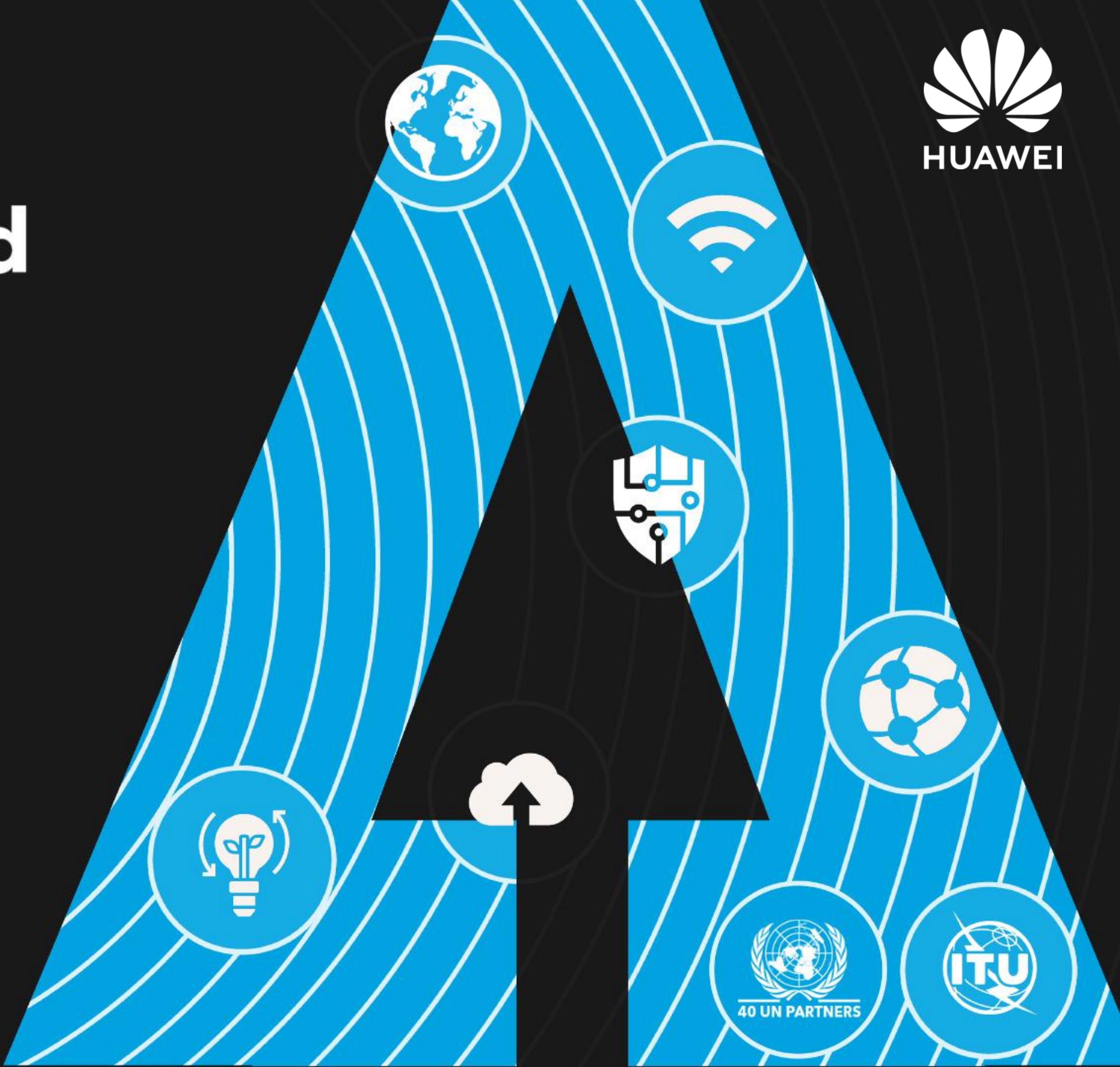
ITU Events

# AI for Good
## Machine Learning 5G Challenge

# *AI/ML for 5G-energy consumption modelling*

**Nicola Piovesan**
Huawei

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**USD 92.4billion**
2022 total revenues

