

Cellular and WLAN Networks Prototyping NI SDR Approach

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WNPE Workshop

Outline

- I. NI Wireless Research
- II. Wireless Networks Prototyping with ns-3 and NI SDR
- III. Cellular/Wi-Fi Coexistence in Unlicensed Bands
- IV. Conclusions

NI Wireless Research

NI Wireless Communications Lead User Program

- Established in 2010
 - Goals: Further wireless research through prototyping
- Research Institutions
 - Academic
 - Industry
- Over 100 research papers published



Prototyping Is Critical for Algorithm Research



“Experience shows that the real world often breaks some of the assumptions made in theoretical research, so **testbeds are an important tool for evaluation under very realistic operating conditions**”

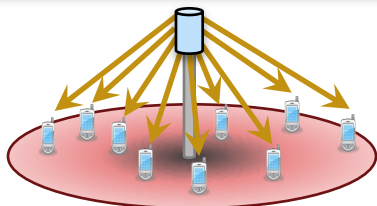
“...development of a **testbed** that is able to test **radical ideas** in a complete, working system is **crucial**”



NSF Workshop on Future Wireless
Communication Research

NI 5G Research Initiatives

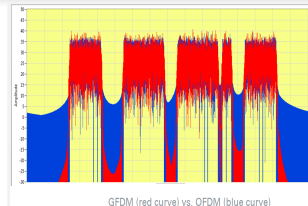
Massive MIMO



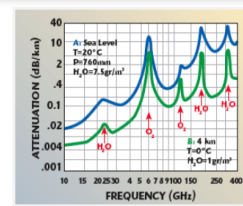
Wireless Networks



Multi-RAT



mmWave



NATIONAL INSTRUMENTS

LabVIEW™



Personal Computers



PXI Systems



USRP RIO

Bristol University Massive MIMO: 1.5Gbps in 20 MHz

- 128 antenna system
- 10 UEs
- $> 1.5\text{Gbps}$ in 20 MHz spectrum
- NI massive MIMO SDR



Prof Mark Beach



Paul Harris

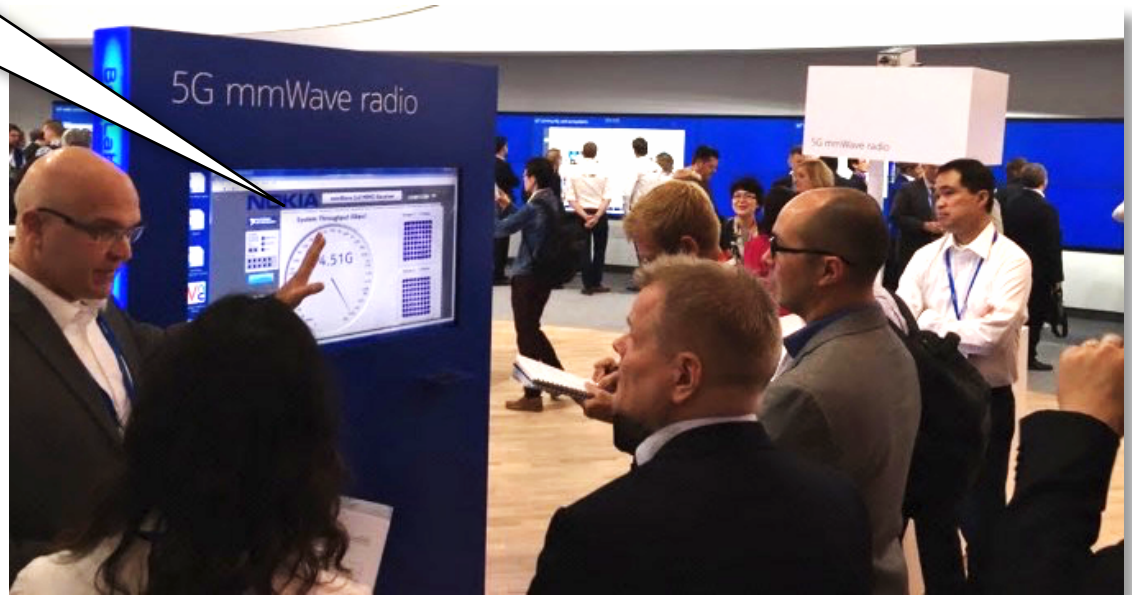
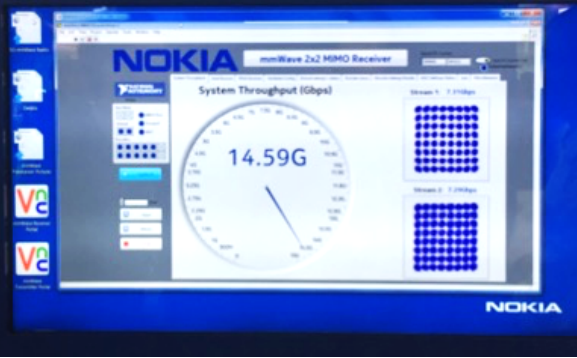


