RP-233158 3GPP RAN#102

Network Energy Saving Enhancements in Rel-19

Edinburgh, UK, December 11-15, 2023

Agenda item: 9.1.1.5

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Overview

Motivations and key proposals for network energy saving enhancements in Rel-19

Energy efficiency is key for mobile networks in general

- **It needs to be considered system-wise as well, in all relevant WIs**

In Rel-18 only a few of the enhancements identified in TR38.864[1] are being specified

- **Given that different techniques apply to different deployments and operating points of the system, it is important to continue the work in Rel-19 with relevant techniques**
- Another aspect to consider is that Rel-18 has focused primarily on RRC Connected, and hence in Rel-19 the focus should be on RRC Idle/Inactive states and low load scenarios

Some key principles can be considered for Rel-19 normative work:

- Avoid techniques that reduce flexibility for network
- Avoid techniques that constrain gNB implementation
- Legacy devices, and coexistence with them, need to be supported, but not necessarily always on all cells
- Any techniques requiring waveform modifications should wait for 6G

Key areas for enhancements:

- **SIB1-less cell and on-demand SSB/SIB1**
- **Paging enhancements for low load scenarios**
- **Enhancements for cell shutdown**
- **Rel-18 leftovers on cell DTX/DRX**
  - Specify inter-node information exchange on cell DTX/DRX
  - Support of multiple DTX/DRX patterns on the same serving cell

[1]TR38.864 “Study on Network Energy Savings for NR”

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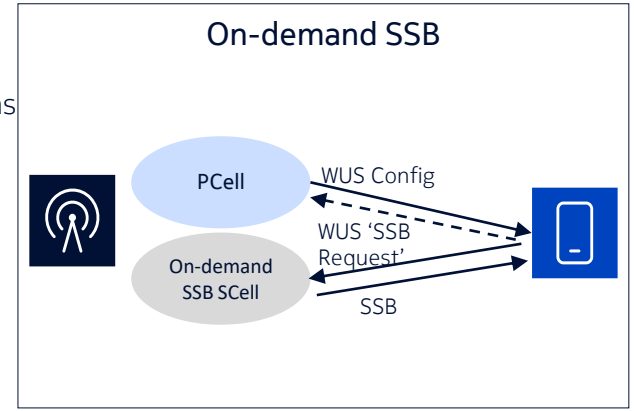
On-demand SSB for UEs in CONNECTED mode

- **Justification:**
  - In Rel.18 SSB-less SCell operation in Inter-band CA is defined for RRC connected
  - However, it is applicable only under certain limitations and several side-conditions needs to be met incl. maximum RTD, maximum frequency and power difference, and TAE between PCell and SCell
- **Objective:**
  - Extend the scenarios in which SCell needs not to transmit SSB regularly but can transmit SSB only on-demand when needed.
  - Enable triggering on-demand SSB transmission upon need, by either sending an uplink wake-up-signal (UL-WUS) (see figure) or a network indication.
  - A legacy signal or channel can be re-used for UL-WUS transmission.



1. Specify procedures and signaling method(s) to support on-demand SSB SCell operation for UEs in connected mode configured with CA, including inter-band CA. [RAN1/2/3/4]
   - Specify triggering method (e.g., UE uplink wake-up-signal using an existing signal/channel, cell on/off indication via backhaul, Scell activation/deactivation signaling, etc.)
   - Note1: on-demand SSB transmission is used by UE for SCell time/frequency synchronization, L1/L3 measurements and SCell activation, and is supported for FR1 and FR2.

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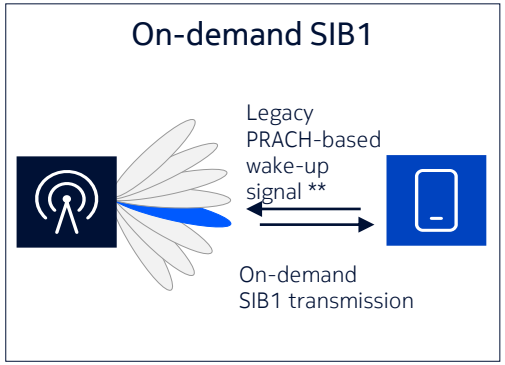
On-demand SIB1 for UEs in IDLE/INACTIVE mode

- **Justification:**
  - Up to Rel-18, a cell needs to transmit SSB and SIB1 regularly to be able to serve RRC IDLE and RRC INACTIVE Ues
  - In Rel-19, it would be beneficial to **eliminate unnecessary transmissions of SIB1**
  - SIB1 transmissions by a capacity/non-anchor cell are **unnecessary whenever there are no devices** in RRC INACTIVE/IDLE present that benefit from the signalling



- **Objective:**
  - Enable UE triggering on-demand SIB1 transmission upon need, by sending an uplink wake-up-signal (UL-WUS) to enable UL data transmissions (see figure).
    - This technique requires the anchor cell (coverage cell) to provide to the UE cross-carrier system information (e.g. for UL-WUS configuration).
    - A legacy signal or channel can be re-used for UL-WUS transmission such as a PRACH preamble.
    - This technique can be supported at least by UEs in RRC IDLE and RRC INACTIVE.