**25.1%**
of total revenues in R&D investment

**170+**
countries and regions

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# Nicola Piovesan

- **About**
  - Senior Researcher at Huawei Technologies, France
  - Assistant Researcher at CTTC, Spain (2016-2019)
  - PhD from Universitat Politecnica de Catalunya, Spain
- **Current Research**
  - Energy Efficiency in 5G and beyond RANs
- **Contact**
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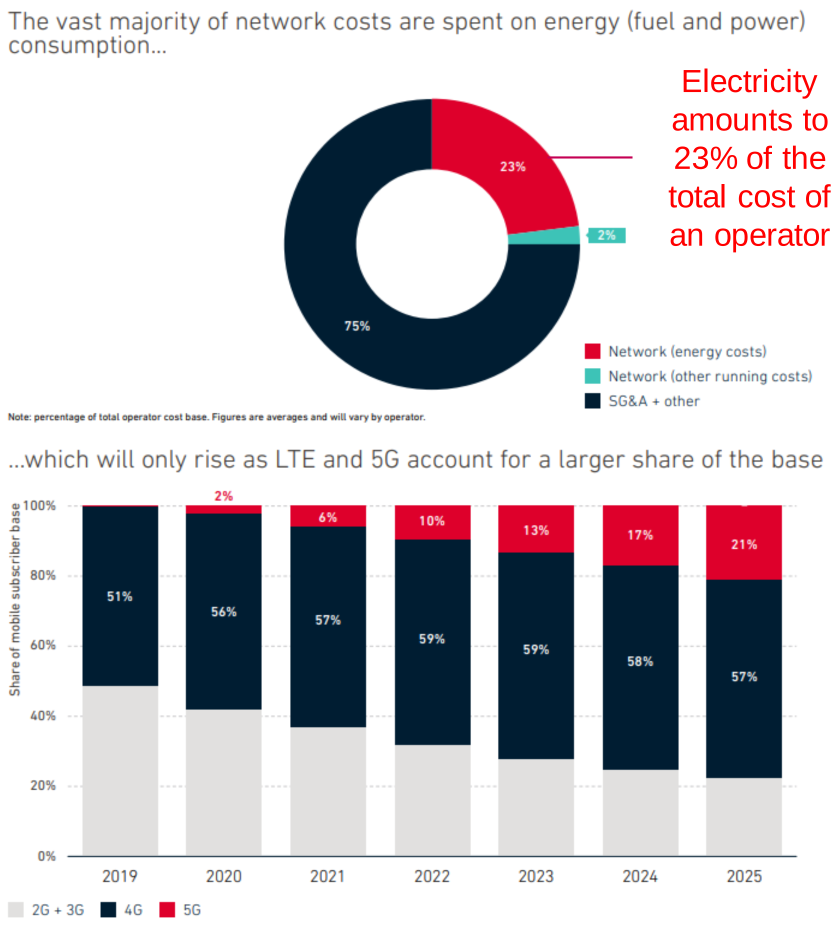
# Introduction

# Telecom industry energy consumption

- The **fifth generation (5G)** of radio technology brings about new
  - services,
  - technologies, and
  - networking paradigms
- The **energy consumption** of cellular networks, however, is concerning
  - The telecoms industry utilizes around 3% of the globally consumed energy [1]
  - The electricity bill of an operator accounts for 90% of its OPEX and 23% of its total expenditure [2]




Network costs (Source: GSMA [2])

[1] GSMA, the 5G guide: A preference for operators, 2019

[2] GSMA, 5G energy efficiencies: Green is the new black, 2020

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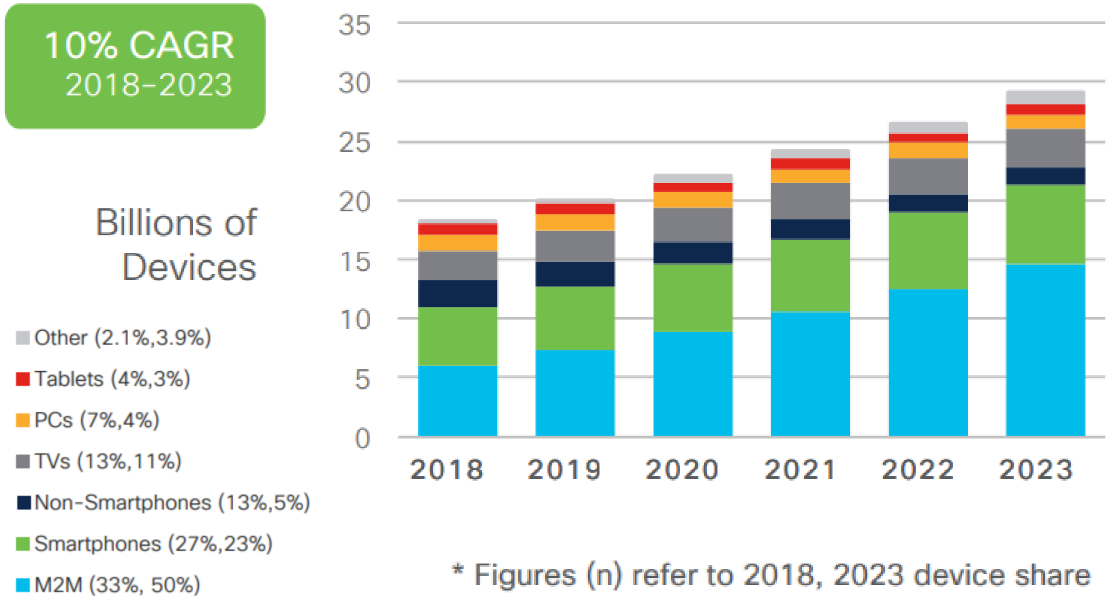
# … and consumption is expected to grow

- Cellular energy **consumption is expected to continue increasing** due to the more infrastructure needed to serve:
  - the growing number of subscribers and devices [3],
  - the larger bit rate services, e.g. 4K HD TV, AR/VR [3], and
  - the requirements of new verticals, e.g. Internet of things (IoT) and industry 4.0 [3]



