A Platform Approach to 5G
From Design – Prototyping – Test

Eric Starkloff
EVP, National Instruments
The Race to 5G

Verizon to be first to field-test crazy-fast 5G Wireless
It expects "some level of commercial deployment" to begin by 2017 for next-generation wireless. That's much earlier than the common industry belief that 2020 will mark the start.

China to roll out 5G broadband mobile equipment trials across 100 cities
High-speed 5G networks can theoretically transmit data 20 times faster than current 4G speed, with less than one tenth of the latency.

Start building commercial 5G networks today
Nokia 5G FIRST allows operators to address the near-infinite capacity demands of new applications anywhere - seamlessly and securely. This industry-first 5G solution provides innovations that will power the global nervous system.

40-Company Coalition Agrees To Accelerate 3GPP 5G NR Specs for 2019 Deployments
Long-Term Track Record of Growth

- 7,500+ Employees
- 50+ Countries
- $1.23 Billion in 2015
- 35,000+ Customers Worldwide
- Over 18% Investment in R&D
NI SERVICES AND SUPPORT

THIRD-PARTY SOFTWARE

WEB SERVICES
PYTHON
C
The MathWorks, Inc. MATLAB®
.NET
VHDL
AND MORE

NI PRODUCTIVE DEVELOPMENT SOFTWARE

NI MODULAR HARDWARE

THIRD-PARTY HARDWARE

ARDUINO
ETHERNET
USB
GPIB
SERIAL
LXI/VXI
AND MORE

MATLAB® is a registered trademark of The MathWorks, Inc.
NI SERVICES AND SUPPORT

700+ Field Engineers
700+ Support Engineers
50+ Worldwide Offices

Open Connectivity
10,000+ Instrument and Device Drivers
1,000+ Sensor and Motor Drivers

Support

1,000+ Alliance Partners
Industry-Leading Technology Partners

Partners

300,000+ Online Members
450+ User Groups
9,000+ Code Examples

Community

8,000+ Classrooms Worldwide

Academia

NI MODULAR HARDWARE

NI PRODUCTIVE DEVELOPMENT SOFTWARE

THIRD-PARTY HARDWARE

THIRD-PARTY SOFTWARE

NI ECOSYSTEM

NI ECOSYSTEM
A Unified Platform for Concurrent Design and Test

- System-Level Test
  - Cyber Physical Test
  - Hardware in the Loop
- Component-Level Test
  - Device characterization
  - Semiconductor ATE

System-Level Prototyping

Component-Level Design

System Implementation

Shared IP
Requirements for 5G Prototype and Test

**Design / Prototype**
- Real time processing
- Tightly integrated I/O
- Synchronization
- Agile RF front ends
- Scalability

**Test**
- Real time processing
- Tightly integrated I/O
- Synchronization
- Agile RF front ends
- Scalability

**System Implementation**

---

Shared IP
NI’s Platform Approach to 5G Prototyping and Test

Other PXI Modular Hardware Components

- Vector Signal Transceiver (VST):
  - 1GHz bandwidth and 9 kHz – 6.5 GHz
  - FPGA for real-time processing

- mmWave Extensions:
  - External mmWave – 60GHz, 28GHz, …
  - Cabled and OTA RF ports
Requirements for 5G Prototype and Test

**Design / Prototype**
- Real time processing
- Tightly integrated I/O
- Synchronization
- Agile RF front ends
- Scalability

**Test**
- Real time processing
- Tightly integrated I/O
- Synchronization
- Agile RF front ends
- Scalability

**System Implementation**

---

Shared IP
### Prototyping Key Technologies to Drive 5G Standards

<table>
<thead>
<tr>
<th>Massive MIMO</th>
<th>mmWave</th>
<th>Multi Radio Access Technologies (RAT)</th>
<th>Wireless Networks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dramatically increased number of antenna elements on base station enabling beamforming.</td>
<td>Utilize potential of extremely wide bandwidths at frequency ranges once thought impractical for commercial wireless.</td>
<td>Improve bandwidth utilization through evolving PHY Level and flexible numerology.</td>
<td>Consistent connectivity meeting the 1000x traffic demand for 5G</td>
</tr>
</tbody>
</table>

- **Densification**
- **SDN**
- **NFV**
- **CRAN**
Prototyping Key Technologies to Drive 5G Standards

- Massive MIMO
- mmWave
- Multi-RAT
- Wireless Networks

Unified Software Architecture

- Reconfigurable Instruments
- High Performance IO
- USRP RIO SDR
- USRP SDR
Prototyping Key Technologies to Drive 5G Standards
University of Bristol Sets New World Record for Spectrum Efficiency – May 2016

3.51 GHz
128 antennas
256 QAM
145.6 bits/s/Hz for 22 users

“In its demonstration, the team used a flexible prototyping platform from National Instruments built with LabVIEW system design software and PXI hardware.”

