Demo: FlexRAN – A Software-Defined RAN Platform

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ABSTRACT

Although SDN is considered as one of the key technologies behind the impending 5G evolution of mobile networks, the opportunity of reaping its benefits is largely still untapped on the Radio Access Network (RAN) side due to the lack of a software-defined RAN (SD-RAN) platform. In this work we demonstrate the capabilities of FlexRAN, an open-source SD-RAN platform developed to fill this void. FlexRAN separates the RAN control and data planes with a custom-tailored southbound API. Besides it features a hierarchical control plane architecture that enables programmability, flexible and dynamic control function placement (allowing different degrees of coordination within and among base stations) and real-time control. Virtualized control functions and control delegation are two key features in FlexRAN that makes these capabilities possible. This demo illustrates the capabilities and the performance of FlexRAN based on a prototype implementation, while its applicability is highlighted through a Mobile Edge Computing use case, where it acts as an enabler of a video bitrate adaptation application based on the radio conditions at the network edge.

KEYWORDS

5G architecture, 5G RAN, software-defined RAN, SD-RAN, RAN softwarization

1 INTRODUCTION

The Radio Access Network (RAN) is a significant part of the mobile infrastructure, responsible for managing the air interface. In particular, the RAN needs to efficiently manage the limited wireless spectrum, performing various complex operations like radio resource allocation, load balancing and mobility management. The recent dramatic increases in mobile data traffic pose a significant strain to the underlying infrastructure and make the optimized management of resources a necessity. This is led in part by the rapid adoption of smartphones and their support of new types of data-hungry services like video streaming and by the emergence of new communications paradigms like machine-to-machine and device-to-device, which are characterized by high control signaling to data ratios. Current mobile networks were not designed with such scenarios in mind and are therefore unable to efficiently cope with them. With respect to the RAN, many solutions have been considered to deal with such issues, including an increased cell density and advanced radio resource management techniques like Coordinated Multipoint and enhanced Inter-Cell Interference Coordination. While such techniques can enhance the network efficiency, they require a high level of coordination among base stations, leading to further increases in the signaling complexity and the capex/opex. These changes, in combination with the requirements of future 5G networks, are necessitating innovation towards newer, more flexible RAN architectures [1].

Software Defined Networking (SDN) is among the key technologies considered in the context of evolving mobile networks [4]. This is brought about by paradigm shifting ideas underlying SDN, which are the separation of the control from the data plane via a well-defined API and the consolidation of the control plane. The same SDN ideas that have proved fruitful in the wired domain could also be seen as a key element in the solution mix to address the aforementioned RAN challenges and this is why there has recently been a significant interest both in the research community and industry on bringing SDN ideas to mobile networks. However, despite the plethora of conceptual proposals for re-architecting the mobile RAN based on SDN principles, there is still a lack of implementable solutions and suitable prototyping/experimentation platforms [3]. Moreover, even the existing designs lack certain desirable features, like the support for real-time control which is essential for many RAN-related operations, the capability to easily implement new control functions and the means to dynamically adapt the control scheme (local vs centralized) to the network requirements following NFV principles.

FlexRAN is a novel software defined RAN (SD-RAN) platform we have developed [2], with the aim of overcoming the aforementioned limitations. In the following, we give an overview of its design and implementation. The focus of this demo is two-fold: (1) showcase the unique capabilities of FlexRAN; (2) demonstrate its potential benefit in the context of emerging 5G mobile networks via the Mobile Edge Computing (MEC) oriented use case of adaptive video streaming over the network edge based on the radio conditions.

2 FLEXRAN

2.1 Design Overview

Figure 1 provides a high-level schematic of the FlexRAN platform, which as shown is made up of two main components: **FlexRAN Control Plane** and **FlexRAN Agent API**. The FlexRAN control plane follows a two-layered design and is in turn composed of a **Master Controller** that is connected to a number of FlexRAN **Agents**, one for each eNodeB. The agents can either act as local controllers with a limited network view and control delegated by the master, or in concert with other agents and the master controller. The control and data plane separation is provided by the FlexRAN Agent API which acts as the southbound API with FlexRAN control plane on one side and eNodeB data plane on the other side.

