COSMOS X-Haul Overview

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Provide experimenter customizable and sliceable front-/mid-/back-haul network and edge cloud research platform supporting research on:

- High capacity, low latency radio/edge cloud networks
- mmWave and fiber convergence
- Optical networking
- SDR/SDN and cloud computing
- Testbed control and management
Fronthaul Networks (d-RoF)

T. Pfeiffer JOCN 2015
Midhaul Networks

Fronthaul Connection

Midhaul Connection

ONDM 2018
# Split PHY Processing

## Possible Split Levels

<table>
<thead>
<tr>
<th>Possible Split Levels</th>
<th>Downlink bandwidth</th>
<th>Uplink bandwidth</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAC - PHY</td>
<td>152 Mbps</td>
<td>49 Mbps</td>
</tr>
<tr>
<td>PHY split I: Soft Bit</td>
<td>173 Mbps</td>
<td>452 Mbps</td>
</tr>
<tr>
<td>PHY split II: Subframe data</td>
<td>933 Mbps</td>
<td>903 Mbps</td>
</tr>
<tr>
<td>PHY split III: Subframe</td>
<td>1075 Mbps</td>
<td>922 Mbps</td>
</tr>
<tr>
<td>PHY split IIIb: Subframe</td>
<td>1966 Mbps</td>
<td>1966 Mbps</td>
</tr>
<tr>
<td>PHY split IV: CPRI encoding</td>
<td>2457.6 Mbps</td>
<td>2457.6 Mbps</td>
</tr>
</tbody>
</table>

Small Cell Forum 2016
Saving Capacity

- Adding midhaul processing reduces wavelength blocking
- Reduced BW & Improved efficiency
- Additional latency

ONDM 2018
Optical Switching

• Use both for configuring topology for different/concurrent experiments & converged wireless/optical experiments
  – Slicing by wavelength or space

• Stackable whitebox ROADM 1 RU
  – Switching time:
    • ~ 1 second
  – Includes optical amplifiers
  – SDN controlled

• High port count space switch
  – Switching time: ~ 100 ms
  – SDN controlled
ROADM Module

20 Add/Drop/Thru ports

Lumentum

96 WDM Channels
X6 Fiber pairs
576 Connections

Flex-grid & Colorless
Front-Haul/CoMP

ROADM/WDM wavelength switching on second timescales

Reconfiguration space switching on ms time scales

T. Bierman, et. al. Comm Mag. 2013
Converged mmWave/Fiber Transmission

Also consider digital RoF

Also consider digital RoF
Programmable Topologies

CC @NYU – 32 AoA
CC @Columbia
6 Fiber Pairs
Programmable Topologies
Programmable Topologies
Long Reach PON

CC @NYU – 32 AoA

CC @Columbia

OLT

PON Split

1 km

ONU

10 km
MidHaul Network

CC @NYU – 32 AoA

CC @Columbia

10 km

1 km
Converged mmWave/Fiber Transmission

- Fixed Wireless Link
- Wavelength Switches
- Columbia Univ.
- Studebaker Hall
- Fixed Wireless Link
- S₂, C₂
- CCNY Campus
- Harlem Street Location
- Access Point
- Mudd Hall
- Edge Data Center
- Eth Switch
- Optical Switch
- S₅, C₅
mmWave Analog RoF

- Ultra-low latency, simple radio head
  - No digitization until data center
- COSMOS: Sub-6 GHz, plus select routes to 40 GHz
  - Can mix down from higher frequencies
- Other bands?

(Figure courtesy of A. Kanno, NICT)
Other Unique Capabilities

- Free space optical
  - High performance, long distance
  - Low cost, short distance
- Hybrid mmWave/FSO
- 100G coherent
- 10G SFP+ OTN
- Fast tunable laser-based switching (~ns)

Advanced Free Space Optical Link
QUESTIONS?