Demo: LabVIEW Based Framework for Prototyping Dense LTE Networks

Rohit Gupta and Bjoern Bachmann
National Instruments
Dresden, Germany
{rohit.gupta, bjoern.bachmann}@ni.com

Russell Ford and Sundeep Rangan
NYU Wireless
New York, USA
{russell.ford, srangan}@nyu.edu

Arianna Morelli
INTECS
Pisa, Italy
arianna.morelli@intecs.it

Vincenzo Mancuso
Institute IMDEA Networks
Brookhaven National Lab
P.O. Box 5000
vincenzo.mancuso@imdea.org

Nikhil Kundargi and Amal Ekbal
National Instruments
Austin, USA
{nikhil.kundargi, amal.ekbal}@ni.com

ABSTRACT

In the demo, we illustrate the integration aspects of LTE testbed using LabVIEW SISO OFDM Physical layer and open source Ns-3 LTE LENA stack. We leverage the NS-3 LENA module, which allows researchers to conduct simulations by emulating large network of base-stations, mobile devices and core network. However, the validity of results produced from such simulations is limited due to the physical layer model and may not accurately reflect the true behavior of densely-deployed LTE networks. Hence, we implemented selected LTE physical channels in LabVIEW to facilitate more realistic emulation of the LTE testbed and integrate it with MAC/higher layers of LENA protocol stack. The main goal of the testbed is to be able to show the artifacts caused in interference limited environment and demonstrate the performance of Enhanced Inter-cell Interference Coordination (eICIC) algorithms proposed by researchers in 3GPP. This demo shows preliminary results and we plan to use this testbed to showcase different aspects of Software Defined Networking (SDN) framework which is used to fine-tune different aspects of dense deployments within EU FP7 CROWD research project.

Categories and Subject Descriptors

C.2.1 [**Computer-Communication Networks**]: Network Architecture and Design - Wireless Communications

Keywords

LabVIEW; LTE; Prototyping; Emulation; Simulation

WiNTECH'14, September 7, 2014, Maui, Hawaii, USA.

ACM 978-1-4503-3072-5/14/09 ...$15.00.
http://dx.doi.org/10.1145/2643230.2643247.

1. INTRODUCTION

Mobile data traffic demand is growing exponentially and the trend is expected to continue for the near future, especially with the deployment of 4G networks. In order to cope with such rapid explosion of traffic demand, mobile network operators have already started to push for denser, heterogeneous deployments. In fact, small cell deployment is one of the key technologies that is expected to solve the growing traffic demand for future cellular networks.

In order the solve the complex challenge of interference in dense deployments, there has been significant amount of research that relies on simulations at PHY, MAC and higher layers and these algorithms need to be validated in lab deployments to evaluate the performance of the entire system in a realistic environment. However, the ever increasing complexity in all layers of cellular wireless systems has made an end-to-end demonstration of the LTE network limited to industrial research labs or large academic institutions. Indeed, although there are commercial programmable platforms, e.g., from Amarisoft [1], etc., those solutions are quite expensive to deploy for an academic institution (beyond the budget of large research projects in the networking field), and require long training.

The main motivation in our project is to build a testbed that is cost-effective and can interface easily with open source simulators like the NS-3 LENA LTE stack [4], which allows us to create a unified platform for both simulations and prototyping. In order to interface NS-3 LTE LENA stack with realistic Physical layer and be able to run in real-time, we implemented some physical layer channels, i.e. Physical Downlink Common Control Channel (PDCCH)/ Physical Downlink Shared Channel (PDSCH) in LabVIEW FPGA due to its innovative graphical system design environment which allows very efficient and fast prototyping. LabVIEW platform is PXI-based or USRP-based and is a very powerful and feature-rich rapid prototyping tool[3] for research in real-time wireless communication systems. It provides a rich heterogeneous environment including multi-

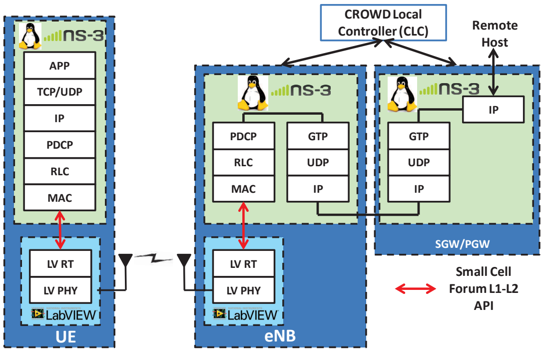

Figure 1: Testbed architecture.

core Windows/Linux PC and real-time operating system (RTOS) running on high-performance general purpose processors (GPP) such as Intel processors and Xilinx Kintex-7 FPGA modules. It also provides a rich set of RF, Digital to Analog Converter (DAC) and Analog to Digital Converter (ADC) modules that can meet the bandwidth and signal quality requirements of 5G systems.

