

An Evaluation of RAN Sustainability Strategies in Production Networks

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The energy challenge in telecommunications

Mobile Network Operators consumed around 320 TWh of electricity in 2022, accounting for **1.3% of global electricity usage**.

The **Radio Access Network** is the largest energy consumer, responsible for **73%** of a typical operator's total energy costs.

Depending on the energy source, this demand leads to **significant CO₂ emissions**, contributing to the environmental impact.



GSMA climate action task force



Measuring energy consumption

Metrics to evaluate energy use at different network levels: network, core, and antennas.

Energy consumption assessment in **different context**: urban/rural areas and RAT.

Energy models based on extensive data collection.

Carbon footprint estimation.

MOBILE COMMUNICATIONS AND NETWORKS

Machine Learning and Analytical Power Consumption Models for 5G Base Stations

Nicola Piovesan, David López-Pérez, Antonio De Domenico, Xinli Geng, Harvey Bao, and Mérouane Debbah

ABSTRACT

The energy consumption of the fifth generation (5G) of mobile networks is one of the major concerns of the telecom industry. However, network energy saving solutions, similar to those developed for 3GPP Long Term Evolution (LTE), such as autonomous cell switch-off/re-activation capabilities for capacity booster cells via X_n/X_2 interfaces. Moreover, 3GPP NR Release 17 has

The authors exploit the knowledge gathered by this framework to derive a realistic and analytically tractable power consumption model, which can be used both theoretical and practical as well as feature selection, development, and frameworks.

Sustainable Connections: Exploring Energy Efficiency in 5G Networks

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Abstract
Although 5G networks offer larger capacity due to more antennas and larger bandwidths, their increased energy consumption is concerning. This paper investigates energy consumption issues

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Optimizing energy consumption

Accurate traffic prediction for timely BS activation/deactivation.

Carrier shutdown transfers the load to neighboring BSs during low-demand periods.

Reinforcement learning methods for policy optimization have been proposed but tested only in simulations.

Energy Saving Technologies and Best Practices for 5G Radio Access Network

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Neural Networks for Cellular Base Station Switching

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Modeling User Transfer During Dynamic Carrier Shutdown in Green 5G Networks

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Through the Telco Lens: A Countrywide Empirical Study of Cellular Handovers

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Abstract

Cellular networks rely on handovers (HOs) as a fundamental ele-

ACM Reference Format:

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Our contribution: a reality check

While many studies have addressed energy efficiency in telecom networks, there's a **lack of empirical evidence on the real-world** impact of energy-saving policies.

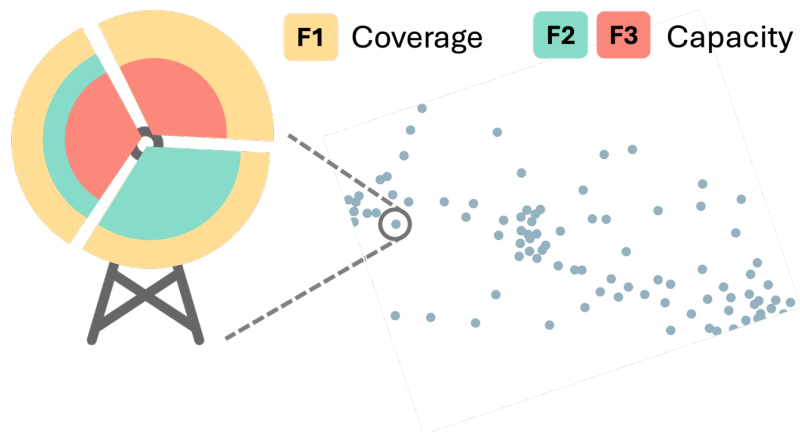
Real evaluation of:

- **Benchmark five** different energy-saving strategies
 - **Measuring** the cell downtime, energy consumption, and user throughput impact.
 - The **trade-off** between energy savings and end-user performance
- **Recommendations** for future energy-saving strategies



Implementing energy saving policies

RANs are **highly redundant** systems.
Antennas at **High frequency** for capacity.
Antennas at **Low frequency** for coverage.



