**3GPP TSG-SA5 Meeting #146-bis-e *S5-231012rev1***

e-meeting, 16-19 January 2023

**Source: Huawei**

**Title: 3GPP Rel-18 work on EE**

**Document for: Endorsement**

**Agenda Item: 6.1**

# 1 References

[1] SP-211440: "New Study on new aspects of EE for 5G networks Phase 2"

[2] SP-211441: "New Rel-18 Work Item on 5G energy efficiency phase 2"

[3] TR 28.913: "Study on new aspects of EE for 5G networks phase 2"

[4] TS 28.310: "Management and orchestration; Energy efficiency of 5G"

[5] TS 28.554: "Management and orchestration; 5G end to end Key Performance Indicators (KPI)"

[6] SP-211621: "LS on Energy Efficiency as guiding principle for new solutions)"

[7] RP-223540: "New WID on Network energy savings for NR"

[8] RP-223002: "Status report for WI: Study on network energy savings for NR"

[9] TR 38.864: "Study on network energy savings for NR"

[10] SP-220446: "Study on Energy Efficiency as service criteria"

[11] TR 22.882: "Study on Energy Efficiency as service criteria"

[12] TS 28.552: "Management and orchestration; 5G performance measurements"

# 2 Rationale

This document aims at providing a comprehensive view of the ongoing work on Energy Efficiency (EE) in 3GPP.

The work can be viewed from 3 different perspectives:

1. Energy Efficiency (EE), which includes:
   1. Defining KPIs to measure the energy efficiency of 5G network entities such as e.g. 5G core network, 5G RAN, network slices, etc.
   2. Defining new, or using already defined, performance measurements / metrics to build the EE KPIs
   3. Specifying the measurement and collection method(s)
2. Energy Saving (ES), i.e. the optimization (by the network operator) of the energy efficiency of the 5G network entities, which includes:
   1. Describing use cases / scenarios in which energy savings may be achieved, and related requirements
   2. Specifying solutions to support these use cases / scenarios and achieve related energy savings
3. Digital Sobriety (DS), i.e. the definition and adoption of best practices (by service users) to help save energy in the 5G network, which includes:
   1. Describing use cases / scenarios in which service users may help save energy in the 5G network, e.g. by changing their behaviour
   2. By extension, it is proposed that digital sobriety also includes how 3GPP may help save energy in the 5G network, e.g. by designing sober, eco-friendly solutions. As an example, amongst various candidate solutions proposed in 3GPP WGs to support use cases / scenarios and requirements, some of them may be more digital sober than others by requiring less volume of data to be processed, stored, transported. This eco-friendly aspect should be considered when selecting the final solution.

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| **3GPP Release 18 work on EE** | | | |
|  | Energy Efficiency | Energy Saving | Digital Sobriety |
| TSG SA |  |  | * LS sent out to all 3GPP TSGs / WGs, in SP-211621 [6] – See quote in NOTE 1. |
| SA WG1 | * Rel-18 SID in SP-220446 [10]. Expected completion date: SA#99 (Mar 2023) – see objectives in NOTE 2. * TR 22.882 [11] – see list of use cases in NOTE 3. |  |  |
| SA WG2 |  |  |  |
| SA WG3 |  |  |  |
| SA WG4 |  |  |  |
| SA WG5 | * Rel-18 SID in SP-211440 [1]. Expected completion date: SA#100 (June 2023) – see objectives in NOTE 4. * TR 28.913 [3] – see key issues in NOTE 5. * Rel-18 WID in SP-211441 [2]. Expected completion date: SA#102 (Dec. 2023) – see objectives in NOTE 6. * TS 28.554 – see defined EE KPIs in NOTE 7. * TS 28.552 [12] – see defined PEE (Power, Energy and Environment) measurements in NOTE 8. | * TS 28.310 [4] – see ES use cases in NOTE 9. | * TR 28.913 [3] - New key issue introduced – see NOTE 10. |
| SA WG6 |  |  |  |
| TSG RAN |  |  |  |
| RAN WG1 |  | * Rel-18 SID in RP-221443 [8]. Expected completion date: RAN#98 (Dec. 2022). Completed. See objectives in NOTE 11. * TR 38.864 [9]. See evaluated techniques for energy saving in NOTE 12. * Rel-18 WID in RP-223540 [7]. Expected completion date: RAN#104 (June 2024). Se objectives in NOTE 13. |  |
| RAN WG2 |  |  |  |
| RAN WG3 |  |  |  |
| RAN WG4 |  |  |  |
| RAN WG5 |  |  |  |
| TSG CT |  |  |  |
| CT WG1 |  |  |  |
| CT WG3 |  |  |  |
| CT WG4 |  |  |  |
| CT WG6 |  |  |  |