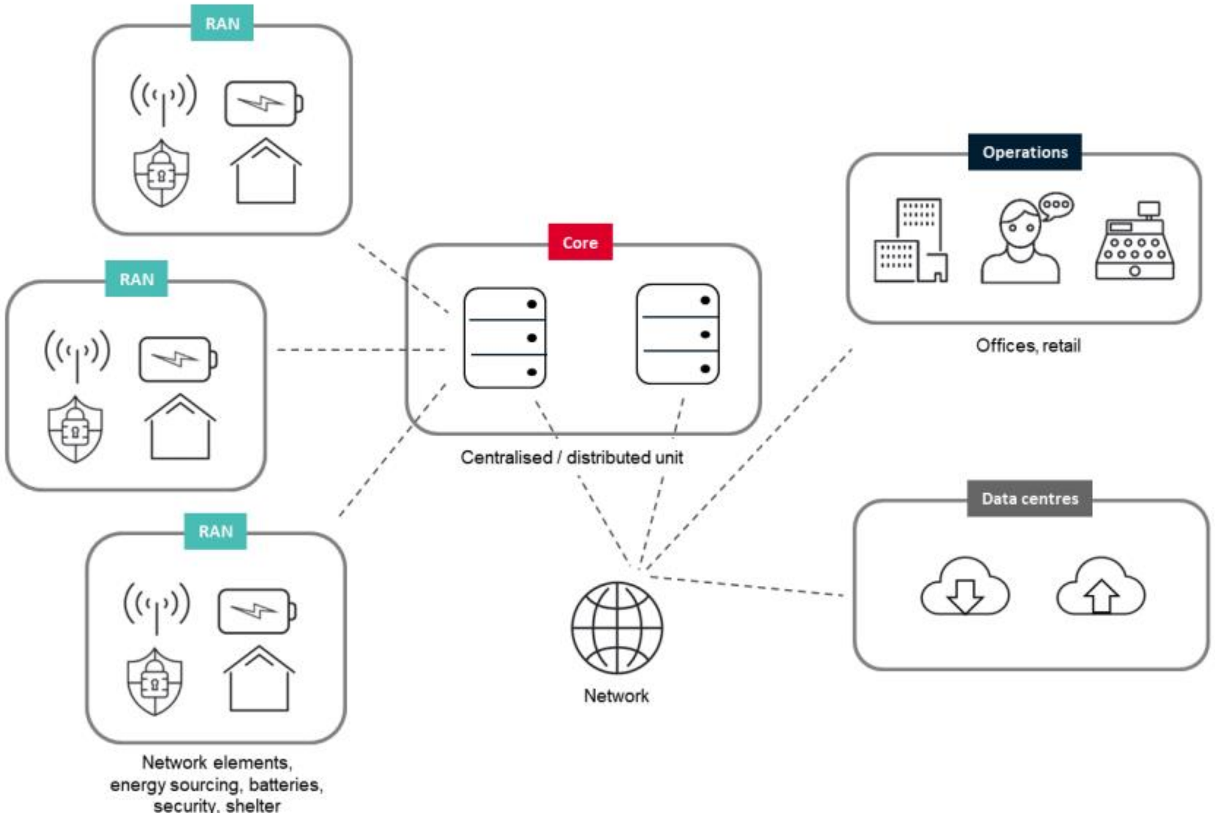

Device forecast – The increasing trend (Source: CISCO [3])


Logic of energy consumption increase

[3] CISCO, Cisco Annual Internet Report (2018–2023), 2020

# Which elements of the NETWORK consume the most?

- The **radio access network (RAN)** consumes most of the energy in a network
  - **73%** of the energy is consumed in the **RAN**,
  - 13% in the **core**,
  - 9% in the **data centers**, and
  - 5% in the rest of the network

