Potential Energy Savings Features in O-RAN
By the Sustainability Focus Group (SUFG)

White Paper: Jan 2025

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Executive summary

This white paper explores advanced strategies to enhance energy efficiency in O-RAN based networks, building on existing techniques such as Cell and Carrier Shutdown and RF Channel Reconfiguration. It introduces innovative approaches for optimizing power consumption in key network elements, including Radio Units (O-RU) through dynamic voltage adaptation and renewable energy integration, and O-Cloud environments via intelligent workload management and energy-efficient Cloud Network Functions. Aligned with 3GPP Release-18 features like Discontinuous Transmission/Reception (DTX/DRX) and spatial power-saving methods, these strategies aim to substantially reduce energy consumption while maintaining high performance and service quality.

Central to these strategies are the intelligent capabilities of the O-RAN framework, particularly the Service Management and Orchestration (SMO), Non-Real-Time RAN Intelligent Controller (Non-RT RIC), and Near-Real-Time RAN Intelligent Controller (Near-RT RIC). Working in harmony, the SMO orchestrates resources across the network, the Non-RT RIC leverages rApps to develop AI/ML-driven long-term optimization policies, and the Near-RT RIC employs xApps to execute near real-time network adjustments. Together, these components provide a cohesive, intelligent framework that drives the dynamic and effective implementation of the energy-saving solutions detailed in this paper, positioning O-RAN as a leader in sustainable and efficient network operations.

Definition of terms, symbols and abbreviations

Terms

Near-RT RIC : Near-Real-Time RAN Intelligent Controller [O-RAN.WG1.OAD]

Non-RT RIC : Non-Real-Time RAN Intelligent Controller [O-RAN.WG1.OAD]

O-CU: O-RAN Central Unit [O-RAN.WG1.OAD]

O-DU: O-RAN Distributed Unit [O-RAN.WG1.OAD]

O-RU: O-RAN Radio Unit [O-RAN.WG1.OAD]

RAN: Radio Access Network. [O-RAN.WG1.OAD]

Abbreviations

For the purposes of the present document, the [following] abbreviations [given in i.1 and the following] apply:

CE	Circular Economy
CG	Configured Grant
CUS	Control User and Synchronization
DMRS	Demodulation Reference Signal
DTX	Discontinuous Transmission
DRX	Discontinuous Reception
FOCOM	Federated O-Cloud Orchestration and Management
ICT	Information and communication technology
MVP-C	Minimum Viable Plan Committee
NE	Network equipment
Near-RT RIC	Near-Real-Time RAN Intelligent Controller
NES	Network Energy Saving
NFO	Network Function Orchestrator

Non-RT RIC	Non-Real-Time RAN Intelligent Controller
O-Cloud	O-RAN Cloud
O-CU	O-RAN Central Unit
O-CU-CP	O-RAN Central Unit – Control Plane
O-CU-UP	O-RAN Central Unit – User Plane
O-DU	O-RAN Distributed Unit
O-RU	O-RAN Radio Unit
PA	Power Amplifier
RAN	Radio Access Network
RIC	RAN Intelligent Controller
SDK	Software Development Kit
SMO	Service Management and Orchestration
SR	Scheduling Request
SPS	Semi-Persistent Scheduling
SSB	Synchronization Signal Block
SO	Service Orchestrator
TR	Technical Report
UC	Use Case
UCTG	Use Case Task Group
UE	User Equipment
ULPI	Uplink Performance Improvement
WG	Working Group
PDCCH	Physical Downlink Control Channel
SPS	Semi-Persistent Scheduling

Acknowledgements

Special thanks must be given to the numerous people contributing to the White Paper, including:

Co-editor and Contributors: Awn Muhammad (Rakuten Mobile Inc) ; Dr Lingasamy V (Rakuten Mobile Inc)

Major reviewers: Kokila J (NEC) ,Vikas Dixit (Jio) , Sabine Demel (DT) , Ashfaq Shariq (ITS-NTIA) , Joselyn Mendes (TF)

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Introduction

This white paper delves into advanced strategies to enhance energy efficiency across O-RAN networks, building on existing techniques such as Cell and Carrier Shutdown and RF Channel Reconfiguration. It highlights innovative methods to reduce power consumption in Radio Units (O-RUs) through solutions like dynamic voltage adaptation and renewable energy integration, while also addressing energy optimization in O-Cloud environments via intelligent workload management and energy-efficient Cloud Network Functions. Aligned with 3GPP Release-18 features, including Discontinuous Transmission/Reception (DTX/DRX) and spatial power-saving mechanisms, these strategies aim to achieve substantial energy savings while maintaining exceptional network performance and service quality.

Crucially, the proposed strategies are powered by the intelligent capabilities of O-RAN's architectural pillars: the Service Management and Orchestration (SMO) platform, the Non-Real-Time RAN Intelligent Controller (Non-RT RIC), and the Near-Real-Time RAN Intelligent Controller (Near-RT RIC). The SMO enables seamless coordination of network resources, the Non-RT RIC leverages AI and machine learning through rApps to generate long-term optimization strategies, and the Near-RT RIC executes these strategies in real-time via intelligent xApps. Together, these components form a unified framework that dynamically adapts to changing network conditions, ensuring the effective implementation of energy-saving solutions. This positions O-RAN as a pioneer in creating sustainable, efficient, and intelligent networks

1- Existing Feature Specified in O-RAN ALLIANCE .

1.1 O-RAN ALLIANCE NES Phase-1

O-RAN ALLIANCE MVP-C Approved 1st phase of Network Energy Savings feature back in 2022 and as part of phase 1 a technical report was published by WG1 UCTG in March 2023 [i.2] and normative work of Cell and Carrier Shutdown use case through O1 interface was specified. The TR from UCTG summarized the key findings and proposed potential solutions for advancing energy efficiency in O-RAN deployments.

The initial phase focused on analyzing various NES techniques and their potential impact on network operation. The key findings included:

1. Cell and Carrier Shutdown:

This technique switches off capacity cells or carriers with minimal or no traffic, allowing neighboring intra-RAT or inter-RAT cells to handle the additional load. This approach can be controlled by either Non-RT RIC or Near-RT RIC utilizing the O-RAN architectural framework; by intelligently turning of cells or carriers, energy savings can be achieved while managing user experience.

2. RF Channel Reconfiguration:

This technique adjusts the active Tx/Rx arrays within an O-RU based on traffic conditions. Lower traffic allows for deactivating a portion of the Tx and/or Rx arrays, subsequently reducing O-RU power consumption. The configuration of O-RU can be modified using OFH by O-DU in reaction to messaging received from near RT RIC through E2 interface. Behavior of Near RT RIC may be modified by A1 Policy received from Non-RT RIC.

3. **Advanced Sleep Modes:**

This technique leverages intelligent sleep mode selection for O-DUs and O-RUs. By analyzing network conditions and traffic patterns, the RIC platform can recommend optimal sleep mode configurations for improved energy efficiency.

4. O-Cloud Resource Energy Saving Mode:

This approach focuses on reducing energy consumption within the O-Cloud infrastructure. Two sub-use cases were identified:

I. Cloud Node Shutdown: This method optimizes resource allocation by consolidating Network Functions (NFs) onto fewer physical O-Cloud nodes, allowing for the shutdown of idle nodes. The Non-RT RIC provides guidance to FOCOM to facilitate this process.

II. Cloud CPU Energy Saving Mode: This method focuses on optimizing power consumption within active O-Cloud nodes by guiding available CPU energy saving states. The Non-RT RIC transmits recommendations to FOCOM for implementation. Both sub-use cases require further examination of feasibility aspects during the normative phase.

This initial phase established a foundation for further exploration and standardization of NES features within the O-RAN ALLIANCE . The identified techniques hold significant promise for reducing the overall energy consumption of mobile networks. Phase 2 focused on refining these approaches and addressing any remaining feasibility concerns to pave the way for their normative standardization within the O-RAN framework.

1.2 O-RAN ALLIANCE NES – Phase 2

The O-RAN ALLIANCE, under the MVP-C framework, approved the second phase of the Network Energy Savings (NES) initiative, with a focus on formalizing specifications for the energy-saving features explored during Phase-1. Building on the findings from the Technical Report (TR) published in Phase-1, extensive work was undertaken across multiple Working Groups (WGs) during Phase-2, which was completed by July 2024.

