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Agenda Item: 9.1.1.5
Source: CMCC
Type: Discussion

Views on further enhancements of network energy saving

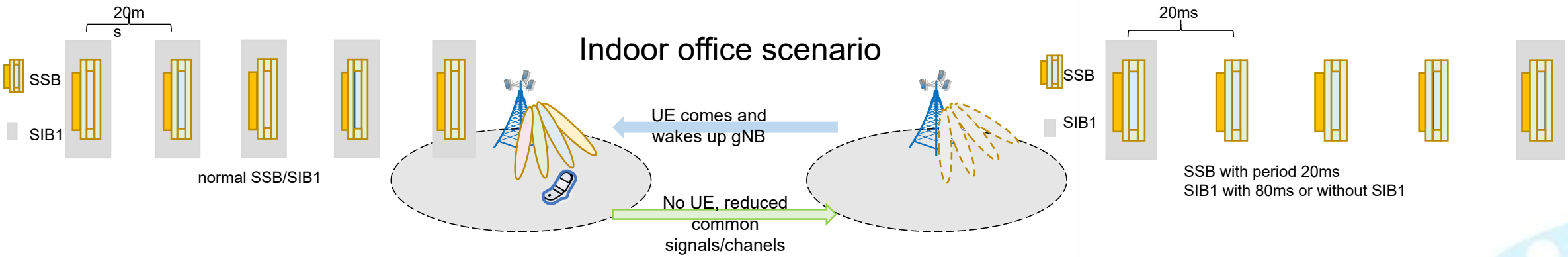
December 2023

Backgroud

- During R18 SI, NES techniques in time, frequency, spatial and power domain has been studied and evaluated, the description of candidate schemes, power saving gain and performance impact, and specification impact are analyzed and captured in TR38.864
- Among the candidate schemes studied in SI, the following are further specified in R18 NES WI
  - Time domain: Cell DTX/DRX
  - Frequency domain: SSB-less SCell
  - Spatial domain: Adaption of spatial elements/antenna ports
  - Power domain: Adaption of transmission power for PDSCH
  - Higher layer power saving schemes including preventing legacy UEs camping on NES cells, CHO procedure enhancement(s), paging enhancement, RRM/RF core requirements
- Techniques specified in WI for time, frequency, spatial, power domain are **mainly related to CONNECTED mode operation**, impact to IDLE/INACTIVE UEs should be avoided
- However, when there is no traffic or no UEs, the transmission of periodic common signals/channels prevents gNB going to deep sleep, enhancement to reduce transmisson of such channels while maintain in time response to UE is needed
- **Observation: Further enhancement to faciliate reduced transmisson of common signals/channels of gNB while maintain in time response to UE is needed**

Motivation of further NES for common signals/channels

- Scenario A: Single carrier scenario (idle/inactive)
  - Take indoor office scenario as example, it has the following characteristics
    - The number of UEs served has obvious time varing characteristics. When there are no users, periodic broadcast signals brings a lot of meaningless energy consumption to the network
      - **gNB can adapt the periodicity or pattern of commmon signals/channels, for example adapt to sparse SSB/SIB1 transmission, or sparse/no SIB1 transmision**
    - While even in non-working hours, UEs will occasionally enter the indoor office area, if the network enters energy saving mode, it needs to be woken up in time
      - **Wake up signals from UE to wake up gNB for normal common signals/channels transmission**



- **Proposal : For single carrier scenario, adaption of common signals/channels and UE waking up gNB are supported for R19 NES at least for indoor scenario**

Motivation of further NES for common signals/channels

- Scenario B: Multi-carrier scenario (idle/inactive)
  - IDLE/INACTIVE operations among multiple CCs (intra or inter-band) are coupled!
    - Usually, multiple carriers may be deployed and collocated in the same site
      - **Legacy option 1:** Anchor CC (e.g., CC1 in Figure 1)
        - All cell acquisition(e.g., SS, system information) signals/channels and cell access (e.g., RACH) procedure are kept
      - **Option 2A:** Light CC (e.g., CC2 in Figure 1):
        - Partial cell acquisition signals/channels and cell access (e.g., RACH) procedure are kept.
          - Only SSB(w or w/o PBCH) transmission is kept, system information is not transmitted, e.g., UE read from anchor carrier.
      - **Option 2B:** AZP(almost-zero-power) CC (e.g., CC3 in Figure 1)
        - Cell acquisition signals/channels are no longer kept (SSB-less) or largely relaxed to longer periodicity, e.g., SSB, system information are not kept, but cell access (e.g., RACH) procedure are kept

