Cellular and WLAN Networks Prototyping
NI SDR Approach

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June 17, 2016

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

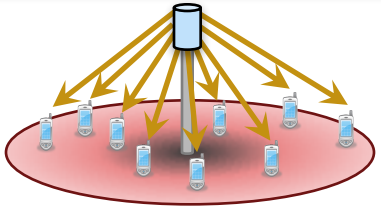
"Experience shows that the real world often breaks some of the assumptions made in theoretical research, so **testbeds are an important tool for evaluation under very realistic operating conditions**"

"…development of **a testbed** that is able **to test radical ideas** in a complete, working system **is crucial**"

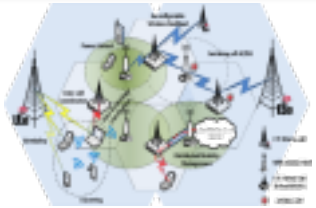
[1]NSF Workshop on Future Wireless Communication Research

NI 5G Research Initiatives

Massive MIMO

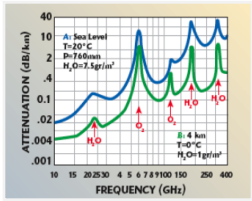


Wireless Networks



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
- > 1.5Gbps in 20 MHz spectrum
- NI massive MIMO SDR

Prof Mark Beach

Paul Harris

University of BRISTOL

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5G mmWave 14.5Gbps Link with Nokia at MWC 2016

Wireless Networks Prototyping with ns-3 and NI SDR

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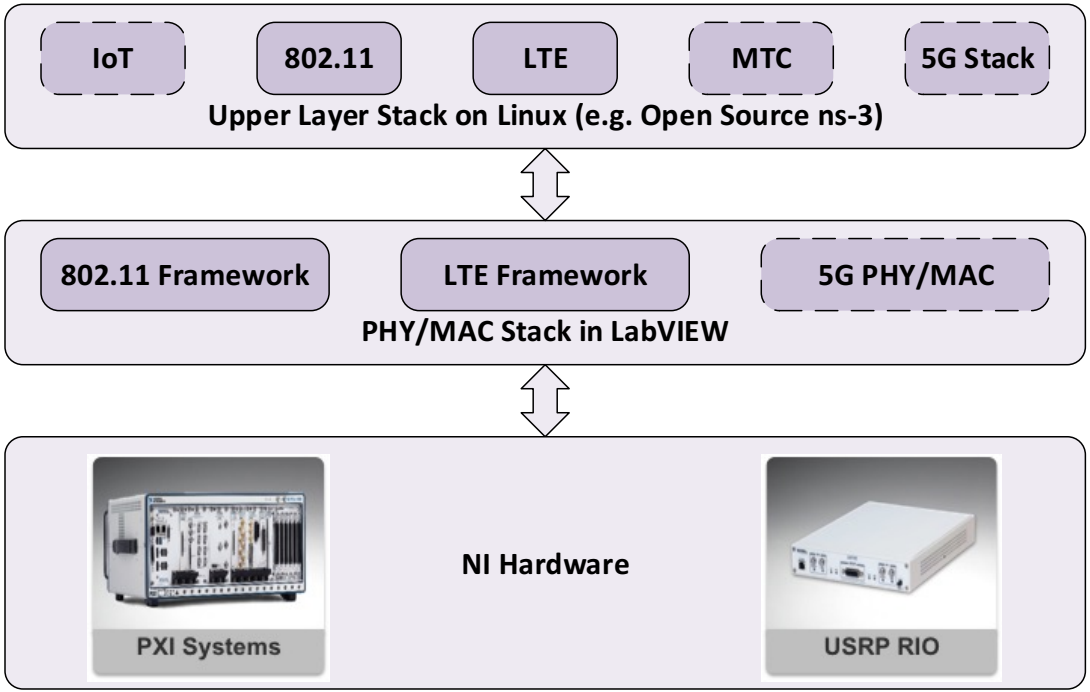
Wireless Networks Prototyping Challenges