Key Features and Specifications:

1. **RF Channel Energy Saving (UC2) - WG2, WG3, and WG4:**
The RF Channel Energy Saving use case was further refined and developed by WG2 and WG3, with significant input from WG4. This use case builds on the concept of RF Channel Reconfiguration, allowing the O-RU to dynamically adjust its active Tx/Rx arrays based on near real-time traffic conditions. By reducing the number of active channels during periods of low traffic, this feature helps minimize energy consumption. WG4 ensured that this functionality operates seamlessly across both the Control Plane (C-Plane) and Management Plane (M-Plane), providing a flexible and efficient approach to energy management.

2. **Advanced Sleep Modes (UC4) - WG2, WG3, and WG4:**
Advanced Sleep Modes, a key use case defined by WG4 with intelligence based controls defined in WG2 & WG3 This use case focuses on intelligent energy management for O-RUs, allowing for more precise control over sleep modes to optimize energy use according to traffic patterns.

3. **O-RU Deep Hibernate Sleep Mode - WG4:**
As part of the enhancements to O-RU Sleep, WG4 introduced the O-RU Deep Hibernate Sleep mode. This mode is particularly effective in conserving energy by completely disconnecting the M-Plane when the O-RU is inactive, ensuring that no unnecessary power is consumed during low or no traffic periods. The recovery period of the O-RU would be based on the timer set after which O-RU will wake up.

4. **A1 Policy and E2-Service Model Enhancements - WG2 and WG3:**
During Phase-2, WG2 and WG3 worked on significant enhancements to the A1 Policy and the E2-Service Model (E2-SM) CCC within the Non-Real-Time RIC and Near-Real-Time RIC frameworks. These enhancements are crucial for managing and optimizing the energy-saving features in real-time. They ensure that the energy efficiency goals are met without compromising network performance, by providing the necessary intelligence and control mechanisms to the RICs.

5. **Technical Report on O-Cloud Energy Savings (WG6):**
WG6 ES TR aimed at reducing power consumption through resource optimization. The key use cases and methods defined by WG6 include:

    - **Use Case 1: O-Cloud Node Shutdown in Idle Mode**
        - **Overview:** Shutting down idle O-Cloud nodes to save energy when they are not needed.
        - **Description:** By consolidating workloads onto fewer nodes, idle nodes can be powered down. The Non-RT RIC provides guidance for executing this shutdown, optimizing resource allocation.

- **Potential Requirements:** Requires real-time monitoring of node activity and the ability to dynamically consolidate workloads.

- **Use Case 2: CPU Core Frequency and Pinning Configuration**
  - **Overview:** Adjusting CPU core frequencies and pinning configurations to save energy based on the current workload.
  - **Description:** Scaling down CPU frequency during low demand and optimizing core pinning can achieve significant energy savings.
  - **Potential Requirements:** Requires accurate, timely data on CPU usage and the ability to adjust CPU parameters dynamically.
- **Use Case 3: C-State Usage for NF Deployment**
  - **Overview:** Leveraging CPU C-states (low-power modes) during Network Function (NF) deployment to reduce energy consumption.
  - **Description:** NFs can be deployed with specific C-state configurations that match their performance needs, allowing unused cores to enter deeper sleep states. This is coordinated by the SMO and Non-RT RIC.
  - **Potential Requirements:** Requires detailed knowledge of NF performance needs and real-time monitoring of CPU states.
- **Use Case 4: O-Cloud Node Cluster Mode Selection**
  - **Overview:** Selecting appropriate node cluster modes based on workload requirements to optimize energy usage.
  - **Description:** Depending on the workload, different cluster modes (e.g., high-performance, energy-saving) are selected to balance energy efficiency and performance. The Non-RT RIC provides the intelligence to switch between these modes as needed.
  - **Potential Requirements:** Requires a flexible and dynamic orchestration system capable of understanding and applying different cluster modes.

Completion of Phase-2:

Phase-2 of the Network Energy Saving initiative was completed by July 2024. This phase focused on refining the approaches developed in Phase-1 and addressing any remaining feasibility concerns, ensuring that these techniques are ready for normative standardization within the O-RAN framework. The collaborative efforts across the working groups resulted in a comprehensive set of features and specifications that promise to significantly reduce the energy consumption of mobile networks, paving the way for further advancements in the O-RAN ALLIANCE ’s energy-saving initiatives.

SMO
1) Receive & manage Policy for optimizing Energy consumption of O-Cloud nodes.
2) Generate optimization Controls or policy towards O-Cloud through O2

Non-RT RIC (rApps)
1) Collects O-Cloud Inventory & telemetry data on node level or O-Cloud level over O2.
2) Collect PM data including Resource Utilization, Mobility and Energy consumption.
3) Train & Deploy AI/ML Model to generate policies based on O1 & O2 data.
4) Generate A1 policies for O-Cloud or E2 Nodes based on priority, load & energy consumption.

Near-RT RIC (xApps)
1) Collect Traffic and Energy related Data from E2 Nodes.
2) Collect E2 Nodes and O-RU Capabilities.
3) Execute E2 Policies based on guidance provided by non-RT RIC.

O-Cloud
1) O2 to expose data toward SMO & Non-RT RIC gather from IMS & DMS.
2) Execute changes recommended by SMO & feedback result of execution.

E2 Node
1) Perform actual energy savings actions on O-RU or E2 Nodes.
2) Collects O-RU and E2 Nodes Measurements for reporting via O1 or E2 interface.

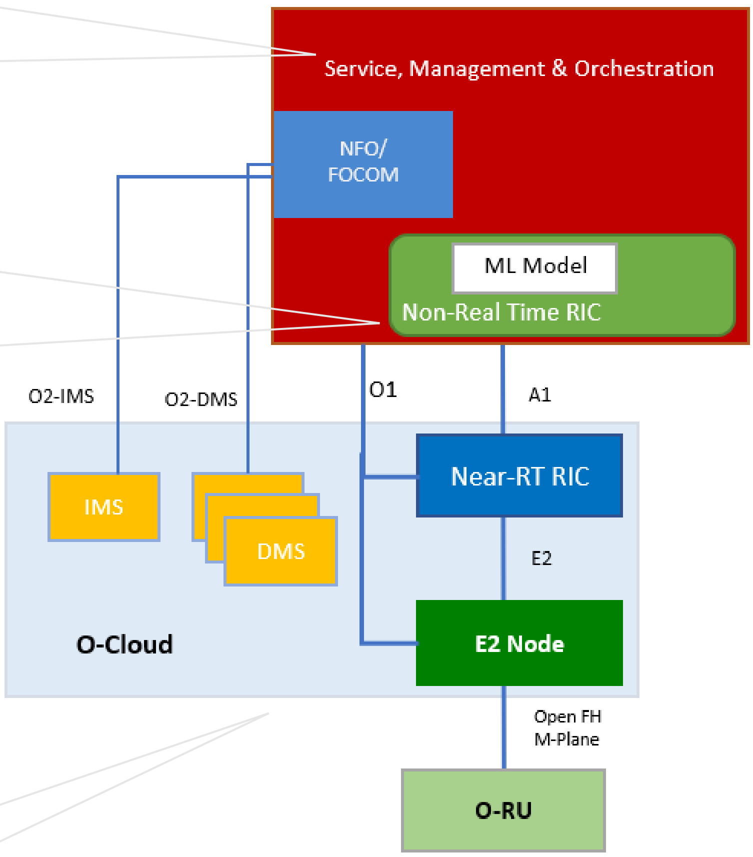

Figure 1: NES Framework

2- Potential Features for next Phase of O-RAN ALLIANCE Energy Savings Package.

Building on the success of the energy-saving features introduced in the earlier stages of O-RAN's Network Energy Savings (NES), this section presents new potential features for the next phase of NES. As the O-RAN ALLIANCE continues to grow and develop, it's becoming increasingly important to explore more advanced strategies that can both further reduce energy consumption and improve overall network performance.

Although Phase 2 of the NES initiative laid a solid foundation by standardizing essential energy-saving features such as RF Channel Reconfiguration, Advanced Sleep Modes, and Cell/Carrier Shutdown, there were still some gaps in terms of efficiency and flexibility. These gaps mainly related to the limitations in dynamic power management, a lack of real-time coordination with renewable energy sources, and insufficient precision in optimizing energy use within cloud-based systems.

The goal of this next phase is to address these gaps by offering a more comprehensive approach to energy management. This approach will involve both hardware improvements (for example, in Radio Units) and system-wide enhancements (such as in the O-Cloud). These new features are designed to adapt dynamically to changing network conditions, traffic patterns, and the availability of power sources. Furthermore, by incorporating 3GPP Release-18 energy-saving features, this phase will enhance O-RAN's capabilities and ensure greater energy efficiency throughout the entire network.