Implementing energy saving policies

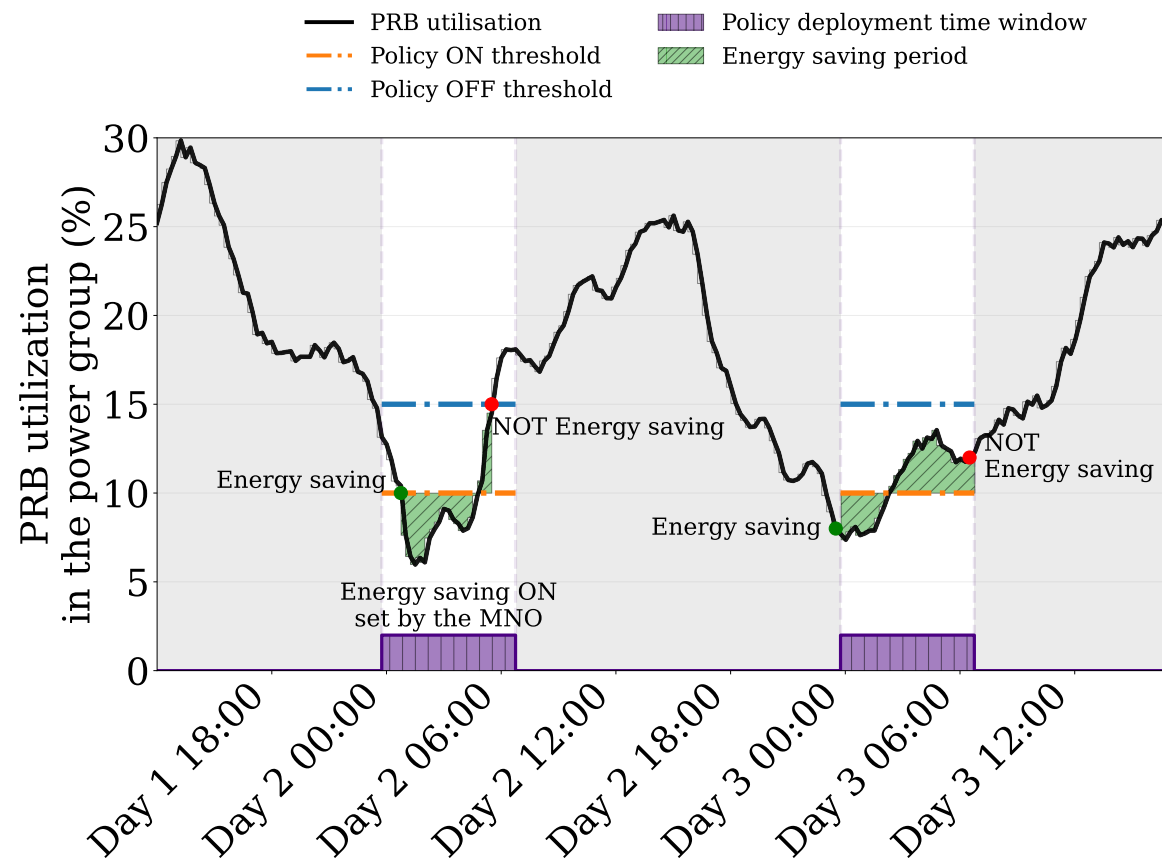
Two-threshold energy-saving framework

- **Power groups:** cohort of antennas in an area
- **Utilization:** KPIs of power groups
- **Thresholds:** ON/OFF trigger
- **Activation time:** stability requirement
- **Deployment time:** night/day, 24H/12H

