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Modeling and Forecasting of Mobile Network Traffic

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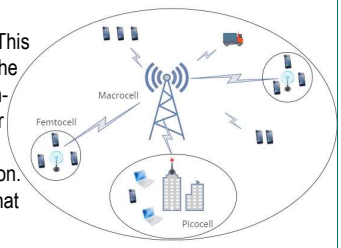
Research context and motivation

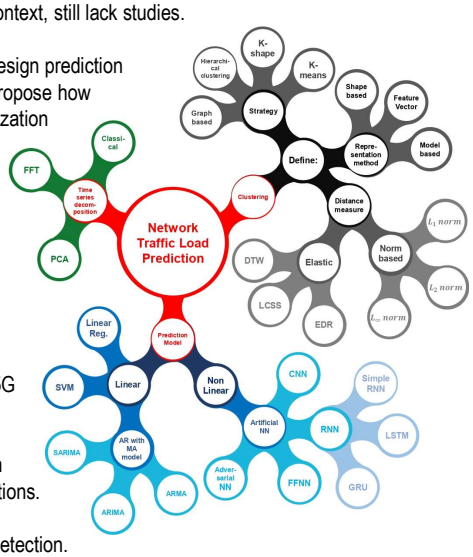
- Over the past decade, networks have embraced a *softwarization* process that is granting increasing control capabilities by operators on their infrastructures. This trend creates new opportunities for network management, many of which build upon anticipatory decision-making paradigms.
- Nowadays, studies related to 5G are on the rise. This technology presents improvements compared to the previous generations: smaller latency, faster down-load and upload, higher bandwidth, higher number of connected devices, data processing speed 100 times faster than 4G, energy consumption reduction. All these developments allow many applications that depend on device-to-device communication.



- 5G network architecture is heterogeneous, that is, includes macro and smaller cells. Hence, optimization problems concerning spectrum allocation, location of these cells, and energy saving of those not serving users are studied. Many of these optimization techniques are developed with **prediction models** based on big data generated by both user and network operator.

Addressed research questions/problems

- The prediction models will be developed for macro-scale environments. They must be capable of forecasting subscribers' demand with high accuracy and low computational complexity, and in real-time.
- The Network Traffic Prediction model should be optimized, so it can minimize the error between predicted and real network traffic load and provide fast predictions allowing anticipatory decision making. Therefore, subsets of this main problem (presented in Figure) applied to such a big context, still lack studies.
- Many papers in the literature design prediction models, however they do not propose how they could be used in an optimization problem.



Addressed problems:

1- Real-time network traffic load prediction models with low computational cost.

2- How to use these models for 5G networks optimization design problems: base stations energy consumption, spectrum allocation, number of base stations.

3- Network traffic load anomaly detection.

Submitted and published works

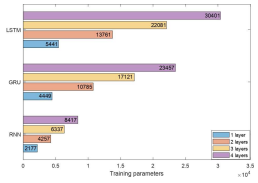
- Ferreira G., Figueiredo L., Lacerda, M. J., and Leite V. J. S., *"ISS control for continuous-time systems with filtered time-varying parameter and saturating actuators"*, Asian Journal of Control, 2022, pp.1-13.
- Ferreira G., Calafiore G. C., Dabbene F., Fiore M., and Ravazzi C., *"Forecasting network traffic: a survey and tutorial with open-source comparative evaluation"*, will be submitted to IEEE Communications Surveys & Tutorials.

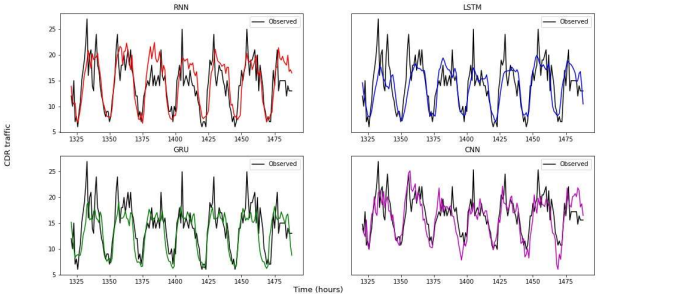
Novel contributions

- New mathematical models to detect regular and irregular structures in the traffic generated by mobile applications in macroscopic scales.
- Radio Access Network online optimization algorithms.
- Closed-loop control of users' flow inside a 5G heterogeneous network.
  - Energy saving.
  - Guaranteed quality of service.

Adopted methodologies

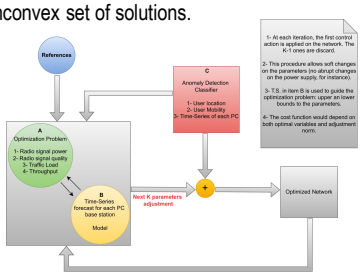
- An extensive *survey paper* with 120 references was developed. The objective was to understand the mathematical formulation of the papers concerned with network traffic prediction over the last 20 years.
- The promising and recently used approaches are compared in accuracy and computational cost.
- Once the most suitable model is selected, classifiers (anomaly detection) and optimization problems (energy consumption minimization with guaranteed user QoS) will be developed.





Future work

- Closed-loop control of the network (big scale problem):
  - Discrete-time dynamic model of the system.
  - Model predictive controller.
  - Connection constraints to guarantee QoS.
  - Nonconvex set of solutions.



List of attended classes

- 01TVOQW – Optimization for Machine Learning (09-02-2022, credits: 6)
- 01TUFRV – All you need to know about research data management and open access (14-04-2022, credits: 3)
- 01UJBRV – Adversarial training of neural networks (06-06-2022, credits: 3)
- 01OUWQW– Convex optimization and engineering applications (05-07-2022, credits: 6)
- 01SCSIU– Machine Learning for pattern recognition (22-07-2022, credits: 4)

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