Proactive Slicing in Multi-Cell Software-Defined Radio Access Networks

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This thesis addresses both academic and experimental system research toward the future 5G-NR/6G access layer and their interworking with the LTE and next generation service-oriented core networks. It focuses on "network slicing", i.e. a transition to a flexible radio access network (RAN), in order to meet user demands in a dynamic and distributed manner. This is also leverages several benefits for the mobile network operator in terms of increased capacity and density, reduced costs, ease of deployment, to name a few.

5G-NR networks are supposed to operate in several different deployment scenarios, e.g., sub-6 GHz and mmMave, and need to remain forward-compatible to new use cases and handle multiple services. The flexibility of 5G-NR(e.g. numerologies, dynamic TDD, or beamforming) has to be used to effectively use the radio resources, therefore, the multiplex multiple services onto a common infrastructure, the corresponding slice service-level agreements need to be enforced within the RAN. The Medium Access Control (MAC) scheduler allocating radio resources to users needs to adapt to fulfill these requirements, including the forward-compatible design of the scheduler, flexible design by considering the heterogeneous service requirements, and the programmability design to provide controller of RAN. The RAN intelligent controller can deploy and release slices, control slices individually, and tailor the slice scheduling according to the service requirements of the slices between the cell sites.

In this thesis we plan to investigate across the following three axes:

- Topic 1: Radio resource allocation in 5G and beyond RAN:
  5G-NR is envisioned as an ultra-flexible, ultra-lean network that can be adapted to different deployment scenarios, and that is supposed to multiplex a variety of services with heterogeneous requirements onto a shared, common infrastructure through corresponding slices. We will start by extending the exiting MAC framework [1] to support different slice algorithms depending on the usage requirements of the service in the considered scenarios (e.g, eMBB, URLLC, and mMTC) which is one of the cornerstones of 5G-NR. To support different deployment scenarios while multiplexing service, it is important to have an extensible and forward-compatible design for the MAC framework. The multiplexing of slices, therefore, depends on the service-level agreement that needs to be mapped to radio resources through suitable slice scheduling algorithms, guaranteeing performance isolation and sharing of resources for multiplexing gains. Further, the MAC framework has to be programmable to allow the management and control slices transporting their services happening dynamically without any impact on the performance of other slices.

- Topic 2: Coordinated Radio Resource Allocation in SD-RAN based on the RAN intelligent controller (RIC)
  While the existing MAC framework only supports a single-cell without considering inter-cell interference in the multi-cell scenario, in this thesis we will extend the MAC framework to support coordinate radio resource management (RRM) through the centralized scheduler that is operating on the top a RIC. The coordination will decrease the effect of devices in the cell-edge region caused by an inter-cell interference and is inevitable to enable higher data rates and capacity in 5G-NR deployments. 5G-NR provides flexibility with different protocol stack enablers; especially the PHY supplies several new features, such as bandwidth parts, extended beamforming capability, or dynamic TDD. A crucial point is to exploit this flexibility and adapt the way radio resources are scheduled and allocated depending on factors. We will design a set of new service models in the RAN controller to monitor, control, coordinate, and optimize the RAN, such as slicing control, traffic control, or mobility control, and also coordinate by managing slices and radio resources in the multi-cell scenario.

- Topic 3: Bringing the Intelligent into RAN

  Because of the increasing densification to scale and highly dynamic, the networks need to proactively manage services/slices, load, interference, and mobility so as to optimize the user experience. We will devise a proactive RRM service model in the RAN controller to coordinate across multi-cells able to predict user performance and enforce proper set of actions into the RAN to guarantee QoS. To design a data-driven controller, the real-time prediction would be a challenge because of intrinsic complexity of RAN coupled with many unknown or dynamic variables.

It is planned to evaluate the performance of the envisioned methods and algorithms both in MatLab, the OpenaAIrinterface (OAI) software-defined radio platform, and the Flexible RAN Intelligent Controller (FlexRIC). Experimentation and validation will be done through emulation and real experimentation in a small-scale deployment at EURECOM Open5G-NR Lab (a living testbed.)

References

[1] Robert Schmidt. “Slicing in heterogeneous software-defined radio access networks”. © EURECOM. Personal use of this material is permitted. The definitive version of this paper was published in Thesis and is available at : PhD thesis. 2021.