



Green Networks: Minimizing Energy Consumption with AI/ML in 4G/5G Mobile Networks

Luis Santo, Head of Radio

Outline

- 1 NOS in numbers
- 2 The AI challenge: becoming data-driven with results
- 3 Power Saving mechanisms @ 4G/5G networks
- 4 Advanced Analytics to minimize energy consumption
- 5 Wrap-up & Future Work



NOS motto: Give more meaning to life, connecting people, enterprises, institutions and things to everything and everybody



Financial

€1,089.3 M Net Financial Debt	€994.7 M Shareholders' Equity	€1,597.5 M Consolidated Revenues
€387.6 M CAPEX*	€603.2 M Consolidated EBITDA AL	€181.0 M Net Profit
€130.5 M² Free Cash Flow	BBB – BBB Stable S&P Stable FITCH	1.81x Net Financial Debt/EBITDA AL ratio

* E.g. lease, spectrum, and other contractual rights ² Total Free Cash Flow before dividends, financial investments, and own share acquisitions

Human Capital

1,835 Employees	1,075 Men	760 Women
42.5 Employees' Average Age	67.7% Lisboa	27.2% Porto
	5.1% Others	

33%
% of Women in Management¹ and Top Management Positions²

¹ Management Positions: managers and directors
² Top Management Positions: Members of the Board of Directors

Operating

5,916.8 k Mobile Voice Customers	1,551.9 k Broadband Customers	31.7%¹ Revenue Market Share
5,427.3 k Homes with Fixed Next Generation Network	1,669.9 k Pay-TV Customers	1,821.7 k Fixed Voice customers
74.8% Ftth Coverage	1,137.2 k Integratad/Convergent Customers	11,014 k Total RGLs

¹ Value referring to IP-G2 according to ANACOM data

Environment

29% Renewable Electricity	-13% Energy consumption per Data Traffic (vs 2022)
99% Waste recovery Rate	528,000 Customer equipment refurbished for reuse

NOS is a Telco and Entertainment company with Mobile & Fixed operation; 5G launched on Nov 21

NOS leads 5G and mobile QoE in Portugal...

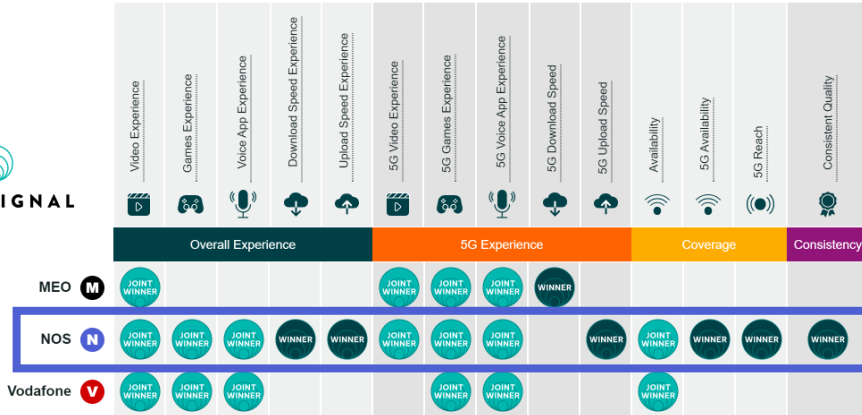


Mobile Experience Awards

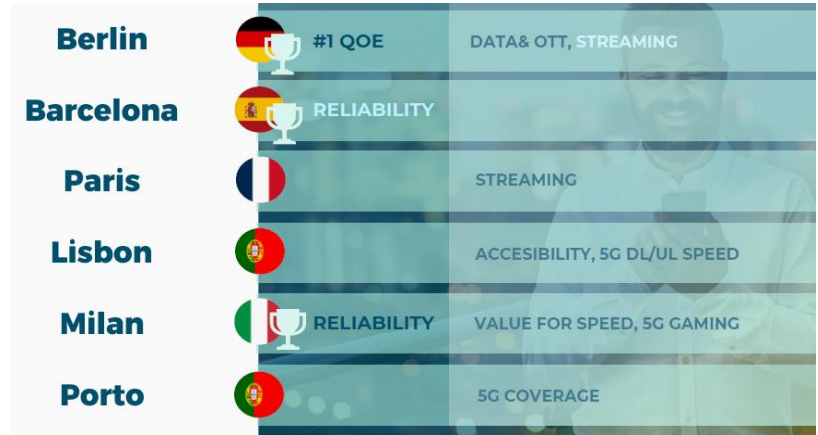
JULY 2023, PORTUGAL REPORT

<https://www.opensignal.com/reports/2023/07/portugal>

<https://medux.com/blog/all-5g-networks-are-not-created-equal-unveiling-true-qoe-5g-eu-rope-ii>



