**3GPP TSG RAN WG1 #111 Draft R1-2212445**

**Toulouse, France, November 14th – 18th, 2022**

**Agenda Item: 9.14.3**

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

**Title: Summary #1 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#110bis-e 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.

# Contact information

Please input the contact information for each company below:

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# Collection of agreements in RAN1#111

# Proposals

## Proposals for 1st online session

## Proposals for 2nd online session

# 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, but other cases still need to be decided.

The following cases are considered separately:

* PUSCH dynamically scheduled by DCI format 0\_0
* PUSCH scheduled by configured grant type 1/2
* PUSCH scheduled by RAR (msg3)
* Other cases/scenarios

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

**Summary of company views from contributions submitted to RAN1#111**

Applicability to PUSCH scheduled or activated by DCI format 0\_0

Yes: ZTE [4], Oppo [12], Nokia [16]

* Need to maximize applicability of dynamic waveform switching [4]
* DCI format 0\_0 is used in coverage-limited scenarios [4][12][16]
* (Except for TC-RNTI) Add 1 bit in case number of bits for DCI format 0\_0 before padding is smaller than DCI format 1\_0 [4]
* (for TC-RNTI) Use same as msg3 initial transmission [4]
* No ambiguity after the UE is connected to network [12]
* Add column to default TDRA table [12]
* May be sufficient to use low MCS and DFT-S-OFDM without repetition [16]
* Can be used to switch CG if indication is applicable to subsequent transmissions [16]
* May not require change to DCI format if implicit method is selected or if indication is applied to subsequent transmission [16]

Study: NTT DOCOMO [23], Qualcomm [25]

* Benefit may not be large, need to handle early indication of capability issue [23]
* Only if no change to DCI format [25]

No: vivo [3], Panasonic [6], CATT [7], Spreadtrum [8], InterDigital [9], Intel [11] (by C-RNTI), Lenovo [15], Ericsson [21], Samsung [24], Mediatek [27]

* (by TC-RNTI) Early indication would be required for UE not in RRC connected, large spec impact [3][23]
* Should keep same payload size for DCI format 0\_0 [6][11][21][25], cannot change size for CSS [6]
* Better if interpretation remains stable during RRC reconfiguration [6][8][9]
* Switching from format 0\_0 to other formats already enables switching [7]
* Supporting format 0\_0 has small benefit, e.g. other formats can be used [7][9][21]
* Can configure DFT-S-OFDM for format 0\_0 if coverage is limited [9]
* Format 0\_0 only supports basic scheduling/fallback operation [8][11][15], e.g. only RA type 1 [7][8], DMRS configuration/port is fixed [8]
* Format 0\_0 only has mandatory fields, should not add bit [8]
* Enhancements for PUSCH in previous releases target non-fallback DCI [15]
* Format 0\_0 is infrequently used, no need for optimization [24]
* Benefit unclear [27]

**Observations on applicability to PUSCH scheduled by DCI format 0\_0**

3 companies support applicability to PUSCH scheduled by DCI format 0\_0 while 10 companies do not support. 2 companies are still open to study.

Majority of companies do not support this case and at this point it seems more likely that the conclusion will be that dynamic waveform indication is not applicable to DCI format 0\_0. However, from moderator perspective discussion on this topic has lower priority than discussion on the dynamic indication solution. In addition, some of the concerns are dependent on the decision on this solution. Moderator recommends discussing this topic after more progress is achieved on the indication solution.

### Pre-meeting comments

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

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| Company | Comments |
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## [MP] Issue #1-2: Applicability to configured grant

**Summary of company views from contributions submitted to RAN1#111**

Applicability to CG type 1

* Yes: ETRI [14], Lenovo [15], Nokia [16], FGI [20], (LG [22])
	+ Beneficial at edge of coverage [14]
	+ Multiple CG configurations would increase gNB complexity/consumption [14]
	+ Retransmissions by DCI (with different waveform) would consume PDCCH capacity [14]
	+ Define application time for the waveform indicated by DCI [15]
	+ Add second DMRS configuration in CG configuration [15]
	+ CG PUSCH is used for latency critical data [16] need to adapt to channel conditions [20]
	+ Switch using MAC CE [20]
	+ Switch if CG is transmitted within N ms after DG switching waveform [22]
* Configurable: InterDigital [9]
	+ In case following latest waveform indication is needed for some CG configuration [9]
	+ Requires two sub-configurations [9]
* Consider: Xiaomi [10], NTT DOCOMO [23]
	+ Benefit of dynamic switching valid for any type of scheduling, but CG type 1 may be difficult [23]
	+ Prefer unified solution between DG and CG [23]
* No: ZTE [4], Panasonic [6], CATT [7], Spreadtrum [8], InterDigital [9], Intel [11], Oppo [12], Sony [17], Apple [19], Samsung [24], Qualcomm [25], Mediatek [27]
	+ No activation DCI exists for CG type 1 [4][6][7]
	+ Requires MAC CE, otherwise change by DCI is subject to false/mis-detection and would increase gNB complexity [6][17]
	+ No benefit of changing only waveform but not resource allocation [6]
	+ Keep principle that all parameters are configured by RRC [8][11][27]
	+ CG type 2 is better candidate for switching [6][9]
	+ Can configure multiple CG configurations instead [11][25]
	+ Additional parameters would need to change [24]
	+ No benefit [24]
	+ Configured parameters may be incompatible with one of the waveforms. Switching would require changing these parameters [25]