University of
BRISTOL



5G mmWave 14.5Gbps Link with Nokia at MWC 2016

5G mmWave radio

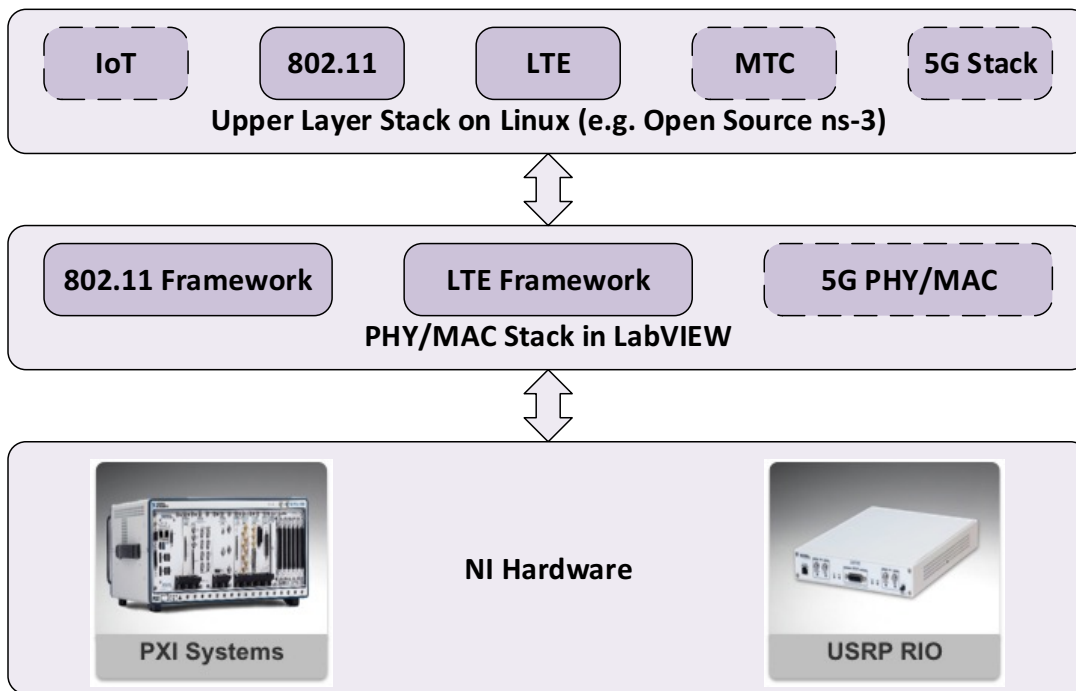


Wireless Networks Prototyping with ns-3 and NI SDR

Wireless Networks Prototyping Challenges

- Prototyping system design requires diverse experience
 - FPGA boards, Processor boards, RF cards etc.
- Complex system integration
 - For example, control and data path APIs to RF card
- Heterogeneous tools, software and hardware
 - Different layers may require knowledge of different tools and IDEs
- Lack of well documented, and easily modifiable code base
 - Need to obtain from diverse sources or spend time to create own code base
 - May need significant modifications to meet prototyping goals
 - E.g.:- Real-time requirements

