1. Flex Project
2. OpenAirInterface: An Open LTE Network in a PC

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FIRE-GENI Workshop
Objectives

Open Cellular Ecosystem

- Open and integrated development environment under the control of the experimenters
- Flexibility to architect, instantiate, and configure the network components
  - at the edge, core, or cloud
- Highly reconfigurable and fully software-based network functions spanning all the layers
- Rapid prototyping of 3GPP compliant and non-compliant usecases
- Instrumental in the development of the key 5G technologies ranging from M2M/IoT and software-defined networking to cloud-RAN and massive MIMO
FLEX project

- **FLEX**: FIRE LTE testbeds for open experimentation
  - Grant Agreement: 612050
  - Call Identifier: FP7-ICT-2013-10
  - Duration: 36 Months (Starting from Jan 2014)
- Open calls: experimentation and enhancements
- Led by UTH
FLEX objectives

- Extend FIRE’s resource pool with LTE resources
- Open Research in 5G
- Open for experimenters, researchers
- OpenCalls
- Controlled Mobility
- Reconfigurability
FLEX Concept

- Develop operational LTE testbeds using two approaches:
  - Setup 1: fully commercial LTE deployment
  - Setup 2: fully opensource LTE deployment
    ■ OpenAirInterface foundation

- LTE experimentation and reconfigurability across all the layers (L1/L2/L3)
  - Following SDN principles with OMF integration
  - Both software and hardware

- Organization of two Open Calls for experimentation with the facilities.
FIRE Testbed extensions
Types of Supported Experiments

- Evaluation of new PHY and MAC layer schemes
  - NOTOS
  - OPEN AIR INTERFA

- Evaluation of new functionality vs. commercial products
  - NOTOS
  - iMinds
Expected Impact

- Cost efficient experimentation with LTE resources, combined with existing heterogeneous equipment.
- Interaction of the end user with the real 4G world.
- Development of Radio API.
- Experimental evaluation of new protocols and ideas paving the way for 5G era.
- Broader use of the FIRE Facilities.
OPENAIRINTERFACE
Openairinterface.org

- Full experimental LTE implementation (Rel 8, partial Rel 10), real time and with interworking functions
  - No serious (open-source) competitor
  - Like openBTS, but EUTRAN + EPC + UE!
  - FDD and TDD mode
  - Flexibility in comparison to full industrial implementations

- Rely on publicly-funded research initiatives (EU ICT, ANR, CELTIC)
Possible configurations

- OAI UE ↔ OAI eNB + OAI EPC
- OAI UE ↔ OAI eNB + Commercial EPC
- OAI UE ↔ Commercial eNB + OAI EPC
- OAI UE ↔ Commercial eNB + Commercial EPC
- Commercial UE ↔ Commercial eNB + OAI EPC
- Commercial UE ↔ OAI eNB + Commercial EPC
- Commercial UE ↔ OAI eNB + OAI EPC
OpenAirInterface Hardware Targets

- **ExpressMIMO II**
  - 1.5/5/10/20 MHz, FDD/TDD (up to 4x4 MIMO, or 4 SISO Component Carriers)

- **USRP B210/X300**
  - Commercial Ettus/National Instruments boards

- **PXle platforms**
  - Under development with NI

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EXMIMO II

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![Diagram of PXle platform components]

- RF RX (4 way)
- RF TX (4 way)
- PCIe (1 or 4 way)
- 4xLMS6002D RF ASICs 250 MHz – 3.8 GHz
- GPIO for external RF control
- Spartan 6 LX150T
- 12V from ATX power supply
OAI LTE in a PC

Demo at Mobicom 2014

Received Wireshark messages at eNB
Received constellation at eNB
OAI soft eNB in a PC (PC+EXMIMO II)
FDD TX/RX filters
Antenna (2.6GHz)
Current Collaboration with US

- Rutgers through FLEX project
  - SDN and OMF

- Alcatel-Lucent Bell Labs (Paris, New Jersey, Stuttgart)
  - Running OAI systems (OAI eNB interconnected with ALU in-house EPC development)
  - Contributions to core access-stratum software
  - Integration with in-house CPRI-based solutions and commercial RRH
  - VRAN Architectures
  - 5G-waveforms (soon)

