**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

Please input the contact information for each company below:

|  |  |  |
| --- | --- | --- |
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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)

|  |  |
| --- | --- |
| 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.
 |
| Intel | 1. We are fine with FL proposal 1-1.
2. We are fine to apply PUSCH dynamically scheduled by DCI format 0\_1/0\_2
3. We do not think we need to consider dynamic waveform switching for PUSCH scheduled by DCI format 0\_0 (except by TC-RNTI).
 |
| Panasonic | a) We support FL proposal 1-1.b) DG-PUSCH scheduled by DCI format 0-1/0-2 should support dynamic waveform switching.c) In order to utilize DCI format 0-0 regardless of RRC status and to keep the same payload size in common search space, no change should be applied. Therefore, our view is that dynamic waveform switching is not required for DG-PUSCH scheduled by DCI format 0-0. |
| vivo | 1. Fine with FL’s proposal 1-1.
2. Applicable.
3. Not preferred.

It’s enough to follow Msg3 waveform configured by RRC for PUSCH transmissions scheduled by fallback DCI. Unified waveform determination mechanism for Msg3 retransmissions and other PUSCH transmissions scheduled by fallback DCI should be pursued. |
| QC | Proposal 1-1 is acceptable.DWS can be applied to DG-PUSCH scheduled via 0\_1/0\_2.For DG-PUSCH scheduled via 0\_0, ensuring robustness of fallback DCI takes precedence. Adding an explicit bit to DCI is definitely not an option here. Open to discuss further as 0\_0 may be relevant to a cell-edge UE. |
| LG | 1. We are fine with FL proposal 1-1.
2. We are fine to support dynamic waveform switching for PUSCH dynamically scheduled by DCI format 0\_1/0\_2
3. We are open to discuss supporting dynamic waveform switching for PUSCH dynamically scheduled by DCI format 0\_0 (except by TC-RNTI)
 |
| China Telecom | 1. We are fine with FL’s proposal 1-1
2. Yes, fine to support the dynamic waveform switching for PUSCH scheduled by DCI format 0\_1/0\_2
3. Yes, fine to support the dynamic waveform switching for PUSCH scheduled by DCI format 0\_0.
 |
| Vodafone | a) We are fine with proposal 1-1b) OK1. c) Same view as QC
 |
| Spreadtrum | a) Support.b) Support.c) Not support. Fallback DCI 0\_0 has high requirement of robustness, and it should be work well during the RRC reconfiguration, which may include the waveform information and would lead to misunderstanding between gNB and UE during the configuration phase if dynamic waveform switching is supported. Besides, the fallback DCI supports basic function and has many scheduling restrictions. Therefore, we think PUSCH scheduled by fallback DCI 0\_0 cannot support dynamic waveform switching. |
| ZTE | 1. We support FL proposal 1-1.
2. Yes, PUSCH scheduled by DCI format 0\_1/0\_2 should be considered.
3. Yes, PUSCH scheduled by DCI format 0\_0 should also be considered. The increase of DC payload is not big issue if similar design as UL/SUL indicator to align with format 1\_0 is adopted.
 |
| Sharp | 1. We support FL proposal 1-1.
2. Yes, PUSCH scheduled by DCI format 0\_1/0\_2 should support the dynamic switching.
3. We are open to consider Msg3. For the other cases, we prefer not considering DCI format 0\_0. We didn’t touch fallback DCI related behavior in Rel-17 CovEnh, and we do not see a strong need of enhancements only for the dynamic switching.
 |
| CMCC | 1. Support.
2. OK

We do not want to apply any change for DCI 0\_0 since this is a fallback DCI format. |
| Transsion | 1. We are fine with FL’s proposal 1-1
2. Yes, we are fine to support dynamic waveform switching for PUSCH dynamically scheduled by DCI format 0\_1/0\_2
3. We are open to discuss whether to support the dynamic waveform switching for PUSCH dynamically scheduled by DCI format 0\_0 (except by TC-RNTI).
 |
| Sony | a) We agree with FL proposal 1-1b) Support applicability for PUSCH scheduled by DCI format 0\_1/0\_2 should support the dynamic switching. c) Support applicability for Msg3 PUSCH |
| Lenovo | Agree with FL proposal 1-1.We support dynamic waveform switching is appliable to PUSCH dynamically scheduled by DCI format 0\_1/0\_2 only considering the restrictions of DCI format 0\_0.  |
| ETRI | We support the proposal 1-1.Answer to b and c would be different from which solutions are adopted. If DCI based solution is used, then further questions can be made about DCI formats or (non)scheduling DCIs, etc. If MAC CE based solution is used, then any DCI format can switch the waveform. In this stage, we prefer to support at least non-fallback DCI formats and FFS fallback DCI format. |

