Cellular and WLAN Networks Prototyping:- NI Software Defined Radio Approach

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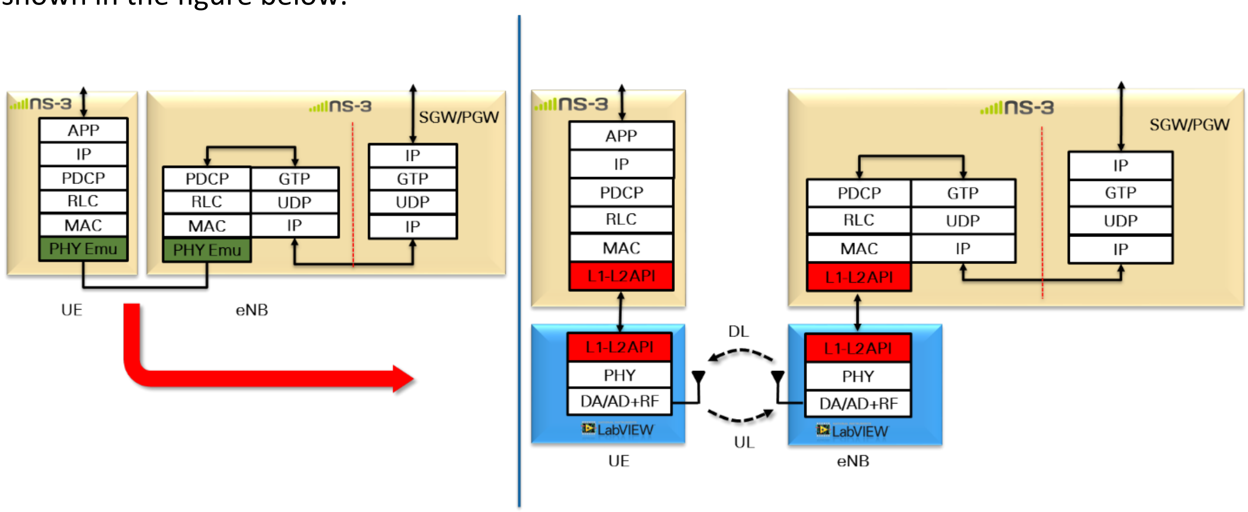
Extended Abstract

The exponential growth in usage of wireless network technologies has not shown any indication of slowing down. A single technological innovation cannot address the emerging requirements on network capacity and per-user throughput, and support variety of applications such as enhanced broadband, internet-of-things (IoT/MTC) and ultra-low latency communications. A heterogeneous mix of technologies will be needed for any high performance network. Examples of technologies being explored include network densification, massive MIMO, expansion into millimeter-wave bands, cellular/Wi-Fi coexistence, and design of flexible and scalable numerology. These have implication on both the physical layer (PHY) design as well as upper layer design of the networks.

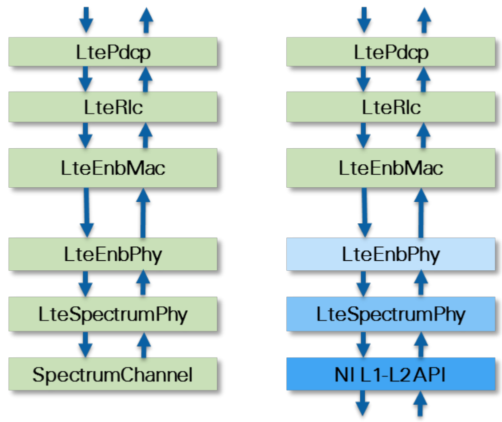
Due to such wide variety of technologies under exploration, real-time testbeds are essential to enhance our understanding and to verify that the promised gains can be obtained in practice. National Instruments (NI) software defined radio (SDR) research teams have been working with researchers both in industry and academia to make high performance real-time prototyping accessible to domain experts. In this presentation, we will share our recent prototyping efforts in 5G cellular (millimeter-wave, massive MIMO, etc.) and IEEE 802.11 (MAC layer research, 802.11ax, etc.) with in depth description of two examples.

As the first example, we describe how to utilize the familiar open source ns-3 LTE simulation stack to develop an end-to-end over-the-air real-time LTE network for research. A basic illustration is shown in the figure below.



