**3GPP TSG RAN WG1 #104b-e R1-2103821**

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

**Agenda Item: 8.2.4**

**Source: Moderator (InterDigital, Inc.)**

**Title: FL Summary for Beam Management for new SCSs**

**Document for: Discussion and Decision**

# **Introduction**

In this contribution, we summarize all issues discussed on beam management and timings associated with beam-based operation for new SCSs to support NR from 52.6 GHz to 71 GHz in RAN#104b-e.

# **Timings Associated with Beam-based Operation**

## Supported values of beamSwitchTiming, beamReportTiming and timeDurationForQCL

### Observations and Proposals from Contributions

|  |  |
| --- | --- |
| **Company** | **Observations and Proposals from Contributions** |
| [Huawei/HiSi, 1] | For 480 kHz SCS (960 kHz SCS), the supported values of “beamSwitchTiming”, “beamReportTiming” and “timeDurationForQCL” are obtained by multiplying a factor of four (eight) to their corresponding values for 120 kHz SCS. |
| [Oppo, 2] | adopt the following beam switch time for 120kHz, 480kHz and 960kHz. FFS for panel activation timing.

|  |  |
| --- | --- |
| SCS | Beam switch time (symbol) |
| 120kHz | 14, 28, 48  |
| 480kHz | 56, 112, 192 |
| 960kHz | 56, 112, 192 |

adopt the following time duration QCL for 120kHz, 480kHz and 960kHz.

|  |  |
| --- | --- |
| SCS | Time duration QCL (symbol) |
| 120kHz | 14, 28  |
| 480kHz | 56, 112 |
| 960kHz | 112, 224 |

adopt the following beam report timing for 120kHz, 480kHz and 960kHz.

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| --- | --- |
| SCS | Beam report timing (symbol) |
| 120kHz | 14, 28, 56 |
| 480kHz | 56, 112, 224 |
| 960kHz | 112, 224, 448 |

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| [Spreadtrum, 3] | adopt the following values of parameters “timeDurationForQCL”, “beamSwitchTiming” and “beamReportTiming” for 480 kHz and 960 kHz.

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| --- | --- | --- |
|  | 480kHz | 960kHz |
| timeDurationForQCL (symbol) | 56, 112 | 56, 112 |
| beamSwitchTiming (symbol) | 112, 224, 336 | 112, 224, 336 |
| beamReportTiming (symbol) | 56, 112, 224 | 112, 224, 448 |

 |
| [vivo, 4] | To determine the processing timing of new numerology, it is preferred to introduce a factor to scale reference values of 120kHz. |
| [Nokia/NSB, 5] | Define parameter values (UE capabilities) for the timeDurationForQCL for the PDSCH scheduling for 480 kHz and 960 kHz SCS and values should be: first value: ≤ 56 symbols (≤ 4 slots) and second value: ≤ 112 symbols (≤ 8 slots) with 480 kHz SCSfirst value: ≤ 112 symbols (≤ 8 slots) and second value: ≤ 224 symbols (≤ 16 slots) with 960 kHz SCSDefine parameter values (UE capabilities) for the beamSwitchTiming for the A-CSI-RS triggering for 480 kHz and 960 kHz SCS and values should be{≤ 56 symbols/4 slots, ≤112 symbols/8 slots, ≤192 symbols, ≤64 slots, ≤96 slots) with 480 kHz SCS{≤ 112 symbols/8 slots, ≤224 symbols/16 slots, ≤384 symbols, ≤128 slots, ≤192 slots) with 960 kHz SCSDefine parameter values (UE capabilities) for the beamReportTiming for 480 kHz and 960 kHz SCS and values should be: {≤ 56 symbols/4 slots, ≤112 symbols/8 slots, ≤224 symbols/16 slots} with 480 kHz SCS{≤ 112 symbols/8 slots, ≤224 symbols/16 slots, ≤448 symbols/32 slots} with 960 kHz SCS |
| [CATT, 6] | The number of symbols for the timeDurationForQCL and beamReportTiming parameter for 480 kHz and 960 kHz SCS should increase in proportion comparing to that of reference lower SCS, e.g., 120 kHz SCS.For 480 kHz and 960 kHz SCS, the number of symbols for part of beamSwitchTiming values should be increased, and the number of symbols for beamSwitchTiming-r16 can be reused. |
| [Futurewei, 8] | For 480 kHz SCS and 960 kHz SCS, the values of “timeDurationForQCL”, “beamReportTiming” and “beamSwitchTiming”, are obtained by scaling their corresponding values for 120 kHz SCS by 4 and 8, respectively.  |
| [Ericsson, 9] | As a starting point for discussion of the UE capabilities, timeDurationForQCL and beamSwitchTiming, an upper bound is given by the FR2 values scaled by 4 or 8 depending on if 480 or 960 kHz SCS is used. Further discuss if this upper bound can be tightened. For the scaled capability values for beamSwitchTiming corresponding to the 224 and 336 OS values from FR2, further discuss supporting finer granularity capability indication for 480 and 960 kHz SCS.As a starting point for discussion of the value of the additional beam switching delay for cross-carrier triggering of aperiodic CSI-RS on carriers with different numerologies, consider d = 8 and 14 for µPDCCH = 3 and 5, respectively. |
| [Intel, 12] | Modify the following RRC parameters to account UE capabilities for beam management with updated values corresponding to SCS 480 kHz and 960 kHz:for timeDurationQCL: Candidate value set for 480 kHz is {28, 56, 112} OFDM symbols, candidate value set for 960 kHz, {56, 112} OFDM symbols;for beamReportTiming: Candidate value set for 480 kHz is {56, 112, 224} OFDM symbols, candidate value set for 960 kHz, {112, 224, 448} OFDM symbols;for beamSwitchTiming: Candidate value set for 480 kHz and 960 kHz is {112, 224, 336, 672} OFDM symbols; |
| [Apple, 13] | Reuse the absolute time duration defined for 120kHz SCS for new SCSs (i.e., scaling up 4/8 times for 480kHz and 960kHz SCS respectively): timeDurationForQCLbeamSwitchTimingbeamReportTiming |
| [Qualcomm, 14] | For UE capability on the following parameters per new SCS, consider as baseline to use values proportionally scaled by $2^{μ-3}$ from values for 120kHz SCStimeDurationForQCL, beamSwitchTiming, beamReportTiming, maxNumberRxTxBeamSwitchDL.  |
| [Samsung, 15] | The baseline of new beam-related UE capabilities for new SCSs can be obtained by multiplying a factor to the value for 120 kHz SCSs, while keeping same or low time duration as 120 kHz. |
| [Sony, 16] | While keeping the same time duration, extend the UE capabilities of timeDurationForQCL, beamSwitchTiming and beamReportTiming from SCS-60kHz and SCS-120kHz to SCS 480kHz and SCS 960kHz respectively. |
| [LGE, 17] | When new values for timeDurationForQCL, beamSwitchTiming, and beamReportTiming are defined for 480 kHz and 960 kHz SCSs, use the absolute time duration for 120 kHz SCS as the upper bound, and reduce the absolute time durations from the upper bound if feasible. |
| [InterDigital, 19] | Motivation to have decreased timing and timeline parameters associated with beam management is doubted as UE needs to decode DCI with similar DCI payload size while absolute amount of decreased PDCCH reception time is relatively smaller than lower SCSs due to smaller symbol duration.UE in 52.6-71 GHz may require a more complex UE implementation to handle higher phase noise, higher subcarrier spacing and increased number of antenna elements/panels.Maintain absolute time durations of timing and timeline associated parameter values in FR2 with 120 kHz SCS for timing and timeline parameter values for NR in 52.6 – 71 GHz.Whether to support reduced absolute time durations for timing and timeline parameters should be carefully studied. |
| [ZTE/Sanechips, 20] | For NR operation in 52.6 ~ 71 GHz, it can reuse the definition of timeDurationForQCL defined in TS 38.306 and adopt scaled values of reference SCS 120 kHz for new SCSs 480/960 kHz as follows.

