3GPP TSG-RAN WG2 #121-bis-e R2-23xxxxx  
Online, 17 – 26 April, 2023

Agenda Item: 8.3.2

Source: InterDigital

Title: Report of [POST121][311][NES] DTX/DRX - gNB and UE behaviours

Document for: Discussion, Decision

# Introduction

This is report for the following email discussion:

* [POST121][311][NES] DTX/DRX - gNB and UE behaviours (InterDigital)
  + - Scope: Provide and summarize companies' views on:
      * Understanding of gNB and UE behaviours during non-active period, including SPS, CG, SR, Dynamic Grant.
      * RAN2#121 discussions and contributions are a starting point.
    - Intended outcome: Report to the next meeting (with agreeable proposals)

The aim of the discussion is to get an understanding of the expected gNB and UE behaviours during Cell DRX and Cell DTX non-active periods, i.e. whether certain transmissions can be made by the UE during cell DRX non-active period and whether certain receptions can be assumed during the Cell DTX non-active period. The scope is to initially focus on whether SPS, CG, SR, and dynamic grants could be received/transmitted during the non-active period.

**The deadline for comments:** Wednesday, April 5th 2023, 12:00 UTC

Companies are invited to provide their contact information for this email discussion here:

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# Background

One objective of on network energy saving (NES) [1] is on Cell DTX/DRX:

* Specify enhancement on cell DTX/DRX mechanism including the alignment of cell DTX/DRX and UE DRX in RRC\_CONNECTED mode, and inter-node information exchange on cell DTX/DRX [RAN2, RAN1, RAN3]
* Note: No change for SSB transmission due to cell DTX/DRX.
* Note: The impact to IDLE/INACTIVE UEs due to the above enhancement should be avoided.

During the study item phase, the following text proposal was captured in TR 38.864 [2] to describe Cell DTX and Cell DRX:

|  |
| --- |
| 6.1.4.4 Higher layer procedures  Cell DTX/DRX is applied to at least UEs in RRC\_CONNECTED state. A periodic Cell DTX/DRX (i.e., active and non-active periods) can be configured by gNB via UE-specific RRC signalling per serving cell. Below examples on Cell DTX/DRX behaviour during non-active periods are assumed to be possible options, and the UE behaviour/impact will be studied:  - Example 1: gNB is expected to turn off all transmission and reception for data traffic and reference signal during Cell DTX/DRX non-active periods.  - Example 2: gNB is expected to turn off its transmission/reception only for data traffic during Cell DTX/DRX non-active periods (i.e., gNB will still transmit/receive reference signals)  - Example 3: gNB is expected to turn off its dynamic data transmission/reception during Cell DTX/DRX non-active periods (i.e., gNB is expected to still perform transmission/reception in periodic resources, including SPS, CG-PUSCH, SR, RACH, and SRS).  - Example 4: gNB is expected to only transmit reference signals (e.g., CSI-RS for measurement).  The study focus on UE behavior when at any point in time the cell activates a single DTX/DRX configuration. It is up to NW whether legacy UEs can access cells with Cell DTX/DRX.  The Cell DTX/DRX mode can be activated/de-activated via dynamic L1/L2 signalling and UE-specific RRC signaling. Both UE specific and common L1/L2 signalling can be considered for activating/deactivating the Cell DTX/DRX mode.  Cell DTX and Cell DRX modes can be configured and operated separately (e.g., one RRC configuration set for DL and another for UL). Cell DTX/DRX can also be configured and operated together. At least the following parameters can be configured per Cell DTX/DRX configuration: periodicity, start slot/offset, on duration. Details related to UE behaviour can be discussed during WI phase. Whether to support multiple Cell DTX/DRX configurations can be discussed later in the WI phase.  It is beneficial to align UE DRX with Cell DTX and DRX alignment among multiple UEs. The alignment mechanism can be discussed during the WI phase.  From RAN2 perspective, Cell DTX/DRX is feasible. |

In RAN2#121, the first meeting of the WI, an initial discussion was had on the expected UE behaviour during non-active periods of cell DTX and cell DRX, and the following was agreed:

**Agreements**

1. There will be no impact to RACH, paging, and SIBs in idle/inactive for both gNB and Rel-18 and legacy UEs
2. Rel-18 NES capable CONNECTED UE(s) can perform RACH and receive SIBs in non-active duration of cell DTX and/or DRX (i.e., same behavior for cell DTX and cell DRX). No further enhancements for CBRA and CFRA will be pursued.
3. Pattern configuration for cell DRX/DTX is common for Rel-18 UEs in the cell. FFS whether we have DTX UE specific inactivity timer. FFS on configuration signaling and stage 3.
4. Confirm study item agreement that we can have separate DTX and DRX configuration. We will focus on designing DTX/DRX for at least single configuration. FFS whether multiple configuration of cell DTX or DRX will be supported.

Further, RAN1 agreed to the following in RAN1#112:

Agreement

* RAN1 continues discussion on the at least following physical layer related aspects of cell DTX/DRX aspects
  + physical layer signals/channels and procedures expected to be impacted during non-active periods of cell DTX/DRX
    - consider impact to at least KPIs from the SI when physical layers/signals/channels are impacted by cell DTX/DRX
* Further discussions on other aspects are not precluded

Agreement

At least the following candidate signals/channels for connected mode UEs, which the UE may be expected to not transmit or receive during non-active periods of cell DTX/DRX, are considered from RAN1 perspective for further discussion. The exact set of signals/channels that the UE may be expected to not transmit or receive is FFS.

* DL
  + Periodic/Semi-persistent CSI-RS (including TRS)
  + PRS
  + PDCCH scrambled with UE specific RNTI
  + PDCCH in Type-3 CSS
  + SPS-PDSCH
* UL
  + SR
  + Periodic/Semi-persistent CSI report
  + Periodic/Semi-persistent SRS
  + CG-PUSCH

Other signals/channels are not precluded

As a first step, this discussion aims at understanding which Uplink signals and channels can be assumed to be dropped or transmitted by the UE during the Cell DRX no-active period, and which Downlink signals and channels can be assumed to be received by the UE during the Cell DRX no-active period. Accordingly, rather than discussing a single blanket UE-gNB expected behaviour during cell DTX/DRX non-active periods, the behaviour is discussed next for each DL and UL channel type.

