**3GPP TSG RAN WG1 #106bis-e R1-211XXXX**

**e-Meeting, October 11th – 19th, 2021**

Agenda Item: 8.7

Source: Rapporteur (MediaTek)

Title: Collection of agreements for UE power saving enhancements for NR

Document for: Information

# Paging Enhancement

This feature is for idle/inactive mode UE power saving enhancement. The following summarize the scope and the RAN1 related agreements.

Please be noticed that:

* There are study phases and the corresponding agreements on evaluation assumptions and observations. Since they are not related to final specification, they are not included in the following table. Yet, they can still be checked in the status reports [1]-[5]
* Decision on physical-layer channel of Paging Early Indication (PEI) is made in RAN #93-e with guidance on RAN1 directions. RAN#93-e agreement is also captured in the following table.

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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 #102-e meeting   **Agreements related to the above scope item are as follows:** |
| **RAN1 #103-e meeting**  Agreements**:** For NR idle/inactive-mode paging enhancement, paging early indication before paging occasion is supported from RAN1 perspective   * FFS: Physical layer design based on DCI, SSS or TRS/CSI-RS * Send LS to inform RAN2 and kindly ask RAN2 to inform RAN1 if there is anything that RAN1 should take into consideration in the physical layer design for this feature, including any other progress RAN2 has made in this WI which may has RAN1 impact |
| **RAN1 #104-e meeting**  Agreement:   * Carrying UE subgroups information is considered in physical layer design for paging enhancement   Agreements:  For the evaluation and comparison of PEI candidate designs based on PDCCH, TRS/CSI-RS and SSS, the following are assumed:   * Behv-A:   + PEI indicates UE should monitor a PO if UE’s group/subgroup is paged   + UE is not required to monitor a PO if UE does not detect PEI at all PEI occasion(s) for the PO * Behv-B:   + PEI indicates whether or not UE should monitor a PO   + UE is required to monitor a PO if UE does not detect PEI at all PEI occasion(s) for the PO |
| **RAN1 #105-e meeting**  Agreement:  For UE subgroups indication in physical layer, maximum of 8 subgroups per PO is supported.  **Conclusion:**  To down-select one solution for PEI physical-layer channel/signal in RAN1 #106-e, using below as a starting point:   * PDCCH-based PEI * SSS-based PEI * TRS/CSI-RS-based PEI   Note: Additional details for each of the above 3 solutions are encouraged for more informed down-selection  Note: further refinement of the above list is possible, e.g., by merging/further splitting, depending on significance of the commonality and/or differences  Agreement:  For paging indication to the subgroups in a PO,   * For PDCCH-based PEI, subgroups in a PO are indicated by one PEI   + One bit in the DCI payload indicating one UE subgroup is supported     - FFS: Whether code-point based mapping is utilized, and, if so, how to map to the subgroups in a PO * For SSS-based PEI, subgroups in a PO are indicated by a set of sequence realizations   + FFS: Sequence mapping design for supporting up to 8 subgroups per PO   + Physical-layer configuration(s) and sequence generation design are subject to no impact to initial access and RRM measurements of legacy UEs * For TRS/CSI-RS-based PEI, subgroups in a PO can be indicated by the following alternatives   + Alt 1:One TRS sequence with orthogonal cover as PEI transmitted in the PEI monitoring occasion where one orthogonal cover of the PEI indicates one subgroup or combination of subgroups     - FFS: Design details for the orthogonal cover   + Alt 2: A set of TRS sequences indicating the subgroups with one selected sequence transmitting in one TRS resource     - FFS: Sequence mapping design for supporting up to 8 subgroups per PO and combination of subgroups   + Alt 3: Multiple TRS/CSI-RS resources FDMed/TDMed /CDMed in the same monitoring occasion where one TRS/CSI-RS resource indicates one subgroup     - Reuse Rel-15/16 CSI-RS FDM/TDM/CDM patterns for supporting up to 8 subgroups per PO * Note : It is RAN1 understanding that Physical-layer configuration(s) for paging early indication to the subgroups is subject to the same idle-mode reception bandwidth as CORESET-0 frequency span |
| **RAN1 #106-e meeting**  Conclusion   * For the evaluation of PEI candidate designs (for which observations made in previous RAN1 meetings), it was implicitly assumed by companies that the following processing can also provide synchronization:   + Processing of SSB(s) of each DRX cycle for serving-cell measurement   + Detection of multi-symbol SSS PEI (s)when transmitted   + Detection of TRS/CSI-RS PEI(s) when transmitted   Note: SSS PEI is assumed to reuse the SSS structure as in legacy SSB  Conclusion  To down-select one solution for PEI physical-layer channel/signal in RAN1 #106-e,   * PDCCH-based PEI * SSS-based PEI |
| **RAN #93-e meeting**   * Support PDCCH-based PEI as the only option   •       Only essential function for PEI is support  •     New DCI format  •     Higher layer configuration, including SS  •     Details of the procedures of PEI monitoring, and identification of MOs before PO  •     Only Behv-A (per RAN1#104e agreement) is supported  •     If TRS availability indication is agreed to be supported in both paging DCI and the DCI format for PEI, same mechanism/principle for TRS availability indication is adopted for the two DCI formats  •     Supporting TRS availability indication in DCI format for PEI shall not delay the completion of essential functionality of PEI |
| **RAN1 #106-bis-e Meeting**  Agreement  For NR Rel-17, paging indications to UE subgroups are carried only in PEI.  Agreement  For PEI, a new DCI format is supported to include at least paging indications to UE group(s)/subgroups of the associated PO(s)   * One bit in the DCI payload indicating one UE subgroup of a PO or one UE group/PO * The maximum number of total bits for paging indication field in PEI DCI format is x   + One PEI can be configured to indicate up to 4 PO(s) in a PF     - FFS whether to supporting map PEI to 3 POs in a PF   + FFS: 1 PEI for POs across multiple PFs   + FFS: value of x   Agreement  A PEI occasion (PEI-O) is a set of *S* consecutive PDCCH monitoring occasions when *nrofPDCCH-MonitoringOccasionPerSSB-InPO* is not configured   * *S* is the number of actual transmitted SSBs determined according to *ssb-PositionsInBurst* in SIB1 * The *K*-th PDCCH monitoring occasion for PEI in the PEI-O has the same QCL assumption as that of the *K*-th PDCCH monitoring occasion for paging in the PO.   + Note: QCL reference is SSB * FFS: Determination of the PEI-O location * FFS: Support of unlicensed spectrum operation with *nrofPDCCH-MonitoringOccasionPerSSB-InPO* configured   Agreement  CORESET # 0 or *commonControlResourceSet* in SIB1 can be used for PEI   * Note: The number of CORESETs configured for a UE follows the requirement of UE feature 3-1     Agreement  Support configuration of a dedicated search space (‘peiSearchSpace’) for PEI   * FFS: Configuration details and whether and how to reuse legacy search space sets, including *pagingSearchSpace* and *searchSpaceSetZero*   Agreement  Determination of PEI-O location for a target PO is based on one of the following alternatives:   * Alt 1: The first PDCCH monitoring occasion of the PEI-O is provided w.r.t. the start of a reference frame determined by a frame-level offset to the PF of the target PO   + FFS: The unit and the range of the frame-level offset   + FFS: The unit and the range of the configuration for the first PDCCH monitoring occasion (e.g., to be the same as those of *firstPDCCH-MonitoringOccasionOfPO*) * Alt 2: The first PDCCH monitoring occasion of the PEI-O is provided w.r.t. the *L*-th SS burst before the first PDCCH monitoring occasion of the target PO.   + FFS: the case that a SSB burst overlaps in time with the target PO   + FFS: *L* = 1, 2 or 3   + FFS: Reference the “start” or “end” of the *L*-th SS burst   + FFS: The unit and the range of the configuration for the first PDCCH monitoring occasion * Alt 3: The first PDCCH monitoring occasion of the PEI-O is provided by a time offset w.r.t. a reference time for the target PO.   + FFS: The exact definition of the reference time, e.g. the first MO of the target PO, the first MO of the first PO indicated by the PEI, the start of the PF for the target PO   + FFS: The unit and the range of the time offset * FFS: Whether any SS burst or TRS burst is needed between PEI-O and PO * Configuration for one PEI indicating multiple POs within a PF should be taken into consideration in the determination of PEI occasion   Decide one of the above alternatives or a single merged solution based on the alternatives in RAN1#107-e meeting.  FFS: Extension for the case one PEI indicates multiple POs across multiple PFs, if supported |

