COSMOS Architecture and Key Technologies

June 1st, 2018

COSMOS Team
COSMOS: System Architecture (2)

- System design based on three levels of SDR radio node (S,M,L) with M,L connected via fiber to optical WDM front-haul
- SDN-based backhaul and compute services, with access to ORBIT, GENI...
- COSMOS control center and general purpose cloud at Rutgers via 32 AoA PoP
Technology Objective

Pushing state of the art in five key technologies:

• SDR
• mmWave
• Optical networking
• SDN and cloud computing
• Testbed control and management
COSMOS: Key Technologies - SDR

- All-software solution adopted for radio technology
- Advanced SDR Radio Nodes at various performance levels and form factors
- Design goal: 400 Mhz – 6 Ghz + 28 Ghz and 60 Ghz bands, ~500 Mhz BW, Gbps
- Signal processing can be spread between radio node & edge cloud RAN
- Team has extensive prior experience with SDR technology (…currently ~50 nodes in ORBIT running DSA, LTE, etc.)
Small Node

**Variant 1:** Intel NUC SFF PC for compute, with WiFi, BLE and sub-6GHz SDR (B205-mini) wireless devices; can be powered with external battery pack

**Variant 2:** Quad-core i7 mini-ITX FF PC for compute, with WiFi, sub-6GHz SDR (B210) and single-beam mmWave SDR device; intended for vehicular deployment.
Medium Node

Variants based on building blocks:

- mmWave RF front-end
- mmWave SDR BB
- Sub-6GHz RF front-end
- Sub-6GHz SDR BB
- Sub 6GHz mon. RF front-end
- Sub-6GHz mon BB
- RF-over-fiber
- 10/100G (Ethernet+Optical)
- Standard compute platform (PC)
- WiFi devices

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Large Node

Multi-enclosure rooftop deployment:

• Multiple antennas
• Up to 8 mmWave basebands (one per beam)
• Number of sub-6GHz SDRs
• Wire and/or optical rooftop signal distribution
• Small rack for edge cloud
• Optical networking equipment
COSMOS: Key Technologies - mmWave

- mmWave a key new technology for the testbed, with limited availability of components
- Leveraging ongoing CU collaboration with IBM to provide mmWave phased arrays (64 antennas, 8 beams) for both 28 Ghz and 60 Ghz
- Extensive mmWave systems expertise at NYU, including prototype systems and channel measurements
SDR Baseband (Medium, mmWave)

- Xilinx Kintex UltraScale (KU085) FPGA (497,520CLB LUTs and 4,100 DSP Slices)
- 8GB DDR4 and 1Gb FPGA configuration Flash
- PCI Express endpoint Gen3 x 8
- Dual FMC (1 x FMC+ HSPC & 1 x FMC HPC)
- SFP+ (10GBps Optical/Ethernet)
- Standalone operation

A/D and D/A

<table>
<thead>
<tr>
<th>FMC120</th>
<th>FMC121</th>
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<tbody>
<tr>
<td>Dual A/D: 1000 Msps</td>
<td>Quad A/D: 1000 Msps</td>
</tr>
<tr>
<td>Dual D/A: 1400 Msps</td>
<td>Quad D/A: 1250 Msps</td>
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<tr>
<td>Coupling: DC</td>
<td>Coupling: DC</td>
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<tr>
<td>Resolution: 16-bit</td>
<td>Resolution: 16-bit</td>
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<tr>
<td>Signaling: JESD204B</td>
<td>Signaling: JESD204B</td>
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SDR Baseband (Large, mmWave)

4 x Xilinx Virtex–7 (VX690T) FPGAs
- 3600 DSP slices per FPGA

64 GB DDR3-1333 ECC RDIMM RAM
- Two 8 GB banks per FPGA
- 10600 Mbps throughput per channel

400 Gbps on-board full mesh inter-FPGA connection

4 FMC-HPC front panel slots with up to 200 Gbps throughput each
- 8 GTH SerDes from each FPGA to its dedicated FMC slot
- 80 LVDS pairs from each FPGA to its dedicated FMC slot

480 Gbps front panel optical connectors
- 12 GTH SerDes from each FPGA to the front panel optical connectors
**COSMOS: Key Technologies – Optical Net**

- Fast and low latency optical x-haul network using 3D MEMS switch and WDM ROADM
  - Configure wide range of topologies
  - Experiment on converged fiber/wireless networks
- Enables fast front-haul connectivity between radio nodes and edge cloud
- SDN control plane for both optical and Ethernet switching
- Leverages results from CIAN NSF ERC, EAGER dark fiber project at Columbia
**COSMOS: Key Technologies – SDN & Cloud**

- SDN control plane used to control x-haul and cloud server connectivity
- Open Network Operating System (ONOS) with radio API extensions
- Compute clusters collocated with radio nodes (M,L) with choice of CPU, GPU and FPGA accelerators
- Also, users have access to regular cloud racks for L3 → applications (GENI & CloudLab clusters at WINLAB)
Cloud Computing Resources

Computing resources distributed across multiple locations:

- Large core-count CPUs
- High-precision clock synchronization (IEEE 1588v2)
- GPU (and FPGA) compute acceleration
- SDN based optical and electrical networking (both TOR and Core)
Edge Cloud Architecture

- Virtualized environment for easy software deployment
- Bare metal access for ultra-low-latency & access to specialized hardware (e.g., FPGA)
- Support for live migration between Edge Cloud sites
COSMOS: Key Technologies - OMF

• Testbed software is a critical component
• OMF control & management software leveraged from ORBIT
• Provides tools for experiment scripting, execution, measurements and data collection
• Supports high-level experiment scripts for ease of use
• Mature open-source technology, proven in multiple research testbeds worldwide
ORBIT Management Framework (OMF)

(a.k.a Control and Management Framework)

Testbed management and experiment orchestration framework
- Open Source community supported project (github)
- In production use since 2005
- Currently at version 6.1
- Use in more than 50 testbeds around the world
ORBIT Measurement Library (OML)

- Push based architecture
- All experiment data in one place – including metadata
- Separation of concerns
  - Instrumentation
  - Collection
- Minimize collection overhead
  - Application CPU time
  - Experimental traffic interference
- Proxy server for disconnected operation
Planned Deployment

- West Harlem
- Area: ~1 sq. mile
- ~9 Large Sites ~40 Medium sites
- Fiber optic connection from most sites
- ~200 Small nodes
  - Including vehicular and hand-held
- Fiber connection to NYU Data Center, Rutgers, GENI/I2
- Interaction with smart community & innovation initiatives (Gigabit center, etc.)