**NOTE 1**: Quote from SP-211621: “

The EE-specific efforts so far undertaken e.g., in SA5 have aimed mostly at improving the energy efficiency by impacting the operations of the system. As we now are starting to specify the 5G-Advanced features, TSG SA kindly requests the recipient WGs and TSGs to consider EE even more as a guiding principle when developing new solutions and evolving the 3GPP systems specification, in addition to the other established principles of 3GPP system design.

TSG SA clarifies that in addition to EE, other system level criteria shall continue to be met (i.e. the energy efficiency aspects of a solution defined in 3GPP is not to be interpreted to take priority or to be alternative to security, privacy, complexity etc. and to meeting the requirements and performance targets of the specific feature(s) the solution addresses).

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**NOTE 2**: Quote from SP-220446: “

The objectives include:

• Define and support energy efficiency criteria as part of communication service to user and application services.

• Support information exposure on systematic energy consumption or level of energy efficiency to vertical customers.

• Gap analysis between the identified potential requirements and existing 5GS requirements or functionalities.

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**NOTE 3**: Use cases from TR 22.282 0.2.0: “

* Energy Utilization as a Performance Criteria for Best Effort Communication
* Use case on supporting different energy efficiency modes in industrial campus
* Energy usage exposure considering possible deployment scenarios
* Energy usage information exposure under NPN RAN sharing
* Use Case on Service Energy Monitoring by an Application Server

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**NOTE 4**: Quote from SP-211440: “

• On the energy consumption of Network Functions:

* Study whether additional virtual resource metrics provided by NFV MANO other than virtual CPU usage, such as e.g. virtual memory usage, virtual disk usage, etc., could participate to define VNF energy consumption,
* Study how the existing virtual CPU usage metric provided by NFV MANO could give more accurate measurements,
* Study a method to estimate the energy consumption of Containerized Network Functions (CNF) and elaborate corresponding energy consumption KPI(s) definition;

• On the energy efficiency KPIs:

o Investigate on the definition of new EE KPIs which consider aspects such as e.g. coverage area, user experience, reliability of URLLC network slice,

o Investigate how to define the energy efficiency KPI for V2X type of network slice,

o Investigate further on definition of the Resource Efficiency KPI, in particular on the Useful Output of 5GC network functions,

o Investigate further for solutions to any outstanding issue from Rel-17;

• On energy saving:

o Study new use cases, requirements and solutions for energy saving, applying to NG-RAN and/or 5GC and/or network slicing, including AI/ML assisted energy saving. This study will focus on end-to-end energy saving use case(s) description and potential solution(s) leveraging the Rel-18 study on AI/ML management,

o Study OA&M support to other 3GPP WGs energy saving use cases and solutions, if any;

• On digital sobriety:

o Study which forms digital sobriety could take in SA5, e.g. minimize the volume of OA&M data (number of operation parameters in MnS APIs, input data to MDAF, etc.) to be transported and/or stored,

o Study if any metrics can be defined to compare different alternative solutions with regards to digital sobriety.

