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XXXIV Cycle

Greener RAN operation through Machine Learning

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Research context and motivation

- Artificial Intelligence and **Machine Learning** based solutions are being increasingly applied in several aspects of the ICT sector and specifically in networking:
  - ➔ network control, management and maintenance, traffic monitoring and analysis, efficient routing, etc

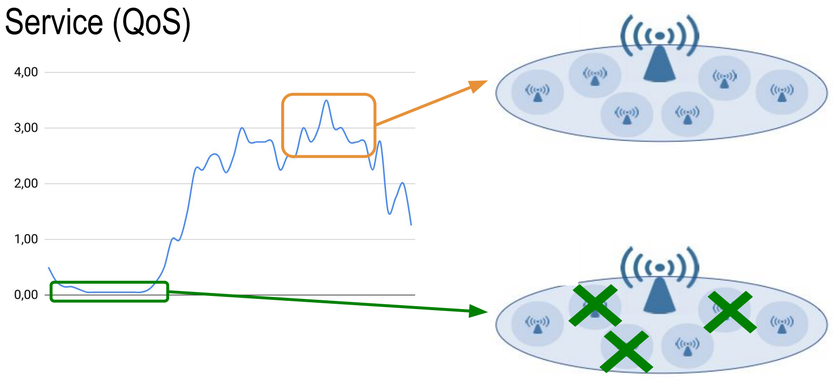
- **Radio Access Networks (RANs)** management:
  - ➔ Used for many purposes, as energy consumption reduction, motivated by sustainability, climate changes and operational costs
  - ➔ Base Stations (BSs) switching: switching to/from sleep mode BSs, according to the traffic demand
  - ➔ RAN energy consumption keeps increasing at a remarkable speed: 12% per year

    The number of mobile device keeps increasing:
    - ➔ 5.7 billion mobile users by 2020
    - ➔ > 11 billion mobile-connected devices

    A fast and huge mobile traffic growth is expected in the next years:
    - ➔ Mobile data traffic will grow at a compound annual growth rate of 46% between 2017 and 2020
    - ➔ Mobile data traffic will reach 77.5 exabyte per month by 2022
    - ➔ The discrepancy between daily and nightly traffic is supposed to increase by 2022: the daily traffic is expected to grow by a factor 4.8, while the nightly traffic demand by a factor 3.7

Addressed research questions/problems

- The last generation of RAN is characterised by an hierarchical structure: this network is composed by macro cell BSs, each supported by a few micro cell BSs, whose radio coverage overlap with the macro cell one. In order to reduce the energy consumption of these networks, **Resource on Demand (RoD)** approaches are used: when the traffic demand is small enough, the unneeded capacity is switched into sleep mode, keeping the desired Quality of Service (QoS)



  - ➔ need to know the near future traffic demand

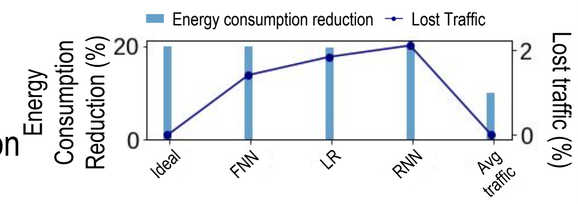
- Machine Learning approaches are currently widely used for the prediction of the time-series
  - ➔ need a suitable ML approach for the RoD application
  - ➔ impact of the estimation error on the performances of RoD: impact on the energy consumption and on the Quality of Service (QoS)
    - ➔ Incorrect deactivation: the provided capacity could be not sufficient
    - ➔ Incorrect activation: energy waste
  - ➔ method to mitigate the effect of the error in the traffic demand forecast on the RoD performance

Submitted and published works

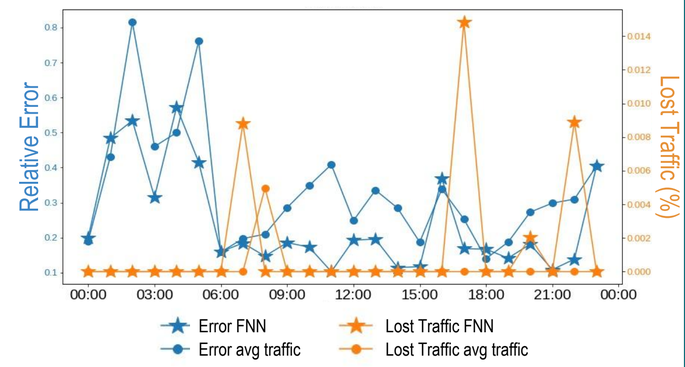
- G. Vallero, M. Deruyck, M. Meo, and W. Joseph, "*Accounting for energy cost when designing energy-efficient wireless access networks*," Energies , vol. 11, no. 3, 2018, [Online]. Available:http://www.mdpi.com/1996-1073/11/3/617
- G. Vallero, D. Renga, M. Meo, and M. A. Marsan, "*Greener ran operation through machine learning*," IEEE Transactions on Network and Service Management , 2019.
- I.Donevski, G. Vallero, M. A. Marsan, "*Neural Networks for Cellular Base Station Switching*", IEEE INFOCOM WKSHPS: SMILING 2019: Sustainable networking through MachIne Learning and Internet of thINGs, Paris, 2019.
- G. Vallero, D. Renga, M. Meo, M. A. Marsan, "*Processing ANN Traffic Predictions for RAN Energy Efficiency*", submitted to IEEE INFOCOM 2020-IEEE Conference on Computer Communications.

