

**Title:** User/network context-aware resource management for constrained-services in 5G and Beyond 5G networks

**Thesis location:** IRISA labs, Rennes

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**Keywords:** 5G and beyond 5G networks, Network slicing, user context-awareness, Machine learning.

## **Context**

5G and Beyond 5G networks are expected to cope with a wide range of services with stringent and sometimes conflicting requirements. Indeed, next generation networks aim to deliver new vertical industries such as automotive driven by industry 4.0, smart cities, e-health and high-resolution video streaming. These constrained services in term of latency and/or data volume can be addressed by bringing the computation and networking resources to the edge of the network, as near as possible to end-users. However, leveraging edge resources leads to more heterogeneity and thus more complexity in resource management.

Network Slicing [1], enabled by Software-Defined Networking (SDN) [2] and Network Function Virtualization (NFV) [3,4] paradigms, is a key feature in 5G and B5G networks that allows Infrastructure providers to share their physical networks among multiple tenants through the instantiation of fully-isolated logical networks. These latter are managed based on the tenants' specific service requirements. Network slicing calls then for efficient solutions to tackle the issue of resources management towards provisioning end-users with satisfying experience.

To be efficient, a resource management solution should then consider:

- the end-user context and environment and specifically in case of mobility that can severely affect the perceived quality by end-users;
- different conflicting objective functions (e.g., completion time, energy consumption, cost, reliability, availability, accessibility, etc.);
- the resource heterogeneity in the context of edge-cloud continuum particularly at the edge where resources are known to be limited.

Thus, the integration of intelligent functions within the network becomes a strong requirement, (i) from one side, to efficiently control and manage the network resources and dynamically react to changes on these resources; (ii) and from the other side, to monitor the end-users' context and capture their environment to anticipate changes on service requirements.

## **Scientific Challenge**

The first challenge to overcome in this thesis is the automation of the service placement aided by relevant network/user context information. Machine Learning technologies has emerged in the last years as a promising solution to provide networks with tools that enable information processing, knowledge inference and intelligent decision-making capabilities. This work is in the continuity of past works dedicated to ML-based user profiling in 5G networks [5]. The latter were dedicated to infer the indoor/outdoor environment of mobile users, characterize their mobility, etc. The next step, considered in this thesis, is to use this inferred information to automate the service/resources placement and ensure seamless service continuity when end-users are mobile in an efficient costless manner.

The second challenge, addressed in this thesis, is the placement of monitoring function in the network edge to acquire relevant information needed to infer the user profile. For this optimization problem, standard approaches have been very recently renewed by machine learning based approaches. The first question is where to place the relevant virtual network functions in order to provide the expected quality of the overall network service, especially in terms of latency and throughput, while minimizing the energy consumption of the system and ensuring minimal resilience against failures. We will consider

automatic scaling and placement of these functions as part of the solution to dynamically adapt the slicing to changes in the initial conditions.

## Thesis objectives

The objective of this thesis is two-fold:

- First, we aim to design a multi-objective resource optimization, when instantiating network slices, that consider the network and user context and allow a seamless service migration in case of user mobility. We aim to leverage the results of precedent work in user profiling [6] to efficiently capture the user context and exploit it to trigger seamless service placement and migration. As a first step of this work, we will consider monolithic services to place in a single node, then we will generalize our solution to multi-components services that can be placed on a set of interconnected nodes.
- The second objective is to place monitoring functions on the user and network edge sides to efficiently capture consistent and pertinent information to infer the network/user context needed to manage the network resources.

## References

- [1] NGMN Alliance, "Description of Network Slicing Concept", Tech. rep., Version 1.0, 2016.
- [2] KIRIHA, Yoshiaki, and Motoo NISHIHARA. "Software-Defined Networking: The new norm for networks Software-Defined Networking: The new norm for networks, 2012." *IEICE transactions on communications* 96.3 (2013): 713-721.
- [3] NFV White paper: "Network Functions Virtualisation, An Introduction, Benefits, Enablers, Challenges & Call for Action, Issue 1", Oct. 2012.
- [4] ETSI GS NFV 002: "Network Functions Virtualisation (NFV); Architectural Framework", Version 1.2.1, Dec. 2014.
- [5] Illyne Saffar, "Machine Learning to Infer User Behavior in 5G autonomic networks", PhD Thesis CIFRE Nokia/Université de Rennes 1, Nov. 2020.
- [6] Marie Line Alberi Morel, Illyne Saffar, Kamal Singh, Sid Ali Hamideche, César Viho, "Improving User Environment Detection Using Context-aware Multi-Task Deep Learning in Mobile Networks", *IEEE Transactions on Cognitive Communications and Networking*, 2022, pp.1-11. (10.1109/TCCN.2022.3205696).

## Required profile

The candidate should hold a Master/Engineer degree in computer sciences, or applied mathematics, or related fields. She or he should have a background in networking and associated main protocols, in machine learning. Knowledge in mobile networks and protocols, optimization problems, graph theory, and network virtualization is a plus.

The applicant should also be motivated by theoretical computations and familiar with software development.

## Application details:

- Please send your applications to the following contacts: [soraya.ait-chellouche@irisa.fr](mailto:soraya.ait-chellouche@irisa.fr) and [cesar.viho@irisa.fr](mailto:cesar.viho@irisa.fr)

The application should include:

- Curriculum Vitae;
- Cover letter;
- Three last academic transcripts;
- Two recommendation letters.

- **Deadline for applications:** March 2023.
- **Start date:** October 2023.