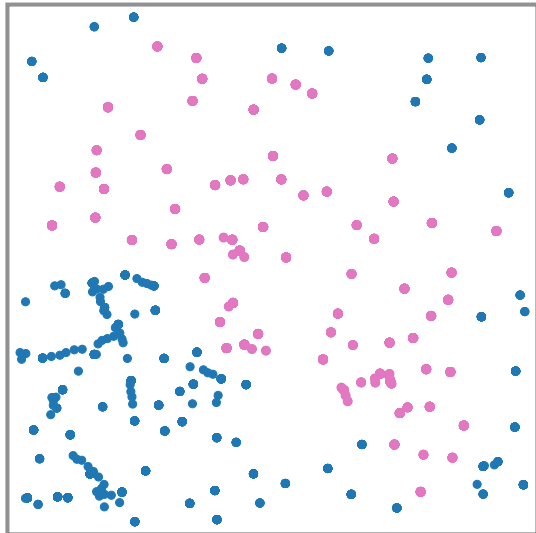
Sustainability goals

VS

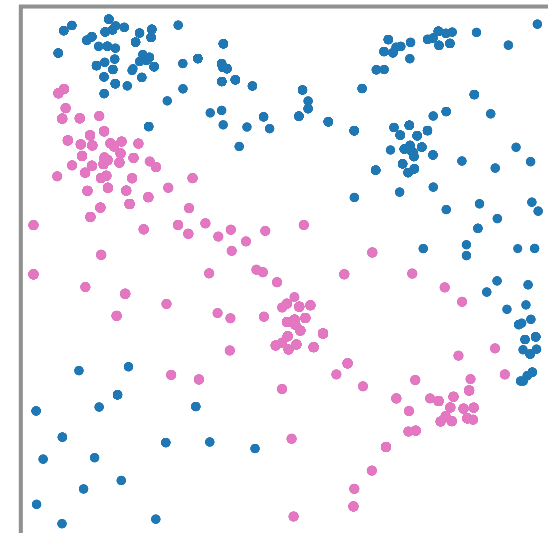
Strict quality Requirements



Spatial characteristics of the trial



Pink: Antennas in the trial
Blue: No part of the trial

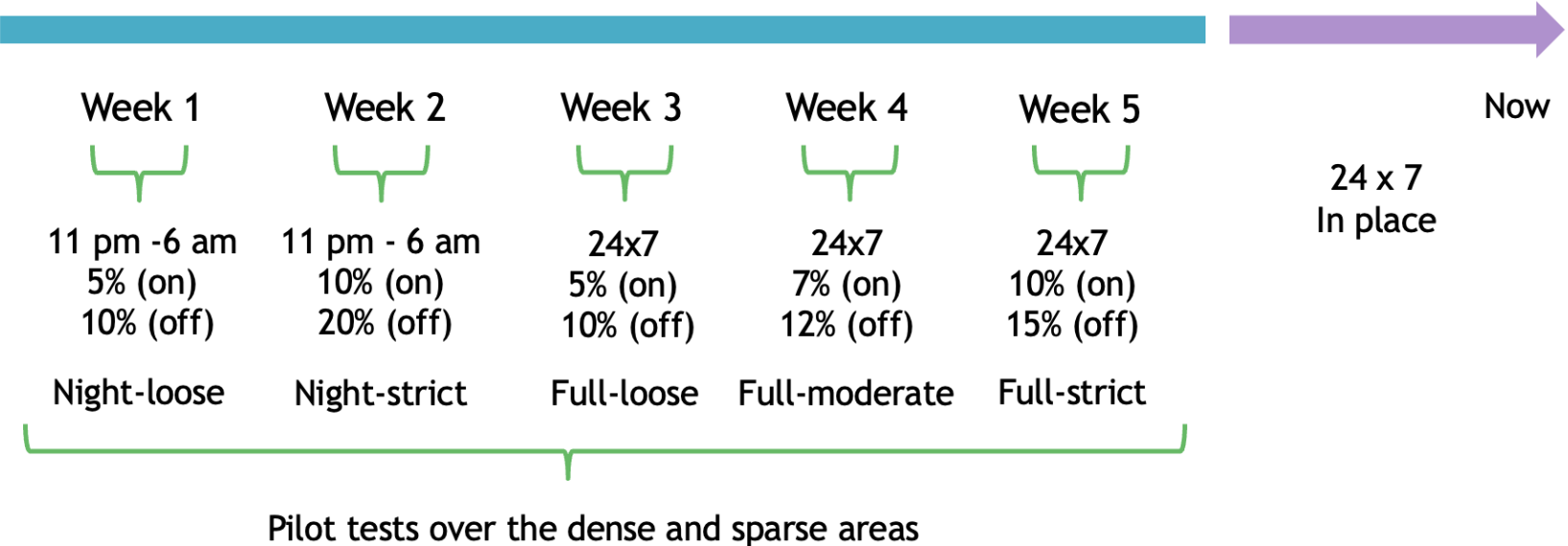


Dense area
Area of 189.28 km^2
Density of 5.41 LTE
antenna per km^2

Sparse region
Area of 4986 km^2
Density of 0.21 LTE
antenna per km^2

Temporal characteristics of the trial

February - March 2023