Mobile Network Experience Report | July 2023 | © Opensignal Limited



Best Mobile Coverage Portugal Q3—Q4 20



Best Mobile Coverage Portugal Q1—Q2 21



Fastest Mobile Network Portugal Q3—Q4 21



Fastest 5G Mobile Network Portugal Q1—Q2 22



Fastest 5G Mobile Network Portugal Q3—Q4 22

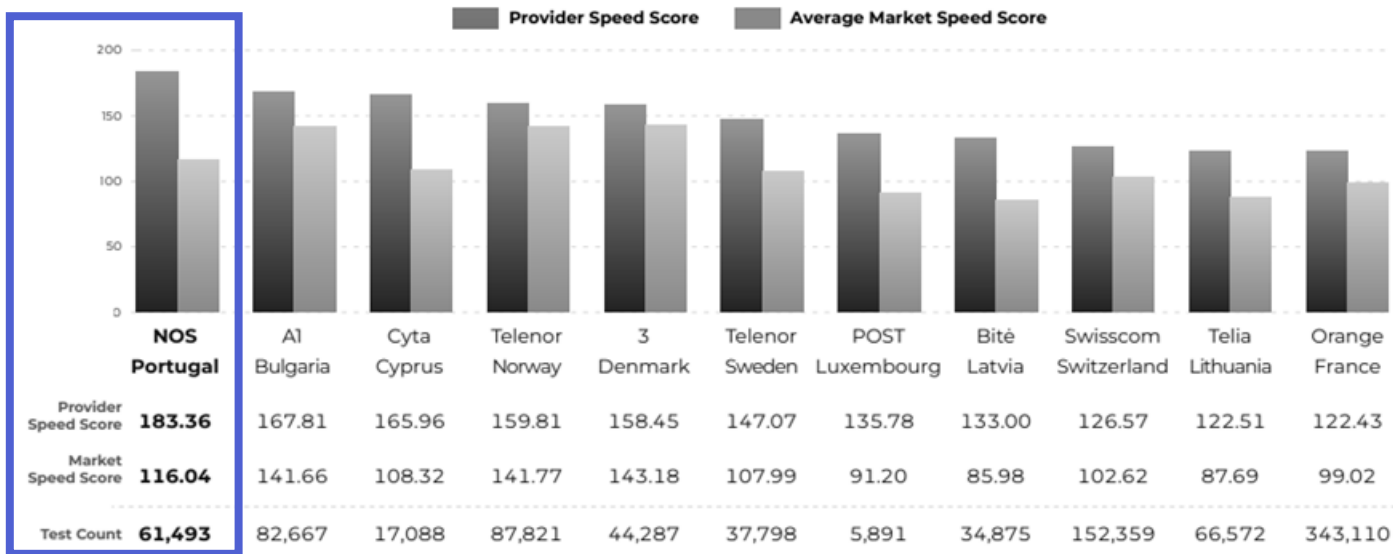
Widest 5G coverage is in Portugal. ...reaching a 5G registration time over 75% across the panel. Porto has the best 5G coverage, with over 90% technology registration...

The most consistent 5G speeds were observed in Lisbon. Lisbon secured first place both in 5G download and upload speeds. The typical (median) download speed in Lisbon was above 537 Mbps, and the typical upload speed was above 53 Mbps. Porto ranks as the second city in terms of download and upload speeds ...

...Europe's Speedtest Awards Winner Q2/Q3 23



NOS in Portugal is Europe's Speedtest Awards Winner for mobile network speed during Q2-Q3 2023. To win this award, NOS Portugal achieved a Speed Score of 183.36, with median download speeds of 190.33 Mbps and median upload speeds of 20.74 Mbps, from more than 16M tests evaluated in several European operators.



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The AI challenge: organizations are far from delivering target results



Companies Are Failing in Their Efforts to Become Data-Driven

by Randy Bean and Thomas H. Davenport

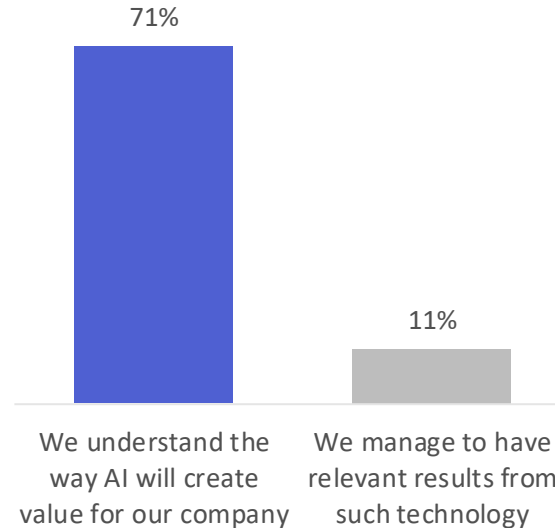
Published on HBR.org / February 05, 2019 / Reprint H04RW4

64 c-level tech and business executives survey



- 72% of survey participants report that they have **yet to forge a data culture**
- 69% report that they have **not created** a data-driven organization
- 53% state that they are **not yet treating data** as a business asset
- 52% admit that they are **not competing** on data and analytics.

The execution gap



Data-driven?

Further, the percentage of firms identifying themselves as being **data-driven has declined in each of the past 3 years** – from 37.1% in 2017 to 32.4% in 2018 to 31.0% this year (2019).

The AI challenge: failure reasons are people/organisation centric



FAILURE HAPPENS DESPITE OF A STRONG INVESTMENT IN TECHNOLOGY

92%

Say that their **pace of investment** in AI and Big Data is **increasing**

88%

Mention a **growing urgency in investing** in AI and Big Data

75%

Mention that the **fear of disruption** is the primary driver for such investments