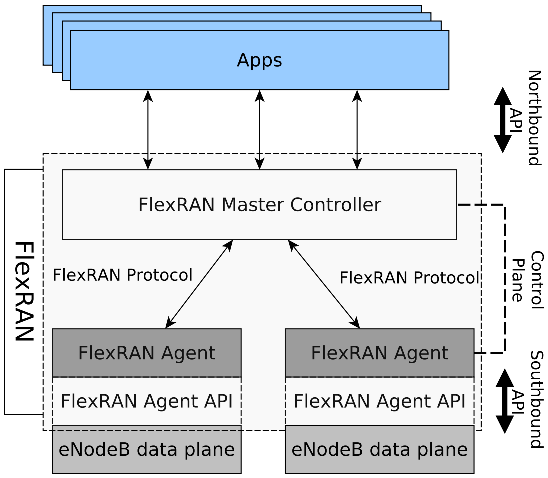


Figure 1: High-level schematic of the FlexRAN platform.

The FlexRAN **Protocol** facilitates communication between the master controller and the agents. As shown in the figure, it allows a two-way interaction between the master and the agents. In one direction, the agent sends relevant messages to the master with eNodeB statistics, configurations and events, while in the other direction the master can issue appropriate control commands that define the operation of the agents. In contrast to typical SDN controllers found in the wired domain, the FlexRAN controller has been designed with support for time critical RAN operations (e.g., MAC scheduling) in mind.

On top of the FlexRAN master controller lies a northbound API, which allows RAN applications to control and modify the state of the underlying network infrastructure (eNodeBs and UEs) based on the statistics and events gathered from the eNodeBs in the FlexRAN control plane. Such applications could greatly vary from simple monitoring applications that obtain statistics reporting which can be used by other apps, to more sophisticated applications that involve control-related RAN functions that modify its state (e.g., MAC scheduler).

2.2 Salient Features

Here we outline the salient features of FlexRAN:

Control and data plane separation - FlexRAN decouples the RAN control and data plane operations, towards reducing the complexity of developing new control solutions, promoting openness and innovation and allowing operators to open their RAN service environment to authorized third-parties to rapidly deploy innovative applications and service endpoints for mobile subscribers, enterprises and vertical segments.

Centralized & real-time control - FlexRAN consolidates the control plane into a single logically centralized controller, enabling easier coordination among the base stations of a region, effectively simplifying the development of new and more sophisticated control applications. Moreover, the FlexRAN platform has been designed in a way that enables support for the deployment of real-time control applications with very stringent time constraints, which is essential for many radio resource management related operations. An example of such a time-critical application would be the MAC scheduler of the LTE RAN, that needs to make and apply scheduling decisions with a very fine time granularity (1ms).

Virtualized Control Functions - FlexRAN allows the flexible and programmable control of the underlying RAN infrastructure through the introduction of a number of virtualized control functions that have a clean structure and well-defined interfaces and are responsible for performing the various control operations of the base station. This allows part of the system's logic, like the mobility manager or the MAC scheduler, to be easily upgraded by replacing or extending the corresponding function without affecting the rest of the system.

Control delegation & policy reconfiguration - The virtualized control functions of FlexRAN are exploited in a more dynamic way through a set of mechanisms designed to allow the delegation of control functions from the master controller to the base stations at runtime and the reconfiguration of their behavior and parameters on-the-fly in a simple and seamless manner. This feature makes the system very flexible and adaptable to the underlying networking conditions and to the specific requirements of the network operator, e.g., by enabling actions like the switching of scheduling from a centralized to a distributed scheme on-the-fly.

User Equipment (UE) transparency - The whole design is completely transparent to the UEs attached to the network. This is a key feature for deploying the system in existing networks and avoiding backwards compatibility problems.

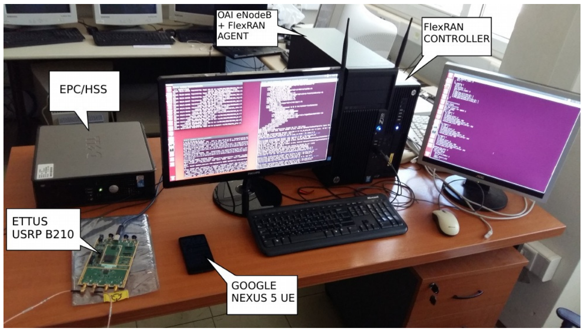
The virtualization of control functions and the control delegation capabilities offered by FlexRAN follow the NFV principles and indeed bring runtime service function chaining capabilities to the RAN, as they add a virtualization layer over the RAN infrastructure and allow the flexible placement of RAN control functions closer or further away from the base station based on the networking conditions, the available computing resources and the requirements of the operator in terms of performance. However, it should be noted that these capabilities relevant to the RAN are yet to be considered by NFV standards specifications, like that of ETSI NFV.