- National Instruments / Ettus Research
  - Support for porting OAI software to Ettus USRP platforms (B210, X310)
  - Roadmap for integration on PXIe high-end industrial platforms
Example Collaboration Areas

- **Standard usage**
  - C-RAN
  - Rapidly deployable eNB and EPC (public safety networks)
  - Wireshark over-the-air: LTE UE tester/sniffer, characterize the commercial eNBs
  - UE/eNB prototypes to test and characterize commercial eNB/UE functionalities
  - Port OAI layer 2 on existing PHY SoC
  - Test tools Soft protocol tester
  - D2D, mmWave, MTC

- **Non-standard usage**
  - IEEE802.21, PMIP and DMM, Exit native IP at the BS
  - SDN, NFV
  - Traffic offloading
  - LTE meshing
  - Mobile-edge computing
  - ....
**Example Use case**

**C-RAN**

- OpenAirInterface uses general-purpose x86 processors (GPP) for *base-band processing and protocols*
  - x86 Baseband DSP

- **Key elements**
  - Real-time / low latency extensions to Linux OS
  - Real-time data acquisition to PC
  - SIMD optimized integer DSP
    - 64-bit MMX $\rightarrow$ 128-bit SSE2/3/4 $\rightarrow$ 256-bit AVX2
  - Parallelism
  - x86-64 : more efficient than legacy x86
OAI BBU performance

Intel Xeon E5-1607 v2@3GHz

OAI BBU DL/UL vs MCS, Tx mode 1

MCS Index vs Timing (us)

- DL: PRB 25
- UL: PRB 25
- DL: PRB 50
- UL: PRB 50
- DL: PRB 100
- UL: PRB 100
OAI BBU performance
*Intel Xeon E5-1607 v2@3GHz*

<table>
<thead>
<tr>
<th>eNB Rx stats (1 subframe)</th>
<th>eNB Tx stats (1 subframe)</th>
</tr>
</thead>
<tbody>
<tr>
<td>OFDM demod: 109.695927 us</td>
<td>OFDM mod: 108.308182 us</td>
</tr>
<tr>
<td>ULSCH demod: 198.603526 us</td>
<td>DLSCH mod: 176.487999 us</td>
</tr>
<tr>
<td>ULSCH Decoding: 624.602407 us</td>
<td>DLSCH scrambling: 123.744984 us</td>
</tr>
<tr>
<td></td>
<td>DLSCH encoding: 323.395231 us</td>
</tr>
<tr>
<td></td>
<td>➔ 730 us (&lt;1 core)</td>
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➔ 931 us (<1 core)

➔ On 3 GHz machine, < 2 cores for 20 MHz eNB

With AVX2 (256-bit SIMD), turbo decoding and FFT processing will be exactly twice as fast
- 1 core per eNB

Configuration
- 20 MHz bandwidth (UL mcs16 – 16QAM, DL mcs 24 – 64QAM, transmission mode 1 - SISO)
**Example C-RAN Setup 2**

- **OAI eNB on the virtualized environments**
  - LowLatency Linux (> 3.14) under Lowlatency KVM
  1. Passthrough PCI-e / USB3 / 10Gb Ethernet
  2. 10Gb Ethernet-based Fronthaul
Next Steps for OAI

- Ensure a path 4G→5G through open-source policy
  => Reference implementation of Rel 13/14 -> 5G
  - Work with new carrier candidates now, short packet low-latency carriers, contention-based access
  - VRAN, MEC architectures
  - Rapidly-deployable EPC/eNB (with LTE or other backhaul)
- “ready to use” for anybody on commodity hardware (PCs + National Instruments)
- More global adoption for innovation and research (Vendor labs, University Labs, etc.) => common tool between industrial and academic research
- Business adoption in test market (Keysight)
Conclusion

- Suitably flexible platform towards an open cellular ecosystem for 4G experimentation and for 5G research
- Open-source reference implementation of 3GPP-compliant LTE system and a subset of LTE-A features
- Real-time indoor/outdoor experimentation and demonstration
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