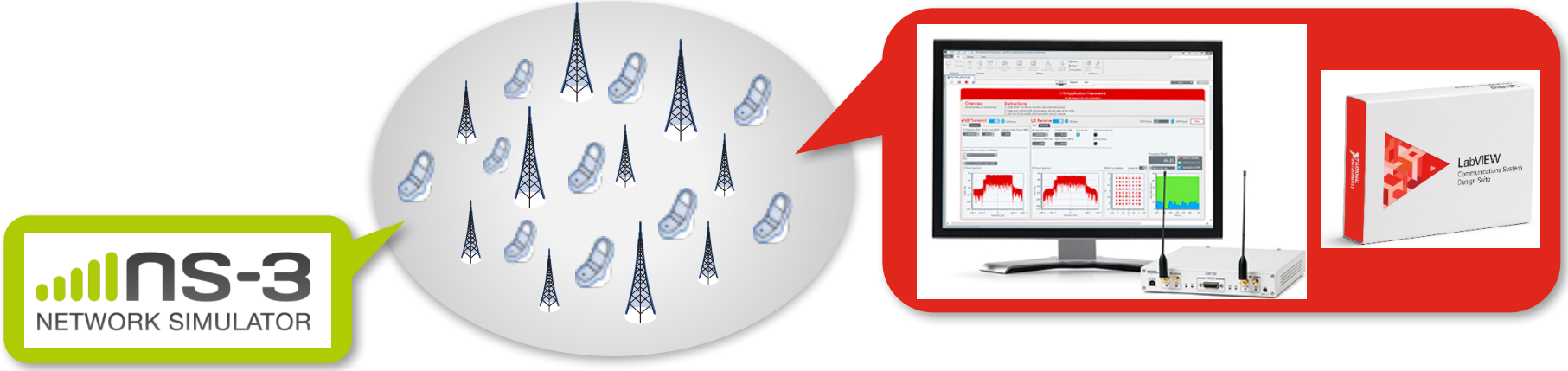
- Prototyping system design requires diverse experience
  - FPGA boards, Processor boards, RF cards etc.
- Complex system integration
  - For example, control and data path APIs to RF card
- Heterogeneous tools, software and hardware
  - Different layers may require knowledge of different tools and IDEs
- 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.