NI Wireless Communications Prototyping Platforms

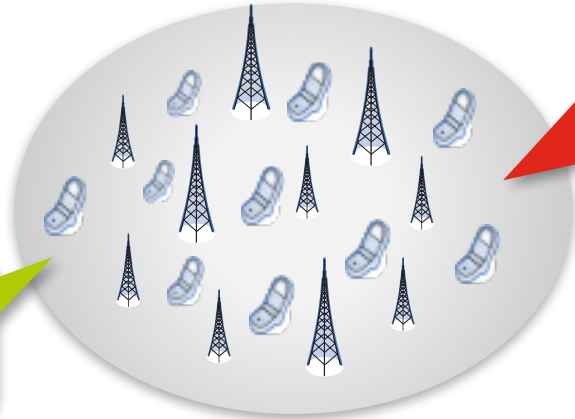


LTE Example:- ns-3 LTE Stack + NI LTE Application Framework

Example integration of one open source protocol stack with FPGA based SDR platform that runs a real-time physical layer implementation in LabVIEW Communications.



ns-3
NETWORK SIMULATOR



- Proof-of-concept of new PHY algorithms in an end-to-end real-time environment.
- Over-the-air experiments with modified upper layer stack (e.g. new MAC procedures).

LTE Application Framework

Real-time over-the-air transmission

Designed for modifiability by algorithm designers

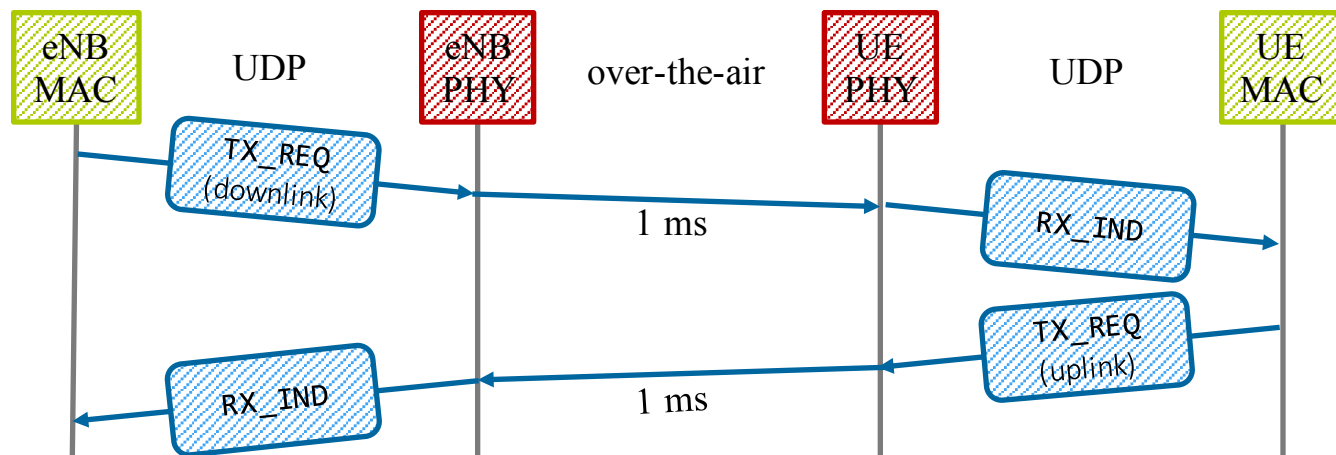
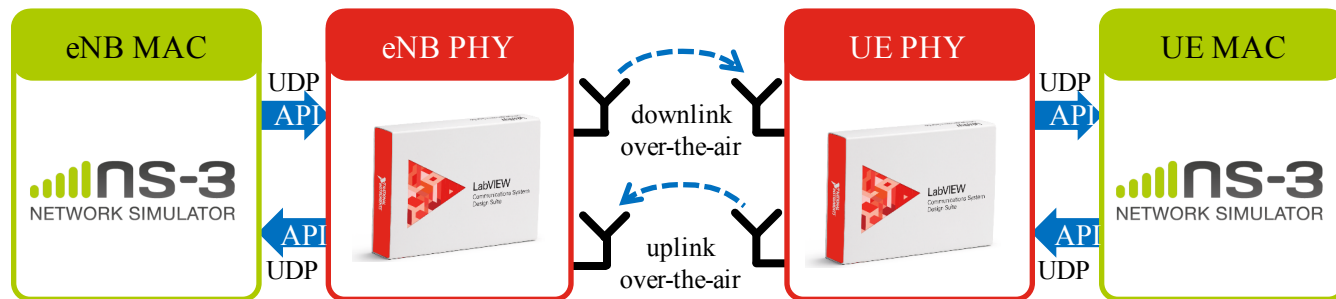
PHY and Basic MAC Key Features