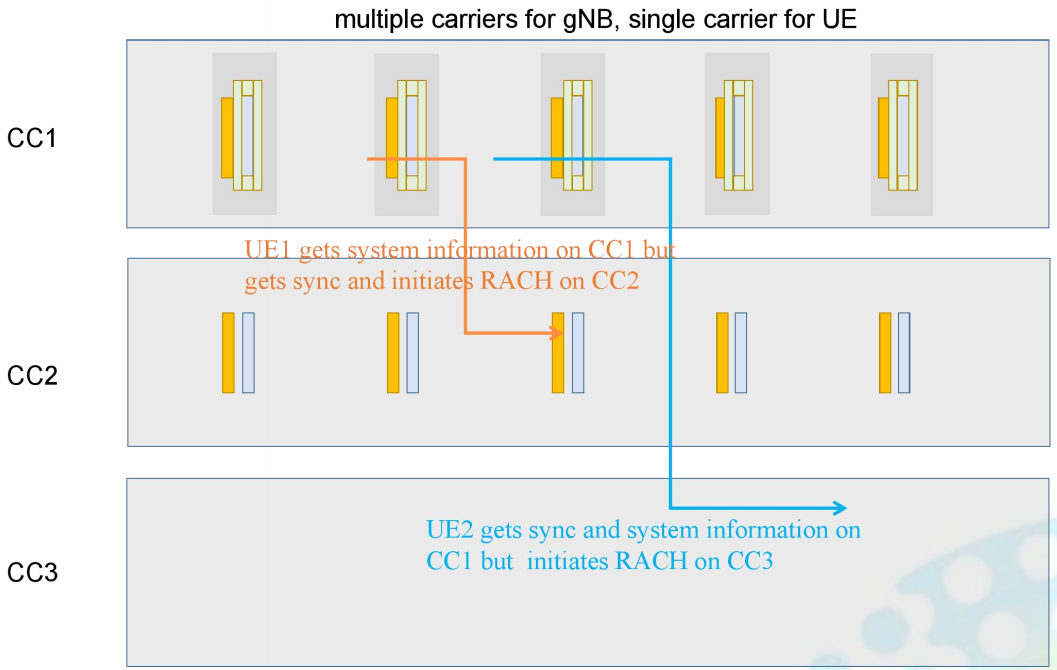


Figure 1. NES cell option 2A and 2B

Motivation of further NES for common signals/channels

Table 1. procures for different NES options in RRC IDLE/INACTIVE

Option		SSB		System information	RACH	RRM
		PSS/SSS	MIB			
1 Anchor CC (legacy behavior)		Y	Y	Y	Y	Y
2A Light CC	2A-1	Y	Y		Y	Y
	2A-2	Y			Y	Y
2B AZP CC	2B-1				Y	
	2B-2					

Note: Y means UE performs related procedures in the current CC

- **Options for different NES CC are shown in Table 1**
  - Study and specify the proper NES options by considering robustness/complexity and efficiency for network power consumption/overhead.
  - Legacy UEs are impacted for option 2A/2B and can only work on anchor CC
  - RRM (if necessary) are relaxed for AZP CC, 'virtual RSRP/RSRQ' can be derived according to anchor cell.
  - RACH transmission can also be considered as UE wake-up signal to enable Light/AZP CC behaves like an anchor CC when needed, other signals/channels are not precluded.
- **Proposal: For multi-carrier scenarios in IDLE/INACTIVE, support NES cell and corresponding enhancements by considering robustness/complexity and efficiency for network power consumption/overhead etc.**

