Energy Efficient 5G Core Network Orchestration With DRL

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MOTIVATION

- **Ever growing energy needs of the ICT sector**. Studies estimates that, in 2020, it contributed for a share between 1.8% and 2.8% to global greenhouse gas emission and between 20% and 40% of mobile operators network operational expense
- The widespread adoption of 5G is expected to increase this share even more. Traditionally attention of manufacturers was mainly paid to the Radio Access Network, but the **5G Core** is becoming increasingly more significant
- Additional challenges presented by **Network Function Virtualization** and **Edge Computing** technologies

It is not possible to rely only on fixed models, but it is necessary to make use of dynamic an adaptable mechanisms for the real-time monitoring of the network power consumption

EXPERIMENTAL MEASUREMENTS

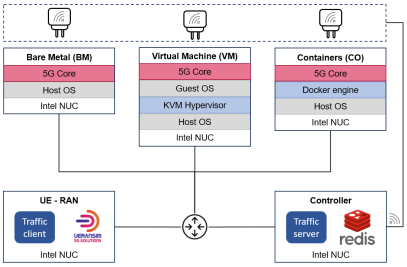
Several studies available in the literature have analyzed the power consumption of cloud infrastructures and data centers, but it is not clear how this knowledge can be translated to the telco world and especially to edge 5G core network deployments running on common off-the-shelf (COTS) hardware

To optimize the power consumption, we first need to reliably measure it

We built an experimental testbed using **COTS hardware and open-source software** to measure the power consumption of heterogenous 5G core network deployments.

Three alternative virtualized deployments:
Bare Metal | Virtual Machine | Container

Commercial smartplugs to measure the hardware power consumption, Scaphandre to measure the per-process consumption via software leveraging the CPU RAPL interface

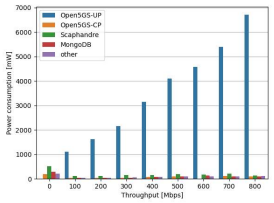


→ *github.com/IncludeArthur/5GC-power-consumption-data*

POWER CONSUMPTION MODELLING

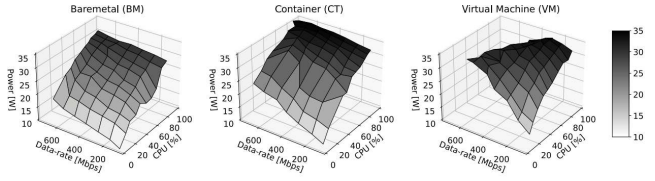
The objective of showcasing the power measurement monitoring methodology in a variety of scenarios and degrees of variability

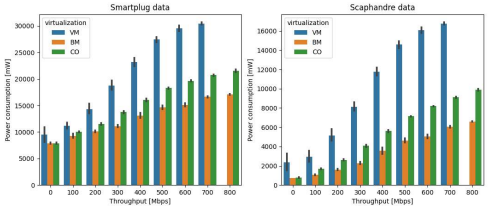
- **Containerized** deployment requires up to **25% more energy** than the bare metal
- **Virtual machine** deployment requires up to **78% more energy** and cannot sustain a throughput higher than 700 Mbps
- The in-kernel packet processing mechanism used by **Free5GC** consumes almost **40% less power** compared to Open5GS

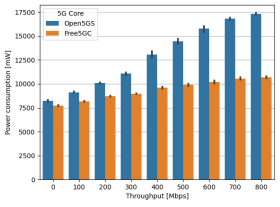


The results are a proof-of-concept used as **validation of the proposed methodology** aimed at making the power consumption of 5G core network **observable** to internal management tools and all stakeholders involved. The approach is agnostic to the hardware infrastructure, virtualization layer and software implementation.

We created a **Digital Twin** of a MEC node hosting a 5G core network to simulate possible what-if scenarios and analyze the potential impact of different orchestration strategies before applying them on the physical system.





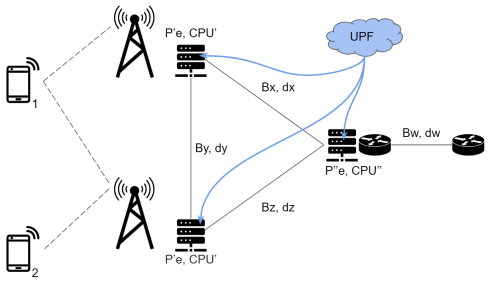


DRL ORCHESTRATION

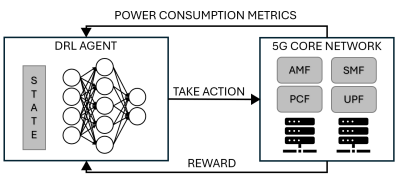
Problem:

Choose where to allocate PDU sessions on different host nodes in an edge-cloud environment

- Nodes have different hardware specifications and power/CPU consumption profiles
- PDU sessions have different duration and Quality of Service (QoS) requirements (latency and bandwidth)



We want to minimize the overall energy consumption while satisfying the desired QoS



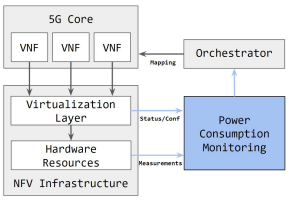
We trained a **Deep Reinforcement Learning** (DRL) agent that interact with the 5G core network deployment by observing the real-time hardware utilization, power consumption and QoS metrics .

The DRL agent decides which cloud or edge host node will serve each incoming PDU session.

The reward function is crafted to minimize the energy consumption across all hosts and penalize QoS violations.

VISION

The ultimate objective is to integrate the power consumption monitoring and intelligence mechanism into an existing standardized NFV management and orchestration framework and achieve a significant degree of **network automation**.



Zero-touch network automation and service management mechanisms can be leveraged to achieve unprecedented operational agility and support new business opportunities and verticals.

Especially useful for **private 5G** network deployments.

6GREEN

Goal: Enable and foster 5/6G networks and vertical applications reducing their carbon footprint by a factor of 10 or more.

- Decompose and map energy and carbon metrics onto the responsible slice or application to incentivize all the players to adopt energy-conscious practices
- Enable automated provision/deprovision of resources, transparent and seamless geographical relocation of service meshes/network slices at runtime

PUBLICATIONS:

1. A. Bellin, M. Centenaro and F. Granelli, "A Preliminary Study on the Power Consumption of Virtualized Edge 5G Core Networks," *2023 IEEE 9th International Conference on Network Softwarization (NetSoft)*, Madrid, Spain, 2023, pp. 420-425, doi: 10.1109/NetSoft57336.2023.10175489.
2. R. Fedrizzi, A. Bellin, C. E. Costa and F. Granelli, "Building the Digital Twin of a MEC node: a Data Driven Approach," *2023 IEEE 9th International Conference on Network Softwarization (NetSoft)*, Madrid, Spain, 2023, pp. 444-449, doi: 10.1109/NetSoft57336.2023.10175423.
3. A. Bellin, F. Granelli, D. Munaretto, "A measurement-based approach to analyze the power consumption of the softwarized 5G core", *Computer Networks*, Volume 244, 2024, 110312, ISSN 1389-1286, doi: 10.1016/j.comnet.2024.110312.
4. A. Bellin et al., "Autonomous Private Mobile Networks: State of the Art and Future Challenges," in IEEE Communications Standards Magazine, vol. 7, no. 2, pp. 24-31, June 2023, doi: 10.1109/MCOMSTD.0005.2200020.