CG type 2:

* Yes: ZTE [4], Panasonic [6], InterDigital [9], xiaomi [10], Intel [11], ETRI [14], Lenovo [15], Nokia [16], Sony [17], Apple [19], FGI [20]
	+ Can reuse solution for DCI format 0\_1/0\_2 [4][6][9][11][14][15][17][19]
	+ Enables adaptation for URLLC traffic [9]
	+ DG and CG PUSCH have same demands for coverage enhancements [10]
	+ Only if activation is in format 0\_1/0\_2 [11]
	+ Preferably from previously received indication, otherwise no change possible after activation [16]
* Open to discuss: CATT [7], NTT DOCOMO [23], Qualcomm [25]
	+ Possibly for activation by format 0\_1/0\_2 only [7]
	+ Benefit of dynamic switching valid for any type of scheduling [23]
	+ Only if solution for DCI format 0\_1/0\_2 is reused [25]
* No: Spreadtrum [8], Oppo [12], Samsung [24], Mediatek [27]
	+ Need to change other parameters on top of waveform [8]
	+ Not needed since multiple CG configurations with different waveforms can be dynamically activated/released [8][25][27]
	+ Activation DCI would not be available timely (?) [12]
	+ Additional parameters would need to change [24]
	+ No benefit [24]

**Observations on applicability to PUSCH scheduled by configured grant**

For applicability to configured grant, as in previous meeting the situation is different depending on whether it is type 1 or type 2.

For CG type 1, 5 companies support applicability to this case while 12 companies do not support and 2 are open. 1 company proposes that applicability is configurable. The main argument for supporting switching for CG type 1 is that it can be used to support critical (URLLC) data and needs to benefit from the power boost of DFT-S-OFDM when the UE becomes power-limited. Non-supporting companies counter that this would increase complexity (e.g. require additional RRC parameters, require that DCI indication applies to subsequent transmissions), go against CG type 1 design, and that other solutions are available (e.g. multiple CG configurations or CG type 2, if supported).

Moderator also notes from the discussion in Issue #2-1 that many companies have concern about the complexity of having DCI indication apply to subsequent transmissions. Considering the situation, moderator recommends concluding on not supporting applicability to CG type 1.

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| **FL proposed conclusion 1-1**: Dynamic waveform switching in R18 is not applicable to configured grant Type 1. |

For CG type 2, 11 companies support applicability to this case while 4 companies do not support, and 3 companies are still open to discuss. Supporting companies identify that any solution identified for the indication by UL scheduling DCI could be reused seamlessly for the activation of CG type 2. CG type 2 can also be used to support URLLC traffic and may address the need for adaptability for this case. Non-supporting companies have concerns about the need to change other parameters on top of waveform (though in Moderator’s understanding such parameters could already be indicated in the activation DCI?) and that the benefit is limited.

Moderator suggests discussing the case of CG type 2 after more progress is achieved for the dynamic indication solution.

### Pre-meeting comments

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 |
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## [LP] Issue #1-3: Applicability to msg3 PUSCH

**Summary of company views from contributions submitted to RAN1#111**

* Yes**:** ZTE [4] (also for retx), Intel [11] (also for retx), Oppo [12], Sony [17]
	+ Same motivation as for msg3 PUSCH repetition [4]
	+ Enables selection based on UE’s channel conditions instead of cell-level [11][12]
	+ Can use same solution as for dynamically scheduled PUSCH (e.g. 1-B-1) [12]
	+ Override SIB field for UE in connected or inactive mode [17]
	+ Based on whether UE requests msg1 repetition (?) for UE in idle mode [17]
	+ Use reserved bit or CSI request bit of the RAR [17]
* Study: Nokia [16], LG [22], NTT DOCOMO [23]
	+ May be possible to leverage specification effort of other cases [16]
	+ Address possible channel degradation during RACH. Also consider retransmission. [22]
	+ Benefit may not be large, need to handle early indication of capability issue [23]
* No/low priority**:** Panasonic [6], CATT [7], Spreadtrum [8], Lenovo [15], FGI [20], Qualcomm [25], Mediatek [27]
	+ Would require PRACH resources for identification of capability [6][25]
	+ Motivation and benefit unclear [7][25][27]
	+ Additional preamble partitioning required [7][8][20]
	+ Possible impact on RAR grant and DCI format 0\_0 [7]
	+ gNB does not have sufficient channel/power information to select [8][15]
	+ msg3 repetition is sufficient [20]

In addition, no company proposes to support dynamic indication for msgA, and one company [7] explicitly proposes to not support it.