Datasets for assessing trials' performance

Network Deployment

- Country wide
- Daily resolution
- Lat, Lon
- Manufacturer
- Generation
- Power
- Azimuth
- Tilt
- Deployment date
- ...

KPIs

- Country wide
- Hourly resolution
- +200 KPIs
- PRB
- Network side
- User side
- ...

Mobility management

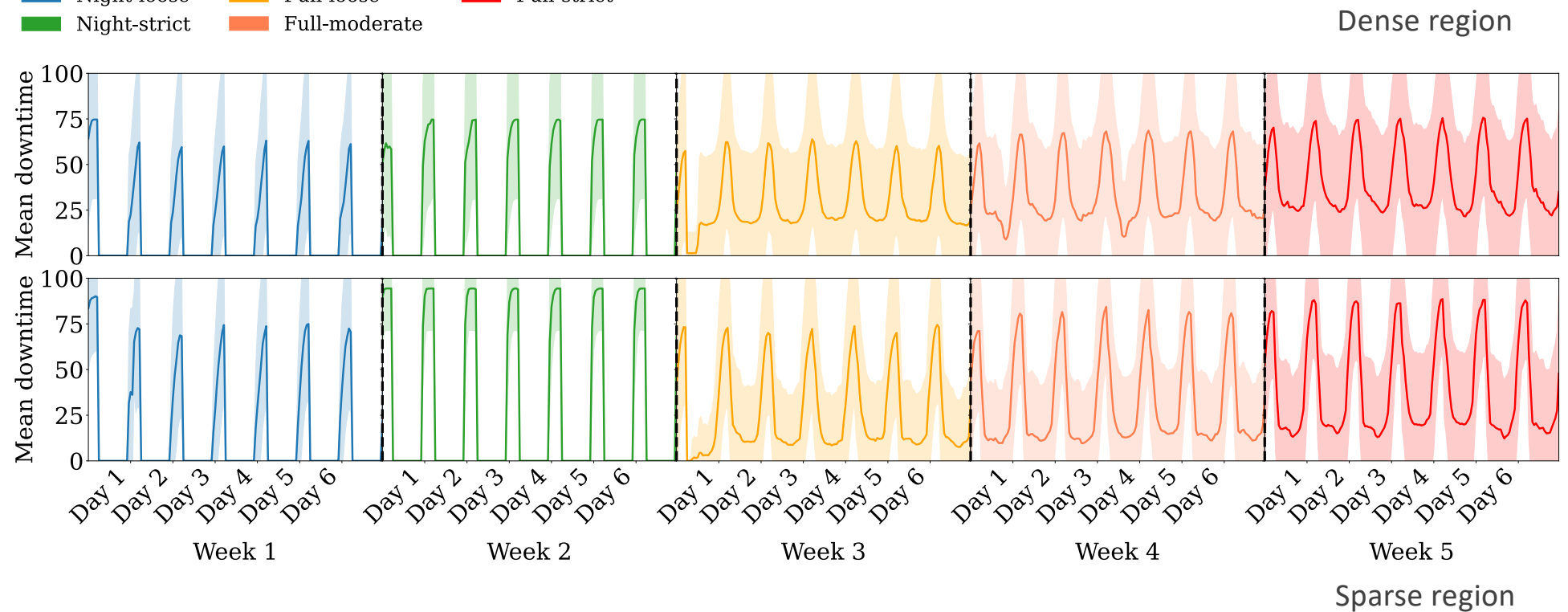
- Country wide
- Real-time resolution
- ~ 5TB per day
- Handover
- Service requests
- Change in TAU
- Attach
- ...