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| --- | --- |
| Subcarrier spacing | Proposed value of *timeDurationForQCL*(symbols) |
| 120 kHz | 14, 28 |
| 480 kHz | 56, 112 |
| 960 kHz | 112, 224 |

For NR operation in 52.6 ~ 71 GHz, it can reuse the definition of beamReportTiming defined in TS 38.306 and adopt scaled values of reference SCS 120 kHz for new SCSs 480/960 kHz as follows.

|  |  |
| --- | --- |
| Subcarrier spacing | Proposed value of beamReportTiming (symbols) |
| 120 kHz | 14, 28, 56 |
| 480 kHz | 56, 112, 224 |
| 960 kHz | 112, 224, 448 |

For NR operation in 52.6 ~ 71 GHz, it can reuse the definition of beamSwitchTiming defined in TS 38.306 and adopt scaled values of reference SCS 60/120 kHz for new SCSs 480/960 kHz as follows.

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| --- | --- |
| Subcarrier spacing | Proposed value of *beamSwitchTiming*(symbols) |
| 120 kHz | 14, 28, 48, 224, 336 |
| 480 kHz | 56, 112, 192, 896, [1344] |
| 960 kHz | 56, 112, 192, 896, [1344] |

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### Summary of views

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| **#** | **Issue** | **Companies’ views** |
| 1.1 | Candidate values of beamSwitchTiming, beamReportTiming and timeDurationForQCL for 120 kHz | beamSwitchTiming* Reuse the existing values (i.e., 14, 28, 48, 224 and 336 symbols)
	+ [Spreadtrum], [Nokia/NSB], [Futurewei], [Ericsson], [Intel], [Apple], [Qualcomm], [Samsung], [Sony], [LGE], IDCC, ZTE/Sanechips
* Define different values (e.g., some of the existing values)
	+ Oppo (14, 28, 48),

timeDurationForQCL* Reuse the existing values (14 and 28 symbols)
	+ Oppo, [Spreadtrum], [Nokia/NSB], [Futurewei], [Ericsson], [Intel], [Apple], [Qualcomm], [Samsung], [Sony], [LGE], IDCC, ZTE/Sanechips

beamReportTiming* Reuse the existing values (14, 28 and 56 symbols)
	+ Oppo, [Spreadtrum], [Nokia/NSB], [Futurewei], [Ericsson], [Intel], [Apple], [Qualcomm], [Samsung], [Sony], [LGE], IDCC, ZTE/Sanechips

Note: Supporting companies with brackets are used when the companies are assuming that they are reusing the existing values for 120 kHz in FR2 for NR in 52.6 – 71 GHz without explicit proposals. |
| 1.2 | Candidate values of beamSwitchTiming for 480 kHz and 960 kHz | Identical absolute time duration (multiplying a factor of four or eight to the corresponding candidate values for 120 kHz SCS) * Huawei/HiSi, Oppo (480 kHz), Nokia/NSB, Futurewei, Ericsson, Apple, Qualcomm, Samsung, Sony, LGE, IDCC, ZTE/Sanechips

Use candidate values which are obtained by multiply a factor of four to the corresponding values for 120 kHz SCS for 960 kHz* Oppo, Spreadtrum

Define different values* Intel (112, 224, 336, 672 for 480/960 kHz)
 |
| 1.3 | Candidate values of beam ReportTiming for 480 kHz and 960 kHz | Identical absolute time duration (multiplying a factor of four or eight to the corresponding candidate values for 120 kHz SCS)* Huawei/HiSi, Oppo, Nokia/NSB, Futurewei, Ericsson, Intel, Apple, Qualcomm, Samsung, Sony, LGE, IDCC, ZTE/Sanechips

Define different values * Intel (56, 112 for 480 kHz and 112, 224, 448 for 960 kHz)
 |
| 1.4 | Candidate values of timeDurationForQCL for 480 kHz and 960 kHz | Identical absolute time duration (multiplying a factor of four (eight) to the corresponding values for 120 kHz SCS)* Huawei/HiSi, Oppo, Spreadtrum (480 kHz), Nokia/NSB, Futurewei, Ericsson, Apple, Qualcomm, Samsung, Sony, LGE, IDCC, ZTE/Sanechips

Use candidate values which are obtained by multiply a factor of four to the corresponding values for 120 kHz SCS for 960 kHz* Spreadtrum

Define different values* Intel (28, 56, 112 for 480kHz and 56, 112 for 960 kHz)
 |
| 1.5 | Signaling method to indicate values of beamSwitchTiming, beamReportTiming and timeDurationForQCL | Absolute values in number of symbols* [Oppo], [Spreadtrum], [Nokia/NSB], [Futurewei], [Ericsson], [Intel], [Apple], [Qualcomm], [Sony], [LGE], [IDCC], [ZTE/Sanechips]

Multiply a factor to the corresponding values of 120 kHz (e.g., 4 for 480 kHz and 8 for 960 kHz)* Huawei/HiSi, vivo

Note: Supporting companies with brackets are used when the companies are providing proposals based on absolute values in number of symbols without explicit proposals.  |

### 1st round discussion

#### Observation 1

For timeDurationForQCL, beamSwitchTiming and beamReportTiming, it is observed that majority of companies are supporting reusing the existing candidate values for 120 kHz in NR 52.6 – 71 GHz. In addition, majority of companies are supporting identical absolute time duration for 480 kHz and 960 kHz (i.e., multiplying a factor of four or eight to the corresponding candidate values for 120 kHz SCS). For a signaling method, two candidate methods (indicating number of symbols or introducing scaling fators) are discussed. Companies are encouraged to share their views on the signaling method.

#### Proposal 1

* For timeDurationForQCL, beamSwitchTiming and beamReportTiming,
	+ Following candidate values of FR2 are reused for 120 kHz:
		- timeDurationForQCL: 14 and 28 symbols
		- beamSwitchTiming: 14, 28, 48, 224 and 336 symbols
		- beamReportTiming: 14, 28 and 56 symbols
	+ Reuse the absolute time duration defined for 120kHz for 480 kHz and 960 kHz
		- Down select one of the following alternatives for UE capability indication method
			* Alt-1: UE reports preferred values in number of symbols
			* Alt-2: Introduce a factor to scale the reference values of 120kHz

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| **Company** | **Input** |
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#### Proposal 1a (updated during GTW session)

Proposal:

For timeDurationForQCL, beamSwitchTiming and beamReportTiming,

* Following candidate values of FR2 are reused for 120 kHz:
	+ timeDurationForQCL: 14 and 28 symbols
	+ beamSwitchTiming: 14, 28, 48, 224 and [336] symbols
	+ beamReportTiming: 14, 28 and 56 symbols
* Reuse the absolute time duration defined for 120kHz as the maximum reportable value for 480 kHz and 960 kHz
	+ Down select one of the following alternatives for UE capability indication method used to report the values
		- Alt-1: UE reports preferred values in number of symbols
		- Alt-2: Introduce a factor to scale the reference values of 120kHz for 480 kHz and 960 kHz respectively
	+ FFS: Whether absolute time duration defined for 480 kHz and 960 kHz can be further reduced

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| **Company** | **Input** |
| LG Electronics | As discussed in GTW session, our understanding on Alt-1 and Alt-2 is:* For Alt-1, a UE is allowed to report any combination of candidate values for any SCSs. For example, 28 symbols of timeDurationForQCL for 120 kHz but 56 symbols of timeDurationForQCL for 240 kHz can be reported by the UE.
* For Alt-2, once a UE reports a value for 120 kHz, the UE does not need to report any value for 480/960 kHz SCS. For example, if a UE reports 28 symbols of timeDurationForQCL for 120 kHz, then timeDurationForQCL for 480/960 kHz is automatically determined by 112/224 symbols for 480/960 kHz SCS, respectively, without additional capability report for 480/960 kHz.