**Observations on applicability to msg3 PUSCH**

4 companies support applicability to msg3 PUSCH while 7 companies do not support, and 3 companies are open to study. Supporting companies identify same motivation as for msg3 repetition, to better support UE’s at cell edge. Non-supporting companies think that the benefit is unclear and have concerns about the complexity, particularly the need for reserving PRACH resources for identification of capability.

Moderator thinks that this issue is lower priority compared to the dynamic indication solution and suggests revisiting this topic later.

### Pre-meeting comments

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

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| Company | Comments |
| CATT | If no company intends to support dynamic indication for Msg A PUSCH, can we make a clear conclusion, e.g. Dynamic waveform switching in R18 is not applicable to Msg A PUSCH? |
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## [LP] Issue #1-4: Other issues related to requirements and scenarios

**Summary of company views from contributions submitted to RAN1#111**

For the scenario of DCI indicating **multiple PUSCHs for different TRPs/cells**:

* One company [5] is open to discuss use of different waveforms of PUSCH targeting different TRPs/cells.

For the scenario of **uplink carrier aggregation**:

* One company [21] proposes that this scenario is assumed to be supported with dynamic waveform switching unless a technical obstacle cannot be overcome.

**Observations on other issues related to requirements**

These issues can be discussed after more progress is made on dynamic indication solution.

# Topic #2: Dynamic switching mechanism

A set of issues concern the mechanism(s) that support dynamic waveform switching for the different cases to support.

## [HP] Issue #2-1: Dynamic indication options

**Summary of company views from contributions submitted to RAN1#111**

RAN1 reached working assumption on options for dynamic waveform indication in RAN1#110bis-e. Companies provided their views on the different options and aspects identified as FFS as summarized below.

Confirming working assumption

Several companies (Fujitsu [5], Lenovo [15], CMCC [18], NTT DOCOMO [23], Mediatek [27]) proposed to confirm the working assumption.

Alt 1-A: New field in scheduling DCI:

* **Preferred or acceptable**: ZTE [4], Fujitsu [5], Panasonic [6], Spreadtrum [8], InterDigital [9], Xiaomi [10], Intel [11], Sony [17], Apple [19], Ericsson [21], LG [22], Samsung [24], Sharp [26], Mediatek [27], NEC [29]
* **Not preferred**: Huawei [2], Oppo [12], ETRI [14], Lenovo [15], Qualcomm [25]

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| **Alt 1-A: New field in scheduling DCI**[4][5][6][8][9][10][11][17][19][21][22][24][26][27][29] |
| Solution | Benefits | Concerns |
| 1-bit new field | -Simple, low specification effort [4][7][8][9][19]-Maintains scheduler flexibility [4][8][11][17][21][28]-Forward compatible [4]-1 bit has insignificant impact on PDCCH coverage/capacity [4][5][24][26], smaller than increase due to DCI alignment between waveforms [10]-No overhead increase if UL DCI smaller than DL DCI [9][26] | -Larger DCI size may reduce PDCCH reliability or increase CCE overhead [2][13][14][15]-May not be suitable for DCI format 0\_0 |

Alt 1-B-1: Reuse existing field in scheduling DCI - Explicit indication by repurposing field

* **Preferred or acceptable**: Huawei [2], Fujitsu [5], Panasonic [6], Spreadtrum [8], InterDigital [9], Oppo [12], China Telecom [13], Lenovo [15], Nokia [16], LG [22], Qualcomm [25], Mediatek [27], Mavenir [28]
* **Not preferred**: ZTE [4], CATT [7], Intel [11], Sony [17], Apple [19], Ericsson [21], Samsung [24], Sharp [26], Mavenir [28]
* **Solution preferences:**
	+ **TDRA**: [2][6][8][9][12][15][22]
	+ **MCS**: [None]
	+ **HARQ process ID**: [16]

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| **Alt 1-B-1: Explicit indication by repurposing field**[2][5][6][8][9][12][15][22][13][15][16][22][25][27][28] |
| Solution | Benefits | Concerns |
| **General** | -No overhead from additional field [2] | -Mixes different functionalities of a same field [24]-Complicates specifications [24][26]-Reduces number of entries of the field for each waveform [21]-Reduces options for coverage-limited UE [17] |
| **TDRA**[2][6][8][9][12][15][22] | -Minor loss of flexibility if only a few rows need DFT-S-OFDM [2][9]-Can control bitwidth by RRC [15]-Add column to table, straightforward approach [2][12][27] | -Reduces flexibility of TDRA field since TDRA and waveform are independent [3][7][11][21][24][26]-Additional RRC overhead [7] |
| **MCS** | (No specific benefit) | -Rows of MCS table are not RRC configurable, thus not possible to choose between waveforms for a certain MCS [2][8] |
| **HARQ ID MSB or LSB** [16] | (No specific benefit) | (No specific concern) |