- SISO configuration with 20 MHz bandwidth
- TDD and FDD frame structure
- LTE channel encoding and decoding
- Up to 75 Mbps throughput
- Data channels : PDSCH and PUSCH
- Simplified control channel: PDCCH
- Downlink and Uplink to enable closed-loop operation with channel state and ACK/ NACK feedback
- Cell-specific and UE-specific reference signals

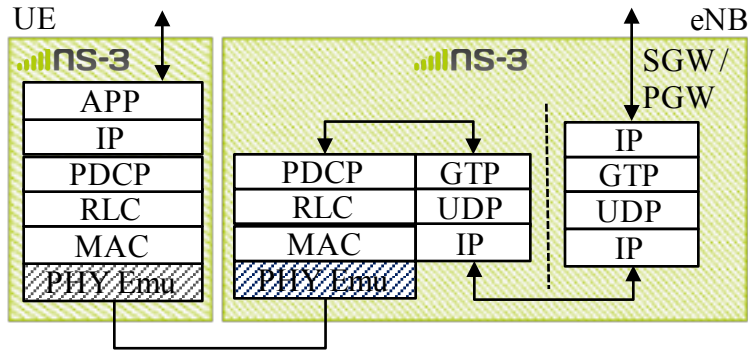


Preintegrated and Ready-to-Run
Real-Time LTE PHY and Basic MAC on
NI Software Defined Radio Hardware
With Video Streaming Sample Application