# Behaviour during Cell DTX/Cell DRX non-active periods

## SPS-PDSCH reception during Cell DTX non-active periods

In RAN2#121, an initial discussion on the gNB and UE behaviour for SPS PDSCH monitoring and reception during the Cell DTX non-active period took place, and the SPS behaviour is FFS. The options below were discussed. During online discussion, many companies shared the understanding that if the gNB is not transmitting on SPS-PDSCH occasions, the UE should not monitor in order to save power, and this also enable greater network energy savings. Some mentioned the concern that the gNB has to stay awake during non-active periods of cell DTX and DRX if the UE is expected to monitor SPS or can transmit on CG occasions during the non-active period. Most companies therefore expressed that option 1 is the most straight forward/less complex as an assumption and leading to most energy savings.

SPS and CG transmissions are also listed in the R1 agreement part of the list of channels that “the UE may be expected to not transmit or receive during non-active periods of cell DTX/DRX”. Companies are therefore encouraged to consider such agreements before repeating the same preferences expressed online. Some companies preferred option 3, stating that gNB has better flexibility to configure some SPS resources to be monitored during the non-active period, depending on the latency of the traffic.

* Option 1: UE can drop monitoring SPS occasions during Cell DTX non-active period. gNB is assumed to be not transmitting PDSCH on such SPS occasions during the Cell DTX non-active period.
* Option 2: UE monitors SPS occasions during Cell DTX non-active period
* Option 3: configure the behaviour from gNB (whether to monitor or not), e.g. per SPS configuration, per cell DTX configuration, or per MAC entity

**Question 1: which of the above options do you prefer for the UE behaviour for SPS monitoring and reception during Cell DTX non-active periods?**

|  |  |  |
| --- | --- | --- |
| Company | Preferred option | Additional comments |
| Apple | Option 2 or Option 3 | First, we think Cell DTX/DRX needs to consider delay sensitive traffic. Otherwise, some key KPI of UE and NW will may degrade under Cell DTX/DRX. During SI, we didn't have clear conclusion on whether/how much KPI decrease can be tolerated in NES. So, we still need to first try to find best tradeoff between NES and performance KPI in normative phase.  Then, for SPS, we think it can be up to NW implementation whether to send SPS-PDSCH or ignore SPS occasion within non-active duration. For example, if one UE's delay sensitive traffic arrives, gNB can use its earlies SPS occasion to transmit. As another example, if traffic with no urgent delay requirement arrives or gNB strives for max NES gain, gNB can choose to wait to next active duration of Cell DTX to transmit it (i.e. not use SPS in non-active duration).  The only cost is that the UE needs to monitor SPS occasion during non-active period (i.e. option 2). But we don't think it will incur much UE power consumption because it is periodic occasion where the UE can sleep in-between 2 consecutive occasions. And please note that UE CDRX also allows UE to monitor SPS in DRX OFF, which implies UE power consumption due to SPS is small. Furthermore, if still concern on UE power consumption, we can also consider some solution to reduce number of monitored SPS occasion (i.e. Option 3). Detailed solution of Option 3 can be further discussed. |
| Lenovo | Option 1 | We see value in keeping things simple. “Cell DTX non-active time” to us means the network is REALLY saving energy, by not transmitting. Having per UE control of “real” DTX on/ off is not useful unless real benefits from field/ simulations are shown. |
| CATT | Option 3 | First, RAN1 agreement is aligned with option 3, since “maybe expected” matches well “can be configured to”.  Then, we prefer making the SPS “skipping” during Cell DTX non-active periods configurable per UE and SPS configuration. As mentioned during the on-line discussion it leaves the flexibility to the network to keep serving critical data traffic for some UEs. One can argue that those UEs should be expected to be HO’ed to another cell, but 1) it assumes there is always a possibility to HO the UE without performance degradation and 2) there could be some time overlap between the Cell transition to Cell DTX and the successful execution of the UE’s HO, in which case it is beneficial to keep serving those UEs while still saving power early thanks to the Cell DTX applied to other UEs. Note also the same holds true for a non-NES-capable UE that needs to be served during the same intermediate period of time from the Cell DTX activation until the successful execution of the UE’s HO.  In other words, option 3 non-only provides more flexibility to network for making use of the Cell DTX feature (and, to this extend, option 1 is included in option 3), but it also brings more NES gain by allowing the network to switch to Cell DTX early, i.e. before all critical UEs and non-NES-capable UEs have successfully hand-off’ed to another cell. |
| BT | Option 1 | The main goal of cell DTX/DRX is to reduce network power consumption that means for us, during cell DTX non-active time, network does not transmit anything apart from it is already agreed by RAN2.  This simple approach will facilitate UE power saving and standardization efforts. |
| Vodafone | Option 1 | I think we define cells which will be able to save the energy and those are not the coverage layer cells. Such cells should handover the UEs to other layers if there is a delay sensitive traffic and again, the amount of such UEs should be very low.. |
| Qualcomm | 1/3 | It would make sense if the cell is going into DTX mode that it suspends data  transmission, and subsequently, the UE should not be monitoring this SPS  occasion, since it is likely that the cell shall allocate the SPS occasions within  the cell DTX active periods.  However, if there is a lot of consensus that there is a case to serve delay  sensitive traffic while deploying cell DTX, it may make sense to also allow  configurable behavior by adding an indication to SPS to bypass cell DTX  configuration as an exception, which a straightforward way to realize option 3  as well.  We do not favor the UE monitoring SPS occasions if the cell decides not to  use them as implied by option 2 |
| NEC | Option-1 | We support to define a simple solution, which actually maximize the energy saving gain for the cell. |
| Huawei | Option 1 | The UE can keep the configuration, but skip the SPS occasions monitoring during Cell DTX non-active periods. Configuration of the behaviour from the gNB to the UE brings unnecessary complexity to the procedure and is a waste of energy.  For SPS/CG/SR (Q1/Q2/Q3), mostly UE behaviour is discussed. We think gNB behaviour also needs to be clarified in these cases, e.g. for SPS the gNB behaviour is to not transmit PDSCH on SPS occasions.  Option 2 is already achievable by UE C-DRX. We would like to see higher network energy saving gains using Cell DTX/DRX compared with the existing mechanisms, i.e. UE C-DRX and intelligent network scheduling. To achieve it the Cell DTX/DRX solution should stop more signals than dynamic data transmission and reception, which can include among others (as listed by RAN1): SPS, CG, SR.  We assume that the Cell DTX/DRX is for a low load scenario and should not be designed to serve all types of traffic (including e.g. delay sensitive, URLLC, etc.) as the NW can always turn off DTX/DRX to serve more demanding traffic. |
| Ericsson | Option 1 or Option 3 | We support Option 1 for the reasons summarized by the Rapporteur (i.e., it is the least complex solution leading to most energy savings, and it is also captured as a potential solution in R1 agreements). We agree with Apple that the Cell DTX/DRX feature should have limited impact on the QoS/QoE requirements, but our opinion is that the transmission schemes relying on preconfigured periodic data transmissions are not the most appropriate candidates for achieving the tradeoff between NW energy savings and the impact on the QoS/QoE. This is because the main purpose of Cell DTX/DRX feature is to enable NW energy savings, and hence one can expect that during Cell DTX/DRX non-active periods the NW will try to avoid preforming periodic data transmissions implied by semi-persistent scheduling mechanisms. Instead, when necessary, the NW would allow occasional data transmissions (i.e., in the case of emergency calls and traffic with high QoS/QoE requirements), which can be naturally accommodated by adopting certain solutions concerning dynamic scheduling schemes disused in Section 3.4.  Alternatively, we are also fine with Option 3 since it basically allows both option 1 and option 2. |
| OPPO | 1/3 | It would be benefit if the gNB does not transmit SPS during Cell DTX non-active duration, which can achieve more NW energy saving gains (even if the gNB may have to transmit SPS for the non-NES capable UEs). Accordingly, the NES-capable UE should keep SPS configuration but does not monitor this SPS.  We understand NES focuses on low load case while may actually degrade the UE’s performance if the corresponding gNB enables the NES techniques. That would be a trade-off between energy saving gains and performance degradation. With this in mind, if the NES cell still needs to serve delay sensitive traffics, we think the NES network needs to take such KPI into account in its strategy, e.g. hand over the UEs with delay sensitive requirement to other cells, schedule DG for the delay sensitive traffic if the gNB knows the traffic characteristics, or enable/disable the SPS monitoring. |
| Intel | Option 3 | In our view, SPS, CG and SR may all affects the QoS of the UE DRBs and this should be left to the network to decide/configure/indicate whether UE should still transmit data on CG and send SR or receive data on SPS. If network does want to avoid the UE from using these occasions, it can anyway (re)configure these SPS transmission occasions and CG and SR reception occasions such that their occasions only occur in the active period of Cell DTX/DRX.  As on the granularity of whether the UE should ignore or consider the occasions, our preference is that it can be done on per cell DTX configuration to simplify the UE behaviour. |
| ETRI | Option1/3 | At least Option 1 should be supported and Option 3 is also fine. |
| Nokia | Option 1 | 3 could also be acceptable if seen needed. |