Alt 1-B-2: Reuse existing field in scheduling DCI - Implicit determination from condition(s) on scheduling information

* **Preferred or acceptable**: Huawei [2], Vivo [3], Fujitsu [5], Panasonic [6], CATT [7], InterDigital [9], Oppo [12], China Telecom [13], ETRI [14], Lenovo [15], Nokia [16], FGI [20], LG [22], NTT DOCOMO [23], Qualcomm [25], NEC [29]
* **Not preferred**: ZTE [4], Spreadtrum [8], Intel [11], Sony [17], Apple [19], Ericsson [21], Samsung [24], Sharp [26], Mediatek [27], Mavenir [28]
* **Solution preferences**:
	+ **RA type/MSB of FDRA**: [2][6][7][15][16][29]
	+ **MCS**: [6][9][23] – Not preferred: [2]
	+ **Number/location of RB’s**: [9][16] – Not preferred: [2]
	+ **Number of repetitions**: [15] – Not preferred: [5]
	+ **SRI**: [20][23]
	+ **Number of CDM group(s) without data**: [None]
	+ **Precoding information and number of layers**: [6][14][23]
	+ **MCS combined with number/location of RB’s**: [16]
	+ **No preference expressed**: [3][5][12][13][22][29]

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| **Alt 1-B-2: Implicit determination from condition(s) on scheduling information**[2][3][5][6][7][9][12][13][14][15][16][20][22][23][25][29] |
| Solution | Benefits | Concerns |
| **General** | -Avoid additional bitfield definition [3][25]-Poor coverage conditions reflected by values of the field [3]-No impact on legacy field [23]-No overhead increase [23] | -Mixes different functionalities of a same field [24]-Complicates specifications [24][26]-Waveform selection may depend on factors not visible in DCI (e.g. cell load, scheduling, fading, antenna blockage) [21]-Restriction in scheduler flexibility [4][5][8][19][27][28]-High specification effort, difficult to choose among many options [4][5][17][26]-Impacts proprietary gNB implementation [21]-May make feature impractical in the real deployment [11] |
| **RA type/MSB of FDRA**[2][6][7][15][16][29] | -Restriction of RA type 1 with CP-OFDM not a big issue, it can still have continuous RBs with proper RBG size [2][7][15]-Sacrifices less flexibility compared to other fields [29] | -Prevents RA type 1 from being used together with CP-OFDM, which was supported since R15 [21] |
| **MCS**[6][9][23] | -DFT-S-OFDM more suitable for low MCS [6] | -Unnecessary MCS limitation to CP-OFDM [2]-Restricts use of DFT-S-OFDM with higher MCS [4] |
| **Number/location of RB’s**[9][16] | -Pcmax sensitive to location of RB within carrier [9]-MPR gap between waveforms is smaller in inner RB region compared to outer RB region [16]-DFT-S-OFDM suitable only if number of allocated RBs is sufficiently small [16] | -Severe flexibility degradation, restricts CP-OFDM to some patterns permanently [2]-No difference in MPR between outer and inner RB region for high order modulation [8] |
| **Number of repetitions**[15] | -UE at cell edge would use repetition [15] | -Restricts use of DFT-S-OFDM to the case of PUSCH repetitions [4]-Introduces dependency with dynamic PUSCH repetition feature [5]-May not correspond to a practical scenario [8] |
| **SRI**[20][23] | -Transmission power depends on UL beam [20]-SRI can indicate rank [23] | - No relationship between SRI and waveform [8] |
| **Precoding info and # of layers**[6][14][23] | -Supports 1 layer with DFT-S-OFDM and 2+ layers with CP-OFDM [6][14][23] | -Prevents rank1 from being used together with CP-OFDM, which was supported since R15 [21]-Not forward compatible with rank>1 DFT-S-OFDM [4] |

Alt 1: Whether indication applies to subsequent transmissions?

* **Yes**: Lenovo [15], Nokia [16]
	+ Supports CG type 1 [15]
	+ Avoids need to indicate waveform for each PUSCH transmission [16]
	+ Avoids overhead from size alignment in every DCI [16]
	+ Avoids scheduling restrictions in every DCI [16]
	+ WID mentions “switching” and not “indication” [16]
* **No**: CATT [7], Spreadtrum [8], ETRI [14], Samsung [24], Qualcomm [25], (Panasonic [6])
	+ Sufficient to apply only to the scheduled PUSCH, associated DCI’s are applicable for subsequent PUSCHs [7][8]
	+ Would be sensitive to mis-detection, may result in gNB and UE not in sync [14][25]
	+ Not in line with 3GPP philosophy [14]
	+ For CG-PUSCH, additional parameters need to change when waveform switch is needed [24]
	+ PUSCH scheduling DCI format 0\_0 can use R17 solution, no need to optimize [24]
	+ Prefer state-less design [6]

Alt 1: Whether indication applies only if condition(s) are satisfied?

