**3GPP TSG RAN WG1 #102-e R1-200xxxx**

**e-Meeting, August 17th – 28th, 2020**

**Agenda Item:** 8.7.1.2

**Source:** Moderator (Samsung)

**Title:**  Summary for TRS/CSI-RS occasion(s) for idle/inactive UEs

**Document for:** Discussion/Decision

# Introduction

This document provides summary for the first round of email discussion on following issues:

[102-e-NR-UE\_pow\_sav\_enh-02] Email discussiona/approval – Taehyoung (Samsung)

* By 8/21 – high priority
* By 8/27 – medium

For the decision, the following phases are to be suggested:

* Phase I (due 20th Aug 3 am PST): Quick check companies view on the priority
* Phase II (20th Aug 6 am PST – 21th Aug 6 am PST): Convergence on high priority proposals
* Phase III (24th Aug 3 am PST – 26th Aug 11 pm PST): Convergence on medium priority proposals

# Discussion

## Background

For a UE operating in IDLE/INACTIVE mode, the UE consumes powers for various activities such as AGC, time/frequency synchronization, RRM measurement, paging monitoring, etc. As illustrated in Figure 1, LTE supports always-on CRS in every subframe, on the other hand, NR supports SSB only which is transmitted with a longer periodicity (e.g., 20ms) compared to LTE CRS. NR UE needs to wake-up much earlier, much longer, and more frequently compared to LTE UE for the subsequent activities. Accordingly, the power consumption for NR UE in IDLE/INACTIVE mode is much higher than that for LTE UE in IDLE mode. Based on the motivation, it is agreed to specify to provide additional TRS/CSI-RS occasion(s) for IDLE/INACTIVE mode UE as in WID for Rel-17 UE power saving enhancements [1].

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| (a) LTE | (b) NR |

Figure 1: Illustration of the timeline of an idle/inactive mode UE for data reception from a serving cell.

Generally, for enabling TRS/CSI-RS for idle/inactive mode, following questions need to be answered:

* How to provide the configuration information for TRS/CSI-RS to idle/inactive UEs?
* How to avoid always-on TRS/CSI-RS transmission?
* How to reduce the signaling overhead?

In the following sections, more detailed list of issues is provided for the email discussion.

## Summary of issues and potential priorities

From the companies contributions [1]-[19], following issues are identified:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **#** | **Issues** | **Description** | **Contributions** | **Tentative Priority** |
| 1 | RS Types | Which type of RS is used?- TRS only- P-CSI-RS- Others (CSI-RS for ‘mobility’, P/AP/SP CSI-RS, etc.) | [3], [5], [13], [16], [19] | High |
| 2 | Configuration method | How to provide the configuration to the UE?- SIB- Others (Dedicated RRC, RRC release message, Pre-configuration in the spec, etc.) | [1], [2], [6], [10], [11], [12], [15], [16], [17], [18], [19] | High |
| 3 | Functionality | What kind of functionalities are supported?- AGC- T/F tracking- Others (RRM measurement, Paging reception indication, beam tracking, etc.) | [2], [3], [5], [6], [7], [8], [10], [12], [18] | Med |
| 4 | Availability | How to provide the information for availability of the configured TRS/CSI-RS occasion(s)?- SIB- L1 signaling- Others (UE autonomous, etc.) | [1], [2], [3], [10], [16], [18], [19] | Med |
| 5 | Configuration details (1) | How to reduce the signaling overhead?Detailed list of parameters for configuration? | [1], [2], [5], [6], [11], [19] | Low |
| 6 | Configuration details (2) | Whether the TRS/CSI-RS occasion is associated with paging occasion or not? | [1], [3], [6], [8], [10], [17], [18] | Low |
| 7 | Others | Individual proposals from the companies |  | Low |

Tentative priority is suggested in the right-most column in the table. It is determined based on the number of contributions mentioning the corresponding issues. For issue#1, it is understood that issue#1 is the most basic one to be decided first for the next-level discussions although the companies does not mention it explicitly in their contributions.

