3GPP TSG RAN#93e
Electronic Meeting, Sept. 13 - 17, 2021
Agenda: 9.0.2
RP-211958

NR network energy saving for Rel-18

China Telecom

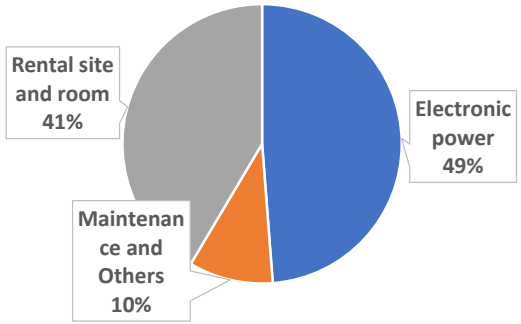
Motivation (1/2) -- A vital issue for operators

5G energy saving -- a vital issue for operators

- 5G network has more base stations compared with 4G, as well as power consumption of a NR base station is **3+ times** higher than LTE, due to higher band, wider bandwidth and more TRXs. The power consumption of 5G network has become a heavy burden to operators;
- The electricity cost of 5G network is **3.8 times** that of 4G;
- Power consumption account for **the largest part of network operating costs** (~49%).

	4G		5G	
Base Station	3RRU	1BBU	3AAU	1BBU
Peak Power (W)	840	170	3450	310
Total Power (W)	1010		3760	

Power consumption: LTE vs. NR



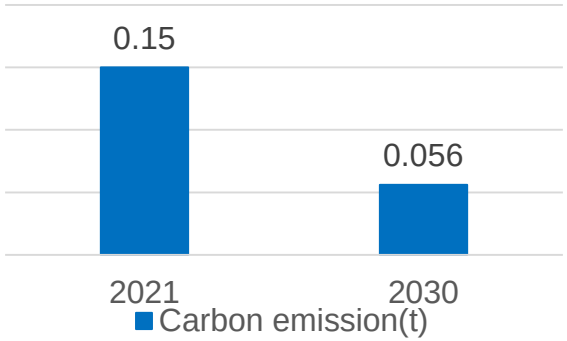
Operating Cost

Motivation (2/2)

Green communication -- a concerned issue for China Telecom

- Emission peak and carbon neutrality is a world-wide environment issue.
  - ✓ China Telecom has drawn up the ‘1236’ strategy for achieving the emission peak till 2030.
- Several tests have been conducted for network energy saving by China Telecom.
  - ✓ Evaluated the impact on performance (e.g. coverage, capacity) with network energy saving techniques in different domains.

Carbon emission plan of China Telecom (t/per 100k operating revenue)



Tests conducted by China Telecom

Summary of RAN Rel-18 Workshop

- More than 20 companies, including operators, network vendors, UE vendors and chip makers provided their views/interests on network energy saving via contributions/email discussion.
- Network energy saving is included in the set of topics for further discussion in the R18 workshop summary (RWS-210659).
- The following aspects were discussed for network energy saving during email discussions/papers during R18 workshop:
  - Evaluation methodology
    - ✓ The power consumption of network/system
    - ✓ The impact on network performance
  - Potential enhancements for network energy saving.
    - ✓ Dynamic and flexible network enhancement for energy saving
    - ✓ UE/intra network assistance information for network energy saving
    - ✓ Others, e.g., improving PA power efficiency

Unified evaluation methodology

- Network Energy Efficiency(EE) has been considered an important performance indicator for NR.
- Series of specifications on network energy efficiency definition and evaluation have been released by many standardization organizations.

