**3GPP TSG RAN WG1 #110 bis-e R1-22xxxxx**

**e-Meeting, October 10th – 19th, 2022**

**Agenda Item: 9.14.3**

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

**Title: [Draft] Summary #2 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

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|  |  |  |
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|  |  |  |

# Collection of agreements in RAN1#110b-e

[To be captured once agreement is made during this meeting.]

# Proposals

## Proposals for [1st check point or GTW]

TBD

## Proposals for [2nd check point or GTW]

TBD

# Topic #1: Applicability of dynamic waveform switching

A first set of issues is related to the type of transmission concerned by dynamic waveform switching. This discussion has high priority since it may impose requirements on the dynamic signaling mechanism. The following cases are considered separately:

* PUSCH scheduled by dynamic grant
* PUSCH scheduled by configured grant type 1/2
* PUSCH scheduled by RAR (msg3)
* Other cases/issues

## [Open][HP] Issue #1-1: Applicability to PUSCH scheduled by dynamic grant

**Summary of company views from contributions submitted to RAN1#106b-e**

DCI format 0\_1/0\_2 only: Spreadtrum [4], vivo [5], CATT [8], Intel [9], Panasonic [12], InterDigital [13], CMCC [21], Ericsson [22], NTT DOCOMO [26]

* Switching from format 0\_0 to other formats already enables switching [8]
* Supporting format 0\_0 has small benefit, e.g. other formats can be used [8][13][22]
* (For TC-RNTI) Supporting format 0\_0 requires early indication and have large impact [5][26]
* Format 0\_0 only supports RA type 1 [8]
* Format 0\_0 is intended for basic functions [21]
* (If DCI-based indication) Increasing payload of format 0\_0 would be undesirable or (for CSS) not feasible [9][12]

All DCI formats: ZTE (3), China Telecom [6], Mavenir [15]

* (except for TC-RNTI) Can use similar design as UL/SUL indicator to align with format 1\_0 [3]
* (for TC-RNTI) Use same as msg3 initial transmission [3]
* Desirable to maximize number of applicable use cases [6]

At least DCI format 0\_0: Nokia [29]

* Format 0\_0 has smaller payload and is more relevant for coverage enhancements [29]

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

A first observation is that no company proposes that dynamic waveform switching is applicable to a channel or signal other than PUSCH.

Furthermore, all companies’ proposals are consistent with the assumption that PUSCH dynamically scheduled is to be supported at least for some cases. A strong majority proposes that it is applicable at least to PUSCH dynamically scheduled by DCI format 0\_1/0\_2 since such formats can support a larger range of functionalities.

Regarding applicability to PUSCH dynamically scheduled by format 0\_0, views from contributions are more diverse. Majority of companies who expressed views on this think that there is not much motivation if one considers that RRC configurability of DCI format 0\_0 combined with dynamic indication for DCI format 0\_1/0\_2 and the possibility of selecting DCI format provides enough flexibility. Some companies also have concerns about feasibility or impact of modifying DCI format 0\_0 (if one assumed a DCI-based indication). However, several companies would prefer to support DCI format 0\_0 to maximize applicability of dynamic switching or because they see this DCI format 0\_0 as more relevant to coverage-limited scenario.

### 1st round

As a starting point, there seems to be consensus from contributions that dynamic waveform switching enhancement is applicable only to PUSCH channel (i.e. not applicable to other transmissions such as PUCCH). Given that this is not explicitly indicated in the scope of the WI description, moderator suggests agreeing on the following:

**FL proposal 1-1**: Dynamic waveform switching enhancement in R18 is only applicable to PUSCH channel.

Further views and comments on applicability for PUSCH dynamically scheduled by different DCI formats are requested. (Regarding DCI format 0\_0, it is suggested to exclude the case of TC-RNTI for issue #1-1 since it is closely related to issue #1-3 on applicability to msg3 PUSCH.)

