DCI aggregation for cross-carrier scheduling should be included for the evaluation. |
| Intel | Observation 1: To support 2-cell scheduling by a single DCI, at least the following bit fields are likely to be duplicated: FDRA, MCS/NDI/RV and Antenna ports/TCI. TDRA field may be duplicated too. |
| ETRI | Observation 1: Multi-cell scheduling via a single DCI should be generally applicable for both the DSS scenario and the non-DSS scenario.Observation 2: Decision on support of the joint multi-cell scheduling should be made by considering both the DSS scenarios and general CA scenarios. If agreed to specify, the design should also target both the scenarios.Observation 3: The multi-cell joint scheduling should allow a sufficiently wide range of scheduling flexibility to support different scenarios.Observation 4: For multi-cell joint scheduling, the principle that one PDSCH does not span multiple cells can be kept to minimize the workload.Observation 5: For multi-cell joint scheduling, scheduling more than two cells using a joint DCI can be considered. |
| Nokia, NSB | Observation 3: The baseline design would be to determine DCI format fields based on primary of the two-cells and interpret the fields for the secondary of the two-cells as in case of BWP switching R15. Some fields could be further optimized or doubled in the DCI format which is FFS. Observation 4: In DSS a typical DCI size with CRC would be 76 bits for single cell DCI, while for double cell DCI could be around 110bits when allowing for fully flexible allocation of TDRA, FDRA, MCS, HARQ ID, RV, NDI and Antenna ports. Observation 5: In FR2 CA a typical DCI format 1\_1 size with CRC would 80bits, while four-cell DCI format could be around 88bits, when allowing for NDI field and 1-bit scheduling indication per cell. |
| InterDigital | Support a single DCI to schedule two PDSCH in different cells. |
| DOCOMO | Observation 2:* The required DCI size for the agreed scenarios should be discussed prior to performance gain discussion.

Observation 3:* In the assumed scenario (e.g. Inter-band CA with PCell (DSS carrier) and an SCell), CRC field attached to DCI (i.e. 24-bit) can be shared between the scheduled multiple cells.

Observation 6:* In the assumed scenario (e.g. Inter-band CA with PCell (DSS carrier) and an SCell), it may be better to separate Time domain resource assignment field for each scheduled cell.

Observation 7: * In the assumed scenario (e.g. Inter-band CA with PCell (DSS carrier) and an SCell), it may be better to separate Frequency domain resource assignment field for each scheduled cell.

Observation 8: * Whether/how to support some indications in DCI for multiple scheduled cells can be considered.
	+ e.g. rate matching indicator, BWP indicator, CSI request and SRS request

Observation 9: * How to determine the size of DCI scheduling PDSCH on multiple cells can be considered.
 |
| Ericsson | Following design aspects for single DCI scheduling PDSCH on two cells should be considered in the study1. When single DCI is used to schedule PDSCH on two cells, whether the two scheduled cells are allowed to have different configuration for at least the following attributes:
	1. Numerology used on each scheduled cell
	2. Channel BW (and BWP BW) of each scheduled cell
	3. MIMO configuration of each scheduled cell
	4. HARQ processes/TBs/MCSs of each scheduled cell
	5. FDRA/TDRA (including type) used for each scheduled cell
2. When single DCI is used to schedule PDSCH on two cells, whether the corresponding DCI format always schedules PDSCH on both cells or whether it is also used to schedule single cell PDSCH.
3. When UE monitors the DCI format for single DCI scheduling PDSCH on two cells, whether the UE can be configured to also monitor existing DCI format(s) scheduling PDSCH on single cell (i.e. 1-0/1-1/1-2).
4. Handling DCI size budget and DCI size-matching when UE is configured to monitor the DCI format for single DCI scheduling PDSCH on two cells.
5. Whether the DCI format supports the functionality of all the DCI fields specified for existing DCI formats or whether it supports only a limited subset of DCI fields.
6. For each DCI field of the DCI format, whether the DCI field jointly indicates the functionality for both cells or whether separate DCI fields for each cell are used to indicate the respective functionality.
 |
| Qualcomm | Proposal 1: Consider further DCI compression schemes that are effective for the cases where the scheduled cells are highly correlated (e.g., intra-band CA).Proposal 2: Following should be realized:* The UE is able to know a set of PDCCH candidates for the DCI format scheduling PDSCHs for a given set of scheduled cells, based on the higher-layer configurations, before blind decodes
* NW can schedule one cell or multiple cells by the DCI format for multi-cell PDSCH scheduling.