## [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

|  |  |
| --- | --- |
| 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.  |
| Intel | We support b), at least for PUSCH activated by DCI format 0\_1 and 0\_2. We do not think this can apply for Type 1 CG-PUSCH, as by nature, it is not based on dynamic scheduling.  |
| Panasonic | a) For Type 1 CG-PUSCH, since there is no dynamic indication in existing specification, it is not necessary to support dynamic waveform switching. To introduce dynamic indication for Type 1 CG-PUSCH would have large specification impact.b) For Type 2 CG-PUSCH, if dynamic switching is supported for DCI format 0-1/0-2, to support dynamic waveform switching via activation DCI with the unified indication mechanism could be considered. |
| Vivo | 1. Open to discuss
2. Applicable if activated by non-fallback DCI, similar to DG PUSCH scheduled by non-fallback DCI.
 |
| QC | Don’t think its critical. May suffice to focus on DG-PUSCH. |
| LG | Agree with Panasonic. We think dynamic waveform switching can be available for Type-2 CG-PUSCH.  |
| China Telecom | We support option b) to support the dynamic waveform switching for Type-2 CG-PUSCH only since there is no dynamic scheduling indication for Type-1 CG-PUSCH.  |
| Vodafone | Fine to prioritize DG over CG |
| Spreadtrum | We think dynamic waveform switching is not suitable for CG-PUSCH initial transmission, since there is no basis for dynamically switching waveforms. For type 1 CG-PUSCH, all transmission parameters cannot be dynamically changed, so dynamic waveform switching cannot be performed. For type 2 CG-PUSCH, if the waveform needs to be changed during transmission, waveform related parameters cannot be changed during the current DCI activation. Thus, we think dynamic waveform cannot be applied to CG-PUSCH. |
| ZTE | 1. Not support. No activation DCI exists for CG type 1. Great specification efforts may be needed to support dynamic waveform switching for CG type 1.
2. Support. Can reuse solution for dynamic grant.
 |
| Sharp | Type 1 CG-PUSCH should not be considered, as it is not based on DCI.Type 2 CG-PUSCH activated by DCI format 0\_1 and 0\_2 can be considered to support the dynamic switching. |
| CMCC | We think this “switching” may be fulfil by indicating different CG configurations. |
| Transsion | 1. Configured grant type 1 is activated/deactivated by RRC signaling, which operates in a semi-static manner. The introduction of a dynamic waveform switching mechanism will break the principle of CG type 1.
2. We are open to discuss it.
 |
| Sony | Type 1 CG-PUSCH – support at configurationType 2 CG-PUSCH – support through activation DCI |
| Lenovo | We think dynamic waveform switching for CG type 1 and CG type 2 has low priority.For CG type 1, up to 12 CG configurations con be configured in a BWP, different CG configurations can be of different waveforms. A UE can transmit PUSCH based on different CG configuration to implicitly switch the waveform. For CG type 2, DCI can activate/deactivate a CG type 2 transmission. By activating/deactivating CG PUSCH transmissions with different waveforms, the gNB can switch the waveform for CG PUSCHs dynamically. The current standard is flexibility enough for CG PUSCH transmission. The focus of R18 should be on dynamic grant PUSCH. |
| ETRI | As commented above, Type2 CG (as well as Type1 CG) can switch waveform by using UL skipping with the existing specification. In addition, in our understanding, Type1 CG does not require any need for resource allocations, however a UE monitors search spaces from which switching waveform can be indicated. We think dynamic indications for Type1 CG are valid solutions.We think that we need to discuss whether the configured grant of both types would be the scope of further efforts, and we prefer supporting both type of configured grants. |