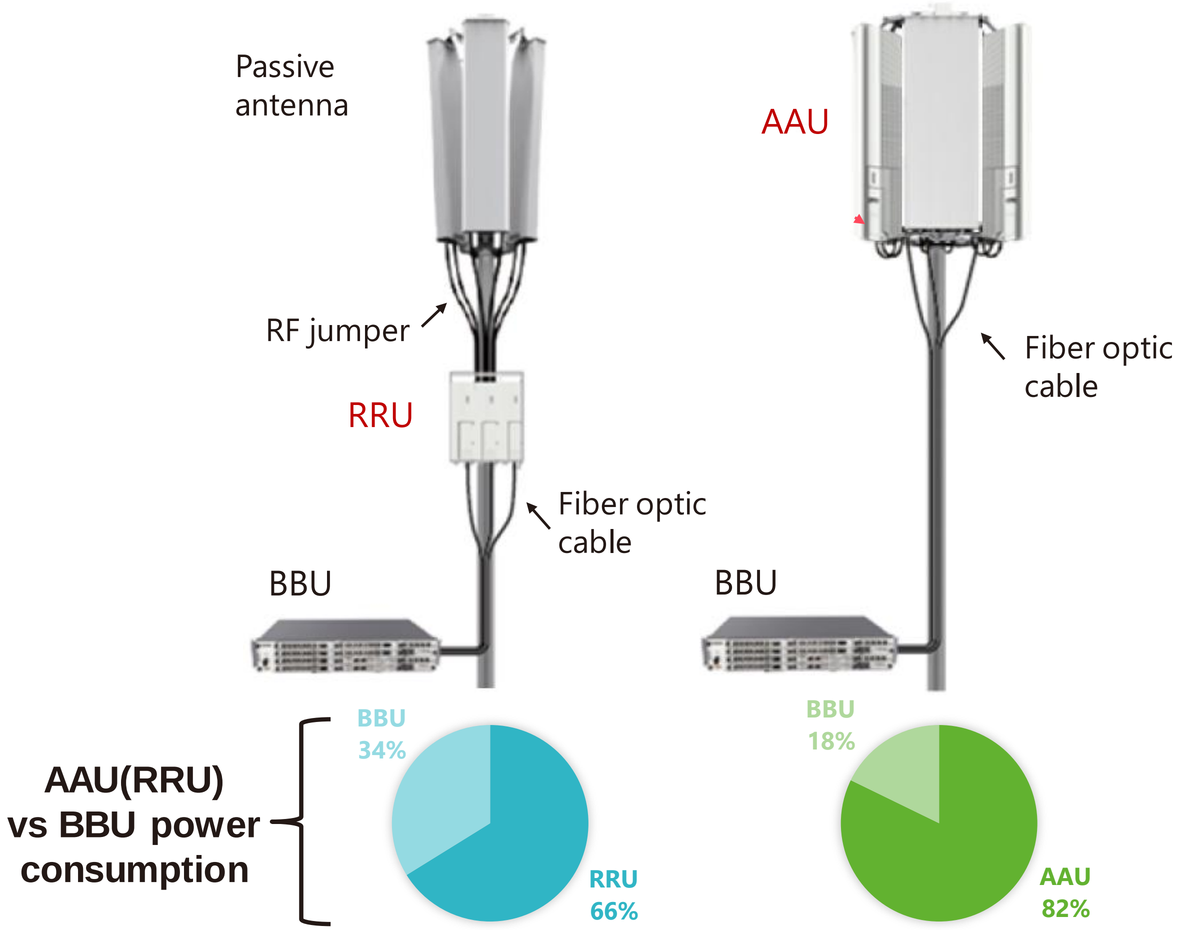



Network decomposition (Source: GSMA [4])

[4] GSMA, Going green: benchmarking the energy efficiency of mobile, 2021

# Which elements of the RAN consume the most?

- The **radios** consumes most of the energy in a base station (BS)*
  - In a non-massive MIMO BS, the radio, a.k.a. **remote radio unit (RRU)**, consumes around 66% of the energy
  - In a massive MIMO BS, the radio, a.k.a. **active antenna unit (AAU)**, consumes around 82%
  - The **base band unit (BBU)** consumes a non-negligible amount of energy




Base station architecture

* For simplicity, allow us to see the RAN as a collection of BSs

# From where is the network energy obtained?

- Around 54% of the total energy used to power networks still comes from **$CO_2$ emitting sources**
  - 43% of total energy consumption is supplied by the **traditional grid**, and
  - 11% from **diesel**
    - more concentrated in developing regions where renewables and grid is less prevalent
- 46% of total energy consumption is supplied by **renewables**

| | Verizon | Vodafone | Telefónica |
|---|---|---|---|
| **Energy consumption** | | | |
| Networks (base stations, data and switching centres) | 89% | 95% | 95% |
| Offices and retail | 9% | 5% | 5% |
| Other | 2% | - | - |
| **Net zero** | 2040 | 2040 | 2030* |
| **Emissions reduction pathway** | Reduce carbon intensity by 50% by 2025 | Reduce $CO_2$ emissions by 50% by 2025 | Reduce $CO_2$ emissions by 70% by 2030 |
| **Renewables** | 50% of total electricity consumption by 2025 | 100% of electricity consumption in European network footprint by 2021 | 100% of total energy consumption by 2030 |
| **Network overhaul** | 2G/3G sunsetting; copper broadband decommissioning; RAN site efficiencies (batteries, air-con systems, power-saving/sleep mode) | | |

Energy consumption and climate targets from major operators (Source: GSMA [4])