## CG transmission during Cell DRX non-active period

Similar to DL SPS, a similar question can be made for CG transmission during Cell DRX non-active period in the UL direction on configured grant resources. The following options are thus also possible:

* Option 1: UE does not transmit on CG occasions overlapping with Cell DRX non-active periods.
* Option 2: UE can transmit on CG occasions overlapping with Cell DRX non-active periods.
* Option 3: UE is configured with the expected behaviour (whether it is allowed to transmit on CG occasions during Cell DRX non-active period or not), e.g. per CG configuration, per MAC entity, or per cell DRX configuration

**Question 2: which of the above options do you prefer for the UE behaviour for CG transmission during Cell DRX non-active period?**

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| --- | --- | --- |
| Company | Preferred option | Additional comments |
| Apple | Option 3 | Similar to SPS, we think delay sensitive traffic needs to be considered. But different from SPS, we think option 2 can't work (i.e. UE can send CG-PUSCH and left to NW implementation whether to receive or ignore). It is because current CG timer mechanism will finally make UE to drop UL traffic in buffer if NW sleeps and thereby doesn't provide A/N to UE's CG-PUSCH transmission (as in CG timer mechanism, UE will assume ACK if CG timer expires but no response is received). It will cause UL data loss and not sync between UE and NW.  For Option 3, we prefer gNB can configure to mute some CG configurations in non-active duration. One simple implementation example is that gNB can choose to mute CG configurations whose associated LCH's priority is low. So, UE and gNB only need to wake up in a subset of CG occasions which are indicated by CG configurations with high LCH priority. We think it can achieve a better tradeoff between NES and system performance. |
| Lenovo | Option 1 | We see value in keeping things simple. “Cell DRX non-active time” to us means the network is REALLY saving energy, by not receiving. Having per UE control of “real” DRX on/ off is not useful unless real benefits from field/ simulations are shown. |
| CATT | Option 3 | Same arguments as for SPS. |
| BT | Option 1 | Similar to question 1, the main goal of this solution is to reduce network power consumption. Consequently, when cell is in DRX mode, it is expected that it does not receive any UL signal apart from the ones already agreed.  This approach simplifies network configuration and reduces both, network and UE power consumption.  There is no need to spend standardization efforts on this. If required, cell DRX can be deactivated. |
| Vodafone | Option 1 | If we follow the suggestion from Apple, then I assume the gNB will be up very often, even the amount of the devices with high LCH priority is low. |
| Qualcomm | 1 as a baseline/3 can be agreed after agreements on alignment | Same to SPS, suspending CG UL transmissons would probably make most sense from NES pov, so we can take option 1 as a baseline. Similar to Q1, we have sympathy to the argument of configurability so that Cell DRX can accommodate high LCH priority/delay sensitive traffic within a cell DRX configuration, with some caveats.  CG is a little bit more complicated than SPS. Allowing CG transmission implies we have to allow CG reTx over DG, after all, if the CG is delay sensitive and cannot wait for Cell DRX active period, the same logic would apply for its retransmission. This means during Cell DRX (and possible Cell DTX if they are jointly configured), we need a mechanism to allow retransmission and DCI feedback. We think that this can be solved with proper UE CDRX alignment with cell DTX/DRX, so we can wait for this ongoing discussion before confirming option 3. The issue if we agree to 3 without agreements on alignment is that MAC may become complicated in deriving Cell DRX exceptions (CG Tx, CG reTx, PDCCH carrying retransmission assumption, etc.), however, a proper alignment may just utilize existing timers to control UE active time and understanding of UE and gNB of when to apply restrictions. |
| NEC | Option-1 | We support to define a simple solution, which actually maximize the energy saving gain for the cell. |
| Huawei | Option 1 | Similar to SPS, the CG configuration can be kept, but the UE does not transmit on CG occasions during Cell DRX non-active periods. In UL, the UE should stop dynamic and CG-PUSCH transmission and SR during the Cell DRX inactive period, to avoid transmission/reception failure.  gNB behaviour for CG option 1 should be: the gNB does not receive any transmission on CG occasions overlapping with Cell DRX non-active periods. |
| Ericsson | Option 1 or Option 3 | Following a similar reasoning as in our answer to Question 1, we support Option 1 and Option 3. |
| OPPO | 1/3 | Similar consideration to SPS. |
| Intel | Option 3 | Same response as in Section 3.2 and it can be per Cell DRX configuration. |
| ETRI | Option 1/3 | At least Option 1 should be supported and Option 3 is also fine. |
| Nokia | Option 1 | 3 could also be acceptable if seen needed. |