Novel contributions

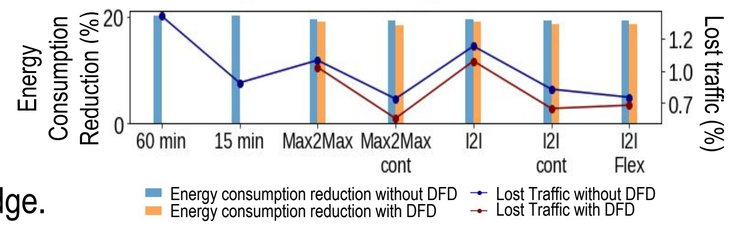
- Machine learning approaches are powerful enough to enable network management mechanisms that adapt to traffic variability:
  - Good trade-off between energy consumption reduction and provided QoS



- Large errors in the forecast do not always imply bad network performance: the **correct estimation** of traffic is important only around the values which are taken as **thresholds** for the decision to activate or deactivate micro cell BSs.

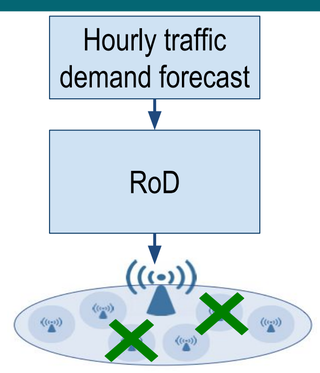


- Machine Learning approaches become particularly effective if their outputs are integrated into **decision processes** that are driven by a deep domain knowledge.

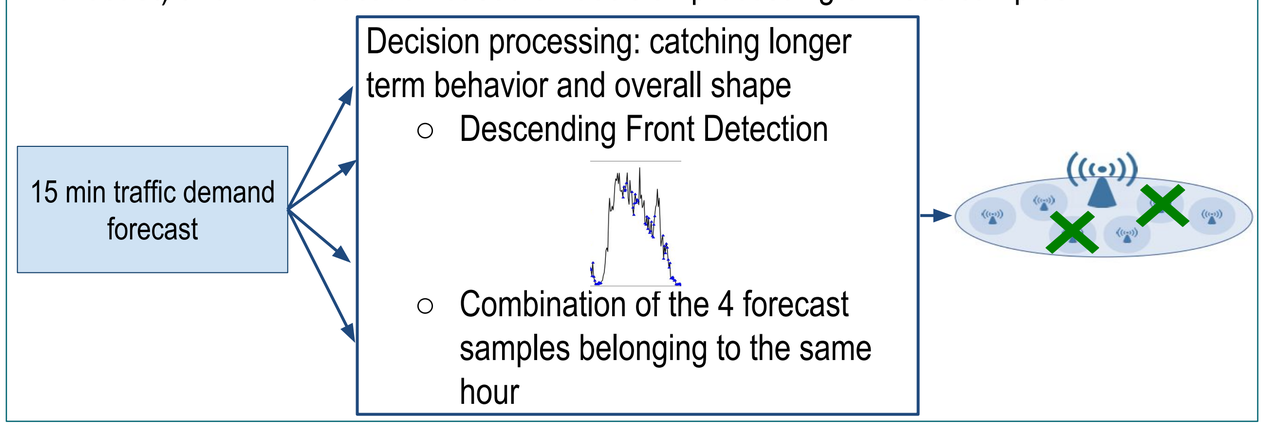


Adopted methodologies

- **Prediction of the hourly traffic demand** and allocation of the RAN resources according to these predictions.
  Different ML approaches are used, based on:
  - ➔ Feed-Forward Neural Network (FNN)
  - ➔ Recurrent Neural Network (RNN)
  - ➔ Linear Regression (LR)
  - ➔ Average hourly traffic demand



- **Reduction of forecast granularity**: from 1 hour to 15 minutes.
  At the beginning of each time slot prediction of the next hour traffic demand (**deeper forecast**) and RAN allocation based on decision processing of these samples



Future work

- Management of a RAN, supplied by a local renewable energy system, when the power grid supply is not available (blackouts in emerging countries, emergency)
  - forecast of the renewable energy generation
  - BSs switching according to the available renewable energy and traffic demand

List of attended classes

- 01LYXRV – Electrical load management, forecasting and control(22/09/2018, credits: 6)
- 01QTEIU – Data mining concept and algorithms (14/12/2018, credits: 4)
- 01RRDIU – Semantic Web (23/01/2019, credits: 4)
- Summer School – Can a network learn? Machine Learning methodologies and applications for next generation networking (July 2019, credits: 6)
- 01RONKG – Python in the Lab (28/08/2019, credits: 4)
- 02LWHRV – Communication (14/05/2019, credits: 1)
- 01RISRV – Public Speaking (13/05/2019, credits: 1)
- 01SWPRV – Time Management (13/12/2018, credits: 1)
- 01SYBRV – Research Integrity (10/09/2019, credits: 1)
- 01QORRV– Writing Scientific Papers in English(28/03/2019, credits: 3)

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