On the 5G Network Slice Design Problem

Wesley da Silva Coelho[1−2], Amal Benhamiche[1], Nancy Perrot[1] , Stefano Secci[2]

[1] Orange Labs, TRM, Chatillon, France

{wesley.dasilvacoelho,amal.benhaminhe, nancy.perrot}@orange.com

[2] Conservatoire National des Arts et Métiers, CEDRIC, Paris, France

stefano.secci@cnam.fr

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1 Introduction

Network Slicing has been receiving increasing attention and closely studied by both industrial and academic communities over the last years. In order to provide an even more flexible environment to support customized networks, the 5G architecture is enhanced by Network Function Virtualization, Software Defined Networking, and Network Slicing techniques. Hence, each Communication Services provider is able to require customized logical network, named Network Slices (NS), specifically tailored to its requirements by infrastructure and network slice providers. In particular, designing end-to-end NSs requires to consider heterogeneous resources and different physical and virtual network topologies, each with specific technical constraints and orchestration policies.

2 Our Contributions

In this work, we model the 5G network slice provisioning as an optimization problem including novel mapping and provisioning requirements raising with the 5G. In particular, we take into consideration novel 5G-specific mapping dimensions, and model the relationship between flexible radio access functional splitting, control-plane and data-plane function separation and sharing policies. Even thought there are several works in the literature addressing related sub-problems, such functional split mode selection [1], network slicing with network function sharing [2] and with notwork function scaling [3], no attention has been given to address jointly all aforementioned sub-problems in order to design 5G network slices. To the best of our knowledge, we propose the first mathematical approach to address 5GNSD problem.

3 5G Network Slice Design Problem

We consider a *physical network* infrastructure characterized by a set of physical nodes and a set of physical links covering different parts, from access sub-networks (e.g. radio and wi-fi access technologies) to application sub-networks. A *physical node* either represents an *access node* (e.g. Radio Distributed Units) or *non-access node* (e.g. servers and routers) while a *physical link* represents an optical fiber link between two physical nodes. Every physical node is characterized by a set of available resources, namely computation (CPU), memory (RAM), and storage. Each physical link is characterized by a bandwidth capacity and a latency value which is the time needed by a flow to traverse that link. Finally, both physical nodes and links have associated utilization costs for each type of available resource.

In addition, we consider a set of *network slice requests* that correspond to customer demands to implement specific Communication Services. A *network slice* is a *virtual network* composed by a set of *virtual nodes* interconnected by a set of *virtual links*. Every virtual node corresponds to a *network functions* and is associated to a physical node while a virtual link corresponds to a path in the physical network. For each slice request, we are given a set of demands, where every demand is defined by an origin node and a destination node, both in the physical network. Moreover, every demand is characterized by a given amount of traffic (measured in Mb/s) to be routed from the origin nodes to the destination nodes. Finally, each slice needs a specific sub-set of *network function service* (NFS) (also knwon as micro-function) to implement the requested service. A NFS is embedded into a network function and has a limited capacity in terms of traffic that can be treated. Additionally, an installed network functions and its embedded NFSs can potentially be used by several network slices.

In this context, we define the 5G Network Slice Design (5GNSD) Problem as follows. Given a physical network, a set of virtual networks, a set of demands and a set of available NFSs for each virtual network, the 5GNSD problem consists in:

- Designing and dimensioning the virtual networks, that is:
  - Determining the number of NFSs needed;
  - Mapping each NFS to a network function;
  - Routing the demands in the virtual networks.
- Allocating physical resources to the virtual networks, that is:
  - Mapping each network having at least one NFS to a physical node;
  - Routing the traffic generated by each pair of network functions in the physical network.

Note that we have different types of constraints: (*i*) capacity constraints in the virtual and physical networks; (*ii*) partial order constraints for the routing in the virtual networks; (*iii*) compatibility constraints for the mapping in both virtual and physical networks.
A solution to 5GNSD problem minimizes the resource allocation, while respecting physical capacity constraints and assuring QoS imposed by each slice request.

4 Concluding Remarks

We show by numerical simulations that flexible splitting proves to be an interesting strategy even for scenarios with strong isolation restrictions. Applying this approach to 5G systems leads to decrease considerably the cost of deployment of virtual environments for the four different control-plane and data-plane function sharing policies proposed. In addition, our results points that the selected mapping strategy has a strong impact on the overall utilization of the physical resources.

References

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