Even though this is the case, we are not in a hurry to decide UE capability signaling details at this stage. So, we suggest to defer the discussion on signaling details.Furthermore, one concern during GTW session was that some of values (e.g., 224/336 symbols for beamSwitchTiming) may not be kept as the absolute time duration for 120 kHz.Based on above observations, we suggest the following modification:For timeDurationForQCL, beamSwitchTiming and beamReportTiming,* Following candidate values of FR2 are reused for 120 kHz:
	+ timeDurationForQCL: 14 and 28 symbols
	+ beamSwitchTiming: 14, 28, 48, 224 and 336 symbols
	+ beamReportTiming: 14, 28 and 56 symbols
* Reuse the absolute time duration defined for 120kHz as the maximum reportable value for 480 kHz and 960 kHz, at least for timeDurationForQCL and beamReportTiming
	+ FFS: Whether absolute time duration defined for 480 kHz and 960 kHz can be further reduced
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## maxNumberRxTxBeamSwitchDL

### Observations and Proposals from Contributions

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| **Company** | **Observations and Proposals from Contributions** |
| [Huawei/HiSi, 1] | For 480kHz/960kHz, supporting the same values for maxNumberRxTxBeamSwitchDL as in 120kHz is challenging for UE implementation as well as system resource utilization. The benefits of keeping the legacy beam switching values need to be justified. Consider smaller values for maxNumberRxTxBeamSwitchDL in 480kHz and 60kHz, e.g., 2, 4, 7. This WI can discuss if the beam switching behavior between adjacent symbols is ambiguous in some cases and if it is necessary to clarify the definition of maxNumberRxTxBeamSwitchDL for those cases.  |
| [Spreadtrum, 3] | Regarding “maxNumberRxTxBeamSwitchDL”, the number of Tx and Rx beam changes UE can perform should be scale down to {2, 4, 7} within a slot. |
| [Nokia/NSB, 5] | Values for maxNumberRxTxBeamSwitchDL should be ≥2 for both 480 and 960 kHz SCS. |
| [CATT, 6] | When SCS is 480KHz or 960KHz, the duration of each OFDM symbol would be shorter. UE may not support performing beam switching as much as 14 times within a slot.For SCS 480kHz/960Khz, the minimum and maximum available value of maxNumberRxTxBeamSwitchDL should be reduced. |
| [Ericsson, 9] | For 480 and 960 kHz SCS, support a value range of {4,7,14} for the UE capability parameter maxNumberRxTxBeamSwitchDL. |
| [Intel, 12] | for maxNumberRxTxBeamSwitchDL: Candidate value set is {2, 4, 7, 14} switches. |
| [Qualcomm, 14] | For UE capability on the following parameters per new SCS, consider as baseline to use values proportionally scaled by $2^{μ-3}$ from values for 120kHz SCStimeDurationForQCL, beamSwitchTiming, beamReportTiming, maxNumberRxTxBeamSwitchDL.  |
| [Sony, 16] | Support new parameter value(s) of UE capability on maxNumberRxTxBeamSwitchDL for SCS 480kHz and SCS 960kHz respectively and these new values e.g. ‘n1’ and ‘n2’ can be FFS. |
| [InterDigital, 19] | It is preferred to support maxNumberRxTxBeamSwitchDL for higher 480 kHz and 960 kHz as well as 120 kHz. |
| [ZTE/Sanechips, 20] | For NR operation in 52.6 ~ 71 GHz, it can reuse the definition of maxNumberRxTxBeamSwitchDL defined in TS 38.306 and allow the maximum number of Tx and Rx beam changes UE can perform within a slot equals to one or two in addition to [4, 7, 14] for SCSs 480/960 kHz.

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| --- | --- |
| Subcarrier spacing | Proposed value of *maxNumberRxTxBeamSwitchDL* |
| 120 kHz | 4, 7, 14 |
| 480 kHz | [1], 2, 4, 7, 14 |
| 960 kHz | [1], 2, 4, 7, 14 |

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| [Docomo, 21] | For timing parameters associated with beam based operation,New value range for maxNumberRxTxBeamSwitchDL may need to be considered for 480/960kHz SCS based on UE capability. |

### Summary of views

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| **#** | **Issue** | **Companies’ views** |
| 2.1 | maxNumberRxTxBeamSwitchDL | Support maxNumberRxTxBeamSwitchDL for new SCSs* Huawei/HiSi, Spreadtrum, Nokia/NSB, CATT, Ericsson, Intel, Qualcomm, Sony, IDCC, ZTE/Sanechips, Docomo

Proposed candidate values * Huawei/HiSi (2, 4, 7), Spreadtrum (2, 4, 7), Nokia/NSB (≥2), Ericsson (4, 7, 14), Intel (2, 4, 7, 14), ZTE/Sanechips (2, 4, 7, 14)
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### 1st round discussion

#### Observation 2

For maxNumberRxTxBeamSwitchDL, it is observed that majority of companies are supporting to introduce new candidate values, however, there’s no clear majority view on the candidate values.

#### Proposal 2

* Introduce new parameter values for maxNumberRxTxBeamSwitchDL
* Companies are encouraged to provide preferred values on maxNumberRxTxBeamSwitchDL

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| **Company** | **Input** |
| LG Electronics | {4,7,14} per slot can be the starting point and we are open to discuss whether 2 is additionally needed or not. |
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## Additional beam switching time delay d

### Observations and Proposals from Contributions

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| **Company** | **Observations and Proposals from Contributions** |
| [vivo, 4] | the issue about UE buffer capability should be considered together with timing determination. |
| [Nokia/NSB, 5] | Additional time delay d is defined when triggering PDCCH with 120kHz or 480kHz has a smaller subcarrier spacing than AP-CSI-RS. Value(s) for new SCSs FFS. |
| [CATT, 6] | Table 1: Additional beam switching timing delay *d*

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| --- | --- |
| **µPDCCH** | **d [PDCCH symbols]** |
| 0 | 8 |
| 1 | 8 |
| 2 | 14 |
| 3 | 26 |
| 5 | 48 |
| 6 | 90 |

 |
| [Ericsson, 9] | As a starting point for discussion of the value of the additional beam switching delay for cross-carrier triggering of aperiodic CSI-RS on carriers with different numerologies, consider d = 8 and 14 for µPDCCH = 3 and 5, respectively. |
| [Intel, 12] | For additional beam switching delay $d$, support [14] PDCCH symbols when $μ\_{PDCCH}=3$ (SCS 120 kHz), support [56] PDCCH symbols when $μ\_{PDCCH}=5$ (SCS 480 kHz). |
| [Apple, 13] | Reuse the absolute time defined for 60kHz for Additional beam switching time delay ‘d’, i.e., 28 symbols for 120kHz and 112 symbols for 480kHz.  |
| [LGE, 17] | Define UE behaviour to determine different QCL assumptions for triggered aperiodic CSI-RS depending on the offset between PDCCH and CSI-RS, after new values are defined for beamSwitchTiming for 480 kHz and 960 kHz SCSs. |
| [InterDigital, 19] | It is preferred to support additional beam switching time delay d for both 120 kHz and 480 kHz. |
| [ZTE/Sanechips, 20] | The following values can be considered for additional beam switching time delay d for triggering AP-CSI-RS when triggering PDCCH with 120/480kHz has a smaller SCS than AP-CSI-RS.

|  |  |
| --- | --- |
| *µPDCCH* | *d* [PDCCH symbols] |
| 3 | 28 |
| 5 | 56 |

 |
| [Docomo, 21] | For timing parameters associated with beam based operation,New parameter values need to be defined for beam switching time delay d for triggering AP-CSI-RS by a PDCCH with a smaller subcarrier spacing than that for AP-CSI-RS. |

### Summary of views

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| **#** | **Issue** | **Companies’ views** |
| 3.1 | Additional beam switching time delay d | **Yes:** vivo, Nokia/NSB, CATT, Ericsson, Intel, Apple, LGE, IDCC, Docomo**No:** |
| 3.2 | Proposed candidate values for 120 kHz and 480 kHz | Ericsson (8, 14), Intel (14, 56), Apple (28, 112), ZTE/Sanechips (28, 56) |
| 3.3 | Definition on UE behaviour to determine different QCL assumptions for triggered aperiodic CSI-RS | **Yes:** LGE**No:**  |

### 1st round discussion

#### Observation 3

For additional beam switching time delay d, it is observed that majority of companies are supporting to introduce new candidate values, however, there’s no clear majority view on the candidate values.