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**NOTE 5**: Key issues from TR 28.913 0.4.0:

* Key Issue #1: Considering additional virtual resources usage to estimate VNF energy consumption
* Key Issue #2: Energy Consumption of containerized VNF/VNFCs
* Key Issue #3: Energy Consumption of RAN nodes
* Key Issue #4: EE KPI for V2X network slice
* Key Issue #5: Customer accepts QoS degradation to save energy
* Key Issue #6: Energy Efficiency KPI of URLLC Network Slice based on its Reliability
* Issue #7: Roles involved in EE KPI building
* Key Issue #8: Energy Saving compensation procedure
* Key Issue #9: RAN energy saving when using backup batteries
* Key Issue #10: Digital sobriety

**NOTE 6**: Quote from SP-211441: “

The objective is to:

• address the cross-WGs/SDOs issues related to energy efficiency / energy saving, for the purpose of coordination;

• address any remaining solutions from pending Rel-17 items;

• consider conclusions from the companion Rel-18 Study on new aspects of EE for 5G networks Phase 2 mentioned in clause 2.3;

• define new KPIs, including for Energy Consumption (EC) and Energy Efficiency (EE), and means to calculate them:

o EE KPI(s) for new types of network slice such as e.g. V2X and new KPIs for any network slice types,

o VM-based NF EC KPI enhanced definition(s) based on:

 more accurate virtual CPU usage metrics if they can be provided by ETSI NFV MANO,

 more virtual resource usage metrics such as e.g. virtual disk usage, virtual link usage, also provided by ETSI NFV MANO,

o Containerized NF EC KPI definition(s) based on latest achievements from ETSI NFV,

o Resource Efficiency KPI of 5GC network functions;

• specify new use cases, requirements and solutions for energy saving, applying to NG-RAN and/or 5GC and/or network slicing, including AI/ML assisted energy saving. This work item will focus on end-to-end energy saving use case(s) description and potential solution(s),

• provide OA&M solutions, if needed, to energy saving use cases and requirements expressed by other 3GPP working groups.

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**NOTE 7**: EE KPIs defined in TS 28.554 17.8.0:”

* NG-RAN data Energy Efficiency (EE)
* 5GC Energy Efficiency (EE)
  + Generic 5GC Energy Efficiency (EE) KPI
  + Energy Efficiency of 5GC based on the useful output of 5GC user plane
* Network slice Energy Efficiency (EE)
  + Generic Network Slice Energy Efficiency (EE) KPI
  + Energy efficiency of eMBB network slice
  + Energy efficiency of eMBB network slice – RAN-based
  + Energy efficiency of URLLC network slice
    - Based on latency of the network slice
    - Based on both latency and Data Volume (DV) of the network slice
  + Energy efficiency of MIoT network slice
    - Based on the number of registered subscribers of the network slice
    - Based on the number of active UEs in the network slice
* 5G Energy Consumption (EC)
  + NF Energy Consumption (EC)
  + Estimated Virtualized Network Function (VNF) energy consumption
  + Estimated Virtualized Network Function Component (VNFC) energy consumption
  + Estimated virtual compute resource instance energy consumption based on mean vCPU usage
  + 5GC Energy Consumption (EC)
  + Network Slice Energy Consumption (EC)
  + NG-RAN Energy Consumption (EC)
    - NG-RAN EC
    - gNB EC

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**NOTE 8**: PEE measurements defined in TS 28.552 18.0.0:”

* PNF Power Consumption
  + Average Power
  + Minimum Power
  + Maximum Power
* PNF Energy consumption
* PNF Temperature
  + Average Temperature
  + Minimum Temperature
  + Maximum Temperature
* PNF Voltage
* PNF Current
* PNF Humidity

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**NOTE 9**: Use cases from TS 28.310 17.4.0:”

* Capacity booster cell partially overlaid by candidate cell(s)
  + Intra-RAT energy saving
  + Inter-RAT energy saving
* Capacity booster cell fully overlaid by candidate cell(s)
* Switch off edge UPFs during off-peak traffic hours

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**NOTE 10**: Quote from key issue description in TR 28.913 0.4.0: “

this key issue aims at studying how SA5 can consider digital sobriety when specifying OA&M concepts, architectures, interfaces, APIs, Network Resource Models (NRM), etc.

NOTE: this key issue and its potential solution(s) do not aim at deriving any potential requirements for the 3GPP management system. Instead, they aim at proposing recommendations to be considered by 3GPP SA5 when developing new, or evolving existing, specifications.

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**NOTE 11**: Quote from RP-221443: “

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.