# TRS/CSI-RS occasion(s) for idle/inactive UEs

This feature is for idle/inactive mode UE power saving enhancement. The following summarize the scope and the RAN1 related agreements. It is noticed that this scope has no study phase.

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| 1. Specify enhancements for idle/inactive-mode UE power saving, considering system performance aspects [RAN2, RAN1]    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   **Agreements related to the above scope item are as follows:** |
| **RAN1 #102-e Meeting**  Agreements:   * New types/patterns of TRS/CSI-RS are not introduced specifically for idle/inactive mode UE.   Agreements:  The TRS/CSI-RS occasion(s) that may be for connected mode UEs can be shared to idle/inactive mode UEs.  -  Note: It is understood that gNB can potentially share the occasions to idle/inactive (which would just mean it up to NW whether to share or not share).  -  Note: It is understood that TRS/CSI-RS in the TRS/CSI-RS occasion(s) may or may not be transmitted.  -  Note: Always-on TRS/CSI-RS transmission by gNodeB is not required  -  At least TRS/CSI-RS occasion(s) corresponding to periodic TRS is supported  - FFS for other RS types  -  FFS: Whether UE blind detection is required or not.  Agreements:  Idle/inactive UE may use the TRS/CSI-RS occasion(s) that are shared to it for functionalities such as:  -           AGC, time/frequency tracking  -           FFS: RRM measurement for serving cell, RRM measurement for neighbor cell, paging reception indication  **Observation:**  It is up to gNB implementation whether or not to transmit a TRS/CSI-RS to idle/inactive UEs even when the TRS/CSI-RS is not needed by connected UEs (e.g., when there is a connected mode UE in a cell but the UE is no longer using the TRS/CSI-RS, or when there is no longer connected mode UE in a cell, etc.)  Agreements:  The configuration of TRS/CSI-RS occasion(s) for idle/inactive mode UE(s) is provided by higher layer signalling  -           FFS higher layer signalling candidates (e.g., SIB, dedicated RRC, RRC release message, etc.)  -           FFS for other signalling candidates (e.g., pre-configuration, etc.)  -           FFS for detailed configuration parameters (e.g., whether and how to reduce the signalling overhead for configuration, etc.)  Agreements:  Further study whether and how to inform the availability of TRS/CSI-RS to idle/inactive mode UE (implicitly or explicitly).  - Note: Availability corresponds to the information for whether TRS/CSI-RS is actually transmitted or not. |
| **RAN1 #103-e Meeting**  Agreements:   * Functionality of RRM measurement for neighbour cell is not supported for TRS/CSI-RS for idle/inactive UE(s).   **Agreements:**   * SIB signalling provides the configuration of TRS/CSI-RS occasion(s) for idle/inactive UE(s).   + Up to RAN2 to decide which SIB is to be used.   + Whether or not to additionally support other high-layer signalling methods (e.g., dedicated RRC, RRC release message, etc.) is up to RAN2   Send an LS to RAN2 informing the above agreements, and   * To further add that RAN1 is working on the detailed physical layer design   Draft LS is endorsed, with final LS in [R1-2009791](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_103\Docs\R1-2009791.zip). 🡪 R1-2009848  Agreements:   * Aperiodic TRS and semi-persistent/aperiodic CSI-RS are not used as TRS/CSI-RS occasion(s) for idle/inactive UEs.   Agreements:  - Target sending an LS to RAN2 and RAN4 to ask whether it is feasible to allow a UE to use the potential TRS/CSI-RS occasion to enhance the SSB based IDLE/Inactive mode evaluations of the serving cell. (to also include agreements from last meeting)  \* Further discussion whether any additional information needs to be included in the LS or not, including potential re-wording of the leading sentence    Agreements:   * Discuss further based on the following alternatives and down-select at RAN1#104-e:   + Alt 1: The availability of TRS/CSI-RS at the configured occasion(s) is NOT informed to the UE.   + Alt 2: The availability of TRS/CSI-RS at the configured occasion(s) is informed to the UE.   + Alt 3. The conditional availability of TRS/CSI-RS at the configured occasion(s) is informed to the UE.     - The condition can be, e.g., existence of paging.   + Alt 4. Combination of the above alternatives.   + FFS for details   + FFS for UE behavior when the availability is not informed.   + Other techniques are not precluded.   + Companies encourage to provide sufficient information for the proposal, e.g.,     - how to achieve power saving gain     - how to minimize impact on NW   how to minimize extra UE implementation complexity   * + - feasibility check on sharing the TRS/CSI-RS between connected UEs and idle/inactive UEs   + Proposals should be consistent with the WID objective.   **Conclusion:**   * TRS/CSI-RS based PEI is discussed in AI 8.7.1.1. * PEI functionality is not further discussed under AI 8.7.1.2. * Note: This does not prevent to potentially use PEI to carry the indication for TRS/CSI-RS presence. |
| **RAN1 #104-e Meeting**  Agreements:  Configuration of TRS/CSI-RS occasion(s) for idle/inactive Ues include at least:   * powerControlOffsetSS, * scramblingID * firstOFDMSymbolInTimeDomain, * startingRB. * nrofRBs, * FFS other parameters * FFS applicable values   Agreements:  The SCS configuration of TRS/CSI-RS occasion(s) for idle/inactive UEs can be discussed and down-selected from following alternatives at RAN1#104b-e:   * Alt1: same as initial BWP * Alt2: configurable parameter   Agreements:  Multiple RS resources can be configured for TRS/CSI-RS occasion(s) for idle/inactive UEs.   * FFS details (including whether or not to restrict the RS to be TRS only)   Agreements:  For a cell with TRS/CSI-RS occasions configured for IDLE/Inactive UEs, IDLE/Inactive UE’s assumption on the availability of TRS/CSI-RS at the configured occasion(s) is informed to the idle/inactive UE based on explicit indication.   * FFS details (e.g., the signalling, detailed information for the TRS/CSI-RS, etc.) * There is no intended blind detection of the presence/absence of TRS/CSI-RS at the UE side in this feature. That is, the UE assumes TRS/CSI-RS is not present if the network does not indicate it is available (or indicates it is unavailable).   **Conclusion**  From RAN1 perspective, there is no consensus on supporting RRM measurement for serving cell functionality for TRS/CSI-RS occasion(s) for idles/inactive UEs.  Agreements:  The configuration of the frequency location of TRS/CSI-RS occasion(s) for idle/inactive UEs are discussed and down-selected from following alternatives at RAN1#104bis-e:   * Alt-1: within initial DL BWP * Alt-2: is not restricted by initial BWP   + IDLE/INACTIVE mode UE is not expected to receive TRS/CSI-RS outside the initial DL BWP.   Agreements:  To study QCL information of TRS/CSI-RS occasion(s) for idle/inactive UEs from following alternatives:   * Alt-1: From higher layer configuration, e.g. qcl-InfoPeriodicCSI-RS * Alt-2: QCL assumptions associated with transmitted SSBs implicitly, e.g. similar to PDCCH monitoring in PO * FFS details * Other alternatives are not precluded   **Conclusion:**  Decide at RAN1#104b-e, whether or not to support periodic CSI-RS in addition to periodic TRS for TRS/CSI-RS occasion(s) for idle/inactive UEs. |
| **RAN1 #104-bis-e Meeting**  Agreement:  SCS of TRS/CSI-RS occasion(s) for idle/inactive UEs is same as SCS of CORESET#0.  Agreement:  Support higher layer configuration of the QCL information of TRS/CSI-RS occasion(s) for idle/inactive UEs.   * FFS details of the QCL information, e.g. associated SSB index   Agreement:  IDLE/INACTIVE mode UE is not expected to receive TRS/CSI-RS outside the initial DL BWP.   * Configuration of the frequency location of TRS/CSI-RS occasion(s) for idle/inactive UEs is not restricted by initial BWP.   Working assumption:  Support at least L1 based signaling for the availability indication of TRS/CSI-RS at the configured occasion(s) to the idle/inactive UEs.   * FFS details, including paging DCI and/or PEI for L1 based signaling * FFS SIB-based signaling/configuration   + **Note:** It is RAN1 understanding that existing SI update procedure is used for SIB based signaling   Agreement:  **Configuration for TRS/CSI-RS occasion(s) for idle/inactive UEs is based on periodic TRS only, including following limitations**   * **Configuration parameters that are necessary to provide configuration of periodic TRS for idle/inactive UEs** * **Applicable values that are necessary to provide configuration of periodic TRS for idle/inactive UEs** * **If the configuration is provided, idle/inactive UEs can always implicitly assume that trs-info is configured.**    + **The parameter trs-info does not need to be provided in the configuration**   Agreement:  For the information provided by a physical layer availability indication of TRS/CSI-RS at the configured occasion(s) to the idle/inactive UEs, one or more alternatives from the following can be supported:   * Alt1: Availability/unavailability information for all or some of configured RS resources using a bitmap or codepoint * e.g. using bitmap, where each bit ~~from a bitmap or a codepoint~~ is associated with at least one resource~~/configuration~~ or a set/group of resources * e.g. a codepoint to indicate a state of availability/unavailability for all or some of configured RS resources * Alt2: value or codepoint to indicate one or more resource/configuration indices that correspond to the available RS resources * FFS whether and how to indicate the ‘availability’ in beam selective manner. * Other alternatives are not precluded |
| **RAN1 #105-e Meeting**  Agreement:  Confirm the following working assumption:  Support at least L1 based signaling for the availability indication of TRS/CSI-RS at the configured occasion(s) to the idle/inactive UEs.   * FFS details, including paging DCI and/or PEI for L1 based signaling * FFS SIB-based signaling/configuration   + Note: It is RAN1 understanding that existing SI update procedure is used for SIB based signalling     Agreement:  **For the information provided by a physical layer availability indication of TRS/CSI-RS at the configured occasion(s) to the idle/inactive UEs, support availability/unavailability information for configured RS resources using a bitmap or codepoint**   * **e.g. using bitmap, where each bit is associated with at least one resource/configuration or a set/group of resources** * **e.g. a codepoint to indicate a state of availability/unavailability for all or some of configured RS resources** * **FFS** **maximum number of** **configured RS resources per physical layer availability indication to support.** * **FFS whether availability/unavailability information is for all or some of configured RS resources**     Agreement:  **Support applicable values for the following configuration parameters as below.**   * **powerControlOffsetSS:** **{-3, 0, 3, 6}dB** * **scramblingID:** **0 to 1023** * **firstOFDMSymbolInTimeDomain:** **0 to 9**   + **firstOFDMSymbolInTimeDomain indicates first symbol in a slot, a second symbol in the same slot can be derived implicitly with symbol index as firstOFDMSymbolInTimeDomain+4** * **startingRB:** **0 to 274** * **nrofRBs:** **24 to 276**     Agreement:  The QCL information of TRS/CSI-RS occasion(s) for idle/inactive UEs is indicated as a SSB index in range of 0 to 63.   * FFS: how the QCL information can be configured, e.g. per RS resource set or per configuration * FFS: QCL type, which is predetermined   **Working assumption:**  **Support paging PDCCH based availability indication of TRS/CSI-RS occasions for idle/inactive UEs.**  **Support PEI based availability indication of TRS/CSI-RS occasions for idle/inactive UEs at least if PDCCH-based PEI is down-selected.**   * **FFS ~~whether and~~ how to enable/disable L1 based availability indication configurable by SIB**   Agreement:  Configuration of TRS/CSI-RS occasion(s) for idle/inactive UEs include:   * periodicityAndOffset {10, 20, 40, 80} ms * frequencyDomainAllocation for row1 with applicable values from {0, 1, 2, 3} to indicate the offset of the first RE to RE#0 in a RB * FFS Configuration index   + details,     - E.g. Per resource or resource set or group of resource sets     - E.g. explicit or implicit indication based on QCL source   Agreement:  Further study supporting SIB based signaling for availability information of TRS/CSI-RS occasions for idle/inactive UEs at least based on the presence/absence of the configuration of the TRS/CSI-RS occasion in SIB\_X in case L1 based availability indication is not configured.   * FFS whether and how SIB based signaling and L1 based signaling can be configured simultaneously |