3GPP

- **38.913** ✓ Define EE as a KPI ✓ Absolute metric: bits/Joule ✓ Traffic load related
- **38.840** ✓ The relative evaluation method for UE energy consumption **32.856** **39.910**
- **21.866** ✓ Study on Energy Efficiency Aspects of 3GPP Standards **……**

ITU

- **ITU-R M.2083** ✓ The EE is included in the framework and overall objectives for future network **ITU-T L.1330**
- **ITU-T L.1310** ✓ EE metrics and measurement methods for telecommunication equipment **ITU-T L.1320**
- **ITU-T L.1315** ✓ The general conception of EE/EER **ITU-T L.1350** ✓ EE measurement methodology **……**

ETSI

- **ES 303 472** **ES 303 475** **ES 203 228** ✓ EE measurement and metrics reference to ITU-T standards
- **ES 202 706-1** ✓ Measurement for EE – part I: power consumption- static measurement method **ES 203 554**
- **TS 202 706-2** ✓ Measurement for EE – part II: EE - dynamic measurement method **……**

ATIS

- **ATIS-0600015** ✓ The base standard for determining telecommunications EE **ATIS-0600015.01** **……**

Evaluation method: evaluation metrics

- **KPI: The Energy Efficiency (EE) metric**

$$EE_i = \frac{V_i}{E_i}$$

- V_i: indicator of the network performance associated with energy consumption in a period of time
  - ✓ Capacity: in bits/Joule [3GPP, ITU-T]
  - ✓ Coverage: in m^2/Joule[ITU-T]
  - ✓ Latency, ……
- E_i: the power consumption in a period of time

- **The evaluation metric**
  - The EE should be associated with the traffic load
  - The system level simulation (SLS) should be used for the evaluation
  - The relative metric (e.g. 3GPP TR38.840) can be used as a starting point
  - The known absolute metrics (e.g. 3GPP 39.913) can also be studied for improving the metric

Evaluation method: energy consumption metric

The energy consumption metric

- The known metric can be utilized

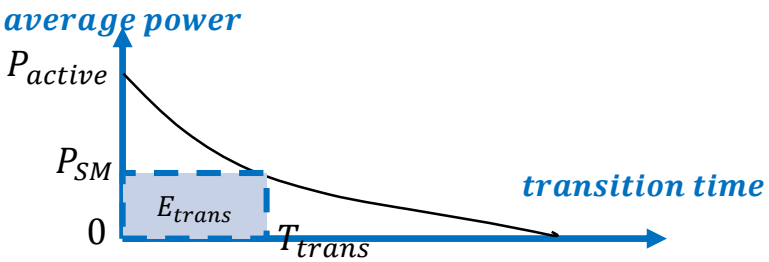
$$E = E_{sleep} + E_{transition} + E_{active}$$

- Sleep mode: the average power consumption of sleep mode.

$$E_{sleep} = P_{aver,sleep} \cdot T_{sleep}$$

- Transition energy: the lower power level of the sleep mode, the longer time for transition

$$E_{trans} = \int_0^{T_{trans}} P_{trans} dt$$



- Active state: the energy consumption with data transmission/reception

$$E_{active} = \int (P_{active,RF} + P_{active,circuit})\, dt$$

Static power consumption of BBU & RRU, corresponding to the circuit

The dynamic power consumption of RF, which is influenced by multiple factors.

$$P_{active,RF} = f(\beta_1, \beta_2, \beta_3, \beta_4) \cdot P_{RF,0}$$

- ✓ β_1:spatial domain factor, e.g. TRX/beam number
- ✓ β_2:frequency domain factor, e.g. CC number, BW
- ✓ β_3:power domain factor, e.g. PSD
- ✓ β_4:other factors, e.g. signal off

Potential scope 1: Study the Evaluation methodology

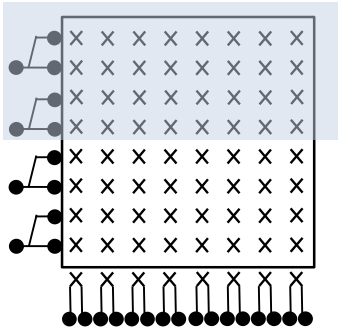
- **Study and develop the energy consumption model**
  - The **relative metric** can be used for energy consumption modeling
    - ✓ the **known** relative/absolute **model** should be utilized.
    - ✓ reflect the sleep states and the associated transition times, the factors impacting the energy consumption of active state.
    - ✓ Identify the **system model and reference configurations** for better reflecting the realistic network, e.g. the traffic/load model.
- **Study and Identify the evaluation metric**
  - **Energy Efficiency** can be a starting point for the **KPI**:
    - ✓ Reflect both energy consumption and network performance/UE experience.
  - Study and identify the **target scenarios**. E.g. FR1/FR2, downlink/uplink, urban/rural
  - Identify the detailed configurations used for **SLS** of the evaluation.