Results

Antennas downtime

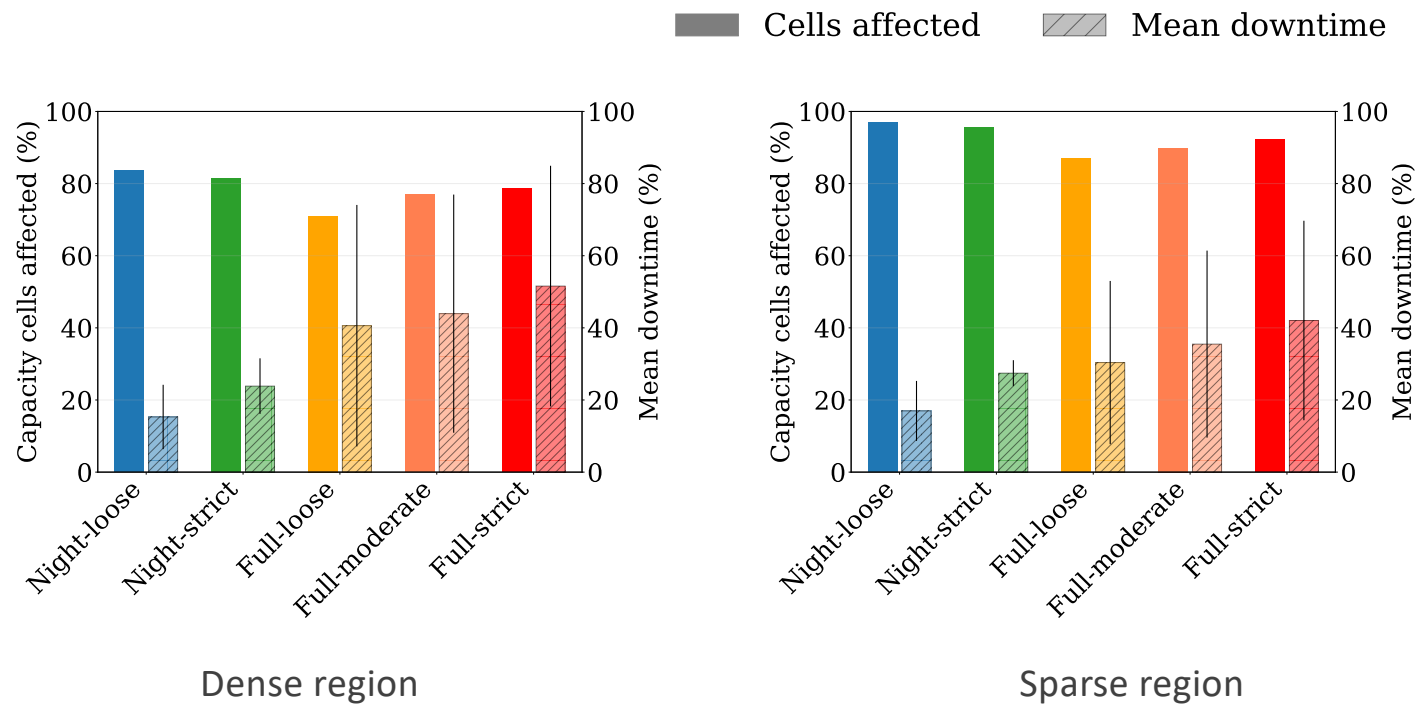
Hourly **time series** of the mean **downtime**