In this demo, we show preliminary results on how LabVIEW-based LTE PHY layer is integrated with the open source NS-3 LTE LENA stack [4]. The main goal of this testbed is create a small-cell dense LTE network which can validate the performance of enhanced Inter-cell Interference Coordination (eICIC) algorithms, for example Almost Blank Sub-Frame (ABSF) [6].

2. DEMO DESCRIPTION

Fig. 1 shows the general overview of testbed architecture, see [5] for more details. The functions of the MAC and higher-layer protocols, including CROWD Local Controller (CLC) applications, run on a Linux computer. The protocol stack communicates with PHY layer running on NI/PXI system over Ethernet using an L1-L2 API that is based on Small Cell Forum API [2]. We have implemented the high throughput baseband signal processing for an "LTE-like" OFDM transceiver for the eNB and UE in LabVIEW using several FlexRIO FPGA modules. We use NI 5791 FlexRIO Adapter Module (FAM) as RF transceiver. This module has continuous frequency coverage from 200 MHz to 4.4 GHz and 100 MHz of instantaneous bandwidth on both TX and RX chains. It features a single-stage, direct conversion architecture, providing high bandwidth in the small form factor.

We have chosen to implement only selected LTE physical layer control/data channels, viz. (PDCCH/PDSCH) to accurately model the behavior of data plane. We use the OFDMA based Physical layer in uplink to simplify the implementation. The demo consists of integration aspects of NS-3 LENA stack and LabVIEW FPGA PHY layer. Currently, we have only PDSCH implemented and we show how NS-3 eNB/UE communicate over LabVIEW physical layer. During the live demo, we show NS-3 logs that are collected in real-time to illustrate aspects of LTE ATTACH Procedure and also data transmission. Fig. 2 shows the overall setup of our proposed prototype, which contains SISO OFDM downlink (eNB + UE). There are five basic elements in our testbed, as described below:

1. Laptop running LabVIEW for developing the SISO OFDM/LTE transmitter/receiver and also deploying the PHY layer code to the PXI systems.

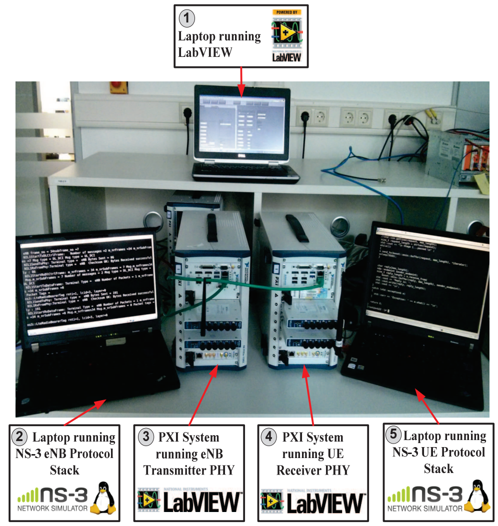

Figure 2: Testbed Setup for eNB-UE downlink scenario.

2. Laptop running the NS-3 eNB protocol stack in Linux.
3. PXI System running the eNB transmitter baseband PHY on Virtex5/Kintex 7 FPGAs with a NI 5791 front-end module functioning as the transmitter DAC and RF upconverter.
4. PXI System running eNB receiver baseband PHY on Virtex5/Kintex 7 FPGAs with a NI 5791 FAM used as the downconverter and ADC.
5. Laptop running the NS-3 UE protocol stack in Linux.

Our demo includes the building blocks that are needed to emulate large and dense networks in a lab, and demonstrate the performance of PHY/MAC cross-layer interference mitigation algorithms like eICIC and ABSF optimization tools recently proposed in the frame of the the CROWD project, as well as in similar research projects.

3. ACKNOWLEDGMENTS

The research leading to these results has received funding from the European Union (FP7/2007-2013) under grant agreement no. 318115.

4. REFERENCES

[1] Amarisoft Corp. Website:http://www.amarisoft.com/ .
[2] LTE eNB L1 API Definition, Small Cell Forum. Website:http://www.smallcellforum.org/.
[3] NI Software Defined Radio. Website:http://ni.com/sdr.
[4] Overview of NS-3 based LTE LENA Simulator. Website:http://lena.cttc.es/manual/.
[5] R. Gupta, T. Vogel, N. Kundargi, A. Ekbal, A. Morelli, V. Mancuso, V. Sciancalepore, R. Ford, and S. Rangan. LabVIEW based Platform for prototyping dense LTE Networks in CROWD Project. In *The 23rd Annual European Conference on Networks and Communications (EuCNC)*, 2014.
[6] V. Sciancalepore, V. Mancuso, A. Banchs, S. Zaks, and A. Capone. Interference Coordination Strategies for Content Update Dissemination in LTE-A. In *The 33rd Annual IEEE International Conference on Computer Communications (INFOCOM)*, 2014.