Energy saving techniques in spatial domain

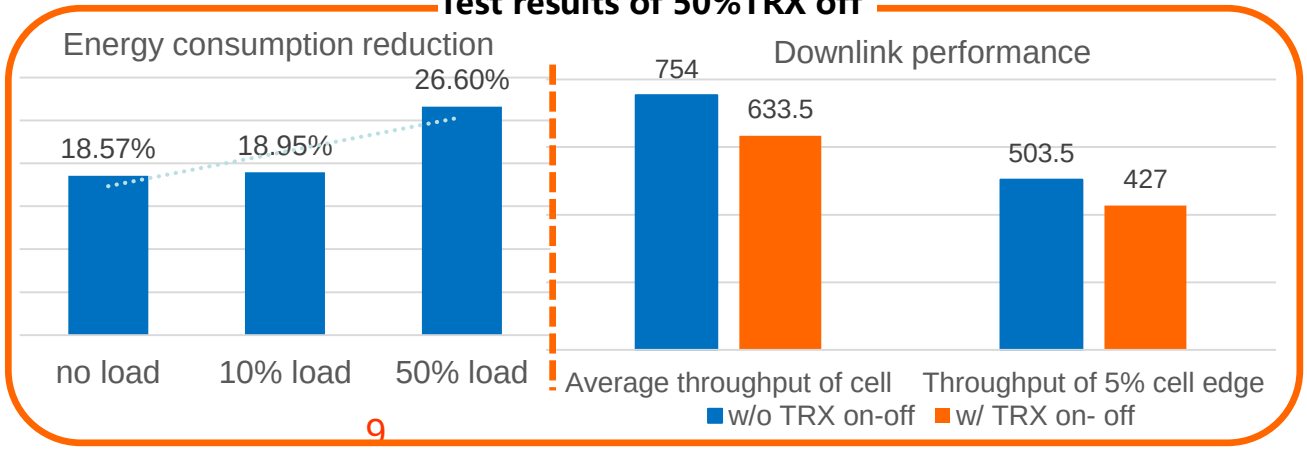
Efficient Dynamic TRX/beam on-off

- **motivation**
  - ✓ According to the test results, by switching off the TRX from 64T to 32T, the energy consumption can be reduced effectively, especially for medium load network.
  - ✓ The cell throughput descends about 15%-20%, which need to be further enhanced
- **Potential enhancement**
  - ✓ Enhance the CSI reporting for better deciding the TRX/panel/beam on-off
  - ✓ Enhance the DRS pattern for UE measurement on ports

