**3GPP TSG RAN WG1 #112bis-e Draft R1-2304222**

**e-Meeting, April 17th – April 26th, 2023**

**Agenda Item: 9.12.3**

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

**Title: [Draft] Summary #5 on dynamic switching between DFT-S-OFDM and CP-OFDM**

**Document for: Discussion and Decision**

# Introduction

RAN approved a WI on further coverage enhancements for NR [1]. The WI includes the following objective:

* *Specify enhancements to support dynamic switching between DFT-S-OFDM and CP-OFDM (RAN1)*

The WI also includes corresponding justification point:

* *DFT-S-OFDM waveform is beneficial for UL coverage limited scenario because of its lower PAPR compared with CP-OFDM waveform. Currently, UL waveform is configured via RRC and this limitation imposes a large barrier to switch over to DFT-S-OFDM waveform for cell-edge UEs practically.*

This contribution summarizes contributions submitted in RAN1#112 under AI 9.14.3 – Dynamic switching between DFT-S-OFDM and CP-OFDM.

Here is the color code used in this summary:

* **FL observations**
* **FL proposals**
* **Questions for the inputs from companies**
* **FL summary based on the companies’ input**
* **RAN1 agreements**

A tag ([Open]/[Closed]) is indicated for each issue for each round of discussion. For a given round, input is requested for issues marked as [Open] only. In addition, a [LP]/[MP]/[HP] tag indicates envisioned priority of each issue in this meeting.

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|  |  |  |
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# Collection of agreements in RAN1#112bis-e

Agreement

For DCI format 0\_1/0\_2 containing dynamic waveform indication, bit width of each field is set to the maximum between the bit width of the field if transform precoding is disabled and the bit width of the field if transform precoding is enabled, if different.

* If, for the waveform indicated in the DCI, the bit width N of a field would be smaller than the bit width of the field set as per the above, UE decodes the field using N least significant bits. If N=0, the UE ignores the field for the indicated waveform.

Agreement

For potential enhancements to assist the scheduler in determining waveform switching, RAN1 to select 1 from the following options:

* Option 1: Reporting of power headroom information for a reference PUSCH using target waveform different from waveform of actual PUSCH.
  + Details FFS.
  + Note: reporting PH information for both waveforms is not precluded.
  + Note: additional trigger for PH for reference PUSCH is not precluded.
* Option 2: New trigger of power headroom report based on waveform switching event.
  + Details FFS.
* Option 3: Both Option 1 and Option 2.
  + Details FFS.
* Option 4: No enhancement.

Conclusion

For PUSCH transmission scheduled by C-RNTI with DCI format 0\_0, UE considers transform precoding enabled or disabled according to *msg3-transformPrecoder* as in legacy.

**Agreement**

Dynamic waveform switching is configured separately for each BWP, within *PUSCH-Config*.

**Agreement**

For UE configured with multi-PUSCH scheduling in time domain in a carrier *(*i.e. *pusch-TimeDomainAllocationListForMultiPUSCH*), DCI format 0\_1 supports 1-bit field for dynamic waveform switching indication.

* When configured, 1-bit field indicates waveform for all scheduled PUSCH transmissions.

**Agreement**

For PUSCH scheduled by DCI format 0\_1/0\_2 with dynamic waveform switching indication field configured, and *useInterlacePUCCH-PUSCH* is not configured, downselect between following options:

* Option 1 (configuration restriction with error case handling):
* UE does not expect *resourceAllocation* set to *resourceAllocationType0*.
* If DFT-S-OFDM is indicated and *resourceAllocation* set to *dynamicSwitch*, UE does not expect MSB of FDRA field set to 0.
* Option 2 (UE only uses *resourceAllocation* if CP-OFDM is indicated):
* If DFT-S-OFDM is indicated, UE applies type 1 resource allocation.
* If CP-OFDM is indicated, UE applies resource allocation according to *resourceAllocation* IE.
* Size of FDRA field is aligned between size for type 1 resource allocation and size according to *resourceAllocation* IE.

**Agreement**

For PUSCH scheduled by DCI format 0\_1/0\_2 with dynamic waveform switching indication field configured, downselect between following options:

* Option 1 (configuration restriction with error case handling):
* UE does not expect *dmrs-Type* to be set to *type2*.
* Option 2 (UE only uses *dmrs-Type* if CP-OFDM is indicated):
* If DFT-S-OFDM is indicated, UE applies DMRS type 1.
* If CP-OFDM is indicated, UE applies DMRS type according to *dmrs-Type*.

Agreement

For configuration of 1-bit dynamic waveform switching indication in DCI format 0\_1/0\_2 per a carrier, downselect between following options:

* Option 1: Separate configuration of presence of dynamic waveform switching field for DCI format 0\_1 and DCI format 0\_2.
* Option 2: Common configuration of presence of dynamic waveform switching field for DCI format 0\_1 and DCI format 0\_2.

# Proposals

## Proposals for 1st GTW (Monday April 17)

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| **FL proposal 2-1**: For DCI format 0\_1/0\_2 containing dynamic waveform indication, bit width of each field is set to the maximum between the bit width of the field if transform precoding is disabled and the bit width of the field if transform precoding is enabled, if different.   * If, for the waveform indicated in the DCI, the bit width N of a field would be smaller than the bit width of the field set as per the above, UE decodes the field using N least significant bits. If N=0, the UE ignores the field for the indicated waveform. |

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| **FL proposal 3-1**: For potential enhancements to assist the scheduler in determining waveform switching, RAN1 to select between following options:   * Option 1: Reporting of power headroom information for a reference PUSCH using target waveform different from waveform of actual PUSCH.   + Details FFS. * Option 2: New trigger of power headroom report based on waveform switching event.   + Details FFS. * Option 3: Both Option 1 and Option 2.   + Details FFS. * Option 4: No enhancement. |

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| **FL proposal 4-1**: Dynamic waveform switching is configured separately for each BWP, within *PUSCH-Config*. |

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| **FL proposal 2-2r1**: For PUSCH scheduled by DCI format 0\_1/0\_2 with dynamic waveform switching indication field configured, and *useInterlacePUCCH-PUSCH* is not configured, downselect between following options:  Option 1 (configuration restriction with error case handling):   * ~~If DFT-S-OFDM is indicated,~~ UE does not expect *resourceAllocation* set to *resourceAllocationType0*. * If DFT-S-OFDM is indicated and *resourceAllocation* set to *dynamicSwitch*, UE does not expect MSB of FDRA field set to 0.   Option 2 (UE only uses *resourceAllocation* if CP-OFDM is indicated):   * If DFT-S-OFDM is indicated, UE applies type 1 resource allocation. * If CP-OFDM is indicated, UE applies resource allocation according to *resourceAllocation* IE. * Size of FDRA field is aligned between size for type 1 resource allocation and size according to *resourceAllocation* IE. |

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| **FL proposal 2-3r1**: For PUSCH scheduled by DCI format 0\_1/0\_2 with dynamic waveform switching indication field configured, downselect between following options:  Option 1 (configuration restriction with error case handling):   * ~~If DFT-S-OFDM is indicated,~~ UE does not expect *dmrs-Type* to be set to *type2*.   Option 2 (UE only uses *dmrs-Type* if CP-OFDM is indicated):   * If DFT-S-OFDM is indicated, UE applies DMRS type 1. * If CP-OFDM is indicated, UE applies DMRS type according to *dmrs-Type*. |

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| **FL proposal 2-4r1**: For UE configured with multi-PUSCH scheduling in time domain in a carrier *(*i.e. *pusch-TimeDomainAllocationListForMultiPUSCH*), DCI format 0\_1 supports 1-bit field for dynamic waveform switching indication.   * When configured, 1-bit field indicates waveform for all scheduled PUSCH transmissions. |

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| **FL proposed conclusion 1-1**: For PUSCH transmission scheduled by C-RNTI with DCI format 0\_0, UE considers transform precoding enabled or disabled according to *msg3-transformPrecoder* as in legacy. |

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| **FL proposal 1-2**: For PUSCH transmission scheduled by RAR or TC-RNTI with DCI format 0\_0, UE considers transform precoding enabled or disabled according to *msg3-transformPrecoder* as in legacy at least if the UE does not use multiple PRACH transmissions in RACH procedure.   * FFS: UE enables transform precoding for PUSCH transmission scheduled by RAR or by TC-RNTI with DCI format 0\_0 if the UE uses multiple PRACH transmissions in RACH procedure. |

## Proposals for 2nd GTW (Wednesday April 19)

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| **FL proposal 3-1r1**: For potential enhancements to assist the scheduler in determining waveform switching, RAN1 to select between following options:   * Option 1: Reporting of power headroom information for a reference PUSCH using target waveform different from waveform of actual PUSCH.   + Details FFS.   + Note: reporting PH information for both waveforms is not precluded.   + Note: additional trigger for PH for reference PUSCH is not precluded. * Option 2: New trigger of power headroom report based on waveform switching event.   + Details FFS. * Option 3: Both Option 1 and Option 2.   + Details FFS. * Option 4: No enhancement. |

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| **FL proposed conclusion 1-1**: For PUSCH transmission scheduled by C-RNTI with DCI format 0\_0, UE considers transform precoding enabled or disabled according to *msg3-transformPrecoder* as in legacy. |

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| **FL proposed conclusion 1-2r2**: For PUSCH transmission scheduled by RAR or TC-RNTI with DCI format 0\_0, UE considers transform precoding enabled or disabled according to *msg3-transformPrecoder* as in legacy.   * The above conclusion can be re-visited only for the case of UE supporting/using multiple PRACH transmissions.   ~~at least if the UE does not support/use multiple PRACH transmissions in RACH procedure.~~   * ~~FFS: UE enables transform precoding for PUSCH transmission scheduled by RAR or by TC-RNTI with DCI format 0\_0 if the UE uses multiple PRACH transmissions in RACH procedure.~~ * ~~FFS: if the UE supports/uses multiple PRACH transmissions.~~ |

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| **FL proposal 2-2r1**: For PUSCH scheduled by DCI format 0\_1/0\_2 with dynamic waveform switching indication field configured, and *useInterlacePUCCH-PUSCH* is not configured, downselect between following options:  Option 1 (configuration restriction with error case handling):   * ~~If DFT-S-OFDM is indicated,~~ UE does not expect *resourceAllocation* set to *resourceAllocationType0*. * If DFT-S-OFDM is indicated and *resourceAllocation* set to *dynamicSwitch*, UE does not expect MSB of FDRA field set to 0.   Option 2 (UE only uses *resourceAllocation* if CP-OFDM is indicated):   * If DFT-S-OFDM is indicated, UE applies type 1 resource allocation. * If CP-OFDM is indicated, UE applies resource allocation according to *resourceAllocation* IE. * Size of FDRA field is aligned between size for type 1 resource allocation and size according to *resourceAllocation* IE. |

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| **FL proposal 2-3r1**: For PUSCH scheduled by DCI format 0\_1/0\_2 with dynamic waveform switching indication field configured, downselect between following options:  Option 1 (configuration restriction with error case handling):   * ~~If DFT-S-OFDM is indicated,~~ UE does not expect *dmrs-Type* to be set to *type2*.   Option 2 (UE only uses *dmrs-Type* if CP-OFDM is indicated):   * If DFT-S-OFDM is indicated, UE applies DMRS type 1. * If CP-OFDM is indicated, UE applies DMRS type according to *dmrs-Type*. |

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| **FL proposal 2-4r1**: For UE configured with multi-PUSCH scheduling in time domain in a carrier *(*i.e. *pusch-TimeDomainAllocationListForMultiPUSCH*), DCI format 0\_1 supports 1-bit field for dynamic waveform switching indication.   * When configured, 1-bit field indicates waveform for all scheduled PUSCH transmissions. |

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| **FL proposal 4-2**: For configuration of 1-bit dynamic waveform switching indication in DCI format 0\_1/0\_2, downselect between following options:   * Option 1: Separate configuration of presence of dynamic waveform switching field for DCI format 0\_1 and DCI format 0\_2. * Option 2: Common configuration of presence of dynamic waveform switching field for DCI format 0\_1 and DCI format 0\_2. |

## Proposals for 3rd GTW (Friday April 21)

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| **FL proposal 2-2r1**: For PUSCH scheduled by DCI format 0\_1/0\_2 with dynamic waveform switching indication field configured, and *useInterlacePUCCH-PUSCH* is not configured, downselect between following options:  Option 1 (configuration restriction with error case handling):   * ~~If DFT-S-OFDM is indicated,~~ UE does not expect *resourceAllocation* set to *resourceAllocationType0*. * If DFT-S-OFDM is indicated and *resourceAllocation* set to *dynamicSwitch*, UE does not expect MSB of FDRA field set to 0.   Option 2 (UE only uses *resourceAllocation* if CP-OFDM is indicated):   * If DFT-S-OFDM is indicated, UE applies type 1 resource allocation. * If CP-OFDM is indicated, UE applies resource allocation according to *resourceAllocation* IE. * Size of FDRA field is aligned between size for type 1 resource allocation and size according to *resourceAllocation* IE. |

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| **FL proposal 2-3r1**: For PUSCH scheduled by DCI format 0\_1/0\_2 with dynamic waveform switching indication field configured, downselect between following options:  Option 1 (configuration restriction with error case handling):   * ~~If DFT-S-OFDM is indicated,~~ UE does not expect *dmrs-Type* to be set to *type2*.   Option 2 (UE only uses *dmrs-Type* if CP-OFDM is indicated):   * If DFT-S-OFDM is indicated, UE applies DMRS type 1. * If CP-OFDM is indicated, UE applies DMRS type according to *dmrs-Type*. |

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| **FL proposal 4-2**: For configuration of 1-bit dynamic waveform switching indication in DCI format 0\_1/0\_2, downselect between following options:   * Option 1: Separate configuration of presence of dynamic waveform switching field for DCI format 0\_1 and DCI format 0\_2. * Option 2: Common configuration of presence of dynamic waveform switching field for DCI format 0\_1 and DCI format 0\_2. |

(Suggested proposal in case Option 1 is agreeable)

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| **FL proposal 4-2r1**: Support separate configuration of presence of dynamic waveform switching field for DCI format 0\_1 and DCI format 0\_2. |

## Proposals for 4th GTW (Tuesday April 25)

Companies discussed pros and cons of the potential enhancements to assist the scheduler in determining waveform switching. Moderator summarized these in tables below for Options 1, 2, 4.

Moderator also asked companies which option(s) are preferred, acceptable or not acceptable. 10 companies responded as follows:

Option 1: Preferred by 6, acceptable for 1 (under condition), not acceptable for 1.

Option 2: Preferred by 2, acceptable for 4, not acceptable for 2.

Option 3: Preferred by 1, acceptable for 5, not acceptable for 1.

Option 4: Acceptable for 2, Not acceptable for 6.

3 companies indicated they want more time to discuss and study.

(Earlier agreement from this meeting):

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| Agreement  For potential enhancements to assist the scheduler in determining waveform switching, RAN1 to select 1 from the following options:   * Option 1: Reporting of power headroom information for a reference PUSCH using target waveform different from waveform of actual PUSCH.   + Details FFS.   + Note: reporting PH information for both waveforms is not precluded.   + Note: additional trigger for PH for reference PUSCH is not precluded. * Option 2: New trigger of power headroom report based on waveform switching event.   + Details FFS. * Option 3: Both Option 1 and Option 2.   + Details FFS. * Option 4: No enhancement. |

Analysis of benefits/concerns for Options 1/2/4:

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| Option 1 | |
| Examples of operation | -UE transmits PHR of current waveform and other waveform. gNB may use DFT-S-OFDM if it allows higher Tx power, otherwise may use CP-OFDM. |
| Benefits | +gNB can determine if change of waveform is beneficial before potential switch and directly determine appropriate scheduling for new waveform.  +[if PHR transmitter together]: guarantees that PHR difference is due to waveform and not some other factor, e.g. path loss change.  +[with new trigger]: waveform can be switched at “optimal” time. |
| Concerns | -Need to specify PHR of target waveform  -May increase PHR overhead  -May impact multiple entry MAC CE (for UL CA) |

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| Option 2 | |
| Examples of operation | -If using CP-OFDM, gNB switches to DFT-S-OFDM using same scheduling parameters (RBs, Tx power). gNB adjusts scheduling parameters based on PHR sent after switch.  -If using DFT-S-OFDM, gNB switches to CP-OFDM using more conservative scheduling parameters. gNB can use “history” of Pcmax difference for the UE to decide how conservative it needs to be. gNB adjusts scheduling parameters based on PHR sent after switch. |
| Benefits | +Provides up-to-date PHR for scheduling after waveform switch |
| Concerns | -Need to specify new PHR trigger (with slight overhead increase)  -Some throughput degradation just after switching to CP-OFDM due to “conservative” scheduling, or due to need for retransmission/fallback to DFT-S-OFDM if scheduling was not sufficiently conservative. |

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| Option 4 | |
| Examples of operation | -gNB gives back-to-back grants using different waveforms and compares quality using DMRS. gNB may use DFT-S-OFDM if SINR is better, otherwise may use CP-OFDM.  -if using CP-OFDM, switch to DFT-S-OFDM if TPC up commands does not increase SINR.  -gNB uses RAN4 requirements to estimate potential difference of Pcmax. |
| Benefits | +No change to the specification. |
| Concerns | -Does not provide information on difference in Pcmax.  -Actual Pcmax difference depends on UE implementation, RAN4 requirements not sufficient.  -DMRS SINR does not provide information unless UE transmits at maximum power.  -DMRS SINR difference between two transmissions may be caused by other factors, e.g. fading and/or interference may be different.  -Need to schedule extra PUSCHs with large number of PRBs / high Tx power to evaluate waveform switch.  -Not possible to know how many PRB’s can be scheduled with new waveform, as PHR after switch is not available. |

# Topic #1: Applicability of dynamic waveform switching

A set of issues is related to the type of transmission concerned by dynamic waveform switching.

In RAN1#110bis-e, RAN1 made agreement that dynamic waveform switching is applicable to PUSCH channel only. RAN1 made a further agreement that it is applicable to PUSCH dynamically scheduled by DCI format 0\_1 or 0\_2. In RAN1#112, RAN1 agreed that dynamic waveform switching is not applicable to PUSCH transmissions with a Type 1 configured grant and concluded that there is no consensus to support PUSCH transmissions with a Type 2 configured grant.

The following cases are considered separately:

* PUSCH dynamically scheduled by C-RNTI with DCI format 0\_0
* Msg3 PUSCH scheduled by RAR or by TC-RNTI with DCI format 0\_0
* Other cases/scenarios

## [LP][Closed] Issue #1-1: Applicability to PUSCH scheduled by C-RNTI with DCI format 0\_0

**Summary of company views from contributions submitted to RAN1#112bis-e**

Applicability to PUSCH scheduled by C-RNTI with DCI format 0\_0

Yes: Oppo [4], ZTE [7], Nokia [10], Mavenir [15]

[Justifications]

* No ambiguity after the UE is connected to network [4]
* Need to maximize applicability of dynamic waveform switching [7]
* DCI format 0\_0 is used in coverage-limited scenarios [4][7][10][15]
* Always configuring DFT-S-OFDM for DCI format 0\_0 inefficient [7]
* Using DFT-S-OFDM more resource-efficient than using PUSCH repetitions [10]

[Proposed solutions]

* Add 1 bit [15] if number of bits for DCI format 0\_0 before padding is smaller than DCI format 1\_0 [7]
* Add column to default TDRA table [4]

Open: NTT DOCOMO [28]

* Cannot use 1 additional bit in DCI [28]

No: Spreadtrum [5], CATT [6], Intel [8], InterDigital [12], China Telecom [13], Panasonic [14], Lenovo [16], ETRI [18], CMCC [19], Mediatek [20], Qualcomm [23], Sharp [24], Ericsson [26], LG [29]

* Supporting format 0\_0 has small benefit, e.g. other formats can be used [6][12][20]
* Can configure DFT-S-OFDM for format 0\_0 if coverage is limited [12]
* Better if interpretation remains stable during RRC reconfiguration [5][12][13][18]
* Better not to increase payload size of DCI format 0\_0 [16][14][8][18][19][23][26], cannot change size for CSS [14][24]
* Format 0\_0 only has mandatory fields, should not add bit [5]
* Format 0\_0 only supports basic scheduling/fallback operation [8][13][16][19][23], e.g. only RA type 1 [5][6], DMRS configuration/port is fixed [5].
* Indication in DCI format 0\_1 or 0\_2 cannot be used to indicate subsequent transmissions [5]
* Would require different solution for this DCI format [23][29], significant specification impact [13]

**Observations on applicability to PUSCH scheduled by C-RNTI with DCI format 0\_0**

4 companies support applicability to PUSCH scheduled by C-RNTI with DCI format 0\_0. 1 company is open. On the other hand, 14 companies do not support any applicability to PUSCH scheduled by DCI format 0\_0.

Majority of companies think there is little, or no benefit given that other formats can be used, and that this DCI format is intended for basic operation and for robustness during RRC reconfiguration. There are also concerns about introducing a field linked to an optional feature to this format and potentially increasing the size.