**Please provide the views on the tentative priority or additional suggestions on the priority in the table below:**

|  |  |
| --- | --- |
| **Company**  | **Comments** |
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## Aligning understanding on WID

Before jumping up the detailed discussions, it would be valuable to align the companies understanding on the WID as mentioned in [19].

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| --- |
| 1. Specify enhancements for idle/inactive-mode UE power saving, considering system performance aspects [RAN2, RAN1]
	1. Study and specify paging enhancement(s) to reduce unnecessary UE paging receptions, subject to no impact to legacy UEs [RAN2, RAN1]

NOTE: RAN1 to check and update, if needed, evaluation methodology in RAN1 #100 meeting* 1. Specify means to provide potential TRS/CSI-RS occasion(s) available in connected mode to idle/inactive-mode UEs, minimizing system overhead impact [RAN1]

NOTE: Always-on TRS/CSI-RS transmission by gNodeB is not required |

Regarding the yellow part, it is understood that the potential TRS/CSI-RS occasion(s) available for connected mode UE may be used for idle/inactive mode UEs. This implies that there would be no new RSs specifically intended only for idle/inactive UEs.

**Proposal for conclusion 1: New RSs specifically intended for IDLE/INACTIVE mode UEs is not introduced.**

**Please provide the views on the above potential conclusion in the table below:**

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| **Company**  | **Comments** |
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Regarding the blue part, it is understood that the TRS/CSI-RS does not required to be always transmitted by the gNB. However, it is still ambiguous whether this note means that it can be solely decided by gNB implementation or additional specification effort for it will be there.

**Question for clarification: What is your understanding on NOTE: Always-on TRS/CSI-RS transmission by gNodeB is not required?**

* **Interpretation#1: gNB may or may not be transmit the configured TRS/CSI-RS and it is up to implementation.**
* **Interpretation#2: Whether the TRS/CSI-RS is transmitted or not is somehow known to the UE (implicitly/explicitly).**

**Please provide the views on the above question for clarification in the table below:**

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| **Company**  | **Comments** |
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## Additional suggestions

**Please provide the any suggestions for the email discussion in the table below:**

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| --- | --- |
| **Company**  | **Comments** |
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# Conclusion

