Programmable RAN Sharing in 5G systems

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Résumé du projet de recherche (Langue 1)

Vision Existing cellular systems, such as LTE, are built upon expensive proprietary equipment and complex control-plane protocols, and thus they do not offer enough flexibility to program the network, and quickly adapt to the network condition. The network openness, flexibility and scalability come from the proper abstraction of low-layer functions in a hierarchical manner. Such abstraction and control approaches are required in 5G radio access networks so that we can orchestrate the network to a ubiquitous and unified service platform. The proper abstraction hides details of the low-layer implementation while providing only the necessary data for information exchange and high layer control and coordination. This will bring multiple key advantages to 5G networks, in that it will: • manage the complexity and greatly simplify the signaling for implementing advanced MAC/PHY layer technologies; • extend self-organizing network features in 5G as the abstraction enables low-layer control entities to be controlled and coordinated; • offer network-wide programmable control plane for rapid creation and deployment of new services, for which the abstraction is the essential step for high-level programmability. Therefore our vision on control and coordination in 5G radio access networks is a simple, open, unified and programmable control framework powered by proper abstraction of low-layer states, behaviors and functions, common control protocols, interfaces and primitives for network coordination and automation, and hierarchy abstraction on network states for efficient resource allocation and spectrum management in the network. Main Objectives

In the last years, much attention (both from Industry and Academia) has been placed on software-defined networking (SDN). In one of its most widely acknowledged definition, SDN essentially consists of two elements: (a) a clear separation of control and data plane, and (b) a well-defined interface or abstraction between control and data plane. This decoupling separates the network intelligence from the infrastructure whose complexities are abstracted away from the control applications. Nevertheless, the underlying SDN concepts are not novel per-se, i.e. software has always been used to control the network and control and data plane have been separated in several network architectures (e.g. in optical networks). The fundamental innovation introduced by SDN essentially consists in a vendor- and programming language-agnostic interfaces to networking gear. While SDN indeed reduces part of the intrinsic complexities of the current networking architectures, its actual embodiments pay little attention to the requirements of the radio access domain. As a matter of fact applying the tools currently available in the SDN ecosystem, e.g. OpenFlow, would essentially result in treating mobile terminal as hosts wired to an Ethernet switch. In a radio access network, however, the concept of a “link”, due to the stochastic nature of the wireless medium, is loosely defined, e.g. allocating a flow at a certain BS can affect the available bandwidth at another BS. The definition of new abstraction methodologies is then of capital importance in order to enable true programmability of the RAN. To this end, this thesis will focus on the Programmability of Radio Access Network (RAN) considering the RAN sharing use case. Two innovative objectives have been identified: • Physical and MAC layer modelling and abstraction to provide a simple network view of low-layer reality and available resources, and thus to enable a scalable and flexible control and coordination framework for complex resource coordination in 5G networks. • Programmable control based on the low-layer abstraction and machine learning techniques with well-defined open interfaces and protocols to greatly simplify the management of heterogeneous mobile networks, to be verified by efficient resource coordination algorithms developed for identified 5G use cases. Radio Access Network Sharing is a mechanism to dynamically allocate and share spectrum (frequency band), radio resources (i.e. time, frequency) and physical resources (e.g. compute, network, storage) among different tenants while maintaining their respective performance isolation. We will explore system trade-offs for a programmable RAN according to the Consistency Availability and Partition tolerance (CAP) conjecture, which states that it is impossible for any distributed system to provide at the same time the following guarantees: consistency, availability, and partition tolerance. In particular, consistency in policy application, network availability and partition tolerance in the face of fading channels, multi-path loss and mobility have not been studied in the wireless sphere, while in the networks literature only some first steps have been taken. As such there is no suitable theoretical model for dealing with the CAP conjecture in a programmable RAN. In addition we plan to study network virtualization and multi-tenancy, namely topology and resource abstractions and performance isolation. The former aims at defining the formalism through which tenants, i.e. the owners of the virtual networks to be instantiated on top of the physical substrate, are sharing resources and specifying their requests. Such request may involve a certain network topology in terms of nodes and links as well as performance constraints in terms for example of expected bandwidth and/or interference. The latter aims at investigating how to assign to each slice its own fraction of network resources (spectrum, radio, hardware), and how a traffic allocation decision, taken inside a slice, can affect the other slices (both logically and from the performance standpoint).

Résumé du projet de recherche (Langue 2)
Final thesis formulation Focusing on the previously presented objectives we therefore plan to extend SDN architecture in order to make it suitable/compatible with the specific requirements of 5G wireless architecture. SDN architecture is composed by southbound and northbound APIs. The main southbound API used nowadays, for wired scenarios, is OpenFlow and basically defines how the controller can instruct forwarding elements to forward packets belonging to a flow when they require it. The northbound API interacting with the controller allow sophisticated policies to be applied (e.g. advanced policies which consider a particular or critical network state). Specific Network applications, applying for example very sophisticated policies will communicate to the controller through the Northbound API and those will be finally delivered to forwarding elements in the form of simple forwarding instructions. The northbound API are needed to build a specific Network Operating System. Today, in contrast with southbound API, there is not a universal Northbound API, this means that the controller is still subject to compatibility with different Network Applications. In this thesis the southbound API's will be studied to perform the proper mobile network lower layer abstractions, towards this API's will be possible to handle different wireless technologies, communicating to technology dependent equipment, which might be also completely virtualized. This will study the most appropriate/needed PHY and MAC layer abstractions and machine learning algorithms that must be provided to instruct properly a complex architecture such as 5G HMN. On top of this the controller will expose Northbound APIs, this will give to different parties (e.g. Applications designers, Mobile operators) the possibility to interact with technology agnostic APIs exposing exclusively an amount of available wireless resources, e.g. extracted toward network graphs, over which the operator can rely on, without worrying about the specific requirements of each technologies and or needed signaling interactions. This northbound API will also require therefore a dedicated and smart way to abstract lower layer access technologies and present them to network applications designers and/or application. These APIs can then be used to build and explore and run new RAN sharing concepts in new network operating system where resource sharing and multi-tenancy are handled in an effective, dynamic and easy way towards new algorithms. Existing controllers, providing a mapping between northern API's polices and southern instructions will be accordingly extended and or a new dedicated controller will be investigated. In this new environment the thesis will investigate and, when possible, apply mobile signaling protocols simplifications managing in controller architecture.