WHITE PAPER

AI-Driven Energy Efficiency for O-RAN

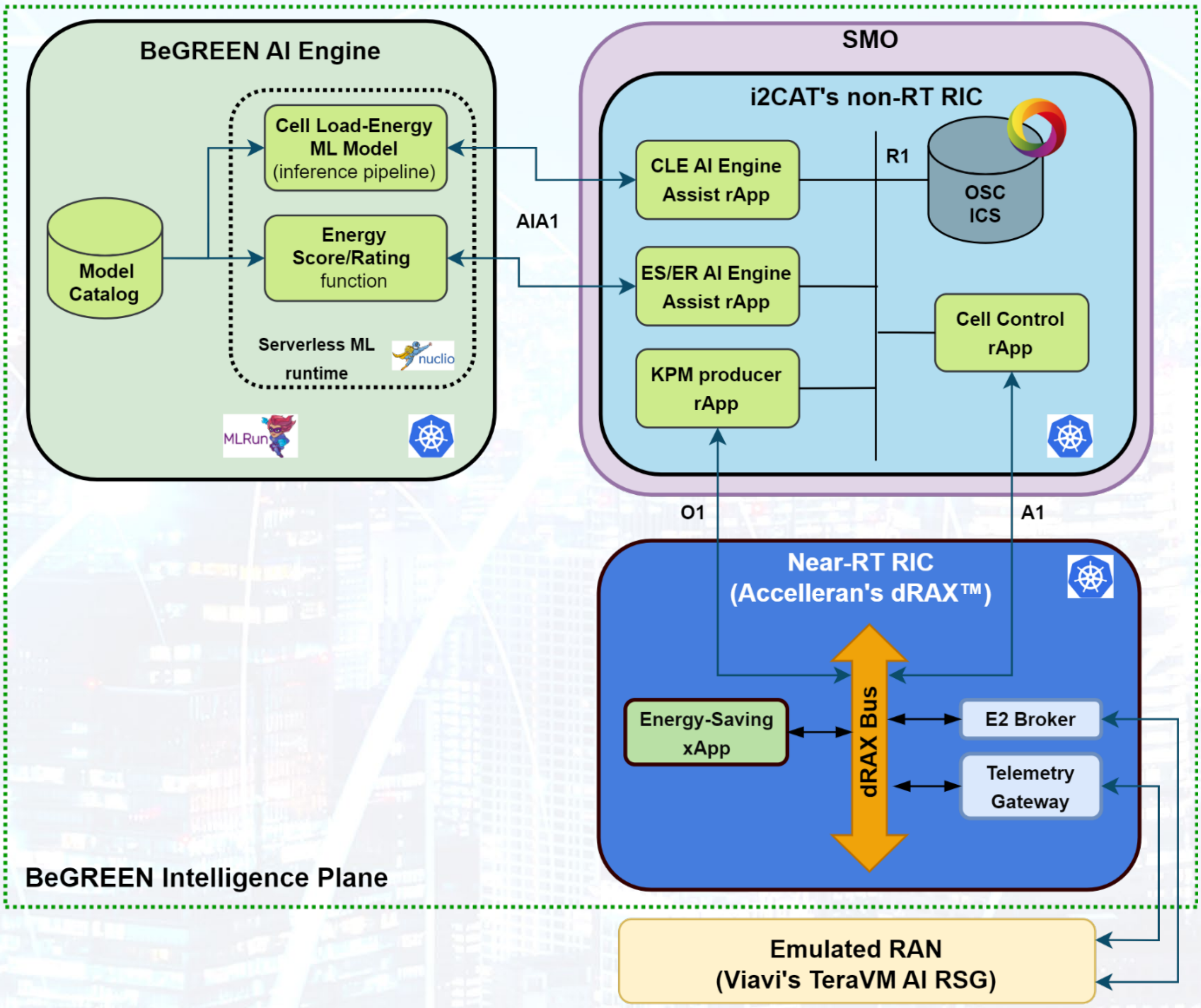
BeGREEN Intelligence Plane

Implementation and Evaluation
by Simulating Realistic O-RAN Environments using
VIAVI TeraVM AI RSG

Mobile networks are the backbone of our connected world, but they consume significant energy. Reducing this consumption is essential for both environmental sustainability and cost-effectiveness. As energy cost and environment concerns grow, energy efficiency is becoming a crucial agenda for the mobile industry. Aligned with this, the IMT-2030 report by the ITU introduces the improving energy efficiency as a key goal for future 6G networks.

