Programmable 5G Avionic Networks

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***Abstract*—On the verge of next generation 5G networks, techniques such as network slicing and edge computing are proposed to further enhance network capabilities by enabling programmability and increasing flexibility. In the Radio Access Network (RAN) side the network slicing is a relatively new concept. Thus, there remain open issues related to the stochastic nature of the wireless channel and scarce wireless resources. Additionally, future multi-tenant systems are envisioned to allow Over-the-top (OTT) service providers and vertical industries to exploit a common network infrastructure for providing their services. In this paper, we identify some of the open issues regarding network slicing in RAN. Moreover considering an aircraft scenario as a 5G use case, we introduce a potential architecture which enables programmability and virtualization by means of Software-Defined Networking (SDN).**

***Index Terms*—Network Slicing, Slice Isolation, 5G, RAN, QoS**

I. Introduction

The next generation 5G networks require novel techniques which promise increased flexibility and cost-efficiency. To this aim, network slicing has gained high attention as an emerging technology which can deliver virtualization and programmability [1]. Network slicing enables the sharing of a common physical infrastructure, by permitting multiple tenants to coexist with each other in an isolated fashion.

While the Network Slicing concept is well investigated in the Core Network (CN), it still remains an open issue for the Radio Access Network (RAN). The stochastic nature of the wireless channels and the scarce resources increase the complexity and introduce an appealing avenue of research. Static resource assignment can provide a solution for the aforementioned problem, however from the resource utilization perspective this approach might result inefficient. Therefore, a dynamic resource assignment approach has been proposed in the literature. This helps adapting to dynamic changes of the wireless channel and leveraging diversity gains, nonetheless, such an approach introduces high complexity.

In order to support multi-tenancy in such systems, the architecture should account for the ability to expose the infrastructure to various Over-the-top (OOT) service providers and offer them methods to deploy their services. To overcome this issue, Software-Defined Networking (SDN) has been proposed and several architectures are presented such as FlexRAN [2]. The latter is the first open source Software-Defined RAN (SD-RAN) platform, which introduces the Application Programming Interface (API) and therefore enforces programmable control logic.

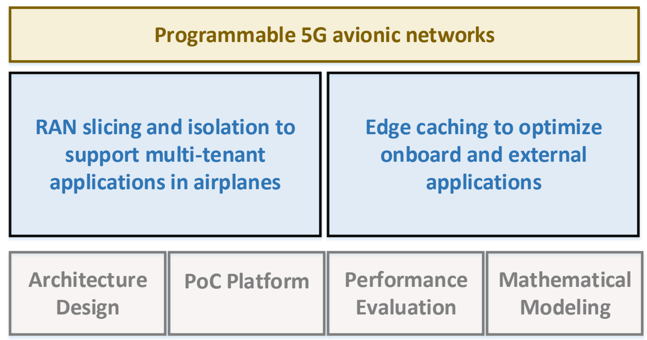

Fig. 1. Research directions for achieving flexibility and programmability in 5G avionic networks.

Considering a representative 5G use-case with high user density, we propose an architecture design for introducing programmability and flexibility in an aircraft in-cabin scenario. We further suggest a solution for RAN slicing, which allows the coexistence of multiple tenants within the aircraft in an isolated fashion.

II. Research Directions

The main research directions leading to the introduction of programmability and flexibility in future 5G avionic networks have been summarized in Fig. 1. Under the main umbrella topic two main research directions are identified. Initially, the emphasis is on the RAN slicing, enabling support for multi-tenant applications in aircrafts. Additionally, edge caching is envisioned as a potential approach to further enhance the network capabilities by promising lower delays and therefore optimizing on-board applications. In this section we introduce some of the most relevant state-of-the-art approaches for the aforementioned topics and identify their benefits and remaining issues.

A. RAN Slicing

Network slicing in RAN recently has received increased attention by many researchers. Moreover, novel techniques such as SDN have been proposed to further facilitate this process [2], [3]. As aforementioned, differently from core networks, in RAN the complexity of the problem consists in the efficient resource allocation, QoS provisioning and ability to sustain isolation among slices. Thus, the majority of researchers focus on efficient resource allocation in a multi-tenant environment

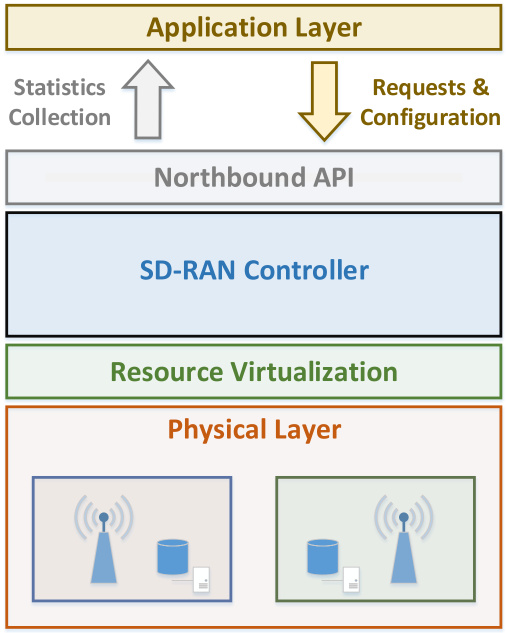

Fig. 2. Programmable 5G avionic architecture.

[4], [5]. From the network efficiency perspective, multiplexing gain is another aspect of network slicing considered in [6]. While all the aforementioned works provide QoS and isolation on the wireless level, none of them fully investigates the isolation regarding the QoS performance. To this aim, in [7] we propose a dynamic RAN slicing approach, which accounts for both isolation and QoS provisioning by applying the Lyapunov approach [8].

B. Edge Caching

Edge Caching has been identified as a solution which can further enhance the network capabilities [9]. It is believed that enhancing RAN with caching capabilities can improve the quality of the services and lead to an optimization from the applications perspective. Therefore, in the literature RAN slicing is often coupled with edge caching [10]. To this end, in our work we consider the wireless resource allocation and edge caching placement as a combined optimization problem.

III. Proposed System Architecture

Considering the open research questions introduced, in this section we focus on the architecture design of the system. Moreover, we will shed light on a solution for enabling network slicing in such a scenario.

The management and orchestration of the system is realized by applying the principles of SDN. The central logic of the architecture is put on a Software-Defined Radio Access Network (SD-RAN) controller. The controller is connected with the Application Layer by means of a Northbound Application Programmable Interface (API), which allows the inter-action of the services with the underlying physical infrastructure and therefore renders flexibility and programmability.

The virtualization of the wireless and caching resources is envisioned to be realized by entities located between the SD-RAN controller and the physical infrastructure. Hence, a new layer is introduced in our architecture, namely the resource virtualization layer. It is then the SD-RAN controller's duty to utilize these resources and by applying sophisticated algorithms, assign them to slices depending on the requirements fetched from the application layer.

In our model, the anticipated functionalities for realizing RAN slicing lie in the tasks of scheduling, admission control, virtualization and isolation provisioning. Consequently, we utilize the same concepts introduced in FlexRAN [2] to enable the proposed network slicing approach. The programmable 5G avionic architecture is illustrated in Fig. 2.

IV. Conclusion

In this paper, we introduced the idea of programmable avionic 5G networks. Moreover, we highlighted the two main research directions and presented selected works on the field, while identifying solutions to further improve the state-of-the-art. Finally, we shed light on one of the research issues by proposing a candidate architecture for future 5G avionic networks. The architecture suggests the use of SDN, which introduces programmability and enhances the flexibility of current avionic networks.

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