■ Night-loose ■ Full-loose ■ Full-strict
■ Night-strict ■ Full-moderate



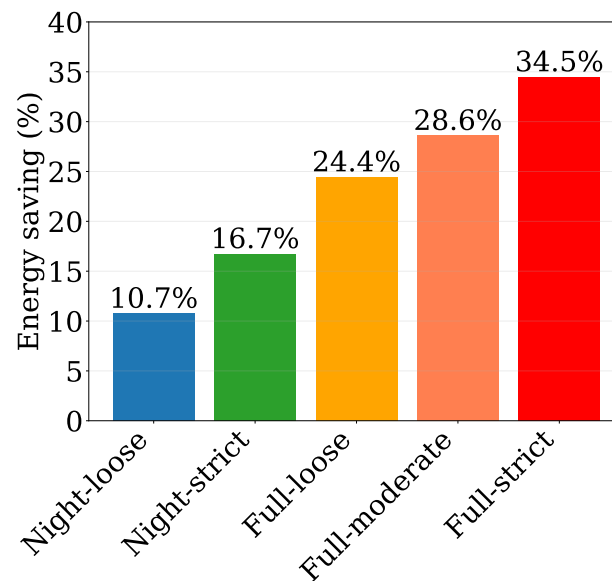
Antennas downtime

Percentage of **capacity cells affected by the energy-saving strategies** and their corresponding mean downtime

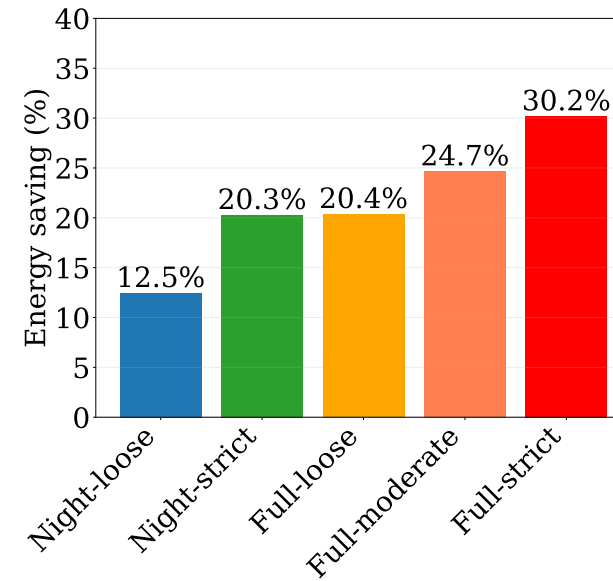


Energy consumption savings

“How much energy would the antennas have consumed without the energy-saving strategies?”