The SNS **BeGREEN** Project takes on this challenge with the design of an Intelligence Plane that combines advanced AI/ML technologies based on O-RAN architecture to create an energy-smart network. This solution enables the seamless integration of advanced AI models, innovative rApps, and xApps to deliver measurable energy savings without sacrificing performance.

This white paper introduces the implementation and validation of the **BeGREEN** Intelligence Plane. The validation is based on a realistic scenario for mobile network operators, focusing on the management of coverage and capacity cells.



Particularly, the showcased solution uses AI-driven decision-making to manage the operational states of network cells dynamically, adapting to real-time traffic demands while optimizing energy use. A realistic evaluation requires a RAN emulator that can create a RAN Digital Twin to mirror real network conditions. For this purpose, **BeGREEN** utilizes the capabilities of **VIAVI TeraVM AI RAN Scenario Generator**.

BeGREEN Intelligence Plane Architecture

The **BeGREEN** Intelligence Plane architecture is a comprehensive system composed of three key entities, each contributing to the overall goal of energy optimization in O-RAN networks.

First, the **AI Engine** serves as the core of the system, hosting AI/ML models that process data from RAN nodes while offloading AI/ML tasks from the RAN Intelligent Controllers (RICs). By decoupling the AI/ML services from the O-RAN control loops in rApps and xApps, the **BeGREEN** Intelligence Plane provides modular and reusable framework, enabling independent model development and deployment. The outputs of these models, such as predictions or optimisation decisions, are seamlessly exposed to control the RAN through AI Engine Assist (AIA) interfaces and the associated rApps and xApps. Additionally, the AI Engine provides key outputs for each network component, including the **Energy Score**, which measures energy efficiency in bits per Joule, and the **Energy Rating**, which compares and ranks the energy efficiency of equivalent network entities, such as cells of the same vendor within the same area, helping to identify areas for improvement.

Second, the **Service Management and Orchestration (SMO) framework** and the **Non-RT RIC** play pivotal roles in managing large-scale, long-term optimizations. They integrate seamlessly with the AI Engine's model outputs exposed by AIA rApps via the Data Management and Exposure (DME) service of the R1 interface, coordinating with control rApps to ensure robust system functionality. These components streamline the interaction between advanced AI insights and operational goals. Based on these insights, control rApps determine appropriate A1 energy-saving policies and communicate them to the Near-RT RIC over the A1 interface. Both control and AIA rApps make use of RAN node data collected and exposed through a Key Performance Measurement (KPM) producer rApp, which connects to the Near-RT RIC via the O1 interface

Third, the **Near-RT RIC** is responsible for real-time actions. It enforces energy-saving policies via the Energy Saving xApp that provide Cell control, such as turning off underutilized cells or reducing transmission power based on the provided A1 policies. One core component is the Telemetry Gateway that oversees telemetry to gather real-time metrics from RAN nodes that inform AI-driven decisions and sync these metrics with the actions provided to control the RAN components. Integrated within Accelleran's dRAX platform, this component ensures rapid, precise responses to changes in network conditions.

Together, these components form a cohesive and intelligent system that effectively addresses the energy efficiency challenges of modern mobile networks. However, to accurately assess their benefits in realistic scenarios before deployment in operational networks, it is essential to validate the solution using RAN emulation tools capable of simulating realistic O-RAN environments. In **BeGREEN**, this is accomplished through the integration of **VIAVI TeraVM AI RSG**. The role of this tool is twofold. First, it enables the thorough testing and validation of rApps and xApps under varying conditions, including user mobility and traffic patterns. By replicating real-world network scenarios, the emulation environment supports the refinement of energy-saving strategies applied through standardized E2 service models. Second, it facilitates the development of AI/ML models using realistic data generated by the emulator and exposed through standardized O-RAN interfaces like E2 and O1. Particularly, a critical feature of TeraVM for the **BeGREEN** project is its ability to simulate realistic energy consumption, enabling an appropriate implementation and evaluation of the proposed optimisations.