Moderator does not see how further discussion can change the situation for this issue, and recommends taking the following conclusion:

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| **FL proposed conclusion 1-1**: For PUSCH transmission scheduled by C-RNTI with DCI format 0\_0, UE considers transform precoding enabled or disabled according to *msg3-transformPrecoder* as in legacy. |

### 1st round

Please indicate if your company position was incorrectly captured or if you would like to add your company position to the summary above. Please feel free to provide any feedback on FL proposed conclusion 1-1:

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| Company | Comments |
| CATT | We support FL proposed conclusion 1-1. |
| Intel | We are fine with the proposed conclusion. |
| QC | Support |
| Panasonic | We support the FL proposed conclusion 1-1. |
| Lenovo | We support FL proposed conclusion 1-1. |
| Apple | We support Proposal 1-1. |
| vivo | Fine.  In our view, waveform of all PUSCH transmissions scheduled by fallback DCI should be the same as legacy. It would be preferred to conclude this together with section 5.2 so that we can focus on discussions on waveform indication of PUSCH scheduled by non-fallback DCI. |
| Transsion | We support this conclusion. |
| LG | Support the proposed conclusion 1-1. It is natural enough to switch waveforms semi-statically via higher layer parameter, i.e., *msg3-transformPrecoder*, since there might be no additional space allowed for the new 1-bit field as the size constraint of the fallback DCI. |
| Spreadtrum | Support. |
| Sharp | We support the FL proposed conclusion. |
| CMCC | Support. |
| Ericsson | Support |
| ETRI | Support the conclusion. |
| Nokia/NSB | We would like to clarify that if DWS is supported for DCI format 0\_0 then another solution should be considered for not increasing the size of fallback DCI.  As discussed in our Tdoc and previous meetings, we do see the motivation for supporting DWS using DCI format 0\_0. |
| MediaTek | Support in principle.  Although we would suggest different wording for simplicity. Since this conclusion doesn’t include anything new, we prefer to say: “There is no conclusion to support PUSCH scheduled by C-RNTI with DCI format 0\_0 for R18 dynamic switching between CP-OFDM and DFT-S-OFDM” |
| Samsung | Support |
| Moderator | @Mediatek: Thanks for the suggestion. However, I am concerned it would be more confusing because it could be interpreted as “DCI format 0\_0 cannot be used if DWS is configured”. I think the wording “as in legacy” makes it clear enough that nothing changes for this DCI format. |

## [LP][Closed] Issue #1-2: Applicability to msg3 PUSCH

**Summary of company views from contributions submitted to RAN1#112bis-e**

Applicability to PUSCH scheduled by RAR and/or by TC-RNTI with DCI format 0\_0

* Yes**:** Oppo [4], ZTE [7], Intel [8], Sony [9], Nokia [10], (Panasonic [14]), Mavenir [15]

[Justification]

* + Enables selection based on UE’s channel conditions instead of cell-level [4][8][10]
  + Improve reliability of msg3 retransmission [8]
  + Other msg3 coverage enhancement techniques not sufficient [9]
  + Cell-level configuration is not always DFT-S-OFDM [10]
  + Support for msg3 retransmission even more important than initial transmission [10]
  + Msg3 repetitions may not be sufficient [10]

[Proposed solutions]

* + Add column to default TDRA table [4]
  + Set waveform to DFT-S-OFDM if number of repetitions is >1 [7]
  + Same waveform for msg3 initial transmission (RAR) and retransmission (TC-RNTI) [7]
  + Override SIB field for UE in connected or inactive mode [9]
  + Indicate in MAC CE or PDCCH order for RACH for UE in connected/inactive state [9]
  + Use reserved bits or CSI request bit of RAR for idle state UE [9]
  + Use DFT-S-OFDM if using/capable of multiple PRACH transmissions [9]([10])[14]
  + Solution should not impact DCI format 0\_0 [10][13]
  + Add 1 bit to DCI format 0\_0 [15]
* Study: NTT DOCOMO [28]
  + Cannot use 1 additional bit in DCI [28]
* No**:** Spreadtrum [5], CATT [6], InterDigital [12], Lenovo [16], Samsung [17], CMCC [19], Mediatek [20], Qualcomm [23], Ericsson [26], LG [29]
  + Additional preamble partitioning required [5][6][12]
  + gNB does not have sufficient channel/power information to select [5][16][17][19][23][26]
  + Would require PRACH resources for identification of capability [17][23]
  + Difficult to introduce indication in RAR and DCI format 0\_0 [6][19][29]
  + Msg3 repetitions are specified and sufficient, latency not a concern [23]
  + Unclear benefit [6][20], gain of using CP-OFDM for msg3 PUSCH is small [12]

In addition, no company proposes to support dynamic indication for msgA, and two companies [5][6] explicitly proposes to not support it.

**Observations on applicability to msg3 PUSCH**

7 companies support applicability to msg3 PUSCH for either or both initial transmission by RAR or retransmission by TC-RNTI with DCI format 0\_0. 1 company is open to study. 10 companies do not support. Non-supporting companies think that the benefit is unclear given that the network has not enough information on the UE situation and have concerns about complexity of supporting indication from RAR or DCI and potential additional RACH partitioning required for indication of capability.

A few companies suggested that the selection of waveform could be tied to the capability or use of PRACH repetitions to be supported in R18. The simplest solution would be that a UE that uses PRACH repetitions also uses DFT-S-OFDM for the transmission or retransmission of msg3. In moderator’s understanding, this solution could address concerns about reliability of msg3 transmission for UE’s capable of PRACH repetition while not requiring any other mechanism for the capability or waveform indication. Thus, it may be worth considering as a potential compromise. This is reflected by the proposal below.

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| **FL proposal 1-2**: For PUSCH transmission scheduled by RAR or TC-RNTI with DCI format 0\_0, UE considers transform precoding enabled or disabled according to *msg3-transformPrecoder* as in legacy at least if the UE does not use multiple PRACH transmissions in RACH procedure.   * FFS: UE enables transform precoding for PUSCH transmission scheduled by RAR or by TC-RNTI with DCI format 0\_0 if the UE uses multiple PRACH transmissions in RACH procedure. |

### 1st round

Please indicate if your company position was incorrectly captured or if you would like to add your company position to the summary above. Please feel free to provide any feedback on FL proposal 1-2.

|  |  |
| --- | --- |
| Company | Comments |
| CATT | We support FL proposal 1-2. |
| Intel | We do not support this proposal. We have not even discussed any interaction between PRACH and Msg3 coverage enhancement yet under AI 9.12.1.  Our concern is mainly regarding the Msg3 repetition, which was defined in Rel-17 for Msg3 coverage enhancement. If UE clearly needs repetitions for Msg3, it is not reasonable to still apply CP-OFDM waveform for Msg3 transmission. In this case, dynamic waveform indication should be applied. |
| QC | Support |
| Panasonic | We support the FL proposal 1-2. We also support the FFS point. For the UE who uses multiple PRACH transmission needs coverage enhancement for Mgs.3 PUSCH transmission. Therefore, to enable DFT-s-OFDM even if CP-OFDM is configured via *msg3-transformPrecoder*.is reasonable. In PRACH repetition, separate RACH resource is supported for PRACH repetition and if multiple values are configured PRACH resource between PRACH repetitions with different number of repetitions are differentiated. Therefore, there is no additional PRACH resource is necessary for the waveform selection for Msg.3 PUSCH. |
| Lenovo | We don’t support dynamic waveform switching for Msg 3 initial transmission or re-transmission. We think DWS and PRACH repetition is two separate methods to realize coverage enhancement for different channel, always bundle them is not reasonable. |
| Apple | OK with Proposal 1-2. |
| vivo | Do not support dynamic waveform switching for Msg3 considering this would require early feature indication and also other impacts that are summarized by feature leader. Msg3 waveform determination should be same as other normal PUSCH transmissions scheduled by fallback DCI. |
| ZTE | Our original intention is if msg3 PUSCH is with repetition, the transform precoding should be enabled and UE will ignore the *msg3-transformPrecoder*, and msg3 PUSCH retransmission will follow the same waveform of the first msg3 PUSCH. From this aspect, we share the same view with Intel.  But if the compromise proposal is supported by majority, we can live up with this proposal. |
| Transsion | We support this proposal as a compromise. |
| LG | We don’t support the proposal 1-2. It seems the proposal has too much consideration effort for Msg.3 transmission, i.e., DWS support that UE capable of Msg.3 repetition. The semi-static waveform configuration that currently support looks sufficient, in this regard we prefer not to support DWS to all the Msg.3 transmission. |
| Spreadtrum | Support the main bullet. Regarding the FFS, we think there is no need to link between Msg1 repetition and DWS for Msg3 PUSCH. The benefit is not clear compared to Msg3 PUSCH repetition. Thus, it is not necessary to use dynamic waveform switching for Msg3 PUSCH. It is enough to determine the waveform according to the current configuration of high-level parameters *msg3-transformPrecoder*. |
| Sharp | We support the FL proposal. |
| CMCC | Support. For the FFS part, we think same procedure as in legacy should also be support. Introducing new mechanism like “set transform precoding enabled when UE use multiple PRACH transmissions in RACH procedure” seems out of scope in this agenda. |
| Ericsson | The FFS is to allow gNB to configure Msg3 waveform aggressively, e.g., CP-OFDM for *msg3-transformPrecoder*. UEs triggering multiple PRACHs will transmit Msg3 with DFT-S-OFDM, and those with single PRACH transmission will use CP-OFDM for Msg3 transmission. However, gNB may make sure a reliable Msg3 transmission by setting *msg3-transformPrecoder* as DFT-S-OFDM. The difference between this gNB configuration and the FFS is that UEs with single PRACH transmission (e.g., cell-center UEs) can use CP-OFDM, rather than the RRC configured DFT-S-OFDM for Msg3 transmission. Is there a coverage gain?  In addition, we have concern of combining two features as one UE capability. Determination of the number of PRACH transmissions is still open in AI 9.12.1. |
| ETRI | We support the proposal but have a question about the FFS. When PRACH repetition is performed, the Msg3 UL grant always indicate one waveform (DFT-s-OFDM) by implementation. Is it correct understanding? |
| Nokia/NSB | We support the FL proposal 1-2 in general. The FFS can be further discussed. |
| MediaTek | We don’t support the FFS point. Dynamic switching and multiple PRACH are separate features. If a UE is only capable of multiple PRACH but not dynamic switching, this FFS point would contradict with such case. |
| Samsung | We support the first part of the proposal as follows, without any connection of the DWS feature with PRACH transmission(s). A conclusion would be more appropriate.  **FL proposal 1-2**: For PUSCH transmission scheduled by RAR or TC-RNTI with DCI format 0\_0, UE considers transform precoding enabled or disabled according to *msg3-transformPrecoder* as in legacy |
| Moderator | @CATT, QC, Panasonic, Apple, ZTE, Transsion, Sharp, ETRI, Nokia/NSB: Thanks for support.  @Intel: the linkage with PRACH is just an FFS at this point. Regarding potential solution linking msg3 waveform with msg3 repetition, my understanding is that there is still the problem that gNB does not know if the UE requesting msg3 repetition is R17 or R18.  @vivo: the idea of linking to PRACH repetition is that it would remove need for additional early indication for the waveform.  @Ericsson: for the FFS, agree that there is no coverage gain if network anyway configures msg3-transformPrecoder with DFT-S-OFDM for all UEs. The gain would be that the network can now configure CP-OFDM for msg3 for single PRACH transmission UE.  @ETRI: the grant for msg3 (RAR or F0\_0/TC-RNTI) does not indicate any waveform. In the FFS, the UE would automatically apply DFT-S-OFDM if it used multi-PRACH.  @Mediatek: For the FFS, my understanding is that it would be independent from the 1-bit DWS indication capability. Any UE that transmits multiple PRACH would apply DFT-S-OFDM for msg3. |

### 2nd round

Based on 1st round comments, about half of companies are supportive of FL proposal 1-2 but the other half has concerns about potential linkage to multiple PRACH capability/usage. Some companies think that it is too early to suggest a solution considering current progress for multiple PRACH functionality. In view of this, moderator suggests modifying as follows:

|  |
| --- |
| **FL proposal 1-2r1**: For PUSCH transmission scheduled by RAR or TC-RNTI with DCI format 0\_0, UE considers transform precoding enabled or disabled according to *msg3-transformPrecoder* as in legacy at least if the UE does not support/use multiple PRACH transmissions in RACH procedure.   * ~~FFS: UE enables transform precoding for PUSCH transmission scheduled by RAR or by TC-RNTI with DCI format 0\_0 if the UE uses multiple PRACH transmissions in RACH procedure.~~ * FFS: if the UE supports/uses multiple PRACH transmissions. |

Please indicate if FL proposal 1-2r1 is acceptable:

|  |  |
| --- | --- |
| Company | Comments |
| NTT DOCOMO | We are open. No strong view on FFS point. |
| ZTE | As the msg3 repetition can be differentiated through the PRACH preambles, why not to directly link the proposal to msg3 repetition? For example, the proposal can be revised as:  **FL proposal 1-2r1**: For PUSCH transmission scheduled by RAR or TC-RNTI with DCI format 0\_0, UE considers transform precoding enabled or disabled according to *msg3-transformPrecoder* as in legacy at least if the UE does not support/use ~~multiple PRACH transmissions~~ PUSCH repetition scheduled by RAR or TC-RNTI with DCI format 0\_0 in RACH procedure.   * FFS: UE enables transform precoding for PUSCH repetition transmission scheduled by RAR or by TC-RNTI with DCI format 0\_0 if the UE uses ~~multiple PRACH transmissions~~ PUSCH repetition transmission scheduled by RAR or by TC-RNTI in RACH procedure. |
| Intel | We share similar view as ZTE. This is mainly for Msg3 repetition, which can be decoupled from PRACH coverage enhancement.  We are fine with the update from ZTE to make compromise and move forward. |
| Nokia/NSB | We support the FL’s proposal for the sake of progress. |
| QC | Intel and ZTE need to respond to Ericsson’s question on why a gNB is not able to set msg3-transformPrecoder to indicate DFT-S-OFDM for all UEs. We have had this same question too.  FL proposal is okay for now. Edits by ZTE/Intel go a step too far. |
| Panasonic | We support FL proposal 1-2r1. |
| NEC | We support the proposal. We don’t think the FFS part has benefits since msg3 has small number of bits and network can always configure DFT-s-OFDM if coverage is the issue of the network, but we can live with it here. |
| Moderator | @ZTE, Intel: I have a question about linking with msg3 repetition. If network gets PRACH resource that requests repetitions, how does the network know if this is from R17 UE or R18 UE? Do you suggest further PRACH partitioning or blind detection of waveform by network? |
| CATT | We prefer to remove the FFS and conclude that DWS is not applicable to Msg3 (re)transmissions. We are also fine with the FL’s proposal for the sake of progress except that we think ‘support’ should be removed since gNB cannot tell whether a UE using single PRACH transmission supports multiple PRACH transmissions or not. |
| China Telecom | We support the proposal. |
| Lenovo | Don’t support. We think the waveform determination of PUSCH transmission scheduled by RAR or TC-RNTI with DCI format 0\_0 is unrelated to whether multiple PRACH transmissions are used or not. They are two separate methods to realize coverage enhancement for different channels. |
| ZTE2 | Response to QC, gNB can set msg3-transformPrecoder to indicate DFT-S-OFDM or CP-OFDM, there is no restriction on the two alternatives from specification.  Response to Moderator, we have a consensus in PRACH enhancement agenda that Rel-17 framework of feature combination (*FeatureCombination-r17*) and additional RACH configuration (*AdditionalRACH-Config-r17*) can be reused for Rel-18 multiple PRACH transmissions to realize the corresponding PRACH resource partitioning, at least in separate case, in the new additional RACH occasion for multiple PRACH, the preambles for msg3 PUSCH repetition (using *FeatureCombination-r17*) can be configured, these preambles can be the identification both for the R18 UE and supporting msg3 PUSCH repetition. Further PRACH partitioning will cost less specification effort as the whole structure of the reusing Rel-17 framework of feature combination and additional RACH configuration has been built. |
| Ericsson | As commented in 1st round, compared with the semi-static DFT-S-OFDM configured for Msg3 PUSCH transmission, the dynamic waveform for Msg3 determined by the number of PRACH transmissions doesn’t improve Msg3 coverage. If the dependency of Msg3 PUSCH waveform on the number of PRACH transmissions is supported, it should have a new RRC parameter to enable/disable it, and it can only be enabled when CP-OFDM is configured for *msg3-transformPrecoder*.  Our first preference is to remove the FFS. Our 2nd preference is to update the proposal as follows.  **FL proposal 1-2r1**: For PUSCH transmission scheduled by RAR or TC-RNTI with DCI format 0\_0, UE considers transform precoding enabled or disabled according to *msg3-transformPrecoder* as in legacy at least if the UE does not support/use multiple PRACH transmissions in RACH procedure.   * ~~FFS: UE enables transform precoding for PUSCH transmission scheduled by RAR or by TC-RNTI with DCI format 0\_0 if the UE uses multiple PRACH transmissions in RACH procedure.~~ * FFS: if the UE supports/uses multiple PRACH transmissions and CP-OFDM is configured for *msg3-transformPrecoder*. |
| LG | We don't think the current proposal is not the mechanism strictly respect to the ‘dynamic’ waveform switching. As some companies commented from earlier round, the linkage of Msg.3 to the PRACH transmission/repetition should be discussed sufficiently first in AI 9.12.1.  Meanwhile, it seems rather better to leave it out the same phrase in the main text even if mention that multiple PRACH to the FFS.  **FL proposal 1-2r1**: For PUSCH transmission scheduled by RAR or TC-RNTI with DCI format 0\_0, UE considers transform precoding enabled or disabled according to *msg3-transformPrecoder* as in legacy ~~at least if the UE does not support/use multiple PRACH transmissions in RACH procedure~~.  FFS: if the UE supports/uses multiple PRACH transmissions. |
| Samsung | We are fine to agree to the first part of the proposal as follows. We don’t support to add a connection with single/multiple PRACH transmissions in this proposal. It can be a separate discussion.  **FL proposal 1-2r1**: For PUSCH transmission scheduled by RAR or TC-RNTI with DCI format 0\_0, UE considers transform precoding enabled or disabled according to *msg3-transformPrecoder* as in legacy |
| Transsion | We are fine with the proposal. |
| CMCC | Basicly fine with the main bullet. For the FFS part, we think that the multiple PRACH transmission and the transform precoding for msg3 should not be added a connection. |
| Sharp | We are OK with the FL proposal 1-2r1 in principle.  For FFS part (i.e. linkage with multiple PRACH transmission), we have same view with Ericsson and Qualcomm. The gNB having a concern on Msg3 coverage can configure DFT-S-OFDM by *msg3-transformPrecoder*. We see no reason for that gNB to configure CP-OFDM by *msg3-transformPrecoder*. |
| Spreadtrum | We prefer to remove the FFS and condition in main bullet. We don’t support DWS is applicable to Msg3 (re)transmissions. There is no need to link between Msg1/Msg3 repetition and DWS for Msg3 PUSCH.  **FL proposal 1-2r1**: For PUSCH transmission scheduled by RAR or TC-RNTI with DCI format 0\_0, UE considers transform precoding enabled or disabled according to *msg3-transformPrecoder* as in legacy |
| OPPO | We think the issue is how to effectively identified the waveform. We are open to the modification by Ericsson that if the CP-OFDM is configured for Msg3 and PRACH repetition, how to determine the waveform.  The simple modification would also be OK as:  **FL proposal 1-2r1**: For PUSCH transmission scheduled by RAR or TC-RNTI with DCI format 0\_0, UE considers transform precoding enabled or disabled according to *msg3-transformPrecoder* as in legacy at least if the UE does not support/use multiple PRACH transmissions in RACH procedure.   * ~~FFS: UE enables transform precoding for PUSCH transmission scheduled by RAR or by TC-RNTI with DCI format 0\_0 if the UE uses multiple PRACH transmissions in RACH procedure.~~   FFS: The waveform, if the UE supports/uses multiple PRACH transmissions. |
| Mavenir | We are fine with the proposal. |
| Sony | We support the FL’s proposal for the sake of progress. |
| Xiaomi | Fine with the proposal |
| Huawei, HiSilicon | Similar comment as LG. The mechanism in the FFS is not dynamic mechanism. Thus, in our understanding, it is out of scope and should be removed at this stage. Or FFS should be about whether it is in the scope. For the proposal, a conclusion seems better because it does not change any spec.    WID:  Specify enhancements to support dynamic switching between DFT-S-OFDM and CP-OFDM (RAN1) |
| Vivo | Share similar as many companies and as is also commented in first round, we can only agree on the first part of the proposal.  **FL proposal 1-2r1**: For PUSCH transmission scheduled by RAR or TC-RNTI with DCI format 0\_0, UE considers transform precoding enabled or disabled according to *msg3-transformPrecoder* as in legacy. |
| Moderator | @Samsung: Actually, this is what the proposal is trying to achieve, i.e. have separate discussion only for the multi-PRACH case. If we only have the conclusion as you suggest, in my understanding it closes the door even for multi-PRACH.  @Huawei, HiSilicon: I understand your point and agree to some extent. However, one can also argue that if we have separate mechanism for the multi-PRACH case and the use of multi-PRACH is determined based on a dynamic aspect (e.g. RSRP) then it is dynamic switching. |

From the comments, moderator observes following:

* Several companies would prefer to make connection with msg3 repetition feature instead of PRACH repetition. However, this seems unacceptable to most companies.
* Many companies also have concerns about making connection with PRACH repetition feature. However, some companies are open to re-discussing this case in the future considering that the design of this feature is on-going for R18.