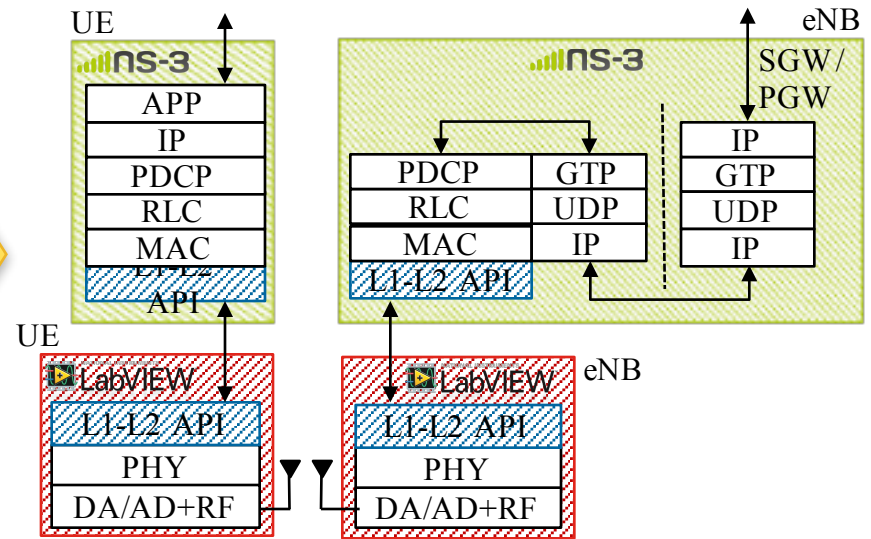
Platform Overview



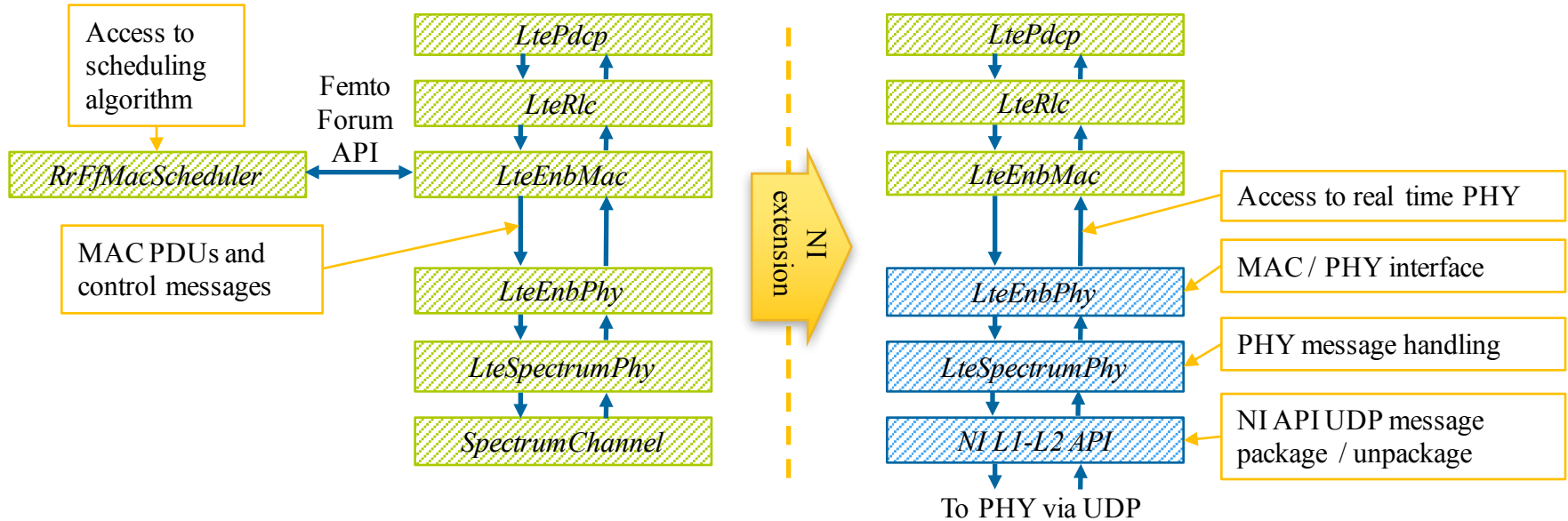
NI Extensions to NS-3



- ❖ Disable PHY emulation
- ❖ Separate eNB and UE
- ❖ Incorporate real PHY

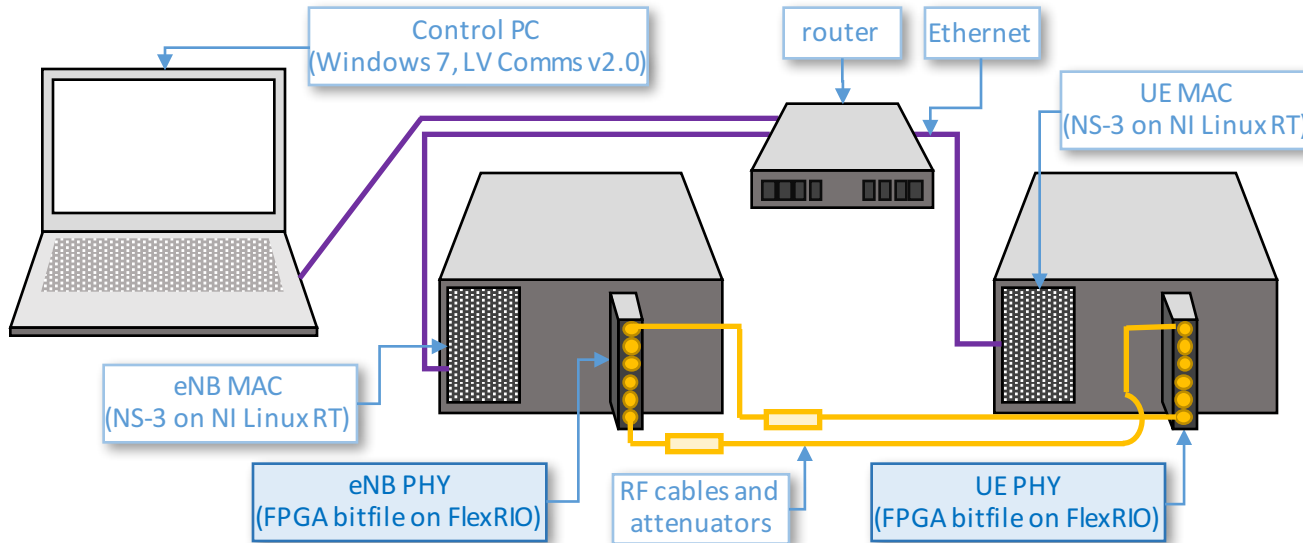


NS-3 LTE Stack Changes

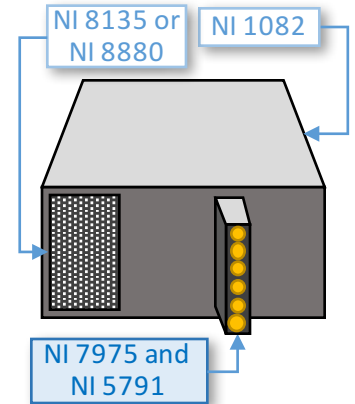


Hardware setup

FlexRIO+FAM Setup



Legend



Acknowledgement

- This effort started as a Lead User collaboration with NYU Poly
 - Russell Ford & Prof. Sundeep Rangan
- Lead to a successful review and conclusion of the EU FP7 funded project “CROWD”