Evaluation of the BeGREEN Intelligence Plane

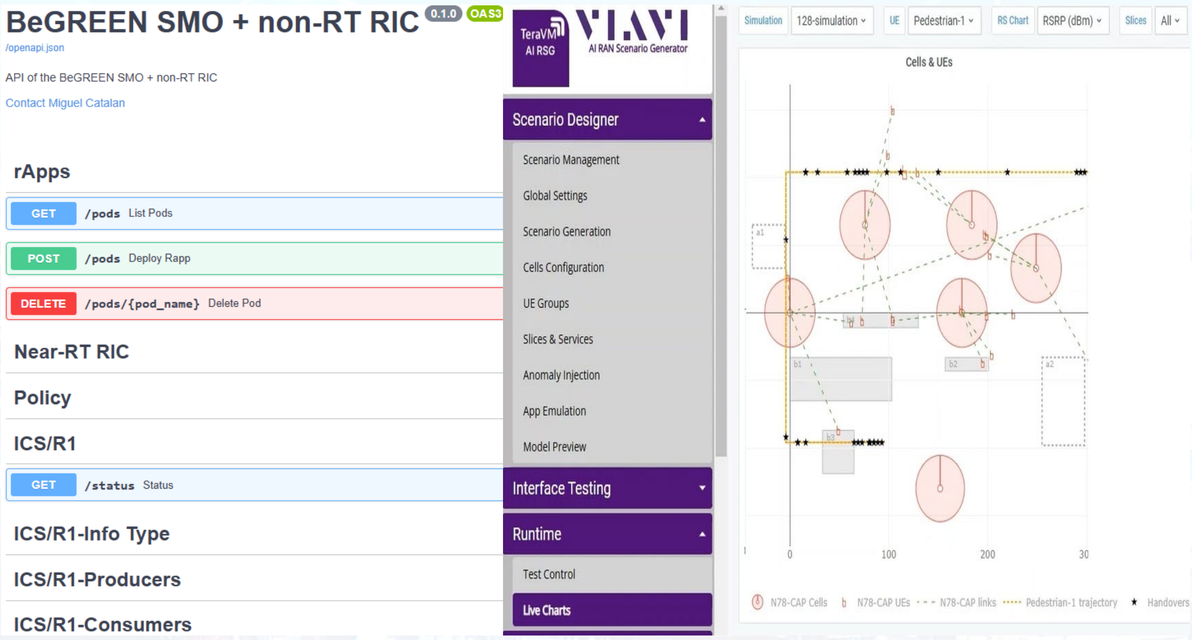
The **BeGREEN** solution is evaluated in a simulated 5G Standalone network featuring dynamic cell configurations inside the TeraVM AI RSG. Particularly, it is considered a replica of a campus network in Adastral Park in the UK, with real cell location and realistic area implementation. By utilizing AI models, the system predicts traffic demands and adjusts cell operations to maintain optimal traffic performance. The simulated scenario includes multiple 5G SA cells, with some acting as capacity layer cells that could be switched off during periods of low demand. Stationary and mobile UEs are introduced to generate downlink traffic, creating a dynamic and realistic test environment. Three essential components support the implementation:

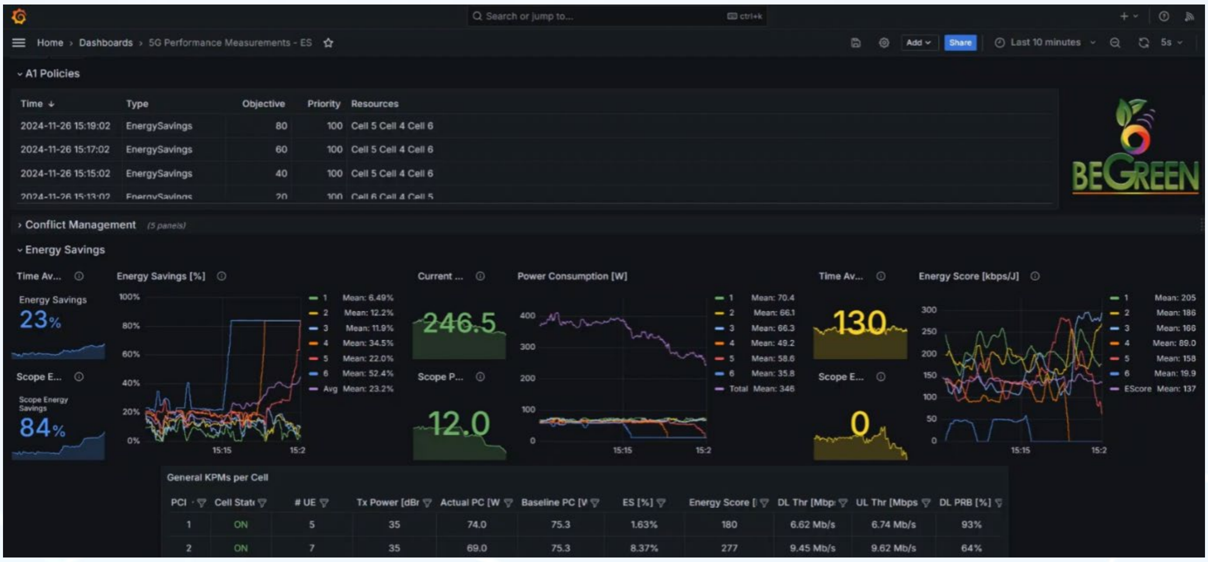
First, the **Cell Load-Energy ML Model** enables control rApps to make decisions about the operational status of network cells. This includes a traffic load predictor, trained to anticipate expected cell loads based on several KPM. Inputs such as cell identifiers, current load demand, and the number of connected UEs are periodically gathered through a subscription to the KPM producer rApp. This data is obtained from the near-RT RIC, which is connected to TeraVM through the Telemetry Gateway component.

Second, the **Cell Control rApp** executes control logic to generate energy-saving policies over the A1 interface. Deployed within the non-RT RIC, this rApp utilizes data from the AIA Assist and KPM producer rApps to make informed decisions. By analysing predicted load and energy metrics, it identifies cells for deactivation or reactivation. Policies are implemented incrementally to adjust energy consumption without disrupting performance, with Energy Scores and Ratings providing feedback on policy effectiveness.

Finally, the **Energy-Saving xApp** enforces the energy-saving policies using the E2 interface. This component determines the optimal operational status for each cell and coordinates actions across multiple cells to align with overall policy goals. When a cell needs to be deactivated, the xApp ensures smooth handovers by leveraging the Smart Handover xApp integrated into the Near-RT RIC framework. This seamless operation is further supported by a Conflict Avoidance mechanism, which guides xApps to prevent sending conflicting action messages to the same RAN component.

In initial evaluations, this implementation demonstrated the effectiveness of the **BeGREEN** Intelligence Plane in achieving significant energy savings, which were visualized through Grafana dashboards tracking metrics, policies, and real-time outcomes. In a particular scenario, the solution achieved energy savings of up to 40% without compromising network performance. Next figure illustrates (a) the **BeGREEN** non-RT RIC Swagger interface, which is used to manage data exposure and rApps, (b) TeraVM AI RSG dashboard, which presents the scenario details, including the status of cells and UEs, and (c) the Accelleran's dRAX near-RT RIC Grafana dashboard, which displays the received A1 policies and the evolution of KPMs during the demo runtime.





Next Steps and Broader Implications

The **BeGREEN** Intelligence Plane is set to continue evolving, with future developments aimed at expanding its capabilities and real-world applicability. Planned advancements include enhancing AI models to address more complex traffic scenarios, leveraging VIAVI TeraVM AI RSG to generate realistic data for even more accurate simulations. Evaluating the **BeGREEN** solution in scenarios that closely mimic real deployments, using the ability of TeraVM AI RSG to simulate thousands of UEs and cells, is a critical next step.

Integration into live networks will validate the system's performance in operational environments, ensuring its reliability and adaptability. Additionally, collaboration with industry partners will drive the adoption of energy-efficient O-RAN solutions across a broader ecosystem, amplifying its impact.

This journey underscores how AI-driven automation can revolutionize mobile network management. By reducing carbon footprints and operational costs, the **BeGREEN** Intelligence Plane aligns technological innovation with sustainability. It sets a new benchmark for energy efficiency, proving that advanced analytics, responsible engineering, and forward-thinking collaboration can create a sustainable and high-performing future for 6G networks.

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