## SR transmission during Cell DRX non-active period

In RAN2#121, an initial discussion on the UE behaviour for whether the UE can transmit SR during the Cell DRX non-active period took place. The options below were discussed, most companies expressed that option 1 is the most straight forward/less complex as an assumption and leading to most energy savings. SR transmissions are also listed in the R1 agreement part of the list of channels that “the UE may be expected to not transmit or receive during non-active periods of cell DTX/DRX”. Some companies expressed the need to have the behaviour configurable, e.g. per SR configuration, to allow reporting of latency-critical data during Cell DRX, as each SR configuration is mapped to a set of LCHs that can trigger the SR.

* Option 1: UE does not transmit SR occasions overlapping with Cell DRX non-active periods, e.g. SR transmissions are dropped during the non-active period.
* Option 2: UE can transmit SR during Cell DRX non-active periods.
* Option 3: The UE is configured per SR configuration with whether SR can be transmitted during Cell DRX non-active period.

**Question 3: which of the above options do you prefer for the UE behaviour for SR transmission during Cell DRX non-active period?**

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| --- | --- | --- | --- |
| Company | | Preferred option | Additional comments |
| Apple | | Option 3 | Similar to SPS/CG, we think delay sensitive traffic needs to be considered. So, we don't prefer Option 1. In addition, option 1 will lead to UE triggering extra RACH (as specified in TS 38.321, if UE triggers SR but SR resource is not available, the UE will trigger RACH). We think the extra triggered RACH will impact both NES gain and system performance (e.g. overload caused by RACH).  Then, similar to CG, we prefer gNB can configure to mute some SR associated with low priority LCH(s) in non-active duration. So, UE and gNB only need to wake up in a subset of SR occasions which are associated with LCH(s) of high priority. We think it can achieve a better tradeoff between NES and system performance, and it can also resolve the issue of extra triggered RACH. |
| Lenovo | | Option 1 | We see value in keeping things simple. “Cell DRX non-active time” to us means the network is REALLY saving energy, by not receiving. Having per UE control of “real” DRX on/ off is not useful unless real benefits from field/ simulations are shown. |
| CATT | | Option 1 | Different from PUSCH, PUCCH reception and decoding (especially SR considering DTX detection) consumes significant gNB processing, hence power. Considering the alternate option for the UE (see Q4) we would prefer gNB to ignore SR detection during the Cell DTX non-active periods.  On the granularity of configuration, we understand the motivation of the per SR configuration is to allow reporting SR for latency-critical data, but doubt about the efficiency of network energy saving if it does not need to detect a given SR configuration resource in a PUCCH but still needs to perform DTX detection for another SR configuration in that PUCCH. |
| BT | | Option 1 | Same reasoning as question 2. |
| Vodafone | | Option 1 | Same reasoning as question 2. |
| Qualcomm | | 3 | For SR we think a configurable approach is the correct one. Obviously, SR of high priority LCH should not be delayed by Cell DRX, furthermore, SR without an available PUCCH report would trigger RACH which consumes UE power and gNB Energy (more than SR). On the other hand, low priority delay tolerant traffic has no urgency in sending SR and thus, can wait until PUCCH during Cell DRX active period to transmit this SR for NES purposes. The NW can find the right balance depending on traffic types and Cell DRX cycle. |
| NEC | | Option-1 | We support to define a simple solution, which actually maximize the energy saving gain for the cell. |
| Huawei | | Option 1 | We prefer that the SR restriction for UEs is mandatory during Cell DRX non-active periods. If SR is allowed, the reception mode of the gNB must be open during every SR PUCCH channel to wait for a possible SR. In that case the gNB can hardly sleep during the inactive period, therefore the NES gain is marginal. Even if the SR would be received by the network, the related data on PUSCH will be delayed until the Cell DRX active period.  In our view, for Cell DRX, the SR restriction is necessary for NES gain.  gNB behaviour for SR option 1 should be: the gNB does not receive any transmission on SR occasions overlapping with Cell DRX non-active periods. |
| Ericsson | | Option 3 or Option 1 | Following similar reasoning as in our answer to Question 1, we are fine with either Option 1 or Option 3, but for this case we think that it would give more flexibility to the NW if this behaviour could be configurable (i.e. option 3), since the NW may want to schedule a particular UE during Cell DRX non-active period based on SR, hence we would prefer option 3 but would also be fine with Option 1. |
| OPPO | | 1 | No transmission of SR in Cell DRX non-active duration benefits NW energy saving gains.  On the other hand, in the case that there is an urgent requirement to require UL grant, the RA-SR can be triggered if SR is suspended during Cell DRX non-active duration. To us, RA-SR collision/power consumption is not a big issue, since NES focuses on low load case. |
| Intel | Option 3 | | Same response as in Section 3.2 and it can be per Cell DRX configuration. |
| ETRI | Option 1/3 | | At least Option 1 should be supported and Option 3 is also fine. |
| Nokia | Option 1 | | 3 could also be acceptable if seen needed. |

**Expected UE behaviour if SR is not to be transmitted on an PUCCH occasion during Cell DRX non-active time**

Assuming that UE does not transmit SR during Cell DRX non-active periods, a discussion point is whether the UE should assume to just drop the SR and delay the transmission until the Cell DRX active time, or the UE should assume that the SR resource is not available and initiate RA-SR. These options are outlined as follows, upon dropping an SR transmission during Cell DRX non-active period:

* Option 1: Keep the SR pending; SR transmission is delayed till the Cell DRX active period.
* Option 2: Initiate RA-SR; cancel the pending SR.
* Option 3: Other behaviour, e.g. depends on whether there is PRACH resource before the Cell DRX active period.

