**3GPP TSG-RAN WG1 Meeting #111 R1-221xxxx**

**Toulouse, France, November 14th – 18th, 2022**

**Agenda Item: 9.7**

**Source: Moderator (Huawei)**

**Title: Comment collection for draftTR 38.864 v0.4.0**

**Document for: Discussion and Decision**

For the below email discussion,

[Post-111-NWES\_TR] Email discussion for endorsement of TR 38.864 update (including conclusion) – Yi (Huawei)

* From Nov 28 until Nov 30

Company’s comments are collected for the TR update draft in

https://www.3gpp.org/ftp/tsg\_ran/WG1\_RL1/TSGR1\_111/Inbox/drafts/9.7(FS\_Netw\_Energy\_NR)/%5BPost-111-NWES\_TR%5D

|  |  |
| --- | --- |
| **Company** | **Comments** |
| CEWiT | Time domain techniques:Based on the study,we think that the techniques A-1-2 and A-1-6 have the potential to provide significant energy saving. Further the techniques can be combined with other techniques such as A-1-1 and A-1-3 for enhancing the energy saving gains and reducing the overhead. For technique A-1-6, the results provided in the study phase shows improvement in energy saving from 4.8% to 14.8% when number of SSBs increases from 1 to 8. Hence the technique A-1-6 will be more useful when the number of beams is more. For e.g. in FR2, with 64 SSBs, the energy saving gain achieved by A-1-6 for cat 1 gNB increases to 21.6% and it will further increase to 59.05% when combined with technique A-1-3. Frequency domain techniques:The base for achieving energy saving gain for the techniques B2 and B3 is because of disabling of frequency band at the gNB. However, the techniques B2 and B3 deals with the procedure to minimize the impact of disabling of frequency band at the gNB on the UE. Both techniques can be advantageous depending on the scenario. For e.g., when the overlap between frequency band disabled at gNB and active BWP of UE is high, then technique B2 is advantageous, whereas B3 has upper hand when overlap between frequency band disabled at gNB and active BWP of UE is low. Thus, the techniques B2 and B3 can be incorporated together and can be applied depending on the scenario, where the exact details for specifying B2 & B3 can be discussed in WI phase. Based on the above, we suggest to update the conclusion as follows:Based on the study, from time and frequency domain, * at least technique A-4 of adaptation of UE DTX/DRX towards Cell DT/DRX is beneficial for network energy savings, and can be recommended,

at least techniques A-1-1, A-1-2, A-1-3, A-1-4 (for paging enhancement), A-1-6, A-3, A-5-1/B-1-1, A-5-2 and techniques B-2 and B-3 together have the potential to provide large gain for network energy savings particularly at empty or low load, and could be potentially combined with each other based on some sources’ results, although it is understood that the gain is not linearly accumulated from each individual technique, e.g.,* + gNB may target network energy savings by A-5-1/B-1-1 without SSB/SIB1, or by A-1-1 with simplified SSB, or by A-1-3 with longer SSB periodicity,
* technique A-3 of UE WUS can be enabled for demanding SSB/SIB1 as in techniques A-5-2, when needed, as a trigger on a gNB targeting energy saving,
* to support techniques A-1-1, A-1-3, A-3, A-5-1/B-1-1 and/or A-5-2, potential feasibility/requirement confirmation from RAN4 is expected for proper synchronization/mobility/SCell (de-)activation,
* whether/which technique(s) to recommend is to be discussed in RAN plenary.

Also, the examples in above part of the conclusion are not clear to us, such as whether the first sub bullet of the example “gNB may target network energy savings by A-5-1/B-1-1 without SSB/SIB1, or by A-1-1 with simplified SSB, or by A-1-3 with longer SSB periodicity,” is representing the use of multiple techniques in combination or it is just saying that energy saving can be achieved by using either one of the mentioned techniques. If it means that the energy saving can be achieved by using techniques individually or in combination then we like to update the first sub bullet in the examples as follows:* + gNB may target network energy savings by A-5-1/B-1-1 without SSB/SIB1, or by A-1-1 with simplified SSB, or by A-1-2 with skipping of SSB/SIB1 transmission occasion, or by A-1-3 with longer SSB periodicity, or by A-1-6 with scheduling of SIB1 without PDCCH.