[4] GSMA, Going green: benchmarking the energy efficiency of mobile, 2021

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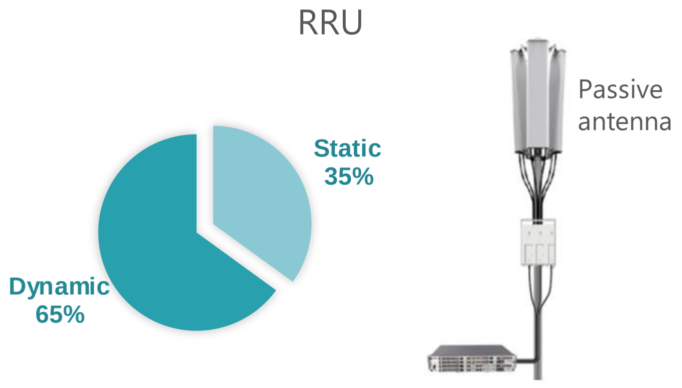
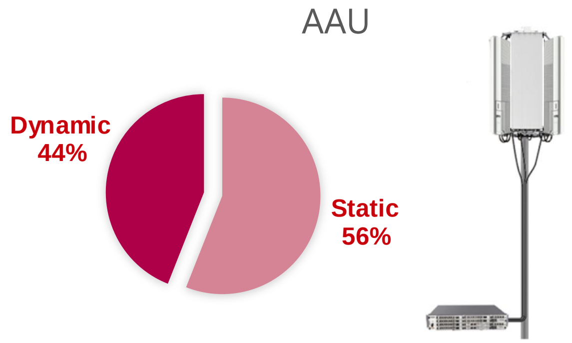
# Energy saving in 5G NR RAN

# RAN architectures and energy consumption

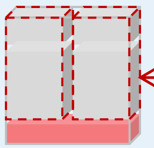
- In a modern RAN, two main types of base stations can be generally found: **remote radio units (RRUs)** and **active antenna units (AAUs)**
- The base station energy consumption can be considered as the sum of a **static** (i.e. traffic independent) and a **dynamic** (i.e. traffic dependent) part
- **Static energy** accounts for 35% of the total energy consumption in RRUs and 56% in AAUs



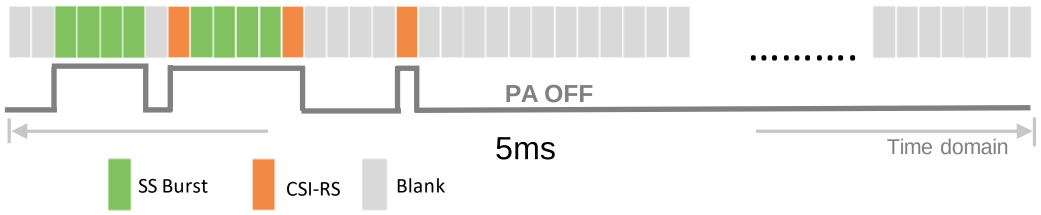



# Main 5G 3GPP NR network energy saving enablers

## Symbol-level Shutdown (cell-DTX)

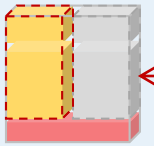


Instantaneous OFDM symbol shutdown when no data is transmitted

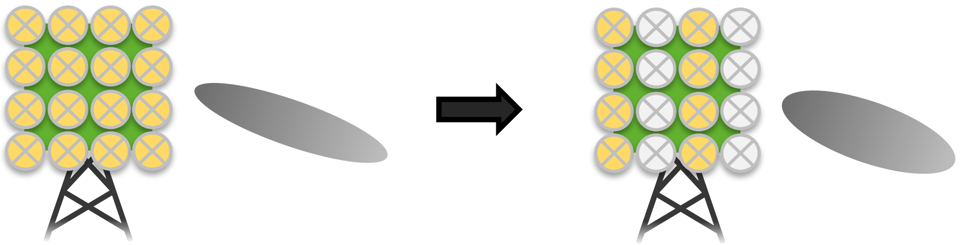



- Instantaneous symbol-level operation
- No UE performance degradation expected
- Around 15% energy savings reported

## Channel-level Shutdown

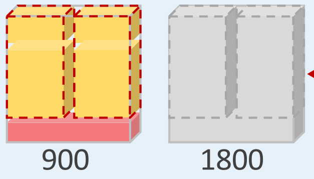


MIMO transceiver / channel shutdown when demand is low

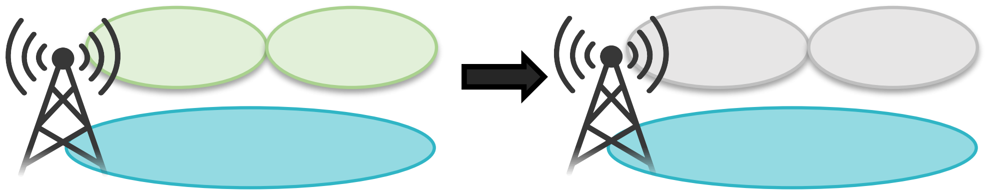


- Operating in the time frame of seconds to minutes
- It can adjust common channel TX power of cell to ensure coverage
- Capacity loss may occur

## Carrier-level Shutdown




Carrier shutdown when demand is low



- Operating in the order of minutes
- Multi-carrier power amplifier can be shutdown if all its carrier are OFF
- Coverage & capacity loss may occur