“This joint venture between the University, British Telecom and Bristol City Council aims to make Bristol the first open programmable city in the world”
Other Massive MIMO examples

- Bristol & Lund: 128 antenna Massive MIMO
- Intel: CRAN-Massive MIMO
- Facebook ARIES Testbed: 96-Antenna Massive MIMO System
- Samsung: Full Duplex MIMO, LTE UE Emulation
Prototyping Key Technologies to Drive 5G Standards

- Massive MIMO
- mmWave
- Multi-RAT
- Wireless Networks

LabVIEW®

Reconfigurable Instruments
High Performance IO
USRP RIO SDR
USRP SDR

3rd PARTY SOFTWARE
NI and Nokia Demonstrate 14.5 Gbps

- 73 GHz
- 2 GHz bandwidth
- 2x2 MIMO
- 64 QAM

“It took about 1 calendar year, less than half the time it would have taken with other tools”

—Dr. Amitava Ghosh, Head of Broadband Wireless Innovation
# Nokia mmWave Prototype Timeline

Using NI’s Platform

<table>
<thead>
<tr>
<th>Event</th>
<th>Frequency</th>
<th>Bandwidth</th>
<th>Streams</th>
<th>Modulation</th>
<th>Peak rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brooklyn 5G Summit 2014</td>
<td>73 GHz</td>
<td>1 GHz</td>
<td>1x1</td>
<td>16 QAM</td>
<td>2.3 Gbps</td>
</tr>
<tr>
<td>NIWeek 2015</td>
<td>73 GHz</td>
<td>2 GHz</td>
<td>2x2</td>
<td>16 QAM</td>
<td>&gt;10 Gbps</td>
</tr>
<tr>
<td>MWC 2016</td>
<td>73 GHz</td>
<td>2 GHz</td>
<td>2x2</td>
<td>64 QAM</td>
<td>&gt;14.5 Gbps</td>
</tr>
</tbody>
</table>
Prototyping Key Technologies to Drive 5G Standards

Massive MIMO

mmWave

Multi-RAT

Wireless Networks

LabVIEW

3rd PARTY SOFTWARE

Reconfigurable Instruments

High Performance IO

USRP RIO SDR

USRP SDR
Verizon and 5G NR – New Generation of Standards

- 2x2 MIMO, 8 CC, 100 MHz per carrier
- 75 kHz sub carrier spacing, 64 QAM
- Hybrid beamforming
- > 5 Gbps scalable to 20 Gbps
Requirements for 5G Prototype and Test

Design / Prototype
- Real time processing
- Tightly integrated I/O
- Synchronization
- Agile RF front ends
- Scalability

System Implementation

Test
- Real time processing
- Tightly integrated I/O
- Synchronization
- Agile RF front ends
- Scalability

Shared IP
# 5G Test System Architectural Requirements

<table>
<thead>
<tr>
<th>Modularity</th>
<th>Frequency and Channel Agility</th>
<th>Software-defined Signal Processing</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Add performance as future requirements emerge</td>
<td>- Flexible mmWave head configurations for Multi-DUT, multi-frequency and beamforming test</td>
<td>- Accelerated measurements using real-time FPGA processors programmed with LabVIEW FPGA</td>
</tr>
<tr>
<td>- Integrate non-RF I/O into same system to maintain small footprint</td>
<td>- Tight timing and synchronization for MIMO configurations</td>
<td>- Achieve demanding EVM requirements through more sophisticated calibration techniques</td>
</tr>
</tbody>
</table>

## Key Open Issues for Test:
- Over the air access
- Test cost of millimeter wave and MIMO
Test Challenge – Complexity vs. Cost

Increasing Complexity

Number of CA Combinations per 3GPP Release (Order of Magnitude)

<table>
<thead>
<tr>
<th>Release</th>
<th>Number of CA Combinations</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>11</td>
<td>20</td>
</tr>
<tr>
<td>12</td>
<td>100</td>
</tr>
<tr>
<td>13</td>
<td>250</td>
</tr>
<tr>
<td>14</td>
<td>500+</td>
</tr>
</tbody>
</table>

Lower Test Costs

WiGig Chipset ASP: Historical & Forecast

32 Antenna Element Radio

Average Selling Price

Source: ABI Research, 2015.
The Old Method for High Frequency Test

- Continuous frequency coverage
- Separate Rx and Tx
- Aggregation of single-function boxes
- Fixed processing resources

Too Big
Too Expensive
Insufficient Performance
The Future of mmWave Test System Architectures

**Intense Signal Processing**
- Accelerated measurements using real-time FPGA processors programmed with LabVIEW FPGA
- Achieve demanding EVM requirements through more sophisticated calibration techniques

**Modular Functionality**
- Add performance as future requirements emerge
- Integrate non-RF I/O into same system to maintain small footprint
- Tight timing and synchronization for MIMO configurations
- High throughput data movement using data buses like PCI Express (PXI)

**Custom, mmWave Port Extension**
- Custom in-house designs deliver top-notch calibration and performance
- Flexible mmWave head configurations for Multi-DUT, multi-frequency and beamforming test
- Calibrated IF & mmWave interfaces
Example mmWave Test System Architecture

Modular approach allows designs to scale with new test configurations for 11ad wider bandwidths for 11ay, and different frequencies for 5G test and automotive radar.

Flexible remote head configuration with support for 60GHz WiGig, 28GHz 5G, 70GHz vehicular radar, and others.

PXI-based IF Up/Down Converter to interface with mmWave head or also with DUT’s IF.

PXI-based baseband options scale from 200MHz bandwidth to 2GHz bandwidth with path to higher bandwidths.
World’s Most Advanced Channel Sounder

1x4, MIMO configuration
7 x 64 permutations

Very fast measurement and switch time
Within in the coherence time of the channel

Joint work between NI and AT&T
A Single Platform from Characterization to Production Enables Measurement Correlation

Common Measurement Science

Test and Measurement Hardware

Measurement Automation Software

Characterization

Production
A Unified Platform for Concurrent Design and Test

- System-Level Test
- Component-Level Test
- Cyber Physical Test
- Hardware in the Loop
- Device characterization
- Semiconductor ATE

- System-Level Prototyping
- Component-Level Design
- System Implementation

- Reduce time to market
- Lower design and test costs
- Iterate as technology evolves