COSMOS: Optical Architecture and Prototyping

www.cosmos-lab.org

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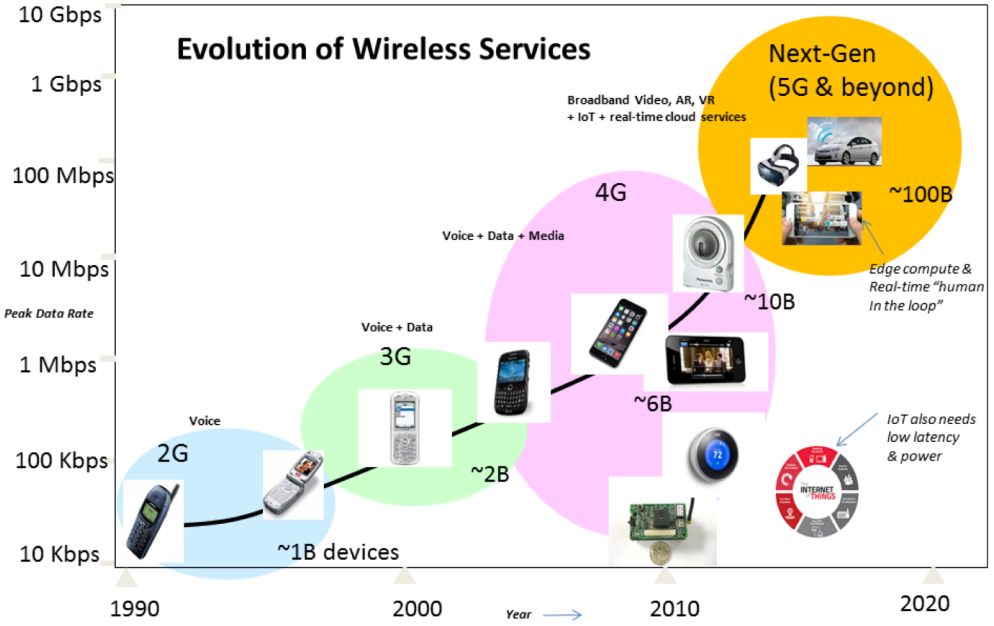
Advancedwireless.org

COSMOS: Project Vision (1)

- Wireless speeds are on a faster-than-Moore's law curve…..
- Services now evolving from high-speed data and video towards AR, VR and IoT with real-time "human-in-the-loop"
- Fast changes in technology and services motivate city-scale next-gen wireless testbed for use by both academic and industry researchers → PAWR



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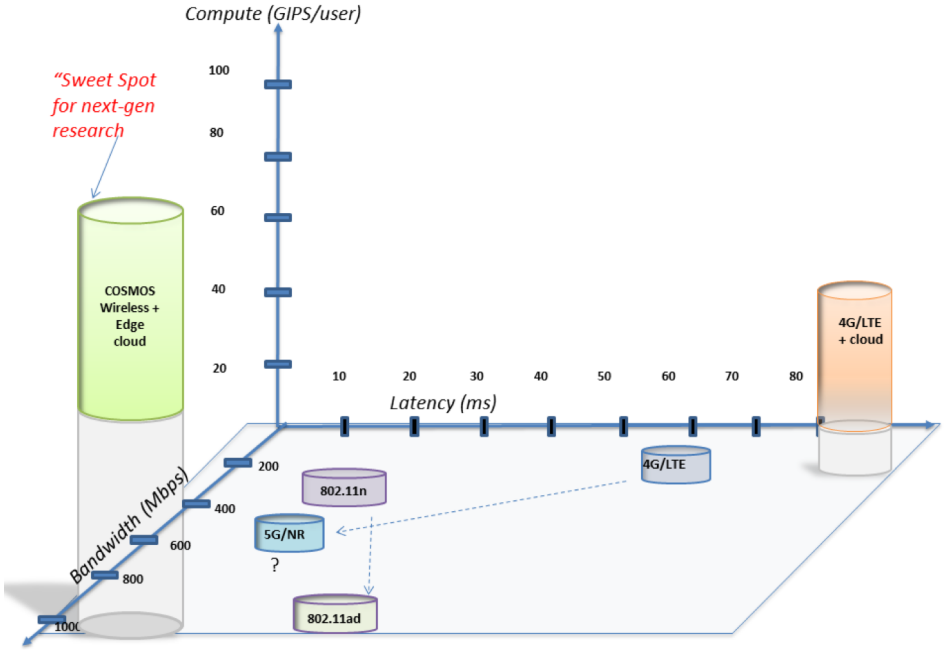
COSMOS: Project Vision (2)

- Latency and compute power are the two new dimensions for characterizing wireless access
- Latency for 4G cellular > 50 ms, while targets for 5G are <10 ms
- Edge computing is the other important dimension for enabling real-time services
- COSMOS will enable researchers to investigate ultra-high speed ~Gbps, low latency <5ms, + edge computing ~10-100 GIPS