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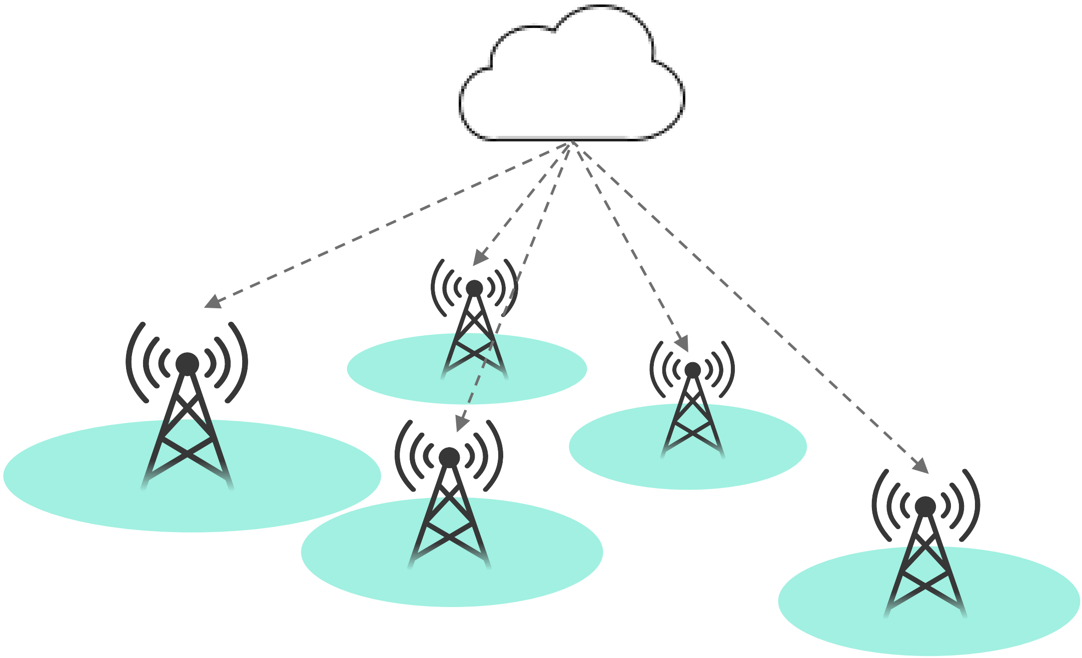
# Energy consumption optimization

- Reducing the network energy consumption requires **optimally configuring the aforementioned energy saving methods**
  - This requires knowing **how this methods impact the energy consumption of different base stations**, e.g. different architectures, products, configurations
  - The accurate **modelling of base station energy consumption** is fundamental!



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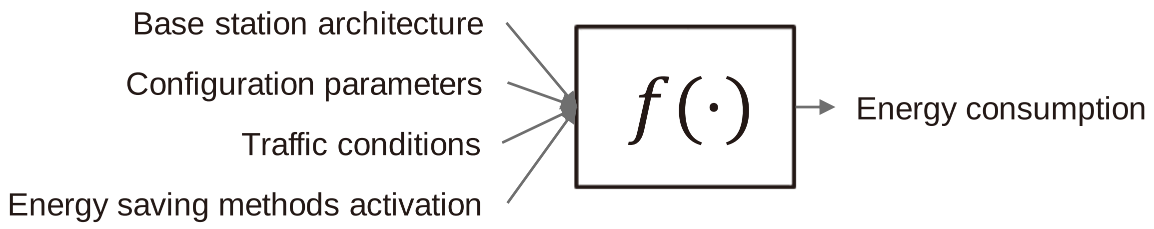
# Problem and challenges

# Objective

- The objective is to accurately estimate the energy consumption of a base station, considering that such value is closely related to the following features:
  - **Base station architecture**, e.g., number of antennas, specific product
  - **Configuration parameters**, e.g., number of cells, bandwidth, frequency
  - **Energy saving methods activation**, e.g., which energy saving feature is activated and for how long
  - **Traffic conditions**, e.g., fraction of resources used to deliver data to the users



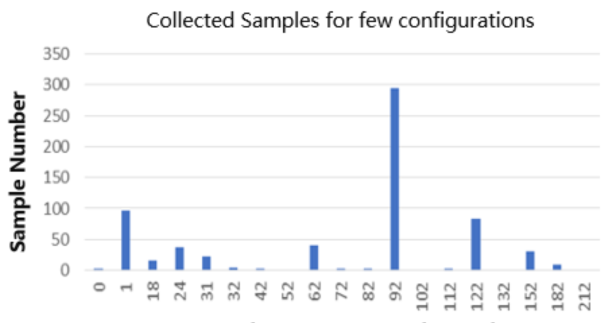
# Challenge objectives

- **Objective B: Achieve generalization across different base station products**
  - Estimate the energy consumption of a new base station product based on measurements collected from existing ones, such as Products A, B, and C
  - For example, if training data is available for these three products, the model must be able to provide an estimate of the energy consumed by Product D

- **Objective C: Achieve generalization across different base station configurations**
  - Predict the energy consumption of newly configured parameters based on a small number of real network configuration parameters
  - For instance, if the training data contains samples collected from many base station products, when the transmit power is set to 30, 35, and 43 dBm, the model must estimate the energy consumed when the transmit power is set to 40 dBm

# Technical challenges

- The **distribution of data** samples is extremely **imbalanced**
  - The proportions of samples in which the energy saving features are activated is greatly affected by the traffic load and type of base station
  - Some values of a parameter may appear only in a reduced number of base stations
- The **mechanism managing the energy saving features** of the base stations
  - Do not have explicit mathematical expressions and the logic is complex