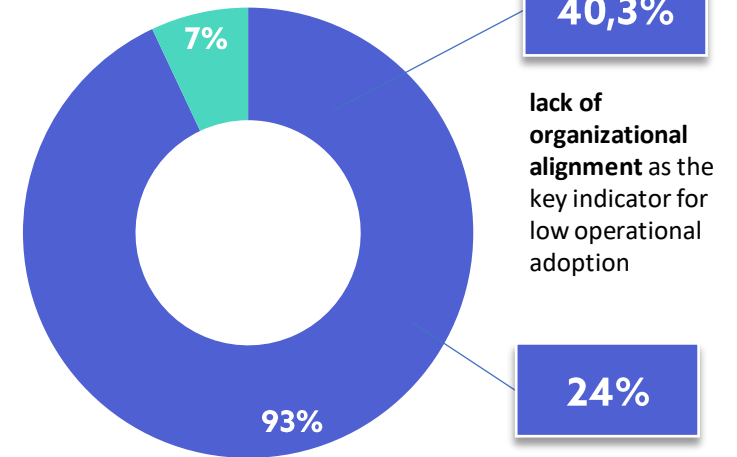
77%

Emphasize that the issue of **operational adoption** of Big Data and AI is a significant topic



Reasons for Big Data and AI investment not being successful

Technology



People and process issues

lack of organizational alignment as the key indicator for low operational adoption

cultural resistance is the fundamental factor for low operational adoption

CoE Advanced Analytics and Artificial Intelligence vision

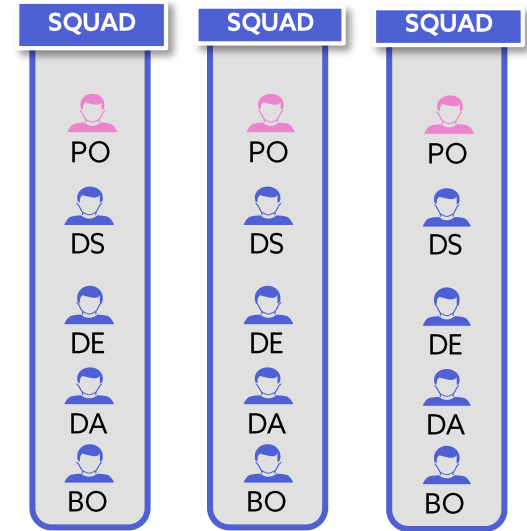


Enablement of the organization to understand and execute advanced analytics in all areas with potential to create impact

OBJECTIVES



ENABLERS

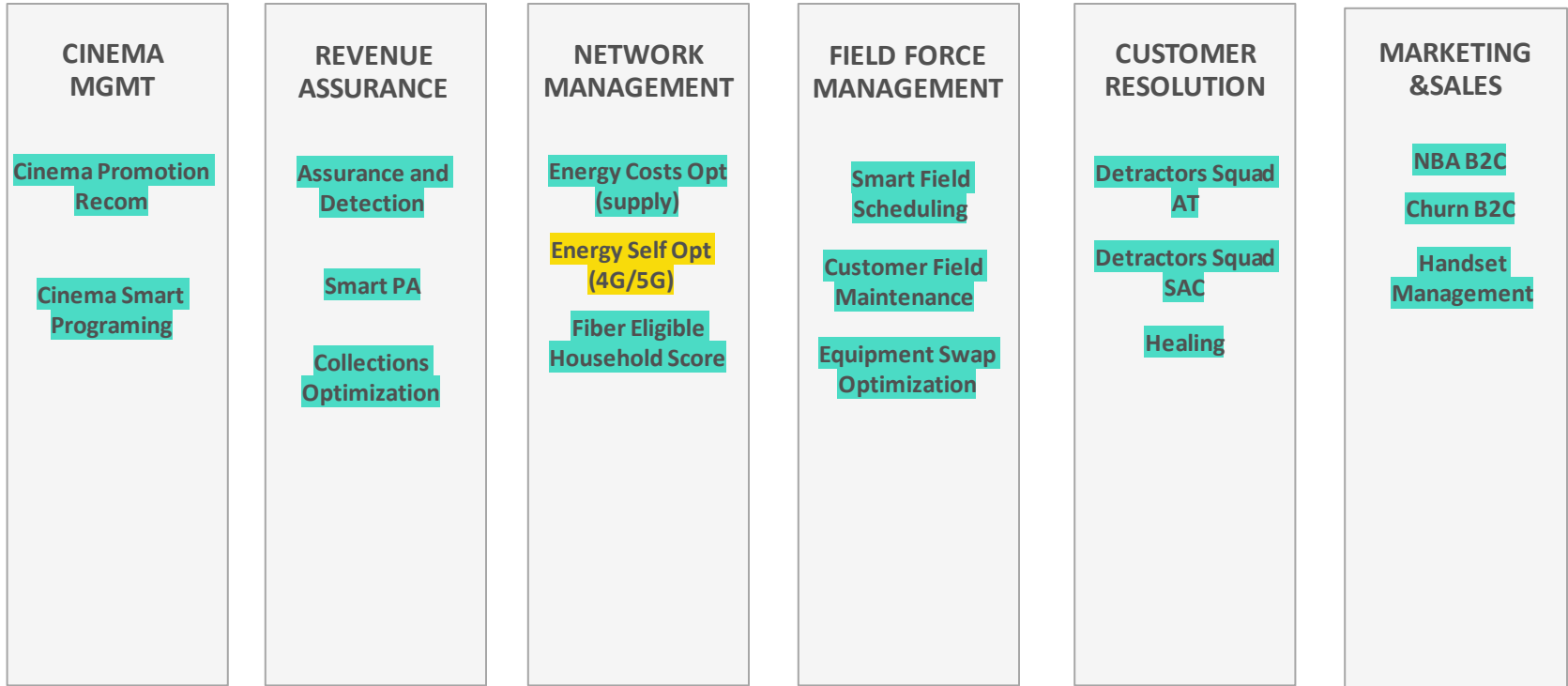


EXECUTION

Advanced Analytics Factory Projects: Energy Self Optimisation (ESO)



Factory AA (non-exhaustive)



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2030/40 as an important milestone for carbon neutrality for Telco's



66 MEMBERS
WITH A GLOBAL NETWORK

More mobile network operators joined the GSMA Climate Action Taskforce in 2023. The Taskforce has grown rapidly over the last three years and now has 66 members, with networks in most countries around the world.