Based on these observations, moderator suggest the following to move forward.

|  |
| --- |
| **FL proposed conclusion 1-2r2**: For PUSCH transmission scheduled by RAR or TC-RNTI with DCI format 0\_0, UE considers transform precoding enabled or disabled according to *msg3-transformPrecoder* as in legacy.   * The above conclusion can be re-visited only for the case of UE supporting/using multiple PRACH transmissions.   ~~at least if the UE does not support/use multiple PRACH transmissions in RACH procedure.~~   * ~~FFS: UE enables transform precoding for PUSCH transmission scheduled by RAR or by TC-RNTI with DCI format 0\_0 if the UE uses multiple PRACH transmissions in RACH procedure.~~ * ~~FFS: if the UE supports/uses multiple PRACH transmissions.~~ |

### 3rd round

Please indicate if FL proposed conclusion 1-2r2 is acceptable.

|  |  |
| --- | --- |
| Company | Comments |
| QC | Support |
| CMCC | OK. |
| Sharp | Support |
| Panasonic | FL proposed conclusion 1-2r2 is acceptable.  We agree to LG’s comment in the 2nd round discussion that the linkage of Msg.3 to the PRACH transmission/repetition should be discussed sufficiently first in AI 9.12.1. After the linkage is decided, we can revisit this issue. |
| Ericsson | We can accept it. |
| OPPO | For the proposal we really see it is different to the DCI by C-RNTI, thus we’d better to be more open for it.  The PRACH would support multiple transmission based on what WID said and the current 9.11.1 progress.  Thus, we can ask more positive conclusion more like in the earlier version:  For PUSCH transmission scheduled by RAR or TC-RNTI with DCI format 0\_0, UE considers transform precoding enabled or disabled according to *msg3-transformPrecoder* as in legacy at least if the UE does not support/use multiple PRACH transmissions in RACH procedure.   * FFS: UE enables transform precoding for PUSCH transmission scheduled by RAR or by TC-RNTI with DCI format 0\_0 if the UE uses multiple PRACH transmissions in RACH procedure. |
| Sony | Support with slight change:  For PUSCH transmission scheduled by RAR or TC-RNTI with DCI format 0\_0, UE considers transform precoding enabled or disabled according to *msg3-transformPrecoder* as in legacy.   * The above conclusion can be re-visited ~~only~~ for the case of UE supporting/using multiple PRACH transmissions. |
| Lenovo | Support. |
| NTT DOCOMO | OK |
| CATT | Fine with the proposal. |
| Nokia, NSB | We see technical merit of linking between multiple PRACH transmissions and initial Msg3 PUSCH waveform. Given that waveform configured in *msg3-transformPrecoder* is not only used for Msg3 but also used for PUSCH scheduled by DCI format 0\_0 (and some other fallback cases), we should not take it as granted that network should always configure DFT-s-OFDM in *msg3-transformPrecoder.* In addition, given that coverage conditions could be different for different UEs in the cell, network can only know if a UE is in coverage shortage or not when receiving Msg1. Therefore, it’s reasonable using DFT-s-OFDM for Msg3 if Msg1 repetition is used by the UE (e.g., in case CP-OFDM is configured in *msg3-transformPrecoder*).  Regarding the concern about the WID, we think that such behavior can also be considered as “dynamic” from UE perspective. There is NO explicit note in the WID saying that “dynamic” should be DCI-based.  We can accept the previous version of the proposal, which is more explicit. Otherwise, we prefer to keep the discussion open. Indeed, if the concern is because of the ongoing work for Msg1 repetitions in AI 9.12.1, then we can continue the discussion here in this AI to exchange companies views for the best use of meeting time, rather than wait and revisit later. |
| Intel | We share similar view as Nokia that in case when network configures CP-OFDM for MSg3 transmission, and for a cell edge UE, it is not reasonable to continue to use CP-OFDM waveform for Msg3 transmission, especially when Msg3 repetition is requested or indicated.  We do not support the proposal. |
| LG | Support the conclusion 1-2r2. We think the revised proposal is explain enough to further re-visit and discuss for the case of UE supporting/using multiple PRACH transmissions from AI 9.12.1. |
| ZTE | Share the similar technical analysis from Nokia. It is reasonable to support the mechanism of waveform switching for msg3 PUSCH repetition. Although we don’t think the proposal aligns our original thought, we can accept the previous version as compromise just like the suggestion from OPPO and Nokia. The previous version can keep this issue open until common sense on link between PRACH repetition and msg3 repetition is achieved. |
| China Telecom | We share the similar with Nokia/Intel/ZTE. We are open to further discuss the DWS for PUSCH repetition. We prefer the former version of the proposal. |
| Samsung | We agree to the first part, and don’t support the sub-bullet.  This proposal is not related to PRACH repetitions. |
| Xiaomi | Same view as Samsung. |
| Transsion | Support |
| Apple | We are ok with this proposed conclusion and previous version is ok for us as well. |
| Spreadtrum | We share same view as Samsung.  There is no need to link between multiple PRACH transmissions and waveform switching for Msg3 PUSCH. It is enough to determine the waveform according to the current configuration of high-level parameters *msg3-transformPrecoder*. |
| Panasonic2 | Although we mentioned that we accept the FL proposed conclusion 1-2r2, we share similar view as Nokia, Intel, and ZTE. Therefore, our more preference is the previous version. |
| MediaTek | Same view as Samsung. We support the main proposal without the sub-bullet. |
| Moderator | @All, thanks for the support and feedback.  It still seems difficult to agree on a conclusion for this topic. The discussion can thus remain open, but for upcoming meetings this topic will remain de-prioritized unless proponents can convince other companies. |

## [LP][Closed] Issue #1-3: Other issues related to requirements and scenarios

**Summary of company views from contributions submitted to RAN1#112bis-e**

For the scenario of uplink carrier aggregation:

* Nokia [10] proposes to further study whether/how DWS feature is enabled for UL CA
  + Largest MPR is considered for intra-band contiguous CA, CC in poor coverage cannot take advantage of larger Pcmax
* Panasonic [14] proposes to discuss whether dynamic waveform switching is supported in CA/DC scenario.
  + Dynamic waveform switching is to be used not in real cell edge but closer to the cell center, therefore should be supported [14]
* Mavenir [15], Ericsson [26] propose that UL CA is assumed to be supported with dynamic waveform switching
  + R17 coverage enhancements features can all be supported in UL CA scenario.
* Ericsson [26] proposes to study whether/how the power sharing across UL carriers affects UL transmission power after waveform switching.

Configured grant type 2

Sony [9] and Mavenir [15] proposes to adopt dynamic waveform switching for Type 2 CG-PUSCH:

* For CG re-activation when a new talk spurt occurs [9]
* Can be used for URLLC, small specification effort [15]

Other

* Spreadtrum [5], LG [29] propose that PUSCH transmission in RRC-connected can support dynamic waveform switching.
* Nokia [10] proposes to further study whether/how DWS feature is enabled for mTRP scenario.

**Observations on other issues related to requirements**

Moderator assumes that dynamic carrier switching is supported in uplink carrier aggregation, although it does not imply that dynamic waveform switching indication will be supported in DCI format 0\_X.

### 1st round

Please indicate if your company position was incorrectly captured or if you would like to add your company position to the summary above.

|  |  |
| --- | --- |
| Company | Comments |
| NTT DOCOMO | Before starting CA consideration here, we’d suggest clarifying the detailed functions of DWS in DCI 0\_1 for self-cell scheduling.  More specifically,   * Is the feature of DWS configured (i.e., turned on/off) by a new RRC parameter?   + DCM’s view: Yes * If above is the case, then what configuration type is assumed for the new RRC parameter? Cell-common? UE-specific? BWP-specific?   + DCM’s view: Open. Needs to decide. We thought UE-specific and BWP-specific is a kind of common understanding. * What is the exact meaning of DWS field indication?   + DCM’s view: Needs to decide.   We see the first two points are treated in section 8.1.1. We’d suggest preparing the place to discuss the last point above under section 6. |
| Intel | Our view is that dynamic waveform switching feature is not directly related to coverage enhancement. This can also be used for capacity improvement. For instance, when UE switches from DFT-s-OFDM waveform to CP-OFDM waveform, rank>1 transmission can be scheduled, which help improve the data rate. In this case, our understanding is that dynamic waveform switching can be supported for UL CA case. |
| Lenovo | Support to study the potential issues for supporting DWS in UL CA case. |
| Vivo | Thanks for FL’s good summary. Our views are actually also provided when discussing the DWS signalling for multiple TB transmissions.  In our understanding, we do not see the reason to not allow dynamic waveform switching for each serving cell when DC/CA is supported. When multiple PUSCH transmissions are scheduled by single DCI 0\_x, DWS for each PUSCH should be treated independently at least for inter-band CA case. |
| ZTE | Support the FL’s observations. |
| LG | We think UE with RRC\_CONNECTED would have clear condition to support DWS, and additionally RRC parameter that enable/disables dynamic waveform switching, e.g., introduce ‘dynamicWaveform’ value in ‘*transformPrecoder*’, can be adopted for on-demand DWS operation. |
| Spreadtrum | Support dynamic waveform switching in UL CA case. We think the PUSCH transmission waveform can be different in different carrier.  For multi-carrier scheduling by DCI 0\_X, there are some remaining issue have not been decided yet. Thus, it is too early to consider the possibility of supporting DCI format 0\_X. In addition, we don’t understand why it has to change PUSCH waveform for more than one co-scheduled cells. It should be discussed under further MC enhancement WI. |
| Ericsson | Yes, it was correct. |
| Moderator | @All, thanks for feedback.  @NTT DOCOMO, regarding “What is the exact meaning of DWS field indication?”. Do you mean the mapping between 0 / 1 and which waveform? (There is a proposal from Huawei on this under 6.1.) |

# Topic #2: Dynamic switching mechanism

## [HP][Closed] Issue #2-1: DCI size alignment between CP-OFDM and DFT-S-OFDM

**Summary of company views from contributions submitted to RAN1#112bis-e**

Option 1: Per-format

* Preferred or acceptable: Huawei [2], InterDigital [12], (Samsung [17]), (Ericsson [26]), (NEC [27])

[Impact on DCI construction/parsing][2][8][12][26]

* + Only requires bit padding at end of DCI [2]
  + Reuse current DCI decoding scheme, lower UE implementation complexity [2][8]
  + DWS indication precedes any field of the DCI format that has waveform-dependent size [2][17], precedes NDI field [17]
  + Can ensure that fields before NDI (e.g. FDRA) are aligned by specification [12]
  + Do not configure simultaneously with Type 0 resource allocation to avoid waveform-dependent fields before NDI [26]
  + Same principle as cross-carrier scheduling [2]
  + Would not prevent usage of CG type 2 PUSCH [2], UE needs to parse DWS field for CG retransmission anyway [2]

[Potential size benefit if new fields are introduced][2][12][27]

* + Easy to introduce new fields, e.g. FDSS for DFT-S-OFDM, smaller DCI size [2][12]
  + Beneficial if there is one field that is larger for DFT-S-OFDM compared to CP-OFDM [27]
* Concerns: OPPO [4], Spreadtrum [5], ZTE [7], Nokia [10], Apple [22], Qualcomm [23], Google [25], NTT DOCOMO [28]

[Impact on DCI construction/parsing][4][5][7][8][10][22][23]

* + New 1-bit field needs to be in the beginning of format (or after NDI) [4][5][8][10]
  + Potential additional complexity when considering other features [23], e.g. multi-cell scheduling [8][23], multi-PUSCH scheduling [23], dynamic switching of TRP transmission modes [23]
  + Requires reading DWS bit before parsing [5][23], adding more features with dynamic DCI parsing increases complexity of DCI decoding [23]
  + FDRA field is before NDI and may have size that depends on resource allocation type configuration [5]([10])[22]
  + Alt-B requires that waveform-dependency of field size is not introduced in future releases before NDI [7][10]
  + *[Additional concerns/observations on decodability of DCI scrambled by CS-RNTI [10] – however moderator thinks they may not be correct because we have alignment between C-RNTI and CS-RNTI]*

[DCI size benefit unclear or negligible][4][5][7][8][24][25][29]

* + UL DCI typically smaller than DL DCI [5][8]
  + Not much difference between payload of CP-OFDM and DFT-S-OFDM in practice because CP-OFDM will use small rank [18]
  + Negligible overhead decrease even if some fields are larger for DFT-S-OFDM in future [24]
  + New field specific to DFT-S-OFDM is hypothetical [29]

Option 2: Per-field

* Preferred or acceptable: vivo [3], OPPO [4], Spreadtrum [5], CATT [6], Intel [8], Nokia [10], (InterDigital [12]), China Telecom [13], Panasonic [14], Lenovo [16], (Samsung [17]), ETRI [18], Transsion [21], Sharp [24], Google [25], (Ericsson [26]), (NEC [27]), NTT DOCOMO [28], LG [29]

[Lower complexity, more robust approach]

* + Clean solution with impact limited to few relevant fields, less complex/risky than per-format [4][6][7][13][14][16][22][23][29]
  + DCI construction invariant to selection of transmission waveform [23]
  + Lower specification effort [5][10][25]
  + No restriction on either position of DWS field nor field size before/after NDI field, more flexible and forward compatible design [3][8][10][16][25]
  + Same principle as for BWP switching, per-field alignment between current and target BWP [8][18]
  + Compatible/pairs well with alignment between CS-RNTI and C-RNTI [5][14][23]
  + Minimize the impact of DWS on type 2 CG PUSCH and its activation/deactivation [28]
  + No additional size comparison step needed between DCIs with different NDI values [29]

[Lower impact to UE implementation]

* + Least disruptive to UE implementation, CG-PUSCH already deployed in the field [23]
  + Can still position new field in front to help parsing other fields [4][5], avoids two passes of parsing and decoding [5]

[New field specific to DFT-S-OFDM]

* + Can leverage zero-padded bits to avoid larger DCI size if new DFT-S-OFDM specific field is introduced in future [10]
  + Beneficial if it is not expected that there is one field that is larger for DFT-S-OFDM compared to CP-OFDM [27]
* Concerns: Huawei [2]
  + Padding bits cannot be reused by new fields [2]
  + Larger DCI size when new fields are introduced in DCI only for DFT-S-OFDM [2]
  + Requires change to current DCI decoding scheme, increases implementation complexity of UEs [2]

Option 3: Per-field alignment for fields preceding NDI field

* Preferred: CMCC [19]
  + Same advantage as Option 1 if a new field is introduced for DFT-S-OFDM [19]
  + Almost all fields influenced by waveform are located after NDI
* Concerns: Huawei [2], Spreadtrum [5], CATT [6], ZTE [7], Nokia [10], Apple [22], Qualcomm [23]
  + More complex, requires both per-field and per-format [2][5][7][22][23]
  + CG type 2 PUSCH is optional feature, should not impact gNBs and UEs that do not implement it [2]
  + May impact PDCCH validation [5](?)
  + Unclear benefit [5][7]
  + Not relevant if fields preceding NDI are not waveform-dependent [6]
  + Larger DCI size compared to option 1 [10]

Option 4: Per-field alignment only for DCI addressed to CS-RNTI

* Preferred: Mediatek [20]
  + Current spec follows per-format alignment for DCI with C-RNTI and per-field alignment for DCI with CS-RNTI [20]
* Concerns: Huawei [2], Spreadtrum [5], ZTE [7], Nokia [10], InterDigital [12], Apple [22], Qualcomm [23], Sharp [24]
  + More complex, uses two DCI alignment methods [2][5][7][12][22][29]
  + Unclear benefit [5][6][7]
  + May remove Option 1 benefit of potentially smaller field size [5]
  + Fields need to have size for CP-OFDM at least equal to size for DFT-S-OFDM otherwise cannot be used for CS-RNTI and NDI=1 [6][10], limitation undesirable [24]
  + DWS field need to be located before first waveform-dependent field [10]
  + Would end up creating two classes of DG-PUSCH [23]
  + If DWS is disabled, DCI for CS-RNTI fallbacks to legacy mode – effectively becomes new DCI format [23]

Other proposals

* Huawei [2] proposes to use 0 and 1 to indicate the waveforms.
* Nokia [10] proposes Option 5: Per-format alignment for DCI addressed to C-RNTI, per-field alignment for CS-RNTI depending on latest DWS waveform indicated by DCI scrambled by CP-OFDM
* Nokia [10] proposes that DCI contains DWS field only within certain time periods only to avoid overhead
  + Panasonic [14] has concerns on complexity and thinks it is not needed.
* [4][10] provides a list of waveform-dependent fields:
  + FDRA, TPMI, Second precoding information, Antenna ports, PTRS-DMRS association, Second PTRS-DMRS association, DRMS sequence initialization
* Sharp [24] thinks it needs to be clarified whether FDRA field size should be set according to *resourceAllocation* for both waveforms, or not [24]
* LG [29] proposes that if CG-PUSCH Type 2 is configured, waveform to be applied should be decided upon its DWS field availability and NDI values at UE.

**Observations on DCI size alignment**

Per-format alignment (Option 1) is preferred by at least 2 companies. 2 other companies did not explicitly express preference in their contributions, but proposals implicitly assume per-format alignment. On the other hand, 8 companies expressed concerns about this option.

Per-field alignment (Option 2) is preferred by 15 companies seems acceptable to 19 companies. 1 company expressed concerns about this option.

In general, companies analyzed the Options on the table from perspective of complexity, forward compatibility, and efficiency.

From the perspective of complexity, majority of companies believe that per-field alignment is generally simpler than per-format alignment because it does not require decoding the DWS field before parsing other fields. Introducing such dependency to the DCI encoding/decoding process is also foreseen to increase the potential for issues when introducing new features in the future. Potential dependency of the position of the NDI field is a drawback from UE perspective because it impacts PDCCH validation for configured grant type 2 activation/release. To address this problem, one sub-option of per-format alignment (Alt. B) imposes condition that no field preceding NDI field has a size that depends on the DWS field. This could be done by aligning fields such as FDRA if necessary. However, companies still have concerns that this is not a robust approach as the condition would have to be maintained in future releases.

From the perspective of efficiency, per-format alignment is more optimal since it guarantees the smallest number of padding bits required for alignment. However, majority of companies noted that this benefit does not exist in practice with currently defined fields since all of them have larger size for one waveform (CP-OFDM). This situation may change if new fields specific to DFT-S-OFDM are introduced, but even if this occurs the overhead benefit is likely to be very small or zero (e.g. if UL DCI is still smaller than DL DCI).

Option 3 and Option 4 were developed as potential compromise solutions during RAN1#112 offline discussions. However, only 1 company showed support for each Option while 7 and 8 companies (respectively) expressed concerns. The concerns are that these solutions further increase complexity by using both alignment methods.

Considering majority view, moderator recommends agreeing on per-field alignment (Option 2).