Currently TS 38.321 specifies “if the MAC entity has no valid PUCCH resource configured for the pending SR” then “initiate a Random Access procedure (see clause 5.1) on the SpCell and cancel the pending SR”. Option 2 thus requires clarifying that SR resources during Cell DRX is to be considered by the UE as a not valid PUCCH resource and also cancelling the pending SR. On one hand, option 2 should not result in less energy savings as it was agreed in RAN2#121 that RA can be transmitted during the Cell DRX non-active period anyway, but in some cases the PRACH resource may not be as periodic as the configured SR resource and thus the RA-SR may be delayed, potentially beyond the Cell DRX active period. Option 1 on the other hand keeps the energy saving level expected for Cell DRX during the non-active period for both the gNB and UE, and the SR transmission is delayed till the Cell DRX active period.

**Question 4: Assuming that SR cannot be transmitted by the UE on an PUCCH occasion during Cell DRX non-active time, which of the above options do you prefer for the UE?**

|  |  |  |  |
| --- | --- | --- | --- |
| Company | | Preferred option | Additional comments |
| Apple | | Option 1 (for SR associated with low priority LCH) | As replied in Q3, we prefer that gNB can configure UE to send SR only in SR resources which are associated with high priority LCH(s), in order to satisfy latency sensitive traffic. Then for the remaining SR resources associated with low priority LCH(s), we think the SR transmission can be simply delayed to next active period (i.e. option 1) because the corresponding traffics are not so important anyway.  For option 2, we totally agree with Rapporteur's analysis that it will lead to both spec impact in TS 38.321 and system issue (e.g. delayed RA-SR). So, option 2 is not preferred.  For option 3, we think it puts a new requirement for the UE to check PRACH resource for triggered SR, which makes the procedure unnecessary complex. |
| Lenovo | | Option 1 | Seems sufficient to us. |
| CATT | | Option 2 | Since gNB has to anyway monitor RACH, UEs with SR can use SR-RACH as backup during non-active periods (UE can consider it has no configured SR configuration during that period). This should only cause limited impact to traffic transmission since one would expect Cell DRX to only be operated in cells with few users. |
| BT | | Option 1 | No need to initiate a RA-SR. UE can wait until next cell DRX active time. |
| Vodafone | | Option 1 |  |
| Qualcomm | | Option 1 | SR can be kept be pending until the next PUCCH occasion that does not overlap with a cell DRX non-active time. RACH would consume more UE power and Network Energy than allowing SR to begin with, so SR can be kept pending as long as it is not pending for too long, which may depend on the Cell DRX non-active duration values to be agreed later. We emphasize that this should not apply to all LCHs as not every LCH should delay SR like that with no chance to trigger RACH (if option 1 get agreed), so this response should be taken combined with the last Question (configurable SR with cell DRX) as an overall position on SR. |
| NEC | | Option-1 |  |
| Huawei | | Option 1 | Initiating RA would deteriorate the energy saving gain and lead to unnecessary signaling, we prefer to delay the SR till the next Cell DRX active period.  If the UE would send RA-SR, it needs to wait until the next RACH occasions, meaning even more latency than when sending PUCCH-SR. |
| Ericsson | | Option 1 | We agree with the Rapporteur’s assessment that Option 2 may result in delays beyond Cell DRX active period (i.e., even longer delays than that of in the case of Option 1). Regarding Option 3, the intended solution is not entirely clear to us and based on our understanding Option 3 may be too complex since one would need to specify the behavior for two cases, i.e., when PRACH resource is present and when PRACH resource is not present before the Cell DRX active period. Hence, we support Option 1. |
| OPPO | | Option 2 | Similar view as CATT. RAN2 already agrees there is no impact to RACH due to NES, so, the gNB anyway has to monitor RACH on any RACH resources configured. |
| Intel | Option 1 with comments | | If UE is configured to ignore SR occasions during non-active period of Cell DRX, it should still assume that the SR PUCCH resource is still configured but only considers only those occasions in active period of Cell DRX is valid.  Network has to ensure that there are valid SR PUCCH resources when Cell DRX is activated. One way to do so is to have 2 SR configurations: One when Cell DRX is not activated and one when Cell DRX is activated. |
| ETRI | Option 1 | |  |
| Nokia | Option 1 | | 2 or 3 does not make sense. |

## Dynamic grants and assignments and PDCCH monitoring

In RAN2#121, monitoring for dynamic grants and downlink assignments during the Cell DTX non-active period was discussed. The main question is whether we can just rely on the UE C-DRX framework for PDCCH monitoring, or whether extra clarification is needed such that the UE doesn’t need to monitor for scheduling for dynamic grants and assignments in the Cell DTX non-active time, even if the UE is in C-DRX Active Time (i.e. to save further UE power). These options are expressed as follows:

**Expected gNB scheduling behaviour during Cell DTX non-active period**

* Option 1: gNB does not schedule UE-specific dynamic grants/assignments during cell DTX non-active periods, even if the UE is in C-DRX Active Time
* Option 2: gNB can schedule UE-specific dynamic grants/assignments during cell DTX non-active periods, but not outside of the UE’s C-DRX Active time. It is left to gNB implementation whether to keep scheduling that UE during its (extended) C-DRX Active Time, even if outside Cell DTX/DRX active period, or to stick to the active periods of Cell DTX periodic pattern.

**Expected UE behaviour for PDCCH monitoring during Cell DTX non-active period**

* Option 1: UE doesn’t monitor PDCCH for dynamic grants/assignments during Cell DTX non-active, even if the UE is in C-DRX Active time (Cell DTX operation overrides the UE C-DRX operation).
  + One possibility to implement it is to stop the UE’s C-DRX Active Time during Cell DTX non-active period.
* Option 2: UE monitor PDCCH for dynamic grants/assignments during the UE’s C-DRX Active time per legacy behaviour, even during the Cell DTX non-active period.