#### Proposal 3

* Introduce new parameter values for additional beam switching time delay d for triggering AP-CSI-RS when triggering PDCCH with 120kHz or 480kHz has a smaller subcarrier spacing than AP-CSI-RS
* Companies are encouraged to provide preferred values on additional beam switching time delay d

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| **Company** | **Input** |
| LG Electronics | Just to clarify our proposal in issue #3-3, it is related to beamSwitchTiming, rather than related to delay *d*. To be specific, in Rel-15/16, different UE behavior was defined depending on whether the offset between PDCCH and CSI-RS is smaller than 48 symbols (i.e., the beam switching threshold) or not. If we define new set of values for beamSwitchTiming (as in Section 2.2), it is also necessary to define beam switching threshold as one of values in the set. |
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## Introduction of beam switching time between signals/channels

### Observations and Proposals from Contributions

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| **Company** | **Observations and Proposals from Contributions** |
| [Huawei/HiSi, 1] | At least for 960kHz SCS, current scheduling restrictions cannot protect the reception or transmission of a signal with a higher priority when an adjacent symbol carries a signal with a lower priority and using different beams. Apply further scheduling restrictions on the adjacent symbol to the signal with a higher priority, when the adjacent symbol carries a signal with a lower priority and using different beams. |
| [vivo, 4] | Supporting the UE capability reporting of beam switching gap and further study P3 beam management. |
| [Nokia/NSB, 5] | No explicit beam switching gap is introduced between DL signals and channels. |
| [CATT, 6] | When the additional beam switching gap is introduced, QCL assumption needs to be investigated. |
| [Futurewei, 8] | For both 480 kHz and 960 kHz SCS, UE is not expected to receive downlink data or control channel or reference signals with different QCL-TypeD properties on adjacent symbols within a slot if that violates its signaled beam switch capability or if this capability is not signaled. |
| [Ericsson, 9] | To allow efficient configuration of reference signal resource sets for beam management for 480/960 kHz SCS, RAN1 should further discuss the introduction of some form of UE capability signalling that can provide the network with knowledge related to the UE beam switch time (on the order of 10s of ns, rather than 10s of symbols). |
| [Lenovo/MotM, 11]: | For supporting NR from 52.6 GHz to 71 GHz in Rel. 17, for the agreed higher subcarrier spacings (numerologies) such as 960kHz, beam switching issue would appear between the contiguous transmissions (such as SSB beams) since the CP length would not be enough for beam switching, and an extra gap might be needed to prevent performance degradation.For supporting NR from 52.6 GHz to 71 GHz in Rel. 17, if higher subcarrier spacings (numerologies) are adopted for SSB, then to allow the beam switching between contiguous SSBs, a gap (for example a symbol gap or post prefix) should be supported between contiguous SSB. |
| [Intel, 12] | For larger SCS, the configuration of time gaps between PDSCH and CSI-RS does not require new specification work as the gaps could be configured relying on existing NR mechanisms. |
| [Qualcomm, 14] | Introduce a minimum interval between start of two consecutive beam switches.The value can be X symbols per SCS and can be UE capability. Introduce explicit beam switch gaps at least in the following scenarios for 480 and 960 KHz SCSs.Between different SSBs.Between CSI-RS resources in a resource set with higher layer parameter Repetition configured as ON. |
| [Samsung, 15] | Reserve one symbol for beam switching gap when using 480 kHz and 960 kHz SCSs. |
| [ZTE/Sanechips, 20] | Rel-15/16 NR specifications have enough flexibility to support beam switching for non-SSB channels/signals with new SCSs 480 kHz and 960 kHz, even if the lengths of CP are not enough for beam switching. |
| [Docomo, 21] | For timing parameters associated with beam based operation,New parameter values need to be defined for beam switching time delay d for triggering AP-CSI-RS by a PDCCH with a smaller subcarrier spacing than that for AP-CSI-RS. |

### Summary of views

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| **#** | **Issue** | **Companies’ views** |
| 4.1 | Introduction of beam switching gap | **Yes:** Huawei/HiSi, vivo, CATT, Futurewei, Ericsson, Lenovo/MotM, Qualcomm, Samsung, Docomo* [Lenovo/MotM]: beam switching issue would appear between the contiguous transmissions (such as SSB beams) since **the CP length would not be enough** for beam switching, and an extra gap might be needed to prevent performance degradation.
* [Qualcomm]: Introduce explicit beam switch gaps at least for **between different SSBs and between CSI-RS resources in a resource set for BM**

**No:** Nokia/NSB, Intel, ZTE/Sanechips* [ZTE/Sanechips] Rel-15/16 NR specifications have **enough flexibility to support beam switching** for non-SSB channels/signals even if the lengths of CP are not enough for beam switching
 |

### 1st round discussion

#### Observation 4

For introduction of beam switching time gap, 16 companies expressed their views. 11 companies are proposing to support beam switching gap due to short CP length of additional SCSs which is not enough for beam switching while 3 companies want to handle it by gNB implementation. More inputs from other companies are requested on whether/how to support beam switching time gap.

Please share your views on whether/how to support beam switching time gap.

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| **Company** | **Input** |
| LG Electronics | Discussion on beam switching time gap needs to be deferred until RAN4 send reply LS to RAN1. |
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#### Proposal 4

TBU

## Other parameters

### Observations and Proposals from Contributions

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| **Company** | **Observations and Proposals from Contributions** |
| [Ericsson, 9] | To support 480 and 960 kHz, RAN1 needs to discuss whether or not the triggering offset for an aperiodic CSI-RS resource set (aperiodicTriggeringOffset) needs to be extended above the current maximum value of 31 slots.The CSI computation delay requirements Z3 and Z3' depend on the value indicated by the UE capability parameter beamReportTiming. All CSI computation delay requirements Z1, Z1', Z2, Z2', Z3, and Z3' should be discussed together. |

### 1st round discussion

#### Observation 5

No clear majority was observed. Please share your views on whether/how to support other timing related parameters.