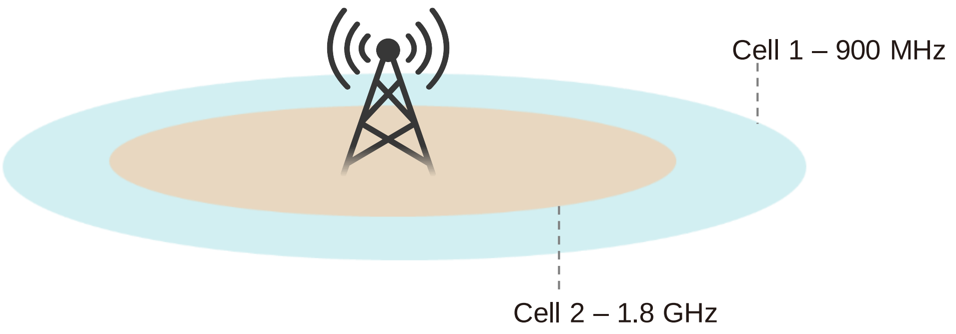


# Source data

# Available datasets

- We consider measurements for **8 days** from **>1000 RRU/AAUs**, comprising **12 different products**

- The following datasets are available:
  - **Base Station basic information**
    - configuration parameters and hardware attributes.
  - **Cell-level data**
    - hour-level counters, including service compliance counters (e.g., load) and energy-saving methods counters (e.g., duration of energy saving mode activation)
  - **Energy consumption data**
    - hour-level energy consumption specifications (e.g., total energy consumption of the base stations)

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# Base Station basic information

- The base station basic information datasets includes the following fields:
  - **BS:** Identifier of the base station
  - **CellName**: Multiple cells can be configured in each BS, they are named CellX, with X=0,1,…
  - **RUType**: Name of the radio unit product
  - **Mode**: Transmission mode
  - **Bandwidth:** Normalized cell bandwidth
  - **Frequency**: Normalized cell frequency
  - **Antennas**: Number of antennas
  - **TXpower**: Maximum transmit power of the cell

| BS | CellName | RUType | Mode | Frequency | Bandwidth | Antennas | TXpower |
|---|---|---|---|---|---|---|---|
| B_0 | Cell0 | Type1 | Mode2 | 365 | 20 | 4 | 6.87 |
| B_1 | Cell0 | Type2 | Mode2 | 532 | 20 | 4 | 6.87 |
| B_2 | Cell0 | Type1 | Mode2 | 365 | 20 | 4 | 6.87 |
| B_3 | Cell0 | Type2 | Mode2 | 532 | 20 | 4 | 6.87 |
| B_4 | Cell0 | Type2 | Mode2 | 532 | 20 | 4 | 6.87 |
| B_5 | Cell0 | Type3 | Mode2 | 189 | 10 | 4 | 6.42 |
| B_6 | Cell0 | Type3 | Mode2 | 189 | 10 | 4 | 6.42 |
| B_7 | Cell0 | Type1 | Mode2 | 365 | 20 | 4 | 6.87 |
| B_8 | Cell0 | Type1 | Mode2 | 365 | 20 | 2 | 6.87 |
| B_9 | Cell0 | Type4 | Mode2 | 532 | 20 | 2 | 6.87 |
| B_10 | Cell0 | Type1 | Mode2 | 365 | 20 | 2 | 6.87 |
| B_11 | Cell0 | Type4 | Mode2 | 532 | 20 | 2 | 6.87 |
| B_12 | Cell0 | Type4 | Mode2 | 532 | 20 | 2 | 6.87 |

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# Cell-level data

- The cell level dataset includes the following fields:
  - **Time:** Time at which the measurement was collected
  - **BS:** Identifier of the base station
  - **CellName**: Multiple cells can be configured in each BS, they are named CellX, with X=0,1,…
  - **Load**: Load of each cell (share of used resources)
  - **Energy saving mode**: Intensity of activation of different energy saving modes

| Time | BS | CellName | load | ESMode1 | ESMode2 | ... | ESMode6 |
|---|---|---|---|---|---|---|---|
| 1/2/2023 0:00 | B_821 | Cell0 | 0.20 | 0 | 0 | | 0.37 |
| 1/2/2023 1:00 | B_821 | Cell0 | 0.14 | 0 | 0 | | 0.39 |
| 1/2/2023 2:00 | B_821 | Cell0 | 0.09 | 0.14 | 0 | | 0.34 |
| 1/2/2023 6:00 | B_821 | Cell0 | 0.04 | 0.50 | 0 | | 0.23 |
| 1/2/2023 7:00 | B_821 | Cell0 | 0.15 | 0 | 0 | | 0.40 |
| 1/2/2023 8:00 | B_821 | Cell0 | 0.22 | 0 | 0 | ... | 0.33 |
| 1/2/2023 9:00 | B_821 | Cell0 | 0.21 | 0 | 0 | | 0.36 |
| 1/2/2023 10:00 | B_821 | Cell0 | 0.17 | 0 | 0 | | 0.40 |
| 1/2/2023 11:00 | B_821 | Cell0 | 0.18 | 0 | 0 | | 0.39 |
| 1/2/2023 12:00 | B_821 | Cell0 | 0.20 | 0 | 0 | | 0.37 |
| 1/2/2023 13:00 | B_821 | Cell0 | 0.24 | 0 | 0 | | 0.35 |
| 1/2/2023 14:00 | B_821 | Cell0 | 0.14 | 0 | 0 | | 0.40 |
| 1/2/2023 0:00 | B_821 | Cell0 | 0.20 | 0 | 0 | | 0.37 |