2. 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.

3. 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.

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**NOTE 12**: Techniques evaluated for energy saving from TR 38.864: “

* Techniques in time domain
  + Technique A-1 Adapting transmission/reception of common channels/signals
  + Technique A-2 Adaptation of UE specific signals and channels
  + Technique A-3 UE wake up signal (WUS) for gNB
  + Technique A-4 Adaptation of DTX/DRX
  + Technique A-5 adaptation of SSB/SIB1 including on-demand SSB/SIB1
  + SCell without SSB in inter-band CA (RAN2)
  + NES Cell without SIB/SSB (RAN2)
* Techniques in frequency domain
  + Technique B-1 Multi-carrier energy savings enhancements
  + Technique B-2 Adaptation of bandwidth part of UE(s) within a carrier
  + Technique B-3 Adaptation of bandwidth of UE(s) within a BWP
* Techniques in spatial domain
  + Technique C-1 Adaptation of spatial elements
  + Technique C-2 Adaptation of TRPs in mTRP operation
* Techniques in power domain
  + Technique D-1 Adaptation of transmission power of signals and channels
  + Technique D-2 Over the air digital pre-distortion
  + Technique D-3 Tone reservation
  + Technique D-4 PA power bias adaptation
  + Technique D-5 UE post-distortion
* Higher layer aspects for network energy savings
  + Cell selection/reselection
  + Connected mode mobility
  + Inter-node Beam Activation
  + Paging Enhancements

”.

**NOTE 13**: Quote from RP-223540: “

4 Objective

4.1 Objective of SI or Core part WI or Testing part WI

The objectives of the work item are the following:

1. Specify SSB-less SCell operation for inter-band CA for FR1 and co-located cells, if found feasible by RAN4 study, where a UE measures SSB transmitted on PCell or another SCell for an SCell’s time/frequency synchronization (including downlink AGC), and L1/L3 measurements, including potential enhancement on SCell activation procedures if necessary [RAN4, RAN2]

2. Specify enhancement on cell DTX/DRX mechanism including the alignment of cell DTX/DRX and UE DRX in RRC\_CONNECTED mode, and inter-node information exchange on cell DTX/DRX [RAN2, RAN1, RAN3]

• Note: No change for SSB transmission due to cell DTX/DRX.

• Note: The impact to IDLE/INACTIVE UEs due to the above enhancement should be avoided.

3. Specify the following techniques in spatial and power domains

• Specify necessary enhancements on CSI and beam management related procedures including measurement and report, and signaling to enable efficient adaptation of spatial elements (e.g. antenna ports, active transceiver chains) [RAN1, RAN2]

• Specify necessary enhancements on CSI related procedures including measurement and report, and signaling to enable efficient adaptation of power offset values between PDSCH and CSI-RS [RAN1, RAN2]

• Note: Above objectives are only for UE specific channels/signals

• Note: Legacy UE CSI/CSI-RS capabilities applies when considering total number of CSI reports and requirements

4. Specify mechanism(s) to prevent legacy UEs camping on cells adopting the Rel-18 NES techniques, if necessary [RAN2]

5. Specify CHO procedure enhancement(s) in case source/target cell is in NES mode [RAN2]

6. Specify inter-node beam activation and enhancements on restricting paging in a limited area [RAN3].

7. Specify the corresponding RRM/RF core requirements, if necessary, for the above features [RAN4]

4.2 Objective of Performance part WI

NOTE: Leave empty if the WI proposal does not contain a RAN performance part.

1. Specify corresponding RRM performance requirements and test cases for the network energy saving techniques [RAN4].

2. Specify the necessary demodulation performance and CSI reporting requirements [RAN4].

3. Specify the BS conformance tests, if necessary [RAN4].

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# 4 Detailed proposal

Proposal No. 1: it is proposed to send a LS to all TSGs and WGs:

* containing the above text,
* asking them to complete the table if and where deemed appropriate,
* proposing them that SA5 maintains such information for the whole Rel-18 timeframe,
* asking them to keep SA5 informed in case of new Rel-18 SI/WI addressing energy efficiency and/or energy saving and/or digital sobriety.