3GPP TSG RAN Meeting #102
Edinbugh, UK – Dec 11th – 15th, 2023

RP-233269
Agenda Item 9.1.1.5

Rel-19 NES: Scope

MediaTek Inc.

Overview – Fundamental NES Dimensions

- NES TR 38.864:

$$P_{active}^{DL} = P_{static}^{DL} + \boldsymbol{s_a} * \left(P_{dyn,ante} + \frac{\boldsymbol{s_p} * \boldsymbol{s_f}}{\eta} * P_{dyn,joint} \right)$$

$\boldsymbol{s_a}$: The ratio of active antennas, $\boldsymbol{s_p}$: The ratio of PSD per TxRU, $\boldsymbol{s_f}$: The ratio of transmit BW

NES Adaptation	TDD 30kHz SCS 100MHz BW	FDD 15kHz SCS 20MHz BW
Time: 50% sleep	280 → 167.5 (40.2% ↓)	200 → 125 (37.5% ↓)
Spatial: $s_a = 1 \rightarrow 0.5$	280 → 167.5 (40.2% ↓)	200 → 125 (37.5% ↓)
Power: $s_p = 1 \rightarrow 0.5$	280 → 212.5 (24.1% ↓)	200 → 155 (22.5% ↓)
Freq. : $s_f = 1 \rightarrow 0.5$	280 → 212.5 (24.1% ↓)	200 → 155 (22.5% ↓)

- **Observation 1**: Time and spatial domain techniques are most effective to achieve NES gain
  - R18 focused on ***PDSCH*** energy saving in time domain (cell DTX/DRX) and spatial domain (Spatial adapt. & CSI enh.)
- **Proposal 1**: Rel-19 to extend time and spatial domain enhancements over ***RS*** and ***common/group channels***

Overview – Fundamental NES Trade-Off

- NES TR 38.864:

$$P_{active}^{DL} = P_{static}^{DL} + \boldsymbol{s_a} * \left(P_{dyn,ante} + \frac{\boldsymbol{s_p} * \boldsymbol{s_f}}{\eta} * P_{dyn,joint} \right)$$

$\boldsymbol{s_a}$: The ratio of active antennas, $\boldsymbol{s_p}$: The ratio of PSD per TxRU, $\boldsymbol{s_f}$: The ratio of transmit BW

NES Adaptation	TDD 30kHz SCS 100MHz BW	FDD 15kHz SCS 20MHz BW
Time: 50% sleep with $\boldsymbol{s_f = 0.5 \rightarrow 1}$ when active	212.5 → 167.5 (21.2% ↓)	155 → 125 (19.4% ↓)
Spatial: $s_a = 1 \rightarrow 0.5$ with $\boldsymbol{s_f = 0.5 \rightarrow 1}$	212.5 → 167.5 (21.2% ↓)	155 → 125 (19.4% ↓)

- **Observation 2**: Reducing active time and antennas, while increasing number of used RBs, achieves good NES gain with minimum data throughput impact
  - R18 focused on ***medium and lower cell load*** cases for exploiting the above trade-off that is *universal for any RF/PA implementation*
- **Proposal 1**: For high cell load case, Rel-19 to further study potential enhancement(s) that is *independent of any specific RF/PA implementation/assumption*

Recommendations on Rel-19 NES Enhancement Scope (1/2)

- Specify time-domain enhancements for Network Energy Savings [RAN1/2/3/4]
  - Specify procedures and signaling method(s) for on-demand SSB and SIB1 transmission [RAN1/2/3/4]
    - Triggering method for on-demand SSB/SIB1 by uplink wake-up signal
    - Adaptation of periodicity, time positions, number of occasions
    - Information exchange between gNBs
    - Minimum impact to legacy UEs
  - Specify support to turn off TRS during DTX [RAN1/2/3]
    - Turn off TRS in some occasions during cell DTX, subject to minimum impact on UE synchronization
  - Specify support for SIB1-less operation in non-anchor cell [RAN2/1/3]
    - SIB1 and paging carried on anchor cell
  - Adaptation of paging occasions [RAN1/2/3/4]
    - Confine paging occasions in time domain
    - No impact to legacy UEs or paging latency

Recommendations on Rel-19 NES Enhancement Scope (2/2)