illustration of 50% horizontal TRX-off



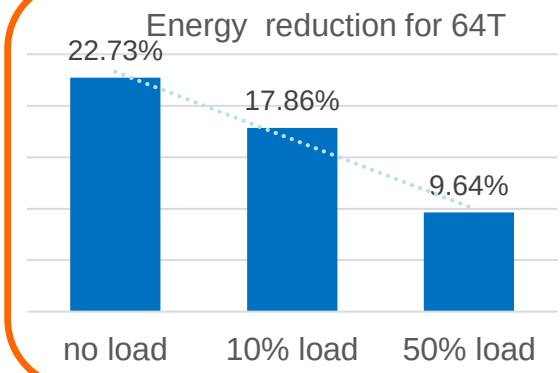
Test results of 50%TRX off

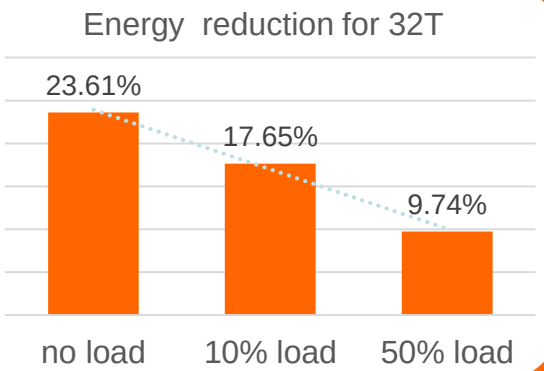


Energy saving techniques in time domain

- **Efficient Dynamic symbol on-off**
  - Motivation：according to the test results, by switching-off the symbols, the energy consumption can be reduced effectively for low load network with nearly no impact on performance.
  - Potential enhancement: The performance can be further compensated with the dynamic adjustment of PRB number.
- **Longer periodicity of common signals/channels**
  - Motivation: the symbol switch-off with less SSB beams and longer periodicity SSB can further reduce the energy consumption in the test

Test results of symbol-off



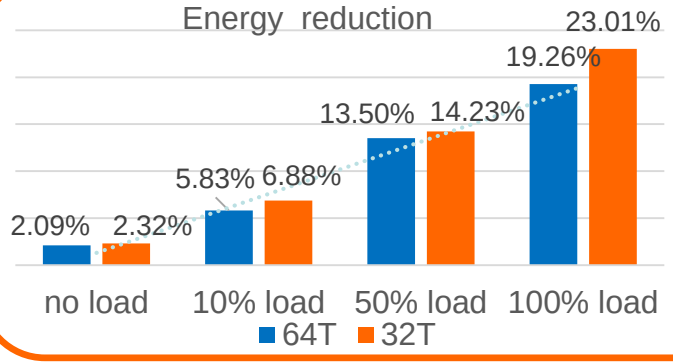


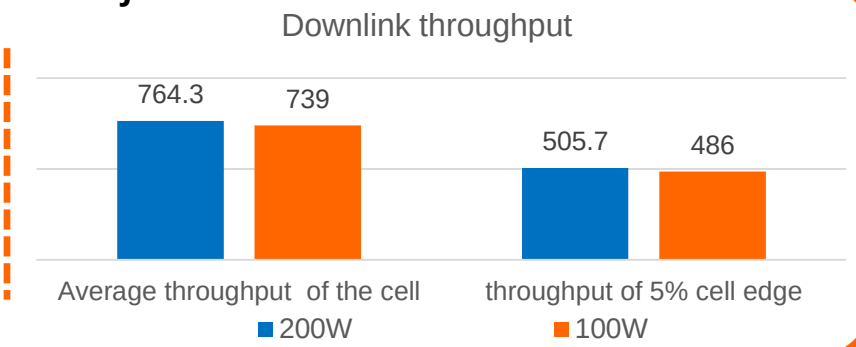
  - Potential enhancement: study the enhancements for reducing the impact on UE call drop rate.

Energy saving techniques in power domain

- **Efficient Dynamic power adjustment**
  - Motivation
    - ✓ Reducing the transmission power by half, the energy consumption can be saved according to our test results. The higher the load, the more energy reduced.
    - ✓ The strategy has nearly no impact on the coverage and throughput.
    - ✓ In the current realistic network, the power adjustment can only be achieve by reboot the network.
  - Potential enhancement:
    - ✓ Dynamic adjusting the PSD and bandwidth at the same time instead of the total power, which may bring the benefits on throughput without extra energy consumption.