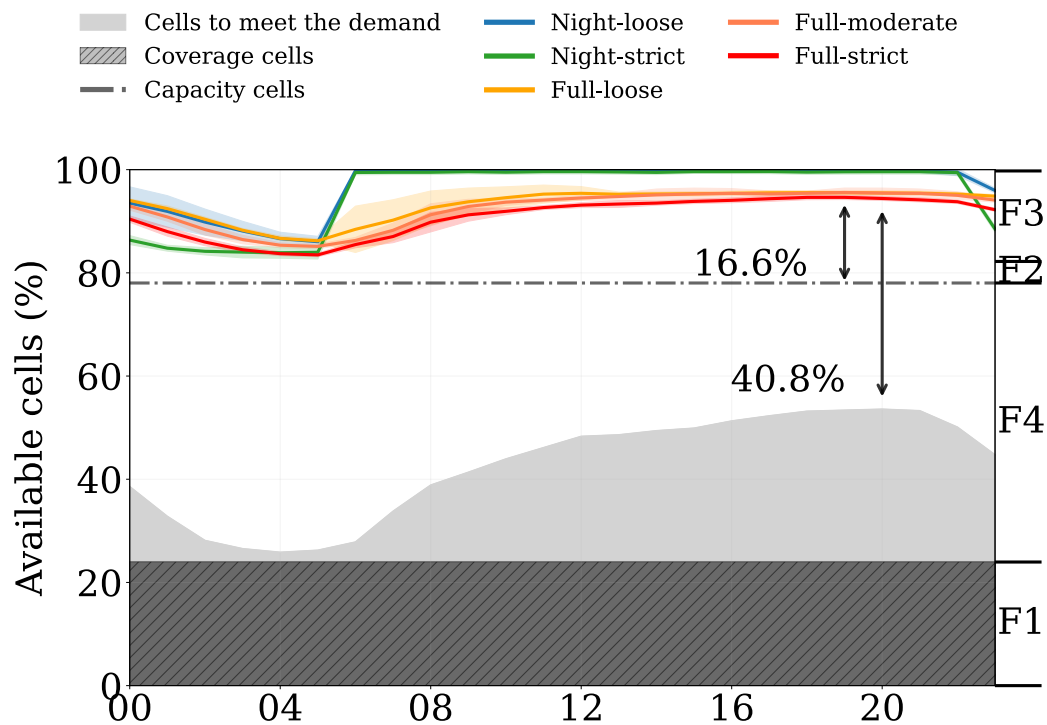


Dense region



Sparse region

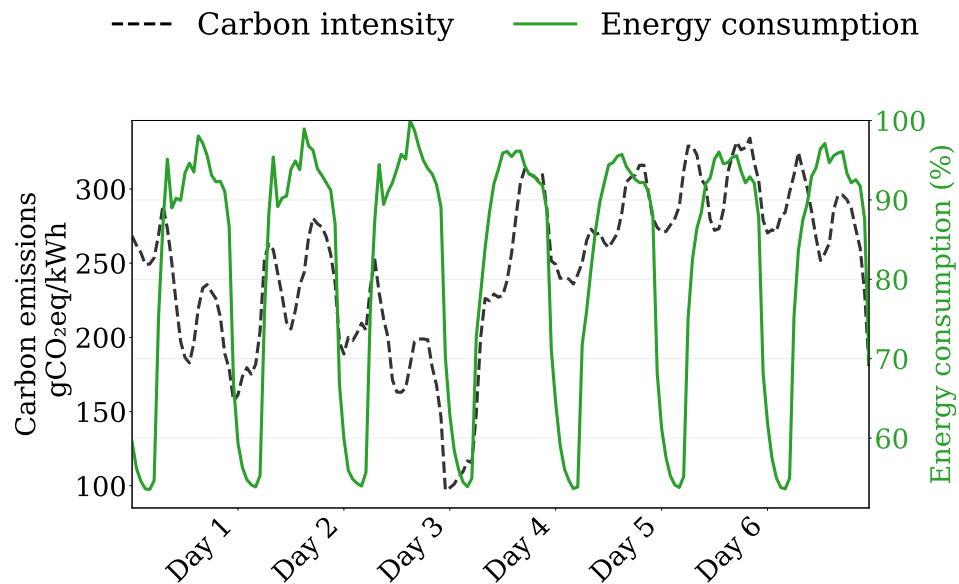
Network usage



Current strategies leave a **significant gap** between the actual available cells and the minimum needed to meet demand, **leaving room for improvement**.

Night-strict and **Full-strict** strategies are the **most effective** within their timeframes.

Carbon efficiency \neq Energy efficiency



- Scope 2 covers indirect emissions from purchased energy, i.e, electricity from the grid.
- Estimated carbon intensity in gCO₂ eq/kWh and energy consumption in the Sparse region during the week of the second trial.
- Carbon emissions during Night-strict week show daily patterns and exploitable day-to-day variability for efficient policies.

Lessons learned

- **Uniform ON/OFF thresholds are sub-optimal** Applying the same thresholds across all cells leads to inefficiencies, too conservative for some cells, and disruptive for others.
- **Potential of dynamic thresholds.** ML can be used to adjust thresholds based on traffic and network context dynamically.
- **Neighbor-aware decisions.** Incorporating information about nearby cell loads could further enhance the performance of sleep strategies.
- **Opportunity for carbon-aware policies.** Considering carbon intensity in cell sleep decisions to improve emissions reduction.



Thank you!

Questions?

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