- Specify spatial-domain enhancements for Network Energy Savings [RAN1/2/4]
  - Adaptation of active antennas for SSB transmission [RAN4]
    - Identify necessary UE measurement behavior changes
    - Complement to time-domain and frequency-domain SSB energy saving techniques (Link)
  - Dynamic TRP on/off in multi-TRP operation [RAN1/2]

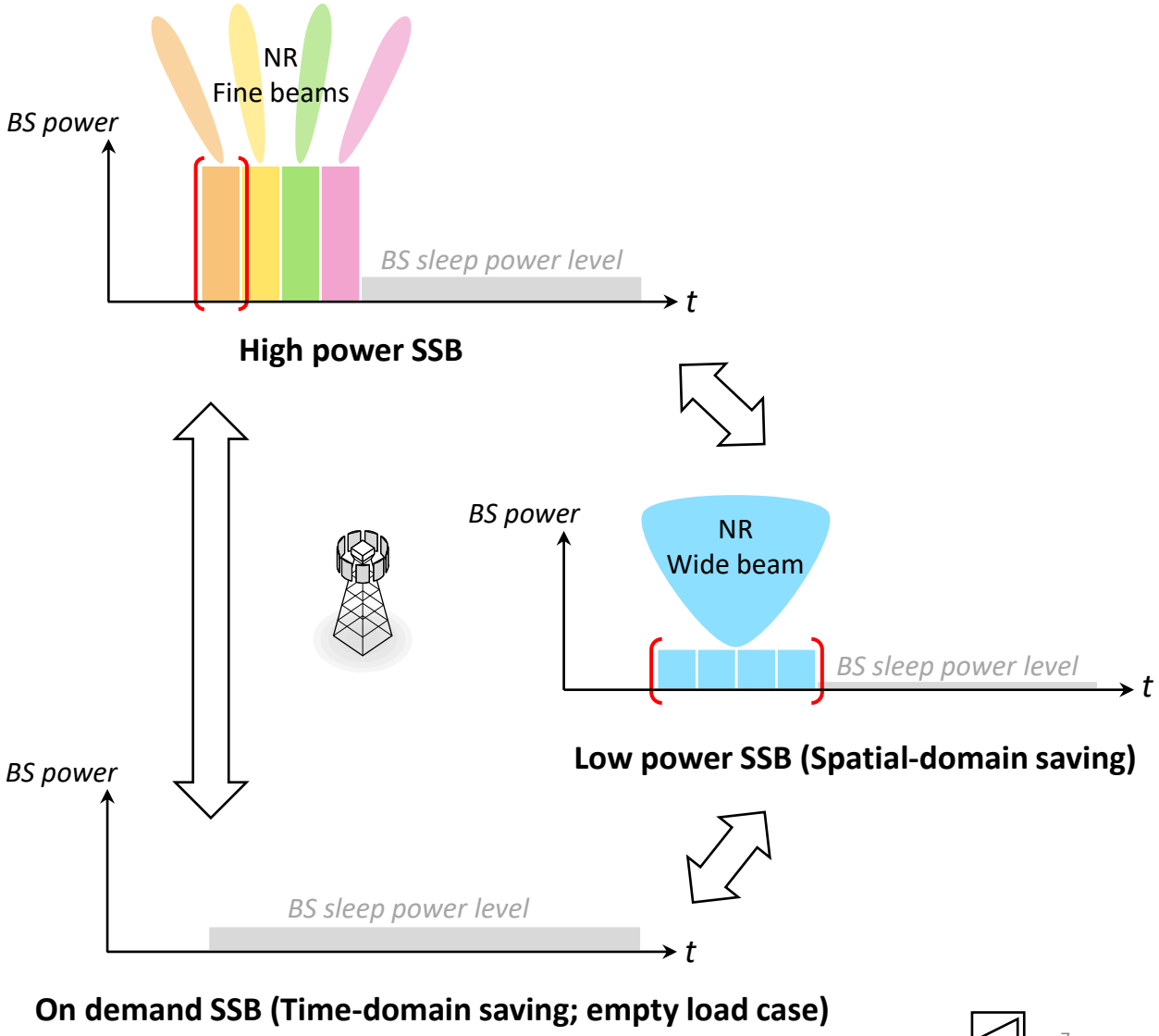
- Study and specify, if beneficial, enhancement(s) for high cell load cases [RAN1/4]
  - Aim for enhancement(s) *independent of any specific RF/PA implementation/assumption*

- Specify corresponding RRM/RF requirements [RAN4]

Thank you!