70 OPERATORS
COMMITTED TO NEAR-TERM CLIMATE TARGETS

Mobile network operators are leaders in proactively committing to voluntary climate targets. Over the past year, eight operators submitted new near-term targets to the Science Based Targets Initiative (SBTI), bringing the global total to 70 operators, representing nearly half of global mobile connection industry. 53 operators have also committed to net zero targets.

80% OF CONNECTIONS DISCLOSED THEIR CLIMATE IMPACTS

A growing number of operators are publicly disclosing their climate impacts. 70 mobile network operators representing over half of mobile connections globally disclosed to the CDP in 2023, compared with 67 operators in 2022. In addition, data was gathered from nine large operators' sustainability reports, bringing the total coverage of disclosures to 80% of connections.

19 OPERATORS RECEIVED AN A-SCORE

The quality of disclosures has improved, with a record 19 operators receiving an A score in 2023. Over a quarter of operators disclosing to CDP received an A, compared with just 15% of all companies disclosing to CDP in 2022. Operators also improved the coverage and quality of Scope 3 disclosures - the most difficult to measure - with nearly two-thirds of operators disclosing to CDP on 10 or more Scope 3 categories.

3/4 OF INDUSTRY'S OVERALL CARBON EMISSIONS ARE SCOPE 3 VALUE CHAIN EMISSIONS

Three-quarters of the mobile industry's overall carbon emissions come from its value chain (Scope 3), highlighting the importance of engaging supply chains and customers. Over 90% of Scope 3 emissions came from just five Scope 3 categories: 1) Purchased goods and services; 2) Capital goods; 3) Fuel- and energy-related activities; 10) Use of sold products; and 12) Investments.

OPERATIONAL EMISSIONS ↓

Operational emissions fell in most regions between 2019 and 2022, led by a 50% reduction in Europe. In North America, Latin America, and Middle East and North Africa, operators reduced their emissions by 20-30%. Achieving the sector's 2030 targets requires the industry's overall emissions, including Scope 3, to fall by around 7% per year to 2030.

6% COMBINED SCOPE 1 & 2 EMISSIONS FELL BY

Operational emissions have fallen despite surging demand for data and connectivity thanks to progress on energy efficiency and renewable energy. Between 2019 and 2022, global internet traffic more than doubled and the mobile connections rose 7% while combined Scope 1 and 2 (market-based) emissions fell 6%.

10-20% ENERGY INTENSITY OF DATA TRANSMISSION FELL BY PER YEAR BETWEEN 2019 - 2022

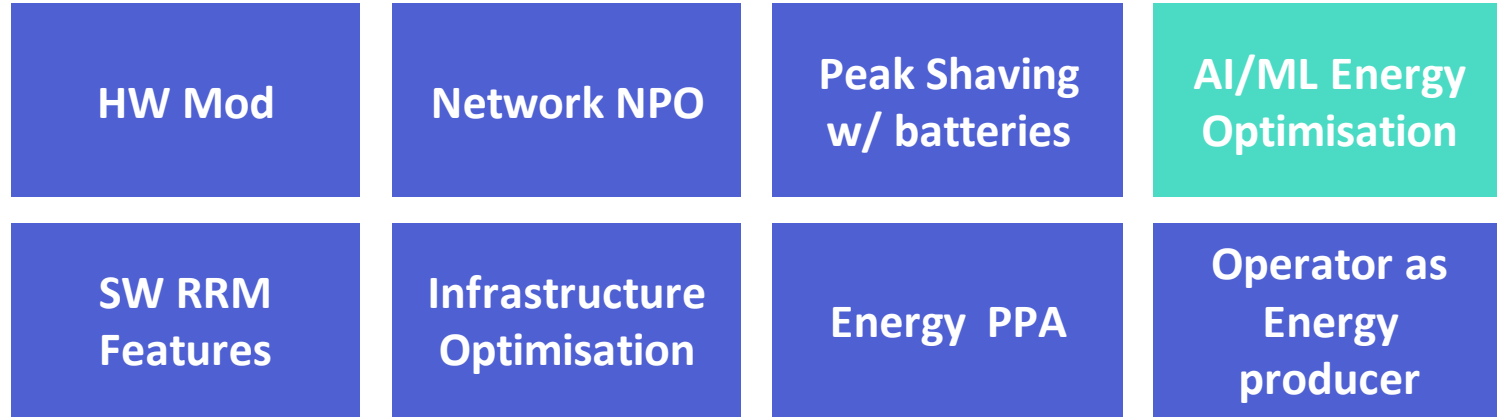
High and volatile energy prices over the past three years have increased the urgency of maximizing energy efficiency. Information from operators show that the energy intensity of data transmission fell by an average of 10-20% per year between 2019 and 2022. Globally, the average connection consumed around 30 kWh in

MOBILE NETWORK OPERATOR	SCIENCE-BASED TARGETS	CARBON NEUTRAL TARGET YEAR	NET ZERO TARGET YEAR
AT&T	2 °C	2035	
BT (EE)	1.5 °C		2045
DT	1.5 °C	2025	2040
SK Telecom	Committed Feb 2020	2050	
Telefonica	1.5 °C		2025/2040*
Telia	1.5 °C	2020	2030
Telstra	Committed Feb 2020	2020	2050
Verizon	Committed Feb 2019	2035	2040
Vodafone	1.5 °C	2030	2040

NOS goal is to reach carbon neutrality by 2040. To that end, we will work on four key objectives: increase our consumption of renewable energy, increase the efficiency of our operations, decarbonize buildings and shops, and make the transition to a low carbon vehicle fleet.