| **RAN1 #106-e Meeting**  Agreement  Support at least one of the following alternatives   * Alt1: L1 availability indication at an occasion provides availability/unavailability information only for RS resources with the same QCL reference as the L1 availability indication occasion. * Alt2: L1 availability indication at an occasion can provide availability/unavailability information for RS resources with QCL references not confined to be the same as for the L1 availability indication occasion   Note:  The occasion mentioned above refers to a signal/channel monitoring occasion (e.g. a paging PDCCH or PEI monitoring occasion) to provide the L1 availability indication.  Note: a RS resource is a RS from configured TRS/CSI-RS occasion(s) for idle/inactive UEs., where the configuration for TRS/CSI-RS occasion(s) for idle/inactive UEs is based on periodic TRS only.  Agreement  L1 based availability indication of TRS/CSI-RS at the configured occasion(s) to the idle/inactive UEs is valid for a time duration starting from a reference point, where   * the time duration can be determined based on at least one from the following (to be down-selected):   + Alt-1: configured by higher layer   + Alt-2: a predefined/configured window   + Alt-3: value indicated by the availability indication, where the value is one of multiple configured time duration(s)   + Alt-4: until when the UE receives another availability indication   + A combination of alternatives or other alternatives is not precluded. * the reference point can be determined as at least one from the following (to be down-selected):   + Alt-1: start of next PO or DRX cycle   + Alt-2: time location where UE receives the indication     - Note: the time location is subject to application delay if agreed   + Alt-3: start of current PO or DRX cycle where UE receive the indication   + Alt-4: a time location which is configured by higher layer   + A combination of alternatives or other alternatives is not precluded.   **Agreement**  For a RS resource configured for TRS/CSI-RS occasion(s) for idle/inactive UEs, a quasi co-location type can be determined as   * + ‘typeC’ with an SS/PBCH block and, when applicable, ‘typeD’ with the same SS/PBCH block |
| **RAN1 #106-bis-e Meeting**  Conclusion  No consensus to support SIB based signaling for availability information of TRS/CSI-RS occasions for idle/inactive UEs  Working Assumption  If TRS resource is configured in SIB, L1 based availability indication is always enabled based on the configuration.  **Agreement**  For L1 based availability indication of TRS/CSI-RS at the configured occasion(s) to the idle/inactive UEs, support availabilityinformation for configured RS resources using a bitmap. where each bit indicates whether associated TRS resource(s) are available.   * support L1 availability indication at an occasion can provide availability information RS resources with QCL references not confined to be the same as for the L1 availability indication occasion   + FFS associated TRS resource(s) per bit, e.g. a bit is associated with a TRS resource set   + Bitmap size is up to X bits     - X = [6] for paging PDCCH based L1 availability indication.     - FFS X for PEI DCI based L1 availability indication     - FFS details about how to configure the DCI field: e.g. start and length of bitmap (e.g. explicitly/implicitly configured) * for paging PDCCH based L1 availability indication, support L1 availability indication at an occasion can provide availability information for all configured RS resources   + FFS whether this needs to be supported regardless of the number of beams or for some configured RS resources * FFS: PEI DCI provides L1 availability indication information only for RS resources with QCL references to be the same as for the L1 availability indication occasion * FFS: indication of unavailability     **Agreement**  At least for paging PDCCH based L1 availability indication of TRS/CSI-RS at the configured occasion(s) to the idle/inactive UEs, the L1 availability indication is valid for a time duration starting from a reference point, where   * the time duration is a validity duration configured by higher layer,   + FFS applicable values, e.g. # of DRX cycles, or multiple of default paging cycle duration (i.e. modification period)   + FFS UE doesn’t expect inconsistent L1 based indication during the time duration * the reference point for start of the validity duration is one of the following alternatives:   + Alt1: SFN of the first PF from the next DRX cycle   + Alt2: SFN of the first PF from the current DRX cycle where UE receives the indication   + Alt3: based on SFN configured by higher layer, i.e. modification period configured as multiple of default paging cycle duration   + Alt4: start of the PF for the PO where UE receives the indication   + Note: the DRX cycle in Alt1 and Alt2 is the default paging cycle broadcast in SIB   + Note: The SFN for the first PF is ~~for (UE mod N) = 0, and can be~~ calculated by (SFN + PF\_offset) mod T = 0 * the time duration can be optionally configured by gNB   + when the time duration is not configured, one of the following alternatives can be considered:     - Alt1: the availability indication is valid until when the UE receives another availability indication.     - Alt2: the availability indication is valid until L1 availability indication is changed by network     - Alt3: default time duration e.g. default paging cycle * FFS whether and how to handle the miss detection issue of L1 signaling   **Agreement**  Configuration of TRS/CSI-RS occasion(s) for idle/inactive UEs include a list of one or more TRS resource sets, where:          a TRS resource set can be configured to include  o   a set of TRS resources up to two consecutive slots,    Note: a TRS resource is same as Rel-15/16, i.e. a CSI-RS in a symbol.  o   at least common configuration parameters:    a QCL reference    firstOFDMSymbolInTimeDomain,    ‘frequencyDomainAllocation for row1’, ‘startingRB’ ,‘nrofRBs’,’powerControlOffsetSS’, periodicityAndOffset’    FFS          scramblingID,          a TRS resource set ID, number of slots {1, 2} or number of symbols {2, 4} if supported          Note: the ‘TRS resource set’ configuration is not (necessarily) identical to ‘NZP-CSI-RS-ResourceSet’ configuration for TRSin R15/16. |