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| **FL proposal 2-1**: For DCI format 0\_1/0\_2 containing dynamic waveform indication, bit width of each field is set to the maximum between the bit width of the field if transform precoding is disabled and the bit width of the field if transform precoding is enabled, if different.   * If, for the waveform indicated in the DCI, the bit width N of a field would be smaller than the bit width of the field set as per the above, UE decodes the field using N least significant bits. If N=0, the UE ignores the field for the indicated waveform. |

### 1st round

Please indicate if your company position was incorrectly captured or if you would like to add your company position to the summary above. Please feel free to provide any feedback on FL proposal 2-1.

|  |  |
| --- | --- |
| Company | Comments |
| NTT DOCOMO | Support 2-1 |
| CATT | We support FL proposal 2-1. |
| Intel | We are fine with the proposal.  This option is aligned with existing mechanisms on DCI size alignment between DCI format addressed to C-RNTI and CS-RNTI, as well as BWP switching as defined in Rel-15. |
| QC | Support |
| Panasonic | We support the FL proposal 2-1. |
| Lenovo | We support FL proposal 2-1. |
| Apple | OK with this proposal. In addition, this DCI size alignment rule should be applied to PUSCH with type 2 CG initial transmission as well, even DWS is not supported to PUSCH with type 2 CG initial transmission. Otherwise, it could not differentiate the CG type 2 PUSCH initial transmission and re-transmission.  Considering if PUSCH with CG type 2 is configured for a UE, the per-field alignment is applied to both CG type 2 PUSCH with NDI=0 and NDI=1. So, there are no additional efforts to support DWS to PUSCH with type 2 CG initial transmission from standard and implementation perspectives.  Therefore, we propose to re-consider supporting “Dynamic waveform switching to PUSCH transmissions with a Type 2 configured grant” in R18. |
| Vivo | Fine. |
| ZTE | Support this proposal. |
| Transsion | We support this proposal. |
| LG | Support FL proposal 2-1. |
| Spreadtrum | Support this proposal. |
| Sharp | We support the FL proposal.  The drawback of option 2 is the overhead for the case that a field for DFT-S-OFDM is larger than that for CP-OFDM, but it should be separately considered since it causes an issue even for current DCI alignment procedure between C-RNTI and CS-RNTI without DWS (e.g. the field of DCI with C-RNTI configured with CP-OFDM may be smaller than the field of DCI with CS-RNTI configured with DFT-S-OFDM).  Except for such case, there is no overhead difference between candidate options. |
| CMCC | OK. Per field alignment helps UE decide bit width of each bit field without firstly decoding the DWS field. |
| Ericsson | Considering both per-format and per-field alignment can work, for the sake of progress, we are fine with the proposal. |
| ETRI | Support the proposal. |
| Nokia/NSB | We are fine with FL proposal 2-1. |
| MediaTek | We are fine with the proposal. |
| Samsung | Either per-format or per-field DCI alignment works. We are fine with the proposal if there is consensus. |

## [MP][Closed] Issue #2-2: Handling of FDRA type/DMRS type

**Summary of company views from contributions submitted to RAN1#112bis-e**

FDRA type

Several companies [3][5][6][10][12][19][25][28] discuss options for handling of FDRA type configuration when dynamic waveform switching indication is configured, considering that FDRA type 0 is not supported for DFT-S-OFDM. The following alternatives are identified:

* Option 1: *resourceAllocation* set to *resourceAllocationType0* is error case: [5][6][19][28]
  + MSB of FDRA set to 0 is error case if DFT-S-OFDM is indicated and FDRA type is set to dynamicSwitch [28]
* Option 2: If DFT-S-OFDM is dynamically indicated, UE applies type 1 resource allocation regardless of how *resourceAllocation* is set or how dynamic indication of FDRA type is set ([6])[10][12][25].

[Benefits]

* + Works regardless of whether the resource allocation type is RRC configured or dynamically indicated and regardless of DCI size alignment solution [10]
  + Does not require setting *resourceAllocation* to *dynamicSwitch* when network wants to use type 0 for CP-OFDM, saves 1 bit [12]

DMRS type

Two companies [6][28] discuss handling of DMRS type when dynamically waveform switching indication is configured, considering that DMRS type 2 is not supported for DFT-S-OFDM. The following alternatives are identified:

* Option 1: *dmrs-Type* set to *type2* is error case
* Option 2: If DFT-S-OFDM is dynamically indicated, UE applies DMRS type 1 regardless of how *dmrs-Type* is set.

Other waveform-specific configuration aspects

Vivo [3], Spreadtrum [5] discuss the potential issue of indicating rank>1 with DFT-S-OFDM.

Vivo [3] proposes to discuss rules to avoid indicating a waveform not supported with pi/2 BPSK.

Spreadtrum [5] proposes that parameters required by both waveforms are configured when dynamic waveform switching is configured.

Spreadtrum [5] proposes to apply MCS table configured for indicated waveform.

**Observations on handling of FDRA type, DMRS type and other waveform-specific configuration aspects**

The alternatives for the handling of FDRA type are to (1) consider that a configuration or indication incompatible with DFT-S-OFDM (i.e. Type 0) is an error case or (2) ignore the configuration when DFT-S-OFDM is indicated and use Type 1 resource allocation. In moderator’s understanding, the issue only exists for the case where *useInterlacePUCCH-PUSCH* is not configured since otherwise resource allocation type 2 is used regardless of how *resourceAllocation* IE is set. This leads to the following proposal:

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| **FL proposal 2-2**: For PUSCH scheduled by DCI format 0\_1/0\_2 with dynamic waveform switching indication field configured, and *useInterlacePUCCH-PUSCH* is not configured, downselect between following options:  Option 1 (configuration restriction with error case handling):   * If DFT-S-OFDM is indicated, UE does not expect *resourceAllocation* set to *resourceAllocationType0*. * If DFT-S-OFDM is indicated and *resourceAllocation* set to *dynamicSwitch*, UE does not expect MSB of FDRA field set to 0.   Option 2 (UE only uses *resourceAllocation* if CP-OFDM is indicated):   * If DFT-S-OFDM is indicated, UE applies type 1 resource allocation. * If CP-OFDM is indicated, UE applies resource allocation according to *resourceAllocation* IE. * Size of FDRA field is aligned between size for type 1 resource allocation and size according to *resourceAllocation* IE. |

For DMRS type, same options are identified:

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| **FL proposal 2-3**: For PUSCH scheduled by DCI format 0\_1/0\_2 with dynamic waveform switching indication field configured, downselect between following options:  Option 1 (configuration restriction with error case handling):   * If DFT-S-OFDM is indicated, UE does not expect *dmrs-Type* to be set to *type2*.   Option 2 (UE only uses *dmrs-Type* if CP-OFDM is indicated):   * If DFT-S-OFDM is indicated, UE applies DMRS type 1. * If CP-OFDM is indicated, UE applies DMRS type according to *dmrs-Type*. |

### 1st round

Please indicate if your company position was incorrectly captured or if you would like to add your company position to the summary above. Please feel free to provide any feedback on FL proposals 2-2 and 2-3.

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| --- | --- |
| Company | Comments |
| NTT DOCOMO | We thank FL for the formulation above, which is indeed a nice starting point. At this stage we support both.  We think both options in each issue work. In this sense, both can be acceptable. Besides, we’d like to note that in our understanding, a main usage of DWS is for UE located “not very far from cell center”, to dynamically change its waveform properly, where RRC reconfiguration is NOT suitable. In other cases, just to configure RRC-level transform precoder only is still workable approach.  Given above, we slightly prefer not to limit NW-side configuration (i.e., prefer option 2 for each of the issues). With this, UE can be operated with either 1) CP-OFDM with its original flexibility or 2) DFT-S-OFDM with its original e.g., robustness against PAPR, dynamically. |
| CATT | For Option 1 in FL proposal 2-2, our understanding is that UE does not expect *resourceAllocation* set to *resourceAllocationType0*, which is not conditioned on the indicated waveform to be DFT-S-OFDM. Otherwise, it is wired that gNB configures DWS and *resourceAllocationType0* but never indicates DFT-S-OFDM.  Option 1 (configuration restriction with error case handling):   * ~~If DFT-S-OFDM is indicated,~~ UE does not expect *resourceAllocation* set to *resourceAllocationType0*. * If DFT-S-OFDM is indicated and *resourceAllocation* set to *dynamicSwitch*, UE does not expect MSB of FDRA field set to 0.   Another Option could be that *resourceAllocation* is applicable to both waveforms except that it is configured as *resourceAllocationType0* and DFT-S-OFDM is indicated.  Option X:   * If *resourceAllocation* set to *resourceAllocationType0,* size of FDRA field is aligned between size for type 0 resource allocation and type 1 resource allocation   + If DFT-S-OFDM is indicated, UE applies type 1 resource allocation. * If DFT-S-OFDM is indicated and *resourceAllocation* set to *dynamicSwitch*, UE does not expect MSB of FDRA field set to 0.   For FL proposal 2-3, similar as above comments to FL proposal 2-2, we suggest the following update to Option 1.  Option 1 (configuration restriction with error case handling):   * ~~If DFT-S-OFDM is indicated,~~ UE does not expect *dmrs-Type* to be set to *type2*. |
| Intel | We think these should be error cases. In case of dynamic waveform switching, a reasonable gNB configuration should avoid such error case. This would be similar to the case when DFT-s-OFDM waveform is configured for PUSCH transmission, UE does not expect to be configured with *resourceAllocationType0* |
| QC | Support both proposals. Okay with the edits made by CATT above. |
| Panasonic | We support FL proposal 2-2 and FL proposal 2-3. Either Option 1 or Option 2 is acceptable. |
| Lenovo | For the first bullet in option 1 in FL proposal 2-2, we think it is not accurate since a UE first receives the RRC signalling, and then receive a DCI for indicating the waveform and resource allocation type. Besides, we don’t support option 1 in both FL proposal 2-2 and FL proposal 2-3 since the flexibility is reduced for CP-OFDM.  We would like to add another method as in the following modified FL proposal 2-2:  **Modified FL proposal 2-2**: For PUSCH scheduled by DCI format 0\_1/0\_2 with dynamic waveform switching indication field configured, and *useInterlacePUCCH-PUSCH* is not configured, downselect between following options:  Option 1 (configuration restriction with error case handling):   * ~~If DFT-S-OFDM is indicated~~, UE does not expect *resourceAllocation* set to *resourceAllocationType0*. * If DFT-S-OFDM is indicated and *resourceAllocation* set to *dynamicSwitch*, UE does not expect MSB of FDRA field set to 0.   Option 2 (UE only uses *resourceAllocation* if CP-OFDM is indicated):   * If DFT-S-OFDM is indicated, UE applies type 1 resource allocation. * If CP-OFDM is indicated, UE applies resource allocation according to *resourceAllocation* IE.   Option 3:   * Separate resource allocation types for DFT-S-OFDM and CP-OFDM are configured.   Similar for FL proposal 2-3:  **FL proposal 2-3**: For PUSCH scheduled by DCI format 0\_1/0\_2 with dynamic waveform switching indication field configured, downselect between following options:  Option 1 (configuration restriction with error case handling):   * ~~If DFT-S-OFDM is indicated,~~ UE does not expect *dmrs-Type* to be set to *type2*.   Option 2 (UE only uses *dmrs-Type* if CP-OFDM is indicated):   * If DFT-S-OFDM is indicated, UE applies DMRS type 1. * If CP-OFDM is indicated, UE applies DMRS type according to *dmrs-Type*.   Option 3:   * Separate DMRS configurations for DFT-S-OFDM and CP-OFDM are configured. |
| Apple | For Proposal 2-2, we don’t think this proposal is necessary. If Proposal 2-1 is agreed, we don’t see any restrictions on FDRA usage.  For Proposal 2-3, it’s gNB configuration issue, a conclusion is enough. |
| Vivo | Fine with the FL’s proposal assuming down-selection would be performed in next step. |
| ZTE | For proposal 2-2, we support Option 1, i.e., error case handling. Option 2 need more specification effort on size alignment of FDRA field.  For proposal 2-3, we also support Option 1. |
| Transsion | The gNB has all the configuration information of the UE, so the gNB should avoid these error cases at the UE side. Therefore, for both proposals, we support option 1 respectively. |
| LG | We don’t support option 2 in FL proposal 2-3. It looks unnecessary DMRS type determination of UE behavior with additional condition since gNB already can configure properly via ‘dmrs-Type’ and ‘transformPrecodingEnanbled’ in DMRS-Uplinkconfig. |
| Spreadtrum | For Option 1, the gNB needs to ensure that type 0 resource allocation and DMRS type 2 is not used for DFT-S-OFDM. We prefer Option 1, it is easy and up to a proper configuration to solve this problem.  We agree with CATT that UE does not expect *resourceAllocation* set to *resourceAllocationType0* cannot conditioned on the indicated waveform to be DFT-S-OFDM. OK with CATT’s modification. |
| Sharp | For FL proposal 2-2, we prefer option 2. In option 1, ‘*resourceAllocationType0’* cannot be configured even for CP-OFDM in DWS case and only ‘*resourceAllocationType1’* or ‘*dynamicSwitch*’ are configurable since ‘*resourceAllocation*’ is semi-statically configured as a common parameter for both waveforms. Basically, ‘*resourceAllocation*’ is a parameter assumed for CP-OFDM and we don’t prefer such configuration restriction. |
| CMCC | Fine. From our understanding, to activate the dynamic waveform switching, RRC signalling is needed. gNB should have clear understanding about the collision between FDRA and DWS, so it should have opportunity to change the FDRA configuration and activate DWS at the same time. Op-1 seems workable. |
| Ericsson | We support the proposals and prefer Option 1. |
| ETRI | We think that it is an error case. We support Option 1 for both proposals. |
| Nokia/NSB | Support both proposals 2-2 and 2-3 from FL. |
| MediaTek | Support |
| Samsung | OK with both proposals. For further discussion whether there is any specification impact. |
| Moderator | @All: thanks for comments.  @CATT: agree we can delete “If DFT-S-OFDM is indicated” under Option 1. But, not sure I would like to add Option X at this point unless we have to.  @Lenovo: I don’t understand what Option 3 achieves on top of Option 2, since the only possible FDRA type for DFT-S-OFDM is type 1?  @Apple: it is not directly related to DCI size alignment issue. It is about interpreting RRC parameters that already exist in the context of DWS. |

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| **FL proposal 2-2r1**: For PUSCH scheduled by DCI format 0\_1/0\_2 with dynamic waveform switching indication field configured, and *useInterlacePUCCH-PUSCH* is not configured, downselect between following options:  Option 1 (configuration restriction with error case handling):   * ~~If DFT-S-OFDM is indicated,~~ UE does not expect *resourceAllocation* set to *resourceAllocationType0*. * If DFT-S-OFDM is indicated and *resourceAllocation* set to *dynamicSwitch*, UE does not expect MSB of FDRA field set to 0.   Option 2 (UE only uses *resourceAllocation* if CP-OFDM is indicated):   * If DFT-S-OFDM is indicated, UE applies type 1 resource allocation. * If CP-OFDM is indicated, UE applies resource allocation according to *resourceAllocation* IE. * Size of FDRA field is aligned between size for type 1 resource allocation and size according to *resourceAllocation* IE. |

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| **FL proposal 2-3r1**: For PUSCH scheduled by DCI format 0\_1/0\_2 with dynamic waveform switching indication field configured, downselect between following options:  Option 1 (configuration restriction with error case handling):   * ~~If DFT-S-OFDM is indicated,~~ UE does not expect *dmrs-Type* to be set to *type2*.   Option 2 (UE only uses *dmrs-Type* if CP-OFDM is indicated):   * If DFT-S-OFDM is indicated, UE applies DMRS type 1. * If CP-OFDM is indicated, UE applies DMRS type according to *dmrs-Type*. |

### 2nd round

Please indicate if FL proposals 2-2r1 and 2-3r1 are acceptable.

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| Company | Comments |
| NTT DOCOMO | Support. |
| ZTE | Fine with the proposals. We support treating as error case.  An understanding for Option 2 for FDRA to be confirmed. The size alignment between size for type 1 resource allocation and size according to *resourceAllocation* IE is to align to the maximum value? |
| Intel | We are still not convinced why we need to discuss these issues. As mentioned in the first round, a reasonable gNB configuration/implementation should avoid such error case. By default, it should be considered as error case. |
| Nokia/NSB | Support. |
| Panasonic | We are fine with FL proposal 2-2r1 and 2-3r1 assuming down-selection is the next step.  For down-selection, our preference is Option 2 for FDRA. To support resource allocation type 1 only when DWS is configured is restrictive.  For DMRS type, we are open for Option1 and Option 2. |
| NEC | If there are two separate PUSCH configurations, one for DFT-s-OFDM and the other for OFDM waveform, similar to separate DG PUSCH and CG PUSCH configuration, then we don’t think the proposal is needed. On the other hand, if only one PUSCH configuration is used for both two waveforms, we can support the proposal. |
| Moderator | @Intel: This means you are in favor of Option 1?  From my perspective we should discuss it at least so that we have common understanding of what the UE should expect.  @NEC: These parameters don’t have separate configuration per waveform in R17. Note that for DFT-S-OFDM, such configuration would not provide any information because FDRA cannot use type 0 and DMRS type cannot be anything else than DMRS type 1. |
| CATT | Fine with the proposal. At least for FDRA, our preference is Option 1. The difference between Option 1 with *dynamicSwitch* and Option 2 with *resourceAllocationType0* is just 1 bit and Option 1 can dynamically change the RA type for CP-OFDM while RA type is fixed for Option 2. |
| China Telecom | We are fine with the proposals. We understand the motivation of the current version of Option1, but does it mean that if CP-OFDM is indicated, the UE should still can’t apply the *resourceAllocationType0* or *dmrs-Type2*. |
| Lenovo | Support option 2 in both FL proposal 2-2r1 and FL proposal 2-3r1 since the flexibility is reduced for CP-OFDM in option 1.  @FL, we think the difference between option 2 and option 3 is that in option 2 a UE always assume resource allocation type 1 is used for PUSCH transmission with DFT-s-OFDM regardless of the configuration; while in option 3, a UE determine the resource allocation type by the configuration which is same as legacy. But we can accept option2. |
| Ericsson | We support the new proposals and Option 1. |
| LG | We think there should consider the case UE to be configured separately for each waveform through RRC signaling at least as we have similar view with Lenovo’s input earlier round. With the modification Option 3 added, we are fine to live with the proposals.  **FL proposal 2-2r1**: For PUSCH scheduled by DCI format 0\_1/0\_2 with dynamic waveform switching indication field configured, and *useInterlacePUCCH-PUSCH* is not configured, downselect between following options:  Option 1 (configuration restriction with error case handling):   * ~~If DFT-S-OFDM is indicated,~~ UE does not expect *resourceAllocation* set to *resourceAllocationType0*. * If DFT-S-OFDM is indicated and *resourceAllocation* set to *dynamicSwitch*, UE does not expect MSB of FDRA field set to 0.   Option 2 (UE only uses *resourceAllocation* if CP-OFDM is indicated):   * If DFT-S-OFDM is indicated, UE applies type 1 resource allocation. * If CP-OFDM is indicated, UE applies resource allocation according to *resourceAllocation* IE. * Size of FDRA field is aligned between size for type 1 resource allocation and size according to *resourceAllocation* IE.   Option 3:   * Separate resource allocation types for DFT-S-OFDM and CP-OFDM are configured.   **FL proposal 2-3r1**: For PUSCH scheduled by DCI format 0\_1/0\_2 with dynamic waveform switching indication field configured, downselect between following options:  Option 1 (configuration restriction with error case handling):   * ~~If DFT-S-OFDM is indicated,~~ UE does not expect *dmrs-Type* to be set to *type2*.   Option 2 (UE only uses *dmrs-Type* if CP-OFDM is indicated):   * If DFT-S-OFDM is indicated, UE applies DMRS type 1. * If CP-OFDM is indicated, UE applies DMRS type according to *dmrs-Type*.   Option 3:   * Separate DMRS configurations for DFT-S-OFDM and CP-OFDM are configured. |
| Transsion | We support these proposals and prefer option 1 for both proposals. |
| CMCC | Support. As we comment in the 1st round, we prefer option 1. |
| Sharp | We support the latest FL proposals, and our preference is Option 2.  For FDRA field, we would like to keep legacy UE procedure as much as possible, and our understanding on configurable RA type with legacy UE (i.e. waveform is semi-statically configured) is  - UE with CP-OFDM: RA type 0, RA type 1 or dynamic switch by *resourceAllocation*  - UE with DFT-S-OFDM: always RA type 1 (by *resourceAllocation*)  In option 1, the configurable RA type with DWS will be  - UE with CP-OFDM: ~~RA type 0,~~ RA type 1 or dynamic switch by *resourceAllocation*  - UE with DFT-S-OFDM: ~~always~~ RA type 1 or dynamic switch by *resourceAllocation*  Although both options work to configure RA type 0 or type 1, option 2 will have more similar operation with legacy UE. |
| Spreadtrum | Fine with the proposal. We support Option 1 at least for FDRA type. In Option 1, the *resourceAllocation* can be set to *resourceAllocationType1* or *dynamicSwitch*. If CP-OFDM is indicated and *resourceAllocation* is set as *dynamicSwitch*, UE can apply type 0 or type 1*.* The flexibility of CP-OFDM can be maintained. Option 1 is easy and up to a proper configuration to solve the problem. |
| OPPO | We prefer Option1 and accept the proposal 2-3r1 |
| Mavenir | We support this proposal and option1. |
| Sony | We support |
| Xiaomi | Fine with the two proposals and we prefer Option 1 |
| Vivo | Fine. |
| Moderator | @All, thanks for support and feedback. It seems that proposals are agreeable to majority. The next step would be to analyze impact of each Option (e.g. spec impact if any, flexibility) to make downselection.  @LG: thanks for suggestion, but I would prefer not to add a third Option which would have very little support. |

## [LP][Closed] Issue #2-3: DCI indicating multiple TBs

**Summary of company views from contributions submitted to RAN1#112bis-e**

Several companies [3][7][8][14][28] discuss whether/how to support dynamic switching indication in case a DCI schedules multiple TBs. Different cases are identified.