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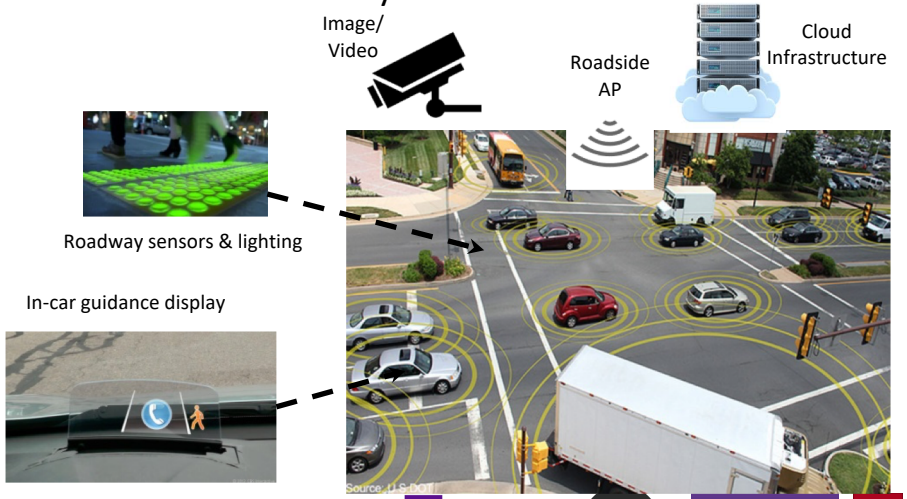
COSMOS: Project Vision (3)

- Ultra-high BW, low latency and powerful edge computing will enable important new classes of real time applications
- Application domains include AR, VR, connected car, smart city (with high-bandwidth sensing), industrial control, …

Industrial Control

Augmented Reality

Smart City + Connected Car



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COSMOS: Project Vision (4)

- Living lab research platform to bring together research addressing critical technological, social, and civic challenges facing the world's mega-cities
- COSMOS as research & innovation engine of NYC ecosystem of smart city projects, broadband community initiatives and many startups developing new applications

Top 25 hot spots by 2025

Cityscope 2025 city rankings

Bold text Developing regions

Normal text Developed regions[1]

Rank	GDP[2]	Per capita GDP[2]	GDP growth[2]	Total population	Children[3]	Total house-holds	Households with annual income over $20,000[4]
1	New York	Oslo	Shanghai	Tokyo	Kinshasa	Tokyo	Tokyo
2	Tokyo	Doha	Beijing	Mumbai	Karachi	Shanghai	New York
3	Shanghai	Bergen	New York	Shanghai	Dhaka	Beijing	London
4	London	Macau	Tianjin	Beijing	Mumbai	São Paulo	Shanghai
5	Beijing	Trondheim	Chongqing	Delhi	Kolkata	Chongqing	Beijing
6	Los Angeles	Bridgeport	Shenzhen	Kolkata	Lagos	New York	Paris
7	Paris	Hwasŏng	Guangzhou	Dhaka	Delhi	London	Rhein-Ruhr
8	Chicago	Asan	Nanjing	São Paulo	Mexico City[5]	Mumbai	Osaka
9	Rhein-Ruhr	San Jose	Hangzhou	Mexico City[5]	New York	Delhi	Moscow
10	Shenzhen	Yŏsu	Chengdu	New York	Manila	Mexico City[5]	Mexico City[5]

NYC location enables experiments and stress testing at scales and conditions that are years ahead of other cities

Link NYC

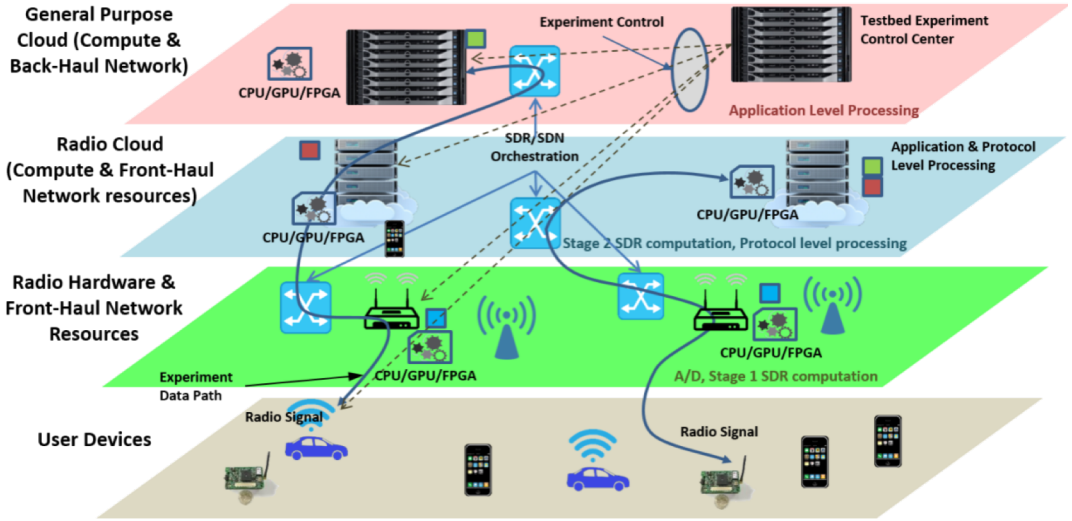
NYC 5G Trials

COSMOS

Rutgers · Columbia University in the City of New York · NYU · NYC · <sh> · The City College of New York · Arizona