The proposed features are grouped into three categories: Radio Unit-related features, O-Cloud-related features, and those focused on the implementation of 3GPP Release-18 energy-saving standards.

3. Radio Unit Related Potential Energy Savings features.

Radio unit consume most amount of energy in a Mobile Network. Hence O-RAN focused mostly on achieving energy savings in O-RU as part of NES Phase 1 and 2.

This section will focus on potential energy savings features for Radio Unit that can be defined in O-RAN in future.

3.1 Enhanced Co-ordination between Radio Unit and Power Source

3.1.1 Description

The feature "Co-ordination between O-RU Power Consumption and External Power Source" focuses on optimizing use of energy more efficiently in O-RAN networks. It does this through integrating data on the type of power source (renewable or non-renewable) and its available capacity, such as remaining battery life, to make informed decisions about energy consumption. It uses a sophisticated approach to assess whether an O-RU is powered by a finite source like a battery or a sustainable one like wind or solar energy. Depending on this assessment, the network can dynamically adjust its operations by prioritizing energy savings or user experience.

3.1.2 Value Proposition

Understanding the type and capacity of a power source, such as whether it's renewable and how much battery life remains, is essential for efficient use of energy-saving features in an O-RU. For instance, if an O-DU or an energy savings application knows that an O-RU is operating on a limited battery supply, it can take necessary actions to conserve energy, like shutting down certain carriers or employing other energy-saving techniques. Conversely, if the O-RU is using renewable energy sources, the system can focus more on providing a better user experience, knowing that energy conservation is less of a concern. Significant work has already been done in this area, particularly by ETSI [i.5] which has developed requirements and data models for external power sources in its ES 202.336 standards -Figure 2 in section 3.1.3. Also 3GPP TR 28.931 under "Key Issue #9: RAN energy saving when using backup batteries" .By adopting or aligning with these established models in the O-RAN context, specifically through the fronthaul M-Plane or O1 interface, it becomes possible to relay crucial power source information to the Service Management and Orchestration (SMO) or O-DU, enhancing overall energy management in O-RAN networks.

3.1.3 Standardization Requirements

- Develop and adopt standardized data models for energy and power source reporting in alignment with existing standards like ETSI and 3GPP.
- Define and standardize the interfaces (such as M-Plane, O1) for reporting the power source data to energy management systems like xApps and rApps within the O-RAN architecture.
- Formulate standards for the R1 or E2 interface that will be used in xApps or rApps for making real-time decisions based on power source analytics.
- Establish protocols for regular and reliable reporting of power source type and capacity to the network's management systems.

Element type	Monitored information	Explanation
alarm	Input/output and battery protective device (gathered or unitary information)	Fuse/Circuit Breaker open or tripped
	Battery discharge (e.g. due to mains loss, mains out of limits or not enough rectifier power)	
	Battery test failure	Battery failed to pass defined test criteria e.g. autonomy time, voltage threshold, state of health (SoH) threshold
	Output low voltage	Voltage of the DC bus falls below pre-set threshold, e.g. due to battery discharge
	Battery over-temperature	Battery temperature exceeds high limit setting
	State of Charge (SoC) low	SoC falls below preset minimum. Signal can be used to actuate external contactor to stop the discharge, start an auxiliary generator or other device
	State of Health (SoH) abnormal	SoH falls below present minimum with pre-defined grace period
	Safe mode actuated	Electronic contactor is open and the IBU or IBS has restricted operation
event	Alarm set and clear	
	Change of operating mode	Change of mode, e.g. charge, discharge, float charge, sleep, safe
data	DC voltage (±0,1 V) - this precision is required for floating voltage (e.g. 54,6 V) derating detection and temperature charge compensation (around -3 mV/K/cell)	
	Charge and discharge battery current I_{Batt}	
	Battery discharge alarm duration	Time period over which battery is discharging e.g. caused by actual mains supply failure or insufficient output power from rectifiers due to failure

Figure 2: Illustrative excerpt from the ETSI standard "ES 202 336-11 v1.1.1," presenting detailed data models for Integrated Battery Units (IBUs) and Integrated Battery Systems (IBS).

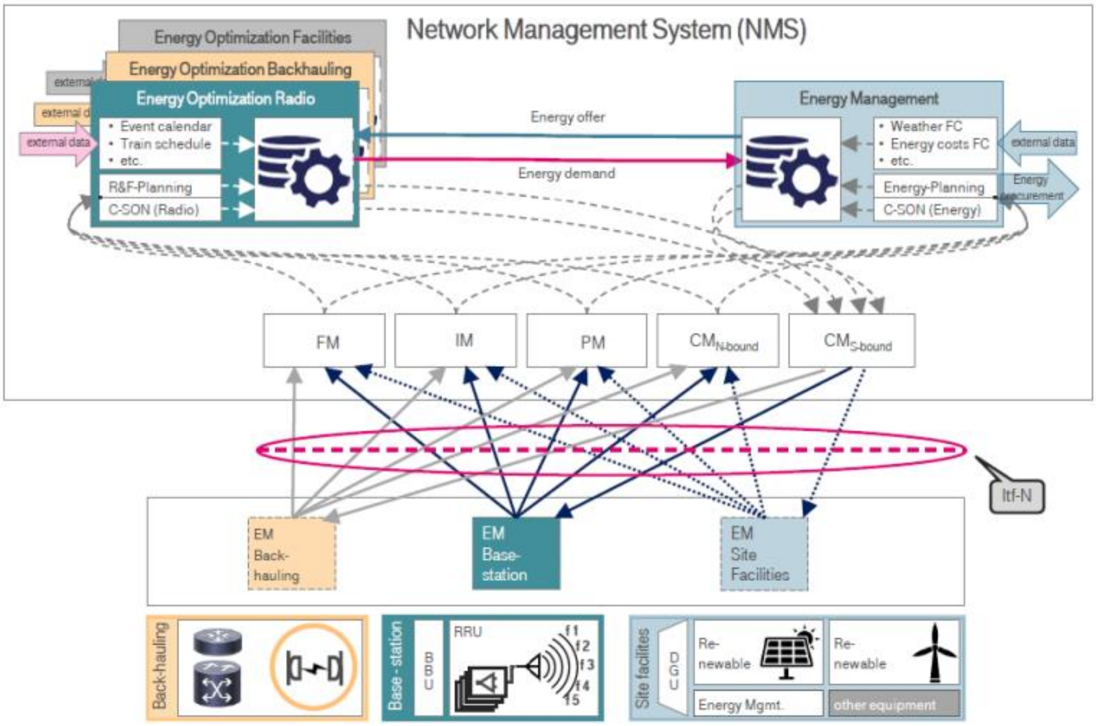

Figure 3 : Illustrative excerpt from NGMN GFN-Metering-White-Paper-v1.0 indicating how this feature can be integrated into network.

3.2 Power Amplifier Dynamic Voltage Bias Adaptation

3.2.1 Description

The feature "Power Amplifier Dynamic Voltage Bias Adaptation" addresses the optimization of energy consumption in Power Amplifiers (PAs) used within O-RAN O-RU. It is a technique where the PA adjusts its bias voltage dynamically based on the traffic load, reducing the backoff margin during periods of low or no traffic load. This adjustment is crucial as the backoff margin directly influences the PA's power efficiency and the quality of signal emissions.

3.2.2 Value Proposition

Based on the traffic load, the optimization of PA characteristics to reduce the power consumption.

3.2.3 Standardization Requirements

Open Fronthaul (WG4) : Standardized Implementation of ways to influce,control the O-RU’s PA Voltage bias from O-DU

Real-Time Adjustment: Standardize E2 interface API’s for how the PA bias voltage is dynamically adjusted in real-time to respond to traffic load changes while maintaining signal integrity.

RIC and SMO Configuration Protocols: Defining the configuration and control protocols for the RIC and SMO, which will govern how the feature is managed across the network.

Energy Saving Reporting: Implementation of reporting mechanisms to quantify the energy savings achieved through this technique, contributing to the broader energy efficiency goals of the O-RAN ALLIANCE .

3.3 Artificial Load Generation

3.3.1 Description

Artificial Load Generation (ALG) is a feature that allows for the simulation of realistic energy consumption patterns within an Open RAN (O-RAN) network. This is achieved by injecting a controlled load into the O-RAN equipment, primarily the Open Radio Unit (O-RU). However, the solution can also extend to monitor the energy consumption of the Open Distribution Unit (O-DU) and Open Central Unit (O-CU).