- Source code and detailed white paper will be released as an example with upcoming LabVIEW Communications v2.0
- A template for combining LabVIEW PHY/MAC with Linux-based stacks for rapid prototyping



Cellular/Wi-Fi Coexistence in Unlicensed Bands

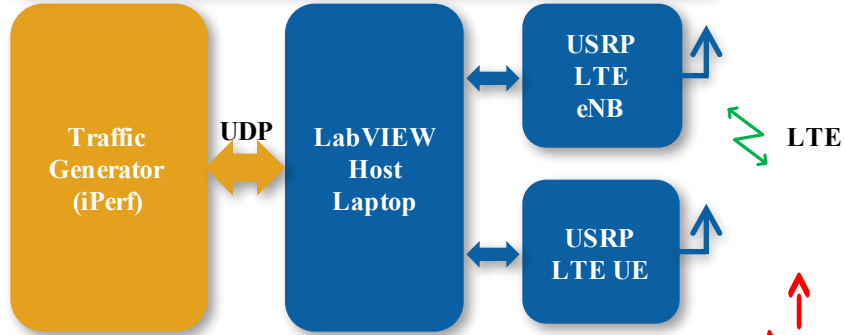
5GHz Unlicensed Spectrum and Cellular Technologies

- New PHY/MAC
 - Licensed Assisted Access (LAA)
 - LTE-Unlicensed (LTE-U)
 - MuLTEfire

- Using 802.11 PHY/MAC
 - LTE Wi-Fi Aggregation (LWA)
 - Wi-Fi Offload (NGH, Hotspot 2.0)

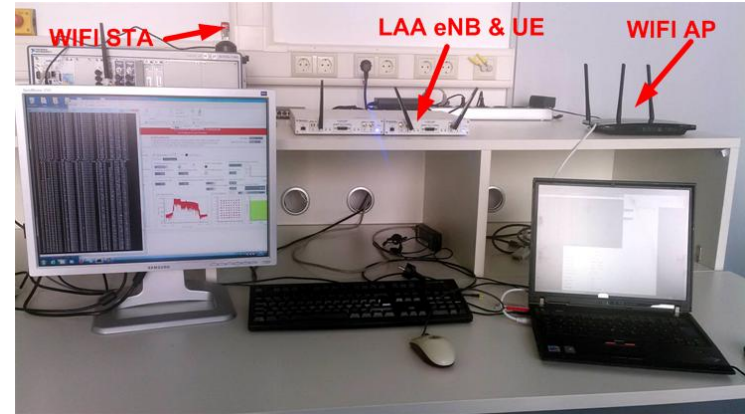
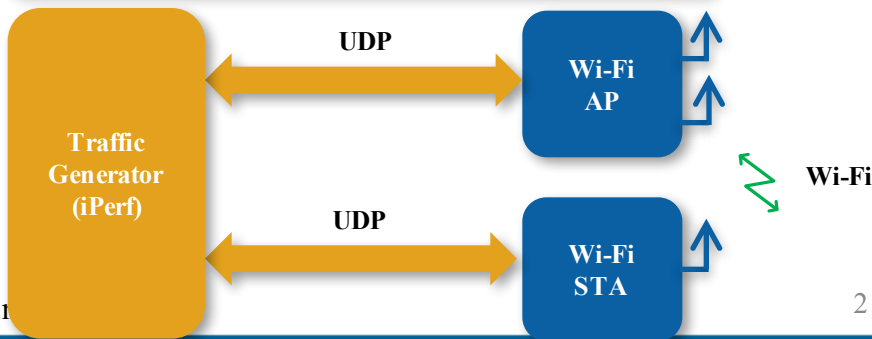
NI LTE/Wi-Fi Coexistence Testbed (1)