Multiple TBs/PUSCHs scheduled in time domain by single DCI for one serving cell [3][8][14][28]

* This case corresponds to multi-PUSCH scheduling using DCI format 0\_1 for shared spectrum access.
* Option 1: Common 1-bit DWS indication for all PUSCHs
  + Intel [8], Panasonic [14], NTT DOCOMO [28]
  + The multiple PUSCH typically experience similar channel conditions and scheduler cannot predict change anyway [28]
* Option 2: N-bit DWS indication for N PUSCHs
  + Vivo [3]

Multiple TBs/PUSCHs on multiple serving cells scheduled by single DCI (format 0\_X)

* Support DWS indication in format 0\_X?
  + Yes: Intel [8] (FFS bits), (vivo [3]), ZTE [7]
  + Discuss in multi-carrier AI: Panasonic [14]
* One or multiple DWS?
  + Multiple bits: vivo [3]
  + Single bit: ZTE [7]
    - Unified solution with single TB/single DCI
    - Can use DFT-S-OFDM (more conservative) or majority waveform (?)
    - Less overhead, less specification effort

2 TBs on single serving cell with 8Tx UL transmission

* Dynamic waveform switching indication not applied because rank>1: ZTE [7]
* Discuss in MIMO AI: Panasonic [14]

**Observations on DCI indicating multiple TBs**

In general, not many companies contributed on these issues as the focus is on the completion of single TB case.

For the case of multi-PUSCH scheduling in time domain using DCI format 0\_1 for shared spectrum access, 3 companies think it should be supported with single-bit DWS field indicating single waveform applicable to all PUSCHs. 1 company thinks it should be supported with multi-bit DWS field indicating waveform to respective multiple PUSCHs. From moderator’s perspective, it seems that single waveform indication applicable to all PUSCHs would be sufficient for this case and same solution as for single TB can be reused without any issue. The following is therefore proposed:

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| **FL proposal 2-4**: For UE configured with multi-PUSCH scheduling in time domain *(*i.e. *pusch-TimeDomainAllocationListForMultiPUSCH*), DCI format 0\_1 supports 1-bit field for dynamic waveform switching indication.   * When configured, 1-bit field indicates waveform for all scheduled PUSCH transmissions. |

For the case of multiple PUSCHs on multiple serving cells scheduled by DCI format 0\_X, 3 companies think that DWS should be supported for this case. One company thinks a single DWS bit should indicate single waveform applicable to multiple serving cells, while another company thinks multiple bits are required. During RAN1#112, majority of companies indicated that discussion on supporting DCI format 0\_X should be lower priority.

For the case of 2 TBs with 8Tx UL transmission, one company indicates that DWS indication should not be configured because DFT-S-OFDM does not support rank > 1. Moderator thinks it may depend on whether fallback to 1 TB is supported for this feature. More progress seems needed in MIMO AI before potential applicability of DWS can be discussed for this case.

### 1st round

Please indicate if your company position was incorrectly captured or if you would like to add your company position to the summary above. Please indicate if FL proposal 2-4 is agreeable.

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| Company | Comments |
| NTT DOCOMO | For DCI 0\_X, we’d suggest discussing it under MCE WI, where for any other DCI field, how to treat in case of MC-DCI was extensively discussed.  For 8Tx, any discussion seems not necessary for now. Support of DFT-S-OFDM for 8Tx UE itself is still not very clear. Agree with FL that waiting for MIMO progress seems reasonable. |
| CATT | We support FL proposal 2-4. |
| Intel | We are generally fine with the proposal. Suggest minor update to avoid confusion with multi-cell scheduling in Rel-18:  **FL proposal 2-4**: For UE configured with multi-PUSCH scheduling in time domain in a carrier *(*i.e. *pusch-TimeDomainAllocationListForMultiPUSCH*), DCI format 0\_1 supports 1-bit field for dynamic waveform switching indication.  When configured, 1-bit field indicates waveform for all scheduled PUSCH transmissions. |
| QC | Support. Single bit suffices. |
| Panasonic | We support FL proposal 2-4. |
| Lenovo | Support. |
| Vivo | Fine with FL’s proposal 2-4 with the update by Intel.  Regarding the support of DWS for DCI 0-x, we think this should be discussed with medium priority since some conclusion from this topic is needed to trigger discussions in DC/CA enhancement topic where different DCI field extension types are introduced.  For multiple layer transmission, we do not think DWS is necessary either. |
| ZTE | Generally fine with this proposal. And FFS should be added as:  FFS: the determination of the waveform for all scheduled PUSCH transmission.  FFS: How to apply the assistance information discussed in section 7, if any. |
| Transsion | We support the proposal modified by Intel. |
| LG | Support. |
| Spreadtrum | Fine with FL’s proposal 2-4. For multi-PUSCH scheduling using DCI format 0\_1 in NR-U, multiple PUSCH typically experience similar channel conditions, so 1-bit waveform indicated field can be applied to all scheduled PUSCH transmissions.  For the case of multiple PUSCHs scheduled by DCI format 0\_X and the case of 2 TBs with 8Tx UL transmission, the applicability of both case can be separately discussed in MC or MIMO AI. |
| Sharp | We support the FL proposal. |
| CMCC | Support. |
| Ericsson | Support. |
| ETRI | We support the proposal. |
| Nokia/NSB | Support FL proposal 2-4 and also fine with the update by Intel. One question for clarification, why do we only consider DCI 0\_1 here? is it because the multi-PUSCH feature is only supported with DCI 0\_1? |
| MediaTek | Support. We agree with Intel’s addition “in a carrier” for clarity. |
| Samsung | OK with the FL’s proposal. |
| Moderator | @All, thanks for support and comments.  @NTT DOCOMO, Vivo: Is MC WI still on-going or in maintenance phase?  @Intel: Thanks for the suggestion. I am fine with it.  @ZTE: I think the waveform is determined by the 1-bit DWS bit. What is left to determine? For the assistance information, better to decide first if we have it.  @Nokia/NSB: Yes, this is my understanding from looking at 38.212. |

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| **FL proposal 2-4r1**: For UE configured with multi-PUSCH scheduling in time domain in a carrier *(*i.e. *pusch-TimeDomainAllocationListForMultiPUSCH*), DCI format 0\_1 supports 1-bit field for dynamic waveform switching indication.   * When configured, 1-bit field indicates waveform for all scheduled PUSCH transmissions. |

### 2nd round

Please indicate if FL proposal 2-4r1 is acceptable.

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| Company | Comments |
| NTT DOCOMO | Yes we support.  Just to respond to comments below:  *[vivo] Regarding the support of DWS for DCI 0-x, we think this should be discussed with medium priority since some conclusion from this topic is needed to trigger discussions in DC/CA enhancement topic where different DCI field extension types are introduced.*  [DOCOMO] Yes, we agree some discussions would need to be accelerated to trigger the discussion in MCE. We need to fix some basic aspects of DWS (e.g., the meaning of DWS indicated value 0 or 1, and its relationship with legacy transformPrecoder).  *[FL] @NTT DOCOMO, Vivo: Is MC WI still on-going or in maintenance phase?*  [DOCOMO] in our understanding MC WI can still work on this issue, if the topic is ready to be discussed in MC WI. |
| ZTE | Support |
| Intel | Support  For the discussion of DWS for multi-cell scheduling, we do not have strong view which WI should be treated. Our initial thought is that it may be good to discuss DWS issue in this AI given that we still have some opens for DWS, but MC enhancement is not in the maintenance phase. |
| Nokia/NSB | Thank you, FL, for the clarification. We support this proposal. |
| QC | Support |
| Panasonic | We support DL proposal 2-4r1. |
| CATT | Support |
| China Telecom | Support. |
| Lenovo | Support. |
| Ericsson | Support |
| LG | Fine with the revised proposal 2-4r1. |
| Samsung | Fine |
| Transsion | Support |
| CMCC | Support. |
| Sharp | Support |
| Spreadtrum | Support |
| OPPO | Support |
| Mavenir | Support |
| Sony | Support |
| Xiaomi | Support |
| Vivo | Support |

Since FL proposal 2-4r1 seems agreeable to all, it is submitted for email approval.

## [LP][Closed] Issue #2-4: Other issues

**Summary of company views from contributions submitted to RAN1#112bis-e**

Two companies [3][18] discuss handling of BWP switching when dynamic waveform switching indication is configured.

* [18] proposes that in case UE switches from a BWP not configured with DWS to a BWP configured with DWS, the 1-bit field for DWS indication is taken from existing field (e.g. MCS).
* [3] proposes to apply RRC-configured waveform of target BWP for PUSCH scheduled by DCI indicating BWP change irrespective of dynamic switching indication in DCI.

Oppo [4] proposes that in configured grant, the PUSCH transmissions other than scheduled by DCI format 0\_1 or 0\_2 in PDCCH scrambled by CS-RNTI with NDI=1 should follow the waveform of the earlier transmission.

CMCC [19] proposes to study potential enhancement to enable UE fallback from DWS to legacy DCI.

Samsung [17] proposes to study whether additional timeline is needed for UL scheduling in case of dynamic waveform switching.

Samsung [17] proposes to study whether enhancement is needed for UCI multiplexing in case a PUCCH overlaps with multiple PUSCHs with different waveforms.

**Observations on other aspects**

In moderator’s understanding, the above issues are of lower priority or can be addressed later, e.g.:

* For BWP switching, it should first be decided if DWS is configured per BWP or UE.
* The waveform for CG retransmission is determined according to DWS indication as per RAN1#110bis-e and RAN1#112 agreements.
* Moderator does not expect that timeline relaxation would be needed based on input from companies during RAN1#110bis-e. However, companies are welcome to provide input on this issue.

### 1st round

Please indicate if your company position was incorrectly captured or if you would like to add your company position to the summary above.

|  |  |
| --- | --- |
| Company | Comments |
| NTT DOCOMO | Agree with FL’s understanding above |
| Lenovo | We share same view as FL that these issues can be discussed later. |
| Vivo | Fine with FL’s assessment and we assume the BWP switching case would be taken care of when detailed DWS signaling is discussed. |
| ZTE | Discuss this later. |
| Spreadtrum | OK with FL’s assessment. |
| ETRI | Agree to the way forward. |
| Nokia/NSB | We share the same view as FL, that the above aspects can be considered as lower priority. |
| Samsung | OK to discuss these issues later. |

# Topic #3: Assistance information for switching waveform

## [HP][Open] Issue #3-1: Assistance information for switching waveform

**Summary of company views from contributions submitted to RAN1#112bis-e**

Support assistance information for a target waveform (“pre-switch assistance”)?

* Yes: Huawei [2], Spreadtrum [5], vivo [3], Xiaomi [11], InterDigital [12], China Telecom [13], Panasonic [14], NEC [27], Lenovo [16], ETRI [18], Ericsson [26], Transsion [21], Apple [22], NTT DOCOMO [28], Nokia [10], Qualcomm [23]
  + Difference of Pcmax between waveforms function of UE implementation [2][5][12][21]
  + Data transmission failure may occur if gNB estimate of power boosting is optimistic [2]
  + Limited performance improvement without enhancement as scheduler cannot decide MCS and RB allocation when switching waveform without power difference info [2][22]
  + gNB may blindly switch back and forth without assisting information [10]
  + Help gNB decide when to trigger waveform switch based on how much additional power a UE can deliver using alternate waveform [23][28]
  + Power headroom related information based on Pcmax,f,c of target waveform [26]
  + Help gNB schedule PUSCH transmission with target waveform properly by providing accurate FDRA and MCS [26]
* Maybe/study: Mediatek [20]
  + Need to quantify potential performance gains considering additional overhead [20]
* No: Oppo [4], ZTE [7], Mavenir [15], Samsung [17], Google [25]
  + Existing PHR sufficient, should be justified by simulation results [4]
  + Unclear benefit [7][17][25], large effort for a simple feature [17][25]
  + gNB can estimate rough difference of PHR between waveforms based on current PHR, SRS estimation or other measurement after waveform switching [7]
  + gNB can learn based on storing history of PHR data [7]
  + Increases overhead of UL signaling and reduces coverage [7]
  + gNB knows whether the UE is at cell edge or in cell center [15]
  + Dynamic switching does not increase need for enhancement compared to RRC switching [15][17]
  + Not required by WID objective [17]

Assumptions for reference PUSCH (RB allocation, MCS) when reporting PH for a target waveform?

* Same as current PUSCH: Huawei [2], Spreadtrum [5], Xiaomi [11], InterDigital [12], Panasonic [14], Transsion [21], Apple [22], Qualcomm [23]
  + Need to adjust in case RB allocation not supported for target [14]
* Assume a default value if actual PUSCH RB allocation not compatible with target waveform: Spreadtrum [5]
* Same inner/outer/edge RB allocation and modulation order as actual PUSCH transmission: Ericsson [26]
* Reuse legacy type 1 PHR based on actual PUSCH but Pcmax is based on target waveform: Ericsson [26]
* Consider MPR, A-MPR and P-MPR when computing PH [23]
* Consider both cases, same or different RB allocation and modulation order [10]
  + To provide precise PH related information of target waveform in different RB regions or for different modulations.
* Virtual PH:
  + No PH for target waveform in that case: vivo [3], Lenovo [16]
* Assistance information can include Pcmax/PH for target waveform or Pcmax/PH difference between waveforms [5]

Enhance PHR MAC CE to include assistance information?

* Yes: (vivo [3]), (InterDigital [12]), ETRI [18], (Ericsson [26]?), Apple [22], Qualcomm [23], (NTT DOCOMO [28]), Nokia [10], China Telecom [13]
  + Reuse R17 PUSCH repetition solution (two PHs in single MAC CE) [18]
  + Report both PH’s (easier gNB implementation) [22][28]
  + Report Pcmax and PH for both waveforms [23]
  + Option 1: both PHRs, Option 2: current PH + PH difference of target [10]
* No: Huawei [2]
  + Information only useful for limited period of time, high overhead [2]
  + Better to include only for target waveform when necessary [2]

Triggering of assistance information or new PHR trigger

* Network request: (Huawei [2]), InterDigital [12], NTT DOCOMO [28]
  + Helps gNB make timely waveform switching decision and adjust resource allocation and MCS selection, but requires additional overhead [2]
  + Better scheduling flexibility [12]
  + Obtain PHR information in timely manner [28]
* PH value becoming higher (lower) than a threshold: Xiaomi [11], NEC [27], InterDigital [12], Transsion [21], Qualcomm [23]
  + PH for CP-OFDM becomes higher than X1 while DFT-S-OFDM is used [27]
  + PH for DFT-S-OFDM becomes lower than X2 while CP-OFDM is used [27]
  + PH becomes lower than threshold and another waveform with better PH is available [23]
  + Concerns: Huawei [2]
    - Cannot help gNB make waveform switching decision [2]
    - May result in too frequent PH reporting [2]
* Waveform has switched (“post-switch assistance”): Huawei [2] (existing PHR), ZTE [7] (existing PHR only), China Telecom [13], CMCC [19], Nokia [10], (Mavenir [15]), Google [25]
  + PHR uses current calculation method [2]
  + Help gNB indicate suitable RB allocation and MCS index after waveform switching [2]
  + gNB can use the information to learn error [7]
  + Send PHR in next uplink transmission after waveform switching [7]
  + After expiry of timer to avoid unnecessary overhead [10]
  + Only if there is change in PL and change in PL difference between waveforms compared to previous report [10]
  + Simplest way to help gNB better evaluate PAPR reduction under different waveforms [25]
* Reuse existing trigger [add assistance info to PHR]: vivo [3], Spreadtrum [5], InterDigital [12], Ericsson [26], Apple [22]
  + Waveform not supposed to change very frequently, existing events sufficient [26]
  + Support shorter values of periodic PHR timer: Apple [22]
  + Additional conditions for including assistance information: vivo [3], Spreadtrum [5], InterDigital [12]
    - Change of waveform since last PUSCH transmission [3]
    - RSRP less than threshold or current path loss is larger than previous moment and exceeds a threshold [5]
    - PH is lower than a threshold [12]
    - PH difference between waveforms is higher than a threshold [12]
* Continuous data error compared with a threshold: Xiaomi [11]
* No enhancement: Oppo [4], Samsung [17]
  + Existing triggering sufficient, should be justified by simulation results [4]
  + Benefit unclear, large effort for a simple feature [17]
  + Not required by WID objective, not specific to dynamic switching (would have been applicable to RRC-based switching) [17]

Recommended waveform or request to switch waveform

* Yes: Spreadtrum [5], Xiaomi [11]
* No: Huawei [2], Ericsson [26]
  + Requires new MAC CE [2]
  + Not helpful to decide MCS selection and RB allocation [2]
  + UE recommended waveform may be based on particular RB allocation and modulation order (current transmission) which gNB may change [26]

Other proposals

* UE reports power reduction due to waveform switching in UE capability reporting [19]
* Discuss scenario when report of PHR for current and target waveforms is close to or overlaps with existing PHR of current waveform [10]
* Study reporting of PHR information considering CA/DC scenario [14]
* Support smaller values of prohibit timer for PHR [15]
* PHR for a target waveform determined from an actual PUSCH using same waveform or reference PUSCH in case no PUSCH uses same waveform [16]
* Support independent open-loop power control parameter for each waveform [29]
  + To immediately change the transmission power after changing waveform [29]

**Observations on assistance information**

From moderator’s perspective, the proposed enhancements for assisting the network with dynamic waveform switching can be classified in two high-level approaches.

First approach (“Pre-switch assistance”) aims at providing information to the network to help determine whether a change of waveform would be beneficial. The minimum enhancement to support this approach is the reporting of power headroom information applicable to a reference PUSCH using a target waveform different from waveform or actual PUSCH. Additional enhancements for the triggering of PUSCH are also possible, but not all companies think these are necessary.

* Based on contributions, 16 companies are supportive of this approach while 5 companies are not supportive, and 1 company thinks that it should be justified by quantified performance gains.

Second approach (“Post-switch assistance”) aims at providing information to the network about the power headroom situation after the switch so that scheduling adjustments can be made (or perhaps reversion to the earlier waveform). The minimum enhancement to support this approach is a new trigger of power headroom information linked to a waveform switching event.

* Based on contributions, 7 companies are supportive of (or open to) this approach while 3 companies think no new trigger is needed.

As a first step, to further clarify situation, moderator would like to ask companies the following about the above high-level approaches.

### 1st round

Please indicate if your company position was incorrectly captured or if you would like to add your company position to the summary above. Please provide answers to the following questions.

Q1: Which of the two approaches do you think is most useful to support DWS? Are both useful?

Q2: If preferred approach is pre-switch assistance, is it acceptable to support only post-switch assistance? If preferred approach is post-switch assistance, is it acceptable to support only pre-switch assistance?