* **Yes**: InterDigital [9], Nokia [16]
	+ Mitigates loss of flexibility or additional overhead from DCI-based indication [9][16]
	+ MAC CE can enable/disable DCI-based dynamic switching indication [9][16]
	+ Latest PHR below a threshold [16]
	+ Conditions on scheduled PUSCH (step by step) [16]
	+ DCI carries waveform indication only if PDCCH is received within a recurring time window [16]
		- DCI size aligned to highest payload between DFT-S-OFDM and CP-OFDM within the window
		- DCI size aligned to latest indicated waveform outside the window
* **Study**: Spreadtrum [8]
	+ Based on PDCCH occasion, may require lots of standards efforts [8]
* **No**: CATT [7], Spreadtrum [8] (RNTI/search space)
	+ Would complicate design [7]
	+ RNTI and search space have no relationship with waveform [8]

Alt 2: Indication from a non-UL scheduling DCI

* **Support or acceptable**: Xiaomi [10], Nokia [16], FGI [20], CEWiT [30]
* **No support**: Huawei [2], Vivo [3], Fujitsu [5], Panasonic [6], CATT [7], Spreadtrum [8], InterDigital [9], Intel [11], Oppo [12], China Telecom [13], ETRI [14], Lenovo [15], Apple [19], Samsung [24], Mediatek [27], Mavenir [28], NEC [29]

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| **Alt 2: Indication from a non-UL scheduling DCI**[10][16][20][30] |
| Solution | Benefits | Concerns |
| DL DCI or group DCI | -DL DCI without scheduled data may avoid overhead increase for PDCCH [10]-Can use indication for subsequent transmission (DG or CG PUSCH) [10]-DL DCI useful when no dynamic UL transmission to be scheduled [16]-Lower latency for indicating switching for CG PUSCH [16]-Group DCI avoids impact on scheduling DCI [16]-Does not alter R17 procedures (?) [30] | -No tangible benefit [2][5], support for CG type 1 not useful [27]-Not needed unless switching is applicable to CG type 1 or DCI format 0\_0 [7][8]-May increase DL DCI size, potential negative impact to DL [2][5]-High specification impact [9][11], requires new field for UL waveform in DCI or other implicit method [14][15]-Need to define application time [2][8][14][28]-May introduce additional delay compared to Alt 1 [11][12][29]-May not work well if gap between non-UL scheduling DCI and PUSCH is too long [15]-Requires handling of false detection or mis-detection, increases gNB complexity [5][6][29]-May require priority handling if both DL and UL DCI are received [2]-Not useful when more UL transmissions are scheduled than DL [3][14]-May not work for CG type 2 if parameters are not compatible [8]-Additional implementation effort to keep state of current waveform in UE and gNB [19]-Group DCI would require new DCI format [8][14], additional PDCCH monitoring, increase gNB complexity [5], not suitable to addressing only coverage-limited UE [5][8], no confirmation available [14] |

Other input

* 2 companies [10][14] would like to re-consider MAC CE as it can save DCI overhead [10][14], can be used for subsequent transmissions including CG&DG PUSCH [10], and is more reliable than DCI [14].
* One company (ETRI [14]) recommends discussing the target scenario for switching before deciding
* One company (Nokia [16]) recommends prioritizing discussion on whether indication is applicable to subsequent PUSCH transmission.

**Observations on dynamic indication options**

In RAN1#110bis-e, RAN1 identified alternatives for dynamic waveform indication in working assumption.

Almost all companies support at least one solution where the indication is from an UL scheduling DCI (Alt 1).

4 companies support (or also support) a solution where the indication is from a non-UL scheduling DCI (Alt 2) and applies to subsequent UL transmissions. 2 companies also support that an indication contained in an UL scheduling DCI (Alt 1) applies to subsequent UL transmissions. The motivations for supporting an indication that applies to subsequent UL transmissions include:

* To support dynamic waveform switching for CG type 1
* To support dynamic waveform switching while enabling that indication is not included in some UL scheduling DCI’s, thus avoiding drawbacks of the indication for these DCI’s

On the other hand, 17 companies expressed concerns about indication from non-UL scheduling DCI (Alt 2) and 5 companies expressed concerns specifically on applying indication to subsequent transmissions for Alt 1. In the latter case, the main concern is that the DCI indication would be sensitive to misdetection resulting in higher gNB complexity to handle the possible error case. Companies expressed same concern for the indication by non-UL scheduling DCI. Additional concerns for the case of indication by non-UL scheduling DCI include the added complexity of defining indication for DL DCI or group DCI (new format) and complexity of defining timelines for application of the waveform and handling of collision cases. Regarding support for CG type 1, it is noted from Topic #1 that majority of companies do not think that this type of transmission should be supported.

Considering the situation, moderator recommends to downselect Alt. 2 from the set of solutions and to not support applying indication to subsequent transmission for Alt 1.

