Multi-RAT Experimentation below 6 GHz

Nicola Michailow*, Clemens Felber† and Vincent Kotzsch‡
National Instruments Corp., Austin, TX, USA
*nicola.michailow@ni.com, †clemens.felber@ni.com, ‡vincent.kotzsch@ni.com

***Abstract*—Driven by novel 5G use cases like ultra-reliable and low-latency communication (URLLC) and massive machine-type communication (mMTC), as well as the strife for higher data rates in enhanced mobile broadband (eMBB), researchers and engineers are in need of prototyping platforms to evaluate new concepts and technologies for future wireless communication systems. In context of the H2020 project "ORCA", a platform for multi radio access technology (multi-RAT) experimentation below 6 GHz is currently being developed [1]. Its goal is to enable experiments with heterogeneous RATs, including LTE, 802.11 and 5G. This will lead to a better understanding of practical trade-offs when dealing with existing and new technologies.**

I. Introduction

Driven by the growing number of connected devices, the coordination and coexistence of heterogeneous wireless technologies has become a key research area today. The European research project "ORCA" supports these efforts by offering facilities that allow scientists to complement theoretical research and simulations by practical evaluation and real-world experiments. The ORCA testbeds are accessible to the research community through several open calls for extensions and experiments. In this poster, we introduce a platform for sub 6 GHz multi-RAT prototyping, discuss different options for radio access technology (RAT) interworking and present a unified L1-L2 application programming interface (API).

II. A Multi-RAT Platform based on ns-3

Operations on higher layers (layer 2 (L2) and above) of a wireless communication system typically require splitting and assembling packets, creating and removing headers, etc. which are easily realized with pointers and buffers on a CPU. In contrast, hardware acceleration is suitable for the computationally intensive layer 1 (L1) processing, which includes modulation, FFT and decoding. With this in mind, we have chosen a combination of a host PC running a Linux real-time (RT) operating system on Intel CPU in combination with the FPGA-based SDR platform USRP-RIO [2].
The following software components have been used to implement the RAT building blocks Long Term Evolution (LTE), 802.11 and 5G:

- For the LTE link, we employ the LTE EPC Network Simulator (LENA) [3] model for the open source network simulator 3 (ns-3) [4], in combination with a real-time implementation of the LTE L1 on FPGA [5], [6].
- For the 802.11 link, similarly, we have combined the ns-3 WiFi module [7] with an FPGA real-time implementation of 802.11 L1 [8]. In contrast to LTE, some of the 802.11 MAC operations require a timing that is challenging to achieve in software. Hence, parts of the lower MAC have also been implemented on FPGA.

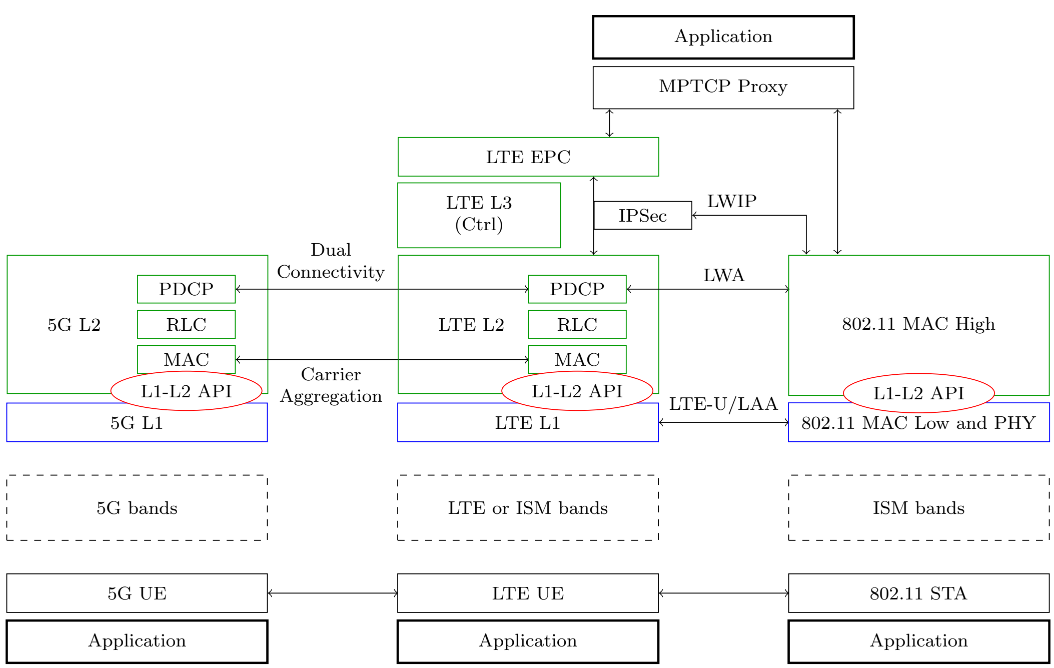

Fig. 1. Multi-RAT platform overview

TABLE I. OVERVIEW OF RAT INTERWORKING TECHNIQUES THAT CAN BE STUDIED WITH THE PROPOSED SDR PLATFORM.