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| **Company** | **Input** |
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#### Proposal 5

TBU

# **Multiple QCL Assumptions for Multiple PDSCHs/PUSCHs**

## Multiple QCL assumptions based on timeDurationForQCL

### Observations and Proposals from Contributions

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| **Company** | **Observations and Proposals from Contributions** |
| [Huawei/HiSi, 1] | In the slots with offset smaller than timeDurationForQCL, UE may receive and buffer signals in each slot using a different beam associated with the lowest CORESET ID of the latest monitored slot.At least for delay sensitive traffics, when the offset of the scheduled PDSCHs using single DCI is smaller than timeDurationForQCL, support receiving each of those PDSCHs with a default TCI state that is associated with a monitored search space with the lowest CORESET ID in the latest slot to that PDSCH.When multi-PDSCHs are scheduled by a single DCI and the offset of a PDSCH is smaller than timeDurationForQCL, consider the solution that a scheduled PDSCH is not transmitted when its default TCI state is not associated with the PDCCH that schedules the PDSCH. |
| [Oppo, 2] | reuse the legacy principle as much as possible for QCL assumption determination: If the offset between the reception of the DL DCI and the corresponding PDSCH is less than the threshold timeDurationForQCL, the UE shall follow the QCL assumption of the CORESET on the latest slot to determine the QCL assumption of the PDSCH. If the offset between the reception of the DL DCI and the corresponding PDSCH is equal to or greater than the threshold timeDurationForQCL, the UE shall follow the TCI-state indication in the DCI to determine the QCL assumption of the PDSCH. |
| [Spreadtrum, 3] | the scheduled PDSCHs with scheduling offset less than timeDurationForQCL are assumed to be quasi co-located with the lowest CORESET ID, and the scheduled PDSCHs with scheduling offset equal to or greater than timeDurationForQCL are assumed to be quasi co-located with the RS(s) in the TCI state.In case of when all of the scheduled PDSCHs have scheduling offset less than timeDurationForQCL, the scheduled PDSCHs are assumed to be quasi co-located with the lowest CORESET ID. |
| [vivo, 4] | do not support different QCL application for multiple PDSCH scheduled by a single DCI. |
| [Nokia/NSB, 5] | If some of PDSCHs in multi-PDSCH scheduling are allocated with scheduling offset less than timeDurationForQCL the UE would have different QCL assumptions for the PDSCHs allocated with scheduling offset than timeDurationForQCL and for the PDSCH allocated with scheduling offset equal to and greater than timeDurationForQCL.Support single TCI state or QCL assumption for the multi-PDSCH transmission in case of some of the PDSCHs are having lower scheduling offset than timeDurationForQCL.gNB can by the configuration/scheduling guarantee that the UE may apply the same QCL-TypeD RS for the reception of the multi-PDSCH transmission even though some of the PDSCHs would have scheduling offset less than timeDurationForQCL.NW ensures single TCI state or QCL assumption across the slots for the multi-PDSCH transmission. |
| [CATT, 6] | PDSCH QCL’d with the RS in the TCI state indicated by the DCI and QCL’d with the first PDSCH scheduled by DCI may both acquire reception gain, there should be some conditions to determine the QCL assumption.When some of the scheduled PDSCHs have scheduling offset less than timeDurationForQCL and some have scheduling offset equal to or greater than timeDurationForQCL, both options below should be supported for the scheduled PDSCHs have scheduling offset equal to or greater than timeDurationForQCL.The scheduled PDSCHs quasi co-located with the RS(s) in the TCI state with respect to the QCL type parameter(s) given by the indicated TCI state in DCI.The scheduled PDSCHs quasi co-located with the RS(s) based on the activated TCI states in the first slot with the scheduled PDSCH. |
| [MediaTek, 7] | For the reception of multi-PDSCHs scheduled by a single DCI within the duration specified by timeDurationForQCL, current Rel-15/16 default beam assumption should be applied. |
| [Futurewei, 8] | Necessity of any changes to default beam assumptions in single DCI multi-slot PDSCH scheduling should be clarified first. |
| [Ericsson, 9] | For all PDSCHs scheduled with a single DCI, when the DCI is not configured with the TCI field, the UE applies the same QCL assumption as specified in Rel-16 for the case when the scheduling offset ≥ timeDurationForQCL with the interpretation that the scheduling offset corresponds to the first scheduled PDSCH.For multiple PDSCHs scheduled by a single DCI, if the scheduling offset for any of the PDSCHs is less than timeDurationForQCL (plus additional delay $d\frac{2^{μ\_{PDSCH}}}{2^{μ\_{PDCCH}}}$ for the case of cross-carrier scheduling, if enableDefaultBeam-ForCCS is configured), the UE applies the same default QCL assumption for all scheduled PDSCHs given by the default QCL assumption for the first PDSCH. For both single and multi-TRP, the default QCL assumption for the first PDSCH is the same as that specified in Rel-16 for the case when the scheduling offset < timeDurationForQCL. |
| [Xiaomi, 10] | For the scheduled PDSCHs have scheduling offset less than timeDurationForQCL, the QCL assumption is the same as the PDSCH in the first TTI, which is determined by R16 behavior. And for the scheduled PDSCHs have scheduling offset equal to or greater than timeDurationForQCL, the QCL assumption is the same as the PDCCH scheduling the PDSCHs when there is no TCI indication field in the scheduling DCI, or the QCL assumption is indicated by the TCI indication field, if it exists, in the scheduling DCI. |
| [Lenovo/MotM, 11] | For NR operation between 52.6 GHz and 71 GHz with high subcarrier spacing values such as 480kHz and 960kHz, specify enhancements to support multiple default beams association for multiple PDSCHs scheduled by single DCI:PDCCH CORESET can be associated with multiple QCL assumptions (beams) that can be used to determine multiple default beams based on lowest CORESET IDDuration/applicability for each of the default beams can also be associated to allow UE to determine when to switch from one default beam to another during the duration of multiple PDSCH transmission |
| [Intel, 12] | When scheduling offset of PDSCH from multi-PDSCH transmission is greater than timeDuraionForQCL and tci-PresentInDCI is enabled, the UE should apply QCI assumption(s) indicated in the scheduling DCI. Otherwise, the UE should apply the default QCL assumption(s) which corresponds to one of the semi-statically configured PDSCH TCI states for the UE.FFS: Which TCI state from the dedicated UE configuration is the default. |
| [Apple, 13] | Support a mechanism to allow a single QCL assumption at least for multi-PDSCH scheduled by a single DCI that have scheduling offset less than timeDurationForQCL.  |
| [Qualcomm, 14] | Support dedicated configuration of default PDSCH beam for better optimization flexibility.gNB can dynamically update the default PDSCH beam via MAC-CE. |
| [Samsung, 15] | Use the first PDSCH occasion as a reference to determine the latest slot containing CORESET to monitor for the case when all of the scheduled PDSCHs have scheduling offset less than timeDurationForQCLUse indicated QCL assumption when an enough gap for beam switching is provided, otherwise keep default QCL assumption. |
| [Sony, 16] | Do NOT support multi-beam operation for single-DCI scheduled multi-PDSCH/PUSCH.For single DCI scheduled multiple PDSCH, UE applies the same default Rx beam from the 1st PDSCH to the last PDSCH.For the case when all scheduled PDSCH are within timeDurationForQCL, UE applies the same default Rx beam of the 1st PDSCH to all other PDSCH. |
| [LGE, 17] | Consider the following approaches when all or some of PDSCHs scheduled by a single DCI have scheduling offset less than timeDurationForQCL.Approach 1: The scheduled PDSCHs that have scheduling offset less than timeDurationForQCL apply the same QCL parameter(s) used for the lowest index CORESET in the latest slot from the first scheduled PDSCH.Approach 2: If at least one of scheduled PDSCHs has scheduling offset less than timeDurationForQCL, all of scheduled PDSCHs apply the same QCL parameter(s) used for the lowest index CORESET in the latest slot from the first scheduled PDSCH. |
| [Convida, 18] | Legacy TCI state indication can be extended for single DCI scheduling multi-PDSCH, for NR from 52.6 GHz to 71 GHz if gap symbol(s) is considered. |
| [InterDigital, 19] | For single-TRP in NR 52.6 – 71 GHz, introduction of multi-beam based transmission for multi-PDSCH scheduling does not provide performance gain considering beam switching gaps and short slot durations for higher SCSs.Performance gain from multi-TRP based multi-beam transmission should be carefully evaluated.When all or some of the scheduled PDSCHs have scheduling offset less than timeDurationForQCL, apply a beam of the firstly scheduled PDSCH for all of the scheduled PDSCHs. |
| [ZTE/Sanechips, 20] | For all PDSCHs scheduled by a single DCI with scheduling offsets less than the threshold timeDurationForQCL, same default QCL assumption(s) can be adopted.For all PDSCHs scheduled by a single DCI with the scheduling offset equal to or greater than the threshold timeDurationForQCL, same QCL assumption(s) can be adopted. |

### Summary of views

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| **#** | **Issue** | **Companies’ views** |
| 6.1 | Support of multiple beams based on timeDurationForQCL | **Yes (multiple beams):** Oppo, Spreadtrum, MediaTek, Futurewei, Xiaomi, Lenovo/MotM, Convida* [Oppo]: reuse the legacy principle as much as possible for QCL assumption determination
* [FW]: Necessity of any changes to default beam assumptions in single DCI multi-slot PDSCH scheduling should be clarified first.