Between 2015 and 2020, we reduced our data traffic energy consumption by 80% (modernization of RAN network, air conditioning dismantling, virtualization and other initiatives)

Breaking the energy curve requires a holistic approach



Savings across the network can reach 30%: all technologies, all bands, all sites, infrastructure and demand cycles; et the right priority by taking a holistic view on energy savings

Energy Consumption is strongly related to #cells, Tx mode and load



NODE Type	4G/5G bands [MHz]	ETSI AVG [W]	ETSI Daily [kWh/day]
Low Capacity	700+800	1 954	47
Mid Capacity	700+800+2100	2 868	69
High Capacity	700+800+2100+1800	3 416	82
Very High Capacity	700+800+2100+1800+2600	4 348	104
High Capacity + 5G mMIMO	700+800+2100+1800+3500	4 735	114
Very High Capacity + 5G mMIMO	700+800+2100+1800+2600+3500	5 667	136

Delta NR3500 (mMIMO 32T32R)

+32 kWh

Delta L2600 (4T4R RRU)

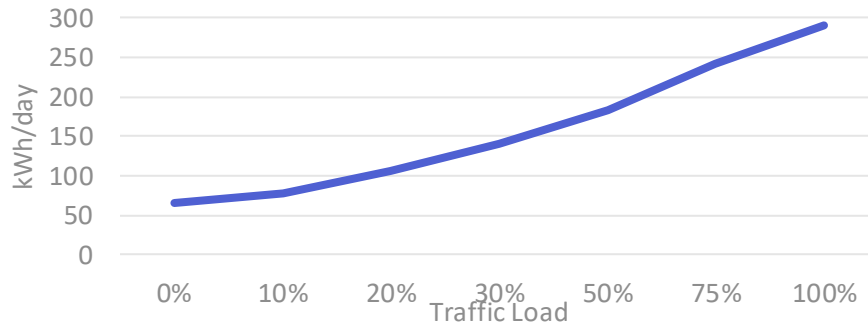
+22 kWh

Delta L1800 (shared RRU)

+13 kWh



kWh/day vs. load for a VHC35 configuration



mMIMO 5G 3500 antennas contribute with high consumption (high capacity); 1800 shares RRU with 2100 (smaller incremental); consumption is not linear with load: 2,4x higher at 50% load vs. 10%

Most impactful features include temporary deactivation of cells



Cell Sleep Mode

- Automatic detection of coverage/capacity cells
- Traffic load controlled sleep on capacity cells/frequencies
- Savings >10%

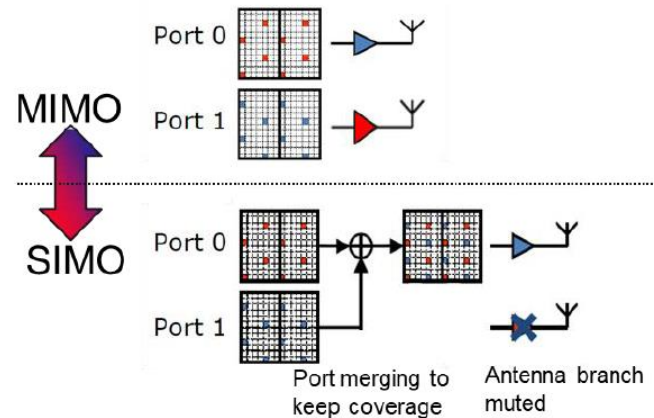
- 1) Radio enters hibernation state with most components turned off
- 2) Automatic cell deactivation and deep sleep trigger performed by OSS based on time periods

Status	Idle	Locked	Deep Sleep
Consumption [W, ind.]	350	240	100
Reduction [%]		-31%	-71%
Energy 6h, 3s, 1d [kWh]	6,3	4,3	1,8
Saving 6h, 3s, 1y [kWh]		-722,7	-919,8
Saving 2000 sites [k€]		-202	-258

Example assuming
0,14€/kWh

MIMO Sleep Mode

- Traffic load controlled sleep of MIMO configuration, branch muting
- Sleep on coverage cells/frequencies
- Proven in field tests >5%
- Average user throughput maintained, reduction of coverage



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Mobile network energy cost is 80% driven by the radio network



MOTIVATION

**80%
Radio**

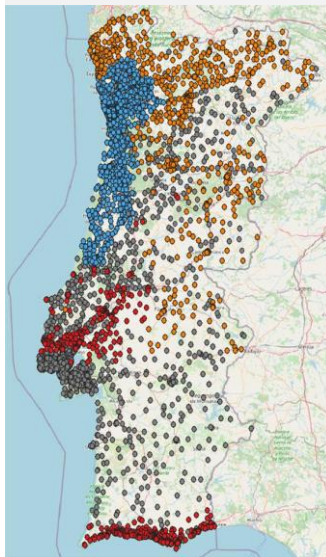
80% Energy of mobile network is radio & baseband

~50%: target sites to be optimised by AI/ML (urban areas)

Before AI/ML, approach considered a static approach, predominantly at lower traffic periods, similar in all sites, not considering QoE