Proposal 3: The UE monitors a set of PDCCH candidates for a DCI format that can schedule PDSCH(s) on a set of cell(s). A field in the DCI format tells the UE on which cell(s) data is actually scheduled amongst the set of cells. |

Discussion points:

Q1: For two PDSCHs on two carriers scheduled by a single DCI, there may be two options:

* Option 1: One PDSCH is cross-carrier scheduled and another PDSCH is self-scheduled.
* Option 2: Both PDSCHs are cross-carrier scheduled;

E.g., in Option 1, the DCI transmitted on cell 1 schedules one PDSCH on cell 1 via self-scheduling and another PDSCH on cell 2 via cross-carrier scheduling; in Option 2, the DCI transmitted on cell 1 schedules one PDSCH on cell 2 via cross-carrier scheduling and another PDSCH on cell 3 via cross-carrier scheduling.

Shall we support at least Option 1 or both options?

Companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **View** |
| Nokia | Should not preclude the possibility that both carriers are cross-carrier scheduled. |
| Apple | If this feature is supported, both options are okay |
| InterDigital  | We are fine with both options  |
| Charter Communications | Fine with both options |
| Huawei, HiSi  | Ok with both options but consider Option 1 should be at least included, e.g. for the scenario of DSS+one NR carrier. |
| Spreadtrum | Fine with both options |
| vivo | Fine with both options |
| Qualcomm | Fine with both options |
| Lenovo, Motorola Mobility | We are fine with both options |
| ZTE | If one-to-two scheduling is introduced, we are fine with both options. |
| NTT DOCOMO | We are fine with both options. |
| CATT | Both should be supported. |
| Intel | If the feature is introduced, both can be supported  |
| LG | If this feature is introduced, Option 1 may need to be prioritized by considering main DSS scenario. |
| ETRI | Fine to support both options. |
| OPPO | Fine to support both options. |
| Ericsson | Performance and complexity impact of both options can be considered in the study  |
| Samsung | OK to consider both options. |

Q2: Will a new DCI format be introduced, or an existing non-fallback DCI be reused to support multi-cell PDSCH scheduling by a single DCI?

Companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **View** |
| Nokia | This is perhaps a specification technicality than something that impacts design and in that sense not a critical item to address at this stage. That said, it might be beneficial to adopt this as a subcase for format 1\_1 rather than a new format in order to avoid having to update all the instances of the spec where the format type is mentioned.  |
| Apple | The more important question is how to treat different DCI field. It is not good to restrict the DCI format at this stage without detailed discussion on the DCI field. |
| InterDigital | New DCI format can be introduced  |
| Huawei, HiSi  | Open for discussion. Share the feeling that this can be addressed in WI phase. |
| Spreadtrum | We are open for further discussion. At this stage, we prefer non-fallback DCI can be reused. |
| vivo | Same view as apple. It may be too early to conclude whether a new DCI format is needed at this stage. We prefer to discuss the DCI field type first, e.g., which information fields should be shared or CC-specific. |
| Qualcomm | Should be discussed once detailed mechanisms are further clarified. |
| Lenovo, Motorola Mobility | We are open for further discussion although we prefer reusing existing non-fallback DCI. |
| ZTE | We also think it may be too premature to discuss this kind of detailed design at this stage. We may need to come back to this issue in the future meeting. |
| CATT | Further discussion is needed. The fundamental issue on whether reusing existing non-fallback DCI or introducing a new DCI format is whether we need to define some new bit fields compared to the current DCI format, i.e. the bit field is exactly same as the current DCI format or new bit fields will be introduced (including totally new bit fields and the current bit fields but doubled in order to support two PDSCHs).  |
| Intel | As commented by other companies, it is too early to discuss this proposal. Above all, we prefer the keep existing budget on the number of DCI sizes |
| LG | Same view with other companies. It seems premature to discuss/decide this kind of details. |
| ETRI | We do not have a strong view for now. Can be discussed further. |
| OPPO | Share view with other companies. It is too early to discuss details. |
| Ericsson | Performance and complexity impact of new DCI format vs. reusing existing DCI formats can be considered in the study |
| Samsung | It is an essential part of the evaluations and companies should state and explain their assumptions and the corresponding impact on comparison metrics – e.g. how often it is assumed that only one cell or both cells are scheduled. Otherwise, there cannot be any meaningful conclusions. |

Q3: Whether the multi-cell scheduling DCI can be also used to schedule a single PDSCH on one carrier?

Companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **View** |
| Nokia | Yes. The DCI format should be able to schedule either one of the two PDSCH carriers without scheduling the other carrier. |
| Apple | This is related to Q4. When one DCI can schedule two PDSCH in different CCs, we also need to support basic operation, i.e. one DCI schedules only on PDSCH. But Q3 and Q4 can achieve the same thing  |
| InterDigital | Yes.  |
| Charter Communications | Yes |
| Huawei, HiSi | Yes |
| Spreadtrum | Yes |
| vivo | Yes. It is beneficial to support dynamic switching between the single-cell scheduling and multi-cell scheduling considering the traffic status, TDD configurations etc.  |
| Qualcomm | Yes |
| Lenovo, Motorola Mobility | Yes |
| ZTE | Although our answer is yes, we still believe it is too premature to discuss the detailed DCI design at this stage.  |
| NTT DOCOMO | Yes |
| CATT | Yes |
| Intel | Though it is not efficient to schedule one PDSCH with the DCI for 2-cell scheduling, however, it is better to allow it. This is also the design principle of multi-TTI PUSCH scheduling in NR-U. |
| LG | If this feature is introduced, yes. |
| ETRI | Yes |
| OPPO | Yes |
| Ericsson | Performance and complexity impact of allowing/not allowing this can be considered in the study.  |
| Samsung | Q2 is more important – if yes to Q3, then it would be assumed that the joint-DCI is used also to schedule one cell in Q2. |

Q4: When UE monitors the DCI format which can schedule two PDSCHs on two cells, can the UE be configured to also monitor existing DCI (i.e., 1-0/1-1/1-2) scheduling a single PDSCH on a single cell?

Companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **View** |
| Nokia | Yes, no need to change the DCI monitoring rules. |
| Apple | This is related to Q3 |
| InterDigital | Depends on the outcome of Q3. |
| Huawei, HiSi | Yes |
| Spreadtrum | Yes for 1-0. We can further check 1-2 if 1-1 is used for multi-cell PDSCH scheduling. |
| vivo | Yes if the BD budget can be kept.  |
| Qualcomm | “Maybe no”. This question relates to the discussions on BD budget and DCI size budget. If the question is asking whether a UE shall monitor all the DCI formats 1\_0, 1\_1, 1\_2, and multi-cell scheduling DCI format on the same cell, then without introducing a new DCI size alignment, the DCI size budget will exceed 3. |
| Lenovo, Motorola Mobility | Yes |
| ZTE | This issue is highly depending on the outcome of Q3. We may need to first discuss Q3. |
| CATT | Yes. The potential issue on DCI size budget raised by Qualcomm is good point. We are open to discuss it.  |
| Intel | DCI 1\_0 is anyway needed which is for fallback and robust operation. Regarding DCI 1\_1/1\_2, better to conclude on Q3 first.  |
| LG | This issue would have dependency with the above Q2 in terms of which DCI format is used for multi-CC scheduling. |
| ETRI | Agree with Intel and LG. |
| OPPO | Yes. The issue on DCI size budget raised by QC needs to be considered. |
| Ericsson | Monitoring of existing DCI formats should be assumed as the baseline for the study and performance/complexity from other options should be compared wrt. baseline. |
| Samsung | Relates to Q2. Also, depends on required DCI size alignment should of course be configured to monitor UL grants for single cell scheduling and then it can also be configured to monitor corresponding DL assignments for single cell scheduling. |

Q5: When UE monitors the DCI format which can schedule two PDSCHs on two cells, whether the BD/CCE budget defined in Rel-15 is kept?

Companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **View** |
| Nokia | Yes |
| Apple | We first need to discuss how BD/CCE is computed since now we break the one scheduling to one scheduled cell mapping rule.  |
| InterDigital | Yes |
| Huawei, HiSi | In general yes as required by WID. But Ok with Apple suggestion. |
| Spreadtrum | Yes. Also support Apple’s comments. |
| vivo | We should keep in mind there is a note in the WID, which gave clear guidance to keep the BD budget unchanged. Note: The total PDCCH blind decoding budget should not be changed as a result of this work |
| Qualcomm | Yes. |
| Lenovo, Motorola Mobility | Yes |
| ZTE | Yes, The WID explicitly mentions that PDCCH blind decoding budget should not be changed. |
| CATT | Yes |
| Intel | Agree with Apple to check how to define BD/CCE.  |
| LG | If this feature is introduced, yes. |
| ETRI | Yes |
| OPPO | Share view with Apple. |
| Ericsson | Existing BD/CCE limits should be assumed as the baseline for the study and performance/complexity from other options should be compared wrt. baseline. |
| Samsung  | Yes |

Q6: Whether the fields in the single DCI which schedules the two PDSCHs on two carriers are shared or separate for each PDSCH?

Companies are encouraged to provide names for each field in the corresponding column of the below table.

**Table 1: Fields in the DCI which can schedule two PDSCHs on two carriers**

|  |  |  |
| --- | --- | --- |
| DCI fields  | Shared indication for the two scheduled PDSCHs | Separate indication for each scheduled PDSCH |
| Identifier for DCI formats | Nokia, HW |  |
| Carrier indicator | Nokia, HW |  |
| Bandwidth part indicator |  |  |
| Frequency domain resource assignment | Nokia (at least for FR2 intra-band CA), HW (Common PRB numbering can be assumed), | Nokia (FR1 DSS) |
| Time domain resource assignment | Nokia (at least for FR2 intra-band CA) | Nokia (FR1 DSS) |
| VRB-to-PRB mapping | Nokia |  |
| PRB bundling size indicator | Nokia |  |
| Rate matching indicator |  | Nokia |
| ZP CSI-RS trigger |  | Nokia |
| Modulation and coding scheme | Nokia (at least for FR2 intra-band CA) | Nokia (FR1 DSS), HW |
| New data indicator |  | HW |
| Redundancy version |  | HW |
| HARQ process number |  | HW |
| Downlink assignment index | Nokia, HW |  |
| TPC command for scheduled PUCCH | Nokia, HW |  |
| PUCCH resource indicator | Nokia, HW |  |
| HARQ timing indicator | Nokia, HW |  |
| Antenna port(s) | Nokia (at least for FR2 intra-band CA) | Nokia (FR1 DSS) |
| Transmission configuration indication | Nokia (at least for FR2 intra-band CA) | Nokia (FR1 DSS) |
| SRS request |  | Nokia |
| CBGTI | N/A |  |
| CBGFI | N/A |  |
| DMRS sequence initialization | Nokia, HW |  |
| 24-bit CRC | Nokia, HW |  |

|  |  |
| --- | --- |
| **Company** | **View** |
| Huawei, HiSi | We provided our view above as current preference. However we also want to express that some of the fields may be predefined or RRC configurable for single DCI usage. We are open to it. |

## HARQ-ACK codebook design

Regarding HARQ-ACK codebook design, there is no issue for Type 1 HARQ-ACK codebook due to the semi-static codebook size. However, for Type 2 HARQ-ACK codebook, since each non-fallback DCI can schedule one or two PDSCHs, when the DCI is missed by UE, there may be misunderstanding between gNB and UE on the number of scheduled PDSCHs. In that sense, HARQ-ACK codebook ambiguity may happen. As a result, how to construct the Type 2 HARQ-ACK codebook needs to be considered in order to synchronize the same understanding between gNB and UE.

**Company views:**

|  |  |
| --- | --- |
| **Company** | **Key Proposals/Observations** |
| Vivo | *Observation 6. To support multi-cell scheduling, the following issues need to be resolved- DCI field design- Any restrictions on the scheduled cells to be paired for multi-cell scheduling- Framework of multi-cell scheduling- Whether to introduce a new DCI format - PDCCH BD budget maintenance if multi-cell scheduling is enabled- HARQ-ACK codebook determination if multi-cell scheduling is enabled* |
| CATT | The HARQ-ACK feedback procedure may also need to be further studied accordingly, e.g. the SCS and scheduling/feedback timing may be different for the different scheduled cells. We also provide some tentative insights below from our side:* For type1 HARQ-ACK codebook, current mechanism can be directly reused if two separate PDSCHs are scheduled on different cells respectively.
* Design of C-DAI and T-DAI in one DCI for counting multiple PDSCHs scheduled by one DCI should be considered.
* HARQ-ACK timing needs to be further considered as the scheduling timing and feedback timing may be both different on the two scheduled cells.
 |
| Intel | Observation 3: Potential specification impacts include but not limited to* The RRC configuration
* Separate design for each DCI field
* UE complexity on PDCCH detection.
* HARQ-ACK transmission.
 |
| ZTE | *Observation 8: If single DCI scheduling two PDSCHs on two carriers is supported, RAN1 needs to further study how to perform the corresponding HARQ-ACK feedback.* |
| Lenovo, Motorola Mobility | *Observation 6: HARQ-ACK feedback for the two PDSCHs scheduled by a single DCI is included in same HARQ-ACK codebook.* |
| Samsung | More important for now is to identify bit savings from fields that have no impact on scheduling (e.g. C-RNTI, TPC, …) and determine the total number of bits. If companies want to re-use FDRA/MCS/… on two cells, additional requirements are then needed such as evaluation of throughout loss through system simulations, description of solutions for operation with different SCS on different cells, … |