2. Specify procedures and signaling method(s) to support on-demand SIB1 for UEs in idle/inactive mode. [RAN1/2/3]
   - Specify triggering method by uplink wake-up-signal using an existing signal/channel.
   - Specify wake-up-signal configuration provisioning to UE via an anchor cell, for on-demand SIB1 operation on non-anchor NES cell.
   - Specify information exchange between gNBs at least for the configuration of wake up signal, if necessary.

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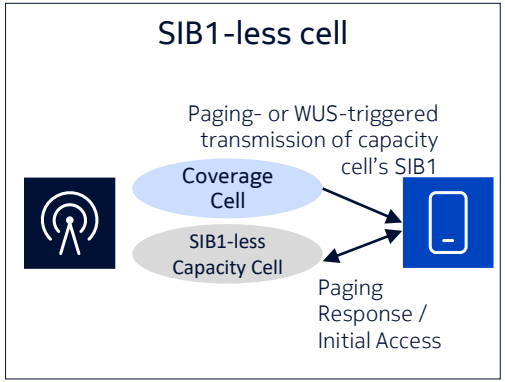
SIB1-less cell for UEs in idle/inactive mode

- **Justification:**
  - Up to Rel-18, a cell has to transmit SSB and SIB1 regularly for RRC IDLE and INACTIVE UEs
  - In Rel-19, it would be beneficial to **eliminate unnecessary transmissions of both SIB1 and of the other SIBs** (SIB2-SIB4) **required for camping on the capacity/non-anchor cell**
    - I.e., SIB1 transmissions for a cell can be triggered only if access to the cell is required
  - It would also be beneficial to **eliminate SIB1 transmission altogether from the capacity / non-anchor cell** allowing longer sleep opportunities esp. if longer SSB periodicity (or on-demand SSB) is further considered
    - The capacity cell can be in deep sleep state and able to quickly reactivate its operations to serve individual UEs to attain highest energy saving while not compromising QoS/QoE



- **Objective:**
  - The UE camps on the coverage/anchor cell and can access the SIB1-less NES cell after it receives the capacity cell's SIB1 from the coverage cell (see figure)
    - UL: Mobile-Originated Initial Access on SIB1-less cell: the UE triggers, on the coverage cell, the on-demand SIB1 procedure to obtain transmission of the capacity cell's SIB1 on the coverage cell
    - DL: UE paging on coverage cell triggers transmission of the capacity cell's SIB1 on the coverage cell for the UE, and paging response on SIB1-less cell

3. Specify support for SIB1-less operation for non-anchor NES cell for UEs in idle/inactive mode. [RAN2/1/3]

- UE can access from SIB1-less non-anchor NES cell, for which the SIB1 is carried on an anchor cell.
- Paging is transmitted on an anchor cell.

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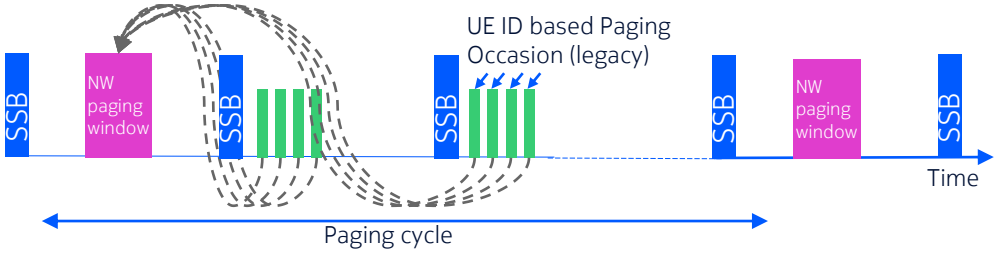
Paging enhancements for low-load scenarios

Clustered paging *(technique A-1-4 in TR 38.864)*

- **Justification**:
  - Currently UEs' paging occasions are distributed in the time domain (this is by design to increase paging capacity and distribute resource usage over time).
  - However, such design negatively impacts the RAN sleeping opportunities because the cell must wake up at different times for paging transmissions (according to the paging occasions) even when the paging load is low