**No (single beam):** vivo, Nokia/NSB, Ericsson, Intel, Apple, Sony, LGE, IDCC, ZTE/Sanechips* [Ericsson]: The UE applies the same QCL assumption as specified in Rel-16 for the case when the scheduling offset ≥ timeDurationForQCL with the interpretation that the scheduling offset corresponds to the first scheduled PDSCH.
* [Sony]: For single DCI scheduled multiple PDSCH, UE applies the same default Rx beam from the 1st PDSCH to the last PDSCH.
* [QC]: Support dedicated configuration of default PDSCH beam and update via MAC CE

**Both:** Huawei/HiSi (based on traffic type), CATT (based on resource reservation), Samsung (if enough gap is provided) |

### 1st round discussion

#### Observation 6

No clear majority was observed on whether to support multiple beams based on timeDurationForQCL. Companies, which propose supporting multiple beams, could not find clear technical motivation to change default beam assumptions and want to reuse legacy principles as much as possible. On the other hand, companies, which propose supporting single default beam, believe that same QCL assumption are already specified in Rel-16 with the interpretation that the scheduling offset corresponds to the first scheduled PDSCH and provide better flexibility with a dedicated configuration and an update via MAC CE. In addition, some companies proposed to support both options based on traffic type, resource reservation and a time gap. More inputs from other companies are requested on the existing specification support and whether/how to support multiple beams based on timeDurationForQCL.

Please share your views on the existing specification support and whether/how to support multiple beams based on timeDurationForQCL.

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| **Company** | **Input** |
| LG Electronics | Existing specification doesn’t support default QCL assumption when multiple PDSCHs are scheduled by a single DCI but with individual TB. Thus, we need a rule at least for the case where all or some of PDSCHs scheduled by a single DCI have scheduling offset less than timeDurationForQCL. In our Tdoc, we proposed two approaches as follows:* Approach 1: The scheduled PDSCHs that have scheduling offset less than *timeDurationForQCL* apply the same QCL parameter(s) used for the lowest index CORESET in the latest slot from the first scheduled PDSCH.
* Approach 2: If at least one of scheduled PDSCHs has scheduling offset less than *timeDurationForQCL*, all of scheduled PDSCHs apply the same QCL parameter(s) used for the lowest index CORESET in the latest slot from the first scheduled PDSCH.
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#### Proposal 6

TBU

## Multiple TCI states/SRIs for multiple PDSCHs/PUSCHs

### Observations and Proposals from Contributions

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| **Company** | **Observations and Proposals from Contributions** |
| [Huawei/HiSi, 1] | In single-TRP scenario, do not indicate a separate TCI state/SRI for each scheduled PDSCH/PUSCH in Rel-17. |
| [Spreadtrum, 3] | For multi-PDSCH scheduling with a single DCI, it is not needed to indicate a separate TCI state for each scheduled PDSCH.For multi-PUSCH scheduling with a single DCI, it is not needed to indicate a separate SRI (indication of TCI can be further discussed) for each scheduled PUSCH. |
| [vivo, 4] | do not support separate TCI state indicator for multiple PDSCH scheduled by a single DCI. |
| [Nokia/NSB, 5] | Support single SRI or a single common UL TCI state (if supported) is used for a multi-PUSCH transmission. |
| [CATT, 6] | If single DCI schedule multi-PUSCH/PDSCH is supported, multiple beam indications of PDSCH with different TCI states need to be investigated.If separate TCI state for each scheduled PDSCH introduced for multi-PDSCH scheduling with a single DCI, the solution for overhead reduction need to be investigated. |
| [MediaTek, 7] | Support only single TCI for multi-PDSCH enhancement.  |
| [Ericsson, 9] | For multiple PDSCHs scheduled with a single DCI for both same and cross-carrier scheduling, support a single TCI field in the DCI that is applicable to all scheduled PDSCHs. To support multi-TRP, the single TCI field can indicate one or two TCI states. The UE applies the QCL assumptions provided by the indicated TCI state(s) for all scheduled PDSCHs if the scheduling offset for the first PDSCH ≥ timeDurationForQCL.As in Rel-16, for multiple PUSCHs scheduled with a single DCI support a single SRI field in the DCI that is applicable to all scheduled PUSCHs. |
| [Xiaomi, 10] | For single TRP and multi-TRP with multi-DCI, there is no need to indicate a separate TCI state for each scheduled PDSCH/PUSCH. For multi-TRP with single DCI, the TCI states for the PDSCHs/PUSCHs belonging to different TRPs should be indicated separately. |
| [Lenovo/MotM, 11] | For NR operation between 52.6 GHz and 71 GHz with high subcarrier spacing values such as 480kHz and 960kHz, specify enhancements to support multiple beams (multiple TCI states with QCL type-D assumption) indication via single DCI and corresponding duration of each beam within the scheduled duration:FFS the number of TCI states (beams) that can be indicated for multiple PDSCH (or PUSCH) across multiple slots by single TCI codepoint in DCI |
| [Intel, 12] | For multi-PDSCH scheduling with single DCI, separate indication of TCI state (or TCI states in case of multi-TRP) per each scheduled PDSCH or subset of scheduled PDSCH transmissions is not supported.For multi-PUSCH scheduling with single DCI, separate indication of SRI and TCI states per each scheduled PUSCH or subset of scheduled PUSCH transmissions is not supported. |
| [Qualcomm, 14] | For single DCI scheduling multiple PDSCH/PUSCH, the indicated TCI(s)/SRI(s) can be different across PDSCHs/PUSCHs with different reliability requirements.PDSCH(s)/PUSCH(s) requiring high reliability can be transmitted via multiple TCIs/SRIs, e.g. SDM/FDM based mTRP schemes. |
| [Samsung, 15] | Support multiple TCI state/SRI indication for multi- PDSCH/PUSCH scheduled by a single DCI. |
| [Sony, 16] | Do NOT support multi-beam operation for single-DCI scheduled multi-PDSCH/PUSCH. |
| [LGE, 17] | Do not consider to indicate a separate TCI state or SRI for each scheduled PDSCH or PUSCH until it is identified as beneficial. |
| [Convida, 18] | TCI state indication methods for single DCI scheduling multi-PDSCH with M-TRP should be considered for NR from 52.6 GHz to 71 GHz. |
| [InterDigital, 19] | Support single beam indication (i.e., single TCI state/SRI indication) for multi-PDSCH/PUSCH scheduling. |
| [Docomo, 21] | For beam indication/application for multi-PDSCH/PUSCH scheduled by single DCI, For multi-PDSCH scheduling with a single DCI, no need to indicate a separate TCI state for each scheduled PDSCH.For multi-PUSCH scheduling with a single DCI, no need to indicate separate SRI(s) for each scheduled PUSCH.For multi-PDSCH scheduling, TCI states for PDSCHs scheduled by a single DCI follows the TCI state applied for the first PDSCH. |

### Summary of views

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| **#** | **Issue** | **Companies’ views** |
| 7.1 | Introduce multiple TCI states for multi-PDSCHs and multiple SRIs for multi-PUSCHs | **Yes:** CATT, Lenovo/MotM, Samsung, Convida* [Samsung]: The multiple PDSCHs or PUSCHs with different QCL assumptions can provide diversity gain. For another example, it is beneficial to support

**No:** Huawei/HiSi, Spreadtrum, vivo, Nokia/NSB, MediaTek, Ericsson, Xiaomi, Intel, Sony, IDCC, Docomo* [vivo]: In case of single TRP, we do not think the beam pair will change during the multi-PDSCH transmission. In case of multiple TRP, different TCI state indicator for multi-PDSCH with different HARQ ID has been supported by introducing the parameter of CORESET pool index which is scheduled by multi-DCI.

