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Thesis Proposal – 2024

Thesis title: Resource allocation in the vehicular slice for remote car driving

Titre français: Allocation de ressources dans la *Slice* véhiculaire pour la conduite à distance

Keywords: mobile communication networks, slicing 5G et 6G, *Resource allocation, provisioning, RAN and core slicing, remote car driving, optimization, AI, deep learning, remote driving, trajectory tracking*

Mots-clés : réseaux mobiles de communication, réseaux 5G et 6G, *allocation de ressources, provisionnement, provisionnement, conduite à distance, Optimisation, IA, Apprentissage profond, suivi de trajectoires*

Résumé

L'objectif de ce projet de thèse est de proposer des mécanismes de réservation de ressources pour des slices incluant des contraintes de débit, de latence pour des utilisateurs en mobilité.

Les cas d'usage typiques sont des applications de télé-opération de robots ou de télé-conduite de véhicules avec des trajectoires entièrement ou partiellement connues à l'avance. Dans nos travaux précédents, nous avons abordé séparément, la réservation de ressources dans la partie cœur du réseau 5G et dans la partie réseau radio d'accès à l'aide d'une modélisation sous forme de problèmes d'optimisation linéaire en nombre entiers ou mixtes sur les entiers. Cependant, ces techniques d'optimisation restent trop complexes pour réaliser une réservation conjointe depuis le réseau d'accès jusqu'au réseau cœur en respectant les contraintes de temps de calcul de la réservation. La prise en compte de connaissances a priori sur les trajectoires des terminaux mobiles est envisagée pour faciliter la résolution du problème conjoint.

En plus de la modélisation sous forme de problèmes d'optimisation, ce projet exploitera les techniques d'apprentissage par renforcement.

Abstract

The aim of this PhD thesis is to propose resource provisioning mechanisms for network slices characterized by stringent rate and latency constraints for mobile users. Typical use-cases include tele-operation of robots or remote car driving. In our previous works, resource provisioning mechanisms considered either the core network or the radio access network. Provisioning is then cast into the framework of (mixed) integer linear programming. Nevertheless, such techniques remain too complex to address problems requiring a joint resource provisioning for the core and the radio access network, while satisfying constraints on the provisioning scheme evaluation delay. Accounting for a priori information on the user equipment trajectories and their associated uncertainty will be considered to facilitate the joint provisioning problem. In addition to mixed integer linear programming tools, deep reinforcement learning techniques will be considered.

Context

Network Slicing [Galis and Makhijani, 2018] is an outstanding solution that allows the operator to flexibly provide dedicated logical networks with (virtualized) functionalities over a common physical infrastructure. The mobile infrastructure is divided into virtual networks, called network slices. Using virtualization technologies, network slicing allows building isolated logical networks, on a per-service basis, on top of a single physical network. By logically isolating control plane (CP) and user plane (UP) network functions (NFs), network slicing [Zhou-2016] can tailor resources to specific vertical markets' needs on a common programmable network infrastructure, thanks to network softwarization technologies such as Network Function Virtualization (NFV) and Software-defined Networking (SDN) [Condoluci-2018]. Thus the functionalities of different slices can be virtualized, independently scaled and displaced in convenient locations to flexibly support various services.. At an early stage, 3GPP has argued the need of a dedicated slice for V2X services because of their services specificities such as safety applications, platooning, remote driving or cooperative driving applications which both demand ultra-low latency and ultra-reliable connectivity over the RAN [3GPP-V2X][Campolo-2018].

As a consequence, V2X slice design is mainly concerned by the RAN slicing aiming at jointly optimizing the functional split selection and radio resource allocation [Matoussi-2020].

Objectives

The objective is to propose in advance resource reservation mechanisms for known resource requests, submitted in advance, and which would include not only the Core Network (CN) resources but also, the Radio Access Network (RAN) [Gutterman, 2019], and consequently coverage constraints with handover possibilities. For the moment, we have separately addressed resource reservation in the core [Luu et al, 2020] [Luu et al, 2021] and in the RAN [Sharara2021-2] [Sharara2022-1] [Sharara2022-2]. A joint consideration is complex to address with the tools we have currently used. The objective of this project is to perform resource reservation of 5G slices from the access network to the core network, in the presence of mobility. More precisely, the aim is to perform the provisioning and reservation of resources in advance, taking into account the resources in the RAN and the core network.

For this purpose, we consider a scenario of tele-operation or tele-driving of vehicles with a known trajectory in advance, in a V2X scenario. The in-advance reservation can occur at least 30 seconds before, or without known trajectory with changes of direction.

Working program

The PhD involves the steps sketched below:

1. Bibliography on Cloud RAN, Open RAN, NFV/SDN, 5G Slicing, V2X slicing, 5G resource allocation, etc.
2. Focus on radio resource provisioning while taking into account a perfectly known trajectory, then, a remotely controlled car future location uncertainty , then several remotely controlled cars sharing the same radio resources with other users.
3. Provide resource reservation in the BBU pool to process the traffic generated by the car. We tackle the problem of resource placement in DU. We perform resource reservation in the core network.
4. The whole reservation and allocation system will be developed enabling mechanisms for both radio, access, and core network resources allocation along the trajectory
5. Collaboration with teams involved in the PEPR Future Networks (PC5), in particular NAI project.

Expected results

Expected results are the following: (1) to develop optimization models (ILP) taking into account all the parameters and constraints, (2) to provide allocation algorithms for radio resource provisioning while taking into account a perfectly known trajectory, and more realistic constraints (3) to provide resource reservation in the ORAN (Open Radio Access Network) framework, (4) to test the proposed solutions in a 5G platform.

Valorization

Work will be published in four international conference and two journal publications at the end of this PhD thesis.

The proposed solutions will be tested on an actual 5G platform. We aim at providing four conference papers and two journal publications at the end of this PhD thesis.

Pre-requisites

The applicant, beyond the Master degree (acquired in telecommunication engineering or computer science, for example), should have good skills in networks protocols, routing, beamforing antennas, simulation/emulation, AI techniques, performance evaluation and C/C++/python programming. Deep learning background would be highly appreciated.

Application

To apply, please provide:

1) a cover letter detailing your suitability for the position in question
2) a detailed CV
3) your publications if any
4) the name and e-mail of one or two referees to support your application

The L2S laboratory is classified as a restricted area (ZRR) and special authorization is required for access (physical or electronic). The hiring of the doctoral student is conditional upon obtaining this authorization.

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