RATs	Technique	Layer	Features
LTE and 5G NR	Dual connectivity (DC)	PDCP	Increase throughput, improve mobility robustness, allow load balancing among eNBs
	Carrier aggregation (CA)	MAC	Larger effective bandwidth for UE by aggregating discontinuous component
LTE and WLAN	License assisted access (LAA)	PHY	Modifications in PHY to facilitate coexistence between WLAN and LTE in unlicensed bands
	LTE in unlicensed spectrum (LTE-U)	PHY	Modifications in PHY to facilitate coexistence between WLAN and LTE in unlicensed bands
	LTE/WLAN aggregation (LWA)	LTE PDCP	The LTE eNB can initiate the offloading of packets at PDCP level, similar to DC
	LTE/WLAN aggr. w/ IPsec (LWIP)	IP	eNB load balancing through aggregation/switching at IP layer, supports legacy WLAN hardware
	Multipath TCP (MPTCP)	Above IP	Inverse multiplexing of TCP packets, backwards compatible with plain TCP

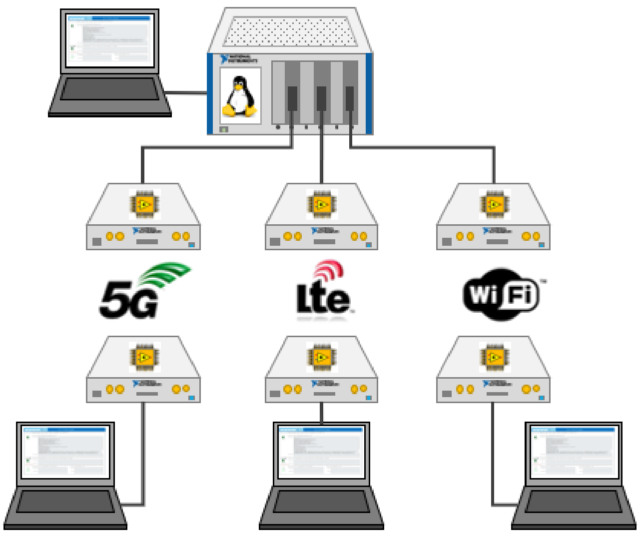

Fig. 2. Realization of the multi-RAT platform with SDR hardware

- For the 5G link, an FPGA implementation of a flexible PHY is being used [9]. Note that there is no standards compliant implementation of 5G L2 and above available yet.

The complete sub-6 GHz multi-RAT platform is depicted in Fig. 1. It is currently in the process of being set up. The time frame is two years, where the focus of the first project year is to set up the RATs and the exploration of LTE and 802.11 interworking. The 5G link will be first treated as a parallel, coexisting RAT. The second project year will be focused on adding interworking connections at the various layers between the different RATs.

With the connection of NI's SDR platform to the higher layer ns-3 network simulator, various deployment and test scenarios are possible that allow for experiments that have not been possible so far. The resulting testbed will assist the design of 5G radio interface and network architecture. It facilitates the prototyping of end-to-end applications, that include the functionality of all layers of a wireless communication system, in real-time and over-the-air environments. Measurement results in the real-time testbed will create understanding of the general requirements of RAT interworking including all aspects of a wireless network.

III. CONCLUSIONS

With our poster, we will discuss with visitors how to implement a SDR-based realization of the proposed multi-RAT experimentation platform as depicted in Fig. 2. We will put particular focus on the mapping of the various RAT's functionalities across a Linux RT operating system on CPU and FPGA hardware. We will show how existing SDR IP like the NI LTE and 802.11 Application Frameworks [5], [8] can be leveraged to speed up the prototyping process.

From software side, we will present an API for the integration of layer 1 and layer 2 and discuss strategies for its implementation w.r.t. to efficiency and re-usability. Such a generalized interface can be applied for the multiple RATs in the testbed and is an integral building block which allows to leverage existing code and quickly integrate new components.

Lastly, we will elaborate how the RAT interworking options presented in Table I can be researched with the proposed platform and also put the work into context with 5G New Radio (5G NR), discuss how it can help speed up the roll-out and adoption of the upcoming technology through prototyping of non-standalone operation mode.

ACKNOWLEDGMENT

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