

Research context and motivation

- Rapid increase in energy demand to operate cellular networks is entailed by staggering growth of mobile traffic, which motivates for efficient base station communication.

ICT global carbon footprint	• Above 2% global CO_2 emissions
Network Densification	• High operating cost function for Mobile Network Operators(MNOs).
BSs power consumption	• 80% of overall network power consumption. • Full power consumption in idle periods

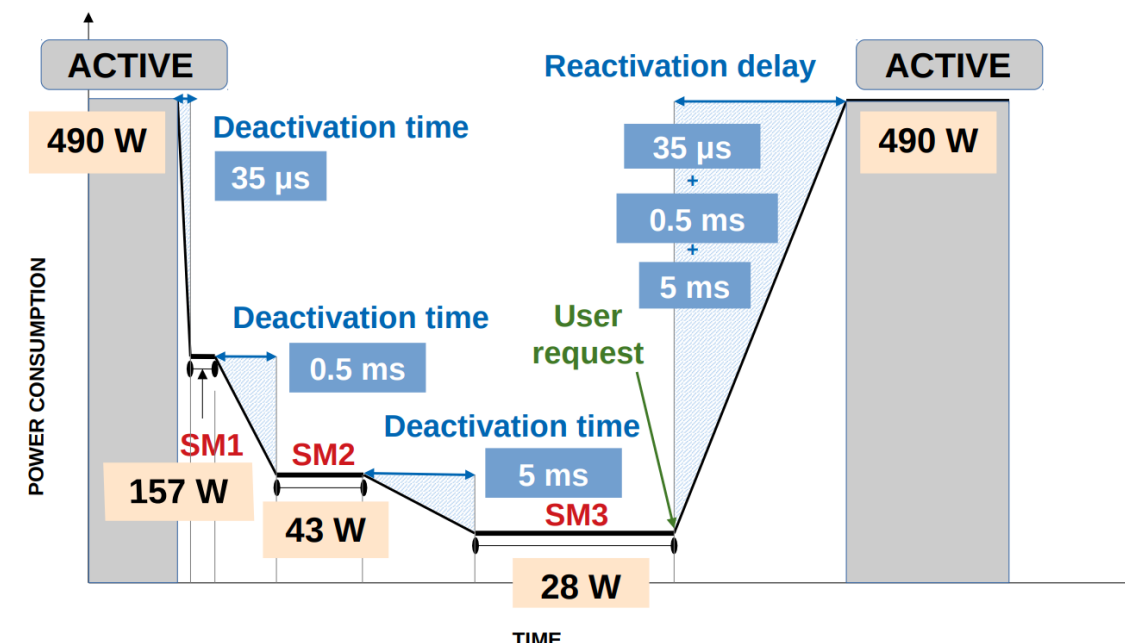
- The conceptual design of 6G highlights the digital segregation of rural and remote areas in terms of connectivity and incorporates it as an objective to address the peculiarities and bridging the digital divide.

Digital divide	• 3.7 billion not connected through internet.
Economic challenge	• Lack of resources for providing connectivity. • Effect on information transfer
Content demand	• Similar contents traverse large network to reach destination. • High network energy consumption
Data Traffic	• Global broadband use cases are video downloading and fast access to websites. • Processing and application overload on cloud

Addressed research questions/problems

Research question R1:

- Advanced sleep modes for energy saving:
 - Advanced sleep mode operation helps in minimizing the BS energy consumption by progressively switching off BS components in low load periods. Deep sleep modes unfortunately have longer reactivation times that may jeopardize QoS.
 - According to the 5G standardization and ITU report on 5G performance requirements, the minimum requirement for user plane latency is 1 ms for ultra-reliable low-latency



communication (URLLC) and 4 ms for enhanced mobile broadband (eMBB) communication.



Closed-form optimization for Delay Conservative Advanced Sleep Mode operation (DCASM) in order to trade off reactivation delays with minimal impact on energy saving.

Research question R2:

- Power line communication over the existing power lines is seen as cost-effective connectivity solution for non supplied rural and remote areas.
 - Rapid growth in data traffic burdens PLC network, that has limited capacity to serve users.
 - It impose challenges on reliable data transmission for long distances.
 - Downloading Video on Demand (VOD) from cloud would pose transmission delays as well as inefficient resource utilization for remote area network which has limited bandwidth for retrieving heavy content.



A PLC network with cache deployed at the edge server and small cache facilities at end nodes can mutually collaborate to provide the most popular content at user premises to boost utilization of low bandwidth PLC links and save precious cloud link resources.