- 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

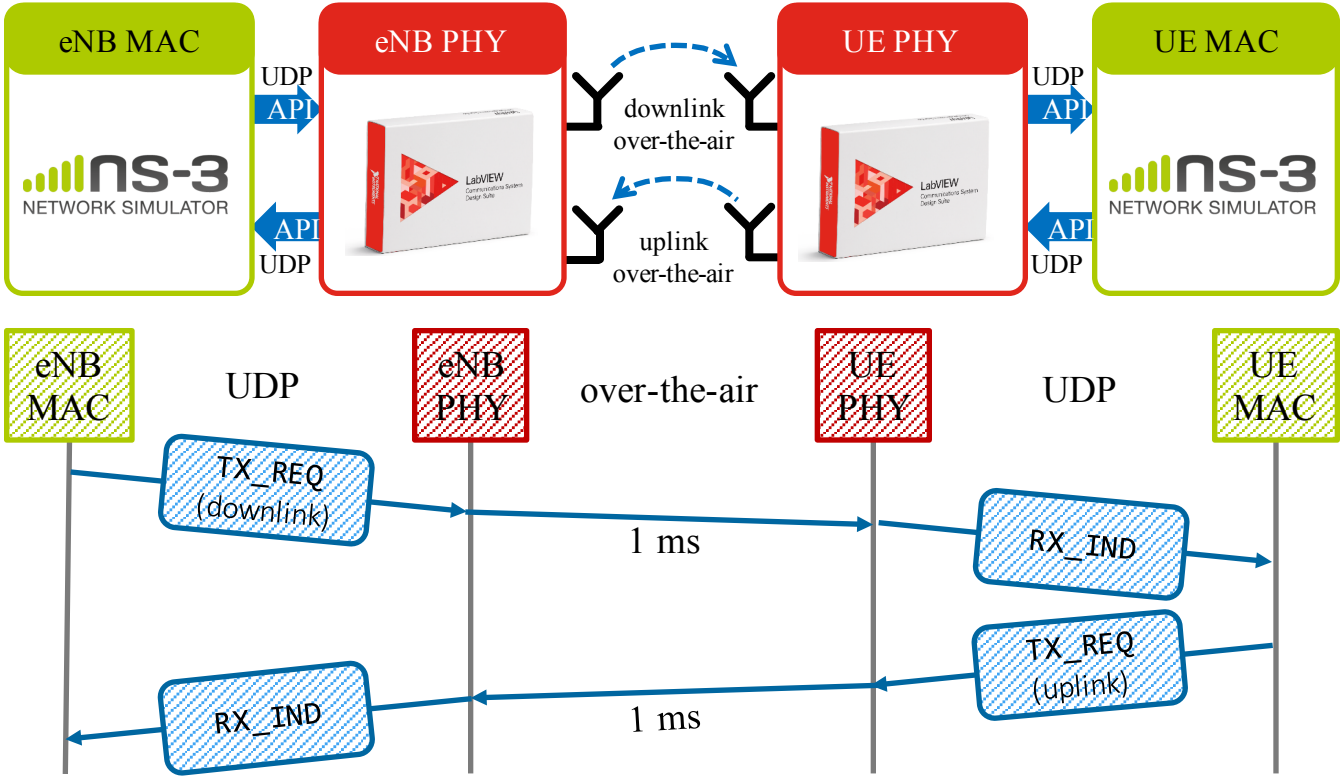
Designed for modifiability by algorithm designers

PHY and Basic MAC Key Features

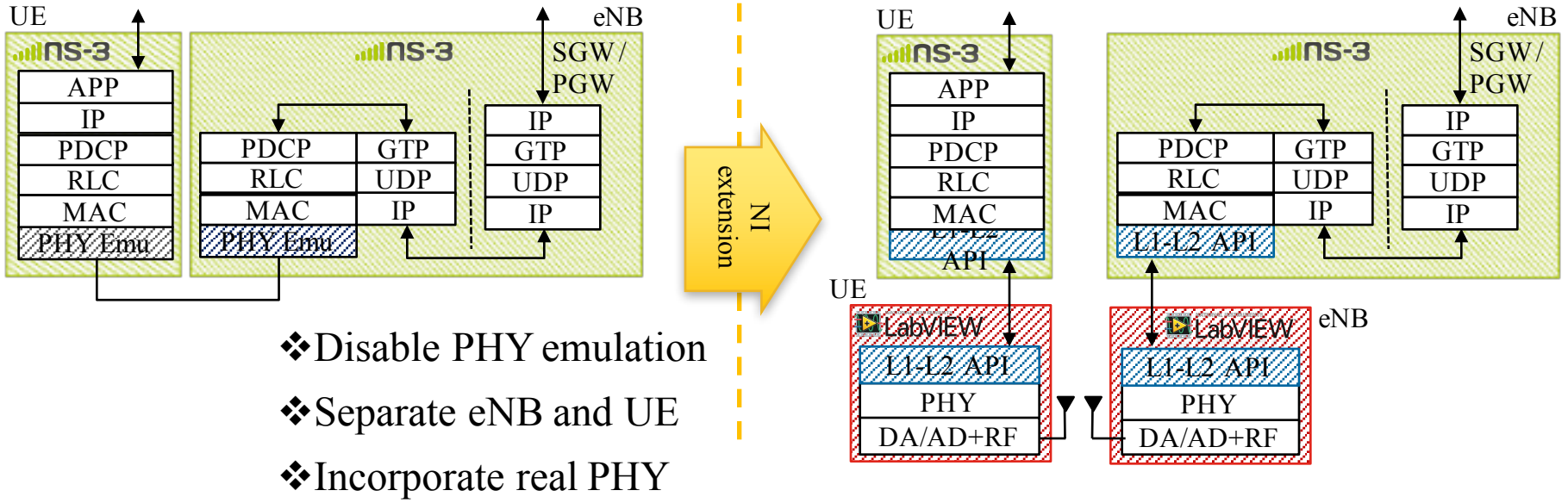
- SISO configuration with 20 MHz bandwidth
- TDD and FDD frame structure
- LTE channel encoding and decoding
- Up to 75 Mbps throughput
- Data channels : PDSCH and PUSCH
- Simplified control channel: PDCCH
- Downlink and Uplink to enable closed-loop operation with channel state and ACK/ NACK feedback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