## [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).

|  |  |
| --- | --- |
| 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.  |
| Intel | We think this should be supported.Msg3-transformPrecoder is a cell specific parameter, which does not consider UE specific channel condition. For example, we defined Msg3 PUSCH repetition in Rel-17. In this case, we do not think it is desirable to consider CP-OFDM waveform for Msg3 PUSCH repetition.  |
| Panasonic | In our view, the main reason to support dynamic switching between DFT-s-OFDM and CP-OFDM is that higher rank operation in good SINR is limited when semi-static DFT-s-OFDM configuration. Therefore, the necessary functionality should be to support dynamic switch between 1-layer transmission with DFT-s-OFDM and 2 or more layers transmission with CP-OFDM. Since Msg.3 PUSCH is limited to 1-layer transmission, the motivation on the applicability to Msg.3 PUSCH is low. |
| Vivo | Do not support.DWS in RRC idle/inactive is a new UE capability which has to be early indicated via e.g. separate PRACH resources. The gain from DWS compare to repetition and retransmissions is not obvious. Considering the large spec. impact, high complexity and the necessity from performance point of view, we do not support DWS for Msg3. |
| QC | Don’t think its necessary to support. Dynamic switching for a UE not yet in connected state, without clear capability report is a major undertaking with no clear benefits. |
| LG | Regarding on Msg3 PUSCH, if the channel quality of the UE is degraded during the RACH procedure, the gNB can dynamically change the UL waveform of Msg3 PUSCH (including the re-transmission of Msg3 PUSCH). Therefore, this issue can be further discuss later. |
| China Telecom | We don’t think it is necessary now. The mechanism for dynamic waveform switching for Msg 3 PUSCH transmissions can be quiet complex since the RACH procedure haven’t done, there is lots of work to do on how the network know whether the UE’s capability and indicate the UE switching the waveform. We may focus on the PUSCH at the point. |
| Vodafone | Similar view as LG above.  |
| Spreadtrum | For normal Msg3 PUSCH, it is not necessary to use dynamic waveform switching. We think it is enough to determine the waveform according to the current configuration of high-level parameters msg3-transformPrecoder. Besides, before the RRC connection set up, gNB can only obtain partial information about the UE. So the gNB cannot do proper and timely waveform switching decision.For Msg3 PUSCH repetition, we are open to discuss as it also has requirement for uplink enhancements, but depend on how much gain can be achieved. |
| ZTE | We support that dynamic waveform switching is supported for Msg3 PUSCH, since it has same motivation as Msg3 PUSCH repetition to enhance the coverage. The concern on DCI payload size can be solved by implicit dynamic waveform indication, for example, if the number of Msg3 PUSCH repetitions is larger than 1, UE can ignore the RRC configuration “msg3-transformPrecoder” and set waveform as “DFT-s-OFDM”. For Msg3 PUSCH retransmission, UE just simply follows the waveform of the initial Msg3 PUSCH. No any separate PRACH resource to indicate the waveform for Msg3 PUSCH is needed. |
| Sharp | Open to study. |
| CMCC | Current spec to determine msg3 waveform based on high-level parameter *msg3-transformPrecoder* seems already enough. |
| Transsion | We don’t think it is necessary. |
| Sony | We support that dynamic waveform switching is supported for Msg3 PUSCH |
| Lenovo | We do not support dynamic waveform switching for Msg 3 PUSCH, the benefit is unclear to us. There is no enough information for gNB to switch the waveform for Msg3 PUSCH dynamically. The configured waveform for this PUSCH is sufficient.  |
| ETRI | We do not think it is necessary since Msg3 repetition factor would be chosen to be within the UL coverage. |

## [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)?

|  |  |
| --- | --- |
| 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?
 |
| Intel | 1. It is clearly out of scope for NR as only CP-OFDM and DFT-s-OFDM waveform are supported for PUSCH.
2. No. It is not clear to us the motivation. This depends on UE specific channel condition.
 |
| Panasonic | a) We are open to consider more than 2 waveforms based on the outcome of 9.14.2.b) No, we don’t see the clear merit. |
| Vivo | 1. No. According to the WID, only DFT-s-OFDM and CP-OFDM are considered in this work item

