**3GPP TSG RAN WG1 Meeting #110-bis-e R1-220xxxx**

**e-Meeting, October 10 – 19, 2022**

**Source: Moderator (Intel Corporation)**

**Title: Discussion Summary for energy saving techniques of NW energy saving SI**

**Agenda item: 9.7.2**

**Document for: Discussion**

# Introduction

In this contribution, moderator summarizes discussions on remaining issues related to potential solutions for network energy saving SI from RAN1 #110-bis-e. SI objectives agreed in RP-220297 is shown below for reference.

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| The objectives of the study are the following:   1. Definition of a base station energy consumption model [RAN1]  * Adapt the framework of the power consumption modelling and evaluation methodology of TR38.840 to the base station side, including relative energy consumption for DL and UL (considering factors like PA efficiency, number of TxRU, base station load, etc), sleep states and the associated transition times, and one or more reference parameters/configurations.  1. Definition of an evaluation methodology and KPIs [RAN1]  * The evaluation methodology should target for evaluating system-level network energy consumption and energy savings gains, as well as assessing/balancing impact to network and user performance (e.g. spectral efficiency, capacity, UPT, latency, handover performance, call drop rate, initial access performance, SLA assurance related KPIs), energy efficiency, and UE power consumption, complexity. The evaluation methodology should not focus on a single KPI, and should reuse existing KPIs whenever applicable; where existing KPIs are found to be insufficient new KPIs may be developed as needed.   Note: WGs will decide KPIs to evaluate and how.   1. Study and identify techniques on the gNB and UE side to improve network energy savings in terms of both BS transmission and reception, which may include:  * How to achieve more efficient operation dynamically and/or semi-statically and finer granularity adaptation of transmissions and/or receptions in one or more of network energy saving techniques in time, frequency, spatial, and power domains, with potential support/feedback from UE, and potential UE assistance information [RAN1, RAN2] * Information exchange/coordination over network interfaces [RAN3]   Note: Other techniques are not precluded  The study should prioritize idle/empty and low/medium load scenarios (the exact definition of such loads is left to the study), and different loads among carriers and neighbor cells are allowed.  The following example scenarios (mapping between scenarios and network loads is left to the study) including single-carrier and multi-carrier deployments are used as the starting point for discussion on prioritized scenarios for the study.  The following example scenarios are listed in no particular order.   * Urban micro in FR1, including TDD massive MIMO (note: this scenario can also model small cells) * FR2 beam-based scenarios (note: this scenario can also model small cells) * Urban/Rural macro in FR1 with/without DSS (no impact to LTE expected in case of DSS) * EN-DC/NR-DC macro with FDD PCell and TDD/Massive MIMO on higher FR1/FR2 frequency   Note 1: legacy UEs should be able to continue accessing a network implementing Rel-18 network energy savings techniques, with the possible exception of techniques developed specifically for greenfield deployments.  Note 2: the study of energy savings specifically for IAB is not part of the scope.  The study should coordinate with RAN4 as needed. |

# Summary of issues

## 2.1 General aspects of Network Energy Saving

* [2] Huawei, HiSilicon
  + Proposal 7: Send LS to RAN2/RAN3 to inform RAN1 identified techniques that may have higher layer impact.
* [8] CATT
  + Proposal 1: Time domain energy saving transition mechanism based on gNB state of system load should be supported for 5G network.
* [12] ZTE, Sanechips
  + For each potential network energy saving technique, their technique description, performance analysis including energy saving gain, impact on UPT and other KPIs, and specification impact should be captured into the TR.
* [16] LGE
  + Proposal #1: Consider to define NES state as operation mode of gNB applying one or more NES techniques, and to indicate whether or not NES state is applied or which NES state should be applied (if multiple NES states are configured).
* [23] Samsung
  + Proposal 1: Support at least the following three network states for the study of network energy saving:
    - Non-energy-saving state: the gNB/UE operates in a legacy way and no network energy saving technic is used;
    - Energy-saving state 1: UE does not transmit/receive any signal/channel;
    - Energy-saving state 2: the UE only transmits/receives a particular set of signal/channel and/or applies bandwidth/PSD/TXRU adaptation for channel transmission/reception;
* [28] CEWiT
  + Observation 4: The adaptation of sleep states at gNB will have an impact on the legacy operations at UE.
  + Proposal 6: Signaling information about sleep state (E.g., type of sleep state, starting time and duration) to connected UE is supported.

### [ACTIVE] 1st Round Discussions

There are several proposals that deal with general aspects of network energy saving being proposed by companies. For some proposals its not clear how the proposals will shape the TR and how they should be treated.

Interested companies are encouraged to provide text proposal that other companies can review for agreement/conclusion. Please provide suggestions below. Moderator will formulate the proposals for review based on comments received.

#### Company Comments

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| Company | Comments |
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## 2.2 Time-domain based Energy saving Techniques

* [1] Futurewei
  + Observation 1: Support of selective transmission/reception of SSB and SIB1 should be enhanced with group-common or cell-common signaling to the UE(s) on the changes in the SSB/SIBs transmissions.
  + Observation 2: Group-common or cell-common signaling of CSI-RS would provide an efficient signaling that supports bandwidth adaptation for network energy savings.
  + Proposal 1: UE grouping and group common signaling to support efficient network resource adaptation should be introduced and supported.
  + Observation 3: Resource adaptation at the multicell-level can provide an effective adaptation towards network energy savings.
  + Proposal 2: Multicell-level resource adaptation, cell-level resource adaptation, and sub-cell-level resource adaptation should be introduced and supported.
  + Observation 4: The UE should support being configured through RRC signaling the different conditions/triggers for the UE to send an UL Wake-Up signal.
  + Proposal 3: Assistance information in the form of an UL wake-up signal from the UE to the gNB should be introduced and supported. Support of an UL wake-up signal that can be specific to different use cases should be studied.
* [2] Huawei, HiSilicon
  + Observation 1: There can be up to 30% symbols for FR1 and 15% symbols for FR2 being active in time for the network to only transmit SSB and SIB1.
  + Proposal 1: The potential techniques of reduction of common signals and channels, particularly SSB and SIB1 and PRACH, should be studied in first priority and should be captured in TR.
  + Observation 2: For a UE operating with single carrier, synchronization with gNB needs to be achieved before the transmission of uplink trigger signal in the technique of on-demand SSB.
  + Observation 3: For a UE operating with single carrier, light/simplified version of SSB, e.g. DRS, can be used as the essential synchronization signal before the transmission of uplink trigger signal for on-demand SSB technique.
  + Proposal 2: Evaluate on-demand SSB/SIB1 transmission with light/simplified common signal with the following assumptions:
    - Two symbol DRS with the broadcast periodicity of 20ms for synchronization before the transmission of uplink triggering signal;
    - The interval between two neighboring WUS occasions can be 20ms, with certain detection probability, e.g. 1%, depending on different UE density and HO probability;
    - Upon receiving WUS, gNB starts to broadcast SSBs and SIB1 periodically from the next SSB-burst, for e.g. 1 or twice for certain reliability.
  + Proposal 3: Further study possible methods to adapt the time domain transmission of common signals, e.g. SSB and SIB1 for NR in consideration of common signals in neighboring LTE carrier that is deployed on the same base station. Note that only changes in NR are expected as per SID.
  + Observation 4: Due to the signaling overhead of reconfiguration/deactivation of UE specific channels and signals, cell-specific or UE group common dynamic signaling for adaptation on UE specific signals and channels is an optimization to further decrease the energy consumption of gNB.
  + Observation 5: The C-DRX adaptation on UE and gNB DTX/DRX (re)configuration should be jointly discussed with the reconfiguration of the UE specific periodic or Semi-Persistent signals considering the current UE C-DRX mechanism does not apply on periodic or Semi-Persistent signals/channels.
* [3] Nokia, Nokia Shanghai Bell
  + Proposal-1: For time-domain NW ES adaptations, enhancements for increasing BS (µ)DTX opportunities can be prioritized.
  + Proposal-2: Study enhancements for extending network sleeping modes opportunities including (µ)DTX indication to UE e.g. for UE power saving.
  + Proposal-3: Enhancements leveraging UE assistance / indication for (de)activation of unnecessarily CG-PUSCH resources can be studied to increase (µ)DRX / network sleeping opportunities.
  + Proposal-4: As part of study of time-domain NW ES techniques, further adaptation / reduction of SSB/SIB1 transmissions can be prioritized.
  + Observation-1: The existing paging design distributes the paging occasions evenly in time, which minimizes the possibility for a base station to sleep between paging occasions.
  + Proposal-5: Study possibilities to save base station energy via time domain enhancements of the paging mechanism.
  + Proposal-6: Study enhancements enabling faster cell deactivation / reactivation and faster offloading of UEs to neighboring cells.
* [4] Spreadtrum Communications
  + Observation 1: The reduction of common signal/channel can provide the energy saving gain, but it needs be realized by other techniques, e.g. dynamic cell on/off and DTX.
  + Proposal 1: Study in which scenarios the reduction of common signal/channel can be reduced without affecting UEs mobility and initial access.
  + Observation 2: Dynamic cell on/off with load balance can provide the energy saving gain.
  + Observation 3: DTX with traffic concentration can provide the energy saving gain, if the energy consumption of empty load is higher than that of a give sleep mode plus transition energy.
* [5] vivo
  + Proposal 1: Support adaptation of common signals and channels and capture the following in TR:
    - Technique description: Dynamic/Flexible adaptation of Dl and/or UL common signals and channels triggered by gNB (e.g., from normal period to long period when gNB becomes inactive state) or UE WUS (e.g., from long period to normal period when needed);
    - Performance analysis: This technique is beneficial for network energy saving especially when gNB is in inactive state;
    - Spec impact: It is needed to specify how to signal the adaptation and related UE behaviour based on the signalling, how to make the adaptation (e.g., period), WUS channel and procedure design to trigger the adaptation.
  + Proposal 2: The benefit and motivation of dynamic adaptation of UE specific signals and channels compared to implementation-based schemes needs to be clarified and evaluated.
  + Observation 1: Wake up of energy saving gNB by neighbour cell gNB can be supported by current implementation.
  + Observation 3: In non-HetNet case, legacy load-based energy saving cell activation can’t be used since neighbor cell gNB has no knowledge on how many UEs (especially idle/inactive UEs) moves to the energy saving cell’s coverage area.
  + Observation 4: The UE WUS scheme can achieve a good BS power gain without a significant reduction in UPT, especially low loads.
  + Proposal 3: Support wake up of gNB by UE WUS and capture the following in TR:
    - Technique description: Wake up of gNB that is in an energy saving state (e.g. no or sparse transmission or reception of common signals and channels) triggered by WUS from idle/inactive/connected state UEs;
    - Performance analysis: This technique is beneficial for network energy saving without significant loss of UE performance;
    - Spec impact: It is needed to specify WUS signal design, WUS configuration design and WUS procedure design.
  + Proposal 4: The benefit and motivation of adaptation of DTX/DRX compared to implementation-based schemes needs to be clarified and evaluated.
  + Proposal 5: The benefit and motivation of adaptation of BS inactive state compared to implementation-based schemes needs to be clarified and evaluated.
* [6] China Telecom
  + Proposal 1: Longer periodicity of SSB/SIB(e.g. 320ms) should be supported for BS energy saving.
  + Observation 1: If the WUS for gNB is supported, the on-demand SSB can be supported with less additional impact at the same time.
  + Proposal 2: On demand SSB should be supported for BS energy saving, especially if WUS for gNB is supported.
  + Proposal 3: The self-adapted configuration of SSB periodicity should be supported for BS energy saving.
  + Proposal 4: The 2-step semi-persistent symbol switch on-off should be supported in Rel-18.
* [7] OPPO
  + Proposal 1: Consider the following text proposal for TR 38.864.
    - Support of association between SSB for a sleeping cell and CORESET#0 for an active cell can be considered, such that SIB1 can be provided in the active cell for the sleeping cell to achieve a tradeoff between access latency and energy saving gain.
  + Proposal 2: Consider the following text proposal for TR 38.864.
    - Support of UE reporting activation/deactivation information for UE specific signals and channels is beneficial to reducing the number of time occasions at gNB side during periods of low activity and can be considered.
  + Proposal 3: Consider the following text proposal for TR 38.864.
    - Support of wake up signal (WUS) for gNB configuration for a UE in connected mode is recommended for a gNB operating in a sleeping mode, where the connected mode UE can transmit a scheduling request via this WUS to gNB to reduce the scheduling latency and UPT degradation.
  + Proposal 4: Consider the following text proposal for TR 38.864.
    - Support of DTX/DRX cycle for gNB is recommended to achieve energy saving gain, where the UE shall not assume SSB or CSI-RS is transmitted during an off period in a DTX/DRX cycle for gNB. Support of association between gNB-WUS or UE-WUS and DTX/DRX cycle for gNB is beneficial to wake up the gNB or the UE and can be considered.
* [8] CATT
  + Observation 1: To achieve obvious network energy saving gain, transmission periodicity of common channels/signals should be long enough to allow gNB to stay in deep sleep state.
  + Proposal 2: With the increase of the transmission periodicity of common control channels/signals in a cell, the impacts on initial access procedure for legacy RRC Idle/Inactive mode UE should be considered and network energy saving gain should be further evaluated in case of providing service to RRC connected mode UEs.
  + Proposal 3: How to prevent the legacy Idle/Inactive mode UE from residing in cells with increased the SSB periodicity by reducing the cell access priority should be considered.
  + Observation 2: For zero system load, with increase of common control channel periodicity, it could obtain network energy saving gain from 18.8% to 82.6% based on different common control channel periodicity.
  + Observation 3: For zero system load, major network energy saving gain could be achieved within the common control channel periodicity of 160ms.
  + Observation 4: From non-zero system load cell perspective, gNB could not enter deep sleep state and limited energy saving gain can be achieved for non-zero system load.
  + Proposal 4: Up to 160ms transmission periodicity of SSB/SIB is preferred for the network energy saving.
  + Proposal 5: Long SSB periodicity containing several short periodic SSB could be configured to achieve trade-off of network energy saving and UE power saving /paging latency.
  + Proposal 6: For Rel-18, semi-static/dynamic cell ON/OFF should be supported for network energy saving.
  + Observation 5: The slot/symbol granularity is not feasible for long transition time of Cell ON/OFF.
  + Proposal 7: Network control mechanism in triggering the transmission of on-demand DRX from the turned-OFF cell (e.g., on-demand SSB) should be considered for the network energy saving.
  + Proposal 8: For semi-static/dynamic cell ON/OFF, on-demand DRS should be studied for network energy saving.
  + Observation 6: It could be observed 23.8% and 47.3% network energy saving gain for semi-static/dynamic cell ON/OFF scheme and with additional gNB DTX scheme during Cell ON respectively.
  + Observation 7: Without achieving DL synchronization, the energy saving cell could not be directly woken up by the UE via the gNB WUS signal.
  + Observation 8: When system load is low and the less number of UEs access the system, the staggering C-DRX configuration for system load balancing becomes unnecessary.
  + Observation 9: gNB could reduce the energy consumption with the DTX transmission in low system load state by allocating same set of C-DRX configuration for all UEs, which including DTX-ON and DTX-OFF.
  + Proposal 9: The gNB DTX/DRX should be considered to reduce network energy consumption for low system load state.
  + Proposal 10: DTX parameters should be configured to Rel-18 UEs through high layers and gNB DTX-ON duration should be associated with Active Time of UEs and cover the reception window of DCI format 2\_6.
  + Proposal 11: DTX/DRX coordination in Uu, Xn and NG should be supported for reduction of network energy consumption.
  + Observation 10: gNB DTX transmission with centralized DRX-ON configuration can obtain 50.1%~75.3% energy saving gain. High Network Energy Saving gain is observed at the low system load.
* [9] Fujitsu
  + Observation 1. When a cell is turned off with short duration (e.g., symbol/slot/subframe-level), keeping UEs connected with the cell can avoid ping-pong handover and frequent activation/deactivation.
  + Proposal 1: During no-load period, base station can turn off the cell to save energy consumption and the following techniques can be considered to extend the cell off duration
    - Enlarging common signal periodicity
      * The impact on initial access procedures for legacy UEs should be avoided
      * FFS: How to avoid impact on initial access procedure for legacy UEs
    - Reducing transmission occasions of UE-specific periodic CSI RS
      * The impact to RLM and RRM measurement operation based on periodic CSI-RS should be addressed
      * FFS: Enhancements on CSI-RS based RLM and RRM measurement operation
  + Proposal 2. Study the following methods to aid discovery of SSB-less cells,
    - via DRS on SSB-less cells
    - via reference signal of another cell (e.g., an anchor cell)
  + Proposal 3. Adopt BWP adaptation as a fast energy saving state switching approach.
    - BWP adaptation can be utilized with frequency/time/spatial/power-domain energy saving techniques.
    - FFS: Enhancement of the existing BWP switching mechanism.
* [10] Intel
  + Observation 1: BS power model category 2 requires cell to have much longer periods of non-activity, e.g. in the order to 640 msec to 10 sec, before deeper sleep modes can be leveraged. Since the user traffic are generated on average of 200 msec, cells that have any active user may not be able to leverage deeper sleep modes. This creates difficulty in obtaining insightful observations even at low load scenarios.
  + Observation 2: More than 30% power saving gains are observed when network is under low loads (below 15% resource utilization) and network increases the common signal transmission periodicity from 20 msec to 160 msec or longer.
  + Proposal 1: RAN1 should investigate further into techniques that allow reduction of common signals (i.e. increasing periodicity) such as SSB, SIB1, and PRACH for low and lightly load scenarios.
  + Observation 3: Up to 25% power saving gains are observed from paging enhancement that compact the POs to be more bursty (e.g. consecutive slots and/or frames) when network is with zero data load (o% resource utilization) but with low paging loads.
  + Proposal 2: RAN1 should investigate further into techniques that allow compacting paging resources into consecutive slots/frames for zero data load scenarios.
* [11] Lenovo
  + Observation 1: SSB periodicity configuration per SSB subset can reduce SSB transmission time substantially (e.g. 20~50% reduction). When a cell is in a cell inactive state only transmitting SSBs and minimum system information, SSB transmission with subset-specific SSB periodicity can achieve 20~50% network energy saving gains.
  + Observation 2: Even though there is a mismatch between an actual SSB transmission periodicity and legacy UE’s assumption, legacy UEs would not select a SSB not being transmitted based on measurement. Thus, impact on the legacy UEs is expected to be minimal.
  + Proposal 1: Support SSB transmission with multiple SSB periodicities for multiple SSB subsets, each SSB periodicity applicable to each SSB subset.
  + Observation 3: Dynamic indication of transmitted SSBs in a SSB burst allows dynamic omission of SSBs and corresponding paging PDCCH/PDSCH and SI PDCCH/PDSCH for a certain duration.
  + Proposal 2: Support dynamic indication of transmitted SSBs in a SSB burst to enable gNB to dynamically omit and add back SSBs that are semi-statically indicated as being transmitted, as frequently as in every 160ms, for network power savings.
  + Proposal 3: Include the following texts in TR38.864:
    - Technique #A-1 Adaptation of common signals and channels
      * When a cell is in a cell inactive state, where the cell transmits only SSBs and minimum system information (e.g. simplified SIB1), the cell can be configured with multiple SSB subsets and corresponding multiple SSB periodicities, i.e. each SSB subset (i.e. SSBs with a subset of SSB indices) associated with one SSB periodicity.
      * When a cell is in a cell active state, where the cell transmits SSBs, system information, paging, TRS/CSI-RS, and user data, the cell can dynamically omit and add back SSBs that are semi-statically indicated as being transmitted, as frequently as in every 160ms.
    - Analysis for technique #A-1
      * When a cell is in a cell inactive state only transmitting SSBs and minimum system information, SSB transmission with subset-specific SSB periodicity can achieve 20~50% network energy saving gains.
      * When multiple SSB-subset specific periodicities are configured in a cell, legacy UEs assuming one SSB periodicity would not select a SSB not being transmitted based on measurement. Thus, impact on the legacy UEs is expected to be minimal.
      * When SSBs are dynamically omitted and added back as frequently as in every 160ms, corresponding paging PDCCH/PDSCH and SI PDCCH/PDSCH can also be dynamically omitted and added back accordingly.
  + Spec impact for technique #A-1
    - Configuration of SSB subsets and corresponding subset-specific SSB periodicities
    - Dynamic indication of time domain positions of transmitted SSBs in a SSB burst
* [12] ZTE, Sanechips
  + The SSB-less and SIB-less scheme can obtain 6.5% ~ 24.2% energy saving gain for TDD and 14.9%~45.5% energy saving gain for FDD in the cases RU=5%~40%. The SSB-less and SIB-less scheme can obtain about 2.1%~11.7% UPT benefits in the cases RU=5%~40%.
  + A serving cell with DL common signal/channel (i.e., SSB, SIB) reduction can be considered for network energy saving.
  + UEs can obtain SIB from an assistant cell.
  + The impact of common signal reduction (e.g. SSB, SIB reduction) on uplink transmission (e.g. PRACH) should be considered.
  + An uplink WUS sent by UE can be considered for DL common signal/channel (e.g., SIB/SSB) adaption or cell activation operation.
  + Capture the following description in the network energy saving techniques in time domain in the TR.
    - Adaptation of common signals and channels.
    - Performance analysis
      * The SSB-less and SIB-less scheme can obtain 5%~14.8% energy saving gain in the cases of RU=5%~25% for TDD and 9.4%~26.4% energy saving gain in the case of RU=5%~15% for FDD.
    - Specification impact may include
      * UEs obtain SIB from an assistant cell.
      * The impact of common signal reduction (e.g. SSB, SIB) on uplink transmission (e.g. PRACH).
      * An uplink WUS sent by UE for DL common signal/channel (e.g., SIB/SSB) adaption or cell activation operation.
* [13] Xiaomi
  + Proposal 1: For dynamic cell on-off, how to reduce the interruption duration for RRC-idle UE and avoid unnecessary handover or simplify the handover procedure for RRC-connected UE should be studied.
  + Proposal 5: Enhancement for NCD-SSB to reduce or avoid PBCH transmission can be studied.
  + Observation 1：Type #0 CSS transmission does not need to be as frequent as SSB.
  + Proposal 6: Reduced Type #0 CSS transmission can be studied.
  + Proposal 7: Reduced transmission for UE request SI can be studied.
* [14] CMCC
  + Observation 1: gNB has to make sure SSB and SIB1 are transmitted at least every 20ms for idle UEs to access the cell, enhancements can be made to reduce SSB/SIB transmission.
  + Observation 2: Reducing SSB/SIB1 transmission for single carrier case will have impact on legacy UEs’ initial access performance, so it should be careful to apply such schemes to network with legacy UEs.
  + Observation 3: Reducing SSB/SIB1 transmission for single carrier case can be considered for new deployment with only new UEs.
  + Proposal 7: The following alternatives can be considered to reduce SSB/SIB transmission,
    - Alt1: Increasing repetition period of SIB1
    - Alt2: Increasing repetition period of PBCH and SIB1
    - Alt3: Increasing repetition period SSB and SIB1
  + Proposal 8: SSB/SIB1 less carrier can be considered for single carrier option with assistance information from other carriers.
  + Proposal 9: When reduced SSB/SIB1 transmission is introduced, the potential specification impacts include:
    - Adapting the repetition periods of common channels/signals
    - On-demand triggering of common channels/signals, including the triggering signaling design, and the triggering procedure.
  + Proposal 10: When SSB/SIB1 less carrier is introduced, the potential specification impacts include:
    - Cross carrier synchronization for single carrier operation
    - System information enhancement to provide other carriers’ information and carrier selection principles for UE
  + Proposal 11: The potential specification enhancement of reducing transmission of UE specific channels/signals includes: dynamic signaling design to reduce transmission of these UE specific channels/signals, by utilizing UE/cell group-level or cell common signaling to allow gNB to minimize configuration overhead and potentially minimize overall gNB activity.
  + Proposal 12: The potential specification enhancements of DTX/DRX of gNB include:
    - Mechanisms to align C-DRX configuration of UE, such as signaling design to align the C-DRX configuration.
    - Defining DTX/DRX pattern for gNB.
    - Wake up signal (WUS) for gNB, including how to provide WUS configuration, such as by RRC release information or by neighboring gNB, and also the wake up related procedure.
  + Proposal 13: Technique aspects related to time domain are summarized as follows:
    - Technique #TD-1: Reducing transmission of common channels/signals
      * Techniques description: SSB and SIB1 are transmitted with a default period, such as 20ms, the power consumption of gNB can be reduced by increasing the periodicity of common channels/signals, such as SSB, SIB1 PDCCH/PDSCH or by introducing SSB/SIB1-less cell. The following alternatives can be considered to reduce SSB/SIB1 transmission,
      * TD1-1: Increasing the periodicity of common channels/signals can be realized by,
        + Alt1: Increasing repetition period of SIB1
        + Alt2: Increasing repetition period of PBCH and SIB1
        + Alt3: Increasing repetition period SSB and SIB1.
        + Specification impacts:

Adapting the repetition periods of common channels/signals

On-demand triggering of common channels/signals, including the triggering signaling design, and the triggering procedure.

* + - * TD1-2: SSB/SIB1 less carrier for single carrier operation, with assistance information from other carriers
        + Specification impact:

Cross carrier synchronization for single carrier operation

System information enhancement to provide other carriers’ information and carrier selection principles for UE

* + - Technique #TD-2: Reducing transmission of common channels/signals
      * Techniques description: reducing the number of time occasions for the following resources during periods of low activity may potentially provide energy saving benefits.
      * CSI-RS, group-common/UE-specific PDCCH, SPS PDSCH, PUCCH carrying SR, PUCCH/PUSCH carrying CSI reports, PUCCH carrying HARQ-ACK for SPS, CG-PUSCH, SRS, positioning RS (PRS).
      * Specification impact:
        + Dynamic signaling design to reduce transmission of these UE specific channels/signals, by utilizing UE/cell group-level or cell common signaling to allow gNB to minimize configuration overhead and potentially minimize overall gNB activity.
    - Technique #TD-3:DTX/DRX of gNB
      * Techniques description: DTX/DRX can be introduced for gNB to provide inactive opportunity. During the inactive duration, gNB does not need to transmit or receive periodic signals/channels, such as common channels/signals or UE specific signals/channels, then the power consumption can be reduced.
      * Specification impact:
        + Mechanisms to align C-DRX configuration of UE, such as signaling design to align the C-DRX configuration.
        + Defining DTX/DRX pattern for gNB.
        + Wake up signal (WUS) for gNB, including how to provide WUS configuration, such as by RRC release information or by neighboring gNB, and also the wake up related procedure.
* [15] NEC
  + Proposal 1: gNB DTX and DRX should be supported, and the impact on UE operation, e.g., the measurement, synchronization and C-DRX procedures, should be considered.
  + Proposal 2: Support configurable periodicity and offset for fully flexible time domain energy saving pattern, and simultaneous multiple configurations should be considered.
  + Proposal 3: Support SS/PBCH transmission with reduced density, on-demand SSB and dynamically adjustable SSB transmission periodicity.
* [16] LGE
  + Proposal #5: It is beneficial to switch off gNB’s periodic/semi-persistent transmission (and/or reception) at least when gNB does not need to transmit data to the UE, in terms of network energy savings.
  + Proposal #6: Study how to support efficient mechanisms to switch off gNB’s transmission (and/or reception) for a specific period of time.
  + Proposal #7: Whether or not to support adjustment of SSB transmission and on-demand procedure for common channels/signals such as SIB1, paging, or PRACH, should be carefully studied at least considering impacts on initial access procedure and measurements, and how to enable on-demand procedure.
  + Proposal #8: Study how to support a mechanism for waking gNB up from NES state when new data arrives at UE.
  + Proposal #9: Consider to support UE’s report of zero buffer status by transmitting PUCCH with negative SR.
  + Proposal #10: Study at least the followings to enhance UE’s DRX mechanism for the purpose of network energy saving.
    - Group common indication for DRX commend, such as DRX command MAC CE and long DRX command MAC CE
    - DRX active time alignment from the gNB’s perspective, by adjusting the starting position of DRX on-Duration via group-common indication or by switching between UE-specific and group-common DRX configurations
    - DRX on/off control for multiple DRX cycles, by informing DRX-off for N DRX cycles with a single indication
    - Minimization of gNB’s activity outside DRX active time, by invalidating CSI-RS reception or UL signal/channel transmission outside DRX active time
* [17] Mediatek
  + Observation 1: For the case of low network load (0% - 15%) while there are still (frequent) user activities (e.g., VoIP), aligning UE DRX offset for aggregated BS activity can achieve good power saving gain, i.e., >28% for Cat 1 BS and >10% for Cat 2 BS.
  + Proposal 1: Aligning UE DRX offsets in a group-specific or cell-specific manner is recommended for network energy saving.
  + Observation 2: Monitoring PRACH preamble for a sleeping cell, e.g., a deactivated small cell, is beneficial for NW to determine whether to turn on/off a BS.
  + Proposal 2: For dynamic BS on/off, enhancement on PDCCH-order-based RA can be used as a BS wake-up request.
  + Observation 3: BS may not trigger cell reselection for an IDLE UE camping on a cell before BS turns off the cell (without cellBarred) because cell reselection is based on RSRP and RSRQ measurement.
  + Proposal 3: For dynamic BS on/off, enhancement on cell reselection for IDLE UE should be investigated to minimize the impact to IDLE UEs.
* [18] Apple
* Technique #A-1 Adaptation of common signals and channels
  + Network energy saving can be realized by flexibly varying the periodicity and/or dynamically changing a transmission pattern (when applicable) of downlink common and broadcast signals, such as SSB/SI/paging/cell common PDCCH, and/or flexibly varying the periodicity of uplink random access opportunities.
    - This also include introducing light version of downlink common and broadcast signals, where for some periodicity occasionone or more common signals/channels can be skipped.
    - This is mainly for BS idle/inactive mode, e.g. cell deactivation without DL data transmission.
    - [Comment] this does not seem to be a complete solution, because mechanisms are necessary to put the BS back to normal operation. It should be clarified what other techniques are needed to make this complete.
  + Support of burst transmission and reception of common signals and channels with more than one periodicity and/or adaptation of a burst pattern, including periodicity, are expected to potentially provide longer inactivity periods for the gNB and potentially provide higher power saving gains.
    - [Comment] Is this only applicable to green field deployment? Does this prohibit legacy UEs from accessing this BS?
  + Support of dynamic adaptation of SSB/SIB transmission or on-demand SSBs/SIB1 transmissions or SSB/SIB1-less operations may also enable long periods of inactivity at the gNB and potentially provide energy savings.
    - [This may include leveraging SSB-less cell operations and potential enhancements for SSB-less cells, e.g. support SSB-less cell operation for inter-band CA. and/or support offloading system information from one cell to another for inter-band CA.]
    - This may include support of signals/channels to aid discovery of cells in lieu of SSBs.
    - This may include support of mechanism for UE to trigger on-demand SSB/SIB1 transmission for fast access/fast cell activation.
    - It should be noted that use of CA means the technique is only applicable to UEs in connected mode.
    - [Comment] If the intention is to use it in the context of CA, should this be merged together with technique B-1? Otherwise, sufficient distinction is needed between the two.
  + [Support of scheduling enhancements for SIB1 along with a long period (rather than the period as the same as the SSB period) adaptation of CORESET 0 (e.g. in a separately configured CORESET) are expected to avoid/reduce redundant DCI transmissions within the CORESET 0 for the gNB and potentially provide higher power saving gains.]
    - This may include support of a long period (rather than the period as the same as the SSB period) of CORESET 0
    - This may include support of scheduling of SIB1 by SSB to avoid transmissions of DCIs within CORESET 0, support of the mechanism to reduce impacts on SSB and overhead
    - [Comment] It is not clear how much benefit can be achieved by omitting PDCCH if SSB still needs to be transmitted. May be deprioritized in our view.
    - ~~Dynamic a~~Adaptation of the periodicity of common channel/signals might have impact to the UE normal access to the network, such as initial access, and legacy UE network access.
    - [Comment] the exact impact should be further clarified for each of the sub-bullets above. For example, would it prohibit legacy UE from accessing the cell or just introduce longer latency for legacy UE to access the cell?
* Technique #A-2: Dynamic adaptation of UE specific signals and channels
  + Network energy saving opportunities may be restricted by UE specific signals and channels that are semi-statically configured such as periodic or semi-persistent CSI-RS, group-common/UE-specific PDCCH, SPS PDSCH, PUCCH carrying SR, PUCCH/PUSCH carrying CSI reports, PUCCH carrying HARQ-ACK for SPS, CG-PUSCH, SRS, positioning RS (PRS).
  + Reducing the number of time occasions for or temporarily disabling the following resources during periods of low activity may potentially provide energy saving benefits.
    - CSI-RS, group-common/UE-specific PDCCH, SPS PDSCH, PUCCH carrying SR, PUCCH/PUSCH carrying CSI reports, PUCCH carrying HARQ-ACK for SPS, CG-PUSCH, SRS, positioning RS (PRS).
    - This may include report of UE assistance information, e.g., UE buffer status to help gNB make decisions.
  + Support of enhancements to synchronize the UE specific signal and channel transmission reception such that they provide longer inactivity periods at the gNB can be considered.
    - Support of configuration signaling of the UE specific signals and channel transmission and reception to be reduced, e.g. by utilizing UE/cell group-level or cell common signaling to allow gNB to minimize configuration overhead and potentially minimize overall gNB activity.
    - Support of group common signaling that indicates to UEs to temporarily stop the transmission/reception of semi-statically configured channels/signals
  + The impact to the UE performance by adaptation of UE specific signal/channels should be included along with the network energy saving performance results.
* Technique #A-3: wake up signal (WUS) for gNB
  + Support of wake up of gNB that is in a dormant power state/energy saving state (e.g., SSB-less/SIB1-less/SSB relaxed state), support of wake up signal (WUS) transmitted by the UE/neighboring gNB including UEs to the gNB (e.g. the gNB/cell in dormant state or the anchor gNB/cell).
    - Whether UE detection of a dormant power state/energy saving state is required before WUS transmission should be identified.
    - Resource reserved for WUS and the assumption of the gNB receiver should be identified
    - This may include support of assistance information from the UEs intended to aid wake up operations by the gNBs.
  + This is mainly for connected mode UEs
  + Can be used in support of techniques #A-1 techniques #A-2 and other techniques. Exact design may depend on the supported technique.
    - The power model of receiving WUS is associated with the gNB receiver sensitivity of WUS decoding, which will reflect the results of UE WUS coverage area.
    - A legacy UE cannot access a gNB in such dormant power state/energy saving state.
* Technique #A-4: Adaptation of DTX/DRX
  + DTX/DRX cycle configuration/pattern at the BS, which can be potentially aligned with the DRX cycle configured for UEs in connected mode or idle mode can potentially provide longer inactivity periods at the gNB.
    - This may include potential enhancements to UE behavior when both cell-specific DTX/DRX cycle and UE DRX cycle are configured.
    - An alternative BS DTX with UE C-DRX alignment would be the use of DTX/DRX patterns that are defined by the BS.
    - [Comment] this sentence seems unclear.
    - The ~~two~~ techniques/approaches of DTX/DRX alignment can be complementary to each other and they may be beneficial to energy savings both at the network and at the UE side.
    - [Comment] It is not clear what are complementary to each other.
  + ~~[Reducing gNB’s activities (e.g. SSB, CG PUSCH, etc.) outside UE DRX active time may potentially provide energy saving benefits, such as SSB or SIB.]~~
  + Reduction of periodically transmitted/semi-static configured channels/signals(e.g. SSB, SIB, CG PUSCH etc.) during the longer inactivity periods (i.e. outside UE’s DRX active time).
  + Controlling UE DRX on/off periods for multiple DRX cycles with a single indication can potentially provide longer inactivity periods at the gNB.
  + This may include group level indication for, such as UE-group signaling or cell-specific signaling, UE DRX commend such as DRX enhanced command MAC CE and long DRX commend MAC CE.
* Technique #A-5: Adaptation of BS inactive state or DTX/DRX
  + Support of gNB entering into sleep mode (or DTX/DRX state) for a period of time along with the indication of active/inactive state, e.g., in terms of start time and duration are expected to potentially provide flexible adaptation at the gNB and can potentially provide higher power saving gains.
    - This may include support of semi-static and/or dynamic gNB active/inactive state (or DTX/DRX state) adaptation.
    - This may include group common signaling for the indication of adapted active/inactive state (or DTX/DRX state)
    - This may include defining corresponding UE behaviors when gNB enters inactive state or sleep mode
* [19] Fraunhofer IIS, Fraunhofer HHI
  + Observation 1: When a gNB is not serving any user, it could be very useful to set larger intervals between SSBs so that the gNB can go into a deeper sleep mode thereby saving energy.
  + Observation 2: The trade-off between network energy saving (NES) gains and initial access performance applies not only to the extended periodicity approach of NES but also to the on-demand SSB transmission approach due to the need for prior DL synchronization.
  + Observation 3: Since legacy UEs performing initial access would expect SSB burst transmissions with 20 ms periodicity, either many cells would be constrained to setting the SSB periodicity to 20 ms or cells transmitting larger SSB periods than 20 ms may be missed by legacy UE performing initial cell search.
  + Proposal 1: The impact of larger SSB periodicities on the initial access of UEs must be studied in detail both from the perspective of legacy UEs and NES-aware UEs (Rel-18 and beyond).
  + Proposal 2: Investigate techniques which increase gNB inactivity as much as possible while attaining acceptable initial cell-search performance.
  + Proposal 3: Improve the UE initial access such that the initial access would not be impacted due to the NES techniques adapting SSB periodicity or via on-demand SSB transmission.
  + Proposal 4: Define a System Presence Indicator (SPI) that indicates to the UEs the presence of gNBs transmitting SSBs within a block of frequencies.
  + Proposal 5: Include the following bullets to the description of Technique #A-1: Adaptation of common signals and channels, in the TR:
    - As adaptations of common channel/signal providing longer inactivity at the gNB for cell deactivation without DL transmission, including dynamic adaptation of the periodicity of transmission (of e.g., of SSBs) and on-demand SSB transmission, might have impact to the UE normal access to the network, such as initial access, and legacy UE network access, techniques to reduce such impact are needed
      * This may include utilizing the introduction of simplified signals in lieu of SSBs or prior to SSBs to improve the initial access process such that the performance would not be affected due to the NES techniques adapting SSB periodicity or via on-demand SSB transmission
      * This may include defining a System Presence Indicator (SPI) that indicates to the UEs the presence of gNBs transmitting SSBs within a block of frequencies in order to improve initial access performance. These SSBs may use a larger periodicity or on-demand through UE trigger, in order to provide energy savings.
  + Observation 4: A System Presence Indicator (SPI) defined for the speed up of Initial Cell Search can serve as the downlink synchronization signal for uplink wake-up signal (UL-WUS).
  + Proposal 6: An uplink wake-up signal (UL-WUS) can also be used to change SSB periodicity from a large value (e.g. 160 ms) to a regular value (20 ms).
  + Proposal 7: Include the following bullets to the description of Technique #A-3: Wake up signal (WUS) for gNB, in the TR:
    - An uplink wake-up signal (UL-WUS) can also be used to change SSB periodicity from a large value (e.g. 160 ms) to a regular value (20 ms).
    - For DL synchronization needed for the UL WUS signal can be obtained via the System Presence Indicator (SPI) defined for the speed up of Initial Cell Search
* [20] Rakuten
  + Proposal 2: Sleep mode of the gNB should be indicated to the UE.
  + Proposal 4: Consider wake-up signal for gNB activation.
* [21] Panasonic
  + Proposal 1: Time domain adaptation should be considered with higher priority. The PDCCH monitoring controlled by DRX adaptation can be considered as starting point. It can be inclusive for other channel/signal related enhancement. When beam sweeping operation is utilized, beam on/off by adapting SSB/CSI-RS can also be considered as a time domain adaptation enhancement.
* [22] Interdigital
  + Proposal 1: Capture the following in TR38.864 (changes from R1-2208185 indicated in red):