COSMOS: System Architecture

- COSMOS architecture has been developed to realize ultra-high BW, low latency and tightly coupled edge computing
- Key design challenge: Gbps performance + full programmability at the radio level
- Developed a fully programmable multi-layered (i.e. radio, network and cloud) system architecture for flexible experimentation



Key Technologies going into COSMOS:

Software Defined Radio (SDR)
mmWave Radio
Software Defined Network (SDN)
Optical X-haul Network
Edge Cloud Computing
OMF Control Software

Planned Deployment

- 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)

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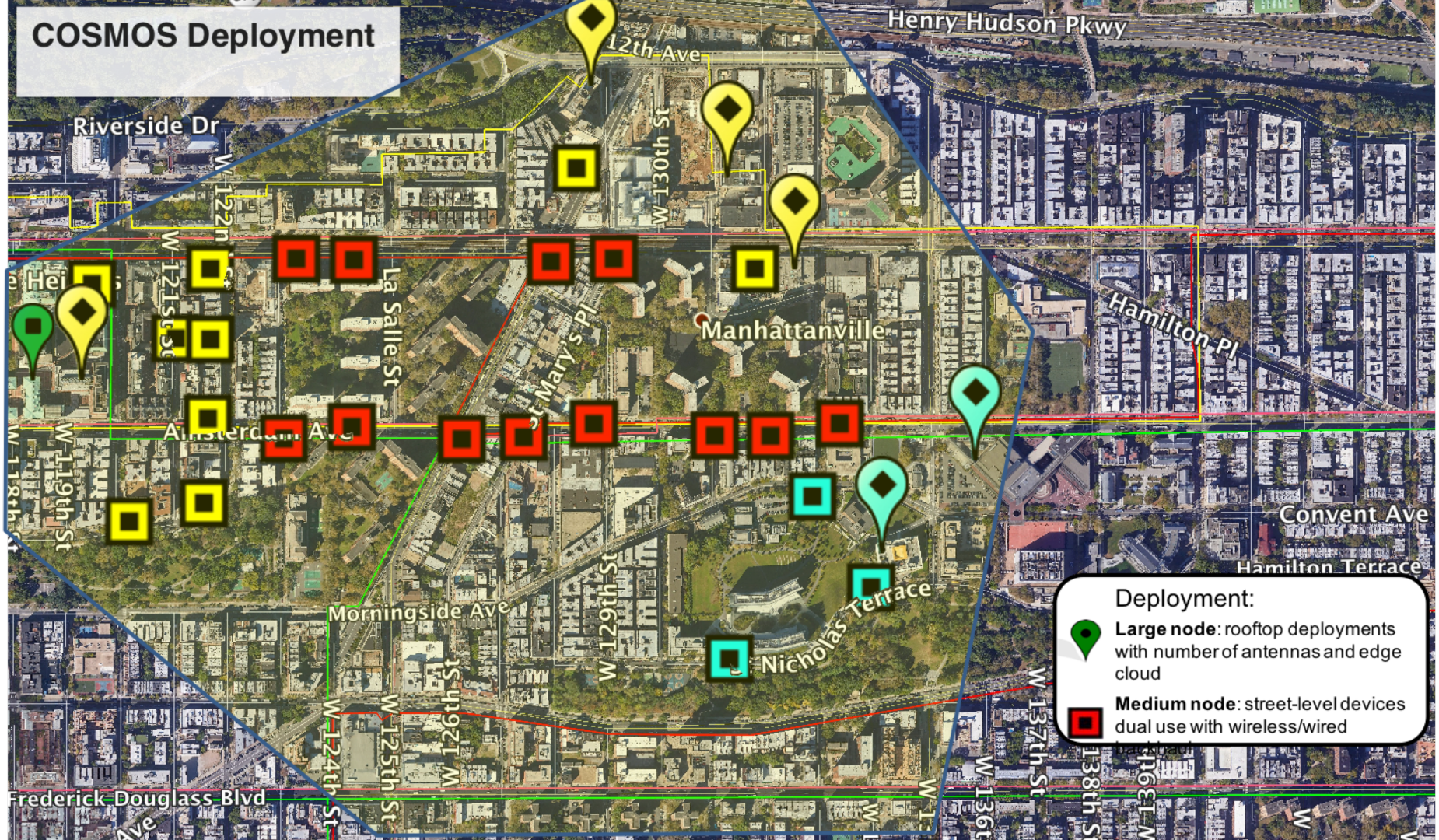
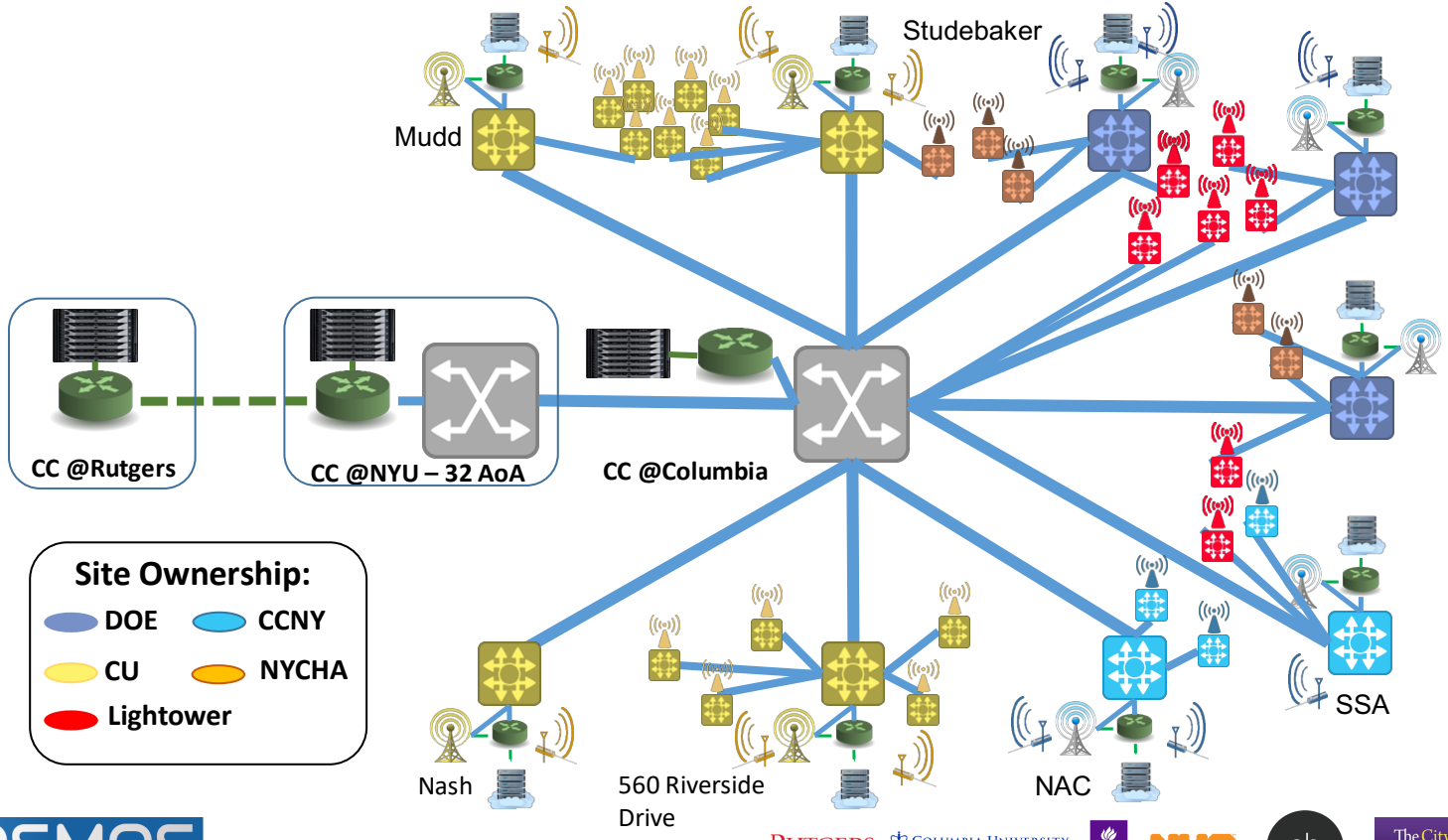
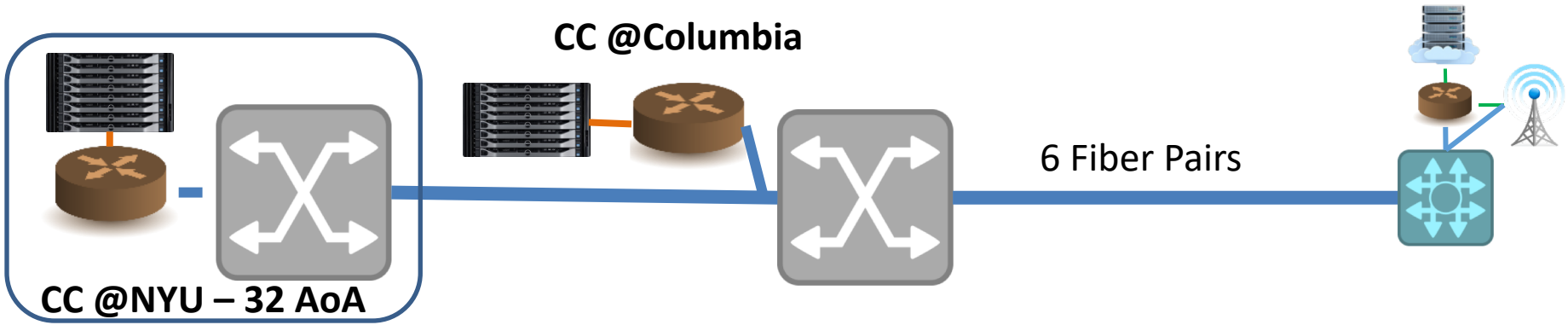