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| --- | --- |
| Company | Comments |
| NTT DOCOMO | Q1: Pre-switch is useful, while post-switch also have somewhat benefits.  Q2: Yes, post switch is better than nothing. But not sure why post-switch is the starting point? From RAN2 perspective, it seems both have some impacts. |
| CATT | From our perspective, we think neither is essential. Although dynamic waveform switching is supported, gNB can still use the existing methods/information to determine whether to switch the waveform or not. |
| Intel | We slightly prefer not to support additional enhancement for assistance information for dynamic waveform switching. This seems not in the main scope for dynamic waveform indication. If there are simulation results to clearly demonstrate the performance gain, we can be open to consider pre-switch assistance. |
| QC | Q1: Open to support both.  Q2: Only post-switch assistance (via a new trigger) may also suffice. The cost to switch back to the original waveform is rather small once DWS is enabled. |
| Panasonic | Q1: We think pre-switch assistance is beneficial in order to the network properly determine the necessity of waveform switching.  Q2: We are open to discuss the necessity of post-switching. |
| Lenovo | Q1: We support the pre-switch assistance. For post-switch assistance, the performance of current PUSCH transmission cannot be guaranteed.  Q2: We think one method is sufficient and support the pre-switch assistance. |
| Apple | The first approach, i.e., Pre-switch, is better without any delay on PHR reporting. It seems not necessary to support both approaches. |
| vivo | Q1: In our view, PHR of new waveform can be put in the same MAC-CE as PHR of RRC configured waveform when the legacy PHR is triggered and when the target waveform is different from the RRC waveform and when the PUSCH is not virtual. This would minimize the specification work and avoid definition of additional triggering mechanism and PHR reporting timeline which are quite complex.  Not sure whether above view is aligned with FL’s pre-switch assistance or post-switch assistance.  Q2: See answer to Q1. |
| ZTE | Q1: We think the second approach (Post-switch assistance) is enough for the enhancement from power headroom aspect. As we have the consensus that the switching of waveform is not so frequent, then after event adjustment of MCS, RB allocation, even reversion to the earlier waveform is enough to enhance the performance of DWS at the lowest specification impact and lower complexity.  Q2: We support post-switching assistance only or no any additional assistance enhancement. |
| Transsion | Q1: We believe that both approaches are useful to support DWS. However, between these two approaches, the first approach (pre-switch) may have less spec impact. If the second approach (post-switch) is supported, then a new trigger mechanism needs to be introduced, and the combination of supporting the new trigger mechanism and the previous trigger mechanism needs to be considered,which will increase the specification workload of RAN2.  Q2: We can support either one of them. |
| LG | Q1: We prefer to pre-switch.  Q2: We share DOCOMO’s view. |
| Spreadtrum | We think First approach (“Pre-switch assistance”) is most useful to support DWS, which can help gNB to select more appropriate waveform. For second approach, its attention to adjust RB allocation and MCS based on the PHR trigger by waveform switching. It can also provide some power information for the next waveform switching and can be further discussed. But we think only post-switch assistance may not be sufficient. gNB may not make a appropriate decision whether to switch waveform or not without Pre-switch assistance. |
| CMCC | We think both of the approaches are useful. |
| Ericsson | Q1: Post-switch assistance is based on the assumption that PUSCH transmission with the new waveform can be successfully received by gNB. However, this is questionable, because gNB doesn’t know how to schedule FDRA and MCS for the PUSCH with the new waveform without information of the possible UE transmission power, and there is no guarantee that the blind change of waveform and blind scheduling of FDRA and MCS can improve PUSCH reception.  Q2: Pre-switch assistance is necessary for a successful dynamic waveform switching. It is not acceptable to support only post-switch assistance. |
| ETRI | Q1: Pre-switch is more useful, because post-switch may have more retransmissions.  Q2: We think pre-switch is necessary. |
| Nokia/NSB | Let us clarify that our understanding here is that “pre-switch” means assisting information is provided before the DWS indication. Therefore, we assume that if the assisting information is reported after a first DWS but before a second DWS it still be considered as “pre-switch” (because it’s used for the second DWS). With this understanding, our companies proposal should be captured as “pre-switch”.  **Q1&Q2:** We think that pre-switch is not only more useful but also more relevant with the context of “assisting information” in DWS. In addition, if pre-switch is considered then post-switch is not needed, because PHR information of the new waveform is already included in the pre-switch. Therefore, we support only pre-switch. |
| MediaTek | Q1: in our view, pre-switch assistance could be more useful than post-switch. However, we have not evaluated this by simulations. Supporting both approaches seems unnecessary to us intuitively. We tend to think that it’s not quite clear to any of the companies how often UE will actually switch between two waveforms back and forth in a real network using dynamic switching. Depending on the duration between two successive dynamic switches, it is possible that neither approach is useful.  Q2: We think, either one approach or no approach is preferred. It is not easy to conclude how much can be gained by either approach without numerical evaluation results. |
| Samsung | Q1/Q2: Before/after a dynamic waveform switch is inessential as the timing when the indication is sent is up to the network. Introducing mechanisms for PHRs associated to each waveform dynamic switch may not be useful and adds complexity to both UE and gNB, besides it can have a large impact on specifications. In principle, if the gNB would receive some PHR information for both DFT-S-OFDM and CP-OFDM, the gNB may use this information when dynamically indicating or configuring the waveform but performance gains remain unclear. It is also noted that the discussion is not within the scope of the WID (it is not specific to DCI-based DWS switching). |
| Moderator | @All, thanks for the comments.  @NTT DOCOMO: From my perspective, “post-switch” is not starting point. I agree that both approaches have some impact.  @Intel, Mediatek, Samsung: I agree that it would be nice to quantify gains, but I am not sure if it is realistic since it depends on scheduling assumption and would require large effort. I doubt that all (any?) PHR enhancements introduced in the past were backed by simulation results, and it seems a bit stringent to now impose this requirement.  @Samsung: the objective of the WID simply states “specify enhancements to support DWS” – any enhancement required to support it (not just dynamic indication) is thus in scope. All companies may not agree on how essential each potential enhancement is, but I don’t think it can reasonably be argued that it is out of scope. Also, even if PHR assistance could also be interesting for RRC-based switching, it seems more needed for dynamic switching. |

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| **FL proposal 3-1**: For potential enhancements to assist the scheduler in determining waveform switching, RAN1 to select between following options:   * Option 1: Reporting of power headroom information for a reference PUSCH using target waveform different from waveform of actual PUSCH.   + Details FFS. * Option 2: New trigger of power headroom report based on waveform switching event.   + Details FFS. * Option 3: Both Option 1 and Option 2.   + Details FFS. * Option 4: No enhancement. |

### 2nd round

During GTW on Monday, FL proposal 3-1 was presented but not agreed due to concern that the possibility of reporting both legacy PHR and PHR for target waveform at the same time could be precluded. In moderator’s understanding, this behaviour is not precluded by the proposal under Option 1 (it is part of the Details in FFS). Suggestions for stabilizing proposal are welcome, but it may be better to avoid long and detailed list of FFSs at this stage.

Please indicate if FL proposal 2-4r1 is acceptable.

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| Company | Comments |
| NTT DOCOMO | To clarify: as Nokia mentioned in GTW, having multiple PCMAX or PHR, one for configured waveform and the other for target waveform, is included in option 1, or preclude? We originally thought such aspect can be considered according to “Details FFS”. |
| ZTE | Support. Option 2 or 4 is preferred. |
| Intel | We can be open to discuss the proposal. For the main bullet, is this the intention to down-select one option from the 4 options? |
| Nokia/NSB | Thank you, FL, for the clarification! But we do not think the current wording of Option 1 includes the option of reporting PH info for both waveforms. We can not interpret this as FFS since there is no guarantee that all companies will have the same understanding without spelling it out explitcitly. The case of reporting PH info of both waveforms deserves to be treated explicitly as one option.   We also would like to clarify that, for Option 1 or the option of reporting PH info of both waveforms, we need to discuss on the triggering of such reporting. Though this can be discussed/considered as to be included in FFS. Can you confirm if this understanding is correct? |
| QC | Support. Our read on Option 1 is that it does not preclude reporting for both waveforms in one PHR. If Option 1 is agreed, we can definitely consider doing that as it will be the most efficient manner to carry information for both waveforms. |
| Panasonic | We agree to the comment during GTW on Monday that reporting both legacy PHR and PHR for target waveform at the same time should also be one possibility for potential enhancement. With the above FL’s explanation that such possibility is under Option 1, we are fine with FL proposal 2-4r1. |
| NEC | Support. |
| Moderator | @All, thanks for comments and support.  @NTT DOCOMO, Panasonic: confirm that this is intention.  @Intel: Yes, the intention is we first select one of the Options. Otherwise, I feel it will be difficult to progress.  @Nokia/NSB: Option 1 does not state or suggest that we remove legacy functionality for PHR. So clearly, legacy PHR can still be reported according to existing mechanisms. Then whether the “target waveform PHR” is reported at the same time or not as the legacy PHR and whether we have new trigger for the new PHR is part of “FFS details”. If no new PHR trigger is supported, then it would most likely have to be reported together with legacy PHR. If we support new PHR trigger(s), then it could be separate or together. If you are worried that one of these possibilities could be interpreted as being precluded, please suggest an alternate wording but at this stage I would prefer not adding complexity/sub-options to the main options. |
| CATT | Fine with the proposal. |
| China Telecom | Support. |
| Lenovo | Support. We prefer option 1 since the performance of the scheduled PUSCH by the DCI which indicates a different waveform may not be guaranteed in option 2. |
| Ericsson | Support the proposal and Option 1.  It is not clear to us how a power headroom report of Option 2 will affect gNB.  With Option 2, if a UE reports a power headroom for the new waveform (DFT-S-OFDM), which is much larger than the one before waveform switching, what’s the point of reporting it to gNB?  If the power headroom of the new waveform is very close to the one before waveform switching, shall gNB switch the waveform back to leverage multiple layer gain? This goes against our understanding on infrequent waveform switching. |
| LG | We respect FL's opinion. As mentioned by contributions, reference PHR for different waveform could be estimated/calculated by gNB if the same power control parameters are used. Thus, it should be addressed how to make the difference between waveforms in terms of PHR.  To apply differences between two waveforms, one easiest way is to configure separated open-loop power control parameter for each waveform, which also can represent different *PCMAX* of each waveform.  In this regard, we would like to add how the network can help the UE as a FFS point in Option 1.   * Option 1: Reporting of power headroom information for a reference PUSCH using target waveform different from waveform of actual PUSCH.   + FFS: how UE calculates reference PHR of the different waveform     - E.g., using different power control parameters |
| Samsung | A follow up on FL’s response in the first round about “any enhancement required to support it (not just dynamic indication) is thus in scope.” Although we were open to studying enhancement, despite not expecting any gain, no company has shown that there is any benefit - only proposals were made. It is not clear that the enhancement is required. |
| Transsion | Support this proposal and prefer option 1. |
| CMCC | Support. |
| Sharp | We support the proposal. |
| Spreadtrum | We suggest to add a Note in Option 1. For example, reporting PH info for both waveforms is not precluded.   * Option 1: Reporting of power headroom information for a reference PUSCH using target waveform different from waveform of actual PUSCH.   + Note: reporting PH information for both waveforms is not precluded.   + Details FFS.   For Option 2, we want to clarify the meaning of “waveform switching event”. Does it mean the condition of waveform switching?  For Option 1 and Option 2, one is related to the PHR content and one is related to PHR trigger, which both needs to be discussed. We wonder the intention to down-select Option 1 and Option 2. If we select Option 1 only, does it mean no new trigger is needed regardless of reporting PH info for target waveform or both waveforms. |
| Mavenir | Support this proposal and prefer option2 or option4. We think gNB can differentiate cell center and cell edge users. Option2 just for resource allocation of PUSCH, because different waveform may has different PHR. |
| Sony | Support – option 2 preferred. |
| Xiaomi | Support at least option.1 ,we are open to option.2 |
| Huawei, HiSilicon | Some clarifications are suggested.  With Option 3, does the proposal mean that no new trigger other than Option 2 is allowed for Option1?  If yes, then it implies both waveform PH’s must be reported in each PHR occasion because there is no signalling to tell UE which waveform for PHR. |
| Nokia, NSB | @FL: Thank you for your clarifications! Concerning “If no new PHR trigger is supported, then it would most likely have to be reported together with legacy PHR. If we support new PHR trigger(s), then it could be separate or together”, this is indeed our understanding as well, though we prefer to spell it out in the proposal. Our preference is to report them together even in case new PHR trigger(s) is/are introduced otherwise the PH info of the current waveform would be outdated. We understand FL’s preference for not adding sub-options/complexity, so we just prefer to explicitly spell out the above in FFSs, and add “at least” in the main bullet of Option 1, as highlighted in red below:  **FL proposal 3-1**: For potential enhancements to assist the scheduler in determining waveform switching, RAN1 to select between following options:   * Option 1: Reporting of at least power headroom information for a reference PUSCH using target waveform different from waveform of actual PUSCH.   + FFS: Triggering event(s) that triggers the report.   + FFS: whether the report also includes power headroom information for the actual PUSCH using the current waveform, e.g., in case a new triggering event is used for triggering the report.   + Other Details FFS. * Option 2: New trigger of power headroom report based on waveform switching event.   + Details FFS. * Option 3: Both Option 1 and Option 2.   + Details FFS. * Option 4: No enhancement. |
| Vivo | Support. |
| Moderator | @All, thanks for support and feedback.  @LG: I think this is next level of discussion. Let’s not seek to identify all FFS issues for all Options in this proposal.  @Spreadtrum: Thanks for the suggestion, I think this Note is reasonable to address the concern. For Option 2 the wording “waveform switching event” is intended to be generic because there are different variants for this Option 2 (e.g. whether PH is sent in PUSCH corresponding to DCI that switches waveform or later). For Option 1, new trigger for the new PH is not precluded.  @Huawei, HiSilicon: Thanks for the question. In Option 1 (and Option 3), new triggers for the new PH are not precluded.  @Nokia/NSB: Thanks for the suggestion. I am fine with adding notes to clarify that reporting PH together, and additional triggers, are not precluded. I hope it is ok. |

Based on the feedback, it seems that majority of companies are ok with the proposal, but some clarifications are desired to ensure that some design sub-options are not precluded. FL proposal 3-1 is updated as follows to clarify the meaning of each Option:

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| **FL proposal 3-1r1**: For potential enhancements to assist the scheduler in determining waveform switching, RAN1 to select between following options:   * Option 1: Reporting of power headroom information for a reference PUSCH using target waveform different from waveform of actual PUSCH.   + Details FFS.   + Note: reporting PH information for both waveforms is not precluded.   + Note: additional trigger for PH for reference PUSCH is not precluded. * Option 2: New trigger of power headroom report based on waveform switching event.   + Details FFS. * Option 3: Both Option 1 and Option 2.   + Details FFS. * Option 4: No enhancement. |

### 3rd round

To progress the discussion and based on comments made in the above, moderator suggests that companies provide their views on the following aspects:

* Is there a way to estimate the potential benefit of Option 1 or Option 2 (over Option 4)?
  + E.g. without assistance info, gNB may have to schedule UE using DFT-S-OFDM over larger portion of the cell. Is the difference linked to the uncertainty in Pcmax difference between waveforms? If yes, how big is this uncertainty?
* For Option 2, how to deal with the issue that PHR can’t be received by network if after the switch the PUSCH quality is too low? The network can realize the problem and switch back after a few attempts, but is there any benefit over Option 4 in that case?
* Any other consideration that may help assess the benefit (or lack thereof) of either Option?

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| Company | Comments |
| QC | Just as a thought exercise, can’t the gNB give the UE two back-to-back grants, one with CP-OFDM and another with DFT-s-OFDM and infer what works better? gNB should be able to infer the quality of PUSCH (uplink SNR) from the DMRS it receives. It can even be a deliberate retx request if we don’t want to tinker with the UE data buffers.  Wouldn’t this be a rather simple way to figure out which waveform works best without even having to wait for PHR? Note that typical PHR periodicity in commercial deployments in 200 ms. Will the gNB really want to wait this long to determine what to do next? Wouldn’t the approach outlined above be more timely?  To be clear, we are open to supporting Options 1 and 2, but we want to see if there are simpler means to accomplish the same. The DCI-based approach that we have adopted seems like a low-cost approach for the gNB to easily sniff the best waveforms and rank for uplink. Its possible this all that’s needed. |
| Panasonic | gNB may calculate power margin for current waveform as follows:  ,  where is parameter representing UE maximum transmit power and is known information at gNB. is used for calculation of the power headroom and is not known information at gNB and reported by PHR MAC CE. is power headroom reported by PHR MAC CE (i.e., power headroom of current waveform).  Then, actual Tx power is as follows.  .  Possible power margin for the other waveform is calculated by , where is possible maximum power of the other waveform.  Based on above calculation, gNB can determine a suitable waveform for dynamic waveform switching by comparing and possible power margin for the other waveform.  Without assistance information (e.g., ), gNB cannot know possible power margin for the other waveform, especially when there is uncertainty in difference between waveforms. |
| Ericsson | Q1: Option 1 has one significant benefit over Option 2 and Option 4 that it assists gNB to decide whether waveform switching is well justified.  Without Option 1, gNB has no clue of increased UE transmission power of the target waveform, and therefore gNB’s scheduling of FDRA, MCS, and a different waveform switching is baseless.  Indeed, if a UE is power limited, one uncertainty lies in Pcmax difference. If a UE has good PAPR reduction techniques, waveform switching may not cause any difference in transmission power. Another UE may have very different PAPR for the two waveforms. E.g., it may require power backoff as large as MPR for CP-OFDM, but it doesn’t require any power backoff for DFT-S-OFDM. Then the transmission power change from waveform switching for the UE is up to the MPR for CP-OFDM, which is also the uncertainty of waveform switching to gNB.  Q2: The problem FL mentioned happens, when gNB overestimates the transmission power increase from waveform switching. In this case, Option 2 and Option 4 are the same. |
| Lenovo | We support Option 1. When the and/or power headrooms of both waveforms are reported, gNB can dynamically select a suitable waveform for PUSCH transmission based on this information. For example, if the of a waveform is higher than the used waveform, gNB can switch the transmission waveform timely. If no enhancement is made (Option 4), gNB only knows the and PH of the current waveform. Its knowledge of and PH corresponding to the other waveform may be outdated, the comparison of and/or PH of different waveforms is meaningless. The gNB cannot make a good decision on the waveform based on outdated information, and this may cause performance degradation. |
| NTT DOCOMO | Qualcomm indeed listed some good usages of the legacy functionalities. It rather motivate pre-switch scheme, right? Because indeed two DCI with DWS=0 and DWS=1 can schedule PUSCHs to be compared for observing the benefit.  We generally agree with Ericsson’s statement above. Another point may be, now that DWS DCI needs to be aligned with bigger size, it would be pretty beneficially for NW to observe if the situation deserves DWS itself. |
| Nokia, NSB (1st comment) | We share similar view as Ericsson above about Q1, that assisting information is needed for gNB to make decision. Further views are as follows:   * Option 2 alone simply provides more up-to-date PHR for scheduling, but it doesn’t provide assisting information for waveform switching/selection. * Option 4 is even worse than Option 2, because the PHR for scheduling is not updated immediately after waveform is switched, but it is only updated in the next report according to legacy configured periodic report, which may come much later. * For Option 1, let us split into two main cases:   + Case 1: If legacy triggering of PHR is used (based on periodicity), in this case Option 1 means that both PHRs of target and current waveforms are reported. However, this report may be too far away from the time when gNB needs to make decision and switch waveform, i.e., the report may be outdated and may not be very useful as assisting information for waveform switching/selection.   + Case 2: If a new triggering event is used, in this case whether PHR of the current waveform is also reported together with PHR of the target waveform is subject to further discussion. Let us further split into two sub-cases:     - Case 2-1: PHR of the current waveform is NOT reported together with PHR of the target waveform upon the event. In this case, gNB needs to rely on PHR of current waveform from the latest report. However, the latest report may be outdated at the time when the event happens, thus using updated PHR of target waveform + outdated PHR of current waveform may not be helpful for gNB to make decision.     - Case 2-2: PHR of the current waveform is reported together with PHR of the garget waveform upon the event. **We think this case provides the most benefit** since both PHRs of both waveforms are up-to-date and being helpful for waveform selection. * For Option 3, we think this **is a special case of Case 2-2 of Option 1**, i.e., in case the event is waveform switching event. We think that if the PHR is reported after a (current) waveform switching, it is used for waveform selection in the next waveform switching. In this case, it may be more beneficial if the PHR is reported after a time duration from the current waveform switching event, instead of immediately reported after the waveform switching. This would help the report being up-to-date for the next waveform switching. Indeed, the time duration could be a duration within which the gNB anticipates that there is no back-and-fort switching needed after one switching. |
| Intel | We think Qualcomm raised a valid point on another potential way to operate the dynamic waveform switching. In case when gNB needs to understand the PH from UE for different waveforms, gNB can simply schedule the UE with DWS = 0 and DWS = 1 in a consecutive manner and informs UE to report PHR for the indicated waveform. This back to back scheduling can enable an efficient solution to enable DWS. It is not clear to us the benefit of Option 1 or Option 2 over this approach. |
| Moderator | @All, thanks for the good discussions.  I think that the approach of analyzing “how could network do switching without enhancement?” as in the comment from Qualcomm above is good. Then I have a few follow-up questions/thoughts:  If the approach outlined by Qualcomm is workable, then what is the use of PHR? It seems that even legacy PHR would not be so useful?  My suspicion, (but maybe network vendors can chime in), is that maybe the network cannot reliably determine is the gain/loss of performance between the two transmissions (CP-OFDM and DFT-S-OFDM) is due to the waveform as opposed to some other factor? (like fading or P-MPR change). If this is the case, this would also be an argument for supporting transmission of PHR for both waveforms at the same time. |
| ZTE | The occurrence mentioned in Q2 has little possibility, gNB has some other report and measurement for example SRS measurement to help decide on the dynamic waveform switching. I don’t think the waveform switching would cause the dropping of PHR, you can see the MCS table, that most indexes in the table are simultaneously suitable for CP-OFDM and DFT-OFDM. Even if the dropping of PHR due to waveform switching, gNB can also know the situation and switch back, this point seems like the way raised by Qualcomm. |
| China Telecom | The approach proposed by Qualcomm is quite workable, but it still need 2 times of PUSCH transmission for making the final decision of the waveform. It requires no more specs impact and modification, but it is not efficiency enough. So, we prefer to enhance the PHR for better performance. Compared with that, we think Option 2 is a more effective method. In our understanding, if the network wants the DWS, it means the current waveform is already suitable for the current network performance. With Option 2, the switching can be done first, and the corresponding PHR will have gNB estimate whether the new waveform is suitable. However, we have the similar view as Ericsson and Nokia that Option 1 does have some advantages over Option 1. Therefore, we are open to discuss both the options on the enhancement of PHR.  For Q2, we share the similar view as ZTE that we may don’t need spend too much time on an occasion with a small possibility to happen. What we need is to enhance the performance of most occasions and won’ t bring occasions that can’t be recovered at the same time. |
| Ericsson | Thanks for the in-depth discussion and questions. In our view, legacy/enhanced PH report can indicate power potential of a UE, which may not be utilized yet.  Received UL signal strength = Tx power – pathloss  gNB can measure the difference between the two PUSCH DMRS of two waveforms, but the difference isn’t exactly the difference of two PCMAX of two waveforms.  Pathloss is one variant, given a time-varying channel. Another reason is that PUSCH transmission power is the minimum of PCMAX and the calculated PUSCH transmission power.    Without sufficient information to schedule #PRBs of a PUSCH with a different waveform, DFT-S-OFDM, it is likely that the calculated scheduled PUSCH transmission power is smaller than PCMAX of DFT-S-OFDM. Thus, the UE would not transmit DFT-S-OFDM with its PCMAX. If we assume pathloss is the same in the two slots, the difference of received PUSCH signal strengths would be no larger than power headroom of CP-OFDM (illustrated with the green arrow). gNB has no idea of the power headroom of DFT-S-OFDM, shown with the red arrow and can’t use the additional transmission power well.    Of course, a gNB can schedule aggressively a larger number of PRBs to exert the power potential of DFT-S-OFDM, only if the PUSCH with lower EPRE can be successfully received by gNB. Not sure such kind of the exercise improves cell coverage or not. |
| Transsion | Similar to some companies, for option 4, the gNB is unable to obtain the accurate Pcmax value and consequent PH value for other waveform. Without Pcmax and PH value, there is no basis for the scheduling of MCS and FDRA. |
| QC | @Ericsson say you are currently using CP-OFDM, you’ll only consider a waveform switch if TPC commands seem to have no impact on the received SNR. This is implicitly indicative of CP-OFDM being at max power. Once this state is confirmed, all you’ll have to do is send the second grant with a TPC command of say 4 dB. This will force the UE to max out its power for DFT-S-OFDM. You’ll then know what the difference in Pcmax is. It seems workable. Remember that all of this is executed when the UE Tx power is already hovering close to its power class limit. So not much headroom left. |
| Apple | The performance benefits of Option 1 and 2 are depending on the quickly PHR report. Waveform switching is so fast per DCI, but the PHR report frequency is slow and could not match the waveform changing. The shorter periodic PHR timer can be considered to provide timely assistant information for gNB scheduling. |
| Spreadtrum | For Q1, we share similar view as Ericsson. Due to the power backoff difference between the two waveforms, the gNB should know the expected UE power backoff change before dynamic waveform switching. Thus, the target waveform PHR is needed to help gNB to select more appropriate waveforms. We prefer “Pre-switch assistance” and Option 1.  In addition, we think the function of DWS field is to inform the UE to perform more efficient uplink transmission using indicated waveform and achieve better coverage performance, not to inform UE to report the PHR for the indicated waveform. |
| Huawei, HiSilicon | Q1: It is hard to conclude that Option 1 has a significant benefit over Option 2.  With Option 2, when switch waveform from CP-OFDM to DFT-S-OFDM, gNB can first assign the same number of RBs and transmission power for DFT-S-OFDM as that of CP-OFDM(continuous RB), and then use the received PHR to further adjust power and RB allocation precisely. It would not bring a significant throughput loss as waveform switching only occurs once for a long time and only one schedule slot has some loss during each waveform switching. Moreover, in this case, there is no wrong waveform switching, any waveform switching will bring some coverage benefits, more or less. Because, DFT-S-OFDM always has a better PAPR performance than CP-OFDM in most cases.  As for switching waveform from DFT-S-OFDM to CP-OFDM, it only happens when gNB has found that the channel state of UE becomes much better than before. In this case, with the help of Option 2, gNB can first allocate a conservative estimation of RB and transmission power for CP-OFDM according to the history report or UE capability report regarding the difference of Pcmax between CP-OFDM and DFT-S-OFDM, and then use the received PHR to further adjust power and RB allocation precisely. It could bring some throughput loss in the first schedule after waveform switching, this loss is related to the estimation accuracy of gNB, i.e., the difference between the conservative estimation and the computed allocation based on PHR.  Q2: When switch waveform from CP-OFDM to DFT-S-OFDM, PHR can be received by network as long as gNB assigns the same RB number and transmission power for DFT-S-OFDM as that of CP-OFDM (continuous RB). Because, DFT-S-OFDM always has a better PAPR performance than CP-OFDM in most cases.  When switch waveform from DFT-S-OFDM to CP-OFDM, PHR can be received by network as long as gNB has accurate evaluation of the improvement of channel state of UE and allocate a conservative estimation of RB and transmission power for CP-OFDM.  @FL, with QC’s approach, in our understanding, PHR is still needed and the best way to get the PHR is Option 2. PHR cannot be derived from received SINRs for both waveform unless a gNB schedules sufficiently large number of PRBs for the two PUSCH. The gNB is still lack of the correct estimation of appropriate number of PRBs until some PHR information is received. For examples,   * If both grants are scheduled for one PRB, then the Tx power for both waveforms is far from the power saturation of both waveform. The SINR information is not helpful to determine the necessity of waveform switching. * If both grants are scheduled for the same large number of PRB to have power saturation for both waveform. Then the SINR information is useful. However, without PHR, the gNB does not know what the exact number of PRBs should be before the pings. Here, it is assumed that a gNB will not schedule arbitrarily large PRBs for the pings without considering the throughput loss. * In case the gNB has the PHR for CP-OFDM, the number of PRBs for such ping of CP-OFDM is known. But since the additional PHR provided by DFT-s-OFDM is still unknown, so the number of PRBs for such ping to have power saturation for DFT-s-OFDM is still unknown.   To solve it, Option 2 seems the best. It provides the key information timely when a gNB doing such pings. |
| LG | We think that Option 1 is the most suitable way to assist the gNB scheduler. Alternatively, Option 2 has an advantage in that it can report PH information referring to the updated target waveform, as commented by Nokia. Compared to Option 4, which does nothing, Option 2 is a better choice.  If the UE reports PH information, including the new PCMAX that reflects the MPR value of the relevant switched waveform, this would significantly aid the gNB in better scheduling. |
| Nokia, NSB (2nd comment) | To follow up on Qualcomm’s question/suggestion, we tend to agree with FL’s suspicion about the reliability of such estimation using back-and-fort switching. We need to further study if there is any impact on scheduling flexibility and/or overhead brought by such approach, following the constraints that make estimation being considerably reliable (e.g, same channel conditions, same number and location of PRBs etc). Our view is that the approach can somehow be considered as part of Option 4. Our first preference is to enhance the PHR, which is a neat and reliable solution. However, it’s fair at this point in time for letting companies further study and comeback in next meeting. |
| Moderator | @All, thanks for the useful analysis. |