|  |
| --- |
| Time Domain Techniques  * Technique #A-1 Adaptation of common signals and channels   + Network energy saving can be realized by flexibly varying the periodicity and/or dynamically changing a transmission pattern (when applicable) of downlink common and broadcast signals, such as SSB/SI/paging/cell common PDCCH, and/or flexibly varying the periodicity of uplink random access opportunities.     - This also include introducing light version of downlink common and broadcast signals, where for some periodicity occasionone or more common signals/channels can be skipped.     - This is mainly for BS idle/inactive mode, e.g. cell deactivation without DL data transmission.   + Support of burst transmission and reception of common signals and channels with more than one periodicity and/or adaptation of a burst pattern, including periodicity, are expected to potentially provide longer inactivity periods for the gNB and potentially provide higher power saving gains.   + Support of [dynamic adaptation of SSB/SIB transmission or] on-demand SSBs/SIB1 transmissions or SSB/SIB1-less operations may also enable long periods of inactivity at the gNB and potentially provide energy savings.     - [This may include leveraging SSB-less cell operations and potential enhancements for SSB-less cells, e.g. support SSB-less cell operation for inter-band CA. and/or support offloading system information from one cell to another for inter-band CA.]     - This may include support of signals/channels to aid discovery of cells in lieu of SSBs.     - This may include support of mechanism for UE to trigger on-demand SSB/SIB1 transmission for fast access/fast cell activation.     - It should be noted that use of CA means the technique is only applicable to UEs in connected mode.   + [Support of scheduling enhancements for SIB1 along with a long period (rather than the period as the same as the SSB period) adaptation of CORESET 0 (e.g. in a separately configured CORESET) are expected to avoid/reduce redundant DCI transmissions within the CORESET 0 for the gNB and potentially provide higher power saving gains.]     - This may include support of a long period (rather than the period as the same as the SSB period) of CORESET 0     - This may include support of scheduling of SIB1 by SSB to avoid transmissions of DCIs within CORESET 0, support of the mechanism to reduce impacts on SSB and overhead   + Dynamic adaptation of the periodicity of common channel/signals might have impact to the UE normal access to the network, such as initial access, and legacy UE network access.   + Specification impacts may include support for UE determination of transmission pattern of the downlink common and broadcast signal, such as based on explicit indication or autonomous detection. Impact to legacy UEs include longer access delays or not being able to perform initial access in the cell when SSBs and SI are not broadcast as expected. * Technique #A-2: Dynamic adaptation of UE specific signals and channels   + Network energy saving opportunities may be restricted by UE specific signals and channels that are semi-statically configured such as periodic or semi-persistent CSI-RS, group-common/UE-specific PDCCH, SPS PDSCH, PUCCH carrying SR, PUCCH/PUSCH carrying CSI reports, PUCCH carrying HARQ-ACK for SPS, CG-PUSCH, SRS, positioning RS (PRS).   + Reducing the number of time occasions for the following resources during periods of low activity may potentially provide energy saving benefits.     - CSI-RS, group-common/UE-specific PDCCH, SPS PDSCH, PUCCH carrying SR, PUCCH/PUSCH carrying CSI reports, PUCCH carrying HARQ-ACK for SPS, CG-PUSCH, SRS, positioning RS (PRS).     - This may include report of UE assistance information, e.g., UE buffer status to help gNB make decisions.   + Support of enhancements to synchronize the UE specific signal and channel transmission reception such that they provide longer inactivity periods at the gNB can be considered.   + Support of configuration signaling of the UE specific signals and channel transmission and reception to be reduced, e.g. by utilizing UE/cell group-level or ccell common signaling to allow gNB to minimize configuration overhead and potentially minimize overall gNB activity.   + The impact to the UE performance by adaptation of UE specific signal/channels should be included along with the network energy saving performance results.   + Specification impacts may include configuration of resources available in each network energy saving state and dynamic indication of a network energy saving state. Legacy UEs are not able to use resources in all network energy saving states. * Technique #A-3: wake up signal (WUS) for gNB   + Support of wake up of gNB that is in a dormant power state/energy saving state (e.g., SSB-less/SIB1-less/SSB relaxed state), support of wake up signal (WUS) transmitted by the UE/neighboring gNB including UEs to the gNB (e.g. the gNB/cell in dormant state or the anchor gNB/cell).     - Whether UE detection of a dormant power state/energy saving state is required before WUS transmission should be identified.     - Resource reserved for WUS and the assumption of the gNB receiver should be identified     - This may include support of assistance information from the UEs intended to aid wake up operations by the gNBs.   + This is mainly for connected mode UEs   + Can be used in support of techniques #A-1 techniques #A-2 and other techniques. Exact design may depend on the supported technique.   + The power model of receiving WUS is associated with the gNB receiver sensitivity of WUS decoding, which will reflect the results of UE WUS coverage area. WUS design may be selected so as to ensure reasonable coverage while enabling low-complexity gNB reception, e.g. sequence-based design.   + Specification impacts may include design of WUS and conditions for triggering WUS transmission. * Technique #A-4: Adaptation of DTX/DRX   + DTX/DRX cycle configuration/pattern at the BS, which can be potentially aligned with the DRX cycle configured for UEs in connected mode or idle mode can potentially provide longer inactivity periods at the gNB.     - This may include potential enhancements to UE behavior when both cell-specific DTX/DRX cycle and UE DRX cycle are configured.   + An alternative BS DTX with UE C-DRX alignment would be the use of DTX/DRX patterns that are defined by the BS.   + The ~~two~~ techniques/approaches of DTX/DRX alignment can be complementary to each other and they may be beneficial to energy savings both at the network and at the UE side.   + [Reducing gNB’s activities (e.g. SSB, CG PUSCH, etc.) outside UE DRX active time may potentially provide energy saving benefits, such as SSB or SIB.]   + Reduction of periodically transmitted/semi-static configured channels/signals(e.g. SSB, SIB, CG PUSCH etc.) during the longer inactivity periods (i.e. outside UE’s DRX active time).   + Controlling UE DRX on/off periods for multiple DRX cycles with a single indication can potentially provide longer inactivity periods at the gNB.   + This may include group level indication for switching to a DRX cycle configured for network energy saving~~, such as UE-group signaling or cell-specific signaling, UE DRX commend such as DRX enhanced command MAC CE and long DRX commend MAC CE~~.   + Specification impacts may include configuration of DRX cycle configured for network energy saving and indication of switching to this DRX cycle. * Technique #A-5: Adaptation of BS inactive state   + Support of gNB entering into sleep mode for a period of time along with the indication of active/inactive state, e.g., in terms of start time and duration are expected to potentially provide flexible adaptation at the gNB and can potentially provide higher power saving gains.     - This may include support of semi-static and/or dynamic gNB active/inactive state adaptation.     - This may include group common signaling for the indication of adapted active/inactive state   + Specification impacts may include design of signaling indicating the network energy states in current or future time periods. Impact to legacy UEs can include longer access delays or not being able to access the cell in some BS inactive states. |

* [23] Samsung
  + Proposal 2: Support semi-static switching and dynamic switching for network states transition (cell ON/OFF) of a serving cell at least for single cell case.
    - For a TDD band, network states transition (cell ON/OFF) switching can apply jointly or separately to DL and UL.
  + Observation 1: Current NR system requires large signaling overhead to adapt time domain resources for p/sp physical layer resources via RRC reconfiguration or semi-static (de)activation per UE.
  + Proposal 3: Support cell-specific/UE group common dynamic adaptation on periodic/semi-persistent physical layer resources in DL or UL for NW energy savings.
  + Proposal 4: Support SSB periodicity larger than 160ms.
  + Proposal 5: Support SSB transmission reduction for Pcell or single cell case.
  + Proposal 6: For DL reception adaptation in the energy saving state (cell OFF),
    - RRC configures whether to monitor the PDCCH in a search space;
    - RRC configures whether to receive the SPS PDSCH per SPS configuration.
  + Proposal 7: For SR/CG PUSCH transmission adaptation for NWES during the energy saving state (cell OFF), study the following options:
    - Option 1) RRC configures whether to transmit the SR/CG PUSCH per configuration;
    - Option 2) UE does not transmit SR/CG PUSCH.
  + Observation 2: Legacy C-DRX results in large transition energy when gNB wakes up multiples times to process noncontiguous ON durations.
  + Observation 3: There is a tradeoff between NW energy savings and UE performance for C-DRX configuration. Current NR system requires large signaling overhead to adapt C-DRX configuration via RRC signaling per UE.
  + Proposal 8: Support UG-specific dynamic adaptation of C-DRX to align or concatenate the ON durations for NW energy saving:
  + Proposal 9: Support gNB wake up request under Pcell/PScell network energy saving state (cell OFF). The following options can be considered.
    - Option 1) UE transmits semi-static configured UL channels X symbols after transmitting gNB wake up request.
    - Option 2) UE monitors PDCCH carrying an ACK for gNB wake up request after transmitting gNB wake up request.
  + Proposal 10: The following channels can be considered to carry the gNB wake up request.
    - PUCCH with SR.
    - PRACH.
    - PUCCH with a new UCI type.
  + Proposal 11: MAC layer decides whether to trigger the transmission of gNB wake up request/UE assistance information.
  + Proposal 12: Consider the following changes to the TP for TR
    - Technique #A-1 Adaptation of common signals and channels
      * Network energy saving can be realized by flexibly varying the periodicity and/or dynamically changing a transmission pattern (when applicable) of downlink common and broadcast signals, such as SSB/SI/paging/cell common PDCCH, and/or flexibly varying the periodicity of uplink random access opportunities.
        + This also include introducing light version of downlink common and broadcast signals, where for some periodicity occasionone or more common signals/channels can be skipped.
        + This is mainly for BS idle/inactive mode, e.g. cell deactivation without DL data transmission.
      * Support of burst transmission and reception of common signals and channels with more than one periodicity and/or adaptation of a burst pattern, including periodicity, are expected to potentially provide longer inactivity periods for the gNB and potentially provide higher power saving gains.
      * ~~Support of [dynamic adaptation of SSB/SIB transmission or] on-demand SSBs/SIB1 transmissions or SSB/SIB1-less operations may also enable long periods of inactivity at the gNB and potentially provide energy savings.~~
        + ~~[This may include leveraging SSB-less cell operations and potential enhancements for SSB-less cells, e.g. support SSB-less cell operation for inter-band CA. and/or support offloading system information from one cell to another for inter-band CA.]~~
        + ~~This may include support of signals/channels to aid discovery of cells in lieu of SSBs.~~
        + ~~This may include support of mechanism for UE to trigger on-demand SSB/SIB1 transmission for fast access/fast cell activation.~~
        + ~~It should be noted that use of CA means the technique is only applicable to UEs in connected mode.~~
      * ~~[Support of scheduling enhancements for SIB1~~ along with a long period (rather than the period as the same as the SSB period) adaptation of CORESET 0 (e.g. in a separately configured CORESET) are expected to avoid/reduce redundant DCI transmissions within the CORESET 0 for the gNB and potentially provide higher power saving gains.]
        + This may include support of a long period (rather than the period as the same as the SSB period) of CORESET 0
        + This may include support of scheduling of SIB1 by SSB to avoid transmissions of DCIs within CORESET 0, support of the mechanism to reduce impacts on SSB and overhead
      * Dynamic adaptation of the periodicity of common channel/signals might have impact to the UE normal access to the network, such as initial access, and legacy UE network access.
    - Technique #A-2: Dynamic adaptation of UE specific signals and channels
      * Network energy saving opportunities may be restricted by UE specific signals and channels that are semi-statically configured such as periodic or semi-persistent CSI-RS, group-common/UE-specific PDCCH, SPS PDSCH, PUCCH carrying SR, PUCCH/PUSCH carrying CSI reports, PUCCH carrying HARQ-ACK for SPS, CG-PUSCH, SRS, positioning RS (PRS).
      * Reducing the number of time occasions for the following resources during periods of low activity may potentially provide energy saving benefits.
        + CSI-RS, group-common/UE-specific PDCCH, SPS PDSCH, PUCCH carrying SR, PUCCH/PUSCH carrying CSI reports, PUCCH carrying HARQ-ACK for SPS, CG-PUSCH, SRS, positioning RS (PRS).
        + ~~This may include report of UE assistance information, e.g., UE buffer status to help gNB make decisions.~~RRC configures whether to receive/transmit a channel per configuration when gNB is in sleep mode.
      * ~~Support of enhancements to synchronize the UE specific signal and channel transmission reception such that they provide longer inactivity periods at the gNB can be considered.~~
      * ~~Support of configuration signaling of the UE specific signals and channel transmission and reception to be reduced, e.g. by utilizing UE/cell group-level or ccell common signaling to allow gNB to minimize configuration overhead and potentially minimize overall gNB activity.~~
      * ~~The impact to the UE performance by adaptation of UE specific signal/channels should be included along with the network energy saving performance results.~~
    - Technique #A-3: wake up signal (WUS) for gNB
      * Support of wake up of gNB that is in a dormant power state/energy saving state (e.g., SSB-less/SIB1-less/SSB relaxed state), support of wake up signal (WUS) transmitted by the UE/neighboring gNB including UEs to the gNB (e.g. the gNB/cell in dormant state or the anchor gNB/cell).
        + Whether UE detection of a dormant power state/energy saving state is required before WUS transmission should be identified.
        + Resource reserved for WUS and the assumption of the gNB receiver should be identified
        + This may include support of assistance information from the UEs intended to aid wake up operations by the gNBs.
        + Wake up signal (WUS) is triggerd by MAC layer.
      * This is mainly for connected mode UEs
      * Can be used in support of techniques #A-1 techniques #A-2 and other techniques. Exact design may depend on the supported technique.
      * The power model of receiving WUS is associated with the gNB receiver sensitivity of WUS decoding, which will reflect the results of UE WUS coverage area.
      * UE transmits semi-static configured UL channels X symbols after transmitting gNB wake up request or UE monitors PDCCH carrying an ACK for gNB wake up request after transmitting gNB wake up request.
    - Technique #A-4: Adaptation of DTX/DRX
      * DTX/DRX cycle configuration/pattern at the BS, which can be potentially aligned with the DRX cycle configured for UEs in connected mode or idle/inactive mode can potentially provide longer inactivity periods at the gNB.
        + This may include potential enhancements to UE behavior when both cell-specific DTX/DRX cycle and UE DRX cycle are configured.
      * An alternative BS DTX with UE C-DRX alignment would be the use of DTX/DRX patterns that are defined by the BS.
      * The two techniques/approaches of DTX/DRX alignment can be complementary to each other and they may be beneficial to energy savings both at the network and at the UE side.
      * [Reducing gNB’s activities (e.g. SSB, CG PUSCH, etc.) outside UE DRX active time may potentially provide energy saving benefits, such as SSB or SIB.]
      * Reduction of periodically transmitted/semi-static configured channels/signals (e.g. SSB, SIB, CG PUSCH etc.) during the longer inactivity periods (i.e. outside UE’s DRX active time).
      * Controlling UE DRX on/off periods for multiple DRX cycles with a single indication can potentially provide longer inactivity periods at the gNB.
      * This may include group level indication for, such as UE-group signaling or cell-specific signaling, UE DRX commend such as DRX enhanced command MAC CE and long DRX commend MAC CE.
    - Technique #A-5: Adaptation of BS inactive state
      * Support of gNB entering into sleep mode for a period of time along with the indication of active/inactive state, e.g., in terms of start time and duration are expected to potentially provide flexible adaptation at the gNB and can potentially provide higher power saving gains.
        + This may include support of semi-static and/or dynamic gNB active/inactive state adaptation.
        + This may include group common signaling for the indication of adapted active/inactive state
        + If gNB enters into sleep mode, the UE doesn’t transmit/receive any signal/channel or only transmits/receives a particular set of signal/channel.
* [24] Ericsson
  + Frequent Rx/Tx activities (e.g., periodic TRS or PRACH occasions) at low-moderate loads increases the network energy consumption.
  + Study and identify techniques minimizing periodic reference signal transmissions, e.g., enabling fully aperiodic TRS for FR1 and FR2 when needed.
  + Study and identify techniques which enable dynamic adaptation of PRACH and PUCCH occasions according to the need.
  + Study and identify techniques in which the UE can assist the network in optimizing its scheduling to maximize its sleep opportunities.
* [25] NTT Docomo
  + Proposal 1: Study CDRX and WUS for gNB for network energy saving techniques.
  + Proposal 2: Study SSB periodicity adaptation such as extended SSB periodicity for network energy saving techniques.
    - Trade-off between power saving gain and initial access and handover performance should be considered.
  + Proposal 3: Study SSB-less SCell for inter-band CA for network energy saving techniques.
* [26] Qualcomm
  + Observation 1: Network energy consumption in this scenario of “gNB in idle mode”, i.e., case of no or few PDSCH, PUSCH, CSI/RS, SRS transmissions, is mainly dependent on SSB transmission and associated downlink and uplink procedures for initial access and system information transmission.
  + Proposal 1: Capture in TR the following description with regards to the reduction/adaptation of transmission/reception of common channels/signals:
    - RAN 1 to focus the work on network energy saving mechanisms for Rel. 17 SSB beam sweeping on the “gNB in idle mode” scenario, i.e., scenario of very low load and in which the gNB activity is largely due to SSB transmission and RACH reception. SSB beam sweeping and associated signaling, e.g., paging, RACH reception is the highest energy contributor in the case of very low load in the cell.
  + Proposal 2: Capture in TR the following description with regards to the reduction/adaptation of transmission of common channels/signals includes:
    - Introducing simplified “light” version of downlink common and broadcast signals, such as SSB:
      * With the term “light SSB” what is meant is either PSS only or PSS and SSS.
      * SSB/”light SSB”, RMSI or paging as well as uplink random access opportunities can be skipped in time and/or spatial domain.
      * on-demand SSBs/SIB1 transmissions or SSB/SIB1-less operations may also enable long periods of inactivity at the gNB.
        + This may include UL channels and associated mechanism for UE to trigger on-demand SSB/SIB1 transmission for fast access/fast cell activation
      * This is mainly useful for BS idle/inactive mode, e.g. for temporary cell switching off without DL data transmission, or in the case in which the BS is actively transmitting common broadcast signals but there is no DL data transmission.
  + Observation 2: Coordination of UE C-DRX configurations across multiple UEs may facilitate BS DTX/DRX implementation for network energy savings.
  + Proposal 3: Capture in TR the following description for semi-static and/or dynamic cell on/off:
    - DTX/DRX cycle configuration/pattern at the BS, which can be potentially aligned with the DRX cycle configured for UEs in connected mode or idle mode can potentially provide longer inactivity periods at the gNB.
      * This may include potential enhancements to UE behavior when both cell-specific DTX/DRX cycle and UE DRX cycle are configured.
      * An alternative BS DTX with UE C-DRX alignment would be the use of DTX/DRX patterns that are defined by the BS. The mechanism of BS DTX in this case is identical to the one just described: the BS pauses DL transmission during DTX period. The difference with the DTX mechanism aligned with the UE DRX cycle is that this proposed mechanism here is that the BS DTX Pattern is initiated by the BS, without the BS necessarily considering the UE C-DRX patterns.
      * The techniques/approaches of DTX/DRX alignment can be complementary to each other.
      * This may include group level indication for, such as UE-group signaling or cell-specific signaling.
  + Proposal 4: Capture in TR the following description for dynamic C-DRX configuration adaptation
    - A UE may be configured with a C-DRX configuration for network energy savings in addition to a legacy C-DRX configuration. The C-DRX configuration for network energy savings can be common to a group of UEs. The UE may receive L1/L2 signalling to switch between the configured C-DRX configurations.
    - Specification impact at least includes L1/L2 signaling to switch between the configured C-DRX configurations (e.g., C-DRX periodicity and/or inactivity timer).
  + Observation 3: Cell wake-up mechanism could enable BS flexibly provision downlink channel transmission (e.g., broadcast channel) and uplink channel reception (e.g., RO, SR, and configured grant) to achieve network energy savings.
  + Observation 4: Cell wake-up mechanism might be applicable to a cell without any connected mode UE (empty scenario) and with some connected mode UEs (low load scenario).
  + Proposal 5: Capture in TR the following description for cell wake-up procedure
    - Cell wake-up procedure is a procedure in which a UE may send a cell wake-up request to help gNB transition from a sleep state to an active state. Furthermore, based on the received request, gNB may broadcast its active time to one or a group of UEs.
    - Specification impact may include cell wake-up request from UE, UE behaviour when base station is in sleep state, and indication of gNB active time.
* [27] ITRI
  + Proposal 1: The energy saving state(s) or sleep mode(s) may be defined for network energy saving.
  + Proposal 2: The following aspects for increasing time domain energy saving opportunities by the gNB can be considered:
    - Dynamic adaptation of UE C-DRX configurations according to the energy saving state(s) or sleep mode(s)
    - Dynamic adaptation of transmission/reception of common signals according to the energy saving state(s) or sleep mode(s)
* [28] CEWiT
  + Observation 1: Mandatory set operations consume energy at the gNB irrespective of the load.
  + Observation 2: Use of lighter version of SSB provides 46% and 11.2% energy saving for no load and low load scenarios.
  + Proposal 1: Support use of light versions of SSB at the gNB based on load.
  + Proposal 2: In case of use of lighter version of SSB by a gNB, study the mechanisms to inform the contents of PBCH to the UE.
  + Proposal 3: Adaptation of SSB periodicity at beam level is supported.
  + Observation 3: Scheduling of SIB1 using SSB will provide an energy saving of 24.06% when compared with scheduling of SIB1 using DCI 1\_0
  + Proposal 4: Scheduling of SIB1 using SSB is supported.
  + Proposal 5: Study mechanisms to overcome increase in size of SSB, scheduling SIB1

### [ACTIVE] 1st Round Discussions

Companies should start thinking about what potential techniques to capture and what information would be captured together with the techniques. Moderator suggests refining the technique description further based on what was discussed in RAN1 #110. Discussion should include any suggestions to splitting or merging the techniques listed.

Please comment further on the following proposals, including comments to address notes from the moderator below.