Please indicate your views on the following:

1. Indicate if FL proposal 1-1 is acceptable.
2. Applicability to PUSCH dynamically scheduled by DCI format 0\_1/0\_2
3. Applicability to PUSCH dynamically scheduled by DCI format 0\_0 (except by TC-RNTI)

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| Company | Comments |
| CATT | We agree with FL proposal 1-1.  We support to apply dynamic waveform switching to PUSCH dynamically scheduled by DCI format 0\_1/0\_2.  We do NOT support to apply dynamic waveform switching to PUSCH dynamically scheduled by DCI format 0\_0. Dynamic waveform switching of PUSCH is already supported by switching between fallback DCI and non-fallback DCI in current specification and is expected to be supported for PUSCH scheduled by non-fallback DCI. To motivation/benefit to additionally support dynamic switching for PUSCH scheduled by fallback DCI is unclear taking into consideration that there are many restrictions of fallback DCI, e.g. fixed RA type, fixed DMRS configuration/port etc. |
| DOCOMO | 1. We support FL proposal 1-1. 2. Yes, PUSCH scheduled by DCI format 0\_1/0\_2 should be considered. 3. We are open to consider DCI format 0\_0. |
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## [Open][HP] Issue #1-2: Applicability to configured grant

**Summary of company views from contributions submitted to RAN1#106b-e**

CG type 1:

* Yes: Xiaomi [16], (Nokia [29])
  + DG and CG PUSCH have same demands for coverage enhancement [16]
* Open to discuss: China Telecom [6], ETRI [18], Ericsson [22], NTT DOCOMO [26], Qualcomm [27]
  + Benefit of dynamic switching valid for any type of scheduling, but CG type 1 may be difficult [26]
  + Prefer unified solution between DG and CG [26]
  + Would require adapting other parameters. Maybe ok if solution for DG PUSCH can be extended to CG PUSCH without further change [27]
* No: ZTE [3], Spreadtrum [4], vivo [5], CATT [8], Panasonic [12], Lenovo [14]
  + No activation DCI exists for CG type 1 [3][8][12]
  + CG type 1 transmission parameters are configured by RRC [4]

CG type 2:

* Yes: ZTE [3], vivo [5], China Telecom [6], (Sony [10]), InterDigital [13], Xiaomi [16], (Nokia [29])
  + Can reuse solution for dynamic grant [3][5][13]
  + DG and CG PUSCH have same demands for coverage enhancement [16]
  + Supported for activation by formats 0\_0/0\_1/0\_2 [16]
* Open to discuss: CATT [8], Panasonic [12], ETRI [18], NTT DOCOMO [26], Qualcomm [27]
  + Possibly for activation by format 0\_1/0\_2 only [8]
  + Maybe ok if solution for DG PUSCH can be extended to CG PUSCH without further change [12][27]
  + Prefer unified solution between type 1 and type 2 [18]
  + Benefit of dynamic switching valid for any type of scheduling [26]
  + Not critical since multiple CG configurations can be dynamically activated/released [27]
* No: Spreadtrum [4], Lenovo [14], Mediatek [20]
  + Need to change other parameters on top of waveform [4]
  + Not needed since multiple CG configurations with different waveforms can be dynamically activated/released [14][27]

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

For applicability to configured grant, the situation is slightly different depending on whether it is type 1 or type 2. For type 1, about half of companies who expressed views think dynamic waveform switching is not applicable and about half are open to discuss or support this case. For type 2, majority of companies either support or are open to discuss applicability to this case. From the contributions, there does not seem to be very strong view that any of the configured grant cases absolutely needs to be supported. It was also noted that for type 2 a UE that supports multiple configurations can already support equivalent functionality by activating/deactivating different configurations. At the same time, companies envision that a solution supporting dynamic switching for the dynamic grant case can most likely support also configured grant type 2 with very little additional effort.

### 1st round

Further views and comments are requested on the following issues and, whether it is critical to support either case or if it could be considered with lower priority.