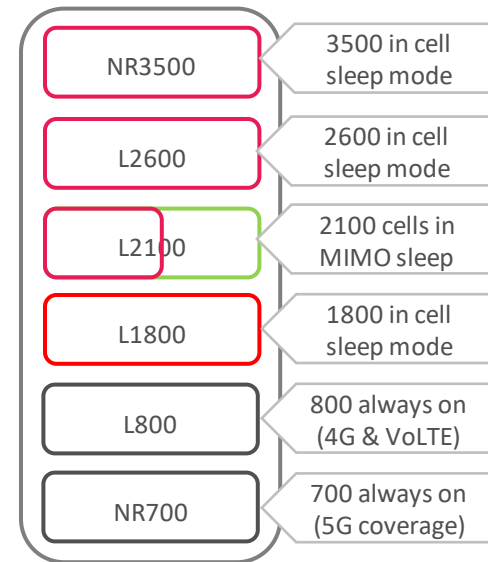
MOBILE NETWORK

4k sites | 12k sectors | 51k cells



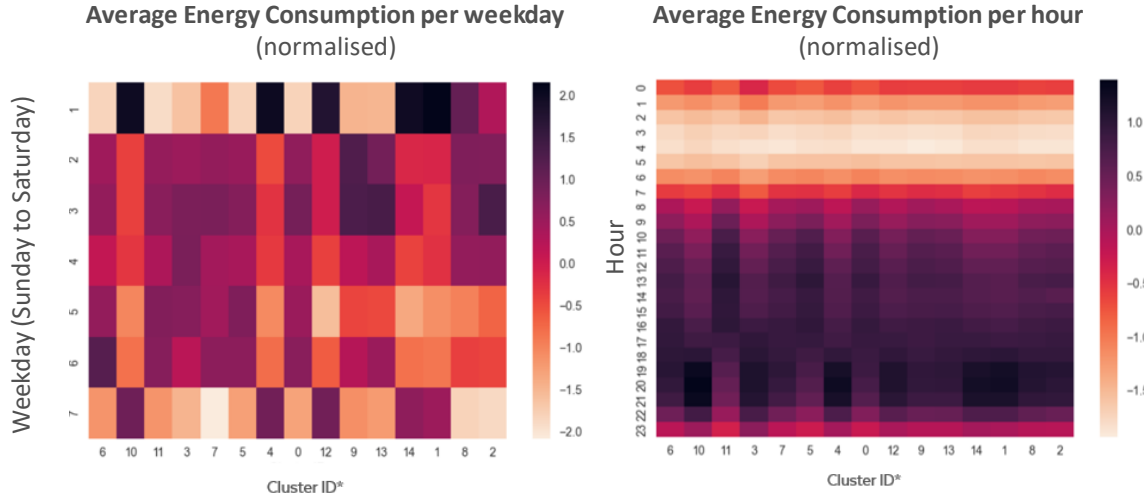
MINIMIZE ENERGY CONSUMPTION

Cell shutdown Options



KEEP EXPERIENCE (DL throughput)

Experience modelling done by sector, actuating on a per cell basis



Sectors were clustered per consumption pattern

Sectors have different configs/#cells, demand and consumption profiles hence Optimisation granularity is by sector, actuating on each sector cells



Radio Feature's Parameters

- # RRC Connected Users
- % used PRBs

Target variable

- DL User throughput [Mbps]

AI/ML Algorithm will change radio feature parameters to ease/delay cell sleep mode per frequency, keeping the defined target throughput

Algorithm estimates target throughput when shutting down cells



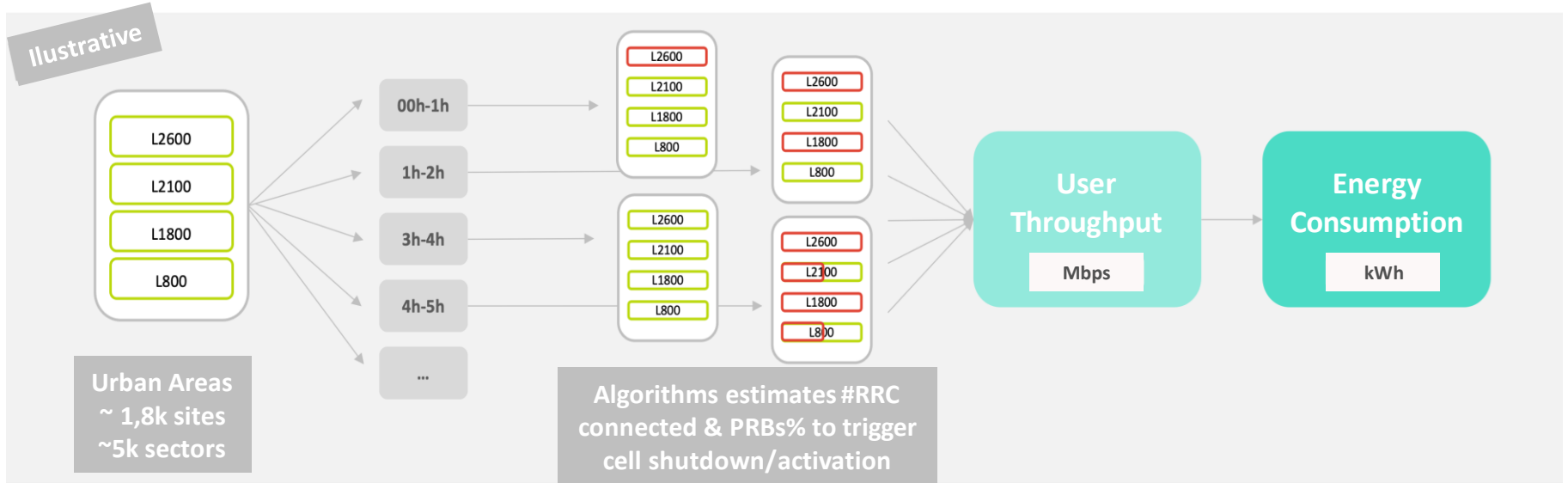
For a given sector with 4x 4G cells...