**[TBD]**

# Summary of proposals

|  |  |
| --- | --- |
| Huawei [1] | ***Observation 1. Providing the potential TRS/CSI-RS for IDLE/INACTIVE mode UE reduces the power consumption of UEs by 6~12% when assistance RS is located in the middle of a SSB periodicity.******Observation 2. The availability of assistance RS needs to be informed to IDLE/INACTIVE mode UE implicitly or explicitly.******Observation 3. The following information is relevant for configuring assistance RS resources:*** ***- RS time/frequency resource;******- sequence generating parameter;******- periodicity/offset;******- QCL parameter.*** ***Proposal 1: Inform the availability of TRS/CSI-RS though legacy paging DCI or early transmitted paging DCI for power saving.******Proposal 2: UE assumes the configured assistance TRS/CSI-RS is transmitted in a configured/pre-defined window, which is close to the start of the PO or close to the end of the SSB bursts before the PO.******Proposal 3: Discuss how to configure assistance RS for IDLE/INACTIVE mode UEs, and how to reduce the signaling overhead for assistance RS configuration if it is configured by SIB.*** |
| vivo [2] | ***Observation 1: For idle/inactive UEs, with TRS/CSI-RS assisted for loop convergence / time-frequency tracking and RRM for serving cell, UE processing timeline can be optimized to save power consumption.******Proposal 1: Further investigate the followings for TRS/ CSI-RS in power consumption evaluation******- whether TRS / CSI-RS can be solely used without SSB for loop convergence / time-frequency tracking******- whether TRS / CSI-RS can be solely used without SSB for RRM for serving cell******Observation 2: Accuracy of RRM/AGC can not be guaranteed at UE, if the CSI-RS configuration is updated but not timely indicated to UE.******Observation 3: If CSI-RS configuration for idle/inactive UE is updated by reusing existing system information acquisition procedure, it will bring about increased notification delay, degraded measurement accuracy, excessive system overhead for paging, and increased UE power consumption.******Proposal 2: The CSI-RS configuration for idle/inactive mode UE can be broadcasted in system information.******Proposal 3: CSI-RS configuration update mechanism can be developped, and following alternatives can be considered.******- Alt 1 : Paging PDCCH indicating on/off state of the SIB configured CSI-RS resource.******- Alt 2 : Paging PDCCH indicating CSI-RS configuration update, and UE to obtain updated CSI-RS configuration with enhanced SIB reception procedure.*** ***Observation 4: UE may need to handle signals/channels with more numerologies if there is no restriction in CSI-RS configuration.******Proposal 4: Further consider restrctions on SCS for CSI-RS resources configured for idle/inactive UEs.******Proposal 5: The CSI-RS/TRS resource should be QCLed with one of the actually transmitted SSBs indicated by SIB1.******Proposal 6: The power difference between CSI-RS/TRS and SSB should be explicitly configured in CSI-RS resource configuration to idle/inactive UEs.******Proposal 7: To facilitate idle/inactive UEs to take full advantage of the CSI-RS resources in UE implementation, the purposes of the CSI-RS resources for connected UEs can also be configured for idle and inactive UEs.*** |
| ZTE [3] | ***Observation 1: In high SINR, due to the gap between the SSB for serving cell measurement and PO, there is 13% energy consumed by light sleep.******Observation 2: In low SINR, due to the multiple SSB processing before PO, UE cannot enter into deep sleep for a duration of several SSB periodicities, the energy contributed by light sleep increases to 39%.*** ***Observation 3: The introduced RS with smaller periodicity can reduce the gap between RRM measurement and paging occasion. The power saving gain is 2.6%.******Observation 4: If the introduced RS can be used for RRM measurement and time/frequency synchronization, the energy consumed by light sleep decreases from 38% to 7%, the power saving gain is 23.8%.******Observation 5: If the introduced RS can be used for time/frequency synchronization, the power saving gain is 23.8%.******Observation 6: It costs more UE energy to detect the invalid RS if the CSI-RS for UE in RRC connected state is reconfigured or updated.******Proposal 1: The following CSI-RS can be considered to be provided to UE in idle/inactive state to reduce UE power consumption.**** ***CSI-RS for mobility***
* ***TRS***

