Joint 5G-LTE-WiFi Prototyping Platform for RAT Interworking Experiments

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***Abstract*—The coordination and coexistence of heterogeneous wireless technologies such as 5G, LTE and WiFi have become a growing area of research these days due to an increased number of connected devices and related communication requirements. This poster presents a prototyping system for joint real-time experimentation of LTE, WiFi and 5G systems with software defined radio hardware that involves real-time FPGA PHY implementations. This platform allows holistic experiments of these communication systems and related interworking functionalities that will lead to a better insight into trade-offs for using these radio access technologies jointly as it is foreseen in practical wireless network deployments.**

I. Introduction

Multiple options to split and aggregate data traffic over different air interfaces are described in standardization bodies with the aim of increasing data throughput, reliability and flexibility. For LTE and 5G-NR, dual connectivity (DC) and carrier aggregation (CA) functionalities are used. For interworking between LTE and WIFI radio access technologies (RAT), LTE-WLAN aggregation (LWA/LWIP) is envisioned [1]. To understand tradeoffs between these technologies, simulations and experimentation setups for joint simulation are needed. Nowadays SDR prototyping platforms only allow separate prototyping of different RATs. In the context of the H2020 project "ORCA" [2], a platform for real-time multi-RAT experimentation is currently being developed that incorporates LTE, WiFi as well as a 5G link. In this poster, we describe this prototyping system utilizing the ns-3 simulator as well as the NI SDR platform. Further we will discuss how this system can be used for joint LTE, WiFi and 5G experiments.

II. 5G-LTE-WiFi Interworking using ns-3

To emulate higher layer protocol stack functionality on top of the physical layer (PHY), we use the open source network simulator ns-3. This environment offers a wide range of modules to simulate wired and wireless transmission systems in a joint fashion. More information about ns-3 can be found under [3]. To accomplish the integration of three different radio access technologies, we make use of the respective ns-3 modules. The ns-3 LTE module [4] incorporates all necessary components such as base station (eNB), user equipment (UE) and even core network functionality to form a complete end-to-end communication system. The ns-3 WiFi module [5] provides functionality for access point (AP) and station (STA). An implementation of 5G-NR is available under [6] but couldn't be used in this setup due to missing functionality in the radio resource control layer. Therefore, the 5G link in the described system is based on the ns-3 LTE module as well, but 5G-related changes where made on the physical layer. To extend the simulation capabilities of ns-3 for real-time end-to-end prototyping, we implemented an application programming interface between PHY and MAC layers (L1-L2 API) for LTE, WiFi. With this, ns-3 can be connected to the NI real-time SDR platform. The API concept was extended to the 5G link such that a 5G real-time PHY implementation can also be interfaced to ns-3. An overview diagram of the complete experimentation platform is shown in Figure 1. The topology is assembled in a single ns-3 main file for further customization and incorporates all components of a real networking environment. A configurable number of remote hosts mimics possible application servers and is interfaced to the internet simulation model using the ns-3 CSMA module. To connect this internet model to the different radio access technologies, a mobile network gateway is implemented. From this gateway, variable routing strategies can direct traffic towards the three different radio access technologies. While LTE and 5G incorporate base stations in the setup, the WiFi path includes an access point. The scenario implementation offers also end user equipment for all three radio access technologies. Each of these end points can be addressed by a unique IP address and can be seen as a combined Multi-RAT UE capable of several different RATs. In addition to this setup, RAT interworking technologies are implemented for experimentation. An LWA/LWIP implementation in ns-3 allows traffic routing from the LTE eNB through the WiFi AP and STA to be transparently re-routed back into the UE. Interworking between LTE/LTE or LTE/5G