Test results of power adjustment





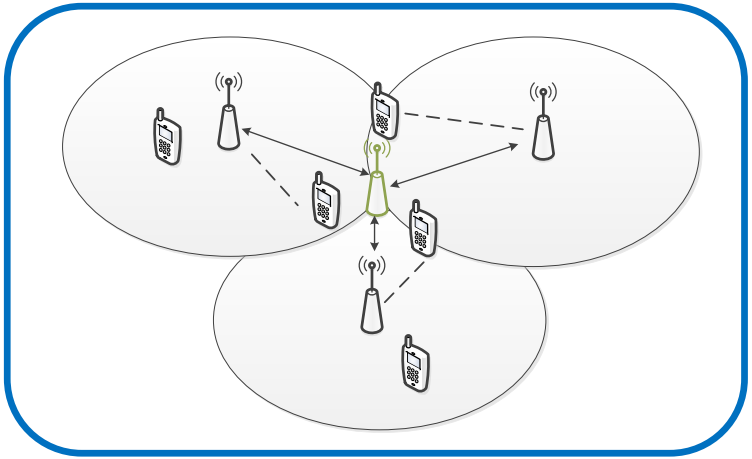
UE assistance information

Motivation

- UE assistance information report is a possible approach to accurate and flexible network energy saving management

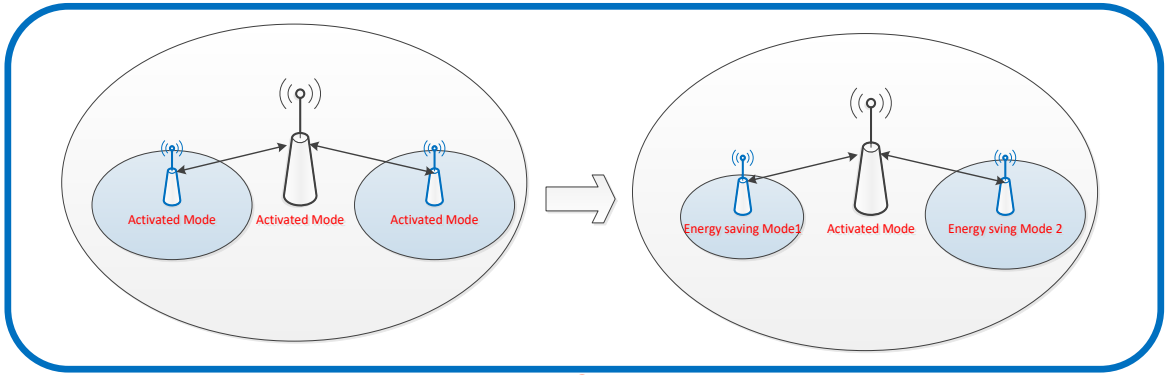
Potential enhancements

- Enable more accurate and flexible gNB/module level energy saving strategy decision, especially for non-tidal case and non-uniform traffic/UE distribution. For example:
  - ✓ UE traffic characteristic information which reflects UE traffic distribution/UE traffic volume change in the time domain/space domain
- Enable timely gNB activation/reactivation as response to the upcoming traffic, the upcoming connected UEs or the idle/inactive UEs of which the traffic is about to arrive. For example:
  - ✓ trigged by UE, e.g. uplink wake-up signal
  - ✓ trigged by the neighbor gNB based with UE's assistance



Intra-network information exchange

- **Motivation**
  - NR R15 specified the signaling of cell switch-off/re-activation via Xn/X2 interface for capacity booster cell scenario, similar to LTE.
  - Enhanced intra-network information exchange is a possible way to fine-grained energy saving operation coordination.
- **Potential enhancements**
  - Intra-network information exchange to support beam level operation coordination
  - Intra-network information exchange to support transmission power adjustment coordination
  - Intra-network information exchange to support energy saving mode extension



Potential scope 2: study the potential energy saving techniques

- **Study the potential network energy saving techniques from at least the following aspects:**
  - Network energy saving enhancement techniques in **spatial domain**
    - ✓ e.g. efficient dynamic TRX/panel/beam on-off
  - Network energy saving enhancement techniques in **time domain**
    - ✓ e.g. efficient dynamic symbol switch-off, longer periodicity of common signals/channels
  - Network energy saving enhancement techniques in **frequency domain**
    - ✓ e.g. efficient multi-carrier adaptation, efficient TX/RX bandwidth adjustment
  - Network energy saving enhancement techniques in **power domain**
    - ✓ e.g. improving PA power efficiency in gNB, dynamic PSD adjustment
  - **UE assistance information**
  - **intra-network information exchange**

Thanks!