Modified NI LTE App Framework



LTE/Wi-Fi interference

COTS Wi-Fi Network or NI 802.11 App Framework



SCPP 3 GSG RAN WCI Meeting #2
Beijing, China, 20th - 23rd August 2015
IR-154740
Agenda Item: 7.2.4.5
Source: National Instruments
Title: Experimental Results on Coexistence of Q1 LAA and Concomitant Wi-Fi Network
Document for: Discussion

SCPP 3 GSG RAN WCI Meeting #1
Beijing, China, 20th - 23rd November 2015
IR-155222
Agenda Item: 6.2.3.1
Source: National Instruments
Title: Experimental Results on Impact of Energy Detection Threshold for Q1 LAA
Document for: Discussion

1. Introduction:
This contribution is an extension of a previous submission to RAN1 [Q]. In this contribution, we present experimental results on LAA and Wi-Fi throughput performance for various LAA, UE, and network scenarios. The experimental work conducted in a controlled, neutral environment of coexistence studies of the standard-based test activities in the laboratory. The test parameters for coexistence evaluation. We provide baseline results for LTE/Wi-Fi coexistence as well as results for coexistence of Wi-Fi and LAA under various configurations. LBT, COT.

2. LAA-Wi-Fi Coexistence Testbed
2.1. Motivation
As per the 3GPP meeting, the success of the integration and network utilization results have been discussed. Furthermore, there have been discussions regarding the proper setting of the EDE threshold. To further the understanding of the coexistence and the prevention of network, LAA method was developed to evaluate its performance with concomitant Wi-Fi AP.

2.2. Description of Testbed
The experimental testbed used to study the coexistence of two Wi-Fi networks and of an LAA network with Wi-Fi network is depicted in Figure 1a and Figure 1b, respectively. The LAA PTT is a modified version of a LTE PTT as described in [2] with discontinuous transmission and CBT operation, under the 3GPP operation requirement of coexistence. The testbed is based on NI LTE AP and station. The stations between the devices are placed to ensure that the RSRP is below -114 dBm. The method setup and detailed experimental parameters are described in annex 1.



IR-155222
Agenda Item: 6.2.3.1
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A coexistence of LAA network with a Wi-Fi network is depicted in Figure 1a and Figure 1b, respectively. The LAA PTT is a modified version of a LTE PTT as described in [2] with discontinuous transmission and CBT operation, under the 3GPP operation requirement of coexistence. The testbed is based on NI LTE AP and station. The stations between the devices are placed to ensure that the RSRP is below -114 dBm. The method setup and detailed experimental parameters are described in annex 1.

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NI LTE/Wi-Fi Coexistence Testbed (2)

- Creating a neutral platform for coexistence algorithm exploration
- Hardware
 - COTS or NI USRP RIO SDR Wi-Fi network
 - LTE network using NI USRP RIO SDR
- LAA/LTE-U example created using NI SDR software
 - LabVIEW Communications
 - LTE application framework (Host and FPGA)
 - Modified to add LAA/LTE-U functionality
 - 802.11 PHY blocks available from 802.11 application framework
- Example code and white paper is available
 - <http://www.ni.com/white-paper/53044/en/>
 - MWC 2016 testbed launch video: <http://videos.microwavejournal.com/video/National-Instruments-LTE-U-and-Test-Measurement>

LAA Modifications to Cellular MAC/PHY

- 802.11-like channel access support
 - Clear channel assessment
 - Discontinuous transmission with a given max TXOP
 - Listen before talk (LBT)
- Figure from 3GPP Spec TR 36.889 v13.0.0