Also, kindly update the reference of CEWiT’s inputs in the Table 6.1.1.2-1 as [24] [27]  |
| vivo | Please find below our suggested changes in conclusion part of the TR in revision mark:Network energy savings for NR have been studied for both FDD and TDD, both FR1 and FR2. Power model comprised of different BS power states/modes for BS power consumption is generated in section 5 by using relative power, which accommodates DL transmission and UL reception, and two types of BS categories. A scaling approach considering BS power split by a static part of power and a dynamic part of power is established for evaluation purpose, reflecting the relationship of BS power consumption with respect to transmission resources/configurations in time, frequency, spatial and power domain.The potential techniques for enabling/improving network energy savings from various domains are evaluated and analysed, as documented in section 6.1- 6.4. Techniques description, performed evaluations and performance impact on selected KPIs including UPT, access delay, latency, UE power consumption, or on averaged energy efficiency etc., as well as legacy UE impact and specification impact are summarized therein. The relevant higher layer procedures and analysis for some techniques are also included in section 6.1. Other common aspects from higher layer are studied and the outcome is documented in section 6.5.The study of time domain techniques can be summarized as follows.Depending on factors such as selected baselines, BS categories, SLS configurations (including reference configurations, traffic models, number/periodicity of reference signals), scaling parameters, and UE profiles (including UE RRC\_IDLE/INACTIVE/CONNECTED mode, DRX configurations), as well as conditions (such as gNB detection, gNB coordination, UE ability of synchronization) etc. and at zero/low load that is targeting NES scenario for time domain techniques, * 3 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% [30] and 7.41% in average,
* 2 sources show technique A-1-2 of skipping one or more of SSB/SIB1 transmission could achieve BS energy savings by 0.3%~25.4% and 8.05% in average,
* 9 sources show technique A-1-3 of adapting the periodicity of SSB longer than 20ms up to 1280ms could achieve BS energy savings by 0.9%~84.8% and 30.9% in average,
* 2 sources show technique A-1-4 of adapting Paging (by 1 source) or SSB transmission patterns (by 1 source), could achieve BS energy savings by 0.2%~42.3% and 15% in average for Paging enhancement or 10.3% for SSB enhancement,
* 1 source shows technique A-1-5 of adapting RACH periodicity/occasions could achieve BS energy savings by 14.4%~24.9% and 20.6% in average,
* 1 source shows technique A-1-6 of scheduling SIB1 by SSB could achieve BS energy savings by 4.8%~14.8% and 10.3% in average,
* 5 sources show technique A-3-1 of UE WUS triggering gNB for SSB/SIB/RACH could achieve BS energy savings by 6.2%~80.7% and 35.57% in average while 1 source show technique A-3-2 of UE WUS triggering gNB for UL reception could achieve BS energy savings by 25.7%~93% and 67.86% in average,
* 6 sources show technique A-4 of UE C-DRX alignment could achieve BS energy savings by 0.2%~71.4% and 27.7% in average,
* 3 sources show technique A-5-2 of on-demand SSB/SIB1 could achieve BS energy savings by 2.6%~43.4% and 20.35% in average,
* Except for technique A-3-2 of UE WUS triggering gNB for UL reception, the evaluation of other techniques is based on the baseline BS power model in Section 5,
* Evaluation scheme of technique A-1-6 of scheduling SIB1 by SSB and technique A-3 of UE WUS matches the proposed technique while evaluation scheme of other techniques is not matching the proposed technique for all or part of sources,
* Technique A-1-1 of simplified SSB, A-1-2 of skipping one or more of SSB/SIB1 transmission, A-1-6 of scheduling SIB1 by SSB, technique A-3-1 of UE WUS triggering gNB for SSB/SIB/RACH and technique A-5-2 of on-demand SSB/SIB1 can’t be supported in current spec/implementation while the result from other techniques may be achieved by legacy mechanism supported by current spec or implementation.
* Technique A-1-4 of adapting Paging and technique A-1-5 of adapting RACH periodicity/occasions may be used in a cell where legacy UE can still use legacy Paging/RACH resources, while other techniques may be enabled for a carrier only when legacy UEs are not using the carrier,
* Technique A-4 of adaptation of UE DTX/DRX towards Cell DTX/DRX is also studied in higher layer. From RAN2 perspective, technique A-4 is considered feasible and beneficial to align UE DRX with Cell DTX and DRX alignment among multiple UEs.
* Technique A-3 of UE WUS is also discussed in higher layer and from RAN2 perspective, it is feasible if RAN1 agrees to support WUS, and details can be discussed in normative phase.