#### Proposal #2-1

* The following descriptions are basis for further discussion and evaluations. If the text agreeable after further updates, discuss on whether to capture into the TR.
* Technique #A-1 Adaptation of common signals and channels
  + Dynamically(1) vary the periodicity and/or a transmission pattern (when applicable) of downlink common and broadcast signals, such as SSB/SI/paging/cell common PDCCH, and/or the periodicity of uplink random access opportunities.
    - This also include introducing simplified version of downlink common and broadcast signals, where for some periodicity occasionone or more common signals/channels can be skipped.(2)
    - This is mainly for BS idle/inactive mode(3), e.g. cell deactivation without DL data transmission.
  + burst transmission and reception of common signals and channels with more than one(4) periodicity are expected to potentially provide longer inactivity periods for the gNB.
  + on-demand SSBs/SIB1 transmissions or SSB/SIB1-less operations may also enable long periods of inactivity at the gNB.
    - This may include signals/channels(5) to aid discovery of cells in lieu of SSBs.
    - This may include mechanism for UE to trigger on-demand SSB/SIB1 transmission for fast access/fast cell activation.
    - It should be noted that use of CA means the technique is only applicable to UEs in connected mode.(6)
  + adaptation of CORESET 0 (e.g. in a separately configured CORESET) to avoid/reduce redundant DCI transmissions within the CORESET 0 for the gNB]
    - This may include support of a long period (rather than the period as the same as the SSB period) of CORESET 0(7)
    - This may include support of scheduling of SIB1 by SSB to avoid transmissions of DCIs within CORESET 0, support of the mechanism to reduce impacts on SSB and overhead(8)
  + Dynamic adaptation of the periodicity of common channel/signals might have impact to the UE normal access to the network, such as initial access, and legacy UE network access.(9)

Notes from the moderator on above:

* Note (1) Need to Clarify (enough to be able to be evaluated by companies)
  + May clarify that whether this is automatically changed by BS or with the aid of DL indication
  + May clarify what is the transmission pattern referring to and when exactly it may be applicable, e.g. for which channel at what conditions.
* Note (2) Need to Clarify (enough to be able to be evaluated by companies)
  + clarify how it is light/simplified may need to be clarified or be reported.
  + clarify which specific channel or signal does this technique target? Or mixed, i.e. for some occasion, SSB is skipped and for some other occasions, SIB is skipped?
  + The former part “light version” seems to explain the channel itself is modified/simplified while the later part seems to say the configuration of such channel is modified. It is unclear whether one or both modifications are part of the technique.
* Note (3) Need to Clarify (enough to be able to be evaluated by companies)
  + Since there is no definition for BS idle/inactive, may clarify whether this is intended from UE perspective, otherwise may need to clarify/modify the terminology.
* Note (4) Need to Clarify (enough to be able to be evaluated by companies)
  + Since the previous bullet also includes change of periodicity, is the difference at a given time there can be multiple periodicities available to UE and UE can choose one of them without e.g. DL indication?
  + May clarify which specific channels this technique target.
* Note (5) Need to Clarify (enough to be able to be evaluated by companies)
  + DL or UL? If this intends to be a UL channel, can this be part of the next sub-bullet, i.e. the one used by “UE to trigger”?
* Note (6) Need to Clarify (enough to be able to be evaluated by companies)
  + If it is for CA, more proper to be placed in frequency domain.
* Note (7) Need to Clarify (enough to be able to be evaluated by companies)
  + CORESET0 does not seem to have periodicity today. Is it intend to say Search Space?
* Note (8) Need to Clarify (enough to be able to be evaluated by companies)
  + The former part may be used to replace the main bullet of this technique as clear for evaluations
  + The latter part may be clarified as part of the same technique (in this case, it could also be part of details for companies to report) or another technique as a separate bullet.
* Note (9)
  + May belong to performance/impact analysis, instead of technique description

#### Company Comments on Proposal #2-1

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#### Proposal #2-2

* The following descriptions are basis for further discussion and evaluations. If the text agreeable after further updates, discuss on whether to capture into the TR.
* Technique #A-2: Dynamic adaptation of UE specific signals and channels
  + Reducing the number of time occasions for the following resources during periods of low activity (10)
    - CSI-RS, group-common/UE-specific PDCCH, SPS PDSCH, PUCCH carrying SR, PUCCH/PUSCH carrying CSI reports, PUCCH carrying HARQ-ACK for SPS, CG-PUSCH, SRS, positioning RS (PRS). (10)
    - This may include report of UE assistance information, e.g., UE buffer status to help gNB make decisions.
  + Support of enhancements to synchronize the UE specific signal and channel transmission reception such that they provide longer inactivity periods at the gNB can be considered.(11)
  + configuration signaling of the UE specific signals and channel transmission and reception to be reduced, e.g. by utilizing UE(12)/cell group-level or cell common signaling to allow gNB to minimize configuration overhead and potentially minimize overall gNB activity.
  + The impact to the UE performance by adaptation of UE specific signal/channels should be included along with the network energy saving performance results.(13)

Notes from the moderator on above:

* Note (10) Need to Clarify (enough to be able to be evaluated by companies)
  + Needs to be specific with techniques, e.g. on how to reduce the occasions on which channel(s).
  + If there are general applicability of various channels, it might be representative to prioritize some for study.
* Note (11) Need to Clarify (enough to be able to be evaluated by companies)
  + need details otherwise can be supported by existing specifications
* Note (12) Need to Clarify (enough to be able to be evaluated by companies)
  + May need details otherwise can be supported by existing specifications
* Note (13) belong to performance/impact analysis, instead of technique description

#### Company Comments on Proposal #2-2

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#### Proposal #2-3

* The following descriptions are basis for further discussion and evaluations. If the text agreeable after further updates, discuss on whether to capture into the TR.
* Technique #A-3: wake up signal (WUS) for gNB(14)
  + wake up of gNB that is in a dormant power state/energy saving state (e.g., SSB-less/SIB1-less/SSB relaxed state), wake up signal (WUS) transmitted by the UE/neighboring gNB(15) including UEs to the gNB (e.g. the gNB/cell in dormant state or the anchor gNB/cell).
    - Whether UE detection of a dormant power state/energy saving state is required before WUS transmission should be identified.(16)
    - Resource reserved for WUS and the assumption of the gNB receiver should be identified (16)
    - This may include support of assistance information from the UEs intended to aid wake up operations by the gNBs.
  + This is mainly for connected mode UEs(17)
  + Can be used in support of techniques #A-1 techniques #A-2 and other techniques. Exact design may depend on the supported technique.
  + The power model of receiving WUS is associated with the gNB receiver sensitivity of WUS decoding, which will reflect the results of UE WUS coverage area.

Notes from the moderator on above:

* Note (14) Need to Clarify (enough to be able to be evaluated by companies)
  + This does not seem to be a standalone technique as itself does not provide energy savings for networks.
  + Can be considered as part of previous techniques, as need of UE assistance information
* Note (15) Need to Clarify (enough to be able to be evaluated by companies)
  + clarify the difference with existing implementation based approaches.
* Note (16)
  + belong to performance/impact analysis, instead of technique description
* Note (17) Need to Clarify (enough to be able to be evaluated by companies)
  + When incorporating A-3 to be part of other techniques, this sentence shall be further revisited.

#### Company Comments on Proposal #2-3

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#### Proposal #2-4

* The following descriptions are basis for further discussion and evaluations. If the text agreeable after further updates, discuss on whether to capture into the TR.
* Technique #A-4: Adaptation of DTX/DRX
  + DTX/DRX cycle configuration/pattern at the BS, which can be potentially aligned with the DRX cycle configured for UEs in connected mode or idle mode can potentially provide longer inactivity periods at the gNB.
    - This may include potential enhancements to UE behavior when both cell-specific DTX/DRX cycle and UE DRX cycle are configured.
  + An alternative BS DTX with UE C-DRX alignment would be the use of DTX/DRX patterns that are defined by the BS. (18)
  + The ~~two~~ techniques/approaches of DTX/DRX alignment can be complementary to each other .
  + [Reducing gNB’s activities (e.g. SSB, CG PUSCH, etc.) outside UE DRX active time such as SSB or SIB.](19)
  + Reduction of periodically transmitted/semi-static configured channels/signals(e.g. SSB, SIB, CG PUSCH etc.) during the longer inactivity periods (i.e. outside UE’s DRX active time).(19)
  + Controlling UE DRX on/off periods for multiple DRX cycles with a single indication which can potentially provide longer inactivity periods at the gNB.
  + This may include group level indication for, such as UE-group signaling or cell-specific signaling, UE DRX commend such as DRX enhanced command MAC CE and long DRX commend MAC CE.

Notes from the moderator on above:

* Note (18) Need to Clarify (enough to be able to be evaluated by companies)
  + Some clarification may be preferred, as there is no BS DTX today and if used, as in the first bullet, it shall be defined first. Therefore it could be same/part of the previous technique.
* Note (19) Need to Clarify (enough to be able to be evaluated by companies)
  + May need clarification of the relationship of the two bullets/techniques

#### Company Comments on Proposal #2-4

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#### Proposal #2-5

* The following descriptions are basis for further discussion and evaluations. If the text agreeable after further updates, discuss on whether to capture into the TR.
* Technique #A-5: Adaptation of BS inactive state (20)
  + gNB entering into sleep mode for a period of time along with the indication of active/inactive state, e.g., in terms of start time and duration.
    - This may include support of semi-static and/or dynamic gNB active/inactive state adaptation.
    - This may include group common signaling for the indication of adapted active/inactive state

Notes from the moderator on above:

* Note (20) Need to Clarify (enough to be able to be evaluated by companies)
  + This is generally true while it may be possible to consider to use this as signaling aspect for previous techniques, otherwise it is unclear what to implement as a technique to achieve BS energy saving. For example, solely with a signaling to tell UE that BS is to go to sleep, the “indication” itself does not provide BS energy saving. If it is associated with BS behavior, such as sleeping, or DTX, then it seems the same as Technique#A-4.

#### Company Comments on Proposal #2-5

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## 2.3 Frequency-domain based Energy Saving Techniques

* [2] Huawei/HiSilicon
  + Observation 6: Use of SSB/SIB1 received from one carrier for other carriers in multi-carrier scenarios can bring considerable energy saving gain for network in low load cases.
  + Observation 7: Multi-carrier SIB-less operation does not have to be used with CA procedure for a UE. Instead, the SIB-less operation can bring significant latency reduction compared to the case where UE using carrier aggregation and handover procedures.
  + Proposal 4: Evaluate SIB1-less operation in multi-carrier scenario, where the SIB1 for one carrier with/without SSB/DRS with low-load is broadcasted on another carrier.
  + Observation 8: For SCell (de)activation, the UE can acquire time and frequency synchronization based on the reference signal, e.g. SSB, TRS and etc., on another CC to further reduce the BS energy and reduce the latency of fast SCell (de)activation.
  + Observation 9: The switching time produced by cell-specific BWP switch at network/gNB side cannot be used for any UE in the cell, resulting decreased spectrum efficiency.
  + Observation 10: Compared with the adaptation of scheduled PRBs in the same BWP, it is not clear how much further network power saving gain/benefit can be achieved by dynamic BWP bandwidth/PRBs adaptation (e.g. via BWP switching or dynamic bandwidth adaptation within a BWP).
* [3] Nokia, NSB
  + Observation-2: From the NW perspective, the dynamic BWP adaptation of UE(s) does not bring benefits to the NW side energy saving.
  + Observation-3: From the NW saving perspective, the benefits of group-common or cell-specific signaling for BWP adaptation operation could be minor if there is a limited number of UEs in the cell in a low-load scenario, which is the target of the Rel18 NW ES study as stated in the SID.
  + Observation-4: From the NW perspective, it is unclear for us on what is the benefits to the NW side energy saving by reducing the UE-side BWP adaptation/switching delay.
  + Observation-5: The NW energy saving gain is quite minor with dynamic adaptation of a resource grid in a carrier, due to NW/gNB running with FFT/iFFT of fixed size.
  + Proposal-7: Proponents provide further details on Technique #B-3, regarding dynamic adaptation of bandwidth of UEs within a BWP.
* [4] Spreadtrum Communications
  + Observation 4: The reduction of common signal/channel can be realized by SCell operations.
  + Observation 5: The dynamic cell on/off and the DTX can be realized by SCell operations.
  + Observation 6: Enabling load balance by bandwidth adaptation can provide the energy saving gain.
* [5] vivo
  + Proposal 6: Support lean Scell technique and capture the following in TR:
    - Technique description: Scell is operating without or with reduced transmission of SSB, SIB1 and/or paging while RACH transmission opportunity can still remain available in the Scell;
    - Performance analysis: This technique is beneficial for network energy saving compared to legacy multi-carrier case 1 and RACH load distribution in multiple carriers compared to legacy multi-carrier case 2;
    - Spec impact: It is needed to specify SSB-less transmission in inter-band CA case including synchronization, measurement and related requirement, offloading system information from one carrier to another carrier, RACH procedure involving anchor carrier and/or non-anchor carriers.
  + Proposal 7:The benefit and motivation of group-common Pcell change need to be clarified.
  + Proposal 8: The details and motivation of faster activation/deactivation of CC need to be clarified.
  + Proposal 9: The benefit of dynamic adaptation of UE operation bandwidth need to be clarified and evaluated.
* [6] China Mobile
  + Proposal 5:
    - The Scells without SSB in inter-band CA should be supported in Rel-18.
    - FFS: Which bands are feasible and the related UE requirements.
    - FFS: the details of mechanism.
* [7] OPPO
  + Proposal 5: Consider the following text proposal for TR 38.864.
    - Support of cell-group based PCell switching for UEs in a going-to-sleep cell can be considered as it is efficient and beneficial to achieve energy saving gain.
* [8] CATT
  + Proposal 12: Dynamic bandwidth adaption for gNB energy saving could be considered in frequency domain.
  + Observation 11: SCell RF turning off operating would introduce additional SCell activation delay and RS overhead to allow UE synchronization and measurements.
  + Proposal 13: Dynamic and fast SCell ON/OFF and activation/deactivation should be studied for network energy saving.
  + Proposal 14: SSB-less transmission in PCell should not be supported.
  + Proposal 15: If SSB enhancement for SCells in case of inter-band CA is considered, DL synchronization, AGC and QCL assumption performance should be ensured.
* [10] Intel
  + Observation 4: Intra-carrier bandwidth adaptation results in significant impact to maximum throughput, which has highly negative impact to total gNB activity time and power consumption. The reduction in power consumption from reduced bandwidth does not seem sufficiently large enough to overcome the loss in throughput and increase in active time duration.
  + Proposal 3: Based on evaluation finds, we suggest deprioritizing any potential enhancements (such as technique B-2 and B-3 from R1-2208185) related to intra-carrier bandwidth adaptation and related optimization.
* [11] Lenovo
  + Proposal 4: To support carrier bandwidth adaptation, study mechanisms for cell-specific resource grid bandwidth adaptation and UE-specific bandwidth adaptation within an active BWP.
  + Proposal 5: Include the following texts in TR38.864:
    - Technique #B-3: Dynamic bandwidth adaptation within a BWP and/or dynamic bandwidth adaptation of a resource grid of a cell
      * Network dynamically changes an active bandwidth of a BWP, and UE does not use resources outside the active bandwidth of the BWP.
      * Network dynamically changes an active bandwidth of a resource grid, and UE does not use resources outside the active bandwidth of the resource grid.
    - Analysis for technique #B-3:
      * For dynamic bandwidth adaptation within a BWP, a UE can perform fast bandwidth adaptation by operating with the maximum bandwidth of the BWP without using resources outside an active bandwidth of the BWP.
    - Spec impact for technique #B-3:
      * Configuration of multiple bandwidths for a BWP and dynamic indication of an active bandwidth of the BWP
      * Configuration of multiple bandwidths for a resource grid and dynamic indication of an active bandwidth of the resource grid
  + Proposal 6: For efficient SCell activation/deactivation management, cell activation request from UE and/or L1-based SCell activation/deactivation can be considered.
  + Proposal 7: Include the following texts in TR38.864:
    - Technique #B-1: Multi-carrier energy savings enhancements
      * UE sends a SCell activation request and monitors L1 indication for SCell activation/deactivation.
    - Analysis for technique #B-1:
      * UE request and L1 signaling enables fast SCell activation and deactivation.
    - Spec impact for technique #B-1:
      * Support of signal/channels for UE request and L1 indication
* [12] ZTE, Sanechips
  + SSB-less SCell or SSB-limited SCell is beneficial to network energy saving.
  + The SSB-less SCell scheme can obtain 5%~14.8% energy saving gain in the cases of RU=5%~25% for TDD and 9.4%~26.4% energy saving gain in the case of RU=5%~15% for FDD.
  + SSB-less SCell should be supported for inter-band CA.
  + The synchronization and TA issue of SSB-less SCell can be handled by NW implementation.
  + TRS is not needed for the SSB-less SCell at least in the case there is no DL traffic in the SCell.
  + Aperiodic TRS is triggered only when it is needed in the SCell activation process.
  + An uplink wake-up mechanism (WUS) can be considered to trigger on-demand RS/SSB transmission in SSB-less SCell
  + Capture the following description of SSB-less for inter-band CA in TR.
    - SSB-less SCell for inter-band CA implemented by configuring one or more SSB-less SCell for UEs.
    - Performance analysis
      * The SSB-less SCell scheme can obtain 5%~14.8% energy saving gain in the cases of RU=5%~25% for TDD and 9.4%~26.4% energy saving gain in the case of RU=5%~15% for FDD.
    - Specification impact may include
      * Uplink WUS to trigger on-demand RS to reduce the impact of SSB-less SCell on user experience.
      * Aperiodic TRS triggered by SCell activation.
* [14] CMCC
  + Observation 4: The power saving gain of dynamic cell specific or group common BWP adaption depends on implementation.
  + Observation 5: The absolute power saving gain of intra-band SSB-less depends on gNB implementation, at least the transmit power for such symbols on Scell can be reduced.
  + Proposal 14: Inter-band Scell with reduced SSB or SSB-less can be studied to reduce power consumption of gNB.
  + Observation 6: Fast activation/de-activation of Scell can be acheived along with intra-band/inter-band SSB-less Scell.
  + Proposal 15: DCI based Scell activation/de-activation can be introduced for intra-band /inter-band SSB-less Scell scenario.
  + Proposal 16: Mechanisms to trigger normal SSB/SIB1 on demand should be studied for inter-band Scell with reduced SSB/SIB1 scenario.
  + Proposal 17: Dynamic indicating of activated Scells can be studied to reduce gNB power consumption.
  + Proposal 18: Dynamic Pcell change can be studied to support fast carriers on/off.
  + Proposal 19: To realize offloading before RRC connected mode for common Pcell, initial access by Scell can be studied.
  + Proposal 20: Technique aspects related to frequency domain multi-carrier scenario are summarized as follows:
    - Technique #FD-1: Multi-carrier energy savings enhancements
      * Techniques description: SCells without or with reduced periodic signals and channels transmission such as SSB can provide power reduction gain.
        + Intra-band CA with SSB-less Scell is already supported, but can be additional enhanced for further power saving, such as fast activation/de-activation.
        + Inter-band CA with SSB-less or reduced SSB Scell.
      * Specification impact:
        + Fast activation/de-activation of Scell.
        + On-demand triggering of normal SSB for fast scheduling on Scell
        + Adaption of Pcell or monitored Scell for fast turning off carriers
        + Initial access from Scell to offload initial access pressure on Pcell
* [15] NEC
  + Proposal 4: enhancement on cell activation/deactivation and cell dormancy should be supported to better support gNB energy saving and minimize the impact on UE operation.
  + Proposal 5: support cell wake-up signal transmitted by UE to wake-up a cell from deep sleeping mode, and UE assistant information carried by the cell wake-up signal can be considered.
  + Proposal 6: Reduced CSI-RS density for frequency domain network energy saving should be considered.
  + Proposal 7: Support reduced bandwidth and default UE BWP for network energy saving mode, as well as autonomous BWP switching.
* [16] LGE
  + Observation: Legacy mechanisms such as SCell (de)activation, BWP switching, and SCell dormancy indication, can be reused for the purpose of network energy savings in frequency domain.
  + Proposal #11: Consider to enhance dormancy operation and indication methods for deactivating frequency domain resources (e.g., SCell (de)activation or BWP switching via group-common DCI or MAC CE) or for adjusting the bandwidth of a given BWP.
* [17] Mediatek
  + Observation 4: For CA use cases with higher data activity, disabling SSB and/or SIB1 for SCell achieves very limited energy saving gains, i.e., <8% for Cat 1 BS and < 1% for Cat 2 BS.
  + Proposal 4: Disabling SSB and/or SIB1 for SCell is NOT pursued for network energy saving.
  + Proposal 5: Enhancements to enable UE group-common or cell-specific BWP configuration and/or switching is recommended for network energy saving
  + Proposal 6: Reducing the BW adaptation delays is NOT pursued for network energy saving due to the reduced UE support on applying BWP adaptation for network energy saving.
* [18] Apple
  + Technique #B-1: Multi-carrier energy savings enhancements
    - The gNB can achieve potential energy savings from operating SCells without or with reduced transmission and reception of periodic signals and channels such as SSB, SI, and CSI-RS for mobility measurements, PRACH, paging, etc.
      * This may include support of mechanism for UE to trigger normal SSB/SIB1 transmission on a SCell for fast access if the SCell can not share synchronization with PCell.
      * This may include leveraging SSB-less cell operations and potential enhancements for SSB-less cells, e.g. support SSB-less cell operation for inter-band CA, and support offloading system information from one cell to another for inter-band CA.
        + Note that intra-band CA cases are already supported by current specification.
      * ~~Currently both Intra-band CA and Inter-band CA scenarios are assumed. In case, the intra-band CA cases are already supported by current specification, then the inter-band CA cases are the focus.~~
      * Moreover, regarding cross carrier synchronization and measurement for inter-band CA cases, involvement of RAN4 WG is needed to study the feasibility, and if feasible, identify necessary requirements and guide for future RAN1 work, i.e. about sync. requirement between carriers, frequency distance requirement between carriers, Rx power difference between carriers, QCL assumption requirement across carriers, etc.
        + [Comment] if we are seriously considering this, we should send an LS to RAN4 for feasibility study. Otherwise, it would not be possible to include it in the future WI.
      * To facilitate leveraging of lean SCells, potential enhancements to provide time and frequency synchronization, and other measurement sources by another cell can be considered.
    - Common signaling to a group of the UEs of PCell change
    - [Comment] This should be and is discussed in RAN2.
    - Ability to quick~~ly~~ activation and deactivation of CC, for example, based on on-demand RS, aperiodic RS, UE request, and L1 response or dynamically switch PCell is expected to potentially provide energy savings at the network.
    - Hardware architecture needs to be carefully considered. For shared hardware components among carriers, switching off or disable one of the carriers may not bring benefits to the network energy saving, since the shared hardware components are still utilized by other active carriers.
  + Technique #B-2: Dynamic adaptation of bandwidth part of UE(s) within a carrier
    - Enhancements to enable UE group-common or cell-specific BWP configuration and/or switching may lower signaling overhead and operational cost (e.g. signaling overhead) for adaptation of BWPs of UE(s) and potentially improve gNB power consumption.
    - Reducing the BW adaptation delays for Rel18 UEs
  + Technique #B-3: Dynamic adaptation of bandwidth of UE(s) within a BWP [and dynamic adaptation of a resource grid in a carrier]
    - Enhancements to enable group-common signaling to adapt the bandwidth of active BWP and continue operating in same BWP reduces the latency and lowers the signaling overhead.
* [19] Fraunhofer IIS, Fraunhofer HHI
  + Observation 5: Multi-carrier energy saving enhancements focusing on NES only on specific carriers can guarantee legacy UE support on other carriers dedicated for backward compatibility serving as a coverage and mobility layer.
  + Proposal 8: Include the following bullets to the description of Technique #B-1: Multi-carrier energy savings enhancements, in the TR:
    - Reserve carriers dedicated for backward compatibility serving as a coverage and mobility layer and supporting legacy UEs so that other carriers on NES mode need not be discoverable
* [20] Rakuten
  + Proposal 3: Consider techniques to reduce common signals/channels in Scells.
* [21] Panasonic
  + Proposal 2: For frequency domain adaptation for network energy saving, cell common adaptation by enhancement of BWP framework should be further considered for better efficiency within the BWP adaptation framework, where the time domain adaptation and/or the beam adaptation can also be supported. For multi-carrier adaptation enhancement, more careful study is needed for clearer benefit due to possible larger specification impact.
* [22] Interdigital
  + Proposal 2: Capture the following in TR38.864 (changes from R1-2208185 indicated in red):