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| **FL proposal 2-1**: Support dynamic waveform indication from UL scheduling DCI (Alt 1)* Indication applies to the scheduled PUSCH and PUSCH repetitions, if any
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Within Alt 1, solution directions were categorized in the working assumption depending on whether a new field is introduced (Alt 1-A), an existing field is repurposed (Alt 1-B-1) or a condition on scheduling information is defined (Alt 1-B-2). From contributions submitted to RAN1#111, 15 companies support solution Alt 1-A, 13 companies support one or more solution(s) within Alt 1-B-1 and 16 companies support one or more solution(s) within Alt 1-B-2. The concern for Alt 1-A is the added 1-bit overhead to the DCI. For Alt 1-B-1 solutions, the main concerns are the loss of flexibility for the repurposed field and added RRC overhead. For Alt 1-B-2 solutions, the main concerns are that it would result in loss of scheduler flexibility and impact to legacy gNB implementation.

Alt 1-A consists of a single solution while Alt 1-B-1 and Alt 1-B-2 include many solutions and support is split between these solutions. To get a clearer picture of the support for well-defined solutions and make progress, moderator recommends to down-select, within Alt 1-B, solutions which did not gather significant support or solutions for which specific concerns were expressed. Based on the summary presented in the above, solutions which appear to have more significant support within Alt 1-B are:

* Indication by TDRA field
* Indication by FDRA type / MSB of FDRA

This leads to the following proposal (with re-labeled alternatives):

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| **FL proposal 2-2**: Support one of the following alternatives for dynamic waveform indication from UL scheduling DCI:* Alt-A: New 1-bit field
* Alt-B: RRC configures waveform for each value of TDRA field
* Alt-C: Indication by RA type: RA type 0 and 1 indicate CP-OFDM and DFT-S-OFDM, respectively
 |

For the FFS point on whether indication applies only if condition(s) are satisfied, 2 companies proposed additional conditions while 2 companies think it would unnecessarily complicate the design. Moderator’s understanding is that some of these conditions (e.g. based on time period of PDCCH) are not applicable if the dynamic indication applies only to the scheduled PUSCH. However, activating/deactivating inclusion of indication in a DCI by MAC CE would still be possible.

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 2-1 and 2-2.

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| --- | --- |
| Company | Comments |
| CATT | We would like to clarify FL proposal 2-1. Moderator said that “moderator recommends to downselect Alt. 2 from the set of solutions and to not support applying indication to subsequent transmission for Alt 1”. But from the proposal, it is not clear that Alt.2 is down-selected. The working assumption from the last meeting is to support at least one of Alt 1 and Alt 2. With the FL proposal 2-1, it seems that Alt 2 is not precluded. If the intention is to downselect Alt 2, it is suggested to make that clear in the proposal.Similar, it is not clear that FL proposal 2-1 precludes applying the indication to subsequent transmission for Alt 1 and it is suggested to make that clear in the proposal.For FL proposal 2-2, we would like to keep MSB of FDRA for Alt-C, which was listed together with FDRA type. |
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## [MP] Issue #2-2: DCI size alignment between CP-OFDM and DFT-S-OFDM

**Summary of company views from contributions submitted to RAN1#111**

Many companies observe that the size/presence of several fields may be different depending on whether transform precoding is enabled or disabled. Such fields include, e.g. [6][23]

* Precoding information and number of layers
* Antenna ports
* PTRS-DMRS association
* DMRS sequence initialization
* FDRA

Align sizes of DCI indicating CP-OFDM and DCI indicating DFT-S-OFDM?

* **Yes**: ZTE [4], Panasonic [6], CATT [7], Spreadtrum [8], Intel [11], China Telecom [13], Lenovo [15], Nokia [16], Ericsson [21], NTT DOCOMO [23], Qualcomm [25], Sharp [26], NEC [29]
	+ Based on size for CP-OFDM: [4][6][11][21][23]([26])
	+ Based on maximum size between CP-OFDM and DFT-S-OFDM: [7][15]([16])[25]
	+ Align on per-field basis: [4][6][7][21][23][26]
	+ Align on per-field or per-DCI basis: [8][15][29]

Several companies [5][27] also discuss size alignment between DL and UL DCI in case indication in new field of scheduling DCI is supported. Contribution [5] suggests adding padding as needed to DCI format 0\_0 to match size of DCI format 1\_0. Contribution [27] also suggests using zero padding.

**Observations on DCI size alignment**

All companies that provided input on this issue agree that there should be DCI size alignment between a DCI indicating CP-OFDM and a DCI indicating DFT-S-OFDM. Furthermore, all companies seem to agree on the principle that each DCI field size should be set as large as necessary to provide the information regardless of the indicated waveform. Most companies assume that for any field, the field size applicable to CP-OFDM is generally (perhaps always) equal or larger than the field size applicable to DFT-S-OFDM. Because of this, some companies propose that the size of each field is set based on CP-OFDM while other companies propose that the size of each field is based on the maximum between the two.