The injected load can be configured to mimic various user behaviours and Scenarios (e.g., Voice, data traffic), enabling comprehensive energy consumption analysis across different network configurations and operating conditions. This data can then be used to optimize energy usage within the O-RAN network.

3.3.2 Value Proposition

- **Faster Green Tech Adoption:** Validates energy efficiency claims before deployment, fostering a sustainable mobile ecosystem.
- **xApp/rApp Training-** Generates diverse real-world traffic loads to train xApps and rApps on actual energy consumption patterns for optimization.
- **O-Cloud Platform ES features -** Enable O-Cloud to test energy consumption and explore energy-saving methods under realistic network loads, facilitating the development of more efficient network management strategies.

3.3.3 Standardization Requirements

Open Fronthaul (WG4) :

Load control parameters: These parameters should allow for configuration of the injected load to mimic various user behaviours and traffic scenarios. This could include specifications for:

- Load level
- Load duration and patterns
- Modulation type (e.g., single carrier, multi-carrier)

Data reporting for energy consumption monitoring:

The O-RU should report data relevant to energy consumption under the injected load, such as:

- Efficiency metrics (e.g., power conversion efficiency)
- Environmental conditions (e.g., temperature)

- **Power Monitoring:**
  - Using O-RAN fronthaul defined “epe-statistics” Measurements. [i,12] Table 6.1.1.2.1-1

O-DU and O-CU Considerations:

- Load Injection Specifications: While the primary focus is on injecting load into the O-RU to simulate radio activity, the standard may also consider guidelines for generating controlled load on the O-DU and O-CU. This could involve specifications for:
- Simulating processing load on the O-DU by injecting data traffic or control messages.

3.4 O-RU Dual mode operation

3.4.1 Description

O-RU dual mode operation is a feature that allows the O-RU to either operate in legacy mode (use one of the beamforming methods defined in O-RAN Fronthaul M-Plane and CUS plan Specification [i.12] [i.13] or in ULPI (Uplink Performance Improvement) mode (DMRS beamforming) or in both modes within an Open RAN (O-RAN) network. This is accomplished by O-DU activating the specific mode in the Open Radio Unit (O-RU) via Fronthaul interface. This solution can also be used to achieve the energy saving in the O-DU and O-RU. Also, this feature can be leveraged for Shared O-RU applications, where two O-DUs share the same O-RU resources and O-RU activated with both legacy and ULPI operational modes with the respective O-DU (for e.g., O-DU#1 and O-DU#2 activated the legacy and ULPI modes in the O-RU, respectively).

Service Management and Orchestration (SMO) or near real time Radio Access Network Intelligent Controller send trigger/command or provides a policy or configuration details to O-DU via O1 or E2 interface. The example conditions for the policy can be as follows:

- Low UE mobility
- Large inter-site / cell distance
  - It can happen when some other O-RUs are turned off completely.
  - It is linked with the time.
  - When the number of users is reduced (e.g., during night-time)

When the UE distribution changes and conditions mentioned in the policy are met or based on the configuration for disabling the ULPI mode to save energy, O-DU disables the DMRS beamforming (ULPI Mode) and enable legacy mode of operation in the Open Radio Unit (O-RU).AI/ML based prediction of traffic, User Equipment (UE) mobility, User Equipment (UE) density, User Equipment (UE) distribution, inter-cell interference, inter-site distance and uplink traffic requirements can lead to decision making on which mode (Legacy or ULPI mode) to operate.

3.4.2 Value Proposition

- **Reduced complexity and energy saving:** DMRS beamforming requires highly complex Open Radio Unit (O-RU) design, hence switching to legacy mode leading to energy savings when Uplink traffic requirements and other ULPI related requirements not there.
- **Optimized Resource utilization:** Understands how traffic impacts energy usage, enabling optimal resource allocation and preventing wasted energy while operating in ULPI mode.

3.4.3 Standardization Requirements

O-RAN may need to specify.

Capability Reporting: O-RU should advertise its capability of supporting the dual mode operation feature and associated parameters to O-DU via Fronthaul M-Plane interface. Similarly, O-DU should also need to advertise its capability to control O-RU dual mode operation.

Activation mechanism: The O-DU should receive a policy or configuration details or guidance from Service Management and Orchestration (SMO) and/or near RT-RIC for the O-RU dual mode operation. The O-DU should be able to switch between legacy and ULPI modes in O-RU via Fronthaul Management and Control Plane. The information and data models to facilitate the O-RU dual mode operation to be defined for the interfaces like O1 and Fronthaul and for the nodes such as O-DU and O-RU.

Data reporting for energy consumption monitoring: The O-RU should report data relevant to energy consumption, such as:

- Real-time and historical power draw
- Energy Efficiency metrics

This can be reported through already defined “epe-statistics” measurements in O-RAN WG4.

The above data could be used by SMO along with other existing performance counters, key performance indicators (KPI) and other measurements to provide the optimal policies to the O-DU on when to activate ULPI mode thereby associated energy saving achievable.

4- O-Cloud Energy saving features.

There is already ongoing work related to O-Cloud energy savings as mentioned in section 1.3

This section will only focus on potencial enhancements that could be potentially specified in O-RAN in due course.

4.1 Intelligent Energy Management and Orchestration

4.1.1 Description

Intelligent Dynamic Service Orchestration within O-RAN would aims to optimize resource allocation and energy usage across the network through advanced service management strategies. This feature encompasses:

- **Lifecycle Management for Energy Efficiency**: Implementing comprehensive lifecycle management of Virtual Network Functions (VNFs) and Containerized Network Functions (CNFs) in O-Cloud, focusing on energy-saving strategies during deployment, scaling, and termination phases.
- **Advanced Resource Management Capabilities**: Utilizing predictive analytics to manage the allocation of O-RAN O-Cloud resources, in a manner that minimizes energy consumption while maximizing network performance and reliability.
- **Host Consolidation:** Targets over-provisioned and underutilized servers, particularly within non-real time work loads environments where CPU overcommitment is less critical. By analyzing actual utilization, opportunities for workload rightsizing and server consolidation can be identified, significantly reducing both capital and operational expenditures.

4.1.2 Value Proposition

This feature significantly enhances O-RAN's operational efficiency by:

- **Reducing Energy Consumption:** Dynamic orchestration and policy management allow for real-time adjustments to resource allocation and workload management, minimizing energy wastage.
- **Increasing Cost Efficiency:** Optimized energy utilization leads to reduced operational costs, offering substantial savings over traditional static resource allocation methods.

4.1.3 Leveraging existing efforts within O-RAN ALLIANCE :

The proposed Intelligent Energy Management and Orchestration feature in O-RAN would effectively utilize a decoupled SMO architecture to optimize energy use within the O-Cloud and broader network operations. This initiative would incorporate several critical SMO components, each tailored to enhance energy management:

- **Network Functions Orchestrator (NFO):** Would manage the orchestration of VNFs and CNFs, aiming to optimize their deployment based on projected energy efficiency metrics and anticipated network demands.
- **Federated O-Cloud Orchestration and Management (FOCOM):** Would ensure efficient energy management across distributed O-Cloud resources by optimizing workload placement and migration towards the most energy-efficient infrastructure.
- **Service Orchestration (SO):** Would integrate energy management strategies into service orchestration processes, facilitating the dynamic allocation and scaling of resources in alignment with energy availability and system requirements.
- **Policy Management Interface (PMI):** Would implement policy-driven controls to achieve energy efficiency targets across the network, dynamically adjusting policies based on real-time energy consumption data.
-
- **Topology and Inventory Visualization (TE&IV):** Would provide precise, up-to-date network topology and resource inventory data to inform and enhance energy distribution and utilization strategies.

4.1.4 Standardization Requirements

To ensure effective implementation of this feature, several standardization efforts are essential:

Standardized Interfaces for Energy Management: Develop and standardize interfaces that allow the NFO, FOCOM, SO, and PMI to interact seamlessly with each other and with external energy data sources, ensuring consistent and efficient energy management across the network.

Policy Definitions and Enforcement Protocols: Establish clear definitions and enforcement protocols for energy management policies, facilitating their integration into the overall network management strategy.

Integration Protocols for TE&IV Data: Formalize protocols for integrating TE&IV data into the energy management process, ensuring that all decisions are based on accurate and comprehensive topology information.