|  |
| --- |
| Frequency Domain Techniques   * Technique #B-1: Multi-carrier energy savings enhancements   + The gNB can achieve potential energy savings from operating SCells without or with reduced transmission and reception of periodic signals and channels such as SSB, SI, and CSI-RS for mobility measurements, PRACH, paging, etc.     - This may include support of mechanism for UE to trigger normal SSB/SIB1 transmission on a SCell for fast access if the SCell, it can not share synchronization with PCell.     - This may include leveraging SSB-less cell operations and potential enhancements for SSB-less cells, e.g. support SSB-less cell operation for inter-band CA, and support offloading system information from one cell to another for inter-band CA.     - Currently both Intra-band CA and Inter-band CA scenarios are assumed. In case, the intra-band CA cases are already supported by current specification, then the inter-band CA cases are the focus.     - Moreover, regarding cross carrier synchronization and measurement for inter-band CA cases, involvement of RAN4 WG is needed to identify necessary requirements and guide for future RAN1 work, i.e. about sync. requirement between carriers, frequency distance requirement between carriers, Rx power difference between carriers, QCL assumption requirement across carriers, etc.     - To facilitate leveraging of lean SCells, potential enhancements to provide time and frequency synchronization, and other measurement sources by another cell can be considered.   + Common signaling to a group of the UEs of PCell change   + Ability to quick~~ly~~ activation and deactivation of CC, for example, based on on-demand RS, aperiodic RS, UE request, and L1 response or dynamically switch PCell is expected to potentially provide energy savings at the network.   + Hardware architecture needs to be carefully considered. For shared hardware components among carriers, switching off or disable one of the carriers may not bring benefits to the network energy saving, since the shared hardware components are still utilized by other active carriers.   + Specification impact includes impact on initial access procedures, including inter-cell-SIB acquisition, inter-cell synchronization, and random access. Legacy UEs are not expected to be able to access a cell with reduced transmission and reception of common periodic signals and channels * Technique #B-2: Dynamic adaptation of bandwidth part of UE(s) within a carrier   + Enhancements to enable UE group-common or cell-specific BWP configuration and/or switching may lower signaling overhead and operational cost (e.g. signaling overhead) for adaptation of BWPs of UE(s) and potentially improve gNB power consumption.   + Reducing the BW adaptation delays for Rel18 UEs   + Specification impacts may include configuration of BWP for network energy saving state and group-common signaling indicating switch to this BWP. * Technique #B-3: Dynamic adaptation of bandwidth of UE(s) within a BWP [and dynamic adaptation of a resource grid in a carrier]   + Enhancements to enable group-common signaling to adapt the bandwidth of active BWP and continue operating in same BWP reduces the latency and lowers the signaling overhead. |

* [23] Samsung
  + Proposal 13: For supporting inter-band CA, RAN1 shall ask RAN4 to investigate at least the following requirements on the carriers to perform CA operation:
    - Synchronization requirement between carriers;
    - Frequency distance requirement between carriers;
    - Reception power difference between carriers;
    - QCL assumption requirement across carriers.
  + Proposal 14: Support a cell-specific and/or UE-Group-specific L1 signaling for cell switching ON/OFF and activation/deactivation.
  + Proposal 15: Support adaptation of BWP for UEs in a carrier, and further support SPS PDSCH reception/Type-2 CG PUSCH transmission without reactivation after the BWP switching.
  + Proposal 16: Consider the following changes to the TP for TR
    - Technique #B-1: Multi-carrier energy ~~savings~~saving enhancements
      * The gNB can achieve potential energy savings from operating SCells without or with reduced transmission and reception of periodic signals and channels such as SSB, ~~SI, and~~ CSI-RS for mobility measurements, PRACH~~, paging~~, etc.
        + This may include support of mechanism for UE to trigger normal SSB~~/SIB1~~ transmission on a SCell for fast access, if the SCell~~, it~~ can not share synchronization with PCell.
        + This may include leveraging SSB-less cell operations and potential enhancements for SSB-less cells, e.g. support SSB-less cell operation for inter-band CA, and support offloading system information from one cell to another for inter-band CA.
        + ~~Currently both Intra-band CA and Inter-band CA scenarios are assumed. In case, the intra-band CA cases are already supported by current specification, then the~~ The inter-band CA cases are the focus, while the enhancements could be potentially applicable to the intra-band CA cases.
        + Moreover, regarding cross carrier synchronization and measurement for inter-band CA cases, involvement of RAN4 WG is needed to identify necessary requirements and guide for future RAN1 work, i.e. about sync. requirement between carriers, frequency distance requirement between carriers, Rx power difference between carriers, QCL assumption requirement across carriers, etc.
        + To facilitate leveraging of lean SCells, potential enhancements to provide time and frequency synchronization, and other measurement sources by another cell can be considered.
      * Common signaling to a group of the UEs of PCell change
      * Ability ~~to quickly~~for quick activation and deactivation of CC, for example, based on on-demand RS, aperiodic RS, UE request, and L1 response or dynamically switch PCell is expected to potentially provide energy savings at the network.
      * Hardware architecture needs to be carefully considered. For shared hardware components among carriers, switching off or disable one of the carriers may not bring benefits to the network energy saving, since the shared hardware components are still utilized by other active carriers.
    - Technique #B-2: Dynamic adaptation of bandwidth part of UE(s) within a carrier
      * Enhancements to enable UE group-common or cell-specific BWP configuration and/or switching may lower signaling overhead and operational cost (e.g. signaling overhead) for adaptation of BWPs of UE(s) and potentially improve gNB power consumption.
      * ~~Reducing the BW adaptation delays for Rel18 UEs~~
      * Enhancements to support SPS PDSCH reception/Type-2 CG PUSCH transmission without reactivation after the BWP switching.
    - Technique #B-3: Dynamic adaptation of bandwidth of UE(s) within a BWP ~~[and dynamic adaptation of a resource grid in a carrier]~~
      * Enhancements to enable group-common signaling to adapt the bandwidth of active BWP and continue operating in same BWP reduces the latency and lowers the signaling overhead.
* [24] Ericsson
  + BW adaptation at the network can potentially save energy at both network and UE side.
  + Potential of reducing the BW adaptation delays for Rel18 UEs can be considered particularly for the case that BW switch does not entail any RF reconfiguration.
  + Study group-common or cell-specific BWP switching.
  + Study techniques which optimize reference signal transmissions over SCells in terms of network energy savings.
  + Techniques allowing on-demand transmission of RSs, e.g., TRS particularly over Scells should be considered.
* [25] NTT Docomo
  + Observation 1: The existing BWP switching can be used for dynamic TX/RX bandwidth adaptation for network energy saving, while it will lead to DL overhead and power consumption due to DCI indications required for each UE in a cell.
  + Proposal 4: Study group-common based BWP switching and group-common BWP for network energy saving techniques.
* [26] Qualcomm
  + Proposal 6: Capture in TR the following description for dynamic UE group specific Pcell switching.
    - In CA operation, the UE is configured with a set of secondary cells in addition to a primary cell. To reduce network power consumption, some secondary cells may be dynamically deactivated or put in a dormant state while a common primary cell may be dynamically configured for a group of connected mode UEs especially when the system load is not high.
    - Scell deactivation/dormancy can provide network energy savings. However, it negatively impacts UPT and coverage. For example, with Set 1 FR1 reference configuration and CA with 2 CCs, Scell deactivation shows 33% average network energy savings when 20 UEs are assumed in a cell. However, it shows 64Mbps for 25 UEs per cell (61% RU) and 210Mbps for 20Ues per cell (39% RU).
    - Specification impact may include dynamic indication of primary cell switch to a group of UEs.
  + Observation 5: SSB/SI can be transmitted at a long periodicity in Scell to reduce broadcast overhead and network power consumption.
  + Observation 6: A long SSB/SI periodicity together with R17 temporary RS should already provide reasonably low Scell activation latency.
  + Proposal 7: Capture in TR the following description for inter-band CA with SSB-less carriers.
    - For inter-band CA with SSB-less carriers, the UE is configured with a primary cell and one or multiple secondary cells that do not transmit SSB. The secondary cells are associated with the primary cell. In particular, the UE may receive or transmit a signal/channel from the secondary cells based on time, frequency and QCL information from the associated primary cell. The technique is applicable to FR1 only.
    - Impact study may include
      * reliability of the time/frequency/spatial information from one carrier with SSB to be used for SSB-less carrier
      * collocation requirements for secondary cells and associated primary cell,
      * band requirements for secondary cells and associated primary cell,
      * requirements on timing difference between secondary cells and associated primary cell
* [28] CEWiT
  + Observation 5: Dynamic adaptation of bandwidth causes deactivation of certain frequency resources assigned to a UE that leads to conflicts, unnecessary transmissions and needless monitoring.
  + Observation 7: Group-common signaling to a number of UEs to adapt the bandwidth of their correspondong active BWPs and continue operating in same BWPs reduces the latency and lowers the signaling overhead.
  + Proposal 7: gNB signaling information about dynamic adaptation of BW to the active UEs is supported
    - Adapting the bandwidth of active BWP of a UE based on signalling from gNB is supported.

### [ACTIVE] 1st Round Discussions

#### Proposal #3-1

* The following descriptions are basis for further discussion and evaluations. If the text agreeable after further updates, discuss on whether to capture into the TR.
* Technique #B-1: Multi-carrier energy savings enhancements
  + operating SCells without or with reduced transmission and reception of periodic(1) signals and channels such as SSB, SI, and CSI-RS for mobility measurements, PRACH, paging, etc.
    - This may include mechanism for UE to trigger normal SSB/SIB1 transmission on a SCell for fast access if the SCell, it cannot share synchronization with PCell.
    - This may include leveraging SSB-less cell operations and potential enhancements for SSB-less cells, e.g. support SSB-less cell operation for inter-band CA, and support offloading system information from one cell to another for inter-band CA.
    - Currently both Intra-band CA and Inter-band CA scenarios are assumed. In case, the intra-band CA cases are already supported by current specification, then the inter-band CA cases are the focus. (2)
    - Moreover, regarding cross carrier synchronization and measurement for inter-band CA cases, involvement of RAN4 WG is needed to identify necessary requirements and guide for future RAN1 work, i.e. about sync. requirement between carriers, frequency distance requirement between carriers, Rx power difference between carriers, QCL assumption requirement across carriers, etc.(3)
    - To facilitate leveraging of lean SCells, potential enhancements to provide time and frequency synchronization, and other measurement sources by another cell can be considered.
  + Common signaling to a group of the UEs of PCell change
  + Ability to quick~~ly~~ activation and deactivation of CC, for example, based on on-demand RS, aperiodic RS, UE request, and L1 response .
  + Hardware architecture needs to be carefully considered. For shared hardware components among carriers, switching off or disable one of the carriers may not bring benefits to the network energy saving, since the shared hardware components are still utilized by other active carriers.(4)

Notes from the moderator on above:

* Note (1) Need to Clarify (enough to be able to be evaluated by companies)
  + Unlike single carrier only case, if this is for CA, the SCell with reduced transmission/reception of the mentioned channels is supported by existing specifications.
  + If this is for CA, then SCell without SSB/SIB is also supported by existing specifications at least for some cases.
* Note (2) Need to Clarify (enough to be able to be evaluated by companies)
  + Modifications may be preferred as it is not “in case” - it is the case that already supported.
* Note (3)
  + Technique aspect should include generally 3 parts: techniques description (with potential need of UE assistance), perform analysis (to be complete after evaluations, potentially including impact on UE side), specification impact (may also include need of UE assistance information that may have RAN2 impact, and can be updated/iterated in next meetings) – in addition to the “impacts on network interfaces” that is agreed from RAN3 last RAN3 meeting, when applicable.
* Note (4)
  + belong to performance/impact analysis

#### Company Comments on Proposal #3-1

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#### Proposal #3-2

* The following descriptions are basis for further discussion and evaluations. If the text agreeable after further updates, discuss on whether to capture into the TR.
* Technique #B-2: Dynamic adaptation of bandwidth part of UE(s) within a carrier
  + Enhancements to enable UE group-common or cell-specific BWP configuration and/or switching.
  + Reducing the BW adaptation delays for Rel18 UEs

#### Company Comments on Proposal #3-2

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#### Proposal #3-3

* The following descriptions are basis for further discussion and evaluations. If the text agreeable after further updates, discuss on whether to capture into the TR.
* Technique #B-3: Dynamic adaptation of bandwidth of UE(s) within a BWP [and dynamic adaptation of a resource grid in a carrier]
  + Enhancements to enable group-common signaling(5) to adapt the bandwidth of active BWP and continue operating in same BWP.

Notes from the moderator on above:

* Note (5) Need to Clarify (enough to be able to be evaluated by companies)
  + This could be the main bullets as replacement of “Dynamic adaptation of bandwidth of UE(s) within a BWP”, otherwise that part in main bullet is already supported by existing specifications.

#### Company Comments on Proposal #3-3

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## 2.4 Spatial-domain based Energy Saving Techniques