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# Energy consumption data

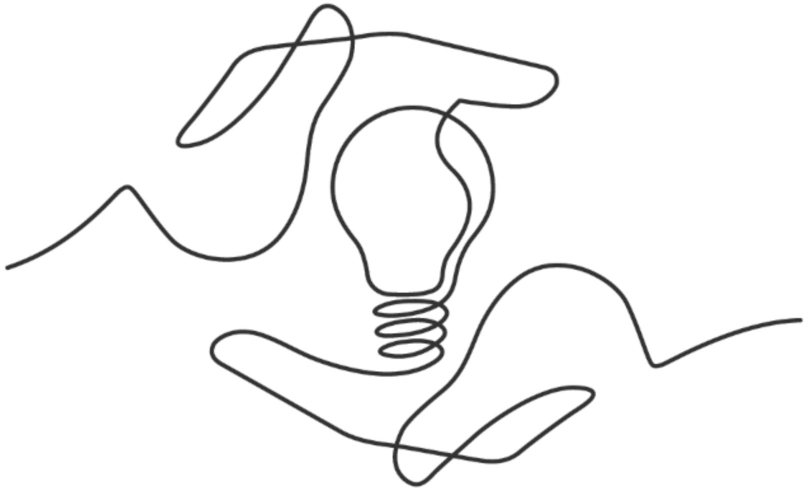
- The energy consumption dataset includes the following fields:
  - **Time:** Time at which the measurement was collected
  - **BS:** Identifier of the base station
  - **Energy**: Energy consumption of the base station

| Time | BS | Energy |
|---|---|---|
| 1/1/2023 1:00 | B_0 | 64.27 |
| 1/1/2023 2:00 | B_0 | 55.90 |
| 1/1/2023 3:00 | B_0 | 57.69 |
| 1/1/2023 4:00 | B_0 | 55.15 |
| 1/1/2023 5:00 | B_0 | 56.05 |
| 1/1/2023 7:00 | B_0 | 82.95 |
| 1/1/2023 8:00 | B_0 | 91.03 |
| 1/1/2023 9:00 | B_0 | 78.17 |
| 1/1/2023 10:00 | B_0 | 72.64 |
| 1/1/2023 14:00 | B_0 | 66.66 |
| 1/1/2023 15:00 | B_0 | 67.56 |
| 1/1/2023 16:00 | B_0 | 72.64 |

# Solution requirements

# Solution evaluation requirements

- Participants are required to submit
  - A **CSV file** including the estimated energy consumption values over the test set
  - A **report** describing the accuracy of the develop model on the training set and explaining their solution architecture, outcomes, and how the model address the challenges
  - The **code** to generate the CSV file given the provided inputs



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# Solution evaluation criteria

- To focus on the **cross-product and cross-configuration generalization** capability of the model, the test set estimation accuracy is evaluated by using a **weighted relative error** method
- The error weight, $w_i$, of the sample corresponding to the **new device and/or new configuration** in the test set is larger and is provided in the test set
- Given the true energy consumption, $y_i$, and the estimated energy consumption, $\hat{y}_i$, the **error metric** is computed as

$$\mathrm{WMAPE} = \frac{\sum_{i=1}^{n}(w_i|y_i - \hat{y}_i|)}{\sum_{i=1}^{n}(w_i|y_i|)}$$

- The final model performance **is ranked according to the minimum WMAPE**

| Time | BS | Energy | w |
|---|---|---|---|
| 1/1/2023 6:00 | B_0 | | 1 |
| 1/1/2023 11:00 | B_0 | | 1 |
| 1/1/2023 12:00 | B_0 | | 1 |
| 1/1/2023 13:00 | B_0 | | 1 |
| 1/1/2023 23:00 | B_0 | | 5 |
| 1/2/2023 7:00 | B_0 | | 5 |
| 1/2/2023 19:00 | B_0 | | 1 |
| 1/4/2023 2:00 | B_0 | | 1 |
| 1/4/2023 5:00 | B_0 | | 1 |
| 1/4/2023 9:00 | B_0 | | 5 |
| 1/1/2023 6:00 | B_0 | | 5 |
| 1/1/2023 11:00 | B_0 | | 1 |

# Timeline and prizes

- **Competition timeline**
  - Registration Open: 06 July 2023
  - Registration Closes: 30 September 2023
  - Competition Phase: 06 July – 30 September 2023
  - Submission deadline: **30 September 2023**
- **Prizes**
  - Internship opportunity at Huawei R&D
  - Cash prize
  - ITU certificate


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