Several companies [8][15][29] identify two possibilities for the alignment, either aligning on per-field basis or aligning on per-DCI basis, without expressing preference. Other companies assume alignment on per-field basis. Moderator’s understanding is that the resulting total DCI size would be the same except possibly for a corner case where a field size for DFT-S-OFDM would be larger than CP-OFDM, if such scenario is possible. For this reason, moderator proposes to agree on aligning on per-field basis which may be simpler. This leads to the following proposal.

|  |
| --- |
| **FL proposal 2-3**: 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 the bit width N of a field for the indicated waveform would be smaller than the bit width of the field set as per the above, UE decodes the field using N least significant bits.
 |

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 2-3.

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| Company | Comments |
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|  |  |

## [LP] Issue #2-3: Other aspects

**Summary of company views from contributions submitted to RAN1#111**

Several companies [3][7][8][15][26] discuss aspects related to RRC configuration:

* Contribution [3] proposes to discuss rules to avoid indicating a target waveform that is not supposed to be supported with rank>1, pi/2 BPSK, FDRA type 0
* Contribution [8] proposes to not support DFT-S-OFDM with rank>1.
* Introduce new RRC parameter for enabling dynamic waveform switching [4][6][22]
* Contribution [7] proposes that DMRS configuration type 2, if configured, applies to PUSCH indicated with CP-OFDM.
* Contributions [7][8] discuss options if *resourceAllocation* IE indicates type 0 in *PUSCH-Config* (e.g. apply to CP-OFDM only or treat as error case)
* Contribution [8] proposes to apply MCS table configured for indicated waveform.
* Contribution [15] discusses configuration of RRC parameters specific to CP-OFDM or DFT-S-OFDM.
* Contribution [26] proposes to enable DCI-based dynamic switching only when legacy RRC parameter transformPrecoder is set to “enable” and determine DCI sizes accordingly
	+ [Moderator question: should be “disable”?]

**Observations on other aspects**

These issues can be discussed after more progress is made on dynamic indication solution.

# Topic #3: Assistance information for switching waveform

## [MP] Issue #3-1: Enhancements to report impact of change of waveform

**Summary of company views from contributions submitted to RAN1#111**

Support enhancements?

* **Yes**: Huawei [2], vivo [3], Spreadtrum [8], InterDigital [9], xiaomi [10], Nokia [16], CMCC [18], FGI [20], Ericsson [21], NTT DOCOMO [23], Samsung [24], Qualcomm [25]
	+ Useful for scheduler to decide PRB allocation [2]
	+ Difference of Pcmax between waveforms function of UE implementation [2][8][9]
	+ Limited performance improvement without enhancement as scheduler cannot decide RB allocation when switching waveform without power difference info [2]
	+ R17 PHR is determined using current waveform [16]
	+ R17 PHR has coarse granularity and does not precisely reflect actual UE power boosting capability [16]
	+ gNB does not know power reduction after waveform switching [18]
	+ gNB needs to know Pcmax and PHR for different waveforms [20]
	+ gNB needs to know if Pcmax would be above required transmit power with target waveform [21]
	+ Avoids latency associated with RSRP measurement reports [24]
	+ Help gNB decide when to trigger and how much additional power a UE can deliver using DFT-S\_OFDM [25]
* **No**: ZTE [4], Fujitsu [5], Oppo [12]
	+ gNB has capability to estimate the difference of PHR (based on RAN4 specification) [4]
	+ Increases overhead of UL signaling and reduces coverage [4]
	+ DFT-S-OFDM is useful when UE is power-limited, rank 1 is optimal and no gain from non-contiguous allocation. Existing PHR, SRS and DMRS provides necessary information for this [5]
	+ Unclear if this should be introduced [12]

Candidate solutions

* **Enhancements to PHR contents**:
	+ Reuse PHR to report power boosting information [2][3][8]
	+ Actual PHR based on actual PUSCH transmission with different waveform [3]
	+ PHR assuming a waveform and/or frequency allocation different from actual PUSCH [9]
	+ Waveform-specific PHR reporting and triggering conditions [16]
	+ UE reports power reduction of waveform switching when reporting dynamic switching capability [18]
	+ Indicate information for different waveforms [20]
	+ Pcmax,f,c of target waveform based on inner/outer/edge RB allocation and modulation order of actual transmission in transmission occasion i [21] (not for virtual PHR)
	+ UE reports PH and Pcmax for each waveform [25]
* **Enhancements to PHR triggering**:
	+ Existing triggering events and PHR report in MAC CE sufficient [21]
	+ UE triggers PHR when PH falls below threshold [25]
	+ Network triggers UE to report PHR [2]
	+ Waveform switching triggers PHR [2][3][18]
* **Other**:
	+ UE reports recommended waveform to gNB [10][16]
	+ UE requests switching between waveforms [24]

**Observations on assistance information**

In RAN1#110bis-e, RAN1 agreed to study and if necessary, specify, enhancements to assist the scheduler in determining waveform switching.