***Proposal 2: The PDCCH monitoring occasion within a PO can also be associated the introduced RS.******Proposal 3: The configuration of CSI-RS is indicated to UE in RRC idle/inactive state via system information.******Proposal 4: To reduce resource overhead, the location of CSI-RS in time domain can be configured in relative to SSB or PO/PF.******Proposal 5: The configuration change notification of CSI-RS can be carried by L1 signaling.*** |
| Sony [4] | ***Observation 1 – Providing synchronization signal block (SSB) as the only reference signal can result in high power consumption at the UE.*** ***Observation 2 – Using reference signals available in connected mode to idle/inactive-mode UE can be beneficial and results in UE power saving.******Proposal 1 – Study the information/configuration to enable the idle/inactive mode UE to use TRS and also validation mechanism whether the UE can use TRS of other UEs.*** |
| MediaTek [5] | ***Observation 1: Compared to general CSI-RS, TRS has some constraints on the configuration. Besides, for the 2 or 4 nzp-CSI-RS-Resource composing one TRS, most of the configurations are the same. Therefore, using TRS as potential RS occasion(s) available in connected mode to idle/inactive-mode UEs requires less signalling overhead than CSI-RS.******Observation 2: For idle/inactive mode UE, the provided potential TRS/CSI-RS occasion(s) should be able to assist gain control (AGC) and time-frequency tracking.******Observation 3: For idle/inactive mode UE, both potential TRS/CSI-RS occasion(s) can provide assistance for gain control (AGC), while TRS provides more significant assistance for time/frequency tracking.******Proposal 1: NW configures one or multiple periodic NZP-CSI-RS-ResourceSet with trs-Info for IDLE mode UE to utilize this (these) potential TRS, since compared to CSI-RS, TRS requires less signalling overhead and provides more significant assistance for time/frequency tracking.*** |
| CATT [6] | ***Obervation1: Reception of two SSB bursts can be as the baseline of power saving gain evaluation of additional TRS/CSI-RS.******Observation 2: Additional TRS/CSI-RS can provide 5.05% ~18.66% power saving gain over SSB based paging reception.******Observation 3: With TRS/CSI-RS occasion associated with paging occasion(s)*** ***• TRS/CSI-RS resource configuration signaling overhead is very low;******• TRS/CSI-RS can be used as power saving signal to indicate paging reception.******Observation 4: With CSI-RS resources configured with SI without association relation with paging occasion(s), TRS/CSI-RS resource configuration usually at least contain CSI-RS pattern / scrambling ID/ QCL information.******Observation 5: As option 1(TRS/CSI-RS occasion is associated with paging occasion) can support paging reception indication, significant power saving gain can be achieved over option 2 (TRS/CSI-RS resources are configured with SI without association relation with paging occasion).******Proposal 1: TRS/CSI-RS configuration for Idle/Inactive mode should be associated with paging occasion(s).*** |
| Beijing Xiaomi Software Tech [7] | ***Observation 1: Additional TRS/CSI-RS before PO can facilitate time-frequency synchronization and RRM measurement to reduce UE wake-up time, as well as acting like WUS.******Proposal 1: Group-based WUS signal using TRS/CSI-RS should be studied.*** ***Proposal 2: How to configure the additional TRS/CSI-RS configuration should be further studied.*** |
| Intel Corporation [8] | ***Proposal 1: SI may include CSI-RS and/or TRS configuration for measurement and/or channel tracking******Proposal 2: If CSI-RS or TRS configuration of RRC connected mode is active in idle/inactive mode, UE may ignore the initial CSI-RS or TRS configuration provided by SI.******Proposal 3: TRS can be periodic with paging DRX cycle and can be monitored at an offset before PO, where the TRS can also be used as wake-up signal.******• TRS burst in each periodic occasion may include repetitions.*** |
| OPPO [9] | ***Observation 1: There would be power saving gain loss when using system information to signal TRS/CSI-RS configuration. The overhead is significant when using paging.*** |
| Samsung [10] | ***Observation #1: For an idle/inactive mode UE, power consumption overhead for synchronization based on SS/PBCH blocks is high due to multiple SS/PBCH bursts used or a large time gap between a nearest SS/PBCH burst and PO.*** ***Observation #2: For an idle/inactive mode UE, power consumption overhead for serving cell RRM measurement based on SS/PBCH blocks is high due to multiple L1 samples needed or a large time gap between SMTC window and PO.******Observation #3: TRS/CSI-RS for synchronization achieves remarkable power saving gain for cell-edge UE but marginal power saving gain for cell-center UE in idle/inactive mode.******Observation #4: TRS/CSI-RS for synchronization and serving cell RRM measurement achieves remarkable power saving gain for both cell-edge UE and cell-center UE in idle/inactive mode.******Proposal #1: Support functionalities of TRS/CSI-RS for idle/inactive UEs, including**** ***Synchronization***
* ***FFS: RRM measurement or indication for paging reception***