Core Network Interworking with SMO (RAN O&M): Standardize the interaction between the core network operations and the SMO to enhance energy efficiency. This includes aligning operational policies, sharing real-time energy usage data, and coordinating energy-saving measures across both RAN and core network components.

4.2 Framework for carbon-efficient CNF/VNF workload placement

4.2.1 Description

Energy and carbon-efficient O-RAN CNF/VNF workload placement will cover the following key aspects:

Carbon Footprint Measurement: Some of the existing industry standards include the definition of metrics and models for right measurement of carbon footprint on account of CNF/VNF operations. This includes accounting for the energy sources involved in the data center operation (if renewable or non-renewable) and the overall environmental effect of deployed infrastructure.

Energy and Carbon Efficient Workload Placement: O-RAN will investigate how CNF/VNF can be placed at most energy efficient and carbon efficient location without cloud. It may consist of scaling or smartly migrating workloads to be run in data centers or distributed clouds located at renewable power, wherever it is feasible.

Interoperability: The standard will prioritize solutions that are interoperable across different O-RAN compliant vendors and network elements. This ensures flexibility and avoids vendor lock-in, fostering a more diverse and sustainable O-RAN ecosystem.

4.2.2 Value Proposition

By strategically using renewable energy and optimizing resource allocation, the O-RAN standard significantly can reduce the carbon footprint of mobile networks. Additionally, it ensures compliance with evolving regulations and fosters a more sustainable O-RAN ecosystem. These efforts translate to cost savings for operators and a greener future for the mobile network industry.

4.2.3 Leveraging Existing Initiatives:

The standard will leverage existing industry efforts:

Green Software Foundation (GSF): Their working group focused on developing a carbon-aware Software Development Kit (SDK) will be a valuable resource. This SDK empowers applications to be aware of their carbon footprint and optimize resource allocation accordingly.

Cloud Native Computing Foundation (CNCF) Sustainability Group: The focus of this group is on Tooling for Carbon Awareness shall be integrated to provide operators with comprehensive insights into the carbon impact of their O-RAN deployments.

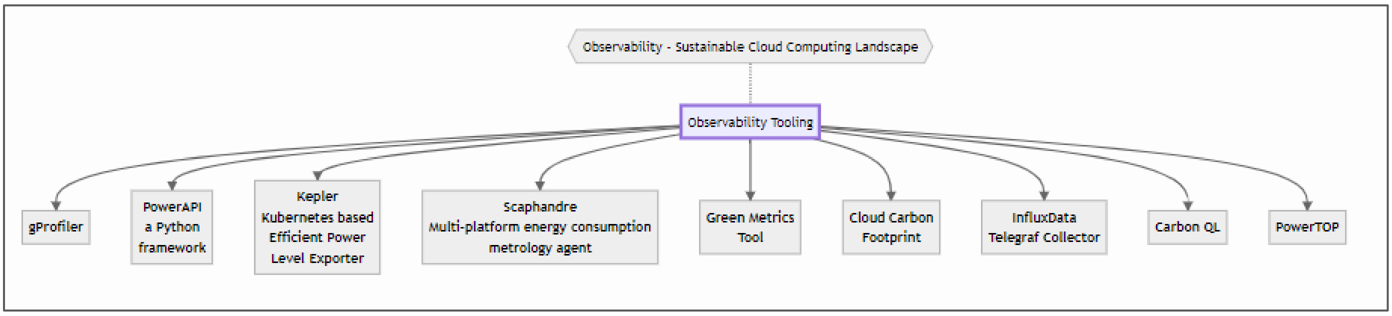

Figure 4: Illustrative excerpt indicating the observability tooling

4.2.4 Standardization Requirements

Integration with Renewable Energy Sources:

Data Exposure: Define a standardized interface for data centers to expose information about their energy sources (renewable vs. non-renewable) and real-time availability of renewable energy. This could leverage existing O-RAN interfaces like the O2 interface for energy management or define a new specific interface that reports energy source information.

Workload Scaling and Migration: Develop standardized protocols for the SMO (using non-RT RIC, NFO/FOCOM) to communicate with CNF/VNF managers and orchestration systems. This allows for dynamic scaling or migration of workloads based on renewable energy availability.

Carbon Footprint Measurement:

Metrics and Models: Establish standardized metrics for measuring the carbon footprint of CNF/VNF operations. This could involve factors like energy consumption, data center location (based on grid mix), and hardware specifications.

Data Collection: Define standardized interfaces for collecting data relevant to carbon footprint, such as energy consumption of CNF/VNFs and data centers. This data can be collected directly from network elements or through existing monitoring solutions.

Policy Management: Define mechanisms for the SMO to enforce relevant regulations through policy configuration. These policies can guide workload placement decisions to prioritize sustainable practices.

Interoperability:

Standardized APIs: Ensure all components involved in workload placement, including SMO, NFO/FOCOM, CNF/VNF managers, and data centers, utilize well-defined and interoperable APIs. This allows for seamless integration across different O-RAN compliant vendors.

Information Modelling: Develop a standardized information model for representing carbon footprint data, energy source information, and workload characteristics. This ensures consistent data exchange across the O-RAN ecosystem.

Building on Existing Work:

Leverage existing efforts from the Green Software Foundation (GSF) on carbon-aware SDKs and the CNCF Sustainability Group's Tooling for Carbon Awareness. Standardize integrations with these tools within the O-RAN framework.

Align with 3GPP's work on data gathering and exposure of carbon emissions (SA2 Work Item for Rel-19 [i,14])

4.3 Energy Efficient Applications / Network Functions

4.3.1 Description

This feature centers on optimizing energy efficiency through tailored application and network function design within O-RAN's O-Cloud. The design approach considers the inherent characteristics of different workloads and the energy-saving capabilities of the underlying cloud infrastructure:

- **Bursty Workloads**: Characterized by unpredictable peaks in CPU usage, common in real-time functions such as those found in 5G RAN. Implementing energy-saving strategies, such as utilizing C-states during periods of inactivity, can significantly reduce power consumption.
- **Sustained Workloads**: These involve consistent CPU demands and benefit from dynamically managed power settings (P-states) that adjust power based on load intensity. This method is effective for tasks with predictable patterns like packet processing.
- **Acceleration Abstraction Layer (AAL) Utilization**: The AAL enables more sophisticated resource management by allowing network functions to utilize hardware accelerators dynamically based on the current load and performance requirements. This not only optimizes processing power usage but also reduces energy consumption by adapting the use of intensive computational resources to only when they are necessary.
- **Development Considerations for Network Functions**: As the interface between CNFs and the O-Cloud is not currently standardized by O-RAN, developers should design CNFs with an understanding of the available energy-saving features of the O-Cloud. This includes optimizing the CNFs to effectively utilize dynamic scaling, power management, and hardware acceleration features provided by the O-Cloud.

4.3.2 Value Proposition

- **Reduced Energy and Operational Costs**: Tailoring applications to leverage the O-Cloud's energy management capabilities can dramatically lower energy usage.
- **Adaptive CNF Design**: Encouraging CNF developers to consider O-Cloud energy efficiencies during the design phase would enable applications that are inherently more energy-efficient and better aligned with the dynamic capabilities of O-Cloud Energy savings mechanisms.

4.3.3 Existing Initiatives:

As mentioned in section 1.3, O-RAN ALLIANCE WG6 is already progressing with O-Cloud energy savaing feature.

This feature will be built upon then specified O-Cloud energy savings features.

4.3.4 Standardization Requirements

To fully realize these benefits, key standardizations are necessary:

- **Energy Efficiency Metrics and Measurement**: Develop standardized metrics and methodologies for quantifying energy consumption and efficiency.
- **Workload-Specific Power Management Protocols**: Standardize techniques for managing power based on workload characteristics, ensuring consistent and effective application across the O-Cloud.
- **Guidelines for Energy-Efficient CNF Design**: Establish guidelines for CNF developers that highlight how to design and optimize network functions considering the energy-saving capabilities of the O-Cloud.
- **Integration of AAL and Enhanced NF Development**: Promote the development and standardization of interfaces and tools that facilitate the integration of CNFs with O-Cloud's energy management features, addressing the current lack of standardized CNF to O-Cloud interfaces.

These enhancements aim to empower O-RAN to manage energy consumption more effectively, fostering a network infrastructure that is both technologically advanced and environmentally responsible.

