Prototyping wireless systems with NI SDR and open source stacks

Clemens Felber
Senior Development Engineer
Wireless Research and Test Mission Statement

Accelerate the innovation of next generation Wireless systems through the National Instruments differentiated Software Defined Radio platform.
NI 5G Lead User Program has enabled critical research since 2010
NI and 5G

1\textsuperscript{st} 100 antenna Massive MIMO

World’s 1\textsuperscript{st} Real-time GFDM system

Bristol: Spectrum Efficiency Record
BT Field Trials

Verizon 28 GHz

1\textsuperscript{st} Field Trial w/ KDDI

Nokia: 1\textsuperscript{st} E-band demo
10 Gb/s OTA

Nokia: 15 Gb/s OTA. New Record!

Samsung: 1\textsuperscript{st} FD MIMO demo

AT&T: World’s Fastest Channel Sounder

1\textsuperscript{st} CRAN Massive MIMO
NI SDR Platform

Open Ecosystem of Software Toolflows

LabVIEW™ GNU Radio Vivado™ python™

C / C++

The Largest Breadth and Depth of HW in the Industry

Proven Customer Success

First 28GHz mm-wave 5G transceiver demoed in US

Massive MIMO gets a boost from National Instruments

Bristol and Lund set a new world record in 5G wireless spectrum efficiency

World’s Most Powerful Emulator of Radio-Signal Traffic Opens for Business

Electronics Weekly

RCR Wireless

DARPA

Bristol University
NI Supports Many Tool Flows

- **System Model**
  - LabVIEW
  - C/C++, MATLAB™, Python

- **GPP Design**
  - LabVIEW
  - GNU Radio (GRC)
  - Embedded Coder™

- **FPGA Design**
  - LabVIEW FPGA
  - RFNoC via GRC
  - HDL Coder™

- **Deploy**
  - SDR Hardware
Updates on USRPs

- Ettus USRP N32x family released
  - 2 channel, 200MHz BW, sub 6GHz, Zynq based USRP
  - Specially designed for Massive MIMO applications through LO sharing capabilities for up to 128 channels

- NI USRP-2974 now officially supporting Ubuntu and Windows 10 on the device

- UHD v4.0 to be released in Q1/2020
  - Improved RFNoC infrastructure
5G Wireless End-to-End Network Prototyping

- Application
- Core Network
- LTE/5G Layer 3
- LTE/5G Layer 2 / MAC
- LTE/5G Layer 1 / PHY
- LTE/5G Band
- LTE/5G UE
- Application

Commercial Protocol Stack
- Open Source Protocol Stack
- API
- Real time PHY
- NI SDR/RF HW

- Radisys
- SRS
- OpenAIR Interface
- NS-3 Network Simulator

- National Instruments
System Partitioning – NI LTE/802.11 Application Framework

Layer 4  
(Transport Layer)

Layer 3  
(Network Layer)

Layer 2  
(Data Link Layer)

Layer 1  
(Physical Layer)

CPU

L2 and L3 in C/C++

API high in C/C++

UDP

Linux Pipes

API low in LabVIEW

DMA FIFO

FPGA

LV FPGA L1

1G / 10GE ETH

API Transport

Application Frameworks  
(real-time PHY layer implementation)

LabVIEW

NS-3

OPEN AIR INTERFACE

USRP-2974
NI’s end-to-end Multi-RAT platform vision

→ Enable 5G Wireless End-to-End Network Prototyping using NI Software Defined Radio Platform including Open Source Protocol Stacks
NI’s Multi-RAT Platform Vision for Research

Cloud SDN/MEC

5G Core
- 5G L3/RRC
- 5G L2
- 5G L1/PHY
- 5G UE

LTE EPC
- LTE L3/RRC
- LTE L2
- LTE or ISM band
- LTE UE

Application

5G Core
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Application

NI Application Frameworks
(real-time PHY layer implementation)

NI Application Frameworks
(real-time PHY layer implementation)
NS-3 integration with NI LTE Application Framework (LTE)

NI extensions to NS-3
1. Disable PHY emulation
2. Separate eNB and UE
3. Incorporate real PHY

Status
- Code public available
- Platform used in EU Research projects
NS-3 integration with NI LTE Application Framework (WIFI)

NI extensions to NS-3

1. Disable PHY, MAC Low/Middle emulation
2. Incorporate real PHY + MAC Low/Middle

Status

- Code public available
- Platform used in EU Research projects

https://github.com/ni/NI-ns3-ApplicationExample
OAI integration with NI LTE Application Framework

- **Status**
  - PoC for eNB interfacing ready
  - UE FAPI is missing for 4G OAI
- **Possible Solution**
  - 5G OAI → UE provides FAPI

Source: https://gitlab.eurecom.fr/oai/openairinterface5g/blob/master/doc/images/oai_enb_block_diagram.png
OAI running on NI USRP 2974 with NI Linux RT

- Cellular End-to-End transmission using Open Air Interface and NI SDR Hardware
- Setup
  - UE runs OAI on Ubuntu Laptop w/ B210
  - eNB runs **OAI build for NI Linux RT** on NI USRP 2974 using internal X310
Comparison NS3 vs OAI

<table>
<thead>
<tr>
<th>NS-3 Advantages</th>
<th>OAI Advantages</th>
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</table>
| ▪ Very good documentation | ▪ Clear separation of UE, eNB, EPC modules  
  → scalable for multi-node setups, E2E possible |
| ▪ LTE + WiFi modules | ▪ Connection to commercial equipment – LTE Rel 8.6 complete |
| ▪ Interface for external traffic → E2E | ▪ Designed for real-time operation |
| ▪ Already integrated with NI Application Frameworks | ▪ Supports UHD → runs with NI B210/X310 |
| ▪ 5G roadmap and framework for SDN/MEC | ▪ No connection to commercial equipment |

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<thead>
<tr>
<th>NS-3 Challenges</th>
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<tr>
<td>▪ Everything runs in one process → limited scalability for multi-node setups</td>
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<td>▪ Not made for SDR prototyping / real time operation</td>
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<td>▪ No connection to commercial equipment</td>
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<table>
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<th>OAI Challenges</th>
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<tr>
<td>▪ Documentation</td>
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<td>▪ Code structure</td>
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<td>▪ Only LTE/5G (WiFi dev cancelled)</td>
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