***Proposal #2: Support configuration of cell-specific TRS/CSI-RS resources included in SIB1.******Proposal #3: Support time alignment between TRS/CSI-RS reception occasion and PO.******Proposal # 4: Support activation or deactivation of TRS/CSI-RS reception for idle/inactive mode UEs based on physical layer signal/channel.******Proposal #5: Support relative power for TRS/CSI-RS reception,*** $P\_{CSI, X}$***, such that*** $P\_{CSI, X}=P\_{MS}+\left(P\_{CSI, 14}-P\_{MS}\right)×\frac{X}{14}$***, where x is occupied symbols of TRS/CSI-RS per slot, and*** $P\_{MS}$ ***is relative power for micro-sleep.***  |
| CMCC [11] | ***Observation 1. Broadcasting the TRS/CSI-RS current using by connected mode UE(s) to idle/inactive-mode UE(s) will cause “always-on RS” or more UE power consumption.******Proposal 1. For one UE, gNB can indicate TRS/CSI-RS occasion(s) have been configured in connected mode beforehand are still effective in idle/inactive-mode.******Proposal 2. gNB can using dedicated RRC signalling or RRC release message to indicate the TRS/CSI-RS be still used in idle/inactive mode.******Proposal 3. The time domain configuration of potential TRS/CSI-RS to idle/inactive UE(s) can be as a larger periodicity of 80ms or as a time window before each PO.*** |
| Spreadtrum Communications [12] | ***Proposal 1: UE can perform AGC, T/F tracking, serving cell measurement with TRS/CSI-RS in idle/inactive mode.******Proposal 2: Both cell specific and UE-specific TRS/CSI-RS configuration should be considered.*** |
| LG Electronics [13] | ***Proposal 1: CSI-RS/TRS types which are used in connected mode can be considered as a starting point to support CSI-RS/TRS transmission for the UEs in idle/inactive mode: periodic, aperiodic, and semi-persistent CSI-RS.*** |
| 14 Panasonic [14] | ***Observation 1: Due to only relying on SSB for time/frequency synchronization and beam tracking, UE needs to wake up one or several SSB periodicities before starting to detect paging PDCCH in the monitoring occasions of the PO.*** ***Observation 2: As the parameters for SSB and paging do not share same periodicity and are configured independently, the gap between SSB and paging can be possibly large and makes UE wake up further earlier before monitoring paging.******Proposal 1: For RRC INACTIVE/IDLE mode UE, new TRS/CSI-RS occasions can be studied to enhance the synchronization and beam tracking before paging monitoring.******Proposal 2: To shorten the UE active time for paging monitoring, the additional TRS/CSI-RS location in time and frequency domain and how to configure should be studied.******Proposal 3: The influence/interaction with UE's periodic frequency/time tracking should be checked for additional TRS/CSI-RS.*** |
| 15 Apple [15] | ***Proposal: Consider the support of indicating periodic TRS/CSI-RS occasions to idle/inactive-mode UEs via broadcast message such as SIB.*** |
| 16 Ericsson [16] | ***Observation 1 TRS is the most suitable connected mode CSI-RS resource whose potential occasion(s) can be provided to the idle UE.******Observation 2 Using TRS during idle mode provides UE power saving gain of up to 4.7% in the most optimistic case under the assumption that there is 100% increase in persistent transmissions by the NW (i.e., a TRS with same periodicity as SSB is always available to the UE).******Observation 3 Idle UEs should be able to handle the case where TRS is present/absent in potential TRS occasions without additional signaling from NW.******Proposal 1 RAN1 should prioritize provisioning of potential TRS occasions to idle/inactive UEs.******Proposal 2 Higher layer signaling is used to convey potential TRS occasions to Idle/Inactive UEs. It is up to the UE to detect whether a potential TRS occasion contains TRS or not (Note: NW is not required to transmit TRS in potential TRS occasions).******Proposal 3 Provisioning of compact TRS configurations by omitting/identifying optional parameters for conveying potential TRS occasions can be considered.*** |
| NTT DOCOMO, INC. [17] | ***Proposal 1: Pre-configured information on TRS/CSI-RS, e.g., resource location, should be indicated to idle/inactive-mode UEs via SIB1 and/or dedicated RRC signalling which was indicated when the UE was in connected-mode.**** ***FFS: how to indicate whether TRS/CSI-RS is available or not dynamically***