For each hour block...

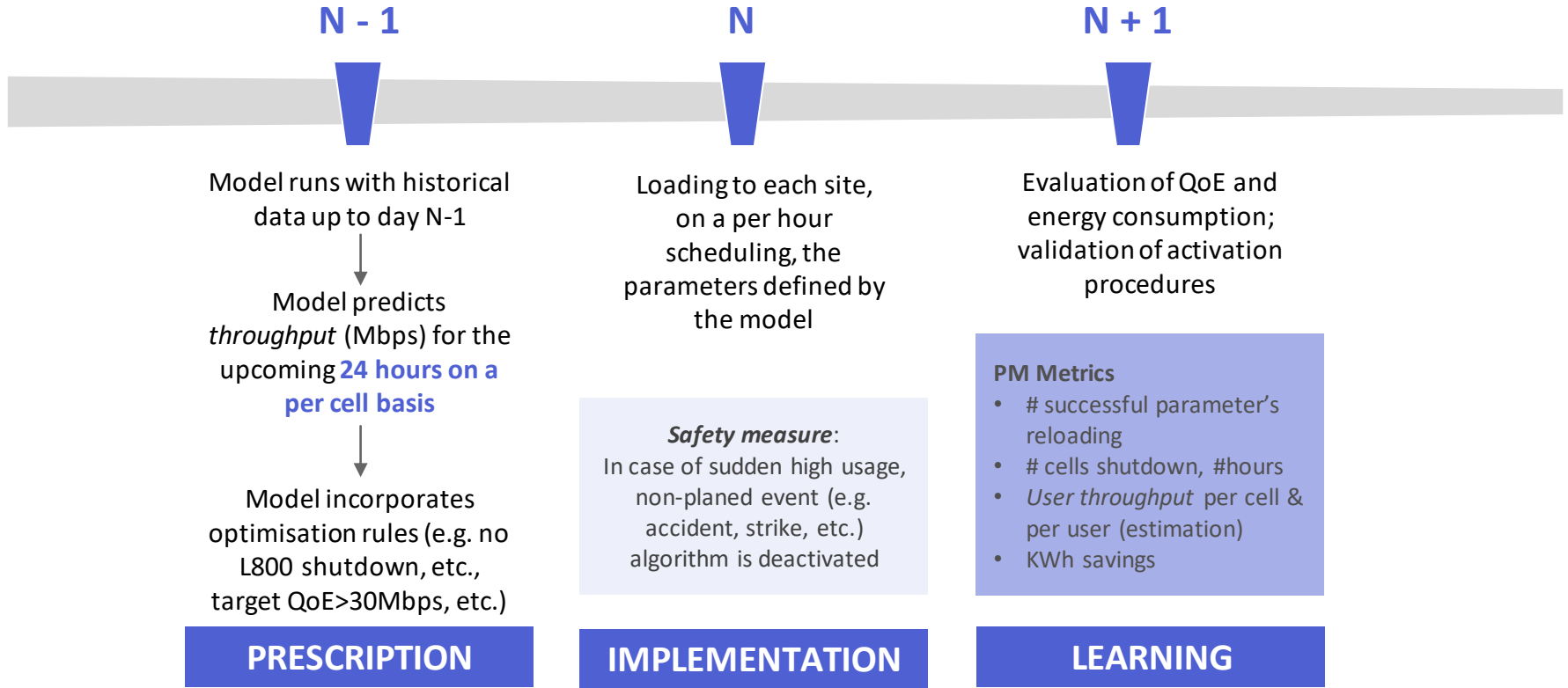
Target cell activation / shutdown is defined...

Keeping QoE above target...

Minimising energy consumption 😊



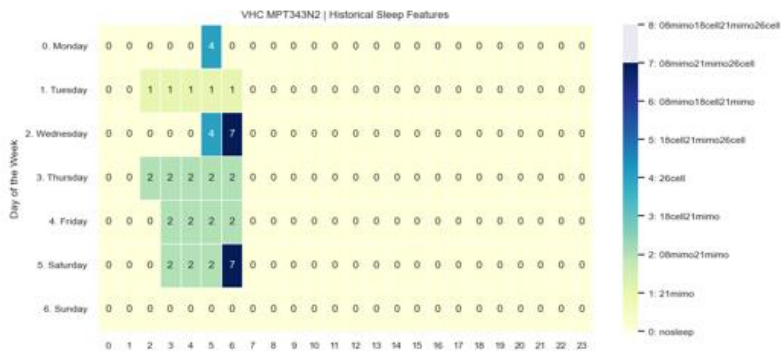
Algorithm learns and adapts the model per sector based on real QoE