4.4 Enhanced Coordination between Data Center, O-Cloud Infrastructure, and Network Functions

4.4.1 Description

This feature enhances energy efficiency through improved coordination across data centers, O-Cloud infrastructure, and network functions:

- **Temperature and Cooling Coordination**: Implements standardized temperature monitoring and control, utilizing energy-efficient cooling strategies to mitigate overheating and reduce energy consumption.
- **Energy Cost Optimization**: Enables dynamic resource usage adjustment based on energy pricing, optimizing operational costs.
- **Provisioning of Nodes and Clusters**: Establishes guidelines for efficient node and cluster provisioning based on workload demands and performance needs.

4.4.2 Value Proposition

- **Thermal Load Balancing Across Data Centers**: Advanced thermal sensing and AI algorithms running as x/rApps in Near Not/RT RIC can assit in distribution of computational loads based on current thermal states, optimizing cooling requirements and improving energy efficiency.
- **Energy-Aware Task Scheduling in O-Cloud**: With integration of Data Center information, Orchestrators can Implements algorithms that schedule tasks based on their energy profile and overall data center load, reducing energy peaks and achieving substantial savings.

4.4.3 Standardization Requirements

To fully realize these benefits, key standardizations are necessary:

Key standardizations include:

- **Standardized APIs for Thermal and Energy Data Exchange**: Develops APIs that allow the Service Management and Orchestration (SMO) to access real-time data such as temperature and energy usage from data centers. This enables informed decision-making regarding network function orchestration, scaling, and resource allocation.
- **Integrated Thermal and Energy Management Protocols**: Standardizes comprehensive thermal management protocols across multiple facilities, ensuring efficient cooling resource allocation and energy usage.
- **Guidelines for Energy-Efficient Provisioning**: Sets forth provisioning criteria based on energy efficiency, enhancing the deployment of network functions, nodes, and clusters.

5. 3GPP Rel-18 RAN features

O-RAN's intelligent architecture, featuring both non-real-time (non-RT) and near-real-time (near-RT) RAN Intelligent Controllers (RICs), is well-positioned to enhance the energy savings features specified in 3GPP Release-18. By leveraging the intelligence of the RICs, rApps & xApps can orchestrate and fine-tune these features by utilizing advanced algorithms and real-time data analytics. This allows for the optimization of network energy consumption by leveraging the potential of AI-driven insights, which dynamically tailor network behavior to achieve maximum efficiency.

It is to be noted that these features would only be supported by UE’s that support 3GPP rel-18 and onwards.

5.1 SSB-less SCell operation for inter-band CA

5.1.1 Description

For an intra-band or inter-band CA SCell, a UE may obtain timing reference and AGC(Automatic Gain Control) source from another serving cell in case the UE is not provided with SSB nor SMTC configuration for this SCell.

5.1.2 Value Proposition in O-RAN

The "SSB-less SCell" feature, as described in [i.8], alows a User Equipment (UE) to receive timing reference from a serving cell other than the one currently providing service, in the absence of a Synchronization Signal Block (SSB) Measurement Timing Configuration (SMTC). This capability can be optimized within the O-RAN framework through the utilization of the RAN Intelligent Controllers (RICs).

In an O-RAN environment, both the Non-RT RIC and Near-RT RIC can play pivotal roles in the optimization process. The non-RT RIC, with its broader view of network management, can perform predictive analytics to anticipate the conditions under which SSB-less SCells would be most beneficial. It can then pre-configure network parameters to ensure seamless switching and timing synchronization without relying on SSB transmission, thereby reducing the energy consumption associated with SSB broadcasts.

The near-RT RIC, with its capability to make decisions in the timescale of milliseconds to seconds, can dynamically control the AGC and adjust the parameters of the SCell in real-time. It can also coordinate among multiple cells to manage the UE's connection efficiently, reducing the need for SSB transmission, which leads to energy savings especially in low traffic scenarios or during off-peak hours.

By integrating these controls with O-RAN's open and intelligent RICs, there is a significant opportunity to not only optimize SSB-less SCells but to also create more energy-efficient network operations that align with the energy-saving goals set out in 3GPP Release-18.

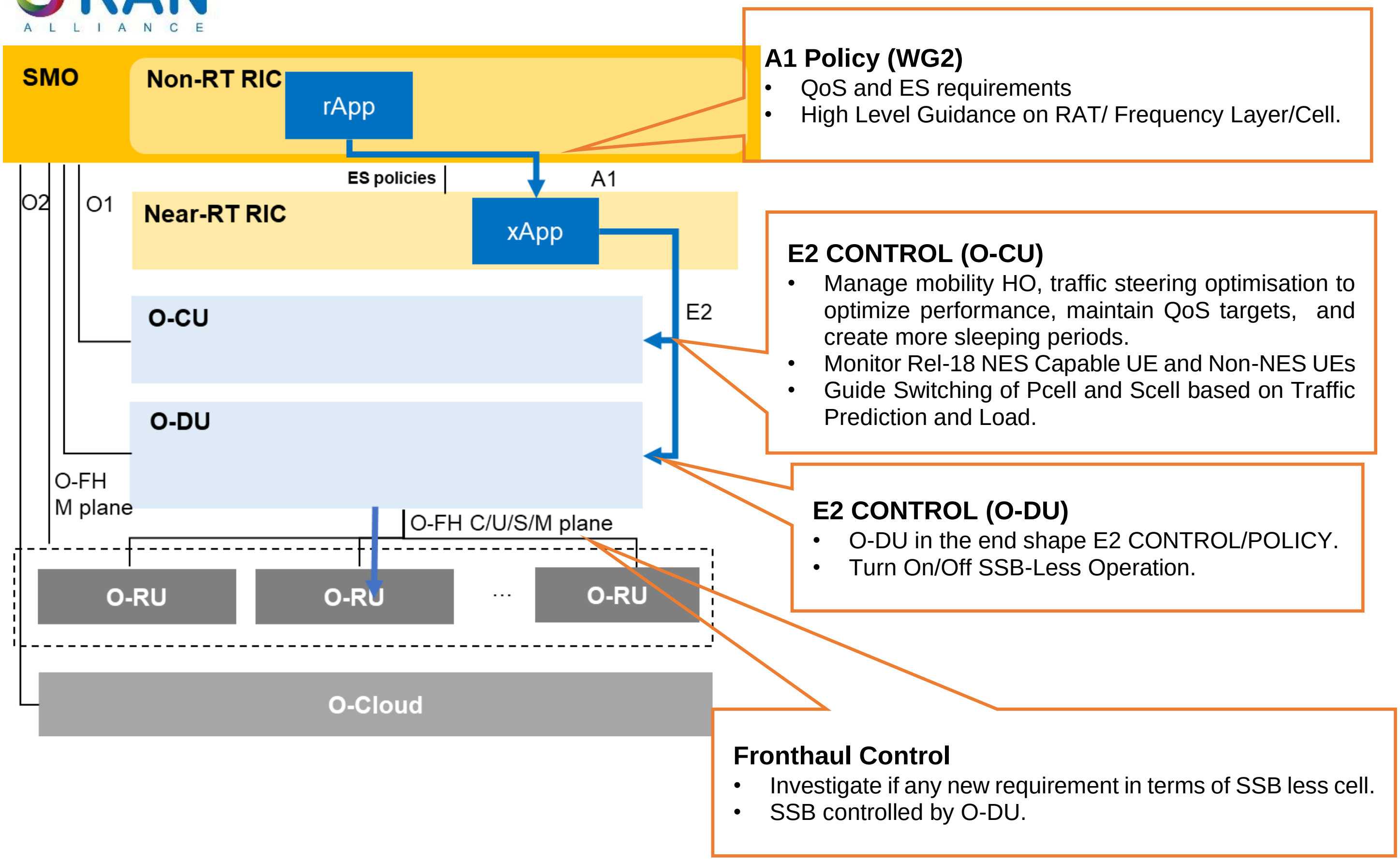

Figure 5: O-RAN overall framework and respective controlling mechanism

5.1.3 Standardization Requirements

Integration with O-RAN Interfaces: Adaptation of the O-RAN interfaces, particularly the E2 interface that connects the near-RT RIC to the O-CU/O-DU, is essential for the communication of control and management policies regarding SSB-less operations.

Policy Control and Management: Frameworks for non-RT RIC policy creation and management to be established, allowing for the configuration of conditions under which SSB-less SCell can be activated or deactivated.

Performance Metrics and Monitoring: Standardization of metrics and KPIs to monitor the performance impact of SSB-less SCells is necessary to ensure that there is no degradation in network quality and to quantify energy savings.