12 companies are supportive of specifying enhancements to assist dynamic waveform switching, while 3 companies are not supportive. Supporting companies believe enhancements are needed otherwise the network cannot estimate Pcmax change with other waveform and cannot rely on MPR requirements from RAN4 since actual power reduction may be significant less than MPR and UE-specific. Non-supporting companies think that the network can estimate from MPR requirements or estimate whether a switch is justified based on other measurements.

Considering the majority support for this feature, it is proposed to agree on the following:

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| **FL proposal 3-1**: Support at least one of the following enhancements to assist the scheduler in determining waveform switching:* Reporting power headroom related information based on PCMAX,f,c applicable to a target waveform and/or a target RB allocation
	+ 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
	+ PH triggered by waveform switching
* Reporting of recommended waveform or request to switch waveform
 |

### Pre-meeting comments

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 3-1.

|  |  |
| --- | --- |
| Company | Comments |
| CATT | Although majority companies prefer to support some enhancements, we think it is premature in RAN1 to agree to support at least one of the listed enhancements for now. The benefits for each solution need more study and discussions. We suggest to change “Support at least one of” to “Study and if necessary specify one or multiple of”. |
|  |  |

# References

|  |  |  |  |
| --- | --- | --- | --- |
| 1 | RP-221858 | Revised WID on Further NR coverage enhancements | China Telecom |
| 2 | R1-2210881 | Discussion on dynamic waveform switching for coverage enhancement | Huawei, HiSilicon |
| 3 | R1-2211035 | Discussions on issues of dynamic waveform switching | vivo |
| 4 | R1-2211049 | Discussion on dynamic waveform switching | ZTE |
| 5 | R1-2211089 | Discussion on Dynamic switching between DFT-s-OFDM and CP-OFDM | Fujitsu |
| 6 | R1-2211134 | Discussion on dynamic waveform switching | Panasonic |
| 7 | R1-2211187 | Dynamic switching between DFT-S-OFDM and CP-OFDM | CATT |
| 8 | R1-2211256 | Discussion on dynamic switching between DFT-S-OFDM and CP-OFDM | Spreadtrum Communications |
| 9 | R1-2211324 | Dynamic switching between DFT-S-OFDM and CP-OFDM | InterDigital, Inc. |
| 10 | R1-2211352 | Discussion on dynamic switching between DFT-s-OFDM and CP-OFDM | xiaomi |
| 11 | R1-2211390 | Dynamic switching between DFT-S-OFDM and CP-OFDM waveform | Intel Corporation |
| 12 | R1-2211476 | Considerations on dynamic switching between DFT-S-OFDM and CP-OFDM | OPPO |
| 13 | R1-2211538 | Discussion on dynamic switching between DFT-S-OFDM and CP-OFDM | China Telecom |
| 14 | R1-2211569 | Dynamic switching between DFT-S-OFDM and CP-OFDM | ETRI |
| 15 | R1-2211575 | Discussion on dynamic switching between DFT-S-OFDM and CP-OFDM | Lenovo |
| 16 | R1-2211597 | Dynamic switching between DFT-s-OFDM and CP-OFDM | Nokia, Nokia Shanghai Bell |
| 17 | R1-2211631 | Further considerations on dynamic waveform switching for NR UL | Sony |
| 18 | R1-2211707 | Discussion on dynamic switching between DFT-S-OFDM and CP-OFDM | CMCC |
| 19 | R1-2211839 | Discussion on dynamic switching between DFT-S-OFDM and CP-OFDM | Apple |
| 20 | R1-2211879 | Discussion on dynamic switching between DFT-S-OFDM and CP-OFDM | FGI |
| 21 | R1-2211897 | Discussion on Dynamic UL Waveform Switching | Ericsson |
| 22 | R1-2211932 | Discussion on dynamic waveform switching for NR coverage enhancement | LG Electronics |
| 23 | R1-2212011 | Discussion on dynamic switching between DFT-S-OFDM and CP-OFDM | NTT DOCOMO, INC. |
| 24 | R1-2212075 | Dynamic switching between DFT-S-OFDM and CP-OFDM | Samsung |
| 25 | R1-2212147 | Dynamic switching between DFT-S-OFDM and CP-OFDM | Qualcomm Incorporated |
| 26 | R1-2212183 | Dynamic switching between DFT-S-OFDM and CP-OFDM for Rel-18 CovEnh | Sharp |
| 27 | R1-2212257 | Dynamic switching between waveforms | MediaTek Inc. |
| 28 | R1-2212272 | Discussion on Dynamic switching mechanism of CP-OFDM and DFT-S-OFDM | Mavenir |
| 29 | R1-2212361 | Discussion on dynamic switching between DFT-S-OFDM and CP-OFDM | NEC |
| 30 | R1-2212431 | Discussion on Dynamic switching between DFT-S-OFDM and CP-OFDM | CEWiT |

# Appendix: Previous agreements

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.)