1. Applicability to configured grant type 1
2. Applicability to configured grant type 2

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| Company | Comments |
| CATT | As summarized above, we do not support dynamic waveform switching for CG type 1.  For CG type 2, although the motivation and benefit is not clear to us yet, we are open to discuss after we have clearer picture of how dynamic switching of DG PUSCH is achieved. If it can be easily extended to CG type 2, it can be considered. |
| DOCOMO | We have identified that dynamic waveform switching for CG type 1/2 itself has a certain benefit. Yes, for e.g., CG type 2, multiple CG configuration can be configured, where some with CP-OFDM while others with DFT-S-OFDM. Selecting one of them could be considered as “dynamic” in some sense. Meanwhile, waveform change in the middle of a CG chain can be considered, where the same benefit as for DG-PUSCH can be obtained.  Having said that, we indeed agree that support for CG-PUSCH will require more specification impact.  In summary, we are open to discuss above. |
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## [Open][LP] Issue #1-3: Applicability to msg3 PUSCH

**Summary of company views from contributions submitted to RAN1#106b-e**

* **Yes**: ZTE [3], Oppo [7], Sony [10]
  + Same motivation as for msg3 PUSCH repetition [3]. Also support msg3 retransmission.
  + Enables selection based on UE’s channel conditions instead of cell-level [7]
* **Open to discuss**: Intel [9], Panasonic [12], InterDigital [13], Apple [21], LG [25], NTT DOCOMO [26], Nokia [29]
  + Enables selection based on UE’s channel conditions instead of cell-level [9][12][13]
  + Consider with lower priority [12]
  + Useful if the UE does not support msg3 repetition [21]
  + Address possible channel degradation during RACH. Also consider retransmission. [25]
  + Benefit may not be large, need to handle indication of capability issue [26]
  + May be possible to leverage specification effort of other cases [29]
* **No**: Spreadtrum [4], CATT [8], Mediatek [20]
  + Motivation and benefit unclear [8][20]
  + Additional preamble partitioning required [8]
  + Possible impact on RAR grant and DCI format 0\_0 [8]

In addition, no company seems to propose to support dynamic indication for msgA, and one company [8] explicitly proposes to not support it.

**Observations on applicability to msg3 PUSCH**

Among contributions who addressed this case, a majority either supports or is open to discuss applicability to msg3. Supporting companies think that it should be supported for the same reason that msg3 repetition is supported in R17 and envision that some networks may utilize this feature as an alternative to msg3 repetition. On the other hand, non-supporting companies note that the benefit may not be large (e.g. network could configure DFT-S-OFDM at cell level), would also have significant specification impact and possibly entail further preamble partitioning.

### 1st round

Further views and comments are requested on whether dynamic waveform indication needs to be supported for msg3 PUSCH (initial transmission and retransmissions).

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| --- | --- |
| Company | Comments |
| CATT | We do not agree with dynamic waveform switching for Msg 3 PUSCH transmissions. Overall, the benefit is unclear and as moderator mentioned above, network can configure DFT-S-OFDM in the first place. For Msg 3 initial transmission, to achieve dynamic switching, further Msg 1 partitioning is required which should be avoided. For Msg 3 retransmission, it is scheduled by DCI format 0\_0 and our view is that dynamic waveform switching is not applicable to PUSCHs scheduled by DCI format 0\_0 regardless of the RNTI. |
| DOCOMO | **Open to discuss as captured above;** however, we would like to hear proponents view on how much the issue could be significant for Msg3 PUSCH. In what case dynamic waveform switching for Msg3 PUSCH is so useful?  Our understanding is that this feature for dynamic waveform switching is useful for the case where e.g., dynamic “switching” is beneficial. In that sense, the main use case could be where pros/cons for both CP-OFDM and DFT-S-OFDM are valid depending on the exact situation. In that sense, we are not quite sure if it is required for Msg3 PUSCH at least during initial access as the information for gNB to understand proper waveform would be quite limited there.  Yes, there are some cases where CBRA would be performed except initial access, like BFR. But we are not sure how larger the benefit could be even in this case. |
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## [Open][MP] Issue #1-4: Other issues related to requirements and scenarios

**Summary of company views from contributions submitted to RAN1#106b-e**

One company [29] proposes that the dynamic switching framework between CP-OFDM and DFT-S-OFDM should be easily extensible to the scenario of switching among **more than two waveforms**.