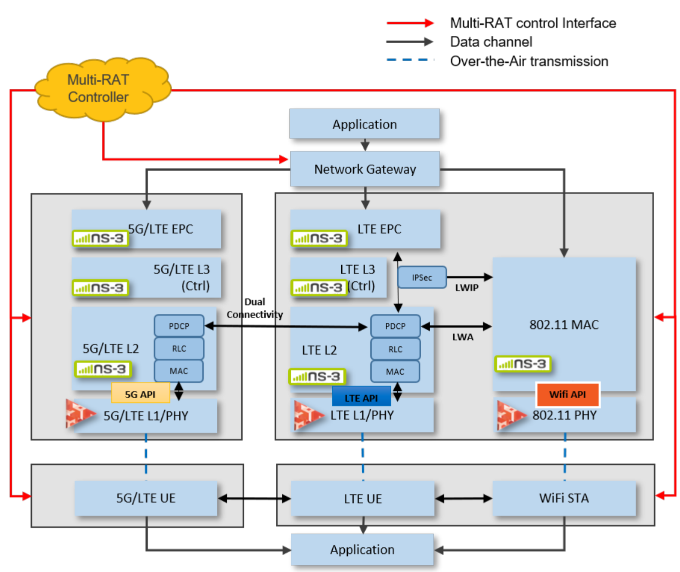

Fig. 1. ns-3 based 5G-LTE-WiFi Interworking System

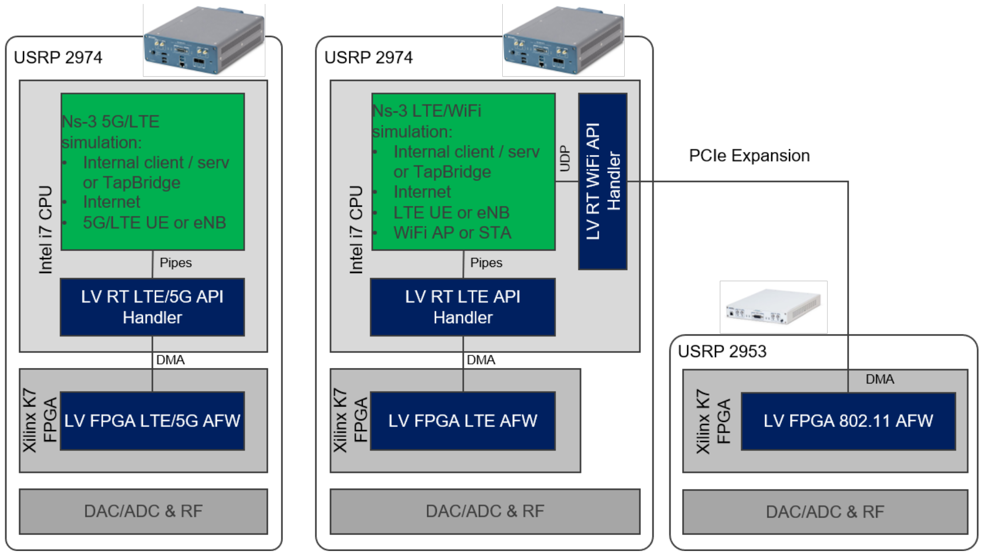

Fig. 2. 5G-LTE-WiFi Prototyping Platform using NI SDR system

is available through a Dual Connectivity implementation that is capable of re-routing traffic from the LTE eNB through either another adjacent LTE eNB or a 5G gNB. Ns-3 offers flexibility and customization options for interfacing a controller entity to adaptively steer routing and interworking decisions based on measurements of network and RAT specific KPIs. With this, a customizable experimentation platform for software defined network (SDN) and Multi-RAT investigations on real-time hardware is available.

III. NI SDR Prototyping System

The real-time prototyping system uses the NI USRP-2974 [7]. This USRP is a stand-alone device that incorporates an Intel Core i7 CPU and a Xilinx Kintex-7 FPGA as well as ADC/DAC and RF. Carrier frequencies from 10 MHz - 6 GHz can be configured with a maximum channel bandwidth of 160 MHz. This systems perfectly suits the needs of the above mentioned prototyping system. The Intel CPU can be used to compile and execute ns-3 as it runs the NI Linux Real-Time operating system. The PHY layer implementations of LTE and WiFi within the prototyping system are realized on the FPGA with NI LTE and 802.11 Application Frameworks [8] / [9]. The 5G PHY layer implementation is based on the flexible numerology GFDM transceiver [10] which offers flexibly switching of subcarrier spacings and more waveform customization options. The extension of the USRP-2974 through a PXI expansion port offers the possibility to add a legacy USRP RIO such that LTE and WiFi paths can be deployed on the two available FPGAs and be accessed jointly by one ns-3 instance that is running on the CPU. The 5G link will run on a separate USRP-2974. The overall system architecture is shown in Figure 2. The setup allows for very compact prototyping and experimentation of the different RATs in a real network setup with real-time FPGA and CPU implementations at hand.

IV. Conclusion

The inclusion of a 5G link into the joint 5G-LTE-WiFi prototyping platform with an interface towards ns-3 is the main contribution and completes the prototyping platform to be used for various new experimentation scenarios. With our poster, we will discuss with visitor's implementation details on the L1-L2 API, specifics of the 5G Link integration and interworking technologies. The entire system will be available throughout ORCA project and its testbeds. It will facilitate the joint prototyping of 5G, LTE and WiFi in a real-time end-to-end testbed and will create better understanding of the general requirements of RAT interworking including all aspects of a wireless network. Furthermore, we will discuss how this system can be flexible controlled and re-configured by an external software entity.

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