# Extension(s) to Rel-16 DCI-based power saving adaptation during DRX Active Time

This feature is for connected-mode power saving enhancement. The following summarize the scope and the RAN1 related agreements.

Please be noticed that there are study phase for this feature and the corresponding agreements on evaluation assumptions and observations. Since they are not related to final specification, they are not included in the following table. Yet, they can still be checked in the status reports [1]-[5]

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| 1. Study and specify, if agreed, enhancements on power saving techniques for connected-mode UE, subject to minimized system performance impact [RAN1, RAN4]    1. Study and specify, if agreed, extension(s) to Rel-16 DCI-based power saving adaptation during DRX Active Time for an active BWP, including PDCCH monitoring reduction when C-DRX is configured [RAN1]  * NOTE: Rel-15 and Rel-16 available power saving solutions should be supported by the UE and included in the evaluation. RAN1 will ask the confirmation from RAN2 that Rel-15 and Rel-16 available power saving solutions are properly utilized.   **Agreements related to the above scope item are as follows:** |
| **RAN1 #103-e Meeting**  Agreements:   * **Specify at least one of the following options for Rel-17 dynamic PDCCH adaptation ~~in time-domain~~ for active time,**   + **Option 1: Search space set group switching,e.g., ~~potential adjustments/enhancements for~~including explicit and implicit search spaceset group switching ~~specified in R16 for NR-U~~**   + **Option 2: PDCCH skipping for a certain duration / DRX cycle** * **FFS: which option(s)~~(e.g. taking into account additional gain of option 1 over option 2, or vice-versa)~~** * **Candidate DCI formats for dynamic PDCCH adaptation include DCI formats 1\_1(including scheduling and non-scheduling DCI), 0\_1, 1\_2, 0\_2, 2\_0, 2\_6.** * **Note:**   + **Companies are encouraged to provide analysis on specification impact,** **power saving benefit and system impact (e.g., packet latency, system overhead)** * **FFS: other schemes are not precluded for further study** |
| **RAN1 #104-e Meeting**  Agreements:   * Strive for a common design for DCI based PDCCH monitoring adaptation in active time for an active BWP to support functionalities inclusive of both SSSG switching and PDCCH skipping for a duration.   + Details FFS   Agreements:   * Further study whether and how to minimize the impact to data scheduling for new transmissions and retransmissions.   + FFS details * Further study the application delay for PDCCH adaptation indication   Agreements:   * For DCI based PDCCH skipping in active time for an active BWP (if supported), the following can be further considered,   + Explicit indication of PDCCH adaptation     - Scheduling DCI       * Format 1\_1       * Format 0\_1       * Format 0\_2/1\_2     - Non-scheduling DCI       * Format 2\_6 in active time       * Format 2\_0       * Format 1\_1 (SCell dormancy case 2)     - additional indication mechanism       * By reusing Rel-16 SCell dormancy indication when CA is configured, FFS details       * By reusing Rel-16 cross-slot scheduling indication when R16 cross-slot scheduling is configured, FFS details   + DCI dynamically indicates a duration/periodic interval for skipping     - FFS: how to indicate the duration/period interval, e.g., number of slots or skipping current DRX   + PDCCH skipping for a duration indicated by minimum scheduling offset   + Others are not precluded   Agreements   * For DCI based SSSG switching in active time for an active BWP (if supported), the following can be further considered,   + Explicit indication of PDCCH adaptation     - Scheduling DCI based       * Format 1\_1,       * Format 0\_1,       * Format 0\_2/1\_2       * ~~Format 1\_0~~     - Non-scheduling DCI       * Format 2\_6 in active time       * Format 2\_0       * ~~Format 1\_0~~       * Format 1\_1 (SCell dormancy case 2)     - additional indication mechanism       * By reusing Rel-16 SCell dormancy indication when CA is configured, FFS details       * By associating Rel-16 cross-slot scheduling indication when R16 cross-slot scheduling is configured, FFS details     - DCI dynamically indicates a duration for the switched SSSG, UE switch back to previous/default SSSG after duration ends   + Timer-based SSSG switching, including RRC configured a timer, UE switch back after timer expired.   + SSSG activation/deactivation   + FFS: Implicit SSSG switching     - SSSG switching triggered by SR     - SSSG switching triggered by RACH     - Default SSSG that a UE monitors when coming out of DRX to monitor an ON duration. * FFS: whether/how to support SSSG switching for multiple groups of cell(s). * FFS: whether/how to support SSSG switching in active time with DCP outside active time * FFS: whether / how to support more than 2 SSSGs,   + FFS: number of SSSGs * FFS: a search space set group to emulate PDCCH skipping * Others are not precluded   Agreements:   * The following alternatives can be considered for DCI based PDCCH monitoring adaptation in active time for an active BWP for power saving   + Alt 1: Enhancement of Rel-16 SSSG switching to support PDCCH monitoring adaptation including skipping for a duration   + Alt 2a: Enhancement of DCI(s) utilized for Rel-16 power saving adaptation for supporting both skipping PDCCH monitoring for a duration and SSSG switching   + ~~Alt 2b: Enhancement of DCI(s) utilized for Rel-16 power saving adaptation for supporting both skipping PDCCH monitoring for a duration and PDCCH monitoring periodicity adaptation~~   + Others not precluded |