For techniques in frequency domain, the study can be summarized as follows.Under various conditions,* 8 sources show technique A-5-1/B-1-1 of SSB- and/or SIB1-less operation could achieve BS energy savings by 0.3%~98.4% and 29.19% in average on the energy saving cell/carrier with 5.5%~18.9% BS energy increase on the associated cell/carrier,
* 1 source shows technique B-1-2 of UE-group PCell switching could achieve BS energy savings by 37.5%,
* 1 source shows technique B-2 of BWP adaptation of multiple UEs within a carrier could achieve BS energy savings by 17.4%~52.2% and 28.5% in average,
* 3 source show technique B-3 of BW adaptation of multiple UEs within a BWP could achieve BS energy savings by up to 1.75%,
* Evaluation of all techniques is based on the baseline BS power model in Section 5,
* Evaluation scheme of technique A-5-1/B-1-1 of SSB- and/or SIB1-less operation and technique B-3 of BW adaptation of multiple UEs within a BWP matches the proposed technique while evaluation scheme of other techniques is not matching the proposed technique for all or part of sources,
* Technique A-5-1/B-1-1 of SSB- and/or SIB1-less operation could achieve expected gain particularly at empty or low/light load, with no or minor UPT gain, while cannot be operated as PCell/PSCell for legacy UEs; technique B-1-2 and B-2 could provide expected gain at the expense of small to medium UPT loss,
* Technique A-5-1/B-1-1 of SSB- and/or SIB1-less operation and technique B-3 of BW adaptation of multiple UEs within a BWP can’t be supported in current spec/implementation while the result from other techniques may be achieved by legacy mechanism supported by current spec or implementation.
* From RAN2 perspective, technique A-5-1/B-1-1 of SCell without SSB in inter-band CA and NES cell without SSB/SIB may need more detailed study in normative phase with feasibility up to RAN1. From RAN2 perspective, techniques B-2 is not considered.

Based on the study and the above observations, from time and frequency domain, * at least technique A-3-1 of UE WUS triggering gNB for SSB/SIB/RACH and A-4 of UE C-DRX alignment is beneficial for network energy savings, and can be recommended,
* at least techniques, A-1-3, A-5-1/B-1-1, A-5-2 and have the potential to provide large gain for network energy savings particularly at empty or low load, and could be potentially combined with each other based on some sources’ results, although it is understood that the gain is not linearly accumulated from each individual technique, e.g.,
* gNB may target network energy savings by A-5-1/B-1-1 without SSB/SIB1, or by A-1-3 with longer SSB periodicity with potential combination of A-3-1 of UE WUS triggering gNB
* whether/which technique(s) to recommend is to be discussed in RAN plenary.

For techniques in spatial domain, over baseline of 32/64 TxRU for a gNB/TRP, the study can be summarized as follows,* 12 sources show technique C-1 of adaptation of spatial elements could achieve BS energy savings by 0~48.2% and 19.02% in average with legacy UE co-existence, at the expense of small to medium negative impact on UPT/latency depending on further enhancement. 4 sources provide evaluation results for dynamic adaptation that matches the proposed technique while 9 sources provide evaluation result for static adaptation.
* 3 sources show technique C-2 of TRP muting in multi-TRP operation could achieve BS energy savings by 19.7%~41.6% and 33.79% in average, at the expense of small to medium negative impact on UPT/latency etc. 1 source provide evaluation results for dynamic adaptation that matches the proposed technique while 2 sources provide evaluation result for static adaptation.
* The result from both techniques may be achieved by legacy mechanism supported by current spec or implementation.

For techniques in power domain, the study can be summarized as follows, * 10 source show technique D-1 of transmission power adaptation could achieve BS energy savings by 2.3%~51.5% with legacy UE co-existence, with small UPT loss/negative impact on latency/UE power consumption. 2 sources provide evaluation results for dynamic adaptation that matches the proposed technique while 8 sources provide evaluation result for static adaptation.
* 1 source shows technique D-2 of over the air digital pre-distortion, technique D-3 of channel aware tone reservation, and technique D-5 of UE post-distortion, could achieve BS energy savings by 8.9%, by 2.1%~9.5%, and by 16.1% respectively, with no/negligible negative impact on UPT/UE power consumption.
* The result from all techniques may be achieved by legacy mechanism supported by current spec or implementation.