Option 1 results in more energy saving for both the UE and the network, but doesn’t allow for further additional time/scheduling flexibility for scheduling retransmissions and HARQ feedback reception/transmission, e.g. while drx-InactivityTimer or drx-RetransmissionTimer is running. It is worth noting that a cell-wide Cell DTX inactivity timer associated with a given Cell DTX configuration was discussed in RAN2#121 without consensus. Option 2 assumes that the UE monitors PDCCH according to the active time in the C-DRX cycle, per legacy assumptions.

Given some papers discuss the desired behaviour differently, depending on whether the PDCCH is for scheduling new transmissions or Re-transmissions, the question is asked twice, once for the scheduling initial transmissions (Q5) and again for retransmissions (Q6).

**Question 5: which of the above options do you agree with for the expected gNB scheduling behaviour and UE behaviour for PDCCH monitoring for dynamic new transmissions during cell DTX non-active period?***Note: it is understood that options under gNB scheduling behaviour have 1-to-1 correspondence to the options under UE PDCCH monitoring behaviour, but separate answer columns are added for completeness.*

|  |  |  |  |
| --- | --- | --- | --- |
| Company | Preferred option for gNB | Preferred option for UE | Additional comments |
| Apple | Option 1 with wording change | Option 1 with wording change | First, we suggest to first discuss the case that UE CDRX is not configured (i.e. only Cell DTX is configured). We think the case that both Cell DTX and UE CDRX being configured will depend on outcome of alignment mechanism and so it is premature to discuss. So, we suggest to postpone the discussion of Cell DTX+UE CDRX.  Then, our preference is below modified option 1:   * gNB side: gNB does not schedule UE-specific dynamic grants/assignments during cell DTX non-active periods when UE CDRX is not configured. FFS when both cell DTX and UE CDRX are configured~~, even if the UE is in C-DRX Active Time~~ * UE side: UE doesn’t monitor PDCCH for dynamic grants/assignments during Cell DTX non-active when UE CDRX is not configured. FFS when both cell DTX and UE CDRX are configured. ~~even if the UE is in C-DRX Active time (Cell DTX operation overrides the UE C-DRX operation).~~   Option 2 is not acceptable to us. It doesn't make sense that the UE wastes its power to detect unnecessary PDCCH when it knows gNB is sleeping (via gNB configured ON-OFF pattern). If concern on delay sensitive traffic, we believe our proposals to allow SPS (in Q1) and subset of CG and SR (in Q2/Q3) can resolve the issue. |
| Lenovo | Option 1 | Option 1 | The UE’s active time when cell is in NES mode should be derived using an AND function of UE C-DRX active time and cell’s active time. |
| CATT | Option 2 | Option 2 | This WI is about network energy saving, not UE power saving. Extensive time was spent in R16 and R17 to address UE power saving resulting in a comprehensive set of new features (many of which addressing DRX enhancements) towards this objective. Note that gNB already has the possibility to implement option 1 with such legacy features e.g. by telling the UE to stop monitoring PDCCH during DRX Active Time via the PDCCH skipping command. Hence we are concerned with further tweaking the legacy UE behavior during C-DRX due to NES.  Note that, as we understand it, options 1&2 are only discussing the UE behavior (monitor/not monitor PDCCH) and so have no impact on the NES gain since it is obviously left to gNB implementation to schedule transmissions or not during Cell DTX/DRX non-active time while the UE in is C-DRX Active Time. |
| BT | Option 1 | Option 1 | We consider there is no need to transmit anything else during the cell DTX non-active periods than what is already agreed. In consequence, there is no need for the UE to monitor for something that will not be transmitted. |
| Vodafone | Option 1 | Option 1 |  |
| Qualcomm | Option 1 (with different understanding) | Option 1 with different understanding | Our understanding is conditioned on: “Cell DTX/DRX cannot occur unless UE in inactive time”.  We think other understandings such as the one proposed by the rapporteur “UE doesn’t monitor PDCCH for dynamic grants/assignments during Cell DTX non-active, even if the UE is in C-DRX Active time” assumes complete decoupling between C-DRX and Cell DRX/DTX. Since we are discussing alignment in the other discussion we should not move forward with agreements that assume no alignment.  From a MAC pov, a UE that is not monitoring PDCCH is not in active time (R17 allows for some PDCCH skipping but this is fully contained in PHY). We think changing this simple and stable UE behaviour with several branches of CDRX behaviour and serving cells’ configurations would make for a very intractable MAC spec and would diminish the likelihood that this feature is implemented.  Thus we would propose a straightforward agreement that “**UE being in CDRX inactive time is a precondition for applying any cell DTX/DRX non-active behaviour**”. Recall that CDRX behaviour already comes from the NW and the SI said that “It is beneficial to align UE DRX with Cell DTX and DRX alignment among multiple UEs. The alignment mechanism can be discussed during the WI phase “. Decoupling those behaviours would not be in line with our understanding of the SI as an original proponent of Cell DTX/DRX and also burdens RAN2 with defining all those complicated behaviours for cell DTX/DRX that would interplay differently with UE active time. But we understand that this argument can be more related to alignment in the other discussion. |
| NEC | Option-1 as baseline | Option-1 as baseline |  |
| Huawei | Option 1 | Option 1 | Not scheduling UE-specific dynamic grants/assignments during cell DTX non-active periods is beneficial for energy saving gains. Rel-18 NES UEs could also stop monitoring PDCCH during the Cell DTX non-active period, when the gNB will not send anything on the PDCCH, for UE energy saving purposes.  Apple’s proposal can be a first step but we assume that UEs in C-DRX state on a NES cell will be a common scenario so it needs to be also described. If Cell DTX is configured, there is no point for the NW not to configure UE C-DRX, otherwise the UE will waste excessive power. |
| Ericsson | Option 2, but | Option 2 | For the expected gNB behaviour, while we think option 2 should be allowed, we do not see the need to spend much time on this since we anyway should specify the UE behavior.  For the sake of achieving the tradeoff between NW energy savings and the impact on the QoS/QoE, the UE can monitor PDCCH for dynamic grants/assignments according to its own UE DRX pattern even during Cell DTX non-active period. In this way, the NW will be able to reach a UE even during Cell DTX non-active period if necessary (e.g., in the case of delay sensitive traffic) and the UE energy savings would not be impacted negatively since the UE would be able to go to sleep modes according to its own UE DRX pattern. Option 1 would remove the possibility to reach a UE, which may have a negative impact on the QoE/QoS. Therefore, we support Option 2, which would allow for the transmissions that are dynamically scheduled during Cell DTX non-active period when necessary. |
| OPPO | Option 1 | Option 1 | In our view, the Cell DTX non-active period will always be the inactive time for UE (in case UE DRX is configured) and UE DRX active time is only possible in the cell DTX active period.  For the impact to QoS/QoE, we understand the gNB knows this KPI and would take it into account, i.e. the gNB would provide a proper Cell DTX configuration to trade off NW power saving gains and UE’s performance. If the non-alignment mentioned in this question eventually arise, the UE anyway needs to follow the NW decision, since at this time NW power saving is cared by the gNB more. |
| Intel | Option 1 | Option 1 | The question seems general to both cases when UE DRX is activated /configured or not. The purpose of Cell DTX is to achieve NES gain. gNB is not going to schedule PDCCH during non-active period and hence UE should not need to monitor PDCCH for new transmissions. |
| ETRI | Option 1 | Option 1 | Considering a discussion topic NW-UE alignment in parallel email-discussion [312][NES], further discussion may be needed when UE is in CDRX active time. So the following option may also be valid.  Option 3) gNB does not schedule UE-specific dynamic grants/assignments during cell DTX non-active periods  FFS: when the UE is in C-DRX Active Time |
| Nokia | Option 1 | Option 1 | Energy saving from both gNB and UE point of view should be taken into account. |

