5G 2.0: Evolving the URLLC Use Case
From Design – Prototyping – Test

James Kimery
Director of Wireless Research
NI 5G Lead User Program has enabled critical research since 2010
**NI and 5G**

- **1st 100 antenna Massive MIMO**
- **World's 1st Real-time GFDM system**
- **Facebook**
- **Bristol: Spectrum Efficiency Record**
- **BT Field Trials**
- **Verizon 28 GHz**
- **1st Field Trial w/ KDDI**
- **Nokia: 1st E-band demo**
- **10 Gb/s OTA**
- **AT&T: World's Fastest Channel Sounder**
- **Samsung: 1st FD MIMO demo**
- **1st CRAN Massive MIMO**
- **Nokia: 15 Gb/s OTA. New Record!**
- **NI and 5G**
- **NI CONFIDENTIAL**
- **UT ECE**
- **WNCC**
- **Lund University**
- **Technische Universität Dresden**
- **National Instruments**
- **Prof. Ted Rappaport**
### 3GPP 5G Timeline

**Standards**

- **Rel-15**
  - Standalone (SA)
  - Non-Standalone (NSA)

- **Rel-16**
  - Field trials

- **Rel-17+ evolution**

**Deploy**

- **Rel-15 Commercialization**
  - eMBB deployments in both mmWave and sub-6 GHz

- **Rel-16 Commercialization**
  - New 5G NR technologies to evolve and expand the 5G ecosystem

**Research**

- mmWave / Spectrum Optimizations
- New networks
- New use cases

**Expanded ecosystem:**

- Smartphone formfactor, Connected laptops, CPE fixed access
- Private networks, Indoor mmW for enterprises, Boundless XR,...
- Industrial IoT, Private network, 5G NR C-V2X,
- IAB, Unlicensed/shared spectrum,...
- Continued eMBB evolution

**Year**

- 2017
- 2018
- 2019
- 2020
- 2021
- 2022
- 2023+
Network Optimizations

Network Slice – V2x, V2I

Network Slice – Factory Automation

Network Slice - eMBB

Virtual Network

EPC

Edge computing

Edge computing
URLLC: Ultra-Reliable Low Latency Communications
IIoT Manufacturing

Network Slice – Factory Automation

Latency is important
But the control topology may be more important
E2E latency is the roundtrip time

What is the E2E Latency?
URLLC: Ultra-Reliable Low Latency Communications

MAC/PHY Perspective

- Flexible numerology
- Grant-free transmissions
- Optimized DCI / UCI formats
- Mini-slots
- Repetitions

### SCS Slot Duration Symbol Duration (us)

<table>
<thead>
<tr>
<th>SCS</th>
<th>Slot Duration</th>
<th>Symbol Duration (us)</th>
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<tbody>
<tr>
<td>15 kHz</td>
<td>1000 us</td>
<td>71.43</td>
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<tr>
<td>30 kHz</td>
<td>500 us</td>
<td>33.33</td>
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<tr>
<td>60 kHz</td>
<td>250 us</td>
<td>17.86</td>
</tr>
<tr>
<td>120 kHz</td>
<td>125 us</td>
<td>8.93</td>
</tr>
</tbody>
</table>

3GPP Rel 15 provides the framework for lower latency
Slot Structure and Timing

Slot = 14 symbols

- 15 kHz
- 30 kHz
- 60 kHz
- 120 kHz

Mini-slot 2, 4, 7 symbol

Traffic Puncturing
### Mini-slots Impact on Timing

<table>
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<tr>
<th>SCS</th>
<th>Symbols per slot</th>
<th>14</th>
<th>7</th>
<th>4</th>
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<td></td>
<td>Symbol Duration (us)</td>
<td>Slots / Frame</td>
<td>Slot Duration (us)</td>
<td>Slot Duration (us)</td>
<td>Slot Duration (us)</td>
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<tr>
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<td>120 kHz</td>
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<td>160</td>
<td>62.5</td>
<td>31.25</td>
<td>17.84</td>
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</table>
4G and Prior Signal Processing Architectures
5G Requires Partition Shift – FPGAs Essential
Tools are Very Important to 5G
NI Perspective: Tools, Hardware, and IP

- **LabVIEW**
  - Comms based MAC
  - Flexible protocol stack Options

- **Layer 1 / PHY**
  - ABB
  - RF

- **Layer 2 / MAC**
- **Layer 3**
- **Core Network**

- **L1-L2 API**
- **NI AFW PHY**
- **NI SDR/RF HW**
### NI Driving 5G 2.0

#### New Applications
- eMBB
- mMTC
- URLLC

#### New Spectrum
- mmWave
- TeraHz
- Unlicensed
- Re-farming LTE

#### Optimizations
- Power
- Reliability
- Latency
- Efficiency
- Coverage

#### Diverse Deployments
- Disaggregation of the functional elements of the RAN
- ORAN
- SDN
- NFV
- MEC

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- 3GPP Compliant PHYs – highly capable
- Open Source Compatibility
- High performance, flexible, FPGA based Platforms