### 4th round

Based on the above input, moderator prepared the following summary of how each option is expected to work, possible benefits and concerns (Option 3 is not included since it combines Option 1 and Option 2).

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| Option 1 | |
| Examples of operation | -UE transmits PHR of current waveform and other waveform. gNB may use DFT-S-OFDM if it allows higher Tx power, otherwise may use CP-OFDM. |
| Benefits | +gNB can determine if change of waveform is beneficial before potential switch and directly determine appropriate scheduling for new waveform.  +[if PHR transmitter together]: guarantees that PHR difference is due to waveform and not some other factor, e.g. path loss change.  +[with new trigger]: waveform can be switched at “optimal” time. |
| Concerns | -Need to specify PHR of target waveform  -May increase PHR overhead  -May impact multiple entry MAC CE (for UL CA) |

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| Option 2 | |
| Examples of operation | -If using CP-OFDM, gNB switches to DFT-S-OFDM using same scheduling parameters (RBs, Tx power). gNB adjusts scheduling parameters based on PHR sent after switch.  -If using DFT-S-OFDM, gNB switches to CP-OFDM using more conservative scheduling parameters. gNB can use “history” of Pcmax difference for the UE to decide how conservative it needs to be. gNB adjusts scheduling parameters based on PHR sent after switch. |
| Benefits | +Provides up-to-date PHR for scheduling after waveform switch |
| Concerns | -Need to specify new PHR trigger (with slight overhead increase)  -Some throughput degradation just after switching to CP-OFDM due to “conservative” scheduling, or due to need for retransmission/fallback to DFT-S-OFDM if scheduling was not sufficiently conservative. |

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| Option 4 | |
| Examples of operation | -gNB gives back-to-back grants using different waveforms and compares quality using DMRS. gNB may use DFT-S-OFDM if SINR is better, otherwise may use CP-OFDM.  -if using CP-OFDM, switch to DFT-S-OFDM if TPC up commands does not increase SINR.  -gNB uses RAN4 requirements to estimate potential difference of Pcmax. |
| Benefits | +No change to the specification. |
| Concerns | -Does not provide information on difference in Pcmax.  -Actual Pcmax difference depends on UE implementation, RAN4 requirements not sufficient.  -DMRS SINR does not provide information unless UE transmits at maximum power.  -DMRS SINR difference between two transmissions may be caused by other factors, e.g. fading and/or interference may be different.  -Need to schedule extra PUSCHs with large number of PRBs / high Tx power to evaluate waveform switch.  -Not possible to know how many PRB’s can be scheduled with new waveform, as PHR after switch is not available. |

Please indicate if you agree with the above summary or if you think anything should be added or deleted.

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| Company | Comments |
| vivo | Agree with FL’s summary.  In addition, according to our understanding, option 1 would always provide PHR of both waveforms at the same time when DWS is enabled (some additional conditions can be applied to avoid too frequent double PHR report), which would provide real PHR difference of different waveforms for each instance since they’re reported together.  The intention of option 2 is to introduce new triggers and denser PHR report so that gNB can be aware of the PHR of target waveform more frequently. However, introducing more frequent PHR report than legacy may be not that necessary, and reusing legacy PHR reporting period/events would be more realistic and this would also require less spec. changes to reduce the workload in remaining limited number of RAN1 meetings for this topic.  Therefore option 1, to combine the PHR of the waveform different from RRC configured waveform with the legacy PHR in one MAC-CE is preferred.  Considering it has been clarified by many companies that this new PHR reporting is essential for more accurate scheduling when DWS is enabled, we do not support option 4 which does not provide PCmax difference as is also pointed out by FL. |
| QC | Okay with the summary. Two questions intended for proponents of Option 1:   1. What is the value of knowing Pcmax if the between the two waveforms is known? 2. How often is the enhanced PHR expected to be reported by the UE? 3. Can the target waveform have a different rank from the actual waveform? We think the crucial switching point is from rank-2 CP-OFDM operation to rank-1 DFT-s-OFDM. Its not clear why CP-OFDM will be preferred for rank-1 transmission when the number of RBs are rather small. Can gNB vendors clarify whether the above is indeed the switch point to focus on? |
| Panasonic | Thank you for the summary. We are basically fine with the summary.  On concern of overhead in Option 1, we think it can be managed by disabling to report PHR of both waveform like Option 4 if/when gNB does not see the need. PHR report can be either (current or target) or both waveform can also be configurable if necessary. |
| Ericsson | Agree with the summary.  For the questions raised by QC,  Q1: the information helps gNB schedules #PRB and MCS, so that the SNR of a PRB can afford the modulation order.  Q2: in our view, the legacy triggering events are sufficient.  Q3: It is a shame we don’t have multi-layer PUSCH transmission with DFT-s-OFDM. Thereby, it is possible that gNB switches a UE from rank-2 CP-OFDM to rank-1 DFT-s-OFDM directly or via rank-1 CP-OFDM. |
| ZTE | Generally fine with the summary.  For one concern on Option 1, The reason of “May increase PHR overhead” may be due to the two PHRs reports are transmitted together and the more frequent PHR report than usual as the PHR of target waveform is reported before each intended decision on **dynamic** waveform switching, legacy triggering events may be out of date for dynamic decision as the long period. So the judgement on the introduction of more frequent PHR report of Option 2 is not fair. Obviously the frequency of need of PHR report of Option 1 is more than other Options. |
| Sharp | We share Qualcomm’s view that switching from Rank 2 CP-OFDM to Rank 1 DFT-S-OFDM is the most important case for DWS. It should be clarified that Option 1 can indicate PHR for Rank 1 DFT-S-OFDM when Rank 2 CP-OFDM is currently used.  We are OK with current summary for option 2 and option 4. |
| LG | We are fine with FL’s summary.  Upon reviewing the summary, it is uncertain whether it is truly advantageous for the gNB to adopt a conservative scheduling when making waveform decisions with additional signaling, especially when Option 2 is implemented. If we plan to introduce real-effective new assistance information, it would be optimal to report PH information for both the current and target waveform to ensure it can effectively aid the gNB's decision-making process, as demonstrated in Option 1. |
| Moderator | @All, thanks for continued feedback and discussion. Please feel free to continue commenting from this table. Please also consider the question I am adding below. |
| China Telecom | We are fine with the summary.  The Options 1 aims to enhancing the PHR with more reporting information so that the DWS can be conducted at the perfect time, while the switching may not always happen in time since the period of current PHR report doesn’t change, the environment of UE may have been worse for a period of time before reporting the PHR.  While the Option 2 aims to enhancing the PHR with more times so that the DWS can be more efficient. The gNB can not only decide when to conduct the DWS according to the PHR, but the PHR is just to assist gNB make the decision. So with Option 2 supported, the gNB can quickly got the feedback of whether the new adopted waveform is suitable. Though not too much performance degradation, Option 2 requires more PHR times.  Both options have the specs impact, one is about the content, the other is about the trigger condition. And we slightly preferred Option 1 since the required new resources for supporting such mechanism can be smaller. |
| Huawei, HiSilicon | For option 1, a concern is potential MAC impact, e.g. changed size of PHR MAC-CE. We prefer not to change the size of PHR MAC-CE in order to have better compatibility with UL-CA. With two PHRs for respective two waveforms at one PUSCH instance, the existing MAC-CE for UL-CA has to be changed. Its RAN2 impacts are unclear for us when a R15 PCell and a Rel-18 SCell enabling DWS is supported because the MAC-CE of PHR for UL-CA may be received and handled by the R15 PCell who is only able to recognize a MAC-CE of PHR with the same size of Rel-15 MAC-CE of PHR.  For option 2, |
| Nokia, NSB | We are generally fine with the summary. For Option 4, can proponent/FL clarify on how to “compare quality using DMRS.”? Is this RSRP? And should the two PUSCHs be scheduled with the same MCS? We would expect that the SINR of the entire PUSCH should be used here, instead of DMRS only, but good to hear your view. |
| OPPO | As understanding those pros and cons a mostly relative evaluation. We are OK, but have to point out those concern may not be strong enough. E.g. the need of scheduling much larger PRBs or Probing larger PRBs is actually not very strong, as the UE will not generally not drastically changed with number PRBs in the coverage limited boundary. The inaccuracy of estimation may not have significant impact to performance. And the “extra” overhead would really worthy the less likely frequent DWS.  Thus, we would study more to justify the option1/2 |
| Moderator | @Huawei, HiSilicon: I added “-May impact multiple entry MAC CE (for UL CA)” to the concerns for Option 1.  @Nokia, NSB: For the quality comparison it would be gNB implementation, likely some kind of SNR measurement. Not sure for the other questions. |

Please indicate, for each Option (1/2/3/4), whether it is Preferred, Acceptable, Not acceptable. If you think more discussion is needed, please indicate what needs to be discussed.

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| Company | Option 1: Preferred/Acceptable/Not acceptable?  Option 2: Preferred/Acceptable/Not acceptable?  Option 3: Preferred/Acceptable/Not acceptable?  Option 4: Preferred/Acceptable/Not acceptable? |
| QC | We think more discussion is needed. Irrespective of any PHR enhancement we make, timeliness is a concern. If we can’t address this, might be best to leave PHR untouched.  Also, we are not really convinced by explanations on why two b2b grants with different waveforms might not suffice. Its seems like a low cost approach to accomplish what we want. Its timely. Also, if changes in rank are desired, then this would definitely be the preferred approach. |
| China Telecom | Option 1: preferred.  Option 2: acceptable.  Option 3: acceptable. Though we don’t think it is needed.  Option 4: not acceptable. |
| Ericsson | To address QC and ZTE’s concern that PHR may be out of date, not timely enough, in our view, gNB may get some hint of a need of waveform switching and then either schedule two back-to-back grants with different waveforms(Option 4) or switch the UE’s waveform directly(Option 1, Option 2). A reliable hint can be a PHR report from UE.  If the channel is very stable, the periodic PHR report is sufficiently timely. In case of a time-varying channel, the configured PL change threshold (dB1, dB3, dB6, infinity) can allow a timely PHR report. Therefore, the legacy triggering events can make sure a timely and up-to-date indication from UE. A paradox of timeliness is “The MAC entity should avoid triggering a PHR when the required power backoff due to power management decreases only temporarily (e.g. for up to a few tens of milliseconds)”  @ZTE, With Option 2, a UE may report a legacy PHR, which triggers waveform switching, and another PHR after waveform switching, i.e., two PHR based on two waveforms separately. This explains more frequent PHR.  We are fine with more discussion. Having said this, we think it is good to make some downs-election, at least to us Option 3 and Option 4 are not acceptable. |
| ZTE | Option 1: Not acceptable.  Option 2: preferred.  Option 3: Not necessary.  Option 4: acceptable.  Reply to Ericsson. For Option 2, we don’t change the behaviour of legacy PHR report, so if your theory on the frequency of PHR report is correct, there is no more additional PHR report before the triggering of dynamic waveform switching for Option 2. Comparing the total amount of PHR report, the Option 2 will not exceed the Option 1 as Option 1 needs two PHRs each time. Considering the PHR after the waveform switching follows the mechanism of legacy PHR and the structure of legacy MAC-CE as much as possible, the specification impact is less than Option 1, so we prefer Option 2. If we pursue the zero specification impact, Option 4 can also be acceptable. |
| LG | We are open to discussing all options. However, if we prioritize the options, Option 1 is the most favorable, while Option 2 and Option 3 are acceptable. Option 4 is also a possibility, but it is of lower priority. |
| Huawei, HiSilicon | Option 1: Not acceptable if the size of PHR MAC-CE is changed considering the compatibility of UL-CA.  Option 2: preferred.  Option 4: Not acceptable  In our previous comment in the last round, our understanding was shared on why PHR report/option 2 is still needed for the approach with two back-2-back grants proposed by QC. |
| Spreadtrum | Option 1: Preferred.  Option 2: acceptable but need further discussion.  Option 3: acceptable but need further discussion.  Option 4: not acceptable. |
| Nokia, NSB | We think more discussion is needed. Given that we have solved most of critical issues for this AI, we can comeback in next meeting for this issue.  Our current position is Option 3 or Option 1. The advantage of Option 3 is that it can provide more up-to-date information, while overhead is not high given that waveforms won’t be switched so frequently. We do not accept Option 2 alone, as it doesn’t provide assisting information for DWS.  We would like to have more time to evaluate if Option 4 really works, as pointed out by Qualcomm and what are the impacts/issues with that option. We also have some questions for FL/proponent of Option 4 in previous conversation. Could you please check? Thank you! |
| OPPO | We also think the options are not “Preferred/Acceptable/Not acceptable” issues.  There should be better technical justification as I comment earlier. |
| Vivo | Option 1: Preferred  Option 2: Not acceptable?  Option 3: Acceptable  Option 4: Not acceptable? |

### 5th round

For this last round of discussions, moderator encourages companies to provide their views on the following issues:

* Questions on “timeliness/triggering” of waveform change from e.g. Qualcomm (for any option)
  + Moderator observes that companies tend to focus on the CP-OFDM -> DFT-S-OFDM scenario, but perhaps equal attention should be paid to the DFT-S-OFDM -> CP-OFDM scenario?
* Questions on Option 4, from e.g. Nokia, NSB
* Concern on impact on PHR format in UL CA if PHR for both current and target waveform is reported (from Huawei). Is a new PHR format required or is there another way?
* Any other concern

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| Company | Comments |
| QC | On DFT-S-OFDM to CP-OFDM switch, I feel timeliness isn’t that critical. Once can be rather conservative on this and not pay too much of a price. Might help if enhancements are tailored to facilitate CP-OFDM to DFT-S-OFDM switch and hence the focus on this case.  Companies bringing up ULCA is rather ironical given the lack of discussions in 9.12.2.  I hope companies are aware that for UL-CA with the use of reference PUSCH, Pcmax is not reported. The entire second octet is dropped. Also, P-MPR, MPR, A-MPR are required to be set to zero. Multi-PHR reporting with reference PUSCH (which is likely the most common scenario, is rather meaningless to drive DWS decisions at the gNB. It is merely intended for a gNB to get a sense of pathloss on the secondary carrier. Suggest keeping the focus on single PHR.  A key question that the gNB vendors need to think about is whether the DWS decision is effectively a rank determination decision. If this is indeed the case, PHR may not be the right venue to solve it.  There are arguments being made about gNB not knowing how many PRBs are needed to max out power. gNB would certainly be able to know this. gNB uses CP-OFDM for a cell-center UE and as the UE moves further away, it may send TPC commands to a UE asking it to increase its tx power. At a certain point uplink SNR begins to plateau even when TPC commands are sent. This would be indicative of UE maxing out its power. Once this occurs, gNB has two options, either go down to a smaller allocation, or try a different waveform (potentially involving a rank change). Its at this point that one needs to consider whether a PHR enhancement or a timely PHR is necessary.  Anyway, lets reconvene in May and discuss further. We remain open to enhancements. |
| Vivo | * In our view, timeline/triggering of legacy can be reused, both directions should be allowed as long as waveform is changed. * Question to option 4, we have similar question and we do not think SINR can provide enough information as commented by many companies. * We do not see an issue of PHR format, RAN2 can define the separate MAC-CE based on RAN1 agreement for reporting both PHR of both waveforms. PHR overhead is not increased compared to the option to reporting only single new PHR with dense reporting occasions. Reporting PHRs of both waveforms in same MAC-CE can ensure the instant information of UE remaining power with respect to both waveforms. * The new PHR reporting should try to reuse legacy PHR reporting timeline and triggering mechanism as much as possible. Reporting PHR with both waveforms in the same MAC-CE as long as the MAC-CE of legacy PHR is triggered (plus some additional conditions e.g. when DWS is enabled by RRC/triggered in the DCI) is the simplest way to reduce the workload. |
| Ericsson | Q1: Regarding the switching from DFT-S-OFDM to CP-OFDM, a power headroom report of target waveform is more necessary. Without such information, even if gNB schedules the PUSCH transmission in the same way except waveform, it may risk putting the UE in a power-limited situation.  Q3: If both the following types of reporting are supported by RAN1, and the receiving gNB does not support R18 increased PHR MAC CE size of the second type, we can discuss how to configure only the first type of report for a UE.   * reporting PH information for one waveform alone * reporting PH information for both waveforms |
| Nokia, NSB | For Q1:  About the timeline/triggering, we think that the PHR may be outdated even if the minimum periodicity of legacy PHR is used (this was mentioned several times by some companies, if we recall it correctly). Note also that a dense reporting of PHR may unnecessarily lead to overhead. In this regard, triggering the report (of both PHRs) using the waveform switching event makes more sense, since it can provide more up-to-date information. However, as we are all aligned that back-and-fort switching is not needed, therefore, both PHRs can be reported some time after the switching. This information will be helpful for the next switching decision.  Concerning switching from DFT-s-OFDM to CP-OFDM, we should treat this similarly as from CP-OFDM to DFT-s-OFDM, given that the switching is not only useful for power boosting or MIMO rank selection, but it also depends on channel condition given that CP-OFDM is more preferred than DFT-s-OFDM in case of frequency selective channel.  For Q2:  Coming back to the back-to-back PUSCH solution, given that the selection between DFT-s-OFDM and CP-OFDM is not only for power boosting, but also for rank selection (as mentioned by some companies) and depends on channel conditions (as discussed above), we are not sure assuming the CP-OFDM PUSCH being boosted to its PCmax is always correct.  Another point that we should consider is how to control the power, i.e., boosting to maximum power for the two PUSCHs? Are we using closed loop power control here? In addition, given that we don’t know the exact PCmax, we may need to slowly ramp down the power. This may impact the merit of UE power saving, given that power control is not only for coverage but also for power saving and interference control.  Accuracy and impact on receiver complexity are questionable as well. Indeed, DM-RS sequences for CP-OFDM and DFT-s-OFDM could be different. In addition, receiver may or may not use the same channel estimation algorithm for both cases. In case they are different, not sure if the comparison is accurate.  Latency and overhead would be other aspects that we should consider, as this back-to-back scheduling should be done prior to the real waveform switching.  For Q3:  We think the extension to UL CA scenario can be discussed as next step and need further discussion. It’s unclear to us whether/how this would impact the PHR design. |

# Topic #4: RRC parameters

## [MP][Closed] Issue #4-1: Configuration of DWS

**Summary of company views from contributions submitted to RAN1#112bis-e**

Several companies (ZTE [7], InterDigital [12], Panasonic [14], Lenovo [16], Samsung [17], ETRI [18], LG [29]) discuss RRC configuration to enable dynamic waveform switching functionality.