COSMOS Deployment
Henry Hudson Pkwy
12th Ave
Riverside Dr
W 130th St
W 122nd St
W 121st St
La Salle St
St Mary's Pl
Manhattanville
Hamilton Pl
Amsterdam Ave
W 119th St
W 118th St
Convent Ave
Hamilton Terrace
W 129th St
Morningside Ave
Nicholas Terrace
W 126th St
W 125th St
W 124th St
Frederick Douglass Blvd
W 137th St
W 138th St
Deployment:
Large node: rooftop deployments with number of antennas and edge cloud
Medium node: street-level devices dual use with wireless/wired

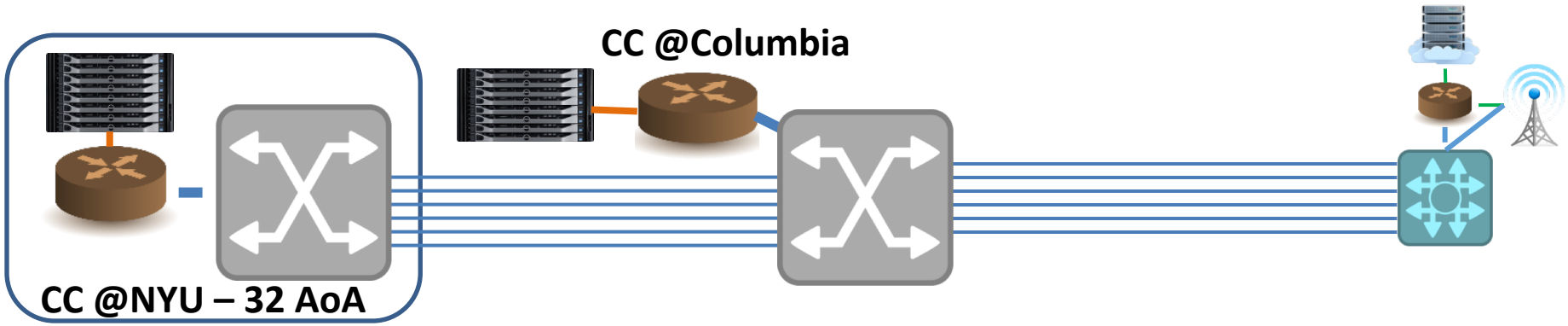
COSMOS Network



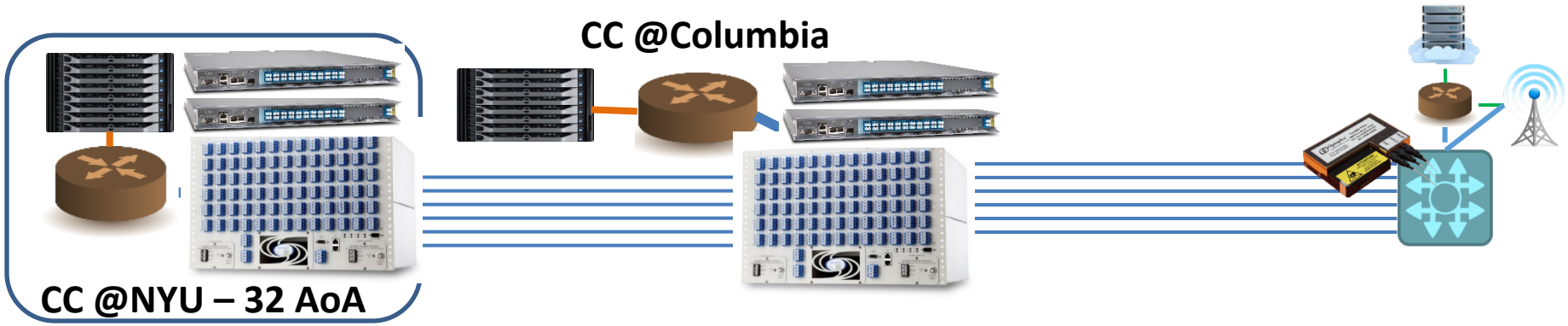
Programmable Topologies



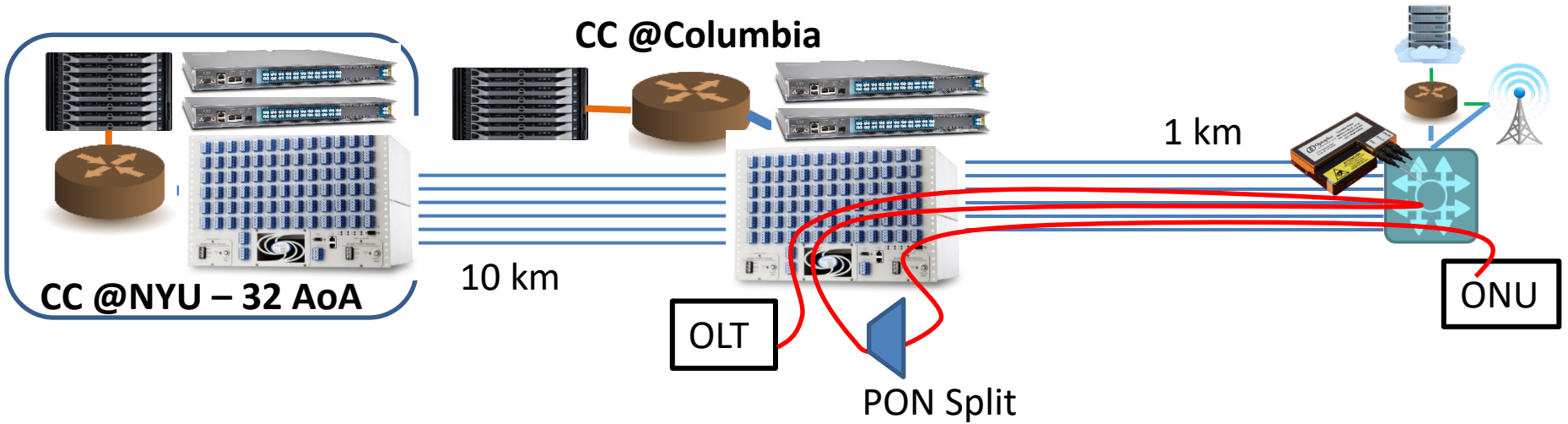
Programmable Topologies



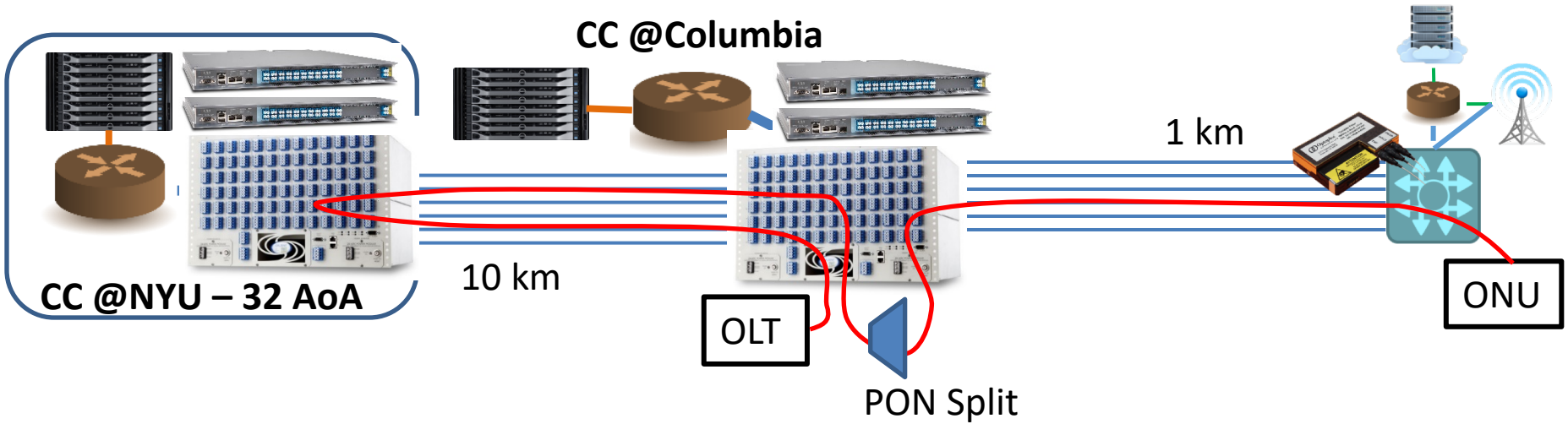
Programmable Topologies



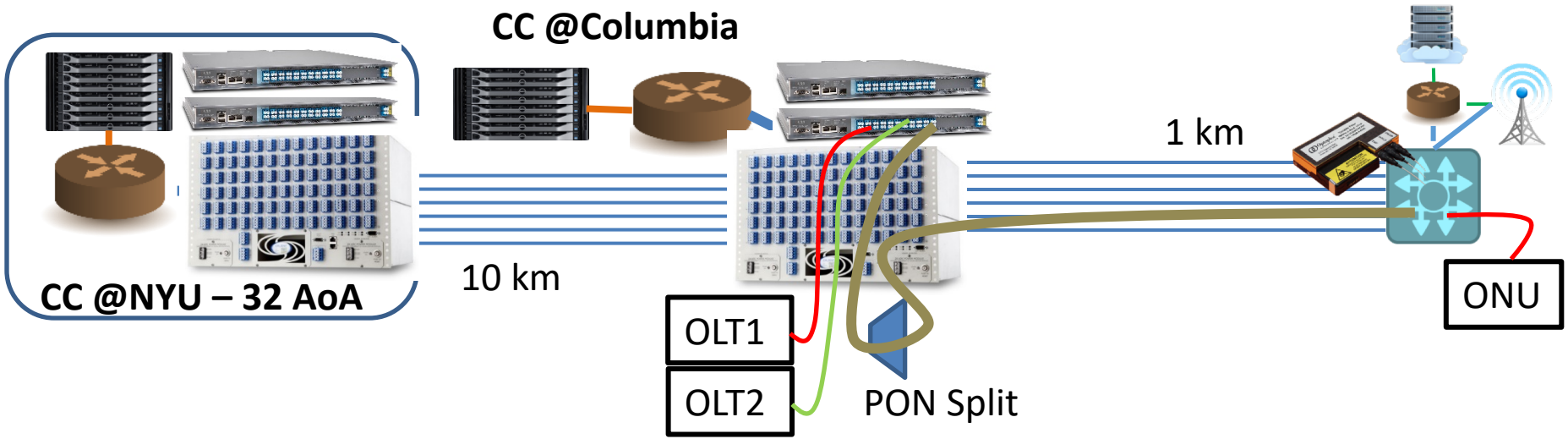
PON



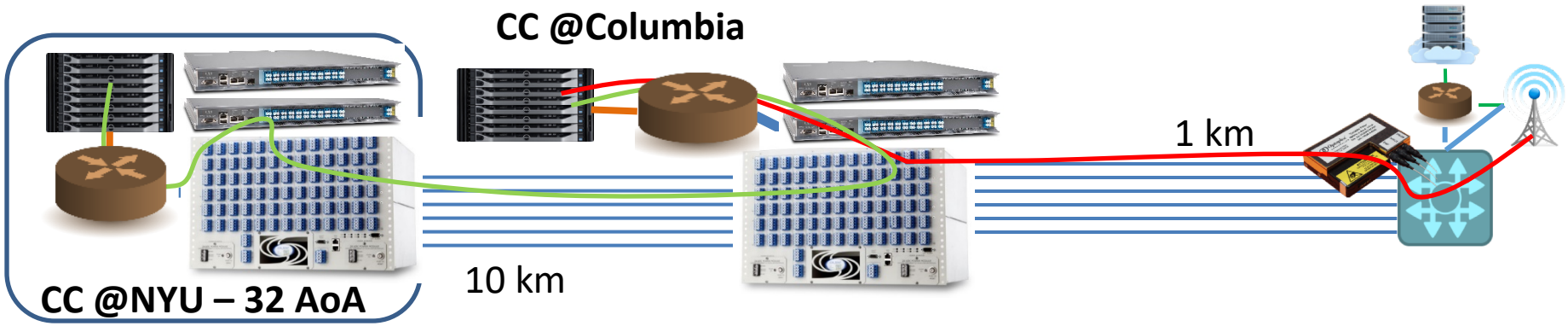
Long Reach PON



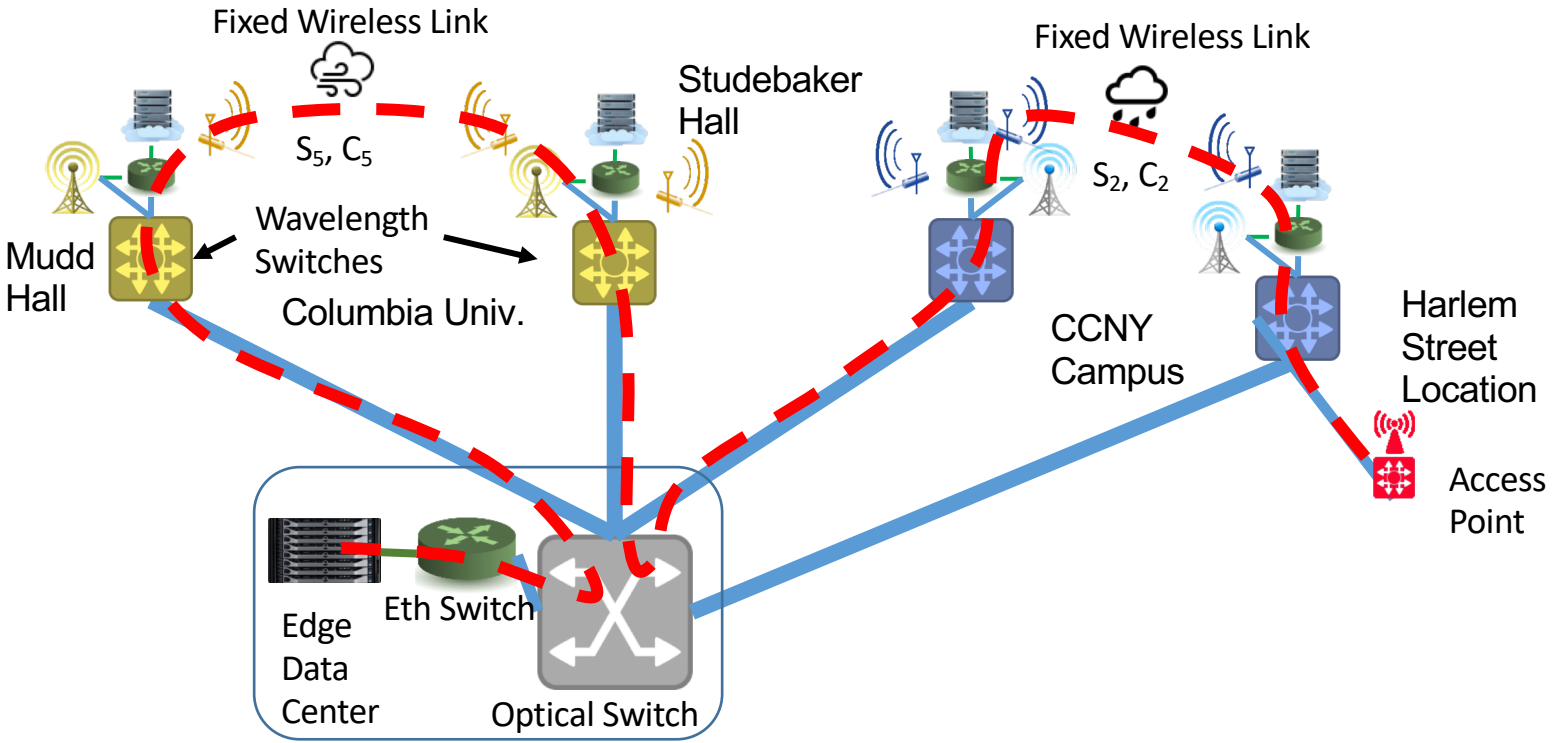