* [2] Huawei/HiSilicon
  + Observation 11: Dynamic antenna adaptation applied to PDSCH has the potential of BS energy savings with room of performance improvement by CSI measurement enhancement, while dynamic antenna adaptation of reference signals has limited potential for energy saving with large specification/performance impact.
  + Proposal 5: Evaluate dynamic antenna port shutdown with one CSI report with multiple CSI results (e.g. 4), corresponding to multiple shutdown pattern(s) prior to or after UE measurement/reports.
  + Observation 12: The spatial domain impact on dynamic TRxP adaptation should be further justified.
  + Observation 13: Considerable power saving gain with small performance loss can be achieved by dynamic PSD back-off using multiple CSIs with different corresponding PSD back-off ratios.
  + Proposal 6: Evaluate dynamic DL transmission power back-off technique assuming one CSI report including multiple CSI results (e.g. 4), in which each corresponds to a power offset between PDSCH and CSI-RS
  + The transmission power of SSB/CSI-RS is assumed to be unchanged.
  + Observation 14: UE assisted power enhancement mechanisms, e.g. OTA DPD and DPoD, cause significant UE hardware impact, and require RAN4 expertise for further study.
* [3] Nokia, NSB
  + Observation-6: At least intuitively, spatial domain techniques such dynamic port adaptation and dynamic TRP adaption are expected to provide important network energy saving gains.
  + Proposal-8: Support considering and evaluating dynamic port adaptation technique in terms of network energy saving gains.
  + Proposal-9: Support considering and evaluating dynamic TRP adaptation technique in terms of network energy saving gains.
  + Observation-7: Dynamic port adaptation would have implications on some CSI-RS configuration parameters. For instance, CBSR (codebook-subset restriction) may be different between the case where a port subset is enabled and the case where this subset is disabled.
  + Proposal-10: For dynamic port adaptation, consider group-common signaling for CSI-RS port disabling/enabling indication.
  + Proposal-11: For enabling dynamic port adaptation, consider low-overhead ways by leveraging existing operations such as ZP-CSI-RS related operation.
  + Proposal-12: Under dynamic port adaptation, consider defining UE behaviour regarding measurements and reporting.
  + Proposal-13: For dynamic port adaptation, consider the impact of the transmission of aperiodic CSI-RS and periodic CSI-RS with different number of ports.
  + Observation-8: For the state-of-art MIMO operation in 5G NR, the adaptation of spatial elements, i.e., adaptation of logical antenna port, is operated at a rather large time scale, due to the hardware limitations with large spatial element activation delays.
  + Proposal-14: Discuss hardware limitations about the time required for gNB to perform spatial elements adaptation.
  + Observation-9: For enabling dynamic TRP muting/unmuting (including for CA cases), similar approaches as for enabling legacy SCell deactivation/activation seem workable, i.e., approaches based on explicit indication and ‘activity-aware’ timer.
  + Proposal-15: For dynamic TRP muting/unmuting, impact on UE measurement and reporting should be considered.
  + Proposal-16: For dynamic TRP muting/unmuting, impact on the Rel-17 per-TRP beam failure and recovery operations should be considered.
  + Proposal-17: For dynamic TRP muting/unmuting, consider how to identify/represent a TRP.
* [4] Spreadtrum Communications
  + Observation 7: The reduction of beams of common signal/channel can provide the energy saving gain, but it needs be realized by other techniques, e.g. dynamic cell on/off and DTX.
  + Observation 8: TRxP(s) on/off adaptation can provide the energy saving gain.
* [5] vivo
  + Observation 5: TRP adaption in Technique #C-2 can be deemed as a set of ports adaptation in Technique #C-1, thus Technique #C-1 and #C-2 can be merged.
  + Proposal 10: Study dynamic adaptation of following types of spatial elements for network energy saving.
    - Type 1: enable/disable all spatial elements associated with a logical antenna port, e.g. a subset of ports of a CSI-RS resource.
    - Type 2: enable/disable part of spatial elements associated with a logical antenna port(s).
    - Type 3: enable/disable all spatial elements associated with a TRP.
  + Observation 6: Dynamic port adaptation (switching between 64 ports and 8 ports) can achieve more power saving gain than semi-static way.
  + Proposal 11 : Study group common signaling to indicate spatial Related information such as the number of ports, the adaptation of CSI-RS configuration, CSI report configuration, TRP adaptation, TCI state updating, etc.
  + Observation 7: Multi-CSI reporting can alleviate the negative impacts of inaccurate CSI tracking.
  + Proposal 12: Study Multi-CSI for network energy saving to facilitate fast port adaptation with good performance.
  + Proposal 13: Support dynamic adaptation of spatial element technique and capture the following in TR:
    - Technique description: Network dynamically adaptat spatial elements for network energy saving and the related changes need to be notified to UEs. The spatial elements can be adapted in the following ways:
    - Type 1: enable/disable all spatial elements associated with a logical antenna port, e.g. a subset of ports of a CSI-RS resource.
    - Type 2: enable/disable part of spatial elements associated with a logical antenna port(s).
    - Type 3: enable/disable all spatial elements associated with a TRP.
    - Performance analysis: This technique can obtain network energy saving gain compared with the baseline which doesn’t have dynamic spatial element adaptation with acceptable UPT loss;
    - Spec impact: The impacts of dynamic adaption in spatial domain include group common signaling to indicate the information about spatial elements adaptation, CSI measurement enhancement and Multi-CSI reporting, etc.
* [6] China Telecom
  + Proposal 6: The CSI reporting should be enhanced for better deciding the TRX switch on-off.
  + Proposal 7: The network can consider self-adapted switch-off the TRX with the reference of PMI.
  + Proposal 8: The CSI-RS should be reconfigured when the TRX switch off is adopted.
* [7] OPPO
  + Proposal 6: Consider the following text proposal for TR 38.864.
    - Support of reducing the number of active transceiver chains or antenna elements is beneficial to achieve energy saving gain and can be considered.
* [8] CATT
  + Proposal 16: Dynamic antenna adaptation at low/middle system load should be considered.
  + Observation 12: Without change of the number/pattern of antenna ports, dynamic reduction of antenna elements has no obvious specification impact.
  + Observation 13: When multiple periodic/SPS CSI associated with different patterns of antenna ports were configured to measure/report by UE, it will require huge UCI overhead/UL resources and additional UE power consumption.
  + Proposal 17: If dynamic antenna ports adaptation was supported, NZP CSI-RS ports adaptation information should be indicated to UE with group/cell common signaling.
  + Proposal 18: If dynamic antenna ports adaptation was supported, enhanced CSI acquisition/reporting to support friendly coexistence with legacy UEs could be further considered.
  + Proposal 19: Aperiodic CSI report mechanism could be used for support of simultaneous multiple CSI reporting associated with different patterns of antenna ports.
  + Proposal 20: If dynamic antenna adaptation was supported, gNB should ensure no performance loss of cell coverage through implementation.
  + Proposal 21: The dynamic antenna adaptation technique to support the coexistence with legacy UE should be further studied.
  + Observation 14: Dynamic antenna adaptation scheme could obtain 6.9% ~ 10.8% network energy saving gain with 1.2%~1.7% UPT loss and 1.7%~ 2.88% latency loss.
  + Observation 15: When the TRP is dynamically turned off, sparse RS could be transmitted to achieve good trade-off between energy saving gain of gNB and CSI measurement performance of UE.
  + Observation 16: If ON/OFF of multi-TRP is dynamically indicated to UE, energy saving gain can be provided for both Network and UE.
  + Proposal 22: Triggering of dynamic ON/OFF of multi-TRP should be considered.
* [9] Fujitsu
  + Observation 2. TxRU(s) reduction can be considered as the most effective technique in spatial domain for network energy saving.
  + Proposal 4. TxRU(s) reduction can be performed for UL or DL transmission, respectively.
  + Proposal 5. To support dynamic TxRU adaptation, the following enhancements of CSI measurement / report can be considered.
    - For type I TxRU adaptation, L1 signaling to update CSI-RS configuration for periodic / semi-persistent CSI reporting is required due to the dynamic change of the number of logical antenna ports.
    - For type II TxRU adaptation, L1 signaling to inform UE to make measurement(s) and generate report(s) based on the CSI-RS transmitted after TxRU adaptation is needed if mapping between logical antenna port to gNB TxRU(s) is updated.
    - Group-common signaling can be considered to avoid obvious increase of signaling overhead.
  + Proposal 6. For TxRU adaptation and power adjustment, RAN1 should focus on the techniques that has no impact on SSB transmission.
  + Proposal 7. Enhancement(s) on RLM and RRM measurement operation is necessary considering the potential transmission power fluctuation of CSI-RS caused by TxRU adaptation and power adjustment.
* [10] Intel
  + Observation 5: Antenna adaptation provides reduction in power consumption from anywhere between 5% to 30% at the expense of cell/user throughput. In the right circumstances, it might be beneficial for the network to be able to choose disablement of sub portions of the antenna to improve power consumption at the expense of some degradation of cell/user throughput.
  + Observation 6: Antenna elements and ports used by PDCCH and PDSCH can be somewhat flexibly controlled by the gNB.
  + Number of ports used by CSI-RS is configured by RRC.
  + UEs do not expect beam pattern used by CSI-RS to dynamically change, and dynamic change of CSI-RS beam pattern may lead to unsuspected results to RLM, RRM measurements (if used by RLM, RRM measurements), and CSI reporting.
  + Proposal 4: Consider support of more efficient signaling methods to update the number of antenna ports (and other related configuration) for CSI-RS.
* [11] Lenovo
  + Proposal 8: Support enhanced beam reporting, which allows a UE to report the best N beams for each TRP/antenna panel independently in one CSI report, for network energy savings.
  + Proposal 9: Include the following texts in TR38.864:
    - Technique #C-2: Dynamic adaptation of TRPs in mTRP
      * gNB can dynamically turn on/off a particular TRP based on enhanced beam reporting.
    - Analysis for technique #C-2:
      * It is desired that enhanced beam reporting maintains same or similar configuration signaling overhead and measurement time compared to Rel-17 group based beam reporting.
    - Spec impact for technique #C-2:
      * Support of UE reporting the best N beams for each TRP independently in one CSI report.
* [12] ZTE, Sanechips
  + When the antenna configuration is reduced from 64TxRUs to 32TxRUs, 17.7%~26.4% energy saving gain can be observed in the case RU=10%~35% with 3.7%~10.9% UPT loss.
  + The spatial domain adaptation with TxRU activation/de-activation should be supported for network energy saving.
  + RRC reconfiguration is needed to update the configuration of reference signals due to the TxRU de-activation, which will increase the signaling overhead and decrease the spectrum efficiency.
  + CSI measurement results may be out-of-state if partial TxRUs are de-activated.
  + The following issues need to be considered for dynamic spatial domain adaptation
    - The mismatch between the reference signal configurations, including CSI-RS, and the number of TxRUs.
    - The measurement/report results, including CSI measurement/report, may be out-of-state even if the reference signal configuration does not need to be updated.
  + Dynamic indication of CSI-RS re-configuration via DCI or MAC CE for spatial domain adaptation should be supported.
  + The enhancement on CSI measurement/report or UE assistance information should be considered for spatial domain adaptation.
  + Capture the following description of dynamic adaptation of spatial elements in TR
    - Adaptation can be further categorized into two types:
      * Type 1: enable/disable all spatial elements associated to a logical antenna port, e.g. a subset of ports of a CSI-RS resource.
      * Type 2: enable/disable of part of spatial elements associated to a logical antenna port(s).
    - UE should be informed an information about the adaptation from gNB via DCI or MAC CE, and perform CSI measurements and reporting according to the indication.
      * The indication includes, e.g., CSI-RS/reporting re-configuration information. It can be different for different adaptation types.
      * Specification impact may include enhancing CSI measurement and reporting procedures, e.g., dynamic indication of re-configuration of CSI-RS, CSI feedback update, transmission power of the reference signal or channel update, UE assistance information.
* [13] Xiaomi
  + Proposal 2: The measurement for RLM/ BFD/ beam selection and recovery/CSI /RRM should be enhanced considering dynamic beam on-off.
  + Proposal 3: Reducing unnecessary DL reference signal transmission for dormant cell can be studied for energy saving.
  + Proposal 4: Flexibly adjusting CSI-RS for RLM/BFD can be studied.
* [14] CMCC
  + Proposal 1: Enhancements can be studied to enable UE to jointly measure CSI-RS or PL RS transmitted before and after TxRUs on/off.
  + Proposal 2: Threshold for beam failure recovery or radio link monitoring may be needed to update together with TxRUs on/off.
  + Proposal 3: Enhancements can be studied to enable adaptation of CQI, RI, or PMI calculation with TxRUs on/off.
  + Proposal 4: Dynamic CSI-RS port adaptation can be studied for semi-static and periodic CSI-RS.
  + Proposal 5: UE reports multiple CSIs in one CSI reporting to feedback antenna muting pattern recommendations to gNB.
* [15] NEC
  + Proposal 8: jointly design of spatial domain and frequency domain techniques should be considered to get good balance among energy consumption, coverage and capacity, e.g., joint antenna on/off and BWP switching.
  + Proposal 9: support SSB and CSI-RS updating mechanism due to the dynamic antenna switching on/off, and techniques to reduce the delay of UE beam measurement and TCI state update after SSB updating should be studied.
  + Proposal 10: Consider using an associated TRX pool index to address the spatial domain configuration whenever the network enters into the energy saving mode.
  + Proposal 11: Consider the activation of different network energy saving techniques (e.g., time, frequency, spatial, power) via semi-static network energy saving configuration.
* [16] LGE
  + Proposal #2: It is beneficial to dynamically adjust the number of gNB’s activated antenna elements, in terms of network energy savings.
  + Proposal #3: Study how to efficiently support dynamically muting TRPs for multi-TRP operation or changing the number of gNB’s transmit antenna elements (e.g., by deactivating a NZP CSI-RS with 32 antenna ports while activating another NZP CSI-RS with 16 antenna ports, or turning off 16 antenna ports out of 32 antenna ports configured for the NZP CSI-RS) and how to handle related issues such as indication methods, beam management, and TCI state/configuration control.
  + Proposal #4: Discuss whether any enhancements for UL signal/channel (e.g., SRS) transmission are needed depending on the number of gNB’s receive spatial elements.
* [17] Mediatek
  + Observation 5: For the NW scenario with light load (15% - 30%), reducing #TxRU from 64 to 32 can bring 15.3% and 16.8% NW energy saving gain, respectively, for Cat 1 BS and Cat 2 BS, subject to 4.8% increment in average data packet latency. Further reducing #TxRU to 16 only bring <6% additional energy saving gain while causing >15% data latency increment.
  + Observation 6: For the NW scenario with medium load (30% - 50%), reducing #TxRU from 64 to 32 can bring 25.3% and 26.8% NW energy saving gain, respectively, for Cat 1 BS and Cat 2 BS, subject to 6.8% increment in average data packet latency. Further reducing #TxRU to 16 only bring <10% additional energy saving gain while causing >70% data latency increment.
  + Proposal 7: Reducing #TxRU by a limited factor is recommended for NW energy saving.
  + Proposal 8: Further investigate how to extend BWP framework to accommodate changing #TxRU in a UE-group-specific or cell-specific manner.
    - At least CSI-RS and CSI reporting related settings should be adapted accordingly
  + Proposal 9: Study on dynamic adaptation of TRPs in mTRP is deprioritized for focusing on energy saving for BS with larger power consumption (e.g., FR1 macro gNBs).
* [18] Apple
  + Technique #C-1: Dynamic adaptation of spatial elements
    - gNB may conserve energy by reducing the number of active transceiver chains or antenna elements.
    - CSI-RS/reporting re-configuration should be indicated to the UEs for spatial adaptation of gNB/cell power state
    - Adaptation can be further categorized into two types:
      * Type 1: enable/disable all spatial elements associated to a logical antenna port, e.g. a subset of ports of a CSI-RS resource.
      * Type 2: enable/disable of part of spatial elements associated to a logical antenna port(s). This may result in changes to the antenna pattern, ~~gains,~~ TCI states, and/or transmission power of the reference signal or channel that uses the antenna port(s).
    - ~~Both~~ Type 1 and Type 2 may have impact on measurement operation, so the potential enhancement may include CSI-RS configurations, CSI-RS and PL RS measurements, CSI reporting, beam failure recovery, radio link monitoring, cell (re)selection and handover procedure.
    - CSI reporting enhancement on muted spatial elements patterns can be considered for assistance information feedback.
    - [Comment] It is not clear how CSI reporting is done on muted spatial elements and how this assists gNB.
    - Support enhancements to UE behaviors due to dynamic adaptation of spatial elements, e.g., measurements, CSI feedback, power control, PUSCH/PDSCH repetition, SRS transmission, TCI configuration, beam management, beam failure recovery, radio link monitoring, cell (re)selection, handover, initial access, etc.
    - The different set of ports such as 64/32/8/4 and their associated CSI-RS configurations may be determined from the hypothesis of TRX On/Off. Spatial configuration for the network energy saving may then be determined by mapping the selected TRX ports setting to an associated configuration index. The configuration index can also be used to select the best of directional beams, NZP-CSI-RS configuration and measurement reporting in reportConfig. Over a certain coherent period, whenever the network enters the energy saving mode, the corresponding spatial domain configuration can then be determined from the configuration index.
    - [Comment] This description does not seem clear. It seems to be discussing a very specific type of enhancements for CSI-RS configuration/measurement/reporting. If this is to be included, should we also include detailed description of other potential solutions?
    - Support of light-weight mechanisms such as DCI/MAC-CE-based, that allow fast CSI-RS reconfigurations.
    - Techniques including conditions/criteria for UE measurements and feedback to gNB for (de)activation of antenna ports.
    - UE feeding back antenna muting pattern recommendations to the gNB.
  + Technique #C-2: Dynamic adaptation of TRPs in mTRP
    - Adaptation is categorized as type 3:
      * Type 3: activate/deactivate a set of spatial elements corresponding to a TRP, e.g., ~~TRP on/off,~~ activating N1-port CSI-RS resource (set) corresponding to one TRP and/or deactivating N2-port CSI-RS resource (set) corresponding to another TRP
    - Type 3 may have impact on redundant CSI measurement or reporting to a muted TRP, so enhancement may include dynamic signaling for TRP ID (CORESETPollIndex).
    - [Comment] It is not clear how dynamic signaling for TRP ID address the issue.
    - ~~Dynamic adaption of non-colocated antenna elements, such as different TRP.~~
    - gNB may conserve energy by reducing the number of active TRPs in the mTRP deployment.
    - This may also include signaling of the adaptation of TRPs in mTRP, e.g. by utilizing group-level or cell common signaling.
    - Support enhancements to UE behaviors due to dynamic adaptation of TRPs, e.g., measurements, CSI feedback, power control, PUSCH/PDSCH repetition, SRS transmission, TCI configuration, beam management, beam failure recovery, radio link monitoring, cell (re)selection, handover, initial access, etc.
* [20] Rakuten
  + Proposal 1: Support UE CSI reports for different CSI configurations.
* [21] Panasonic
  + Proposal 3: As of spatial/antenna domain adaptation for network energy saving, the SSB on/off can be discussed and potentially supported together with time domain adaptation. It may possibly be supported by using BWP framework. For the enhancement to the TCI frameworks and CSI feedback, it needs more investigation on whether additional mechanism is needed, especially considering the ongoing work on Rel.18 MIMO enhancement on unified TCI framework for single/multiple-TRP
* [22] Interdigital
  + Proposal 3: Capture the following in TR38.864 (changes from R1-2208185 indicated in red):

|  |
| --- |
| Spatial Domain Techniques   * Technique #C-1: Dynamic adaptation of spatial elements   + gNB may conserve energy by reducing the number of active transceiver chains or antenna elements.   + CSI-RS/reporting re-configuration should be indicated to the UEs for spatial adaptation of gNB/cell power state   + Adaptation can be further categorized into two types:     - Type 1: enable/disable all spatial elements associated to a logical antenna port, e.g. a subset of ports of a CSI-RS resource.     - Type 2: enable/disable of part of spatial elements associated to a logical antenna port(s). This may result in changes to the antenna pattern, ~~gains,~~ TCI states, and/or transmission power of the reference signal or channel that uses the antenna port(s).   + ~~Both~~ Type 1 and Type 2 may have impact on measurement operation, so the potential enhancement may include CSI-RS and PL RS measurements, beam failure recovery, radio link monitoring, cell (re)selection and handover procedure.   + CSI reporting enhancement on muted spatial elements patterns can be considered for assistance information feedback.   + Support enhancements to UE behaviors due to dynamic adaptation of spatial elements, e.g., measurements, CSI feedback, power control, PUSCH/PDSCH repetition, SRS transmission, TCI configuration, beam management, beam failure recovery, radio link monitoring, cell (re)selection, handover, initial access, etc.   + The different set of ports such as 64/32/8/4 and their associated CSI-RS configurations may be determined from the hypothesis of TRX On/Off. Spatial configuration for the network energy saving may then be determined by mapping the selected TRX ports setting to an associated configuration index. The configuration index can also be used to select the best of directional beams, NZP-CSI-RS configuration and measurement reporting in reportConfig. Over a certain coherent period, whenever the network enters the energy saving mode, the corresponding spatial domain configuration can then be determined from the configuration index.   + Support of light-weight mechanisms such as DCI/MAC-CE-based, that allow fast CSI-RS reconfigurations.   + Techniques including conditions/criteria for UE measurements and feedback to gNB for (de)activation of antenna ports.   + UE feeding back antenna muting pattern recommendations to the gNB.   + Adaptation of subset/number of ports for CSI-RS resources can be efficiently indicated to group of UEs by configuring for each UE a group identity to each CSI-RS resource and indicating change by UE-group common signaling including the group identity of applicable CSI-RS resources. * Technique #C-2: Dynamic adaptation of TRPs in mTRP   + Adaptation is categorized as type 3:     - Type 3: activate/deactivate a set of spatial elements, e.g., TRP on/off, activating N1-port CSI-RS resource (set) and deactivating N2-port CSI-RS resource (set)   + Type 3 may have impact on redundant CSI measurement or reporting to a muted TRP, so enhancement may include dynamic signaling for TRP ID (CORESETPollIndex).   + Dynamic adaption of non-colocated antenna elements, such as different TRP.   + gNB may conserve energy by reducing the number of active TRPs in the mTRP deployment.   + This may also include signaling of the adaptation of TRPs in mTRP, e.g. by utilizing group-level or cell common signaling.   + Support enhancements to UE behaviors due to dynamic adaptation of TRPs, e.g., measurements, CSI feedback, power control, PUSCH/PDSCH repetition, SRS transmission, TCI configuration, beam management, beam failure recovery, radio link monitoring, cell (re)selection, handover, initial access, etc |

* [23] Samsung
  + Proposal 17: Consider mechanisms to dynamically mute CSI-RS ports for NW energy savings.
  + Proposal 18: Consider mechanisms of power adaptation on CSI-RS ports for NW energy savings.
  + Proposal 19: Consider mechanisms of beam adaptation on CSI-RS ports for NW energy savings.
  + Proposal 20: Consider CSI feedback reporting enhancement for each codebook (Type-1 (R15), Type-2 (R16), eType-2 (R17 Port-selection)) with dynamic adaptation of spatial elements.
  + Proposal 21: Consider both s-TRP and m-TRP scenarios for adaptation on CSI-Ports for NW triggered and UE autonomous operation.
  + Proposal 22: Consider DCI and/or MAC CE based signalling for fast indication of NW energy saving specific TCI and CSI-RS reconfiguration.
  + Proposal 23: Consider TCI to CSI-RS port mapping for fast re-configuration during NW energy saving operation.
  + Proposal 24: Consider the following changes to the TP for TR
    - Technique #C-1: Dynamic adaptation of spatial elements
      * gNB may conserve energy by reducing the number of spatial elements e.g.: active transceiver chains ~~or~~, subarrays, antenna elements, panels, TRPs).
      * CSI-RS/reporting re-configuration should be indicated to the UEs for spatial adaptation of gNB/cell power state. Support mechanisms to trigger gNB/cell power state and to recover back into normal network power state.
      * Adaptation can be further categorized into two types:
        + Type 1: enable/disable all spatial elements associated to a logical antenna port, e.g. a subset of ports of a CSI-RS resource.
        + Type 2: enable/disable of part of spatial elements associated to a logical antenna port(s). This may result in changes to the antenna pattern, TCI states, and/or transmission power of the reference signal or channel that uses the antenna port(s).
        + ~~Type 1 and Type 2~~Type 3: activate/deactivate a set of spatial elements, e.g., TRP on/off, activating N1-port CSI-RS resource (set) and deactivating N2-port CSI-RS resource (set).
      * Type-2 and Type 3 should also consider power adaptation on the spatial elements associated with the antenna ports.
      * Type 1, Type 2 and Type 3 may have impact on measurement operation, so the potential enhancement may include CSI-RS and PL RS measurements, beam failure recovery, radio link monitoring, efficient and dynamic reconfiguration (using MAC CE, DCI, etc.), cell (re)selection and handover procedure.
      * CSI reporting enhancement on muted spatial elements patterns can be considered for assistance information feedback.
      * Support enhancements to UE behaviors due to dynamic adaptation of spatial elements, e.g., measurements, CSI feedback, power control, PUSCH/PDSCH repetition, SRS transmission, TCI configuration, beam management, beam failure recovery, radio link monitoring, cell (re)selection, handover, initial access, etc.
      * The different set of ports such as 64/32/8/4 and their associated CSI-RS configurations may be determined from the hypothesis of TRX On/Off. Spatial configuration for the network energy saving may then be determined by mapping the selected TRX ports setting to an associated configuration index. The configuration index can also be used to select the best of directional beams, NZP-CSI-RS configuration and measurement reporting in reportConfig. Over a certain coherent period, whenever the network enters the energy saving mode, the corresponding spatial domain configuration can then be determined from the configuration index.
      * Support of light-weight mechanisms such as DCI/MAC-CE-based, group common L1 signaling, etc. that allow fast CSI-RS reconfigurations.
      * Techniques including conditions/criteria for UE measurements and feedback to gNB for (de)activation of antenna ports should be considered.
      * UE feeding back antenna muting pattern recommendations, CSI reporting enhancement on muted or adapted spatial elements/patterns, etc. should be considered for assistance information feedback to the gNB.
    - Technique #C-2: Dynamic adaptation of TRPs in mTRP
      * Adaptation is categorized as type 3:
        + Type 3: activate/deactivate a set of spatial elements, e.g., TRP on/off, activating N1-port CSI-RS resource (set) and deactivating N2-port CSI-RS resource (set)
      * Type 3 may have impact on redundant CSI measurement or reporting to a muted TRP, so enhancement may include dynamic signaling for TRP ID (CORESETPollIndex).
      * Dynamic adaption of non-colocated antenna elements, such as different TRP.
      * gNB may conserve energy by dynamically reducing the number of active TRPs in the mTRP deployment.
      * This may also include signaling of the adaptation of TRPs in mTRP, e.g. by utilizing group-level or cell common signaling.
      * Support enhancements to UE behaviors due to dynamic adaptation of TRPs, e.g., measurements, CSI feedback, power control, PUSCH/PDSCH repetition, SRS transmission, TCI configuration, beam management, beam failure recovery, radio link monitoring, cell (re)selection, handover, initial access, etc.
* [24] Ericsson
  + A need for increasing number of transceiver chains is foreseen in gNBs in the future, especially at higher frequencies.
  + For efficient beam management, increased number of transceiver chains results in a higher number of energy consuming components and reference signal transmissions.
  + Higher number of antennas results in a high energy consumption even in low to medium load scenarios.
  + Changes in gNB port to antenna mapping may require reference signal reconfiguration.
  + To avoid recurrent reconfigurations, it is necessary for the gNB to acquire knowledge of what performance the different muting patterns would result in prior to the actual transceiver muting decision.
  + In current specifications, multiple CSI-RS resources need to be configured in the UE so that the gNB can get CSI feedback for different antenna muting layouts, which can increase physical resource usage.
  + Reference signal reconfigurations via RRC is slow and leads to excessive energy consumption.
  + Study methods that allow the UE to provide CSI feedback for different port muting patterns based on one CSI-RS resource configuration.
  + Different port muting patterns can be associated with different subset of ports of a CSI-RS resource set configuration. DCI and/or MAC-CEs can be used to indicate to UE(s) which subset of ports to measure/report and when.
  + Using few antennas for data transmission, while maintaining some reference signals transmission in the background on more antennas still brings major energy savings.
  + Excessive CSI reporting/polling for turning on/off transceiver chains is quite energy consuming both for the UE and for the network.
  + Study and identify techniques including conditions/criteria for UE measurements and feedback to gNB for (de)activation of CSI-RS ports.
  + Study optimized CSI reporting contents allowing the UE to provide compact CSI feedback for different antenna muting patterns, e.g., relative reports compared to a baseline.
* [25] NTT Docomo
  + Proposal 5: Dynamic adaptation of spatial elements can be categorized into three types. They can be used for both single TRP scenario and multi-TRP scenario
    - Type 1: Enable/Disable one or some of the port(s) of the RS resource
    - Type 2: Enable/Disable the RS resource (s)
    - Type 3: Enable/Disable the CSI report configuration(s)
* [26] Qualcomm
  + Observation 7: Dynamic antenna port adaptation could help gNB dynamically adapt antenna port configurations for reducing network power consumption.
  + Observation 8: Dynamic antenna port adaptation could be implemented by the current NR specifications, but such implementation is not efficient.
  + Observation 9: Some enhancements on physical layer procedures e.g., CSI framework and/or transmit power signaling might be introduced to make dynamic antenna port adaptation more efficient.
  + Proposal 8: Capture in TR the following description for dynamic gNB antenna port adaptation
    - Dynamic gNB antenna port adaptation is a technique that allows the gNB to dynamically turn on/off some chains for transmitting and/or receiving PDSCH and/or PUSCH. The technique is not applicable to broadcast channels/signals (e.g., SSB/SI/paging).
    - Reducing the number of antenna ports can provide the network energy savings at the expense of reduction in UPT and coverage. For example, with Set1 FR1 reference configuration, reducing the number of antenna ports from 64 to 32 provides 22% and 21% average network energy savings in low and light load scenarios, respectively. However, the average UPT is reduced by 31% in low load and 30% in light load. Furthermore, the DL SINR at 5 percentile (i.e., cell edge users) is reduced by 4.5dB in low load and 9dB in light load.
    - Specification impact may include enhancing physical layer procedures (e.g., CSI framework) to efficiently achieve network energy savings gain with minimal impact to user experience.
  + Observation 10: Dynamic TRP dormancy might be implemented by the current NR specifications, but such implementation is not efficient.
  + Observation 11: Some TRP dormancy enhancements e.g., UE group specific TRP dormancy indication to make dynamic TRP dormancy more efficient.
  + Proposal 9: Capture in TR the following description for dynamic TRP adaptation
    - Dynamic TRP adaptation is a technique that allows the gNB to dynamically turn on/off one of TRPs.
    - For Set 1 FR1 reference configuration, reducing multi-TRP to single TRP can provide 40% average network energy savings with 16% average UPT reduction in low load, and 24% average network energy savings with 22% average UPT reduction in light load.
    - Specification impact may include dynamic TRP indication from gNB to one or a group of UEs.
* [27] ITRI
  + Proposal 3: The following aspects for the adaptation of number of spatial elements of the gNB can be considered:
    - Dynamic adaptation of the number of antenna ports according to the energy saving state(s) or sleep mode(s)
    - Dynamic adaptation of the number of antenna elements according to the energy saving state(s) or sleep mode(s)
* [28] CEWiT
  + Proposal 8: gNB dynamically adapting the logical ports for energy saving is supported.
  + Proposal 9: gNB dynamically signaling information about ports adaptation to the UE is supported.
    - UE implicitly updating the CSI-RS resource configuration based on ports adaptation is supported.