5.2 Cell DTX/DRX mechanism in time domain

5.2.1 Description

To facilitate reducing gNB downlink transmission/uplink reception active time, UE can be configured with a periodic cell DTX/DRX pattern (i.e. active and non-active periods).

The pattern configuration for the cell DTX/DRX is common for the UEs configured with this feature in the cell. The cell DTX and DRX patterns can be configured and activated separately. A maximum of two cell DTX/DRX patterns can be configured per MAC entity for different serving cells. When cell DTX is configured and activated for the concerned cell, the UE may not monitor PDCCH in selected cases or does not monitor SPS occasions during cell DTX non-active duration. When cell DRX is configured and activated for the concerned cell, the UE does not transmit on CG resources or does not transmit a SR during cell DRX non-active duration. This feature is only applicable to UEs in RRC_CONNECTED state and it does not impact Random

Access procedure, SSB transmission, paging, and system information broadcasting. Cell DTX/DRX can be activated/deactivated by RRC signalling or L1 group common signalling. Cell DTX/DRX is characterized by the following:

- *active duration:* duration that the UE waits for to receive PDCCHs or SPS occasions and transmit SR or CG. In this duration, the gNB transmission/reception of PDCCH, SPS, SR, CG, periodic and semi-persistent CSI report are not impacted for the purpose of network energy saving.

- cycle: specifies the periodic repetition of the active-duration followed by a period of non-active duration.

Active duration and cycle parameters are common between cell DTX and cell DRX, when both are configured.

Once the gNB recognizes there is an emergency call or public safety related service (e.g. MPS or MCS), the network should ensure that there is no impact to that service (e.g. it may release or deactivate cell DTX/DRX configuration). The network should also ensure that there is at least partial overlapping between UE's connected mode DRX on-duration and cell DTX/DRX active duration, i.e. the UE's connected mode DRX periodicity is a multiple of cell DTX/DRX periodicity or vice versa.

5.2.2 Value Proposition in O-RAN

Using near-real-time RAN Intelligent Controllers (near-RT RIC), the network can dynamically configure DTX/DRX patterns based on real-time data and predictive analytics, adjusting the activity of the network elements in response to fluctuating traffic demands. This smart adaptation reduces power consumption during low-traffic periods without impacting the user experience.

Moreover, the Service Management and Orchestration (SMO) component of O-RAN can provide a holistic view of network energy performance, allowing for strategic planning of energy-saving policies across the network. By using advanced algorithms that consider both energy efficiency and service quality, O-RAN can ensure that network elements are only fully active when needed, minimizing unnecessary energy usage.

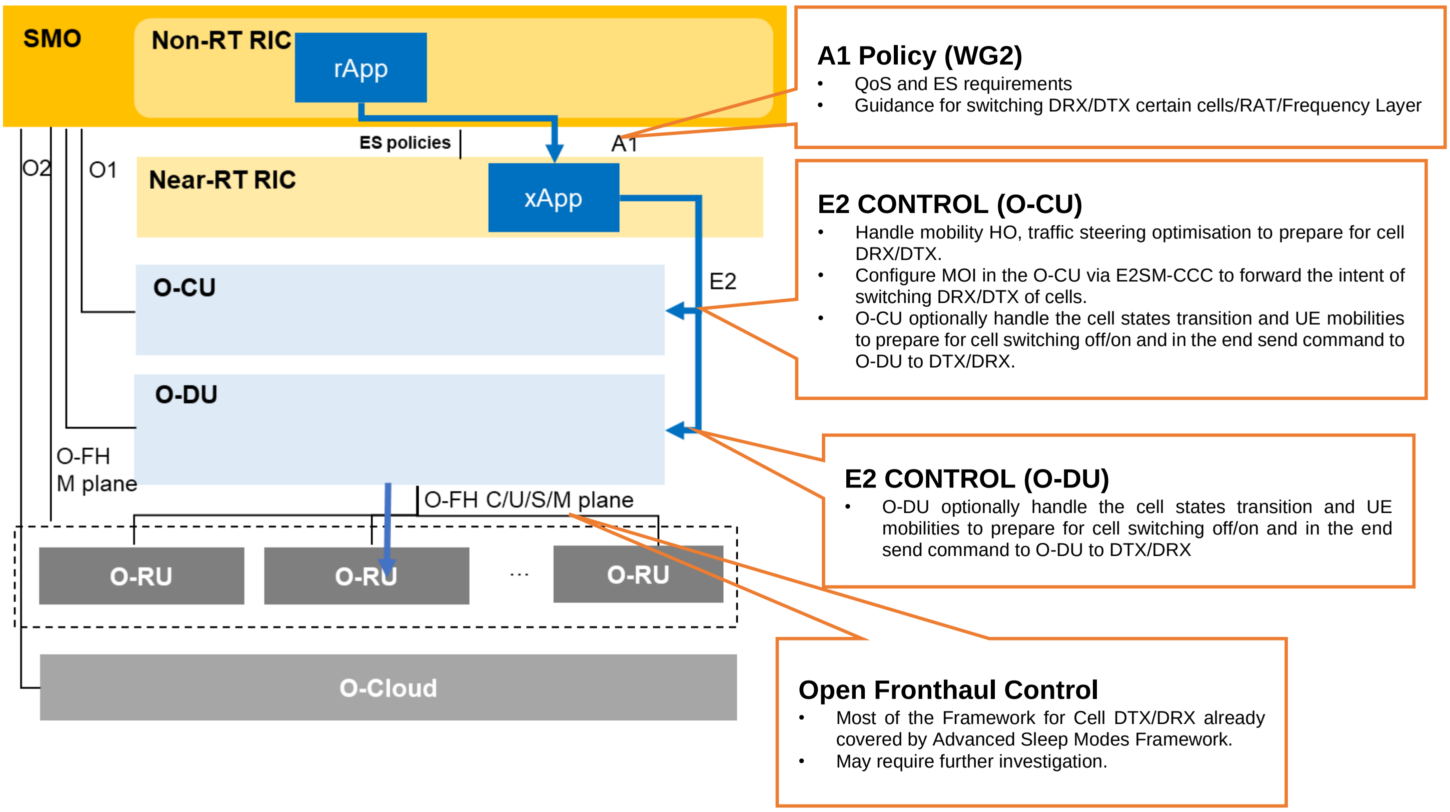

Figure 6: Various interfaces and associated control mechanisms

5.2.3 Standardization Requirements

Protocol Adaptation: Develop protocols for the E2 interface to enable the communication of DTX/DRX configurations and commands between the near-RT RIC and the O-DU/O-CU. This is already specified as part of Advance sleep modes feature, may require further enhancements in context to UE DTX/DRX cycles.

Scheduling Algorithms: Standardize scheduling algorithms that factor in the DTX/DRX configurations, ensuring they are executed without impacting the critical services and emergency call requirements.

Energy Savings Reporting: Standarize the reporting mechanism for the near-RT RIC to measure and analyze the energy savings from DTX/DRX patterns, contributing to informed decision-making for network energy policies.

5.3 Techniques in Spatial and Power domains

5.3.1 Description

This feature enables granular control over the network's spatial and power resources by leveraging user equipment (UE) feedback. The UEs are configured to report Channel State Information (CSI) based on various sub-configurations, each representing different spatial domain patterns or power offsets. This information allows the gNB to make informed decisions about muting certain transceivers or adjusting transmission power to optimize network performance.

5.3.2 Value Proposition

Optimizing the "Spatial and Power Domain Adaptation" feature using O-RAN ALLIANCE 's intelligent framework, specifically through near Real-Time RIC (near-RT RIC) and non-Real-Time RIC (non-RT RIC), presents several advantages. The near-RT RIC can leverage its rapid decision-making capability to analyze UE-reported Channel State Information (CSI) in almost real-time, enabling instantaneous adjustments to transceiver activity and transmission power. These adjustments, based on detailed CSI entries regarding spatial domain patterns and power offsets, lead to more efficient resource allocation and power usage in the network.

The non-RT RIC complements this by utilizing its broader view of network performance data to optimize these spatial and power adaptations over the long term. It can analyze trends and develop intelligent policies that can be fed back into the near-RT RIC, thus refining its real-time decision-making processes. This synergy between the two RICs enhances network efficiency, reduces energy consumption, and can potentially improve the overall user experience by ensuring optimal signal quality and network performance.