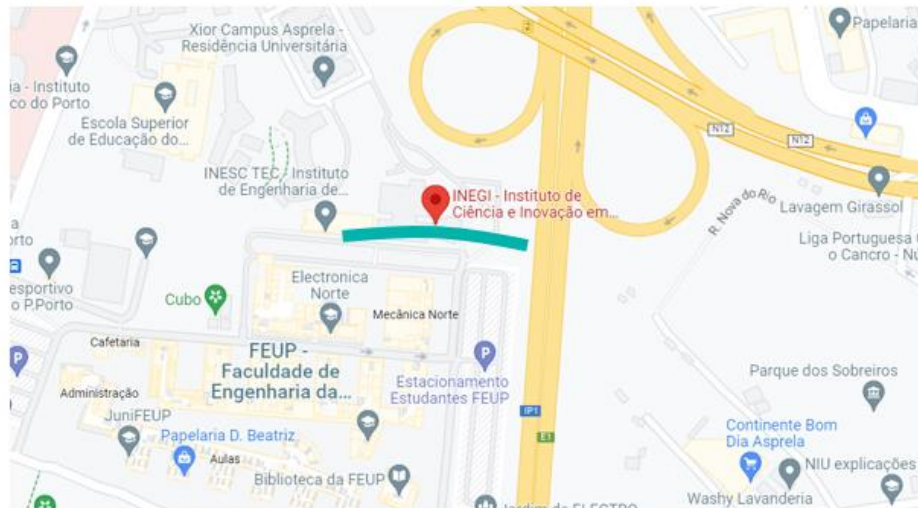
AI/ML added significant power savings when compared to static



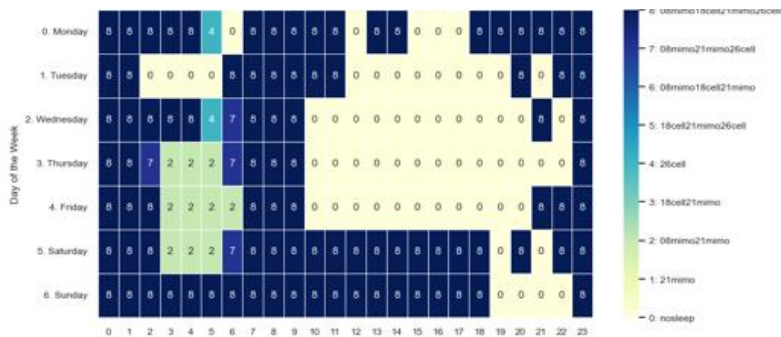
Sector shutdown profile: **static model** (night shutdown)



Sector shutdown serving area: **FEUP** (Porto University Area)



Sector shutdown profile: **AI/ML model** (QoE target)

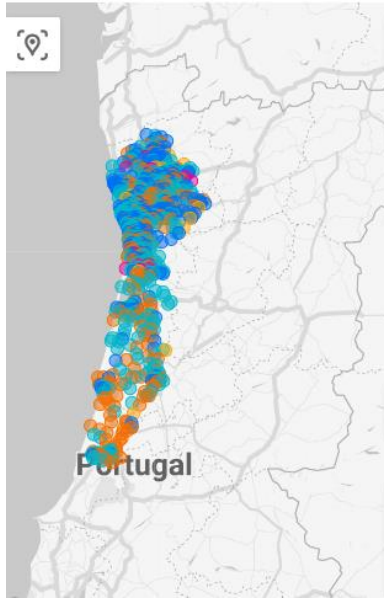


Much more hours with several cells in shutdown (higher energy savings) while keeping QoE >30 Mbps vs static model (only night shutdown)

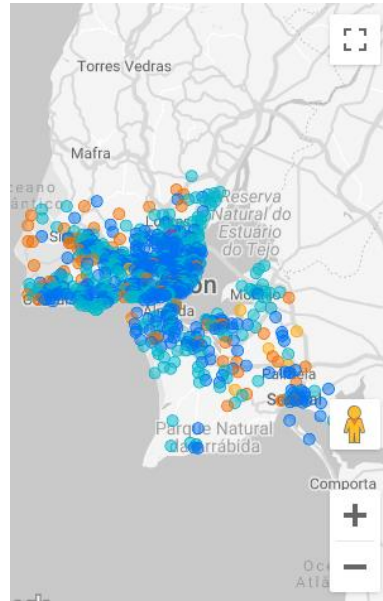
ESO AI/ML is running on metropolitan areas, achieving ~8% savings



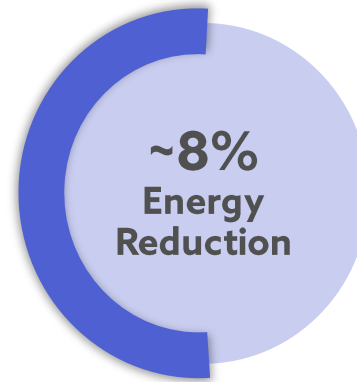
Porto & North:
~1000 sites



Lisbon & Setúbal:
~800 sites



Estimated savings/year
[% , T CO2]



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Wrap-up and Future Work



- 1 Despite the AI momentum, most companies are still targeting to improve results and optimise process and people transformation;
- 2 Telco's are targeting carbon neutrality to 2023/2040; AI/ML energy optimisation is just a small part of a holistic approach to minimise carbon footprint and net zero targets
- 3 Energy Consumption is strongly related to #cells, Tx mode and load and hence addressing 5G mMIMO and 4G 2600/1800 bands is a must to reach relevant gains
- 4 NOS developed an advanced AI/ML algorithm that prescribes RRM feature settings for each cell on the next day, assuming a minimum QoE, and adapts in case of deviations
- 5 Results allowed to save 8% (~0,5M€/year) of the energy in the two main metropolitan urban areas, avoiding 1k Ton Co2 emissions
- 6 Future work is centered in upgrading SW features and HW optimizing the deep sleep gain and redesigning the algorithm to 5G SA (currently developed to 5GNSA)



Thank you!

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