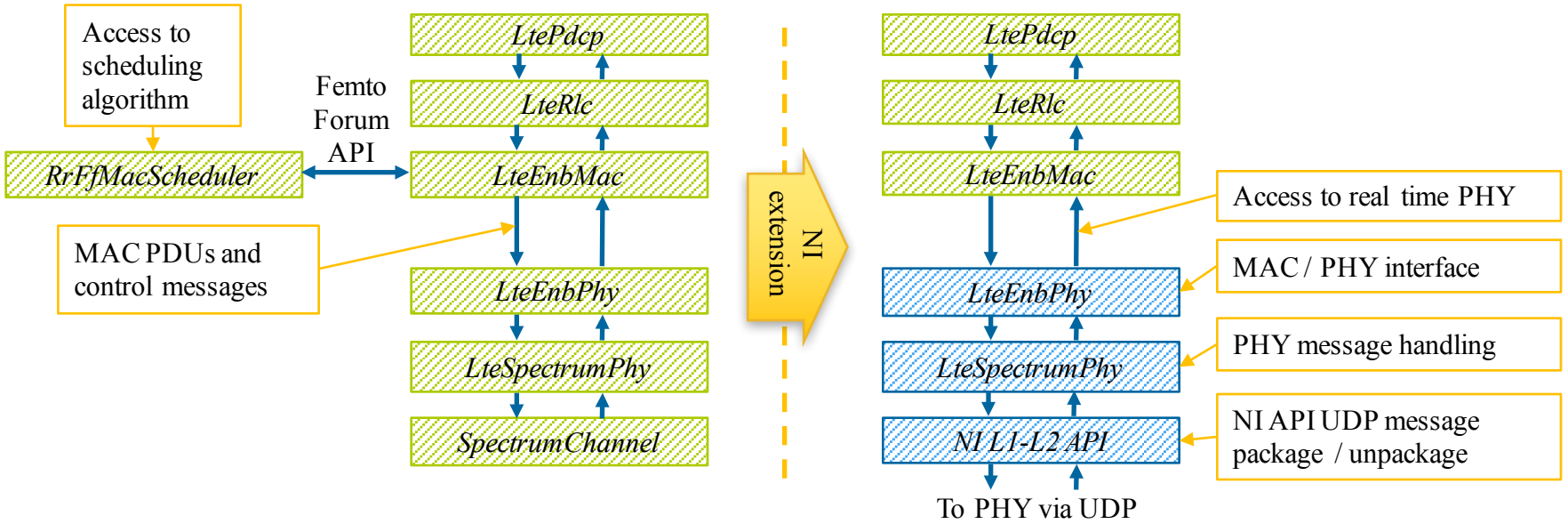


NI Extensions to NS-3



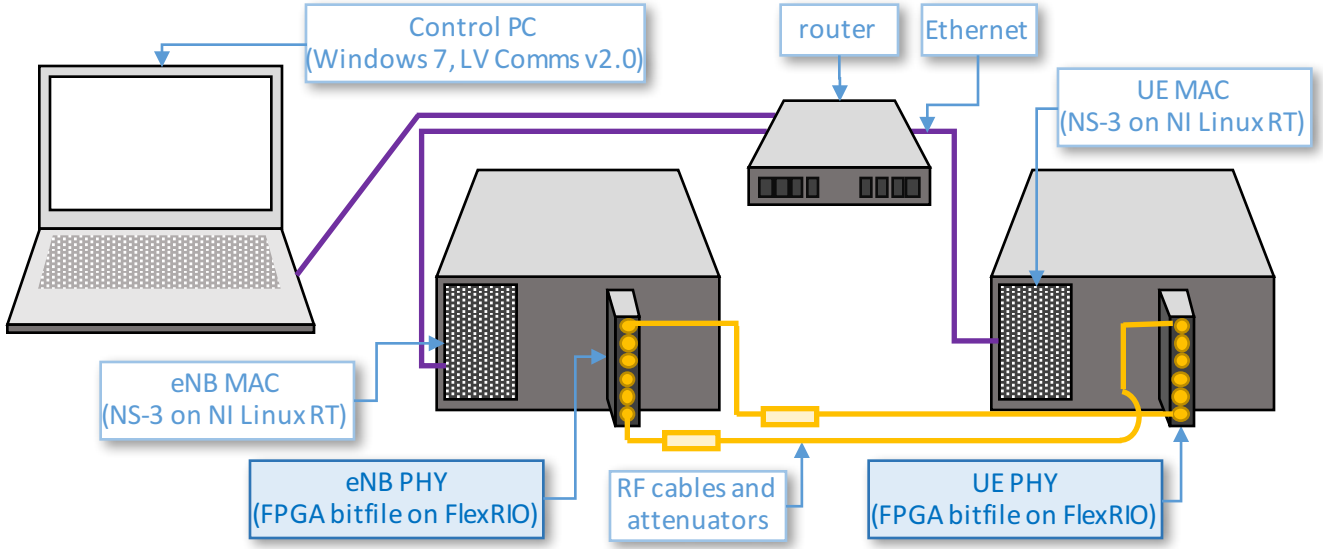
- Disable PHY emulation
- Separate eNB and UE
- Incorporate real PHY

NS-3 LTE Stack Changes

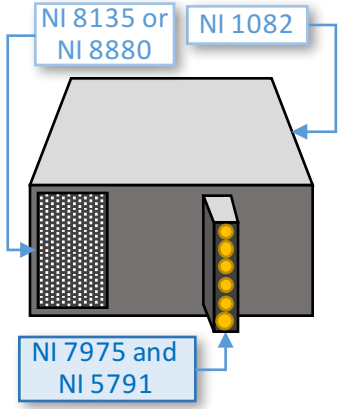


Hardware setup

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”