* Considering possibility of supporting additional waveforms because of the WID objective of specifying enhancements to reduce MPR/PAR.

For the scenario of **PUSCH repetitions**:

* One company [13] is open to discuss change of waveform before the end of repetitions
  + To address possible degradation of radio conditions when duration of repetition bundle is long
* One company [22] proposes that a change of waveform does not take effect in the middle of multi-slot PUSCH transmission
  + To avoid having to drop some repetition(s) due to circuit reconfiguration

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

One company [24] suggests that dynamic waveform switching could be supported **only from CP-OFDM to DFT-S-OFDM** but not from DFT-S-OFDM to CP-OFDM.

**Observations on other issues related to requirements**

The above issues were raised by only one or a few companies. However, it would be good gather companies’ views on at least the first issues since it may potentially impact the design of the dynamic switching solution.

### 1st round

Further views and comments are requested on the following issues:

1. Is it a requirement that the dynamic switching solution can readily be extended to more than 2 waveforms (to account for possible outcome of 9.14.2)?
2. Supporting change of waveform within a set of PUSCH repetitions (for single or multiple TRP’s)?

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| --- | --- |
| Company | Comments |
| CATT | Whether to support FDSS is subject to further study/discussion. We do not think that needs to be considered for now.  We are not clear about the motivation/benefit to support change of waveform within a set of PUSCH repetitions. |
| DOCOMO | 1. This needs to see the progress in 9.14.2. 2. Open to discuss, although we would like to understand what is the issue when it is supported for PUSCH repetitions? |
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# Topic #2: Dynamic switching mechanism

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

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

**Summary of company views from contributions submitted to RAN1#106b-e**

Companies discussed possible options for the dynamic indication mechanism. Most of the following options were identified in a TEI proposal from R17 [30]. The definition used here for the scheduling DCI options is slightly different than in [30], i.e. “new field” or “reuse existing field” instead of “explicit” or “implicit”. With the “explicit/implicit” definition, the solution of reusing/extending TDRA field could be interpreted as an explicit indication. There are also several options identified in contributions that were not included in [30].

Alt 1-A: New field in scheduling DCI:

* **Preferred**: ZTE [3], Spreadtrum [4], Intel [9], Mediatek [20], Apple [21], Sharp [24]
* **Open**: Vivo [5], China Telecom [6], CATT [8], Sony [10], NEC [11], Panasonic [12], InterDigital [13], Lenovo [14], Mavenir [15], Xiaomi [16], CMCC [17], ETRI [18], Fujitsu [19], Ericsson [22], Samsung [23], LG [25], CEWiT [28], Nokia [29]
* **Not preferred**: Huawei [2], Oppo [7], NTT DOCOMO [26], Qualcomm [27]

Alt 1-B: Existing field in scheduling DCI

* **Preferred**: Huawei [2], Oppo [7], NTT DOCOMO [26]
* **Open**: Vivo [5], China Telecom [6], CATT [8], Sony [10], NEC [11], Panasonic [12], InterDigital [13], Xiaomi [16], CMCC [17], ETRI [18], Fujitsu [19], Samsung [23], LG [25], Qualcomm [27], CEWiT [28], Nokia [29]
* **Not preferred**: ZTE [3], Spreadtrum [4], Intel [9], Lenovo [14], Mavenir [15], Mediatek [20], Apple [21], Ericsson [22], Sharp [24]

Existing fields suggested or mentioned include (including options already outlined in [30]):

* FDRA: [2][8][12][29]
  + RA type [2], MSB of RA type [8]
  + Number of RBs below threshold [29] or multiple of 2,3,5 [30]
  + Location of RB allocation within carrier [29]
* TDRA: [2][7][12][13][25]
  + Add one column to the table
* MCS: [12][13]
  + MCS below threshold [30]
* Antenna port(s)
  + FDMed DMRS based on Number of DMRS CDM group(s) without data [30]
* Precoding information and number of layers [30]
* SRI [26]
* Number of repetitions for msg3 [3]

In addition, the following is noted:

* One contribution [29] suggests that reinterpretation of existing field could be applicable for a subset of PDCCH occasions to mitigate the issue of scheduler restriction.
* One contribution [29] suggests using a condition over a combination of existing fields to indicate the waveform.