(1) Clustered paging in low load scenarios



- **Objective**: reducing the number of paging transmissions in low-load scenarios
  - By clustering in time the paging of Rel19 UEs in fewer Paging Occasions, which are common or contiguous for different UEs
  - See the 'network paging window' in the figure, in which the paging occasions of different UEs are confined
    - This can be achieved by adjusting the UE's PO/PF calculations of Rel.19 UEs
    - The same paging latency is ensured for Rel.19 UEs as in legacy as their Paging Occasions are only clustered together
  - Legacy UEs can continue using legacy paging, therefore there shall be no impact.

4. Adaptation of common signal/channel transmissions. [RAN1/2/3/4]

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- Adaptation of paging occasions including confining the paging occasions in the time domain
  - Note: there shall be no impact to legacy UEs nor paging latency increase

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Enhancements for cell shutdown

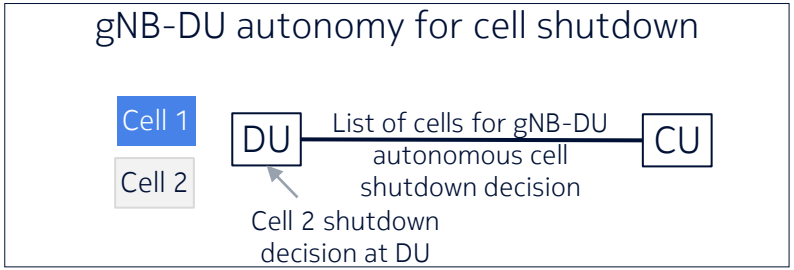
Motivation: The cell shutdown procedure is one of the most energy-effective means used to save power, but it is currently relatively slow.

- In Rel.18, CHO enhancements are considered primarily for robustness of traffic offloading at cell shutdown.

(1A) gNB-DU autonomy for cell shutdown; (1B) gNB-CU control of gNB-DU/CU-UP deactivation during low load

- Currently, gNB-CU is responsible of cell switch OFF and ON decisions, and then gNB-CU indicates the decision to gNB-DU for the gNB-DU to initiate offloading and cell deactivation. However, cells are managed by the gNB-DU, which is aware of cell load and energy consumption.
- Thus, gNB-DU autonomous decisions for cell shutdown would be beneficial as the gNB-DU is more capable of determining the possible gains, and can make the procedure faster
- (1B): Enablers for CU-CP to configure targeted CU-UP(s) or DU(s) to release the ongoing traffic and go to sleep mode for a certain time
- **To enable the above, new F1-C signalling is necessary**

[Specify support for Cell on/off optimization in split gNB deployment, to support gNB-DU assisted/initiated cell (de)activation or gNB-DU autonomy for cell shutdown.] [RAN3]



(2) Enable faster decrease of SSB transmit power at cell shutdown

- Cell deactivation is done by multi-step SSB power ramp down (i.e. graceful shutdown), which is slow as it requires SI modification.

(3) Enable finer control of cell reselection procedure at cell shutdown

- Currently, the network cannot flexibly control to which frequency layer UEs should reselect, after the cell in which they are camping is shutdown.

4. Adaptation of common signal/channel transmissions. [RAN1/2/3/4]

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- Cell shutdown enhancements including faster SSB power ramping down and controlled cell resection at cell shutdown [RAN2/RAN3]

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Further considerations on power-domain techniques

- TR38.864 includes initial studies on power-domain techniques where gNB PA is operating in its non-linear domain, e.g. technique D-5
- In general, the **compensation of non-linearity by UE receiver implies processing of the full signal transmitted by the gNB PA, including all PRBs in all carriers**.
  - This is true also for measurements from own and neighboring gNBs, e.g. for CSI or RRM purposes
- In practice, this means that these techniques are mostly applicable for scenarios with a couple active UEs in a local neighborhood, i.e. isolated cells.
  - **From network perspective this is a relatively low load scenario**, despite the fact that a couple UEs are momentarily having large amount of downlink traffic
- Any further study on this topic should be preceded by characterization of the applicable scenarios and underlying assumptions, including deployment aspects (e.g. intra-, inter-band CA), mobility assumptions, data traffic and scheduling assumptions, etc
- Also the potential mechanisms for power saving gains need to be properly characterized taking into account practical gNB PAs.
- **At the moment it is not clear whether there is any energy saving gain potential with these techniques, with practical PAs and practical deployments in mind**

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