http://www.ict-crowd.eu/

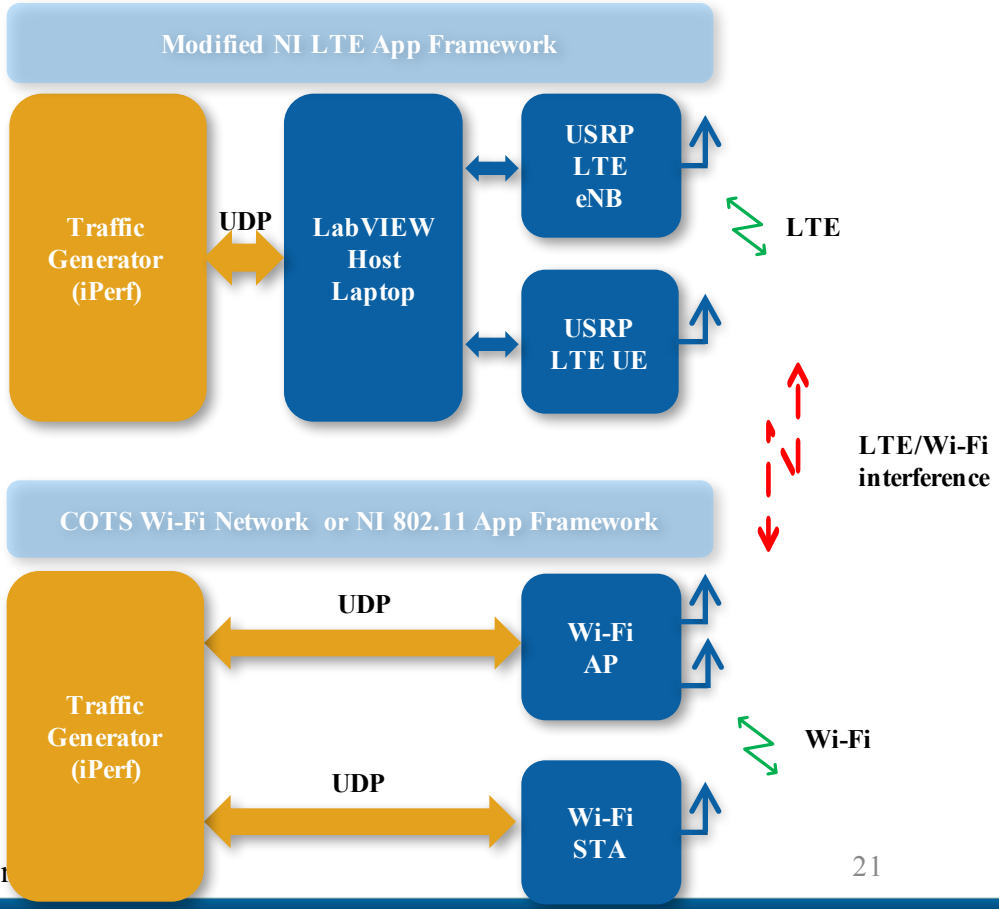
- Source code and detailed white paper will be released as an example with upcoming LabVIEW Communications v2.0
- A template for combining LabVIEW PHY/MAC with Linux-based stacks for rapid prototyping

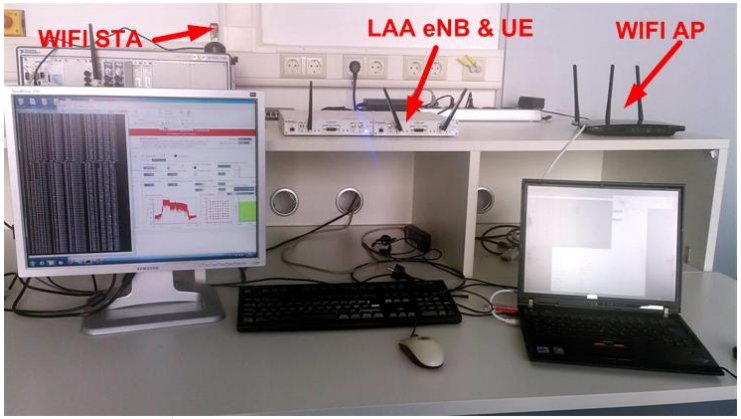
Cellular/Wi-Fi Coexistence in Unlicensed Bands

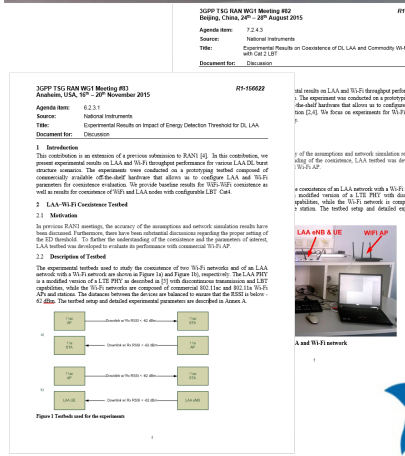
5GHz Unlicensed Spectrum and Cellular Technologies