Alt 2: MAC CE

* **Preferred**: CMCC [17]
* **Open**: Vivo [5], NEC [11], InterDigital [13], Lenovo [14], Mavenir [15], Xiaomi [16], ETRI [18], Ericsson [22], Samsung [23], Qualcomm [27], CEWiT [28]
* **Not preferred**: Huawei [2], ZTE [3], Spreadtrum [4], China Telecom [6], Oppo [7], CATT [8], Intel [9], Sony [10], Panasonic [12], Fujitsu [19], Mediatek [20], Apple [21], Sharp [24], LG [25], NTT DOCOMO [26], Nokia [29]

Other options:

* DCI without scheduled data [16] or downlink DCI [29]
* Group-common DCI ([4], not preferred), [16]
* Search space [11]
* RNTI [11]
* BWP ID ([18], not preferred)

The following Table summarizes the points made in contributions for the different options:

|  |  |  |
| --- | --- | --- |
| Option | Benefits | Concerns |
| New field in scheduling DCI | -Simple, low specification effort [6][19][20][21][22][29]  -Maintains scheduler flexibility [9][11][29]  -Can change on per-PUSCH basis | -New field may add overhead and reduce coverage [2][18][19][29] and may not be warranted by frequent switching [27]  -Possible increase of DCI size for DFT-S-OFDM to align with CP-OFDM [16][17]  -May not be suitable for DCI format 0\_0 |
| Reuse existing field in scheduling DCI | -No overhead from additional field [27][29]  -Can change on per-PUSCH basis | -May introduce significant scheduler restrictions for use of CP-OFDM compared to R15 [3][9][22]  -Waveform selection may depend on factors not visible in DCI (e.g. cell load, scheduling, fading, antenna blockage) [22]  -Possible increase of DCI size for DFT-S-OFDM to align with CP-OFDM [16][17]  -Higher complexity and specification effort [29]  -Not readily extensible to >2 waveforms [29]  -Rank-based solution not forward-compatible with rank 2 DFT-S-OFDM [3]  -FDM DMRS based solution does not work for DCI format 0\_0 [3] |
| MAC CE | -No increase of DCI overhead [4][11][22][29]  -No DCI size alignment issue [17][28]  -No scheduling restriction [22][27]  -Can support CG [16][22]  -Can change multiple BWPs [14] or serving cells [18] at the same time  -Forward compatible to >2 waveforms [29] | -Larger latency [2][3][4][9][19][20][29]  -Need to define timeline for application [18][26][27]  -Not possible to change on per-PUSCH basis [29]  -Overhead from MAC CE [24]  -Requires RAN2 involvement [26][29] |
| DL or non-scheduling DCI | -Already used for R17 beam indication [16]  -Lower latency [than MAC CE] [29]  -Can support CG with lower overhead (when no UL DCI would otherwise be transmitted) [29] |  |

**Observations on dynamic indication options**

Support for the main options in submitted contributions is rather diverse. Many companies expressed openness to adopt one of several options. However, for each main option there are at least several companies that have concerns. The main concerns are the additional overhead for option 1-A, the loss of scheduler flexibility for option 1-B and the excessive latency for option 2.