*•Specify enhancements to support dynamic switching between DFT-S-OFDMand CP-OFDM(RAN1)*1. For single TRP, we do not see the need to change the waveforms. But for transmissions to/in different TRPs/cells, the channel state and link qualities are different, there’s no reason to restrict them to have same waveforms and thereby independent waveform switching is preferred.
 |
| QC | On (a): This consideration can take a back seat for now. At this point nothing is agreed, and the situation will stay the same for the next couple of meetings.On (b): prefer to have all repetitions carried by the same waveform type. |
| LG | 1. Agree with Intel. It is out of scope of Rel-18 CE.
2. We think dynamic waveform switching is not preferred for PUSCH repetition in single cell. But, we are open to discuss supporting dynamic waveform switching in multiple PUSCH transmissions for multiple TRPs.
 |
| China Telecom | 1. We prefer no to consider the situation at the point. We need to wait for the conclusions of FDSS and AI 9.14.2 to know whether the switching between more than 2 waveforms can happen, but we are open to discuss in later meetings.
2. The motivation and benefits seems unclear for us now, we prefer not to support it at the point.
 |
| Vodafone | 1. Same view as CATT, DCM, Panasonic and QC
2. Same view as DCM
 |
| Spreadtrum | a) It is out of scope.b) Not support.  |
| ZTE | 1. We are open to discuss it depending on the outcome of 9.14.2.
2. The motivation/benefit to support change of waveform within a set of PUSCH repetitions should be identified first.
 |
| Sharp | 1. Switching between DFT-S-OFDM with FDSS and DFT-S-OFDM without FDSS and switching between CP-OFDM with FDSS and CP-OFDM without FDSS can be left to AI9.14.2, if necessary. AI 9.14.3 should focus on switching between DFT-s-OFDM and CP-OFDM only, as described in the WID.
2. No, we do not see the clear motivation. On the contrary, it would make the repetition behaviour too complex.
 |
| CMCC | 1. We are open to wait progress in 9.14.2
2. Not support.
 |
| Transsion | 1. We think it can be discussed further.
2. For single TRP, we see no benefit in supporting dynamic waveform switch for a set of PUSCH repetition, since the channel status does not change significantly. For multiple TRPs, it is worth investigating to support change of waveform within a set of PUSCH repetitions, considering that the channel status of the different UE-TRP links are not same,
 |
| Sony | a) We do not think that it is currently a requirement to extend to more than two waveforms but open to discussb) No, we do not see merit in this |
| Lenovo | a) Only CP-OFDM and DFT-s-OFDM are supported for PUSCH by current standards, and in the WID, it is saying “dynamic switching between DFT-S-OFDM and CP-OFDM”. We should focus on dynamic switching between these two waveforms.b) We are open to discuss the waveform switching within a set of PUSCH repetitions if clear benefit is shown. If supported, the dynamic indication mechanism should be addressed in issue #2-1. |
| ETRI | a) We think the scope of WI is switch between two waveforms. b) We are open to discuss. |

# 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

|  |  |
| --- | --- |
| 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. |
| Intel | 1. we are generally fine with the benefit or concerns listed in the table. For explicit signalling, we tend to think DCI format 0\_0 does not need to enhanced to support dynamic waveform switching so the concern for this can be removed.