- 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)







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

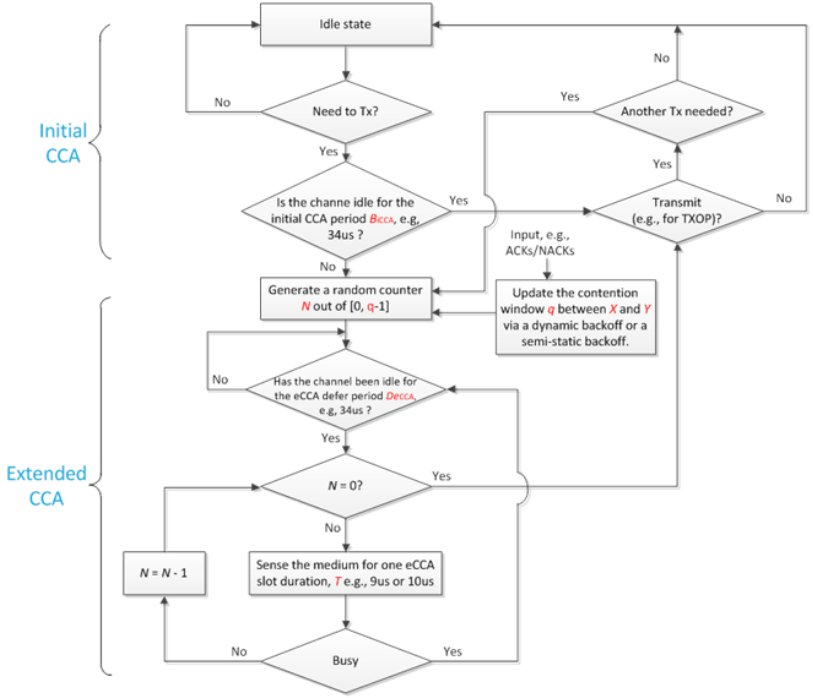
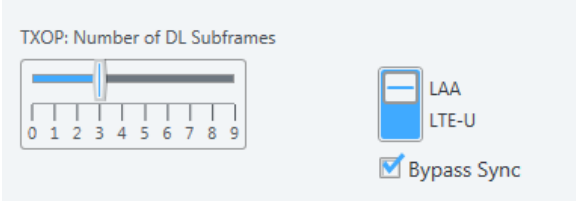
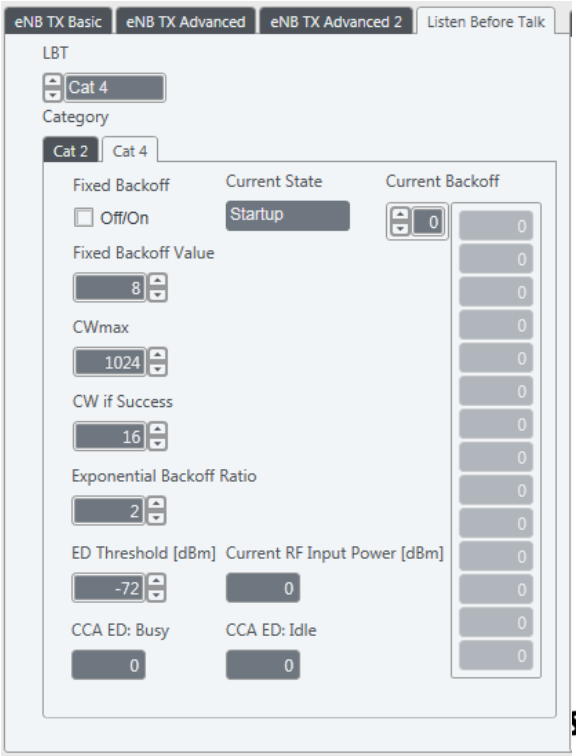


Figure 7.2.1.6-1: Flowchart of DL LAA SCell Cat 4 LBT procedure

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/