### 1st round

Further views and comments are requested on the following issues:

1. Any benefit or concern to add (or remove) in the above Table?
2. Many solutions grouped under 1-B (reuse existing field) but may not have equal impact on loss scheduler flexibility. Are there some solutions that are preferable from that perspective?
3. Any other comment

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| --- | --- |
| Company | Comments |
| CATT | According to the WID, the objective of dynamic waveform switching does not involve RAN2.   |  | | --- | | * Specify enhancements to support dynamic switching between DFT-S-OFDM and CP-OFDM (RAN1) |   Therefore, we think MAC CE based solution is out of scope, which clearly needs RAN2’s involvement.  For DL or non-scheduling DCI solution, we assume it is supplementary proposals for specific purpose, e.g. for dynamic switching of CG. Then clearly, it depends on the other discussions whether the target use case is supported or not. And the proposal requires additional specification efforts.  Therefore, we think scheduling DCI based solutions should be the baseline.  We agree the different solutions under 1-B have different impact on scheduling flexibility and we are open to further discuss. |
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## [Closed][LP] Issue #2-2: DCI size alignment between CP-OFDM and DFT-S-OFDM

**Summary of company views from contributions submitted to RAN1#106b-e**

Many companies [3][4][6][8][11][12][14][26][28] 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. [12][26]

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

If the indication is included in scheduling DCI (new field or existing field), the following options are identified:

* Align DCI size [3][4][6][8][11][12][14][26]
  + Based on highest payload (i.e. CP-OFDM) [3][8][11][12][14][26]
  + Based on lowest payload (i.e. DFT-S-OFDM) ([26], not preferred)
* Not align DCI size ([26], not preferred)[28]

Several companies [3][20] also discuss size alignment between DL and UL DCI in case indication in new field of scheduling DCI is supported. Contribution [3] suggests adding padding as needed to DCI format 0\_0 to match size of DCI format 1\_0. Contribution [20] also suggests using zero padding.

**Observations on DCI size alignment**

This issue can be discussed if/after it is agreed to adopt indication by scheduling DCI.

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

**Summary of company views from contributions submitted to RAN1#106b-e**

Several companies [3][12][14][21][25][26] discuss aspects related to RRC configuration.

* For configuring the dynamic waveform switching feature, contributions [3][12][25][26] propose defining a new RRC parameter. Contribution [21] proposes that the configuration is UE-specific.
* Contribution [14] discusses configuration of RRC parameters specific to CP-OFDM or DFT-S-OFDM.
* Contribution [25] proposes to define a default waveform.
* Contribution [4] proposes to apply MCS table configured for indicated waveform.
* Contribution [8] proposes that DMRS configuration type 2, if configured, applies to PUSCH indicated with CP-OFDM.
* Contributions [4][8] discusses options if *resourceAllocation* IE indicates type 0 in *PUSCH-Config* (e.g. apply to CP-OFDM only or treat as error case)

**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

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

**Summary of company views from contributions submitted to RAN1#106b-e**

Several companies (Huawei [2], InterDigital [13], Ericsson [22], Samsung [23], Nokia [29]) propose enhancements to assist the scheduler in determining when to indicate waveform switching.

Companies provided following justifications:

* Performance improvement from feature may be limited if the network cannot accurately estimate possible power increase after waveform switch [2][22]
* Scheduler cannot rely on MPR requirement since the actual power reduction may be smaller [2][22]
* Difference of Pcmax between waveforms function of UE implementation [2][13]
* R17 PHR has coarse granularity and does not precisely reflect actual UE power boosting capability [29]
* R17 PHR is determined using current waveform [29]
* Useful for scheduler to decide PRB allocation [2]

Companies suggested following examples of possible enhancements:

* Report information on power boosting that would result from waveform switching [2]
* Report power headroom under assumption of waveform different than waveform used for actual PUSCH [13]
* Report power information related to target waveform, e.g. Pcmax,c or PH with assumption of modulation order and RB allocation [22]
* UE requests switching to DFT-S-OFDM when experiencing worsening channel conditions [23]
* Report power headroom for both waveforms [29]
* PHR request to indicate PHR before waveform switching [2]
* Reuse waveform switching signaling to trigger PHR [2]

On the other hand, one company (Spreadtrum [4]) thinks that the scheduler can trigger waveform switching based on current measurement (SRS) and/or reporting information (PHR).

**Observations**

There seems to be significant interest in supporting this type of enhancement especially from network vendors. Since these enhancements may require involvement from other working groups and there is no strong dependency with other topics, discussions should start early. It would be good to collect views from companies that did not discuss this in their contributions.