**Both:** Qualcomm (based on priority) |

### 1st round discussion

#### Observation 7

Majority of companies (13 companies) do not want to introduce multiple TCI states for multi-PDSCHs and multiple SRIs for multi-PUSCHs. The majority of companies believe that beam pair will not change during the multi-PDSCH transmission in case of single TRP. In addition, for multi-TRPs, different TCI states can be indicated by utilizing multiple DCIs with different CORESET pool ID. On the other hand, 5 companies believe that different QCL assumption can provide diversity gain for multiple PDSCHs/PUSCHs.

#### Proposal 7

For NR operation in 52.6-71GHz, different QCL assumption for multiple PDSCHs/PUSCHs scheduled by a single DCI is not supported.

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| **Company** | **Input** |
| LG Electronics | In general, we are supported of Proposal 7. In addition, it would be better to clarify that it is for single TRP and FFS on m-TRP case. |
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## Other beam indication related issues

### Observations and Proposals from Contributions

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| **Company** | **Observations and Proposals from Contributions** |
| [CATT, 6] | In initial access, the beam adaptation for Msg3 and Msg4 transmission can be adapted based on the beam measurement report from UE. |
| [Ericsson, 9] | Do not support scheduling of multiple PDSCHs with a single DCI where the TB(s) corresponding to one or more of the PDSCHs is(are) mapped over multiple slots by legacy TB repetition (semi-statically configured by pdsch-AggregationFactor or dynamically indicated by repetitionNumber in TDRA table). Beam indication procedures for such a combination are not needed.As in Rel-16, do not support scheduling of multiple PUSCHs with a single DCI where one or more of the PUSCHs is(are) mapped over multiple slots by legacy TB repetition (Type A or B repetition). Beam indication procedures for such a combination are not needed. |
| [Lenovo/MotM, 11]:  | For NR operation between 52.6 GHz and 71 GHz with high subcarrier spacing values such as 480kHz and 960kHz, if a UE is going to transmit a set of consecutive PUSCH transmissions including both dynamically scheduled PUSCH transmissions and CG-PUSCH transmissions, the UE can select the latest indicated UL Tx beam to transmit the consecutive UL CG and DG transmissions. |
| [Qualcomm, 14] | Support UE report of recommended SSB in Msg3/A in initial access.Support dynamic beam update of periodic channel/RS.The contents of configured TCI states can be dynamically updated.The contents may include any QCL source RS ID, e.g. both TypeA/D RS IDs, and corresponding BWP/CC ID. |

### Summary of views

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| **#** | **Issue** | **Companies’ views** |
| 8.1 | Support of multi-PDSCHs/PUSCHs with TB repetition and beam indication mechanism | **No:** Ericsson |
| 8.2 | QCL assumption update for configured grant PUSCH transmissions | **Yes:** Lenovo/MotM |
| 8.3 | Beam report in Msg3/A | **Yes:** CATT, Qualcomm |
| 8.4 | Dynamic beam update of periodic channel/RS  | **Yes:** Qualcomm |
| 8.5 | Dynamic update of TCI state configuration | **Yes:** Qualcomm |

### 1st round discussion

#### Observation 8

No clear majority was observed. Please continue discussion.

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| **Company** | **Input** |
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#### Proposal 8

TBU

# **Beam Management for Shared Spectrum Operation**

## Observations and Proposals from Contributions

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| **Company** | **Observations and Proposals from Contributions** |
| [Huawei/HiSi, 1] | In order to mitigate the impact of LBT failure in BFD procedure, support transmitting complementary aperiodic CSI-RS when LBT failure occurs on periodic BFD-RS. |
| [Oppo, 2] | holding the discussion on AP-CSI-RS for BFR/BFD until the LBT procedure has been made clear in agenda item 8.2.6. |
| [Nokia/NSB, 5] | For P-TRS transmissions in the cell, it would be beneficial to have a mechanism to be able to transmit P-TRSs dropped due to LBT failure.A beam specific (SSB specific) aperiodic TRS transmission that could be triggered for one or multiple UEs at a time to “patch” non-transmitted P-TRS using certain beam (certain SSB as QCL-TypeD source)Multiple transmission opportunities for the P-TRS within a time periodIn case of directional LBT (if applied), consider impacts on beam management in the COT, e.g. * impact on validity of the configured DL RSs for L1-RSRP measurement and reporting and
* impact on beam switching application time within the COT (e.g. the case when the new beam is or is not QCLed with the LBT beam of the COT).

Support of multi-slot CSI-RS can be provided by having a slot offset (could reuse the parameter CSI-ResourcePeriodicityAndOffset currently applicable only for periodic and semi-persistent resource) parameter for the aperiodic CSI-RS resource where the offset would be calculated from the slot where the first CSI-RS resource of the same set is allocated. |
| [CATT, 6] | When UE can not measure the periodic CSI-RS at the scheduled transmission instance for beam management due to LBT failure, gNB could transmit aperiodic CSI-RS and indicate to the UE as the alternative measurement. Aperiodic CSI-RS could be used as the alternative solution of missed L1 RSRP measurement of periodic CSI-RS due to LBT failure with little specification change. |
| [MediaTek, 7] | The feasibility of AP-CSI-RS triggering for accommodating the periodic CSI-RS transmission prevented by LBT failure needs to be studied when the gap between DCI and the triggered AP-CSI-RS is smaller than the threshold beamSwitchTiming. The feasibility of increasing periodic RS transmission occasion for accommodating the periodic CSI-RS transmission prevented by LBT failure needs to be studied with respect to the minimization of resource and impact on measurement procedure when more measurements on missing RS due to LBT failure.  |
| [Futurewei, 8] | Utilize aperiodic CSI-RS transmission to address impact of LBT failure on periodic RS transmissions intended to support beam failure recovery.Consider support for low latency beam (QCL-TypeD) switch of periodic RS transmissions after sustained LBT failure. In No-LBT deployments consider specification of channel vacation policies accounting for disparity among co-existing devices. |
| [Ericsson, 9] | Enhancement of existing BFD procedures by introduction of ap-CSI-RS is not needed for operation in shared spectrum. The existing BFI counter and timer can be adjusted to compensate for occasional LBT failure causing a missing instance (period) of a periodic BFD RS (SS/PBCH block and/or p-CSI-RS). |
| [Xiaomi, 10] | Beam measurement based on periodic CSI-RS can be still supported in NR for 52.6 to 71 GHz.Aperiodic CSI reports can be triggered to patch a non-transmitted periodic CSI-RS. |
| [Lenovo/MotM, 11] | For NR operation in unlicensed bands between 52.6 GHz and 71 GHz, the following potential enhancements related to periodic transmissions of RS such as P-TRS should be specified to deal with LBT failure:Termination of periodic RS transmission on beams where consecutive LBT failures are encounteredDynamic switching of the QCL assumption (beams) for periodic RS transmission where consecutive LBT failures are encountered, where:Multiple QCL assumptions (multiple beams) can be configured to the RS resource and beam switch can be triggered once the continuous number of LBT failures reach a certain threshold value |
| [Intel, 12] | No special handling of periodic RS transmissions is needed to address interruptions due to LBT failure as well as no special means are needed to distinguish between LBT failures and beam failures. |
| [Samsung, 14] | Support multi-slot aperiodic CSI-RS/SRS scheduled by a single DCI for beam management in 60 GHz unlicensed band.Further investigate the issue on the uncertainty of RS transmission due to LBT for 60 GHz unlicensed band. |
| [Sony, 16] | Depending on periodic BFD RS and CBD RS, UE would not be able to evaluate DL quality at the periodic occasion(s), due to no indicated COT.Support aperiodic CSI-RS for beam failure detection (BFD) and candidate beam determination (CBD) at least for unlicensed bandStudy and specify if needed single DCI scheduled multiple aperiodic CSI-RS and/or aperiodic SRS across multiple slots. |
| [LGE, 17] | The following aspects can be considered to enhance beam management operation when channel access scheme is used for unlicensed spectrum.How to provide more opportunities of CSI-RS or SRS transmission considering LBT failureHow to enhance beam failure procedure considering not transmitted BFD-RS due to LBT failure |
| [InterDigital, 19] | Absence of periodic/semi-persistent RSs may impact on performance of fine time/frequency tracking, beam failure recovery and beam/CSI reporting.Introduce an enhanced mechanism to patch non-transmitted periodic/semi-persistent RSs due to LBT failuresSupport RS transmission based on candidate RSs when LBT fails for periodic/semi-persistent RSs.Support RS pre-emption based on gNB indication to achieve accurate fine time/frequency tracking, beam failure recovery and beam/CSI. |
| [ZTE/Sanechips, 20] | Study and evaluate the impact of LBT and the limitation of COT length on the procedure of beam failure detection. |
| [Docomo, 21] | Beam failure detection/recovery procedure in NR 52.6-71GHz can consider following potential enhancements,whether to introduce aperiodic RS monitoring for beam failure detection |