***Obaservation 1: It would be beneficial TRS/CSI-RS is located near paging occasion in terms of power consumption and performance.******Proposal 2: The resource location of TRS/CSI-RS can be indicated based on the resource location of paging occasion.*** |
| Qualcomm Incorporated [18] | ***Observation 1: Power saving gain of additional TRS/CSI-RS depends on the number of SSBs used for loop update and location of the TRS/CSI-RS relative to the PO.******Observation 2: Whether a TRS/CSI-RS can provide more processing gain than a SSB depends on channel frequency selectivity, bandwidth of the TRS/CSI-RS and frequency drifting rate.******Observation 3: TRS/CSI-RS is especially beneficial for decoding broadcast PDSCH.******Observation 4: From power saving perspective, it is preferred to have the TRS overlap with or very close to the PDSCH.*** ***Proposal 1: If it is agreed that network configures TRS/CSI-RS for time/frequency tracking and AGC loop update, the UE assumes TRS/CSI-RS is transmitted only when page message is transmitted for the UE.*** ***Proposal 2: The TRS/CSI-RS can be UE group based for idle/inactive UEs.******Proposal 3: Network configures cross-slot scheduling for PDCCH CRC scrambled by P-RNTI for the scheduling of paging PDSCH.******Proposal 4: If TRS/CSI-RS is adopted, TRS/CSI-RS can be optionally used for RRM measurement.******Proposal 5: If TRS/CSI-RS is adopted, information of TRS/CSI-RS can be provided to idle/inactive UEs by******• Pre-configuration in SIB or specifications******• Unused bits in DCI format 1\_0 with CRC scrambled by P-RNTI******• UE hypothetical detection of the other information.*** |
| Nokia, Nokia Shanghai Bell [19] | ***Observation: Actual specification work for objective 1b would seem to fall under RAN2 jurisdiction.*** ***Proposal: Do not introduce new RSs spesifically intented for IDLE/Inactive mode UEs.******Proposal: While network can provide RS configuration to IDLE/Inactive UEs, UE shall not assume that the RS are always present. UEs are required to autonomously detect the presence of RS when in RRC Idle/Inactive.*** ***Proposal: At least initially, RAN1 should focus on periodic tracking RS (TRS) related information for the serving cell only.*** |

# References

1. RP-200938, “Revised WID UE Power Saving Enhancements for NR”
2. R1-2005263 Assistance RS occasions for IDLE/inactive mode Huawei, HiSilicon
3. R1-2005389 Discussion on TRS/CSI-RS occasion(s) for idle/inactive UEs vivo
4. R1-2005521 Reference signal for RRC idle and inactive UEs ZTE
5. R1-2005583 On the usage of TRS/CSI-RS for the UE in Idle Mode Sony
6. R1-2005616 On TRS/CSI-RS occasion(s) for idle/inactive mode UE power saving MediaTek Inc.
7. R1-2005720 Configuration of TRS/CSI-RS for paging enhancement CATT
8. R1-2005739 Discussion on TRS CSI-RS occasions for idle/inactive UEs Beijing Xiaomi Software Tech
9. R1-2005885 Discussion on TRS/CSI-RS reception during idle/inactive mode Intel Corporation
10. R1-2006042 RS occasion for idle/inactive UEs OPPO
11. R1-2006158 On TRS/CSI-RS occasion(s) for idle/inactive Ues Samsung
12. R1-2006222 Discussion on potential TRS CSI-RS occasion(s) for idle/inactive UEs CMCC
13. R1-2006269 Consideration on TRS/CSI-RS occasion(s) for idle/inactive UEs Spreadtrum Communications
14. R1-2006312 Discussion on TRS/CSI-RS occasion(s) for idle/inactive UEs LG Electronics
15. R1-2006386 Potential enhancements for TRS/CSI-RS occasion(s) for idle/inactive Ues Panasonic
16. R1-2006528 Indication of TRS/CSI-RS for idle/inactive-mode UE power saving Apple
17. R1-2006666 Provisioning of potential TRS/CSI-RS occasion(s) for Idle/Inactive UEs Ericsson
18. R1-2006737 Discussion on TRS/CSI-RS occasion for idle/inactive UEs NTT DOCOMO, INC.
19. R1-2006816 TRS/CSI-RS for idle/inactive UE power saving Qualcomm Incorporated
20. R1-2006897 On RS information to IDLE/Inactive mode Ues Nokia, Nokia Shanghai Bell