| **RAN1 #105-e Meeting**  Agreement:   * PDCCH schedules data and also indicates PDCCH monitoring adaptation by SSSG switching and PDCCH skipping for a duration is supported.   + At least DCI format(s) 1-1, 0-1, 1-2 and 0-2 can be used for the indication(s)   Agreement:   * ~~At least~~ one of  Alt 1 and Alt 2 is supported, to be decided in RAN1#106, * Alt 1: Supporting SSSG  switching to emulate PDCCH skipping functionality,   + Alt 1-1: by an ‘empty’ SSSG which no SS set(s) is configured for the ‘empty’ SSSG, UE does not monitoring PDCCH on the ‘empty’  SSSG,   + Alt1-2: by a ‘dormant SSSG’ which may have associated SS sets, and monitored conditionally (e.g., depending on HARQ NACK or RTT/ReTx timers) * Alt 2: PDCCH schedules data and also indicates PDCCH monitoring adaptation by PDCCH skipping for a duration is supported.   + FFS details, including     - e.g., joint / separate indication of SSSG switching and PDCCH skipping     - Determination of the duration(s) for PDCCH skipping, e.g.,       * by RRC signaling,       * by DCI indication       * Implicitly, to the end of C-DRX active time   Agreement:  At least SSSG#0 and SSSG#1 switching is supported for Rel-17 SSSG switching indicated by PDCCH scheduling data and/or timer.   * FFS: support of more than 2 SSSGs |
| **RAN1 #106-e Meeting**  Agreement   * At most 2 bit indication in self-scheduling DCIs (i.e., DCI format 1-1/0-1/1-2/0-2) can be specified for triggering the PDCCH monitoring adaptation in a single cell   + FFS: the bit size of the indication is configurable   + FFS: bit mapping to the PDCCH monitoring behaviour   + FFS: details of indication of multiple cells case   Agreement  Select either package 1 or package 2  Package 1         UE behavior after receiving PDCCH indication of monitoring adaptation can be one of the followings,   * + - Working Assumption: Beh 1: PDCCH skipping is not activated     - Beh 1A: PDCCH skipping means stopping PDCCH monitoring for a duration X       * FFS the possible values for X       * FFS: Whether and how to support more than one skipping duration(s)       * FFS: whether to continue monitoring PDCCH scrambled by C-RNTI for Type 0/1/1A/2 CSS or not     - Beh 2: stop monitoring SS sets associated with SSSG#1 and SSSG#2 (if confirmed) and monitoring  of SS sets associated to SSSG#0 (legacy behaviour)     - Beh 2A: stop monitoring SS sets associated with SSSG#0 and SSSG#2 (if confirmed)  and monitoring  of SS sets associated to SSSG#1 (legacy behaviour)     - Working Assumption: Beh 2B(if confirmed): stop monitoring SS sets associated with SSSG#0 and SSSG#1 and monitoring  of SS sets associated to SSSG#2 (if confirmed)          Note: The number of supported SSSG is left to UE feature discussion.         FFS: UE capability of supported UE behaviors         Indication of Beh 1A when SSSG(s) are not configured is supported.         Working assumption: Indication of Beh 1A for current SSSG when two SSSG(s) are configured is supported         FFS: Indication of Beh 1A when three SSSG(s) (if supported) are configured         Y bits is configured for scheduling DCIs (i.e., DCI format 1-1/0-1/1-2/0-2) indicating PDCCH schedules data and also PDCCH monitoring adaptation   * + - FFS how the UE behavior(s) defined above mapping to Y bits     Note: at most Y = 2         Working Assumption at most 3 SSSGs is supported to be configured.   * + - FFS: whether or how SSSG can be configured to be monitored conditionally (e.g., depending on HARQ NACK or RTT/ReTx timers)     - FFS: whether or how non-default SSSG to another non-default SSSG          FFS details of timer(s) for switching between SSSG(s)   * + - UE fallbacks to default SSSG (i.e., SSSG#0) after timer expiration.     - R16 timer for SSSG switching and the corresponding behavior is as baseline          FFS whether the timer(s) is configured per SSSG, ~~or~~per BWP or other approaches.         FFS whether the skipping duration(s) is configured per SSSG, per BWP, or other approaches.         FFS PDCCH monitoring adaptation indicated by non-scheduling DCI         PDCCH based monitoring adaptation is ~~limited~~applied to USS and type-3 CSS.    Package 2 (Alt 1 and Alt 2)   * If alt 1 is supported,   + supporting SSSG  switching to emulate PDCCH skipping functionality by an ‘empty’ SSSG (i.e. Alt 1-1)or ‘dormant’ SSSG(i.e. Alt 1-2)     - Y bits is configured for scheduling DCIs (i.e., DCI format 1-1/0-1/1-2/0-2) indicating SSSG index.       * FFS dynamic indication of ~~initial~~ timer value(s)       * FFS details     - At most [3] SSSGs is supported to be configured.       * Note: including‘empty’ SSSG or ‘dormant’ SSSG     - ~~FFS support of single timer to switch to default SSSG#0  or support of multiple timers between SSSGs~~     - FFS whether one or more of the following timer(s) is supported for switching between       * Option 1: Non-default SSSG to default SSSG (i.e., SSSG#0)       * Option 2: Non-default SSSG to another non-default SSSG       * Option 3: Default SSSG (i.e., SSSG#0) to non-default SSSG(s)     - FFS: down selection between ‘empty’ SSSG (i.e. Alt 1-1)or ‘dormant’ SSSG(i.e. Alt 1-2)     - ~~FFS: whether ‘empty’ SSSG and ‘dormant’ SSSG, can be looked as a skipping duration and whether to introduce a SSSG state.~~     - FFS: whether the timer is configured per SSSG, per BWP, or other approaches.     - ~~FFS: whether multiple timer duration(s) can be configured by RRC, and DCI dynamically indicates a timer duration~~     - ~~FFS: do we need to define default SSSGs and for what purpose?~~     - Note: description of ‘empty’ SSSG and ‘dormant’ SSSG has been provided in RAN1#105-E * If alt 2 is supported,   + PDCCH schedules data and also indicates PDCCH monitoring adaptation by PDCCH skipping for a duration is supported.     - Y bits is configured for scheduling DCIs (i.e., DCI format 1-1/0-1/1-2/0-2) indicating PDCCH monitoring adaptation ~~(including  SSSG index, and/or PDCCH skipping duration(s))~~       * ~~Alt 2-1:~~         + FFS: Determination of the duration for PDCCH skipping, e.g.,   One skipping duration configured by RRC signaling,  Multiple candidate values of skipping duration configured by RRC signaling and use DCI to dynamically indicate one of the configured skipping duration  by specification   * + - * + FFS: possible value(s) of the duration         + FFS: joint or separate indication with SSSG switching       * ~~Alt 2-3:~~         + FFS: whether introduce SSS/SSSG specific skipping indication via e.g. bitmap, codepoint, joint indication with a minimum scheduling offset value     - FFS: whether the skipping duration is configured per SSSG, per BWP, or other approaches.     - FFS: PDCCH skipping indicated by non-scheduling DCI     - FFS: interaction with SSSG switching (when configured), e.g. impact to skipping when SSSG timer expires, which SSSG after PDCCH skipping is monitored, etc.   Agreement  package 1 in above agreement is selected. |
| **RAN1 #106-bis-e Meeting**  **Agreement**  **Confirm the four working assumptions(extracted from package 1)**  Working assumption(extracted from package 1):  Beh 1: PDCCH skipping is not activated  Working assumption(extracted from package 1):  Indication of Beh 1A for current SSSG when two SSSG(s) are configured is supported  Working assumption(extracted from package 1):  At most 3 SSSGs is supported to be configured for PDCCH monitoring adaptation.  Working assumption(extracted from package 1):  Beh 2B: stop monitoring SS sets associated with SSSG#0 and SSSG#1 and monitoring of SS sets associated to SSSG#2.  **Agreement**  Scheduling DCIs indicating timer value for a SSSG is not supported.  **Agreement**  For Beh 1A,   * + The UE can be configured to be indicated by DCI a value of X ~~slots~~ (i.e., skipping duration) among ~~up to~~ *~~M~~**~~= {1, 2, 3}~~*multipleRRC configured values by scheduling DCIs indicating PDCCH schedules data     - The bits for indicating PDCCH monitoring adaptation also indicating skipping duration. Details FFS     - ~~The maximum value of~~ *~~M~~* ~~= [2 or 3]~~     - ~~Note: M = 1 is not precluded.~~   **Agreement**  The bit mapping of DCI indication PDCCH monitoring adaptation is as follows,   * For Case 1 (i.e., PDCCH skipping), the following is supported   + 1-bit in scheduling DCI is supported to indicate PDCCH monitoring adaptation UE behaviors if *M*=1     - ‘0’ is Beh 1 and ‘1’ is Beh 1A   + 2-bit in scheduling DCI is supported to indicate PDCCH monitoring adaptation UE behaviors if *M*=2 or 3     - ‘00’ is Beh 1     - ‘01’ is Beh 1A with skipping duration 1     - ‘10’ is Beh 1A with skipping duration 2     - ‘11’ is Beh 1A with skipping duration 3 if M=3, reserved if M=2 * For Case 2  (i.e., 2 SSSG switching) , the following is supported   + 1-bit in scheduling DCI is supported to indicate PDCCH monitoring adaptation UE behaviors     - ‘0’ is Beh 2 and ‘1’ is Beh 2A * For Case 3 (i.e., 3 SSSG switching) , the following is supported   + 2-bit in scheduling DCI is supported to indicate PDCCH monitoring adaptation UE behaviors     - ‘00’ is Beh 2     - ‘01’ is Beh 2A     - ‘10’ is Beh 2B     - [‘11’ is reserved]       * ~~FFS ‘11’ is Beh 1A~~ * For Case 4 (i.e., 2 SSSG switching with PDCCH skipping) , the following is supported   + 2-bit in scheduling DCI is supported to indicate PDCCH monitoring adaptation UE behaviors,     - ~~Indicated UE behaviors are Beh 1A, 2, 2A and FFS whether indicate Beh 1~~     - FFS details bit mapping     - ~~FFS Timer behavior (e.g., reset timer value) for PDCCH monitoring adaptation indication when Beh 1A is indicated~~ * FFS: For Case 5 (i.e., 3 SSSG switching and skipping)   + 2-bit in scheduling DCI is supported to indicate PDCCH monitoring adaptation UE behaviors     - ‘00’ is Beh 2     - ‘01’ is Beh 2A     - ‘10’ is Beh 2B     - ‘11’ is Beh 1A   + FFS Timer behavior ~~(e.g., reset timer value) for PDCCH monitoring adaptation indication~~ when Beh 