In general, it would be good to first agree on a set of alternatives for down-selection in the upcoming meeting.  |
| Panasonic | b) Since the main reason to support dynamic switching between DFT-s-OFDM and CP-OFDM is that higher rank operation in good SINR is limited when semi-static DFT-s-OFDM configuration, the necessary functionality should be to support dynamic switch between 1-layer transmission with DFT-s-OFDM and 2 or more layers transmission with CP-OFDM. Then, just to support the implicit indication based on number of layers would be the most straightforward design. |
| vivo | For “New field in scheduling DCI”, following items should be included in the 3rd column as well:-Higher complexity and specification effort -Rank-based solution not forward-compatible with rank 2 DFT-S-OFDM-FDM DMRS based solution does not work for DCI format 0\_0For “DL or non-scheduling DCI”, it requires new DCI format discussions if I understand correctly. In addition, rules to avoid rank/DMRS Type/FDRA configurations not supported with some waveform are also needed. |
| LG | For the sake of progress, it may be desirable to consider the proposal listing all possible options in this meeting. |
| China Telecom | The issue is important but we think we should focus on the situation and condition for waveform dynamic switching first. The down-selection can be done later or in the next meeting. |
| Vodafone | We are supportive of a DCI-based switching mechanism due to lower latency compared to MAC-CE and also it could avoid RAN2 involvement. For the implicit signalling, perhaps more than one indicator can be used to avoid scheduling flexibility concerns |
| Spreadtrum | We think “explicit” or “implicit” instead of “new field” or “reuse existing field” may be clearer. We are open to reuse existing field, but reluctant to support implicit indication by setting some conditions, which would limit the flexibility of gNB scheduling. From our perspective, explicit DCI-based indication is most straightforward and simplest. For explicit indication, whether to add new field or reuse existing bit can be discussed further. It is also possible to indicate waveform by TDRA field in the DCI by associating different waveforms with different rows of TDRA table.For “DL or non-scheduling DCI solution”, we share the similar view with CATT. |
| ZTE | 1. We are fine with the summary table.
2. Number of repetitions for msg3 is an implicit indication for the waveform decision of Msg3 PUSCH transmission. This scheme is only valid for Msg3, so we suggest to discuss it in the Msg3 session.
 |
| Sharp | The table looks fine to us. |
| CMCC | The switching between two waveform can be divided into two directions. For switching from CP-OFDM to DFT-S-OFDM, in current spec, it can be realized by multiple DCI from non-fallback DCI to fallback DCI. For switching from DFT-S-OFDM to CP-OFDM, the latency for MAC CE based signalling is acceptable, and this changing direction is unproper in coverage limited scenario. MAC CE based signalling can also avoid matters about DCI size alignment and increase of DCI overhead. We are open to further discuss three options. |
| Transsion | We are fine with the table. |
| Sony | We are fine with summary tableReusing fields will impact legacy behaviour |
| Lenovo | We have concern on DL or non-scheduling DCI solution. For DL scheduling DCI, the DCI size will be increased and for non-scheduling DCI, while existing field used for dynamic switching waveform also needs discussion. And the application time of the waveform switching needs to be defined. Besides, the UE’s behavior becomes more complexity. For example, if there is no PDSCH scheduling before a PUSCH transmission, in a window for example, the UE should receive a non-scheduling DCI dedicated for switching the waveform. But if the waveform switching is in scheduling DCI, a UE just needs to decode the UL-scheduling DCI only. |
| ETRI | We think that the table with pros and cons can be more complete after the Topic #1 has some outcome. |

## [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.

|  |  |
| --- | --- |
| Company | Comments |
| CATT | For now, we do not see the need for such enhancements. More discussions are needed. |
| Intel | We tend to think this is out of scope for this AI. We do not see the need to further optimize the PHR for enhancement on dynamic waveform switching. Further discussions are needed to clarify the motivation and benefit.  |
| Panasonic | We are supportive to consider PHR aspects. |
| vivo | We’re open to study this with medium priority in coming meetings given the justifications summarized by feature leader, although in this first meeting we can focus on HP items. |
| QC | Support. Open to enhancing the PHR framework to facilitate DWS. |
| LG | We think that more discussions are needed to clarify the benefit. |
| China Telecom | Support.  |
| Spreadtrum | We think gNB can trigger waveform switching based on the current measurement and/or reporting information. But we are open to consider other assistant information if such enhancement can help gNB to select more appropriate waveforms. |
| ZTE | We are open to this issue. More discussion are needed. For PHR, we think gNB has the capability to estimate the difference of PHR between DFT-s-OFDM and CP-OFDM. |
| Sharp | Open to discuss |
| CMCC | We think current reporting can help gNB comprehend the UE condition. We can further discuss this issue. |
| Transsion | We are supportive to enhance the PHR framework. |
| Sony | Open to discuss |
| Lenovo | We are open for more discussion on this issue. |

# References

|  |  |  |  |
| --- | --- | --- | --- |
| 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 |  |