All the above companies identify the need for configuring by RRC whether dynamic waveform switching is enabled. However, several issues still need to be discussed.

Configurability level

Two companies [12][18] propose that dynamic waveform switching is configurable per BWP. One company [16] proposes that parameters applicable to both waveforms are configured within one PUSCH-Config, which implies configurability per BWP. At the beginning of RAN1#112, moderator also asked this question to companies and majority of companies were preferring per-BWP. From moderator’s perspective, configurability per BWP seems natural since parameter *transformPrecoder* which controls the waveform for dynamic grant in R17 is under *PUSCH-Config* which is configured by BWP.

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| **FL proposal 4-1**: Dynamic waveform switching is configured separately for each BWP, within *PUSCH-Config*. |

Two companies [12][16] propose that presence of the 1-bit dynamic waveform switching indication can be configured separately for DCI format 0\_1 and DCI format 0\_2. Other companies [7][14][17][29] discussing RRC enabling/disabling the indication do not discuss this aspect. Some additional discussion may be needed on this.

For the RRC indication, options include (1) additional value to *transformPrecoding* parameter indicating dynamic switching [14][17] or (2) additional RRC parameter indicating if dynamic switching is enabled or disabled [7][14][29]. Both options can be further studied.

One company [16] proposes that parameters for CP-OFDM and DFT-S-OFDM are included under a same PUSCH-Config parameter instead of separate PUSCH-Config parameters. In moderator’s understanding, parameters for both waveforms are already included within PUSCH-Config. In case some parameter for one waveform or the other is missing, it seems reasonable to continue with the same approach.

### 1st round

Please indicate if your company position was incorrectly captured or if you would like to add your company position to the summary above. Please indicate:

* If FL proposal 4-1 is agreeable
* If you think presence of dynamic waveform switching indication can be configured separately for DCI format 0\_1 and 0\_2.

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| Company | Comments |
| NTT DOCOMO | Yes, we agree with 4-1. We are open for common/separate configuration for DCI 0\_1 and 0\_2. Meanwhile, we think the reason of having two separate DCI formats is to enable UEs to decode two DCI formats with different purpose. DWS’s need could also be different in between in our view. Thus separate configuration seems reasonable to us. |
| CATT | We support FL proposal 4-1.  We agree with separate configuration of presence of dynamic waveform switching indication for DCI format 0\_1 and 0\_2. |
| Intel | It may be good to first discuss dynamic waveform switching in case of BWP switching. If this is supported, then we are fine with FL proposal 4-1 |
| QC | Support. We too think separate configuration for formats 0\_1 and 0\_2 will be needed. |
| Lenovo | We are fine with FL proposal 4-1; and we think the presence of dynamic waveform switching indication can be configured separately for DCI format 0\_1 and 0\_2. |
| Apple | We support Proposal 4-1, and DWS is separately configured for DCI format 0\_1 and 0\_2. |
| vivo | Fine with FL’s proposal.  And in this case, we assume DWS bit(s) in a DCI would be reserved when BWP switching is indicated by the DCI. |
| ZTE | Support the proposal 4-1. |
| Transsion | We support this proposal.  We believe that the presence of DWS indication can be separately configure for DCI format 0\_1 adn 0\_2. |
| LG | Support the proposal 4-1. But, we are questionable for the necessity of supporting each format indicated separately for DCI format 0\_1 and DCI format 0\_2. |
| Spreadtrum | Support FL proposal 4-1 and DWS can be separately configured for DCI format 0\_1 and 0\_2. |
| Sharp | We support the FL proposal. |
| CMCC | Support FL proposal 4-1. |
| Ericsson | Separate RRC configurations are needed for C-RNTI in *PUSCH-Config* and CS-RNTI with NDI=1 in *ConfiguredGrantConfig*.  No need to have separate RRC parameters for DCI 0\_1 and 0\_2. |
| ETRI | Support the proposal 4-1. The compact DCI format may or may have different fields. |
| Nokia/NSB | We are fine with FL proposal 4-1. On separate configurations for format 0\_1 and 0\_2, does it mean that if DWS is not enabled for one DCI format then the DWS indication field is considered as reserved for the DCI format? Otherwise, what is the motivation? |
| MediaTek | Support the proposal.  We don’t see a need to have separate RRC parameters for DCI 0\_1 and 0\_2. |
| Samsung | OK with proposal. |
| Moderator | @All: thanks for comments and support.  @Intel: I think dynamic BWP switching discussion would be next step after we agree on this. |

### 2nd round

Since FL proposal 4-1 seems agreeable to all, moderator would like to submit for email approval. Regarding separate configurability for DCI format 0\_1 and 0\_2, it seems that more discussion is needed. Moderator’s understanding is that the argument for separate configurability is that the presence of DWS field increases the payload of the DCI compared to semi-static configuration of DFT-S-OFDM, while the objective of DCI format 0\_2 is to have reduced DCI payload compared to DCI format 0\_1. On the other hand, one argument for common configurability is that in R17 we do not seem to have separate configuration for the *transformPrecoding* parameter.

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| **FL proposal 4-2**: For configuration of 1-bit dynamic waveform switching indication in DCI format 0\_1/0\_2, downselect between following options:   * Option 1: Separate configuration of presence of dynamic waveform switching field for DCI format 0\_1 and DCI format 0\_2. * Option 2: Common configuration of presence of dynamic waveform switching field for DCI format 0\_1 and DCI format 0\_2. |

Please indicate if FL proposal 4-2 is agreeable. Please feel free to indicate any additional motivation for Option 1 or Option 2 in the above.

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| Company | Comments |
| NTT DOCOMO | Proposal to suggest down-selection itself is fine for us.  As said, we are open to discuss, but for now we feel option 1 seems reasonable. We believe the importance of 1-bit overhead could be quite different between DCI 0\_1 and DCI 0\_2. Compact DCI intends to maximize DCI reliability by prioritize DCI overhead reduction than NW control in our understanding. Then it may be a realistic case that NW wants DWS to be configured in DCI 0\_1 while not to be configured in DCI 0\_2  @Ericsson, we do not quite understand why per-RNTI configuration could be beneficial. Do you intend to make a DCI format with different RNTI non-aligned, unlike the legacy spec?  @Nokia, in our understanding, alignment between DCI 0\_1 and DCI 0\_2 is not required per the specification now. Or if we overlook something, please let us know. The potential benefit of having separate configuration could rather be to enable independent configuration in between so that one configuration doesn’t affect on the other. |
| ZTE | Support. Prefer Option 1 |
| Intel | We are fine with the proposal.  We prefer Option 1 with the motivation as mentioned by NTT DOCOMO. DCI format 0\_2 typically has smaller size compared to DCI format 0\_1. |
| Nokia/NSB | We are fine with the proposal. @NTT DOCOMO: Thank you for the clarifications. We were wondering if the alignment is constrained by the (3+1) rule on the DCI size budget. We understand your explanation on the motivation and can be open to that. Thank you! |
| QC | Lets go with Option 1. Many other features make a distinction between 0\_1 and 0\_2. |
| Panasonic | We are fine with FL proposal 4-2 and we prefer Option 1. |
| NEC | Fine with the proposal and prefer option 1. |
| CATT | Support and we prefer Option 1. |
| China Telecom | Support, and we prefer Option 1. |
| Lenovo | Support Option 1 that different DCI formats may indicate different waveforms for different purposes. |
| Ericsson | Support. Option 1 is fine. |
| LG | Fine with the proposal. We think option 1 is better way to configure both DCI formats separately to take advantage of the configurable DCI format 0\_2. |
| Samsung | Proposal is fine. No strong motivation for either option. |
| Transsion | Support the proposal and prefer option 1. |
| CMCC | Fine. |
| Sharp | WE support the FL proposal and prefer option 1. |
| Spreadtrum | Support and we prefer Option 1. |
| OPPO | We are fine with the proposal. We prefer option 2 as this will be equally needed for dynamical wave form switching. |
| Mavenir | Support and we prefer Option 1. |
| Sony | Support |
| Xiaomi | Support ,and we prefer Option 1 |
| Vivo | Fine. |

### 3rd round

Based on 2nd round, it seems that the proposal is agreeable to all. There is also significant majority that prefers Option 1. Then one possibility would be to try to agree on separate configurability directly unless companies would like more time to analyze further.

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| **FL proposal 4-2r1**: Support separate configuration of presence of dynamic waveform switching field for DCI format 0\_1 and DCI format 0\_2. |

Please indicate if FL proposal 4-2r1 is acceptable now, or if you prefer agreeing on FL proposal 4-2 first and make further analysis before downselection.

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| Company | Comments |
| QC | Support |
| CMCC | Fine. |
| Sharp | Support |
| Panasonic | We support FL proposal 4-2r1. |
| Ericsson | Support FL proposal 4-2r1 |
| OPPO | It is not very necessary to have 2 separate configurations. This would mean 2 different RRC parameter to enable the DWS.  I checked with earlier features. There are many indication configured commonly for format x\_1/x\_2. For PDCCH skipping and SSSG switching of power saving, a single parameter is for both DCI format.  There do have some separated cases like enhance PUSCH repetition. But this is due to the different time domain mapping Type A and Type B.  So we would better to think about the simpler single configuration. |
| Sony | Support |
| Lenovo | Support. |
| CATT | Support |
| Nokia, NSB | We are fine with FL’s proposal 4-2r1. |
| Intel | Support |
| LG | Support. |
| ZTE | Support. |
| China Telecom | Support. |
| Xiaomi | Support |
| Transsion | Support |
| Apple | Support |
| Spreadtrum | Support. |
| MediaTek | We don’t see a strong need to have separate configurations. The argument about compact DCI size is about 1 bit difference, which is not too much. If majority of companies feel strongly about having separate configurations, we can live with the proposal. |
| Moderator | @All, thanks for support/feedback.  @Mediatek: thanks for flexibility. Just a quick note, I think in general the difference is more than 1 bit because DCI size needs alignment between waveforms. |

# References

|  |  |  |  |
| --- | --- | --- | --- |
| 1 | RP-221858 | Revised WID on Further NR coverage enhancements | China Telecom |
| 2 | R1-2302352 | Discussion on dynamic waveform switching for coverage enhancement | Huawei, HiSilicon |
| 3 | R1-2302511 | Discussions on remaining issues of dynamic waveform switching | vivo |
| 4 | R1-2302575 | Considerations on dynamic switching between DFT-S-OFDM and CP-OFDM | OPPO |
| 5 | R1-2302625 | Discussion on dynamic switching between DFT-S-OFDM and CP-OFDM | Spreadtrum Communications |
| 6 | R1-2302692 | Dynamic switching between DFT-S-OFDM and CP-OFDM | CATT |
| 7 | R1-2302761 | Discussion on dynamic waveform switching | ZTE |
| 8 | R1-2302788 | Dynamic switching between DFT-S-OFDM and CP-OFDM waveform | Intel Corporation |
| 9 | R1-2302865 | Considerations on dynamic waveform switching for various PUSCH types | Sony |
| 10 | R1-2302882 | Dynamic switching between DFT-s-OFDM and CP-OFDM | Nokia, Nokia Shanghai Bell |
| 11 | R1-2302972 | Discussion on dynamic switching between DFT-s-OFDM and CP-OFDM | Xiaomi |
| 12 | R1-2303018 | Dynamic switching between DFT-S-OFDM and CP-OFDM | InterDigital, Inc. |
| 13 | R1-2303036 | Discussion on dynamic waveform switching between DFT-s-OFDM and CP-OFDM | China Telecom |
| 14 | R1-2303039 | Discussion on dynamic waveform switching | Panasonic |
| 15 | R1-2303085 | Discussion on solutions for NR dynamic switching between DFT-S-OFDM and CP-OFDM | Mavenir |
| 16 | R1-2303092 | Discussion on dynamic switching between DFT-S-OFDM and CP-OFDM | Lenovo |
| 17 | R1-2303155 | Dynamic switching between DFT-S-OFDM and CP-OFDM | Samsung |
| 18 | R1-2303207 | Dynamic switching between DFT-S-OFDM and CP-OFDM | ETRI |
| 19 | R1-2303258 | Discussion on dynamic switching between DFT-S-OFDM and CP-OFDM | CMCC |
| 20 | R1-2303355 | Dynamic switching between waveforms | MediaTek Inc. |
| 21 | R1-2303382 | Discussion of dynamic switching between DFT-S-OFDM and CP-OFDM | Transsion Holdings |
| 22 | R1-2303510 | Discussion on dynamic switching between DFT-S-OFDM and CP-OFDM | Apple |
| 23 | R1-2303617 | Dynamic switching between DFT-S-OFDM and CP-OFDM | Qualcomm Incorporated |
| 24 | R1-2303641 | Dynamic switching between DFT-S-OFDM and CP-OFDM for Rel-18 CovEnh | Sharp |
| 25 | R1-2303644 | Discussion on dynamic switching between DFT-S-OFDM and CP-OFDM | Google Inc. |
| 26 | R1-2303663 | Discussion on Dynamic UL Waveform Switching | Ericsson |
| 27 | R1-2303682 | Discussion on dynamic switching between DFT-S-OFDM and CP-OFDM | NEC |
| 28 | R1-2303733 | Discussion on dynamic switching between DFT-S-OFDM and CP-OFDM | NTT DOCOMO, INC. |
| 29 | R1-2303752 | Discussion on dynamic waveform switching for NR coverage enhancement | LG Electronics |
| 30 | R1-2302222 | Summary #4 on dynamic switching between DFT-S-OFDM and CP-OFDM | Moderator (InterDigital) |

# Appendix: Previous agreements

RAN1#112

Agreement

For single TB scheduled by single DCI, support new 1-bit field for dynamic waveform indication from UL scheduling DCI.

Note: no change of the current size alignment procedure between UL DCI and DL DCI.

Conclusion

There is no consensus to support “Dynamic waveform switching to PUSCH transmissions with a Type 2 configured grant” in R18.

Agreement

Dynamic waveform switching in R18 is not applicable to PUSCH transmissions with a Type 1 configured grant.

Conclusion

The dynamic waveform indication in a DCI containing a dynamic uplink grant applies only to PUSCH transmission(s) corresponding to the dynamic uplink grant.

RAN1#111

**Agreement**

**For DCI based solution,**

* For supported dynamically scheduled PUSCH, support dynamic waveform switching indication from UL scheduling DCI

Note: “Supported dynamically scheduled PUSCH” is to be confirmed in further discussion

Note: It does not imply that the waveform switching indication applies to other transmission or not

* Indication from non-UL scheduling DCI is not supported.

Note: the working assumption made in RAN1#110b-e for “Support at least one of the following options for the dynamic waveform indication in R18” does not need to be confirmed

Working Assumption

Support new 1-bit field for dynamic waveform indication from UL scheduling DCI

* Note: no change of the current size alignment procedure between UL DCI and DL DCI

Agreement

Study the necessity of the following potential enhancements to assist the scheduler in determining waveform switching:

* Reporting power headroom related information based on PCMAX,f,c applicable to a target waveform
  + Target waveform can be same or different from waveform of an actual PUSCH transmission
  + FFS target RB allocation and/or target modulation order can be same or different from respective properties of an actual PUSCH transmission
  + FFS determination of target waveform, target RB allocation, target modulation order
  + FFS details, e.g. report PCMAX,f,c or Type 1 power headroom for a waveform, or difference thereof between waveforms
* PHR triggering enhancements, e.g.
  + Network-triggered PHR
  + PH becomes lower (higher) than a threshold
  + PHR triggered by waveform switching
* Reporting of recommended waveform or request to switch waveform
* Other solutions not precluded

RAN1#110bis-e

Agreement

Dynamic waveform switching enhancement in R18 is only applicable to PUSCH channel.

**Working Assumption**

Support at least one of the following options for the dynamic waveform indication in R18:

Alt 1: Indication from an UL scheduling DCI

* Alt 1-A: New field in scheduling DCI
* Alt 1-B: Reuse existing field in scheduling DCI
  + Alt 1-B-1: Explicit indication by repurposing field, e.g.
    - Add one column to TDRA table
    - Add one column to MCS table(s)
    - Other solutions not precluded
  + Alt 1-B-2: Implicit determination from condition(s) on scheduling information, e.g.
    - RA type, MSB of RA
    - Number of RBs (below threshold or multiple of 2,3,5)
    - Location of RB allocation within carrier and the associated MPR
    - MCS below threshold
    - Number of PUSCH repetitions (or whether PUSCH repetition is used) and/or TBoMS
    - Number of DMRS CDM group(s) without data
    - Precoding information and number of layers
    - SRI
    - Condition over multiple types of scheduling information
    - Other types of scheduling information not precluded
* Indicated waveform applies at least to the scheduled PUSCH transmission
  + FFS: Whether it also applies to subsequent transmissions, and of which type
* FFS: DCI formats can contain the indication
* FFS: Indication applies only if condition(s) are satisfied (e.g. PDCCH occasion, /RNTI, /Search space of the scheduling DCI, latest PHR reported by the UE, etc.)

Alt 2: Indication from a non-UL scheduling DCI

* FFS: DCI formats that can provide the indication (e.g. Downlink DCI, UE-group common DCI)
* FFS: Types of subsequent transmissions to which indication is applicable

**Agreement**

To study and if necessary, specify, enhancements to assist the scheduler in determining waveform switching, such as:

* Reporting power headroom related information
* Other solutions are not precluded

**Agreement**

Dynamic waveform switching enhancement in R18 is applicable to PUSCH scheduled by DCI format 0\_1 or 0\_2 in PDCCH with CRC scrambled with C-RNTI, MCS-C-RNTI, or CS-RNTI with NDI=1.

* Note: The above does not imply that dynamic switching enhancement in R18 is applicable or not applicable to other cases of PUSCH (e.g. PUSCH transmission with a Type 1 or Type 2 configured grant, PUSCH scheduled by DCI format 0\_0).

R1-2210749 Summary #4 on dynamic switching between DFT-S-OFDM and CP-OFDM Moderator (InterDigital, Inc.)