**Question 6: which of the above options do you agree with for the expected gNB scheduling behaviour and UE behaviour for PDCCH monitoring for dynamic Retransmissions during cell DTX non-active period?**

|  |  |  |  |
| --- | --- | --- | --- |
| Company | Preferred option for gNB | Preferred option for UE | Additional comments |
| Apple | FFS | FFS | We think the discussion on retransmission can be postponed after conclusion of new transmission (Q5) is clear. In detail, our view is:   * If option 1 of Q5 is agreed, we think RAN2 can further discuss whether mechanism similar to RTT timer and CDRX retransmission timer can be introduced, or retransmission-less. * If option 2 of Q5 is agreed, it seems retransmission can be treated the same way as new retransmission.   For the moment, we think it is hard to discuss retransmission on-fly. |
| Lenovo | Option 1 | Option 1 |  |
| CATT | Option 2 | Option 2 | For the same reasons as initial transmissions, see Q5. |
| BT | Option 1 | Option 1 |  |
| Qualcomm | FFS | FFS | Same comment. There is a mechanism to extend active time of the UE for a retransmission (also unclear whether this is an UL or DL transmission), but either way, the UE has well established behavior to handle retransmission with inactive time (per HARQ process). This should be kept as is. UE can use its legacy mechanism for retransmission which is wholly controlled by the NW.  We do not see a need to design a different scheme to do the same thing per-serving cell and have the MAC entity check too many conditions (the legacy CDRX branch and the cell DTX branch then transmission vs retransmission) to derive its active time behavior. |
| NEC | Option-1 as baseline | Option-1 as baseline |  |
| Huawei | Option 1 | Option 1 | The retransmissions, which are scheduled, can be delayed to the next Cell DTX active period. |
| Ericsson | Option 2, but | Option 2, but | For the expected gNB ehavior, while we think option 2 should be allowed, we do not see the need to spend much time on this since we anyway should specify the UE behavior.  Our opinion is that the NW should take care of retransmissions and we support Option 2 as a possible solution. However, we think that the details can be left for FFS once the agreements for **new transmissions** are reached (i.e., the agreement concerning Q5). |
| OPPO | Option 1, but | Option 1, but | From PDCCH monitoring perspective, we do not see the need to distinguish the new transmission and retransmission, since the UE can not be aware of the transmission type until the UE has successfully decoded PDCCH. But, we may consider some impact to HARQ-related timer.  However, we are also fine to leave this discussion until we achieve agreements for Q5. |
| Intel | Option 1 if SPS/CG is ignored during non-active period of Cell DTX  Option 2 if SPS/CG occasions are valid during non-active period of Cell DTX | Option 1 if SPS/CG is ignored during non-active period of Cell DTX  Option 2 if SPS/CG occasions are valid during non-active period of Cell DTX | If UE still needs to use the SPS/CG occasions during the non-active period, there may retransmissions for the SPS/CG using DG and these needs to be handled and Option 2 is needed. If SPS/CG occasions are ignored, then Option 1 is ok. Hence, we think that whether UE is allowed to monitor PDCCH for retransmissions should also be made configurable as like SPS and CG. |
| ETRI | Option 1 | Option 1 | Prefer to apply the same approach for initial transmission and retransmission. |
| Nokia | Option 2 | Option 2 | As long as it starts to have data transmission, retransmissions could be prioritized over DTX. If needed, could also consider the priority of the LCHs in the initial transmission or the priority of the UL grant for initial transmission. |

**Expected UE behaviour for DG-PUSCH transmission during Cell DRX non-active period**

Assuming that scheduling has been received by the UE either for dynamic grant transmission or a dynamic PDSCH assignment reception, it is fair to assume that the UE should follow the NW instruction and transmit PUSCH on the dynamic grant even in Cell DRX non-active periods or receive PDSCH even in Cell DTX non-active periods. But some papers suggest discussing the alternatives.