WDM PON



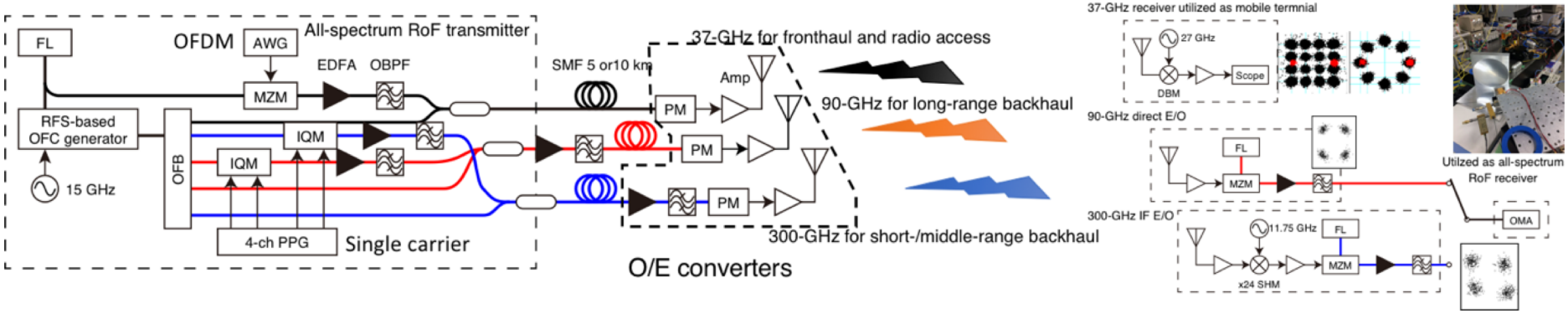
MidHaul Network



Converged mmWave/Fiber Transmission



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

(Figure courtesy of A. Kanno, NICT)

Connected Projects

- Significant ongoing local tech-projects that:
  - Will act as a base for the COSMOS testbed deployment
  - Will benefit from the testbed once it is deployed
- Gigabit Center
  - Education & community resource center—& COSMOS node
- S&CC, DoT/DoEd/DoE projects from user community
- New America project: resilient mesh network in East Harlem
- 135th St. Smart City Corridor
- And building…

Harlem Hospital

Partnerships and Users

- 67 Partners: Industry, Tech and Venture partners shown, Government Local, City and State, Community Boards, School Districts, Local Community and experimenters from the research community
- Plus ***advancedwireless.org PAWR consortium***