Based on the study and the above observations, from spatial and power domain,* at least a technique based on C-1 is beneficial for network energy savings, and can be recommended. Technique C-2 has the potential to provide large network energy saving gain and could be potentially combined with technique C-1.

For other higher layer aspects for network energy savings, from their perspective, the study can be summarized as follows.* It is feasible to handle legacy UEs and NES-capable UEs via cell (re-)selection techniques. It is also feasible and possible to enhance the CHO framework to handover UEs faster.
* Group HO is not considered.
* Inter-node beam activation and paging enhancement need more study in normative phase.

Based on the study, a means that can prevent legacy UEs from camping on NES cells (of which definition can be left to WI phase) by configurations, and/or allow NES-capable UEs to (down-)prioritize specific NES cell(s) on specific frequency, is needed. CHO enhancement for faster handover can be considered in WI phase.The main updates are in the following aspects:1. For time-domain techniques, energy saving gain is updated to zero or empty load since this is really targeting scenario for time-domain techniques;
2. Average energy saving gain is added for all evaluated technique or sub-techniques;
3. Adding observation on evaluation feasibility, whether the evaluation scheme and proposed technique matches, whether to have possible support by legacy mechanisms and etc.
4. Update the recommended technique based on the following rules:
* Number of sources providing evaluation is larger than 2
* Average ES gain is larger than 15%
* Evaluation is based on baseline power model in Section 5
* Evaluation scheme and proposed technique matches for at least more than 2 sources

Besides, the recommended technique is better not to be supported by legacy mechanism and the feasibility is estimated by RAN2 if involved.Based on the above guideline, technique A-3-1 of UE triggering SSB/SIB/RACH, technique A-4 of UE C-DRX alignment and technique C-1 of dynamic port selection are recommended.Note the above updates are based on the following technique summary table:

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Technique | No. Sources | ES gain (%) | EvaluationFeasibility | Evaluation scheme matching | UE impact | Possible support by legacy mechanism | RAN2 feasibility |
| min | max | avg |
| A-1-1 | 3 | 0.7 | 30.49 | 7.41 | Yes | Yes for 2 sources and No for 1 sourceProposed scheme is simplified version of SSB. However,1 source reporting combined large gain from both only PSS and SSS transmitted from SSB, and half-reduced SIB1 transmission. | No evaluation | No | - |
| A-1-2 | 2 | 0.3 | 25.4 | 8.05 | Yes | No for all sourcesProposed scheme is dynamic adaptation of SSB occasion. However, performance of dynamic adaptation of SSB numbers is not provided | No evaluation | No | - |
| A-1-3 | 9 | 0.9 | 84.8 | 30.9 | Yes | No for all sourcesProposed scheme is dynamic adaptation of SSB/SIB1 period. However,performance of dynamic SSB/SIB1 periodicity adaptation is not provided. | No evaluation | YesThe period of SSB/SIB1 can be adapted by SIB1 in current spec. | - |
| A-1-4 | 2 | 0.5 | 42.3 | 14.48 | Yes | Unclear whether the proposed scheme is dynamic adaptation of paging resourceIf so, the performance of dynamically adapting paging configurations is not provided. | No evaluation | YesProper configuration may achieve to concentrate paging resource in one PF. | - |
| A-1-5 | 1 | 14.4 | 24.9 | 20.6 | Yes | No for all sourcesPerformance of dynamic RACH configuration is not provided. | On UPT/access delay/latency, this scheme increases access delay/latency from 10ms to 70ms | YesThe period of RACH can be adapted by SIB1 in current spec. | - |
| A-1-6 | 1 | 4.8 | 14.8 | 10.3 | Yes | Yes | No evaluation | No | - |
| A-2 | 0 |  |  |  |  |  |  |  |  |
| A-3-1WUS trigger SSB/SIB1/RACH | 5 | 6.2 | 80.7 | 35.57 | Yes | Yes | When WUS period is 20ms, marginal UPT loss, access delay/latency increment and UE power consumption increment are observed.  | No | Yes |
| A-3-2WUS trigger UL reception | 1 | 25.7 | 93 | 67.86 | NogNB is assumed to be in a state such that the main UL receiver is still in deep sleep when detecting wake-up signal and gNB is able to wake up **from deep sleep to active in one slot** after WUS detection.No RAN1 agreement of feasible power model for low power WUS detection | Yes | There is latency reduction observed | YesSR may be used as a kind of WUS with low power detection | Yes |
| A-4 | 6 | 0.2 | 71.4 | 27.7 | Yes | Yes for UE C-DRX alignment schemeNo evaluation results for informing cell DTX/DRX to UE | one result shows there is marginal negative impact while one result shows it can be up to 15.5% | YesProper RRC configuration/ reconfiguration can achieve cell DTX/DRX | Yes |
| A-5-2On-demand SSB/SIB1 | 3 | 2.6 | 43.4 | 20.35 | Yes | No for 2 sourcesProposed scheme is on demand SSB/SIB1. However, 2 sources evaluate zero load without any triggering of SIB1 transmission | Performance impact of on demand SSB/SIB was not provided. | No | - |
| A-5-1/B-1-1SSB- and/or SIB1-less operation | 8 | 0.3 | 98.4 | 29.19 | Yes | Yes | In most results for SSB and/or SIB saved from one carrier of two carriers, the UPT is not negatively impacted while one result shows slightly increased UPT. | No | RAN2 discussed but conclude that the feasibility isleft to RAN1 |
| B-1-2Dynamic Pcell switching | 1 | 37.5 | 37.5 | 37.5 | Yes | NoBaseline: Keep 2 CCs activatedEnhancement: deactivate 1 CC and keep 1CC activated | UPT degrades by 14% if one Scell goes to dormant state. | YesHandover command can be used for Pcell switching in current spec | - |
| B-2 | 1 | 17.4 | 52.2 | 28.5 | Yes | NoBWP switching delay is not modelled. | UPT loss by 28.4%~14.47%, and packet latency increases by 6.44%~39.4% | YesBWP switching can be done by DCI in current spec | - |
| B-3 | 3 | -75.4 | 1.75 | -26.71 | Yes | Yes | significantly reduced UPT, and additionally reduced average EE | YesBWP bandwidth can be changed by RRC reconfiguration or BWP switching | - |
| C-1 | 12 | 0.00 | 48.2 | 19.02 | Yes | Yes for 4 sources with dynamic adaptationNo for 8 sources with static adaptation only | UPT loss of 0.3%~18.5% observed | YesWith CSI reports respect to different number of spatial elements available, gNB is able to dynamically adjust the number of spatial elements for PDSCH transmission in current specification. | - |
| C-2 | 3 | 19.7 | 39 | 33.79 | Yes | Yes for 1 source with dynamic adaptationNo for 2 sources with static adaptation | UPT loss of 7.27%~28.7% | YesRRC reconfiguration can enable or disable one or more TRPs. | - |
| D-1 | 10 | 2.3 | 40.5 | 16.08 | Yes | Yes for 2 sourcesNo for 8 sourcesProposed scheme is dynamic adaption of PDSCH power. However, 8 sources reports semi-static power adaptation only. | UPT loss is observed from 2.03%~19.49% | YesDynamic PDSCH power adaptation can be achieved in the following two legacy way:1. UE reports CSI based on one PDSCH power offset and gNB implementation to estimate CSI for other PDSCH power;2. gNB configures multiple CSI-RS with different power offset | - |
| D-2 | 1 | 8.9 | 8.9 | 8.9 | NoNote PA scaling values used for this NW ES scheme are not covered by RAN1 power consumption scaling model. | NoModeling of OTA information is not provided | On UPT/latency, no negative impact is observed. | YesgNB can implement DPD without OTA informaiton | - |
| D-3 | 1 | 2.1 | 9.5 | 4.53 | NoNote PA scaling values used for this NW ES scheme are not covered by RAN1 power consumption scaling model. | NoModeling of tone reservation is not modeled | On UPT/latency, no negative impact is observed. | YesCurrent legacy rate matching pattern may be used for tone reservation | - |
| D-4 | 0 |  |  |  |  |  |  |  |  |
| D-5 | 1 | 16.1 | 16.1 | 16.1 | NoNote PA scaling values used for this NW ES scheme are not covered by RAN1 power consumption scaling model. | NoModeling of UE complexity is not provided | On UPT or latency, there is no negative impact observed. | YesgNB can implement DPD without UE involvement to achieve PAPR reduction | - |