The following UE behaviour options for dynamic UL transmission in non-active duration of Cell DRX:

* Option 1: UE can transmit on PUSCH dynamic grants during Cell DRX non-active periods if scheduling was received by the UE.
* Option 2: if PDCCH indicates UL grant and the PUSCH occasion overlaps with Cell DRX non-active period, the UE drops the corresponding uplink transmission.
* Option 3: it is up to gNB implementation to avoid the issue, e.g. gNB to postpone the transmission of PDCCH to a later active period if its indicated PUSCH will be in the Cell DRX non-active period

**Question 7: Which of the options above do you prefer for the behaviour for PUSCH transmission on dynamic grants during Cell DRX non-active periods if scheduling was received by the UE?**

|  |  |  |
| --- | --- | --- |
| Company | Preferred option(s) | Additional comments |
| Apple | Option 3 | We think the simplest way is Option 3 (i.e. it is up to gNB implementation to avoid the issue case, e.g. gNB may postpone the transmission of PDCCH to next cycle). And because PDCCH and indicated PDSCH/PUSCH are sent by the same cell, gNB implementation can well handle it.  Both option 1 and option 2 need extra specification on UE behaviour in TS 38.321, which is unnecessary. |
| Lenovo | Option 3 | Based on our responses above, this situation should not occur – gNB should be careful. |
| CATT | Option 1 | We don’t think option 2 makes sense as it would mean the gNB sends an UL grant knowing the UE will ignore it.  As for option 3, we don’t quite get the point of it because, for us it does not really tell about the UE behaviour: does option 3 mean UE ignores PDCCH during non-active period? For us, option 3 does not contradict option 1, i.e. option 3 is included in option 1. Indeed, even if allowed to schedule an UL grant during Cell DRX non-active period, the gNB always has the flexibility to avoid it by implementation. Since we prefer not making it mandatory for gNB to avoid PUSCH transmission in the non-active period, option 3 is not preferred. |
| BT | Option 2 or option 3 | At this point in time, we consider option 1 can be excluded.  Further discussion on option 2 and 3 is required. |
| Qualcomm | 1 | We already agreed that we are looking at periodic patterns for Cell DTX/DRX thereby eliminating the need for dynamic (few ms scale) adaptations, so there does not seem to have a need to save energy on the grant cancellation scale.  On the other hand, scheduling a DG-PUSCH can be a good mechanism for the NW to override Cell DRX without the need for a full-on reconfiguration, i.e., if the NW dynamically decides that it wants to receive a specific UL transmission from a UE that happens to fall into a cell DRX period, scheduling a DG-PUSCH can be a simple and fast enough to do that. If option 2 is agreed for example, the NW would have no way to receive an important UL transmission other than deactivating Cell DRX for all UEs in the cell and reactivating shortly thereafter, so it is much simpler to just assume if a NW configures DG then this should override Cell DRX non active period. |
| NEC | Option-1 or Option-3 | UE should follow the gNB scheduling |
| Huawei | Option 3 | We think this case should be prevented by the gNB. The transmission of PDCCH should be either postponed or the gNB should go out of Cell DTX/DRX state if needed.  We would like to suggest a wording change to be clear that the intended gNB behaviour is to postpone the transmission:  “it is up to gNB implementation to avoid the issue, ~~e.g.~~ i.e. gNB to postpone the transmission (…)” |
| Ericsson | Option 1 | Agree with the rapporteur, i.e., the NW will only send a dynamic grant if it expects the UE to follow it, hence the UE should be allowed to transmit on PUSCH dynamic grants even during Cell DRX non-active periods. |
| OPPO | Option 1 or 3 | DG is controlled by the gNB. If there is DG-PUSCH during Cell DRX non-active periods and its scheduling was received by the UE, it means the gNB would like to receive such DG-PUSCH, otherwise the gNB can postpone such scheduling.  On the other hand, if the case can be avoided by the gNB implementation(i.e. Option 3) and it may not degrade much UE’s performance, it is also good to simplify the spec impact/UE behavior. |
| Intel | Option 1 or Option 3 | Option 2 does not make sense to us that network will waste PDCCH resources for scheduling PUSCH occasion to be dropped by UE. We have a slight preference for Option 1 to have a clear UE behaviour. |
| ETRI | Option 3 | Option 1 and Option 2 may reduce NES performance, and the gNB should be scheduled so that this situation does not occur. |
| Nokia | Option 3 |  |

**Expected UE behaviour for dynamic PDSCH reception during Cell DTX non-active period**

Similarly, the following UE behaviour options for dynamic reception of PDSCH assignments in non-active duration of Cell DTX:

* Option 1: UE receives dynamic PDSCH assignments during Cell DTX non-active periods if scheduling was received by the UE.
* Option 2: if PDCCH indicates a DL assignment and the PDSCH overlaps with Cell DTX non-active period, the UE drops the PDSCH.
* Option 3: it is up to gNB implementation to avoid the issue, e.g. gNB to postpone the transmission of PDCCH to a later active period if its indicated PDSCH will be in the Cell DTX non-active period

**Question 8: Which of the options above do you prefer for the behaviour for reception of dynamic PDSCH assignments during Cell DTX non-active period?**

|  |  |  |
| --- | --- | --- |
| Company | Answer | Additional comments |
| Apple | Option 3 | Similar comment as Q7. |
| Lenovo | Option 3 |  |
| CATT | Option 1 | See Q7. |
| BT | - | First step is to identify if network will send the dynamic PDSCH during cell DTX non-active period.  We consider that PDSCH is not sent during cell DTX non-active period. With this assumption, RAN2 is encouraged to identify the scenario described in Q8 occurs. |
| Qualcomm | Option 3 | The issue in DL seems to be solvable by implementation. Especially if we align UE CDRX, then the NW can simply keep the UE awake for a DL Tx, i.e., with proper alignment this issue would probably not occur.  The reasoning is that UE expecting PDSCH means that UE is in its active time which means Cell DTX should also be in active duration (from this UE point of view, other UEs can be inactive and applying proper Cell DTX restrictions) |
| NEC | Option-1 or Option-3 | UE should follow the gNB scheduling |
| Huawei | Option 3 | Same comment as for Q7. In this case we also prefer to be clear about the intended gNB behaviour by changing “e.g.” to “i.e.” in the wording of option 3. |
| Ericsson | Option 1 | Following a similar reasoning as in our answer to Question 7 we support Option 1. |
| OPPO | Option 1 or 3 | Similar view as Q7. |
| Intel | Option 1 or Option 3 | Same response as Q7 |
| ETRI | Option 3 | Similar response as Q7 |
| Nokia | Option 3 |  |

# Conclusion

This is the report document for email discussion on the expected gNB and UE behaviours during Cell DRX and Cell DTX non-active periods. As an outcome of this discussion, the following proposals are made:

TBD

# References

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12. R2-2300611, “Considerations of Cell DTX and DRX”, Intel Corporation
13. R2-2300632, “Cell DTX/DRX mechanism”, InterDigital
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15. R2-2300819, “Discussion on Cell DTX/DRX”, CATT
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