Q7: Whether HARQ-ACK codebook determination needs to be enhanced when multiple PDSCHs are scheduled by a single DCI?

Companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **View** |
| Nokia | No |
| Apple | No |
| InterDigital | No |
| Huawei, HiSi | Given companies contributions we think it is not necessary to make decision for this question for now. Can be left to WI. |
| Spreadtrum | We are open to further discussion. And agree with CATT’s proposal in principle. |
| Vivo | TBD. Prefer to address the previous questions first.  |
| Qualcomm | TBD. Prefer not to close the door for any changes. |
| Lenovo, Motorola Mobility | We are open for further discussion. |
| ZTE | We believe it is too premature to discuss the detailed design at this stage. |
| CATT | TBD. For type1-codebook, we intend to say no as the HARQ-ACK codebook is generally determined by the semi-static configurations for PDSCH, HARQ-ACK timing, etc. For type2-codebook, it is determined by a dynamic behaviour, i.e. the received DCI. However, the key difference is that two PDSCHs are scheduled by a single DCI. The current mechanism may need to be modified. |
| Intel | Better to wait for progress on design details of multi-cell scheduling.  |
| LG | Similar view with other companies. It seems premature to discuss/decide this kind of details. |
| OPPO | TBD. |
| Ericsson | Impact on HARQ-ACK codebook (if any) can be considered in the study |
| Samsung | Not important for now – a change is needed but it is trivial. |

## Other issues

Regarding other issues not mentioned above, companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **View** |
|  |  |
|  |  |

# Miscellaneous (Low priority)

Regarding some low priority issues, companies’ views are summarized as below:

|  |  |
| --- | --- |
| Company | Key Proposals/Observations |
| Huawei, HiSilicon | *Observation 11: Using single DCI scheduling multi-carriers has large potential to be deployed with other NR features, deployment scenarios and services.* |
| vivo | *Proposal 3. Clarify whether PUSCH multi-cell scheduling should be studied.* |
| ZTE | *Proposal 2: If TU permits, RAN1 considers one DCI scheduling two PDSCHs on the same carrier instead of one DCI scheduling two PDSCHs on two carriers.* |
| MediaTek | Proposal 3: Both 1-stage DCI aggregation and 2-stage DCI aggregation for cross-carrier scheduling should be included for the evaluation. |
| ETRI | Observation 5: For multi-cell joint scheduling, scheduling more than two cells using a joint DCI can be considered. |
| Nokia, Nokia Shanghai Bell | *Proposal 1:* *Support multi-cell DCI in R17, focus on multiple SCell (2 or more) with the same/similar carrier size and SCS first. Strive to keep DCI format 1\_1 payload <106bits (including CRC).* |

Discussion points:

One company [13] propose both 1-stage DCI aggregation and 2-stage DCI aggregation for cross-carrier scheduling. For 1-stage DCI, DCIs for the scheduled cells are aggregated into a 1-stage DCI in a PDCCH. For 2-stage DCI, DCIs for the scheduled cells are aggregated into a 2-stage DCI, where 1st stage DCI is carried in a PDCCH and 2nd stage DCI is carried in a set of REs indicated in the 1st stage DCI.

Q8: Whether to support two-stage DCI for scheduling multiple carrier PDSCHs?

Companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **View** |
| Nokia | No |
| Apple | Do not prefer two-stage DCI |
| InterDigital | No |
| Charter Communications | No |
| Huawei, HiSi | Open to discuss.  |
| vivo | No |
| Qualcomm | No |
| Lenovo, Motorola Mobility | No.Since we have quite limited TU for this topic, it is not possible to fully discuss the two-stage DCI design. |
| Intel | No |
| LG | No |
| ETRI | No |
| OPPO | No |

Discussion point:

Q9: Whether to support more than 2 carriers scheduled by a single DCI?

Companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **View** |
| Nokia | Yes |
| Apple | No |
| InterDigital | No |
| Charter Communications | Concerns over DCI payload size |
| Huawei, HiSi | Yes. We see a larger potential in such case, and this is also some operator’s interest. |
| vivo | This is not allowed by the WID scope* + Study, and if agreed specify PDCCH of P(S)Cell/SCell scheduling PDSCH on multiple cells using a single DCI
		- The number of cells can be scheduled at once is limited to 2
		- The increase in DCI size should be minimized
 |
| Qualcomm | Yes |
| Lenovo, Motorola Mobility | It is better to only support up to 2 carriers in Rel-17 and can be extended to more than 2 carriers in next phase. |
| ZTE | No, unless the WID is updated. |
| Intel | No |
| LG | No |
| ETRI | Yes |
| OPPO | No, out of scope. |

Q10: Whether to support multiple PDSCHs on same carrier scheduled by a single DCI?

Companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **View** |
| Nokia | Not a priority item, can be discussed in a later stage. Should not include multi-TRP operation. |
| Apple | We do not need to discuss this at this stage. This can be discussed if we agree to support two PDSCHs in different CCs, then we can discuss whether two CCs can be the same |
| InterDigital | We should focus on the different carrier scenario |
| Charter Communications | Focus only on multi-cell scenario |
| Huawei, HiSi | Focus on the scope and the above can be discussed in a later stage. |
| vivo | No, this aspect is out of the scope. |
| Qualcomm | For this, we need to discuss how to support multi-cell PDSCH scheduling on the serving cells having different SCSs.  |
| Lenovo, Motorola Mobility | It is better to only focus on current scope in Rel-17 and can be extended in next phase. |
| ZTE | The question may be misleading. Our original proposal is trying say that RAN1 doesn’t support one PDCCH schedules two PDSCHs **on two carriers**, and instead RAN1 supports one PDCCH schedules two PDSCHs **on the same carrier**. For one PDCCH schedules two PDSCHs on the same carrier, almost all the DCI fields can be shared between the two PDSCHs. According to the Rel-16 PUSCH design, maybe only 1-3 additional bits should be sufficient. Besides, the standard effort would be minor since we already define multi-PUSCH scheduling in NRU. We can try to reuse the same design there.@Nokia, this is not related to M-TRP design. M-TRP is trying to schedule one TB from two TRPs via one PDCCH. However, the proposal here is trying to schedule two TBs. @Apple, the proposal here is trying to replace one PDCCH schedules two PDSCHs on two carriers. Thus, we didn’t see the need to bundle this two together. |
| NTT DOCOMO | We think it’s better to focus on multiple PDSCHs on different carrier since a main target of the WID is to improve PDCCH capacity in DSS and CA case. |
| Intel | We prefer to limit the discussion to two PDSCHs on two carriers |
| LG | No, it seems out of WI scope. |
| ETRI | No |
| OPPO | No |

Q11: Whether to support multiple PUSCHs on multiple carriers scheduled by a single DCI?

Companies are encouraged to provide comments in the table below.

|  |  |
| --- | --- |
| **Company** | **View** |
| Nokia | No. Could be discussed in Rel-18. |
| Apple | It is out of the WID scope |
| InterDigital | We don’t think we will have time to discuss and support it. |
| Charter Communications | Agree with Apple |
| Huawei, HiSi | Yes. We see a larger potential in such case, but perhaps this can also be discussed later. |
| vivo | We prefer to focus on the two PDSCH scheduling which is clearly included in WID, whether to extend the solution to PUSCH scheduling should be addressed later at RAN plenary.  |
| Qualcomm | Open for this.  |
| Lenovo, Motorola Mobility | It is better to only focus on current scope in Rel-17 and can be extended in next phase. |
| ZTE | No, unless the WID is updated. |
| Intel | No, out of scope.  |
| LG | No, it seems out of WI scope. |
| ETRI | UL scheduling can be considered in a next release considering the limited timeline of this WI. |
| OPPO | Open for this. |