## Summary of views

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| **#** | **Issue** | **Companies’ views** |
| 9.1 | Whether to enhance RS transmissions to deal with LBT failure | **Yes:** Huawei/HiSi, Nokia/NSB, MediaTek, Futurewei, Lenovo/MotM, Samsung, Sony, LGE, IDCC, ZTE/Sanechips, Docomo* [Nokia/NSB]: A beam specific (SSB specific) aperiodic TRS transmission that could be triggered for one or multiple UEs at a time to “patch” non-transmitted P-TRS using certain beam (certain SSB as QCL-TypeD source)
* [IDCC]: Support RS pre-emption based on gNB indication to achieve accurate fine time/frequency tracking, beam failure recovery and beam/CSI.

**No:** CATT, Ericsson, Xiaomi, Intel* [Ericsson]: The existing BFI counter and timer can be adjusted to compensate for occasional LBT failure causing a missing instance (period) of a periodic BFD RS (SS/PBCH block and/or p-CSI-RS).
* [Intel]: No special handling of periodic RS transmissions is needed to address interruptions due to LBT failure as well as no special means are needed to distinguish between LBT failures and beam failures
 |

## 1st round discussion

### Observation 9

It is observed that majority of companies (15 companies) want to introduce enhancement on RS transmission to deal with LBT failure. The supporting companies believe that patching failed RSs or transmitting multi-slot RSs for CSI-RS (e.g., for tracking and beam failure recovery) and SRS are beneficial. On the other hand, 4 companies believe that failed RSs can be handled by gNB implementation and no special handling is needed.

### Proposal 9

For NR operation in 52.6-71GHz, support enhancement on RS transmission to deal with LBT failure.

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| **Company** | **Input** |
| LG Electronics | It would be better to describe more details on which kind of enhancements is need for RS transmission to deal with LBT failure. |
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# **Beam Failure Recovery**

## Observations and Proposals from Contributions

Please note that observations and proposals on enhancements of monitoring/candidate RSs are captured in section 4.1.

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| **Company** | **Observations and Proposals from Contributions** |
| [Ericsson, 9] | For the new beam identification (NBI) procedure, the 28 symbol window for decoding PDCCH in recoverySearchSpaceId may need to be revisited for the case that a serving cell is configured with 480 or 960 kHz SCS. |
| [Qualcomm, 14] | Support partial BFR for single TRP. |
| [InterDigital, 19] | Due to the narrower beamwidth in 52.6 – 71 GHz, UE may not successfully recover dynamic blockage based on the existing BFR operation.Enhanced BFR operation to provide better reliability and efficiency should be considered for higher frequencies.Support partial BFR to achieve better reliability in 52.6 – 71 GHz.  |

## Summary of views

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| **#** | **Issue** | **Companies’ views** |
| 10.1 | Timing enhancement | **Yes:** Ericsson (28 symbol window for decoding PDCCH needs to be revisited.**No:** |
| 10.2 | Support of partial BFR  | **Yes:** Qualcomm, IDCC**No:** |

## 1st round discussion

### Observation 10

No clear majority was observed. Companies are requested to share their views on whether and how to enhance beam failure recovery.

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| **Company** | **Input** |
| LG Electronics | It should be clarified that the motivation of those suggestions are to cope with LBT failure in unlicensed band. Otherwise, they seem to be out of scope. Furthermore, partial BFR can be discussed in Rel-17 FeMIMO WI. |
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### Proposal 10

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# **Supporting Efficient Beam Management**

## Observations and Proposals from Contributions

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| **Company** | **Observations and Proposals from Contributions** |
| [Xiaomi, 10] | To support more beams, the maximal number of reference singles in one CSI-RS resource set should be increased. Or, multiple aperiodic CSI-RS resource sets associated with one aperiodic trigger state should be allowed to be used for beam measurement.An implicit or explicit way to indicate UE the report method, which refers to reporting the measurement results separately or jointly, is needed when multiple aperiodic CSI-RS resource sets are triggered by single DCI for beam measurement.It is beneficial to support group-based triggering of aperiodic CSI reports for UEs configured with same periodic CSI-RS resources used for beam measurement.There is a limitation on the number of periodic CSI-RS resource used for beam measurement in Rel15/16.Some enhancements are needed to deal with this limitation if the number of beams more than maxNrofNZP-CSI-RS-ResourcesPerSet are expected to be used in 52.6-71GHz. |
| [Qualcomm, 14] | Investigate sub-band based beam report. |
| [Convida, 18] | Enhancement of beam operation for unlicensed bands should be investigated to mitigate interference and optimize system performance due to hidden node for NR from 52.6 GHz to 71 GHz. |
| [InterDigital, 19] | In order to compensate increased pathloss and maintain cell coverages in 52.6 – 71 GHz, utilization of narrower beam than FR2 is expected.If the existing beam management mechanism is applied with the same number of beams, more frequent RRC reconfiguration and MAC CE signaling are expected.Increased signaling overheads and latencies will lead to inefficient system operation and corresponding performance degradation of NR in 52.6 – 71 GHz.Essential enhancements should be considered for beam management in 52.6 – 71 GHz e.g., increased maximum number of CSI-RS resources and configured/activated TCI states. |
| [Docomo, 21] | For beam management in 52.6-71GHz, discuss the following:whether to increase the number of configured CSI-RS resources for beam management.whether to support reporting more than 4 beams for beam reporting in one report instance, if the number of configured CSI-RS resources in a resource set for beam management is increased. |

## 1st round discussion

### Summary of views

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| **#** | **Issue** | **Companies’ views** |
| 11.1 | RS enhancement to deal with increased number of beams | **Yes:** Xiaomi, IDCC, Docomo**No:** |
| 11.2 | CSI reporting enhancement | **Yes:** Xiaomi, Qualcomm, Docomo**No:** |

### Observation 11

No clear majority was observed. Companies are requested to share their views on whether/how to support efficient beam management.

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| **Company** | **Input** |
| LG Electronics | It should be clarified that the motivation of those suggestions are to cope with LBT failure in unlicensed band. Otherwise, they seem to be out of scope. |
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### Proposal 11

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