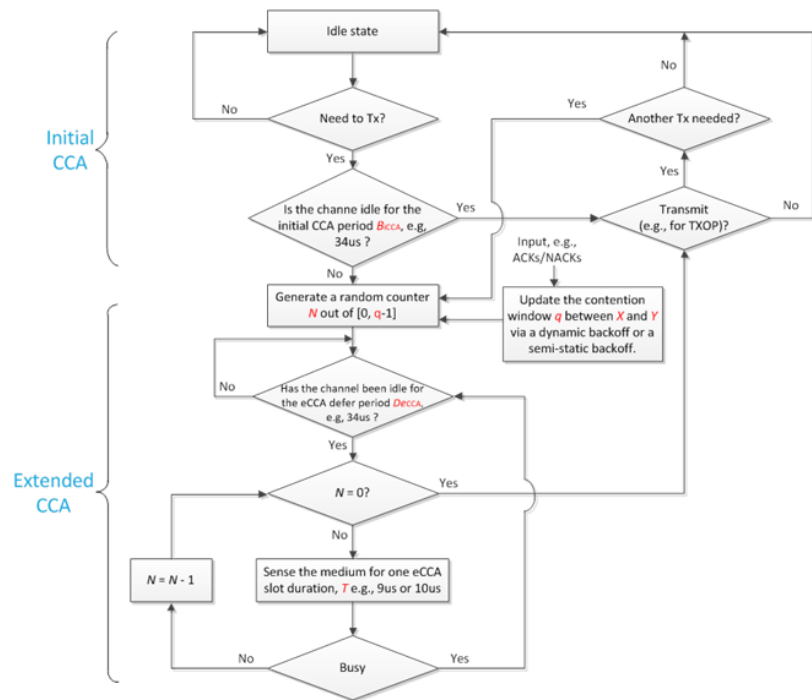
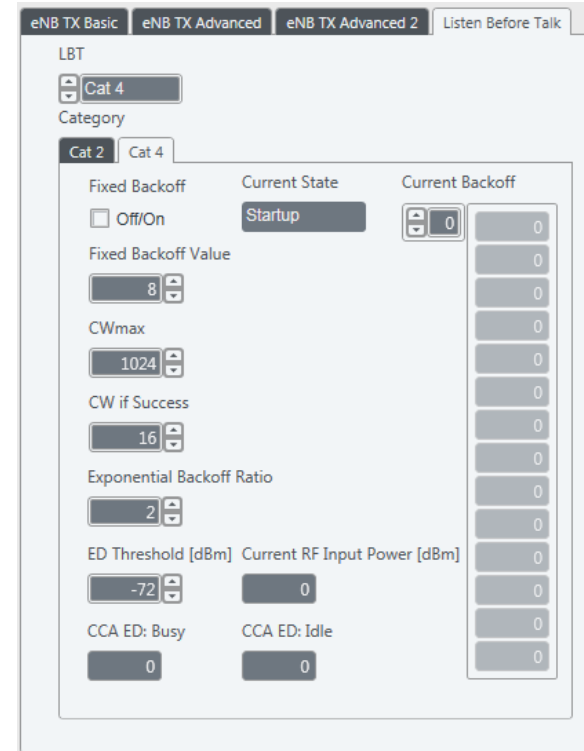
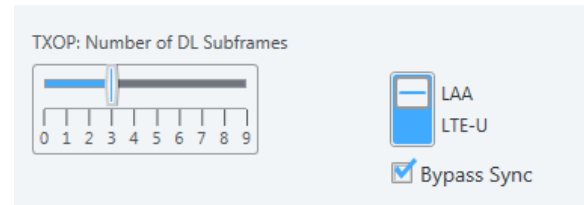


Figure 7.2.1.6-1: Flowchart of DL LAA SCell Cat 4 LBT procedure

Feature Set in Example Code

- LAA
 - Listen before talk:
 - Configurable CCA-ED threshold
 - Cat 2: Configurable duration
 - Cat 4: Configurable contention window size (CWS)
 - Discontinuous transmission (DTX)
 - LBE (LAA): Configurable TXOP
- LTE-U
 - FBE (LTE-U): configurable duty cycle
- Coexistence metrics
 - Throughput measurements
- Traffic generation
 - iPerf



Conclusions

Summary

- NI offers a platform for **flexible, open** and **scalable real-time** prototyping across MAC and PHY layers (LTE + WiFi + etc.).
- The platform will enable faster evaluation of algorithms with **simulations** and **prototyping**.

Thank you.

Contact

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Further reading

- NI 5G <http://www.ni.com/5g/>
- LabVIEW Communications 802.11 Application Framework White Paper <http://www.ni.com/product-documentation/52533/en/>
- LabVIEW Communications LTE Application Framework White Paper <http://www.ni.com/white-paper/52524/en/>
- LabVIEW Communications LTE/Wi-Fi Coexistence Testbed White Paper <http://www.ni.com/white-paper/53044/en/>
- CROWD White Paper <http://www.ni.com/white-paper/52339/en/>
- CROWD Project website <http://www.ict-crowd.eu/>
- NS3 LTE Module Documentation <http://lena.cttc.es/manual/>