Motivation of further NES for common signals/channels

- Scenario C: Multi-carrier scenario (Connected)
  - SSB transmission on Scell is on demand
    - SIB1 on PCell, as legacy
    - SSB transmission on SCell can be turned off (NES SCell), when
      - No data to be transmitted on SCell
      - only SSB-less capable UEs is scheduled on SCell
    - When UEs without intra SSB-less/inter SSB-less capabilities want be served by SCell
      - Trigger SSB transmission by wake up signals to Pcell, e.g. by PRACH or SR resources,

Proposal: For multi-carrier scenarios in Connected, support on demand SSB on SCell by UE triggering, by reusing existing signals/channels

NES CC activation/deactivation

- Scenarios to be addressed for NES CC activation/deactivation
  - Scenario 1: Traffic arrival
    - Both MT/MO service initialization are considered
    - Paging or RACH procedure enhancement can be considered to effectively let the UE working on proper cell and activating NES cell/SCell when there is no such signal/channel are Tx/Rx on the current CC.
  - Scenario 2: cell reselection/selection
    - Activation the NES cell for cell reselection UE is to ensure the UE good mobility performance.
    - For cell reselection,
      - Option 1: UE WUS is considered to wake-up NES cell.
      - Option 2: for single CC case, cell-level coordination is needed, e.g., UE WUS is only considered to be transmitted to current cell, network decide and anticipate the neighboring cell(NES cell) and activate that.
    - FFS WUS signal/channel design and configuration, procedure before and after WUS, including conditions for triggering WUS

Network power saving benefit

- According to TR 38.864, power saving performance of above techniques has been studied during R18 SI

• **Technique A-1 Adapting transmission/reception of common channels/signals** "Technique A-1 adapts the transmission pattern (when applicable) of downlink common and broadcast signals, such as SSB/SI/paging/cell common PDCCH, and/or the transmission pattern/availability of uplink random access opportunities. Adaptation of the transmission pattern includes changes to periodicity, time resource locations, and omitting of specific signals/channels. The transmission pattern can be adapted semi-statically or dynamically."	-4 sources show technique A-1-1 of **simplified SSB without PBCH or with partial PBCH** could achieve BS energy savings by **0.7%~30.49% in range**, with no observed impact on UPT due to empty load. -9 sources show technique A-1-3 of statically **adapting the periodicity of SSB longer than 20ms up to 1280ms** (with current maximum periodicity being 160ms) could achieve BS energy savings by **0.9%~84.8% in range**, meanwhile when traffic occurs and load increases, the UPT significantly decreases and the latency/access delay/UE power consumption increases proportionally as the periodicity of SSB/SIB increases compared to a corresponding baseline
• **Technique A-3 UE wake up signal (WUS) for gNB** "Technique A-3 enables the UE to send an uplink wake-up signal to request transitioning of a cell from no or reduced transmission/reception activity to active transmission or reception of a channel/signal. The technique can be applied to UEs in one or more RRC states. The UE wake up signal (WUS) by technique A-3-1 may be used to trigger the SSB/SIB transmission. It can be used to trigger SSB/SIB1 transmissions with technique A-5. It can also be used to trigger gNB to wake up with technique A-4."	-5 sources show technique A-3-1 of **UE WUS triggering gNB for SSB/SIB/RACH**, with the assumption of ideal detection of UE WUS, could achieve BS energy savings by **6.2%~80.7%** in range with UPT loss by 0%~24.2%, while 1 source shows technique A-3-2 of **UE WUS triggering gNB to wake up in case of uplink traffic arrival** could achieve BS energy savings by **25.7%~93% in range**, with latency reduction of 0%~45.5% depending on the SR periodicity assumed in the baseline, -Note technique A-3-2 of UE WUS triggering gNB to wake up in case of uplink traffic arrival assumes that gNB can detect WUS during sleep state.
• **NES Cell without SIB/SSB** From RAN2 perspective, the technique is studied from time domain. The description of this technique, analysis of network energy saving and performance impact as well as impact on legacy UE and RAN1 specification, can be found in clause 6.1.5 for Technique A-5-1 and in clause 6.2.1 for Technique B-1-1	In general, for **SSB and/or SIB saved from one carrier of two carriers**, 8 resources observed BS energy savings gain, by **5.1%~98.4% for empty load, 3.0%~58.4% for low load**, and 1.0%~7.9% for light load, 0.3%~5.7% for medium load. When traffic load is low, network may turn off SCell for energy saving. The results are for FR1 only.