2.3 Implementation Outline

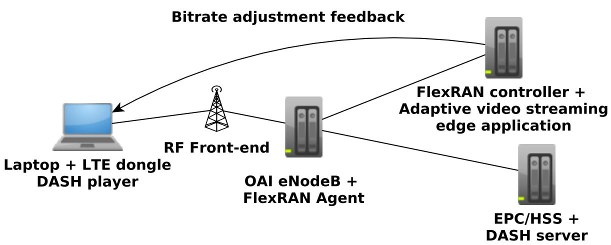
As a proof of concept, we have developed an open source prototype implementation of the FlexRAN platform. The FlexRAN controller is built from scratch using C++ with support for x64 Linux systems. The implementation supports both a real-time and non real-time mode of operation to cater for different time criticalities of the deployed applications and the requirements of the network operator. The FlexRAN agent was implemented in C on top of the open source LTE/LTE-A implementation of OpenAirInterface (OAI)[1]. The platform offers full transparency to UEs (incl. commercial UEs). FlexRAN Agent has been integrated into the most recent versions of OAI. The rest of FlexRAN has also been made publicly available[2] and is already being used by around 15 research groups from academia and industry worldwide.

[1] http://www.openairinterface.org/

[2] http://networks.inf.ed.ac.uk/flexran/



(a) Basic FlexRAN demonstration setup



(b) MEC use case setup

Figure 2: Demonstration setup

3 DEMONSTRATION

The goal of this demonstration is twofold:

- Firstly, to demonstrate the feasibility of realizing flexible software defined control in an LTE RAN using FlexRAN while maintaining full transparency for the attached UEs.
- Secondly, to highlight the value of FlexRAN as an enabler of emerging 5G use cases by demonstrating the use of FlexRAN in a scenario of adaptive bitrate video streaming at the network edge in the context of MEC.

For the first part of the demonstration, we use an LTE network testbed setup similar to Fig 2a, composed of a commercial LTE-enabled smartphone and 3 nodes; one acts as the eNodeB and is connected to a Software-Defined Radio (SDR) RF front-end, one acts as the EPC of the LTE network and the other acts as the FlexRAN controller. The eNodeB has two versions of OAI installed, a vanilla version and a modified version that provides support for the FlexRAN agent. Through this setup we demonstrate the feasibility of the FlexRAN-enabled LTE architecture and its transparency for the UE, by running in turn the vanilla and the modified version of OAI at the eNodeB and streaming in both cases an online video at the UE, noting the seamlessness for the user. Moreover, we show the control delegation and virtualized control function capabilities of FlexRAN by swapping a remote downlink MAC scheduler running at the master controller with a local one running at the FlexRAN agent while the UE is streaming an online video. This experiment demonstrates the flexibility of placing control functions closer or further away from the base station, while the service at the UE remains uninterrupted.

For the second part of the demonstration, the testbed is slightly modified by replacing the smartphone with a laptop-based UE,

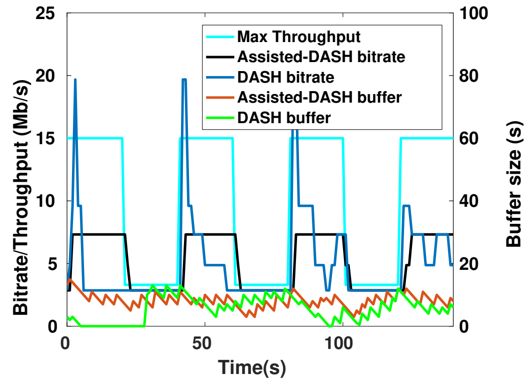


Figure 3: Rate adaptation of DASH vs controller-assisted DASH and corresponding buffer sizes

equipped with an LTE dongle (Fig 2b). The relevant scenario demonstrates how FlexRAN can be used as an edge computing application deployment platform, using as a concrete example the use case of adaptive bitrate video streaming. More specifically, we consider the case of MPEG-DASH as a streaming service, where a DASH server is deployed at the EPC and a DASH player is running at the laptop-based UE. An edge computing application is deployed over the FlexRAN controller and uses the FlexRAN protocol to obtain network information from the MAC layer of the eNodeB (CQI measurements, throughput per UE, etc) at a fine time granularity (1ms). This information allows the edge application to react in the changes observed at the radio link conditions between the eNodeB and the UE in real-time by re-adjusting the bitrate of the UE DASH player accordingly. As a result, we show (Figure 3) that the edge computing enabled video streaming is more reactive to changes in the network conditions, leading to an improved streaming quality compared to the conventional DASH streaming (no video freezes and buffer stalls).

ACKNOWLEDGMENTS

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