### 1st round

Please indicate if you are supportive of enhancements to assist the scheduler in determining when to indicate waveform switching. If so, please indicate if you have preference for specific schemes.

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| Company | Comments |
| CATT | For now, we do not see the need for such enhancements. More discussions are needed. |
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# References

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| --- | --- | --- | --- |
| 1 | RP-221858 | Revised WID on Further NR coverage enhancements | China Telecom |
| 2 | R1-2208413 | Discussion on dynamic waveform switching for coverage enhancement | Huawei, HiSilicon |
| 3 | R1-2208490 | Discussion on dynamic waveform switching | ZTE |
| 4 | R1-2208577 | Discussion on dynamic switching between DFT-S-OFDM and CP-OFDM | Spreadtrum Communications |
| 5 | R1-2208673 | Discussions on dynamic switching between DFT-S-OFDM and CP-OFDM | vivo |
| 6 | R1-2208785 | Discussion on dynamic switching between DFT-S-OFDM and CP-OFDM | China Telecom |
| 7 | R1-2208848 | Supporting of dynamic switching between DFT-S-OFDM and CP-OFDM | OPPO |
| 8 | R1-2208965 | Dynamic switching between DFT-S-OFDM and CP-OFDM | CATT |
| 9 | R1-2209080 | Dynamic switching between DFT-S-OFDM and CP-OFDM waveform | Intel Corporation |
| 10 | R1-2209117 | Considerations on dynamic waveform switching for NR UL | Sony |
| 11 | R1-2209160 | Discussion on dynamic switching between DFT-S-OFDM and CP-OFDM | NEC |
| 12 | R1-2209162 | Discussion on dynamic waveform switching | Panasonic |
| 13 | R1-2209205 | Dynamic switching between DFT-S-OFDM and CP-OFDM | InterDigital, Inc. |
| 14 | R1-2209225 | Discussion on dynamic switching between DFT-s-OFDM and CP-OFDM | Lenovo |
| 15 | R1-2209248 | Discussion on solutions for NR dynamic switching between DFT-S-OFDM and CP-OFDM | Mavenir |
| 16 | R1-2209273 | Discussion on dynamic switching between DFT-S-OFDM and CP-OFDM | xiaomi |
| 17 | R1-2209365 | Discussion on dynamic switching between DFT-S-OFDM and CP-OFDM | CMCC |
| 18 | R1-2209413 | Dynamic switching between DFT-S-OFDM and CP-OFDM | ETRI |
| 19 | R1-2209433 | Discussion on Dynamic switching between DFT-s-OFDM and CP-OFDM | Fujitsu Limited |
| 20 | R1-2209523 | Discussion on dynamic switching between waveforms | MediaTek Inc. |
| 21 | R1-2209610 | Discussion on dynamic switching between DFT-S-OFDM and CP-OFDM | Apple |
| 22 | R1-2209674 | Discussion on Dynamic UL Waveform Switching | Ericsson |
| 23 | R1-2209761 | Dynamic switching between DFT-S-OFDM and CP-OFDM | Samsung |
| 24 | R1-2209790 | Dynamic switching between DFT-S-OFDM and CP-OFDM for Rel-18 CovEnh | Sharp |
| 25 | R1-2209804 | Discussion on dynamic waveform switching for NR coverage enhancement | LG Electronics |
| 26 | R1-2209927 | Discussion on dynamic switching between DFT-S-OFDM and CP-OFDM | NTT DOCOMO, INC. |
| 27 | R1-2210015 | Dynamic switching between DFT-S-OFDM and CP-OFDM | Qualcomm Incorporated |
| 28 | R1-2210115 | Discussion on Dynamic switching between DFT-S-OFDM and CP-OFDM | CEWiT |
| 29 | R1-2210167 | Dynamic switching between DFT-s-OFDM and CP-OFDM | Nokia, Nokia Shanghai Bell |
| 30 | R1-2109024 | Rel-17 TEI proposals |  |