### [ACTIVE] 1st Round Discussions

Companies should start thinking about what potential techniques to capture and what information would be captured together with the techniques. Moderator suggests refining the technique description further based on what was discussed in RAN1 #110. Discussion should include any suggestions to splitting or merging the techniques listed.

Please comment further on the following proposals, including comments to address notes from the moderator below.

#### Proposal #4-1

* The following descriptions are basis for further discussion and evaluations. If the text agreeable after further updates, discuss on whether to capture into the TR.
* Technique #C-1: Dynamic adaptation of spatial elements
  + reducing the number of active transceiver chains or antenna elements.
  + CSI-RS/reporting re-configuration should be indicated to the UEs for spatial adaptation of gNB/cell power state
  + Adaptation can be further categorized into two types:
    - Type 1: enable/disable all spatial elements associated to a logical antenna port, e.g. a subset of ports of a CSI-RS resource.
    - Type 2: enable/disable of part of spatial elements associated to a logical antenna port(s). This may result in changes to the antenna pattern, ~~gains,~~ TCI states, and/or transmission power of the reference signal or channel that uses the antenna port(s).(1)
  + ~~Both~~ Type 1 and Type 2 may have impact on measurement operation, so the potential enhancement may include CSI-RS and PL RS measurements, beam failure recovery, radio link monitoring, cell (re)selection and handover procedure. (2)
  + CSI reporting enhancement on muted spatial elements patterns can be considered for assistance information feedback. (2)
  + Support enhancements to UE behaviors due to dynamic adaptation of spatial elements, e.g., measurements, CSI feedback, power control, PUSCH/PDSCH repetition, SRS transmission, TCI configuration, beam management, beam failure recovery, radio link monitoring, cell (re)selection, handover, initial access, etc. (2)
  + The different set of ports such as 64/32/8/4 and their associated CSI-RS configurations may be determined from the hypothesis of TRX On/Off. Spatial configuration for the network energy saving may then be determined by mapping the selected TRX ports setting to an associated configuration index. The configuration index can also be used to select the best of directional beams, NZP-CSI-RS configuration and measurement reporting in reportConfig. Over a certain coherent period, whenever the network enters the energy saving mode, the corresponding spatial domain configuration can then be determined from the configuration index.
  + Support of light-weight mechanisms such as DCI/MAC-CE-based, that allow fast CSI-RS reconfigurations.(3)
  + Techniques including conditions/criteria for UE measurements and feedback to gNB for (de)activation of antenna ports.(4)
  + UE feeding back antenna muting pattern recommendations to the gNB.

Notes from the moderator on above:

* Note (1) Need to Clarify (enough to be able to be evaluated by companies)
  + Refinement may be preferred as they are generally discussing the same issues
* Note (2) Need to Clarify (enough to be able to be evaluated by companies)
  + Refinement may be preferred as they are generally discussing the same issues
* Note (3) Need to Clarify (enough to be able to be evaluated by companies)
  + Does this include similar technique in time domain, e.g. dynamic adaptation of UE specific signals and channels?
* Note (4) Need to Clarify (enough to be able to be evaluated by companies)
  + This does not sound like techniques, rather applicable scenarios/cases that could be captured together with results, as part of performance analysis.

#### Company Comments on Proposal #4-1

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#### Proposal #4-2

* The following descriptions are basis for further discussion and evaluations. If the text agreeable after further updates, discuss on whether to capture into the TR.
* Technique #C-2: Dynamic adaptation of TRPs in mTRP
  + Adaptation is categorized as type 3:
    - Type 3: activate/deactivate a set of spatial elements, e.g., TRP on/off, activating N1-port CSI-RS resource (set) and deactivating N2-port CSI-RS resource (set)(5)
  + Type 3 may have impact on redundant CSI measurement or reporting to a muted TRP, so enhancement may include dynamic signaling for TRP ID (CORESETPollIndex).
  + Dynamic adaption of non-colocated antenna elements, such as different TRP. (6)
  + This may also include signaling of the adaptation of TRPs in mTRP, e.g. by utilizing group-level or cell common signaling.
  + Support enhancements to UE behaviors due to dynamic adaptation of TRPs, e.g., measurements, CSI feedback, power control, PUSCH/PDSCH repetition, SRS transmission, TCI configuration, beam management, beam failure recovery, radio link monitoring, cell (re)selection, handover, initial access, etc

Notes from the moderator on above:

* Note (5) Need to Clarify (enough to be able to be evaluated by companies)
  + need to clarify the difference with Type 1.
* Note (6) Need to Clarify (enough to be able to be evaluated by companies)
  + More clarification may be preferred to understand the relationship with previous bullets and what exactly to be evaluated, compared to C-2 and C-1.

#### Company Comments on Proposal #4-2

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## 2.5 Power-domain based Energy Saving Techniques

* [3] Nokia, NSB
  + Proposal-18: Considering enhancing the configuration of the power offset between PDSCH and NZP CSI-RS to assist NW energy saving operation.
  + Proposal-19: To minimize the impact on MIMO performance, the CSI report from UE can be extended to assist the network for adjustment of the transmission power and/or bandwidth assignment.
  + Observation-10: The role of UE feedback and possible RAN1 relevance for the adaptation of digital pre-distortion by the gNB, use of digital post-distortion by the UE and adaptation of transceiver filtering operation requires further clarification.
  + Observation-11: The use of tone reservation together with DFT-s-OFDM in uplink might enable lower PAPR, however the complexity of using tone reservation on top of CP-OFDM in downlink requires further study.
* [5] vivo
  + Proposal 14: The benefit of adaptation of transmission power of signals and channels need to be clarified and evaluated.
  + Observation 8: PA efficiency enhancement at BS side (e.g., ET and DPD) can be achieved by BS implementation without spec impact.
  + Proposal 15: The benefit of spec-involving BS PA efficiency enhancement technique compared to implementation-based scheme (ET and DPD) should be clarified at cost of UE complexity.
* [8] CATT
  + Observation 17: In case of support of low transmission power, static power consumption of PA/RF and low PA efficiency could degrade network energy saving gain significantly.
  + Observation 18: Compared with RF chains ON/OFF adaptation in spatial domain, dynamic adjustment of gNB’s transmission power has limited energy saving gain.
  + Proposal 23: The power scaling of the DL Tx power variation in NES power model should be determined for identifying the NES technique in power domain.
  + Observation 19: Digital pre-distortion technique could increase the PSD of DL link and the DL coverage but provide limited impact in gNB power consumption.
* [10] Intel
  + Observation 7: Transmission power adaptation in some situations does result in reduction in power consumption anywhere between 15% to 30% at the expense of some cell/user throughput. In the right circumstances, it might be beneficial for the network to be able to update the transmission power such that all UEs can be aware of the update efficiently.
  + Proposal 5: Consider support of more efficient signaling methods to update the transmission power (offset) of CSI-RS. This includes transmission power offset between CSI-RS and SSB, and CSI-RS and PDSCH.
* [11] Lenovo
  + Proposal 10: Consider supporting multiple SSB burst configurations in a cell, where each SSB burst configuration corresponding to one network node within the cell includes separately configured SSB positions in burst and SSB transmit power.
  + Proposal 11: Include the following texts in TR38.864
    - Technique #D-1: Adaptation of transmission power of signals and channels
      * Different network nodes within a cell transmit different sets of SSBs with different SSB transmission power.
    - Analysis for technique #D-1:
      * Some network nodes within a cell reduce SSB transmission power (including turning off) for energy saving.
    - Spec impact for technique #D-1:
      * Support of multiple SSB burst configurations in a cell to allow each network node within a cell to set SSB transmission power separately.
* [12] ZTE, Sanechips
  + Fixed DL transmission power cannot adapt to requirements of NW power saving, UE power saving and interference management.
  + Dynamic power adjustment can help UE and gNB power saving and keeps performance impact under control.
  + 9.4%~21% network energy saving gain is observed in the case RU=10%~40% when NW transmission power is reduced by 3dB.
  + More dynamic DL power allocation and information reported by UE can be considered for NW ES in power domain.
  + Dynamic DL power control for reference signal can be considered for NW ES in power domain.
  + The following aspects for power domain adaptation techniques should be captured in the TR
    - Feature description for adaptation of transmission power of reference signals/channels
      * Dynamic power control, e.g., dynamically reducing the transmission power or PSD of signals and channels, e.g. SSB, CSI-RS, PDSCH
      * UE feedback/report power information, e.g., CSI reporting, power adjustment indication, etc.
    - Performance impacts:
      * Energy saving gains, UPT loss, and other evaluation metrics by adaptation of transmission power
    - Specification impacts:
      * Indication of power adaptation, e.g., via DCI or MAC CE
      * UE feedback information, e.g., CSI reporting, power adjustment indication
      * Co-existence issue or any other spec impacts
* [14] CMCC
  + Proposal 21: To reduce initial access impact for legacy UEs, SSB transmission with lower power for some occasions can be considered.
  + Proposal 22: Dynamic indication of powerControlOffsetSS can be applied for the adaptation of CSI-RS transmission power.
  + Proposal 23: Dynamic indication of powerControlOffset can be applied for the adaptation of PDSCH transmission power.
  + Proposal 24: CSI reporting enhancement can be considered for gNB to adjust DL transmission power.
  + Proposal 25: Technique aspects related to power domain are summarized as follows:
    - Technique #D-1: Adaptation of transmission power of signals and channels
      * Network energy savings could be potentially obtained by reducing the transmission power or PSD of various signals and channels, e.g SSB, CSI-RS, PDSCH, during specific scenarios or situations.
        + Specification impact: signaling of SSB transmission power pattern, signaling of modified power ratio between CSI-RS and PDSCH or between SSB and CSI-RS to provide adaptation of flexible power ratio values.
      * Network energy savings could be potentially obtained by transmission power adaptation with UE feedback information.
        + Specification impact: multiple CSIs in one CSI reporting to feedback DL transmission power recommendations to gNB.
* [16] LGE
  + Proposal #12: Investigate impacts of power adaptation for SSB and/or NZP CSI-RS if transmit power for SSB and/or NZP CSI-RS can be dynamically changed.
* [17] Mediatek
  + Observation 7: For the NW scenario with light load (15% - 30%), reducing PSDCH power/PSD-level by 6dB can bring 17% NW energy saving gain for Cat 1 BS and Cat 2 BS, subject to 6% increment in average data packet latency. On the other hand, further power/PSD-level reduction brings ≤1% additional energy saving gain while causing ≥6% data latency increment.
  + Observation 8: For the NW scenario with medium load (30% - 50%), reducing PSDCH power/PSD-level by 6dB can bring ≥26% NW energy saving gain for Cat 1 BS and Cat 2 BS, subject to 10% increment in average data packet latency. On the other hand, further power/PSD-level reduction brings ≤3% additional energy saving gain while causing ≥14% data latency increment.
  + Proposal 10: Reducing PDSCH power/PSD-level by a limited factor is recommended for network energy saving.
  + Proposal 11: Further investigate how to extend BWP framework to accommodate changing PDSCH power/PSD-level in a UE-group-specific or cell-specific manner.
  + Proposal 12: If agreed, LS to request RAN4 for providing suggested power consumption scaling for PA related transceiver processing enhancements. Meanwhile, RAN1 can discuss the feasibility of UE support for the schemes.
  + Observation 9: From UE feasibility point of view, “channel aware tone reservation that decrease PAPR” is more feasible than other transceiver processing enhancements because of UE can provide the additional information to BS along legacy CSI measurement and reporting operations.
* [18] Apple
  + Technique #D-1: Adaptation of transmission power of signals and channels
    - Network energy savings could be potentially obtained by reducing the transmission power or PSD of various signals and channels, e.g SSB, CSI-RS, PDSCH, during specific scenarios or situations.
      * Support of signaling of modified power ratio between CSI-RS and PDSCH/SSB or between SSB and CSI-RS are expected to provide adaptation of flexible power ratio values and potentially reduce overhead, e.g. by utilizing group-level or cell common signaling.
      * This may include enhancements on CSI-RS based measurements, such as beam management, beam failure recovery, radio link monitoring, cell (re)selection and handover procedure
    - The transmission bandwidth may be adapted jointly with transmission power to keep the similar reception performance.
    - Network energy savings could be potentially obtained by transmission power adaptation with UE feedback information, e.g, CSI reporting, power adjustment indication, etc.
    - ~~Dynamic adaptation of power offset(s) between PDSCH and CSI-RS.~~
    - The linear reduction of PAE (power added efficiency) when Tx power reduction should be included in the scaling of the power model.
      * [Comment] This sentence needs rephrasing.
    - This will impact legacy UEs if the transmission power of common signals/channels is adapted.
  + Technique #D-2: enhancements to [gNB digital pre-distortion] and UE post-distortion
    - Transmission energy efficiency at the network can be potentially improved with use of [enhanced over the air digital pre-distortion at the gNB and/or] post-distortion at the UE.
      * Whether and how much improvement of the PAE (power-added efficiency) should be disclosed.
    - In gNB digital pre-distortion over the air, the UEs assist the gNB in reducing nonlinear impairments introduced by the PA, by processing (e.g., calculation of the cross correlation of received signal after applying non-linear kernels) and reporting the information needed for gNB digital pre-distortion, on training signals
    - In UE post-distortion, the gNB assist the UE in reducing nonlinear impairments introduced by its PA (e.g., non-linear equalization stage that will “invert” the non-linearity), by sending RS signal at low periodically or some signaling to the UE.
    - [Comment] This should be discussed in RAN4.
  + Technique #D-3: adaptation of transceiver processing algorithm
    - Transmission energy efficiency at the network can be potentially improved with use of techniques such as channel aware tone reservation that decrease PAPR.
      * The UE must be notified of the sub-carriers carrying the TR signal, as using existing patterns (e.g., CSI-RS) is not practical
    - gNB may opt to use different transceiver processing algorithms, e.g. different receive filtering, different transmitter digital pre-distortion methods, etc,, including some that may favor lower power consumption at the expense of degraded system performance. For example, disabling use of DPD that would potentially increase out of band emissions or tx EVM, but would potentially conserve transmitter power consumption. Different transceiver processing algorithms at the gNB should be transparent to the UE.
    - Power model for the scaling of different transceiver processing algorithm should be provided with justification.
    - [Comment] This should be discussed in RAN4.
  + Technique #D-4: PA Input Power Bias ("input backoff”) Adaptation
    - Technique(s) allowing to modify/reduce the input power bias (“input power backoff”) in cases of no or very low load in the cell and in neighbor cells.
    - The PA energy consumption consists around ~70 % of the energy consumed at the BS.
    - The majority of this energy consumed at the PA is due to the input power bias (“backoff”).
    - In some cases, especially when the cell and neighbor cells are almost empty, reducing this input power bias (“backoff”) results in significantly lower energy consumption.
    - This input power bias adaptation results in lower output PAPR, which is translated into some in band and out of band emissions being generated.
    - With appropriate signal processing techniques, it is possible to “steer” the unwanted emissions either to the in-band signal or out-of-band.
    - With suitable base station coordination and by steering the unwanted emissions onto carrier frequencies in which their impact can be traced, it is possible to avoid any eventual impact onto UEs in the cell or in neighbor cells.
    - In general, this technique is activated only in case of zero or very low load in the cells; hence, the expectation is that no UEs will be affected by the generated in-band or out-of-band emissions.
    - The effect of PAE to the scheme should be disclosed.
    - [Comment] This should be discussed in RAN4.
* [21] Panasonic
  + Proposal 4: gNB power domain adaptation for energy saving can possible be controlled by the frequency and antenna domain adaptation. The adaptation of Tx power of different channels without impacting coverage may possibly work without specification impact so can be down prioritized. PA efficiency related discussion may involve RAN4 expertise, if necessary.
* [22] Interdigital
  + Proposal 4: Capture the following in TR38.864 (changes from R1-2208185 indicated in red):

|  |
| --- |
| Power Domain Techniques   * Technique #D-1: Adaptation of transmission power of signals and channels   + Network energy savings could be potentially obtained by reducing the transmission power or PSD of various signals and channels, e.g SSB, CSI-RS, PDSCH, during specific scenarios or situations.     - Support of signaling of modified power ratio between CSI-RS and PDSCH/SSB or between SSB and CSI-RS are expected to provide adaptation of flexible power ratio values and potentially reduce overhead, e.g. by utilizing group-level or cell common signaling.     - This may include enhancements on CSI-RS based measurements, such as beam management, beam failure recovery, radio link monitoring, cell (re)selection and handover procedure   + The transmission bandwidth may be adapted jointly with transmission power to keep the similar reception performance.   + Network energy savings could be potentially obtained by transmission power adaptation with UE feedback information, e.g, CSI reporting, power adjustment indication, etc.   + Dynamic adaptation of power offset(s) between PDSCH and CSI-RS.   + The linear reduction of PAE (power added efficiency) when Tx power reduction should be included in the scaling of the power model. * Technique #D-2: enhancements to assist ~~[~~gNB digital pre-distortion~~]~~ and UE post-distortion   + Transmission energy efficiency at the network can be potentially improved with use of [enhanced over the air digital pre-distortion at the gNB and/or] post-distortion at the UE.     - Whether and how much improvement of the PAE (power-added efficiency) should be disclosed.   + In gNB digital pre-distortion over the air, the UEs assist the gNB in reducing nonlinear impairments introduced by the PA, by processing (e.g., calculation of the cross correlation of received signal after applying non-linear kernels) and reporting the information needed for gNB digital pre-distortion, on training signals   + In UE post-distortion, the gNB assist the UE in reducing nonlinear impairments introduced by its PA (e.g., non-linear equalization stage that will “invert” the non-linearity), by sending RS signal at low periodically or some signaling to the UE.   + Specification impacts may include reporting information for gNB digital pre-distortion assistance, and indication to the UE of whether it needs to apply non-linear equalization for a transmission. * Technique #D-3: adaptation of transceiver processing algorithm   + Transmission energy efficiency at the network can be potentially improved with use of techniques such as channel aware tone reservation that decrease PAPR.     - The UE must be notified of the sub-carriers carrying the TR signal, as using existing patterns (e.g., CSI-RS) is not practical   + gNB may opt to use different transceiver processing algorithms, e.g. different receive filtering, different transmitter digital pre-distortion methods, etc,, including some that may favor lower power consumption at the expense of degraded system performance. For example, disabling use of DPD that would potentially increase out of band emissions or tx EVM, but would potentially conserve transmitter power consumption. Different transceiver processing algorithms at the gNB should be transparent to the UE.   + Power model for the scaling of different transceiver processing algorithm should be provided with justification. * Technique #D-4: PA Input Power Bias ("input backoff”) Adaptation   + Technique(s) allowing to modify/reduce the input power bias (“input power backoff”) in cases of no or very low load in the cell and in neighbor cells.   + The PA energy consumption consists around ~70 % of the energy consumed at the BS.   + The majority of this energy consumed at the PA is due to the input power bias (“backoff”).   + In some cases, especially when the cell and neighbor cells are almost empty, reducing this input power bias (“backoff”) results in significantly lower energy consumption.   + This input power bias adaptation results in lower output PAPR, which is translated into some in band and out of band emissions being generated.   + With appropriate signal processing techniques, it is possible to “steer” the unwanted emissions either to the in-band signal or out-of-band.   + With suitable base station coordination and by steering the unwanted emissions onto carrier frequencies in which their impact can be traced, it is possible to avoid any eventual impact onto UEs in the cell or in neighbor cells.   + In general, this technique is activated only in case of zero or very low load in the cells; hence, the expectation is that no UEs will be affected by the generated in-band or out-of-band emissions.   + The effect of PAE to the scheme should be disclosed. |