 |
| NOKIA/NSB | Regarding Chapter 7: Conclusion, we have the following revision proposal.Network energy savings for NR have been studied for both FDD and TDD, both FR1 and FR2. Power model comprised of different BS power states/modes for BS power consumption is **~~generated~~ defined** in section 5 **for evaluation purposes** by using relative power, which **~~accommodates~~ includes different sleep and active states (including** DL transmission and UL reception**)**, and two types of BS categories. A scaling approach considering BS power split by a static part of power and a dynamic part of power is established for evaluation purpose, reflecting the relationship of BS power consumption with respect to transmission resources/configurations in time, frequency, spatial and power domain.The potential techniques for enabling/improving network energy savings **~~from~~ in** various domains are evaluated and analysed, as documented in section 6.1- 6.4. Techniques description, performed evaluations and performance impact on selected KPIs including UPT, access delay, latency, UE power consumption, or on averaged energy efficiency etc., as well as legacy UE impact and specification impact are summarized therein. The relevant higher layer procedures and analysis for some techniques are also included in section 6.1. Other common aspects from higher layer are studied and the outcome is documented in section 6.5.The study of time domain techniques can be summarized as follows**. [NOKIA:] The lists below cover only the ES gains of all investigated techniques, the UPT impact should be added for each technique to show a full picture.** Depending on factors such as selected baselines, BS categories, SLS configurations (including reference configurations, traffic models, number/periodicity of reference signals), scaling parameters, and UE profiles (including UE RRC\_IDLE/INACTIVE/CONNECTED mode, DRX configurations), as well as conditions (such as gNB detection, gNB coordination, UE ability of synchronization) etc., * 3 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% [30],
* 2 sources show technique A-1-2 of skipping one or more of SSB/SIB1 transmission could achieve BS energy savings by 0.3%~25.4%,
* 2 sources out of 9 sources show technique A-1-3 of adapting the periodicity of SSB longer than 160ms up to 1280ms could achieve BS energy savings by 3.4%~83.6%,
* 2 sources show technique A-1-4 of adapting Paging (by 1 source) or SSB transmission patterns (by 1 source), could achieve BS energy savings by 0.2%~42.3% for Paging enhancement or 10.3% for SSB enhancement,
* 1 source shows technique A-1-5 of adapting RACH periodicity/occasions could achieve BS energy savings by 14.4%~24.9%,
* 1 source shows technique A-1-6 of scheduling SIB1 by SSB could achieve BS energy savings by 4.8%~14.8%,
* 6 sources show technique A-3 of UE **sending uplink wake-up signal (**WUS) **to request a transmission / reception of a channel/signal from the ~~triggering~~** gNB could achieve BS energy savings by -2.4%~93%, **where using legacy signals/channel could already provide large part of the ES gain.**
* 6 sources show technique A-4 of adaptation of UE DTX/DRX towards Cell DT/DRX could achieve BS energy savings by 0.2%~71.4%,
* 3 sources show technique A-5-2 of on-demand SSB/SIB1 could achieve BS energy savings by 2.6%~43.4%,
* Except for technique A-4 of adaptation of UE DTX/DRX, the gains from the above techniques are expected at the expense of increased negative impact on UPT/latency (including for legacy UEs), from small to relatively large as traffic increases, unless at empty load,
* Technique A-1-4 of adapting Paging and technique A-1-5 of adapting RACH periodicity/occasions may be used in a cell where legacy UE can still use legacy Paging/RACH resources, while other techniques may be enabled for a carrier only when legacy UEs are not using the carrier,
* Technique A-4 of adaptation of UE DTX/DRX towards Cell DT/DRX is also studied in higher layer. From RAN2 perspective, technique A-4 is considered feasible and beneficial to align UE DRX with Cell DTX and DRX alignment among multiple UEs.