The ns-3 LTE module contains a PHY abstraction to emulate the different physical channels and does not include a full-fledged PHY layer implementation. This abstraction is replaced by a real-time LTE PHY layer implementation provided by the NI LTE Application Framework utilizing FPGAs. A generic L1-L2 message based interface has been developed to communicate between the ns-3 LTE upper layers and the NI LTE PHY. Modifications in the ns-3 system were needed to connect the upper layer stack via the L1-L2 interface with the LTE PHY as well as for real-time operation of the ns-3 stack. A basic illustration of the changes is shown in the figure below. Overall, these changes are aiming at:

- Stack operation in LTE real-time (1ms TTI timing)
- API for connection with the physical layer
- Start in eNB or UE mode (enable a semi standalone mode)



In general, the system template can also be utilized to connect other standards compliant stacks such as open air interface (OAI) and srsLTE with the NI LTE Application Framework.

As a second example, we describe a platform for studying cellular technologies in unlicensed bands such as LTE unlicensed (LTE-U) and licensed assisted access (LAA). Due to the spectrum crunch, the cellular ecosystem is looking to utilize unlicensed spectrum, specifically in the 5GHz band, to improve performance. This can be done using existing technologies (Wi-Fi) or by modifying cellular technologies to aggregate those channels directly into the cellular PHY and MAC layer. The latter approach, represented by LTE-U and LAA, has caused disagreement between cellular and Wi-Fi ecosystems and resulted in controversies. In this presentation, we show a neutral modifiable prototyping platform which exposes important configuration options such as LTE-U duty cycle, LAA energy detection threshold, LAA listen before talk algorithms etc., which provides the opportunity to evaluate performance in realistic scenarios. Results from this platform was used in a couple of contributions by NI to 3GPP RAN1 during LAA standardization process.

Presenter Bio

Amal Ekbal received his B.Tech. degree in Electrical Engineering from Indian Institute of Technology, Madras, in 2000, and M.S. and Ph.D. degrees in Electrical Engineering from Stanford University in 2002 and 2008 respectively. He joined the Corporate Research and Development group at Qualcomm, Inc. in 2005 and worked on system design, prototyping and ASIC implementation of wireless communication systems. From 2011, he is with the Advanced Wireless Research Team at National Instruments where he is focused on next generation WLAN and cellular system design and algorithms, tracking standards and market trends in WLAN technologies, and prototyping wireless communication protocol stacks using software-defined radio (SDR) architectures.

National Instruments Wireless Research Background

National Instruments (NI) SDR and wireless research teams have been working on a variety of innovative projects involving wireless network performance evaluation. NI designs a wide variety of prototyping platforms that can address high-performance as well as low-cost scenarios with FPGAs, general purpose processors (GPP) running real-time operating systems (RTOS) or general purpose operating systems, and RF front-ends. NI also provides a graphical programming language called LabVIEW that enables domain experts to program the SDR hardware. LabVIEW supports other programming languages too such as C/C++ and FPGA IP developed using other languages such as VHDL. Open source code bases such as GNU Radio for USRP are also supported. NI LabVIEW Communications System Design Suite provides real-time LTE and 802.11 Application Frameworks that give a starting point for researchers in wireless communication systems to implement, modify and test their algorithms. A variety of reference designs that address 5G systems such as millimeter-wave and massive MIMO are also active topics of joint research.

Some highlights from joint wireless prototyping research projects which NI wireless teams participated in recently is listed below. These projects use NI hardware platforms and build on top of the reference designs developed by NI.

- Samsung demonstrated a proof-of-concept full dimensional MIMO (FD-MIMO) system during NI Week 2015 which was subsequently standardized in 3GPP LTE.
- EU FP7 project CROWD used a proof-of-concept version of the ns-3-based platform described earlier in this submission and completed successful European Commission review in 2015.
- Nokia demonstrated a 5G proof-of-concept millimeter-wave system using a beamforming-based MAC and a 1GHz bandwidth multi-Gbps MIMO PHY in mobile world congress (MWC) 2016.
- Lund and Bristol University demonstrated a massive MIMO system with 128 antenna base station and 12 clients while setting a world record in spectral efficiency among 5G candidate systems. Intel also demonstrated its version of the massive MIMO system in MWC 2016.
- Texas A&M University demonstrated a multi-node 802.11 MAC research platform in SIGCOMM 2015.