* [23] Samsung
  + Proposal 25: Support dynamic adaptation of downlink PSD and associated UE measurement procedure.
  + Observation 4: For a given data rate (low to medium), a combination of power and frequency domain adaptation would provide a balance between energy saving and system performance.
  + Proposal 26: Support joint adaptation of gNB transmission bandwidth and power spectral density.
  + Proposal 27: Consider the following changes to the TP for TR
    - Technique #D-1: Adaptation of transmission power of signals and channels
      * Network energy savings could be potentially obtained by reducing the transmission power or PSD of various signals and channels, e.g SSB, CSI-RS, PDSCH, during specific scenarios or situations.
        + Support of signaling of modified power ratio between CSI-RS and PDSCH/SSB or between SSB and CSI-RS are expected to provide adaptation of flexible power ratio values and potentially reduce overhead, e.g. by utilizing group-level or cell common signaling.
        + This may include enhancements on ~~CSI-RS based~~UE measurements, such as beam management, beam failure recovery, radio link monitoring, cell (re)selection and handover procedure
      * The transmission bandwidth may be adapted jointly with transmission power to keep the similar reception performance.
      * Network energy savings could be potentially obtained by transmission power adaptation with UE feedback information, e.g, CSI reporting, power adjustment indication, etc.
      * Dynamic adaptation of power offset(s) between PDSCH and CSI-RS.
      * The linear reduction of PAE (power added efficiency) when Tx power reduction should be included in the scaling of the power model.
    - [Technique #D-2: enhancements to [gNB digital pre-distortion] and UE post-distortion
      * Transmission energy efficiency at the network can be potentially improved with use of [enhanced over the air digital pre-distortion at the gNB and/or] post-distortion at the UE.
        + Whether and how much improvement of the PAE (power-added efficiency) should be disclosed.
      * In gNB digital pre-distortion over the air, the UEs assist the gNB in reducing nonlinear impairments introduced by the PA, by processing (e.g., calculation of the cross correlation of received signal after applying non-linear kernels) and reporting the information needed for gNB digital pre-distortion, on training signals
      * In UE post-distortion, the gNB assist the UE in reducing nonlinear impairments introduced by its PA (e.g., non-linear equalization stage that will “invert” the non-linearity), by sending RS signal at low periodically or some signaling to the UE.]
    - [Technique #D-3: adaptation of transceiver processing algorithm
      * Transmission energy efficiency at the network can be potentially improved with use of techniques such as channel aware tone reservation that decrease PAPR.
        + The UE must be notified of the sub-carriers carrying the TR signal, as using existing patterns (e.g., CSI-RS) is not practical
      * ~~gNB may opt to use different transceiver processing algorithms, e.g. different receive filtering, different transmitter digital pre-distortion methods, etc,, including some that may favor lower power consumption at the expense of degraded system performance. For example, disabling use of DPD that would potentially increase out of band emissions or tx EVM, but would potentially conserve transmitter power consumption.~~ Different transceiver processing algorithms at the gNB should be transparent to the UE.
      * Power model for the scaling of different transceiver processing algorithm should be provided with justification.]
    - [Technique #D-4: PA Input Power Bias ("input backoff”) Adaptation
      * Technique(s) allowing to modify/reduce the input power bias (“input power backoff”) in cases of no or very low load in the cell and in neighbor cells.
      * ~~The PA energy consumption consists around ~70 % of the energy consumed at the BS.~~
      * ~~The majority of this energy consumed at the PA is due to the input power bias (“backoff”).~~
      * ~~In some cases, especially when the cell and neighbor cells are almost empty, reducing this input power bias (“backoff”) results in significantly lower energy consumption.~~
      * This input power bias adaptation results in lower output PAPR, which is translated into some in band and out of band emissions being generated.
      * With appropriate signal processing techniques, it is possible to “steer” the unwanted emissions either to the in-band signal or out-of-band.
      * With suitable base station coordination and by steering the unwanted emissions onto carrier frequencies in which their impact can be traced, it is possible to avoid any eventual impact onto UEs in the cell or in neighbor cells.
      * ~~In general, this technique is activated only in case of zero or very low load in the cells; hence, the expectation is that no UEs will be affected by the generated in-band or out-of-band emissions.~~
      * The effect of PAE to the scheme should be disclosed.]
* [24] Ericsson
  + Lowering the gNB output power for UEs in good coverage may have very limited impact on throughput.
  + UEs need to be aware of PDSCH power offset changes in relation to reference signals, otherwise the CSI reports and UE internal receiver settings may become invalid.
  + PDSCH power offsets to reference signals (CSI-RS), as well as power offset between CSI-RS and SSB are configured via RRC signalling which is rather slow.
  + Multiple power offset between PDSCH and CSI-RS, or CSI-RS and SSB can be configured to one NZP-CSI-RS resource and MAC-CE/DCI can be used to indicate which power offset to use for CSI measurement and report.
* [25] NTT Docomo
  + Proposal 6: For dynamic power adaptation on RS (such as SSB and CSI-RS) and channels (such as PDSCH), it is better to take down-selection for further investigation. Several key KPIs should be considered for this down-selection work.
    - Specification impact
    - Power saving effect
    - Cell discovery performance
* [26] Qualcomm
  + Observation 12: Dynamic transmit power adaptation could help gNB dynamically adapt PA operation for achieving network energy savings.
  + Proposal 10: Capture in TR the following description for dynamic downlink transmission power adaptation
    - Dynamic downlink transmission power adaptation is a technique that allows the gNB to dynamically adjust the transmit power of one or multiple downlink signals/channels. The technique is not applicable to broadcast channels/signals (e.g., SSB/SI/paging).
    - Reducing the DL transmit power level can provide network energy savings. However, it negatively impacts UPT and coverage. For example, with Set 1 FR1 reference configuration, reducing the DL transmit power level from 55dBm to 52dBm provides 9% and 6% average network energy savings in low and light load scenarios, respectively. However, it reduces 10% and 16% average UPT in low and light load scenarios, respectively. Furthermore, the DL SINR at 5 percentile (i.e., cell edge users) is reduced by around 4dB in low load and 2.5dB in light load.
    - Specification impact may include enhancing physical layer procedures (e.g., CSI and/or downlink transmission power signalling framework) to efficiently support dynamic downlink transmission power adaptation for network energy savings with minimal impact to user experience.
  + Observation 13: OTA DPD increases the EVM at the transmitter by 2.5dB to 6dB based on the PA transmission power, increasing bits/Joule (one of the KPIs reducing network power consumption as explained at the beginning of this section).
  + Proposal 11: Study the over the air training digital pre distortions method (OTA DPD) for DPD at the gNB’s transmission chain.
  + Observation 14: DPoD increases the EVM at the transmitter by between 3dB and 8dB based on the PA transmission power and received SNR, increasing bits/Joule (one of the KPIs reducing network power consumption as explained at the beginning of this section).
  + Observation 15: DPoD increases the throughput between 10% and 25% in most received SNRs (using higher MCSs). This throughput increase is reflected in higher bits/Joule (one of the KPIs reducing network power consumption).
  + Proposal 12: Study DPoD (Digital post distortion) for increasing efficiency at the gNB’s transmitter.
  + Observation 16: Channel aware TR technique provides gain between 1dB and 3dB over no TR waveform in SNRs between -5 and 25 dBs, varying on the received SNR.
  + Proposal 13: study Channel Aware Tone Reservation technique that allows reduction of PAPR of the DL, using dynamic selection of subcarriers and method to notify the UEs.
  + Proposal 14: Capture in TR the following description for gNB power amplifier mechanism to reduce gNB energy consumption:
    - Power amplifier (PA) backoff reduction (“relaxation) in empty to low loaded scenarios.
    - RAN 1 to study the following:
      * Network energy savings obtained by gNB PA backoff adaptation.
      * Impact of gNB PA backoff adaptation onto system performance
* [27] ITRI
  + Proposal 4: The following aspects for adaptation of transmission power by the gNB can be considered:
    - Dynamic adaptation of transmission power according to the energy saving state(s) or sleep mode(s)
* [28] CEWiT
  + Proposal 10: Dynamically adapting the DL transmission power at gNB in specific set of frequency and time resources utilizing assistance information from the UE is supported.

### [ACTIVE] 1st Round Discussions

Companies should start thinking about what potential techniques to capture and what information would be captured together with the techniques. Moderator suggests refining the technique description further based on what was discussed in RAN1 #110. Discussion should include any suggestions to splitting or merging the techniques listed.

Please comment further on the following proposals, including comments to address notes from the moderator below.

#### Proposal #5-1

* The following descriptions are basis for further discussion and evaluations. If the text agreeable after further updates, discuss on whether to capture into the TR.
* Technique #D-1: Adaptation of transmission power of signals and channels
  + reducing the transmission power or PSD of various signals and channels, e.g SSB, CSI-RS, PDSCH, during specific scenarios or situations.
    - signaling of modified power ratio between CSI-RS and PDSCH/SSB or between SSB and CSI-RS to provide adaptation of power ratio values, e.g. by utilizing group-level or cell common signaling.
    - This may include enhancements on CSI-RS based measurements, such as beam management, beam failure recovery, radio link monitoring, cell (re)selection and handover procedure
  + The transmission bandwidth may be adapted jointly with transmission power to keep the similar reception performance.
  + UE feedback information, e.g, CSI reporting, power adjustment indication, etc.
  + The linear reduction of PAE (power added efficiency) when Tx power reduction should be included in the scaling of the power model. (1)

Moderator notes:

* Note (1) Need to Clarify (enough to be able to be evaluated by companies)
  + It seems unclear whether this is part of the technique or part of modeling discussion.

#### Company Comments on Proposal #5-1

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| Company | Comments |
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#### Proposal #5-2

* The following descriptions are basis for further discussion and evaluations. If the text agreeable after further updates, discuss on whether to capture into the TR.
* Technique #D-2: enhancements to [gNB digital pre-distortion] and UE post-distortion
  + [enhanced over the air digital pre-distortion at the gNB and/or] post-distortion at the UE.
    - Whether and how much improvement of the PAE (power-added efficiency) should be disclosed.
  + In gNB digital pre-distortion over the air, the UEs assist the gNB in reducing nonlinear impairments introduced by the PA, by processing (e.g., calculation of the cross correlation of received signal after applying non-linear kernels) and reporting the information needed for gNB digital pre-distortion, on training signals
  + In UE post-distortion, the gNB assist the UE in reducing nonlinear impairments introduced by its PA (e.g., non-linear equalization stage that will “invert” the non-linearity), by sending RS signal at low periodically or some signaling to the UE.

#### Company Comments on Proposal #5-2

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#### Proposal #5-3

* The following descriptions are basis for further discussion and evaluations. If the text agreeable after further updates, discuss on whether to capture into the TR.
* Technique #D-3: adaptation of transceiver processing algorithm
  + channel aware tone reservation that decrease PAPR.
    - The UE must be notified of the sub-carriers carrying the TR signal
  + gNB may opt to use different transceiver processing algorithms, e.g. different receive filtering, different transmitter digital pre-distortion methods, etc,, including some that may favor lower power consumption at the expense of degraded system performance. For example, disabling use of DPD that would potentially increase out of band emissions or tx EVM, but would potentially conserve transmitter power consumption. Different transceiver processing algorithms at the gNB should be transparent to the UE.(2)
  + Power model for the scaling of different transceiver processing algorithm should be provided with justification.(3)

Moderator notes:

* Note (2) Need to Clarify (enough to be able to be evaluated by companies)c
  + belong to specification impact
* Note (3) Need to Clarify (enough to be able to be evaluated by companies)
  + Should this be discussed in power model?

#### Company Comments on Proposal #5-3

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#### Proposal #5-4

* The following descriptions are basis for further discussion and evaluations. If the text agreeable after further updates, discuss on whether to capture into the TR.
* Technique #D-4: PA Input Power Bias ("input backoff”) Adaptation
  + Technique(s) allowing to modify/reduce the input power bias (“input power backoff”) in cases of no or very low load in the cell and in neighbor cells.
  + This input power bias adaptation results in lower output PAPR, which is translated into some in band and out of band emissions being generated. (4)
  + With appropriate signal processing techniques, it is possible to “steer” the unwanted emissions either to the in-band signal or out-of-band. (4)
  + With suitable base station coordination and by steering the unwanted emissions onto carrier frequencies in which their impact can be traced, it is possible to avoid any eventual impact onto UEs in the cell or in neighbor cells. (4)
  + In general, this technique is activated only in case of zero or very low load in the cells; hence, the expectation is that no UEs will be affected by the generated in-band or out-of-band emissions.(4)
  + The effect of PAE to the scheme should be disclosed.

Moderator notes:

* Note (4) Need to Clarify (enough to be able to be evaluated by companies)
  + Some refinement may be preferred to split these into: technique description part (needed to evaluate) and performance/impact analysis (to be analyzed after evaluations)

#### Company Comments on Proposal #5-4

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| Company | Comment |
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## 2.6 Other Energy Saving Aspects/Techniques

* [12] ZTE, Sanechips
  + UE assistance information can help network to better acquire UE’s requirements, so that the energy saving techniques can be adjusted more accurately to reduce the impact on user experience and assist network energy saving.
  + The UE assistance information can be considered for network energy saving.
* [17] Mediatek
  + Proposal 13: Efficient UE-group/cell-wise signaling and adaptation mechanism should be developed for useful NW energy saving techniques; otherwise the signaling overhead and power consumption will reduce the energy saving benefits.
  + Proposal 14: For maximum UE support, extend Rel-15 BWP adaptation framework as the UE-group/cell-wise signaling and adaptation mechanism for NW energy saving.
* [18] Apple
  + Technique #E-1: UE assistance information or feedback/report to further facilitate gNB network energy saving
    - Support of PUCCH transmission with negative SR report can be considered to aid gNB’s decision on whether to go into a dormant power state or not.
    - Support of UE’s mobility status and location can be considered to aid gNB’s perform energy saving techniques
    - UE assistance information including traffic relation information, such as pattern, volume etc.
    - UE report of certain measurement, e.g., based on discovery reference signal.
      * [Comment] This can be merged into A-1.
    - UE assistance data for gNB to assess whether it can go into a sleeping state, e.g. polling number of idle UEs, polling UEs beyond certain coverage.
* [23] Samsung
  + Proposal 28: Support PUCCH transmission with negative SR.
  + Proposal 29: Support UE assistance information for SSB request during network energy saving state.
  + Observation 5: UE assistance signaling for indicating an SR/CG PUSCH transmission is beneficial for network power consumption.
  + Proposal 30: Support UE assistance information for indicating an SR/CG PUSCH transmission during network energy saving state.
  + Proposal 31: Consider the following changes to the TP for TR
    - Technique #E-1: UE assistance information or feedback/report to further facilitate gNB network energy saving
      * Support of PUCCH transmission with negative SR report can be considered to aid gNB’s decision on whether to go into a dormant power state or not.
      * Support of UE’s mobility status and location can be considered to aid gNB’s perform energy saving techniques
      * UE assistance information including traffic relation information, such as pattern, volume etc.
      * UE report of certain measurement, e.g., based on discovery reference signal.
      * UE assistance data for gNB to assess whether it can go into a sleeping state, e.g. polling number of idle UEs, polling UEs beyond certain coverage.
      * UE request of SSB configuration
      * SR/CG PUSCH transmission indication

### [ACTIVE] 1st Round Discussions

Companies should start thinking about what potential techniques to capture and what information would be captured together with the techniques. Moderator suggests refining the technique description further based on what was discussed in RAN1 #110. Discussion should include any suggestions to splitting or merging the techniques listed.

Please comment further on the following proposals, including comments to address notes from the moderator below.

#### Proposal #6-1

* The following descriptions are basis for further discussion and evaluations. If the text agreeable after further updates, discuss on whether to capture into the TR.
* Technique #E-1: UE assistance information or feedback/report to further facilitate gNB network energy saving (1)
  + Support of PUCCH transmission with negative SR report can be considered to aid gNB’s decision on whether to go into a dormant power state or not.
    - Support of UE’s mobility status and location can be considered to aid gNB’s perform energy saving techniques
  + UE assistance information including traffic relation information, such as pattern, volume etc.
  + UE report of certain measurement, e.g., based on discovery reference signal.
  + UE assistance data for gNB to assess whether it can go into a sleeping state, e.g. polling number of idle UEs, polling UEs beyond certain coverage.

Moderator notes:

* Note (1)
  + This is generally true however as it is assisted information, instead of techniques standalone, it may be preferred to be included/reflected into each technique, using a separate sub-section.

#### Company Comments on Proposal #6-1

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# Suggested Proposals for Agreement/Conclusion

[TBD]

# Agreements/Conclusions from RAN1 #110-bis-e

[TBD]

# Reference

1. R1-2208382, “Potential enhancements for network energy saving,” FUTUREWEI
2. R1-2208425, “Discussion on network energy saving techniques,” Huawei, HiSilicon
3. R1-2208519, “Network energy saving techniques,” Nokia, Nokia Shanghai Bell
4. R1-2208562, “Discussion on network energy saving techniques,” Spreadtrum Communications
5. R1-2208655, “Discussion on NW energy saving technique,” vivo
6. R1-2208777, “Discussion on potential network energy saving techniques,” China Telecom
7. R1-2208833, “Discussion on network energy saving techniques,” OPPO
8. R1-2208988, “Network Energy Saving techniques in time, frequency, and spatial domain,” CATT
9. R1-2209023, “Discussion on network energy saving techniques,” Fujitsu
10. R1-2209064, “Discussion on Network Energy Saving Techniques,” Intel Corporation
11. R1-2209127, “Network energy saving techniques,” Lenovo
12. R1-2209196, “Discussion on NW energy saving techniques,” ZTE, Sanechips
13. R1-2209296, “Discussions on techniques for network energy saving,” xiaomi
14. R1-2209349, “Discussion on network energy saving techniques,” CMCC
15. R1-2209425, “Discussion on network energy saving techniques,” NEC
16. R1-2209453, “Discussion on physical layer techniques for network energy savings,” LG Electronics
17. R1-2209501, “On network energy savings techniques,” MediaTek Inc.
18. R1-2209592, “Discussion on network energy saving techniques,” Apple
19. R1-2209612, “On Network Energy Saving Techniques,” Fraunhofer IIS, Fraunhofer HHI
20. R1-2209618, “Discussion on network energy saving techniques,” Rakuten Symphony
21. R1-2209633, “Discussion on potential network energy saving techniques,” Panasonic
22. R1-2209655, “Potential techniques for network energy saving,” InterDigital, Inc.
23. R1-2209743, “Network energy saving techniques,” Samsung
24. R1-2209859, “Network energy savings techniques,” Ericsson
25. R1-2209914, “Discussion on NW energy saving techniques,” NTT DOCOMO, INC.
26. R1-2209997, “Network energy saving techniques,” Qualcomm Incorporated
27. R1-2210031, “Discussion on potential L1 network energy saving techniques for NR,” ITRI
28. R1-2210113, “Discussion on Network energy saving techniques,” CEWiT