For techniques in frequency domain, the study can be summarized as follows.Under various conditions,* 8 sources show technique A-5-1/B-1-1 of SSB- and/or SIB1-less operation could achieve BS energy savings by 0.3%~98.4% on the energy saving cell/carrier with 5.5%~18.9% BS energy increase on the associated cell/carrier,
* 1 source shows technique B-1-2 of UE-group PCell switching could achieve BS energy savings by 5.8%~37.5%,
* 1 source shows technique B-2 of BWP adaptation of multiple UEs within a carrier could achieve BS energy savings by 17.4%~52.2%,
* 3 source show technique B-3 of BW adaptation of multiple UEs within a BWP could achieve BS energy savings by up to 1.75%,
* Technique A-5-1/B-1-1 of SSB- and/or SIB1-less operation could achieve expected gain particularly at empty or low/light load, with no or minor UPT gain, while cannot be operated as PCell/PSCell for legacy UEs; technique B-1-2 and B-2 could provide expected gain at the expense of small to medium UPT loss,
* From RAN2 perspective, technique A-5-1/B-1-1 of SCell without SSB in inter-band CA and NES cell without SSB/SIB may need more detailed study in normative phase with feasibility up to RAN1. From RAN2 perspective, techniques B-2 is not considered.

Based on the study, from time and frequency domain, * at least technique A-4 of adaptation of UE DTX/DRX towards Cell DT/DRX is beneficial for network energy savings, and can be recommended,
* at least techniques A-1-1, A-1-3, A-1-4 (for paging enhancement), A-3, A-5-1/B-1-1, A-5-2 and technique B-2 have the potential to provide large gain for network energy savings particularly at empty or low load, and could be potentially combined with each other based on some sources’ results, although it is understood that the gain is not linearly accumulated from each individual technique, e.g.,
* **For gNB targeting energy saving, A-1-1 and A-5-2 may be combined with technique A-3 (UE WUS) for network synchronization and demanding SSB/SIB1 transmission**
* **gNB may target network energy savings by A-5-1/B-1-1 without SSB/SIB1~~, or by A-1-1 with simplified SSB, or~~**
* **gNB may alternatively target network energy saving by A-1-3 with longer SSB periodicity,**
* **~~technique A-3 of UE WUS can be enabled for demanding SSB/SIB1 as in techniques A-5-2, when needed, as a trigger on a gNB targeting energy saving,~~**
* to support techniques A-1-1, A-1-3, A-3, A-5-1/B-1-1 and/or A-5-2, potential feasibility/requirement confirmation from RAN4 is expected for proper synchronization/mobility/SCell (de-)activation,
* whether/which technique(s) to recommend is to be discussed in RAN plenary.

For techniques in spatial domain, over baseline of 32/64 TxRU for a gNB/TRP, the study can be summarized as follows,* 12 sources show technique C-1 of adaptation of spatial elements could achieve BS energy savings by 0~48.2% with legacy UE co-existence, at the expense of small to medium negative impact on UPT/latency depending on further enhancement.
* 3 sources show technique C-2 of TRP muting in multi-TRP operation could achieve BS energy savings by 19.7%~41.6%, at the expense of small to medium negative impact on UPT/latency etc.

Based on the study, at least a technique based on C-1 is beneficial for network energy savings, and can be recommended. Technique C-2 has the potential to provide large network energy saving gain and could be potentially combined with technique C-1.For techniques in power domain, the study can be summarized as follows, * **With transmission power reduction on PDSCH,** 10 source show technique D-1 of transmission power adaptation could achieve BS energy savings by 2.3%~51.5% with legacy UE co-existence, with small UPT loss/negative impact on latency/UE power consumption,
* 1 source shows technique D-2 of over the air digital pre-distortion, technique D-3 of channel aware tone reservation, and technique D-5 of UE post-distortion, could achieve BS energy savings by 8.9%, by 2.1%~9.5%, and by 16.1% respectively, with no/negligible negative impact on UPT/UE power consumption.

Based on the study, at least a technique based on D-1 is beneficial for network energy savings, and can be recommended.For other higher layer aspects for network energy savings, from their perspective, the study can be summarized as follows.* It is feasible to handle legacy UEs and NES-capable UEs via cell (re-)selection techniques. It is also feasible and possible to enhance the CHO framework to handover UEs faster.
* Group HO is not considered.
* Inter-node beam activation and paging enhancement need more study in normative phase.

Based on the study, a means that **one** can prevent legacy UEs from camping on NES cells (of which definition can be left to WI phase) **~~by configurations~~**, and/or allow NES-capable UEs to (down-)prioritize specific NES cell(s) on specific frequency, **is ~~are~~** needed **if any methods are specified that degrade legacy UE performance to operate in RRC\_IDLE/RRC\_INACTIVE states on corresponding cell**. CHO enhancement for faster handover can be considered in WI phase. |
|  |  |
|  |  |