Highlight

- Both IDLE/INACTIVE and CONNECT mode enhancement for NES are considered
- Single CC and multiple CC scenarios are considered
- For multiple CC case
  - light CC and AZP CC solution can be considered, necessary enhancement should take robustness/complexity and efficiency for network power consumption/overhead into consideration
    - RACH on light CC and AZP CC are considered
    - Enhancement for working procedure of light CC and AZP CC with or without on demand SSB/SIB1 are both considered
  - NES SCell can also be considered, SSB is on demand triggered
- UE WUS is efficient way for on demand SSB/SIB1 enhancement
- At least for traffic arrival (both MT/MO) and cell reselection/selection, NES cell activation/deactivation procedure enhancement should be considered.
- Design of UE wake-up signal (WUS) should consider two ways, one for existing gNB implementation, another for new gNB implementation with additional wake-up receiver (WUR)

Potential objectives

- Less common signal/channels transmission (SSB/SIB1-less) for NES cell for IDLE/INACTIVE states
  - Necessary L1 and higher layer procedures to support adaption of common signal/channels such as SSB/SIB1 on NES cell, including possible indication of reduction/zero SSB/SIB1, and to activate the NES cell to normal cell
    - Specify UE wake-up-signal for activating NES cell to normal cell
      - Design of UE wake-up signal (WUS)
        - by considering
          - Existing gNB implementation
          - New gNB implementation with additional wake-up receiver (WUR)
        - [Potential WUS including, RACH/SRS/…]
      - WUS configuration, procedure before and after sending WUS, including conditions for triggering WUS
  - Necessary L1 and higher layer procedures to support SIB1-less/paging-less and reduced/zero SSB on non anchor NES cell for idle mode, with normal SSB/SIB1/paging on anchor non-NES cell
    - For MT/MO service initialization, paging or RACH procedure enhancement can be considered to effectively let the UE working on proper cell, e.g. access from non-achor NES cell
    - For MT/MO service initialization and cell selection/reselection, non anchor NES cell can also support on demand SSB by UE triggering, e.g. UE wake-up-signal
  - Necessary gNB information exchange to support the NES cell operations (RAN3)
- On demand SSB for NES SCell for CONNECTED states
  - Specify necessary enhancement to support reduction/zero SSB and on demand SSB triggering, maximum reuse of UE wake-up signal for IDLE/INACTIVE states

Potential objectives

- Consider the following three scenarios
  - Scenario A: Single carrier scenario (idle/inactive)
    - Some of the cells are 'NES cell' and *on-demand* to transmit common signals/channels for power saving, e.g., SSB/SI
    - UE WUS to wake-up NES cell with the assistant information from non-NES cells, e.g., information for 'NES cell''s configuration
  - Scenario B: Multi-carrier scenario (idle/inactive)
    - Multiple carriers deployment with ***anchor carrier*** (e.g., non NES cell) and reduced/zero SSB/SIB transmission on ***non-anchor carrier*** (e.g., 'NES cell'), NES cell can support all RRC state operation with less/no SSB/SIB on it, and can also be *on-demand* triggered to normal SSB/SIB1 transmision
    - UE receive SSB/SIB/paging on non NES cell, system information of NES cell is obtained from non NES cell, and UE can access on both non NES cell and NES cell
      - UE measurement for non-anchor cells are skipped and derived from anchor cell (minimize specification impact from UE measurement)
  - Scenario C: Multi-carrier scenario (connected)
    - SSB transmission on Scell is on demand
      - SIB1 on PCell as legacy, SSB transmission on SCell can be turned off (NES SCell), UE can trigger SSB transmission on SCell by wake up signals to Pcell, e.g. by PRACH or SR resources

Thank you!