1A is indicated * Note: The UE can be configured to be indicated by DCI a value of X ~~slots~~ (i.e., skipping duration) among *M* RRC configured values by scheduling DCIs indicating PDCCH schedules data * FFS whether to restrict Skipping duration to be shorter than SSSG initial timer value * FFS whether the configuration is same or different for DCI format x\_1 and DCI format x\_2   **Agreement**  -         The value of the SSSG switching timer in slots for ~~monitoring PDCCH in the active DL BWP of the serving cell~~ SSSG#1 and/or SSSG#2 ~~before moving to the default search space group is~~ can be configured as  o    {[1...20,40,60,80,100]} for 15 kHz SCS,  o    {[1...40, 80,100,160,200]} for 30 kHz SCS,  o    {[1...80, 160,200,320,400]} for 60kHz SCS,  o    {[1...160,320,400,640,800]} for 120kHz SCS    **Agreement**  -         If the UE monitors PDCCH according to SSSG#1 and the timer expires, the UE starts monitoring PDCCH according to Beh 2.  ~~-~~If the UE monitors PDCCH according to SSSG#2 and the timer expires,  o    Alt 1: the UE monitoring PDCCH according to Beh 2  o    Other alternatives are not precluded  -         Timer can be optionally configured.    **Agreement**  **Select one of the alternatives from the following:**  -         Alt 1: Separate RRC configuration for timer value(s) is supported for switching from SSSG#2 to SSSG#0 and from SSSG#1 to SSSG#0 respectively.  -         Alt 2: the timer value(s) for switching from SSSG#2 to SSSG#0 and from SSSG#1 to SSSG#0 is common and configured per cell.  -         Alt 3: the timer value(s) for switching from SSSG#2 to SSSG#0 and from SSSG#1 to SSSG#0 is common and configured per BWP.    **Agreement**  The following application delay for a scheduling DCI based PDCCH monitoring adaptation indication can be considered~~is as follows~~,  -         For PDCCH skipping,  o    Option b  o    Option f  o    Option d for downlink grant and Option c for uplink grant  o    Option i  o    Option j  o    Note: down-select ~~between~~ based on the options in RAN1#107-E  -         For SSSG switching,  o    Option a  o    Option d for downlink grant  and Option c for uplink grant  o    Option h  o    Option b  o    Option d for downlink grant and Option g for uplink grant  o    Note: down-select ~~between~~ based on the options in RAN1#107-E  -         The Options a – j is defined as follows,  o    Option a: the application timelines provided in Table 10.4-1 in TS38.213 for search-space group switching for unlicensed band form is reused.  u      cid:_Foxmail.1@18eb52f6-dc3e-e3a8-a795-e1500bca27ec for SCS configuration cid:_Foxmail.1@076d200a-68c8-f19d-0f89-c48005855920, FFS X = 25 or 39  u      FFS: cid:_Foxmail.1@ba993c66-7a51-2996-99cb-79179fa013b9  o    Option b:  the application delay needed for PDCCH processing for Rel-16 minimum application delay for K0min/K2min indication is reused/extended.  o    Option c: PDCCH monitoring adaptation command applies after PUSCH transmission if triggered by UL DCI  o    Option d: PDCCH monitoring adaptation command applies after HARQ-ACK transmission (or plus some margin for HARQ-ACK decoding).  o    Option e: after successfully decoding TB.  o    Option f:  Application delay should be “ZERO”  for PDCCH monitoring adaptation. PDCCH monitoring adaptation would be applied after UE receive the additional PDCCH monitoring adaptation control signaling bit(s) in DCI  o    Option g:  Application delay(s) are configured via RRC signaling  o    Option h:  Application delay applies after drx-RetransmissionTimerUL expires  o    Option i: Leave up to implementation  o    Option j: UE applies the skipping immediately (e.g. next symbol/slot) after the UE receives the indication in DL assignment. If the UE fails to decode the associated PDSCH and transmits a NACK, skipping is canceled in the slots after the NACK transmission. Option g ( application delay configured via RRC signaling) is used for uplink grant. If RRC signaling is not provided, UE applies the skipping immediately (e.g. next symbol/slot) after the UE receives the indication in UL grant.  o    Other options not precluded.  -         FFS reference points for the application delay,  ~~o        e.g., the PDCCH monitoring indication applies at a first slot that is at least~~cid:_Foxmail.1@05ceccc1-d053-d9f2-23fa-a708d2595672~~symbols after the last symbol of the PDCCH, where T is defined as application delay~~  -         FFS whether the same or different and how application delay for PDCCH monitoring adaptation indicated by DCI and timer expiration  -         FFS non-scheduling DCI if supported |

# Reference

1. RP-201701, “Status report for WI UE Power Saving Enhancements for NR”, Rapporteur (MediaTek), RAN #89-e meeting
2. RP-202685, “Status report for WI UE Power Saving Enhancements for NR”, Rapporteur (MediaTek), RAN #90-e meeting
3. RP-210733, “Status report for WI UE Power Saving Enhancements for NR”, Rapporteur (MediaTek), RAN #91-e meeting
4. RP-211452, “Status report for WI UE Power Saving Enhancements for NR”, Rapporteur (MediaTek), RAN #92-e meeting
5. RP-212612, “Status report for WI UE Power Saving Enhancements for NR”, Rapporteur (MediaTek), RAN #93-e meeting