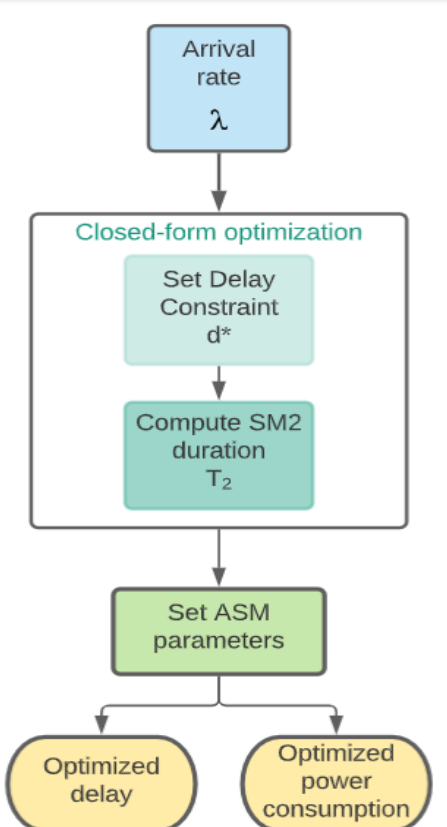
Submitted and published works

- M. Meo, D. Renga, and Z. Umar, "Advanced sleep modes to comply with delay constraints in energy efficient 5g networks", IEEE 93rd Vehicular Technology Conference (VTC2021-Spring), 2021, pp. 1–7
- D. Renga, Z. Umar, and M. Meo, "Trading off delay and energy saving through Advanced Sleep Modes in 5G RANs", IEEE Transactions on Wireless Communications
- Zunera Umar and Michela Meo, "A collaborative caching over PLC for remote areas", 32nd International Telecommunication Networks and Applications Conference (ITNAC)

Adopted methodologies

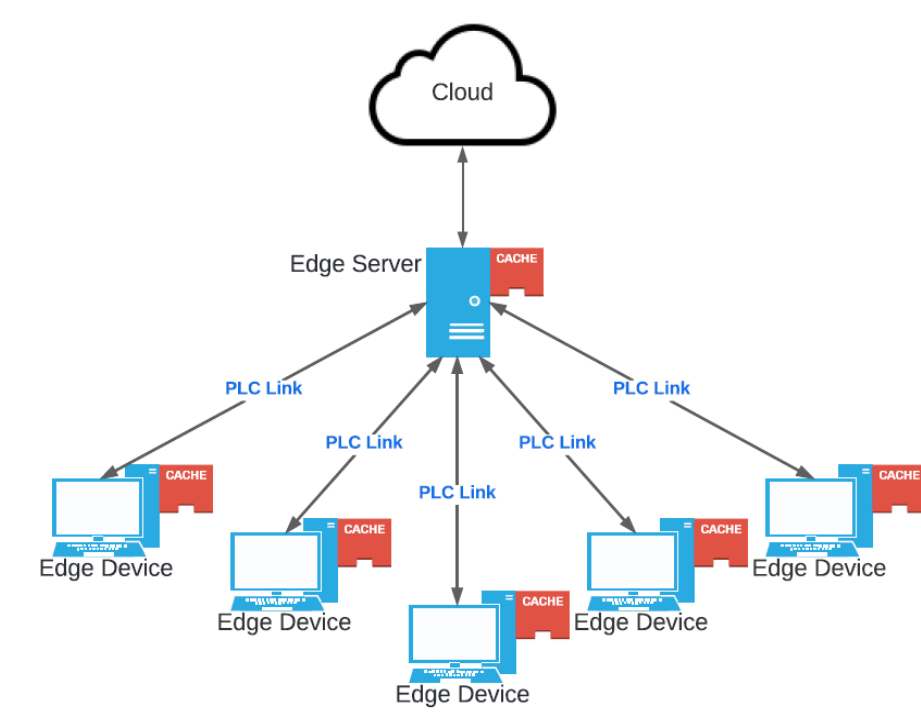
R1 Methodology: DCASM Operation:

- A specific target is set for the maximum allowed average delay, let it be denoted by d^* .
- The arrival rate is estimated and fed as input to the mathematical framework which provides the optimal setting of T_2 such that the delay requirement is met while the power consumption is minimized, under the estimated value of the traffic.



R2 Methodology: Collaborative caching on PLC network:

