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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| **Company** | **Delegate name** | **Email address** |
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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:

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| 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?**

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| 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. |
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## 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. |
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## 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. |
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**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?**

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| 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. |
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## 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.*

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| 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. |
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**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?**

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| 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. |
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**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?**

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| 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. |
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**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?**

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| Company | Answer | Additional comments |
| Apple | Option 3 | Similar comment as Q7. |
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# 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

1. RP-223540, “New WID: Network energy savings for NR”, Huawei
2. TR 38.864, “Study on network energy savings for NR”, v 18.0.0
3. [RP-213554](http://ftp.3gpp.org/tsg_ran/TSG_RAN/TSGR_94e/Docs/RP-213554.zip), “Study on network energy savings for NR”, Huawei.
4. R2-2300230, “Discussion on cell DTX/DRX”, Huawei, HiSilicon
5. R2-2300247, “Cell DTX and DRX support”, NEC
6. R2-2300378, “Considerations on Cell DTX/DRX”, KDDI Corporation
7. R2-2300444, “Initial discussion on DTX-DRX mechanism”, vivo
8. R2-2300456, “Discussion on DTX DRX mechanism”, OPPO
9. R2-2300491, “Alignment to Cell DRX”, Lenovo
10. R2-2300492, “Alignment to Cell DTX”, Lenovo
11. R2-2300539, “Cell DTX-DRX Mechanism”, Qualcomm Incorporated
12. R2-2300611, “Considerations of Cell DTX and DRX”, Intel Corporation
13. R2-2300632, “Cell DTX/DRX mechanism”, InterDigital
14. R2-2300701, “Discussion on Cell DTX / DRX”, Apple
15. R2-2300819, “Discussion on Cell DTX/DRX”, CATT
16. R2-2301064, “Discussion on cell DTX and DRX mechanism for NES”, ZTE Corporation, Sanechips
17. R2-2301230, “Discussion on network DTX/DRX”, CMCC
18. R2-2301399, “Further aspects on cell DTX/DRX”, Ericsson
19. R2-2301515, “Further details on Cell DTX/DRX”, Nokia, Nokia Shanghai Bell
20. R2-2301550, “Discussion on DTX/DRX for NES”, Samsung
21. R2-2301733, “Discussion on DTX/DRX mechanism”, LG Electronics Inc.
22. R2-2301776, “Discussion for Cell DTX/DRX”, NTT DOCOMO, INC.
23. R2-2301854, “Further discussion on Cell DTX/DRX”, MediaTek Inc.
24. R2-2301882, “Cell DTX and DRX”, Fraunhofer IIS