# References

1. [R1-2007580](file:///D%3A%5CRAN1%5CRAN1%23103-e%5Ctdocs%5CR1-2007580.zip) Discussion on multi-carrier scheduling using single PDCCH Huawei, HiSilicon
2. [R1-2007696](file:///D%3A%5CRAN1%5CRAN1%23103-e%5Ctdocs%5CR1-2007696.zip) Discussion on joint scheduling vivo
3. [R1-2007840](file:///D%3A%5CRAN1%5CRAN1%23103-e%5Ctdocs%5CR1-2007840.zip) Discussion on multi-cell PDSCH scheduling via a single DCI CATT
4. [R1-2008063](file:///D%3A%5CRAN1%5CRAN1%23103-e%5Ctdocs%5CR1-2008063.zip) Discussion on multi-cell PDSCH scheduling via a single DCI LG Electronics
5. [R1-2008111](file:///D%3A%5CRAN1%5CRAN1%23103-e%5Ctdocs%5CR1-2008111.zip) Discussion on multi-cell PDSCH scheduling via a single DCI Spreadtrum Communications
6. [R1-2008196](file:///D%3A%5CRAN1%5CRAN1%23103-e%5Ctdocs%5CR1-2008196.zip) On the use of one DCI format for scheduling on two cells Samsung
7. [R1-2008285](file:///D%3A%5CRAN1%5CRAN1%23103-e%5Ctdocs%5CR1-2008285.zip) Discussion on multi-cell PDSCH scheduling via a single DCI OPPO
8. [R1-2008452](file:///D%3A%5CRAN1%5CRAN1%23103-e%5Ctdocs%5CR1-2008452.zip) Views on Rel-17 DSS Multi-cell PDSCH scheduling via a single DCI Apple
9. [R1-2008696](file:///D%3A%5CRAN1%5CRAN1%23103-e%5Ctdocs%5CR1-2008696.zip) Discussion on multi-cell PDSCH scheduling via a single DCI ASUSTeK
10. [R1-2008831](file:///D%3A%5CRAN1%5CRAN1%23103-e%5Ctdocs%5CR1-2008831.zip) Discussion on Multi-cell PDSCH Scheduling via a Single DCI ZTE
11. [R1-2008835](file:///D%3A%5CRAN1%5CRAN1%23103-e%5Ctdocs%5CR1-2008835.zip) Multi-cell scheduling and dormancy Charter Communications
12. [R1-2008929](file:///D%3A%5CRAN1%5CRAN1%23103-e%5Ctdocs%5CR1-2008929.zip) Discussion on multi-cell PDSCH scheduling via a single DCI Lenovo, Motorola Mobility
13. [R1-2008963](file:///D%3A%5CRAN1%5CRAN1%23103-e%5Ctdocs%5CR1-2008963.zip) Evaluation on On Multi-cell PDSCH Scheduling via Single DCI MediaTek Inc.
14. [R1-2009004](file:///D%3A%5CRAN1%5CRAN1%23103-e%5Ctdocs%5CR1-2009004.zip) On 2-cell scheduling via single DCI Intel Corporation
15. [R1-2009024](file:///D%3A%5CRAN1%5CRAN1%23103-e%5Ctdocs%5CR1-2009024.zip) Discussion on multi-cell PDSCH scheduling via a single DCI ETRI
16. [R1-2009047](file:///D%3A%5CRAN1%5CRAN1%23103-e%5Ctdocs%5CR1-2009047.zip) On support of Single DCI scheduling two cells Nokia, Nokia Shanghai Bell
17. [R1-2009086](file:///D%3A%5CRAN1%5CRAN1%23103-e%5Ctdocs%5CR1-2009086.zip) Discussion on the support of single DCI scheduling multi-cell InterDigital, Inc.
18. [R1-2009196](file:///D%3A%5CRAN1%5CRAN1%23103-e%5Ctdocs%5CR1-2009196.zip) Discussion on multi-cell PDSCH scheduling via a single DCI for NR DSS NTT DOCOMO, INC.
19. [R1-2009207](file:///D%3A%5CRAN1%5CRAN1%23103-e%5Ctdocs%5CR1-2009207.zip) Study on single DCI scheduling PDSCH on multiple cells Ericsson
20. [R1-2009278](file:///D%3A%5CRAN1%5CRAN1%23103-e%5Ctdocs%5CR1-2009278.zip) Views on multi-cell PDSCH scheduling via a single DCI Qualcomm Incorporated