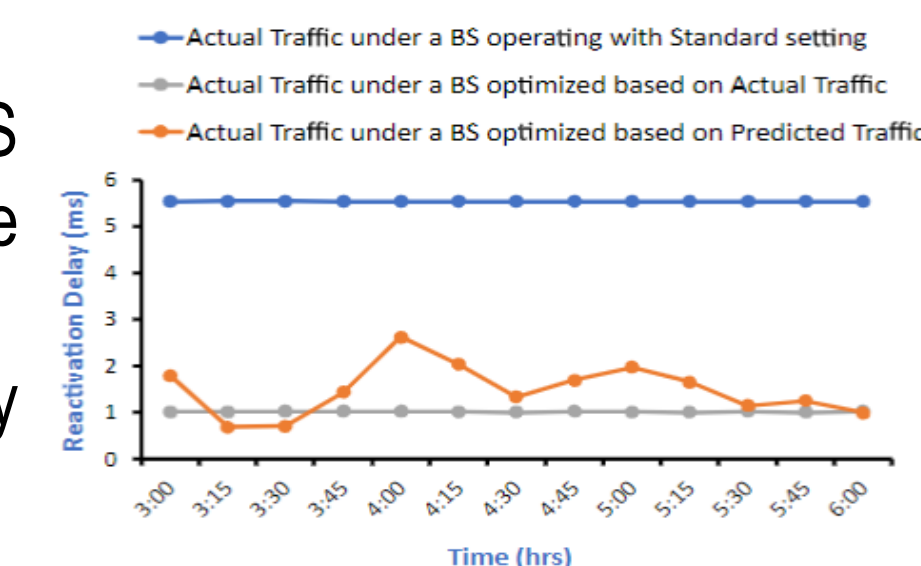
- At the access network, an edge server (ES) equipped with caching is deployed to manage the local edge devices (EDs) that are connected through the PLC network. EDs are equipped with caches as well.
- Caching is based on content popularity defined according to Zipf distribution with a skewness parameter α .
- At the central node (ES), contents with high popularity index are stored, whereas a comparatively less popular contents are cached at the user nodes (EDs) to support collaborative caching. This strategy helps the EDs to retrieve a large number of contents from the ES without the need to use the link to the cloud.



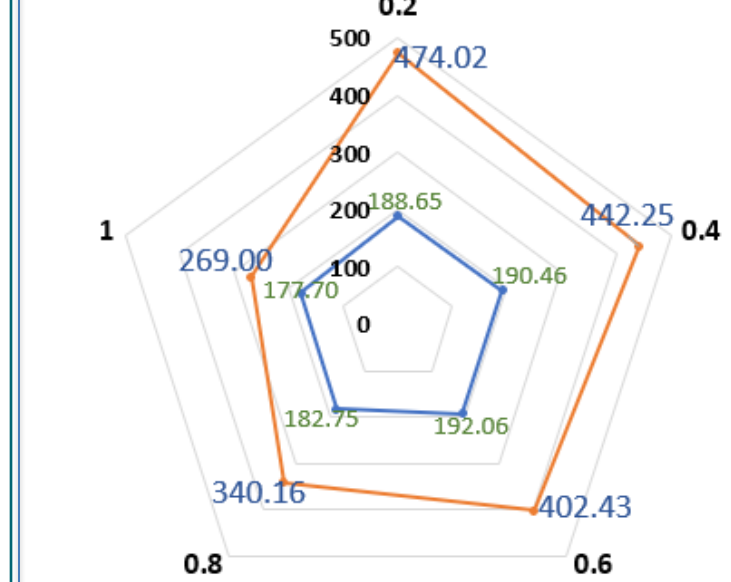
Novel contributions

R1 outcome:

- With DCASM, it is possible to dynamically adapt BS operation to traffic to achieve energy saving while guaranteeing delay constraints raised in 5G scenarios.
- DCASM performance is not significantly affected by limited traffic prediction errors.



With losses (blue line) and With partial cloud link (orange line)



R2 outcome:

- Collaborative sharing among ES and EDs works better when popularity is well known (α approaches ~ 1), in which case the average download time will be reduced, since users can get the popular content in their premises and low bandwidth PLC network is effectively utilized.

Future work

- In future, we would like to adapt a recommendation system into the collaborative caching scheme in order to minimize the loss of requests when data is unavailable in local caching system. The video files that are close in match to the previous requests will be suggested to the users in order to facilitate the demand.
- Machine learning algorithm to predict the future demand from previously available data. Matching the prediction with available data cached in ES and Eds and recommending the closest one to the user.

List of attended classes

- 01DPIRO – Advanced Topics in Energy Storage System and Electric Vehicle Drivetrain Design (07/09/2022, 4)
- 02LWHRV – Communication (16/12/2020, 1)
- 01QTEIU – Data mining concepts and algorithms (1/2/2021, 4)
- Tutorial – AI4NETS –AI/ML for data communication Networks (2/11/2020,1)
- 01QRXIU – Multimedia communications: technological advances and social implications (9/3/2021, 4)
- 02SFURV – Programmazione scientifica avanzata in matlab (26/5/2022, 6)
- 5G International PhD school (01/12/2020,4)
- 08IXTRV – Project management (29/11/2020, 1)
- 01RISRv – Public speaking (24/11/2020, 1)
- 01SYBRV – Research integrity (6/1/2021, 1)
- 01QFFRV – Tecniche innovative per l'ottimizzazione (23/7/2021, 4)
- 02RHORV – The new Internet Society: entering the black-box of digital innovations (28/10/2021, 1)
- IEEE/DEI Summer Ph.D. School of Information Engineering "Silvano Pupolin" – SSIE 2022 (11/7/2022,6)
- 01SWPRV – Time management (25/11/2020, 1)
- 01QORRV – Writing Scientific Papers in English (23/6/2021, 3)