5.3.3 Standardization Requirements

CSI related Enhancement in Near RT RIC: Protocols for managing multiple CSI entries through the near-RT RIC, ensuring that spatial and power domain changes rely on accurate and timely information. This is distinct from the Phase-2 Energy savings feature "RF Channel Reconfiguration," as these Rel-18 features involve the UE, and the gNB must set up multiple CSI entries on the UEs and configure the RF Channels according to UE feedback

O-RU Configuration and Control: Develop standards for configuring and controlling network parameters related to spatial and power domain adaptation, including guidelines on how transceivers should be muted and associated transmission power adjusted.It is to be noted that this is already specified in O-RAN ALLIANCE as part of RF Channel Reconfiguration (TRX Control) feature and may not require new specifications.

A1 Policy Frameworks: Create frameworks for the non-RT RIC to develop policies based on long-term data analysis that can guide the near-RT RIC in its real-time adaptations.

Performance Metrics and Monitoring: Define performance metrics to monitor and evaluate the impact of spatial and power domain adaptations on the network's energy efficiency and user experience.

5.4 Mechanism to prevent legacy UEs camping and enhancements on CHO procedure.

5.4.1 Description

The "Conditional Handover" feature, as outlined in 3GPP Release-18, is an enhancement to the existing handover mechanisms, particularly tailored to scenarios where the source cell is implementing network energy-saving solutions like cell DTX/DRX or cell turn-off. This feature introduces additional triggering conditions for handover, particularly in the context of Network Energy Saving (NES) scenarios. It allows User Equipment (UE) to be notified, possibly through Downlink Control Information (DCI), to activate specific handover conditions configured with NES event indications. This ensures seamless handover even when the source cell is in an energy-saving mode, thus maintaining network performance and service continuity.

5.4.2 Value Proposition

Leveraging the intelligent and open framework of the O-RAN ALLIANCE can significantly optimize the Conditional Handover (CHO) feature introduced in 3GPP Release-18. This feature adapts handover procedures based on the energy-saving status of network cells, can be greatly enhanced by the real-time decision-making and adaptability inherent in the O-RAN architecture.

Enhanced Network Efficiency: With near-Real-Time RAN Intelligent Controller (near-RT RIC), the O-RAN network can intelligently manage handovers, especially when source cells are in energy-saving modes like DTX/DRX or are powered off. This dynamic management ensures efficient use of network resources, optimizing both energy consumption and network capacity.

Predictive Analytics: Utilizing the non-Real-Time RIC (non-RT RIC) for longer-term analysis and predictive insights, the O-RAN network can anticipate scenarios where CHO will be beneficial. This foresight allows for proactive adjustments to network parameters, enhancing overall network reliability and efficiency.

5.4.3 Standardization Requirements

Integration with Energy-Saving Features: Ensure that the conditional handover feature is harmonized with other energy-saving features like cell DTX/DRX for cohesive network operation.

Performance Metrics and Monitoring: Implement metrics to monitor the impact of this feature on handover success rates, network performance, and energy efficiency.

5.5 Inter-node beam activation and enhancements on paging

5.5.1 Description

Inter-Node Beam Activation: An O-RAN node can request and activate specific Synchronization Signal Block (SSB) beams based on the energy-saving status of the network. This process is managed via the E2 interface, facilitating dynamic and efficient beam management.

Paging Enhancements: This aspect utilizes the E2 interface for selective paging in O-RAN. By employing intelligent algorithms at the Near-RT RIC, the network can identify stationary UEs or those in specific areas, paging them through targeted SSB beams rather than across all beams within a cell.

5.5.2 Value Proposition

Optimized Energy Consumption: The O-RAN's intelligent framework, through near-RT and non-RT RICs, can significantly enhance energy efficiency by controlling beam activation and paging based on real-time network conditions and historical data analytics.

Enhanced Network Coverage and Capacity: The Paging Enhancements feature in O-RAN is highly effective in saving energy for O-RUs by enabling selective activation of Synchronization Signal Block (SSB) beams. This targeted approach ensures that only necessary beams are activated for paging stationary UEs or those in specific areas, significantly reducing the energy otherwise expended in broadcasting across all beams. Consequently, this precise and efficient use of radio resources directly translates into lower energy consumption for O-RUs.

5.5.3 Standardization Requirements

E2 Interface Specifications for Beam Management: Develop and standardize enhancements to the E2 interface that support dynamic beam activation and management. This includes defining protocols for O-RAN nodes to request and activate specific Synchronization Signal Block (SSB) beams based on real-time energy efficiency data and network demands.

Integration Protocols with Near-RT and Non-RT RICs: Establish protocols that outline how data from both near-RT and non-RT RICs can be leveraged to dynamically control beam activation and paging operations. This includes standardizing data formats and communication mechanisms that allow efficient data exchange between RICs and O-RAN nodes.

Energy Efficiency Metrics for Beam and Paging Management: Create and standardize metrics that assess the energy efficiency of beam management and paging strategies. These metrics should provide a clear framework for evaluating the energy savings achieved through these techniques.

Conclusion

This white paper has explored the current energy-saving features developed by the O-RAN ALLIANCE and proposed ideas for the next phase of the Energy Savings Package. The focus has been on advancing standardized approaches to energy efficiency across the O-RAN ecosystem, from the Radio Unit (O-RU) to the O-Cloud. By balancing energy savings with performance, coverage, and reliability, the aim is to create a more sustainable and adaptable RAN infrastructure.

Some key areas of innovation include improved coordination between radio units and power sources, adaptive techniques for optimizing power amplifier efficiency, and enhanced operational modes for O-RUs to reduce energy usage during low-traffic periods. On the O-Cloud side, smarter resource management and the development of carbon-efficient workload placement frameworks represent a shift toward greener cloud operations, a critical step given the increasing role of virtualization in modern networks.

The integration of advanced 3GPP Release-18 features, such as SSB-less SCell operation and Cell DTX/DRX mechanisms, further underscores O-RAN’s forward-looking approach. These features enhance the network's ability to save energy without compromising its capabilities.

At the heart of these efforts are the intelligent platforms within the O-RAN architecture: the Service Management and Orchestration (SMO), Non-Real-Time RAN Intelligent Controller (Non-RT RIC), and Near-Real-Time RAN Intelligent Controller (Near-RT RIC). The SMO ensures cohesive policy management and resource optimization across the network, while the Non-RT RIC applies AI and machine learning to create effective long-term energy strategies. The Near-RT RIC plays a critical role in executing these strategies in near real-time, allowing the network to adapt dynamically to changing conditions.

Looking ahead, the O-RAN ALLIANCE's commitment to standardizing these energy-saving features will be essential. It not only aligns with global sustainability goals but also supports the broader deployment of energy-efficient, open, and intelligent networks. By focusing on innovation and collaboration, O-RAN continues to lead the way toward a more sustainable future for telecommunications.

References

The following referenced documents are not necessary for the application of the present document, but they assist the user regarding a particular subject area.

[i.1] O-RAN.WG1.OAD-R003-v08.00: "O-RAN Architecture Description"

[i.2] O-RAN.WG1.NESUC-TR-R003-v02.00: "O-RAN Network Energy Saving Use Cases Technical Report 2.0"

[i.3] O-RAN.WG1.Use-Cases-Deatiled-Specification-R003-v11.00: "Use Cases Detailed Specification".

[i.4] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications"

[i.5] ETSI ES 202 336-11: "Environmental Engineering (EE); Monitoring and control interface for infrastructure equipment (power, cooling and building environment systems used in telecommunication networks); Part 11: Battery system with integrated control and monitoring information model.

[i.6] 3GPP TR 38.864: "Study on network energy savings for NR"

[i.7] 3GPP TS 38.8300: "NR; NR and NG-RAN Overall description; Stage-2"

[i.8] 3GPP TS 38.331: "NR; Radio Resource Control (RRC); Protocol specification"

[i.9] NGMN "Green Future Networks - Metering for Sustainable Networks"

[i.10] Open RAN MOU "Open RAN Technical Priority "Release 3" Document - April 2023"

[i.11] ETSI EN 303 47 "Environmental Engineering (EE); Energy Efficiency measurement methodology and metrics for Network Function Virtualisation (NFV)"

[i.12] O-RAN Open Fronthaul M-Plane "O-RAN-WG4-MP-v15"

[i.13] O-RAN Open Fronthaul CUS-Plane "O-RAN-WG4-CUS-v15"

[i.14] SA2 Work Item on energy efficiency for Rel-19 SP-231192