SSB Energy Saving Techniques

- Rel-18 identifies solutions in
  - Frequency domain: SSB-less Scell
  - Time domain: On-demand SSB
  - Limitation: Co-located & tight sync, empty load
- Spatial domain SSB energy saving
  - Reduces #antennas for SSB transmission
    - Reduce 1/2 #antennas can give **>40%** BS energy saving gain
    - Can be used for cases w/o co-located, tight sync, or empty load
    - Complement to SSB-less Scell and on-demand SSB solutions; network has the flexibility to apply the best solution(s)
  - Enhancements for minimizing UE impacts
    - Whether/how to adapt thresholds for RLM/BFD, cell re-selection, and those based on SSB power as reference
    - Whether/how to perform SSB power accumulation with minimum impact to UE power consumption
  - Applicable to other common/group channels (SIB1, paging channels, etc.)



NES Gain with Spatial-Domain SSB Energy Saving (1/2)

- Power consumption model for SSB:
  - Active power

$$P_{active}^{DL} = P_{static}^{DL} + \boldsymbol{s_a} * \left(P_{dyn,ante} + \frac{\boldsymbol{s_f} * \boldsymbol{s_p}}{\eta} * P_{dyn,joint} \right)$$

$\boldsymbol{s_a}$: The ratio of active antennas,
$\boldsymbol{s_f}$: The ratio of transmit BW, $\boldsymbol{s_p}$: The ratio of PSD per TxRU

  - Sleep power

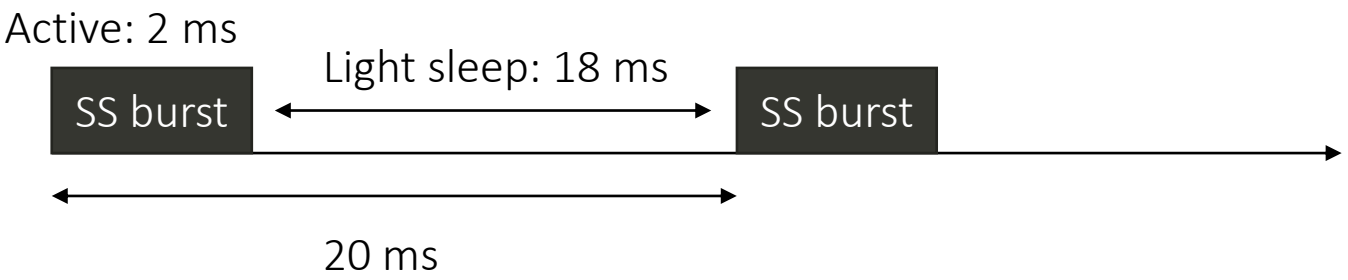
	baseline	Reduced w.r.t $s_a/2$*
Light sleep	25	12.5
Overhead	90	45

* Assume reduction can be achieved by
- Minimum non-RF components for SSB TX (thus residue/sleep power proportional to s_a)
- Dedicated TX with reduced s_a for SSB

Cat 1 BS configuration	TDD 30kHz SCS 100MHz BW	FDD 15kHz SCS 20MHz BW
P_{static}^{DL}	55	50
$P_{dyn,ante}$	90	60
$P_{dyn,joint}$	135	90
η	1	1
$\boldsymbol{s_f}$	20 (RB) / 273 (RB)	20 (RB) / 106
(s_a, s_p) baseline	(1/8, 8)	(1/4, 4)
Active power	76	81
Active power ($s_a \rightarrow s_a/2$)	66	66

NES Gain with Spatial-Domain SSB Energy Saving (2/2)

- SSB transmission timeline and average power:



$$Average\ power = \frac{2\ (ms) \times Active\ power + 18\ (ms) \times Light\ sleep + Ligth\ sleep\ overhead}{20\ (ms)}$$

- BS energy saving gain with low-power SSB transmission with reduced #antennas:

TDD 30kHz SCS 100MHz BW	FDD 15kHz SCS 20MHz BW
34.6 → 20.1 (41.9% ↓)	35.1 → 20.1 (42.7% ↓)