ROADM and Optical Layer

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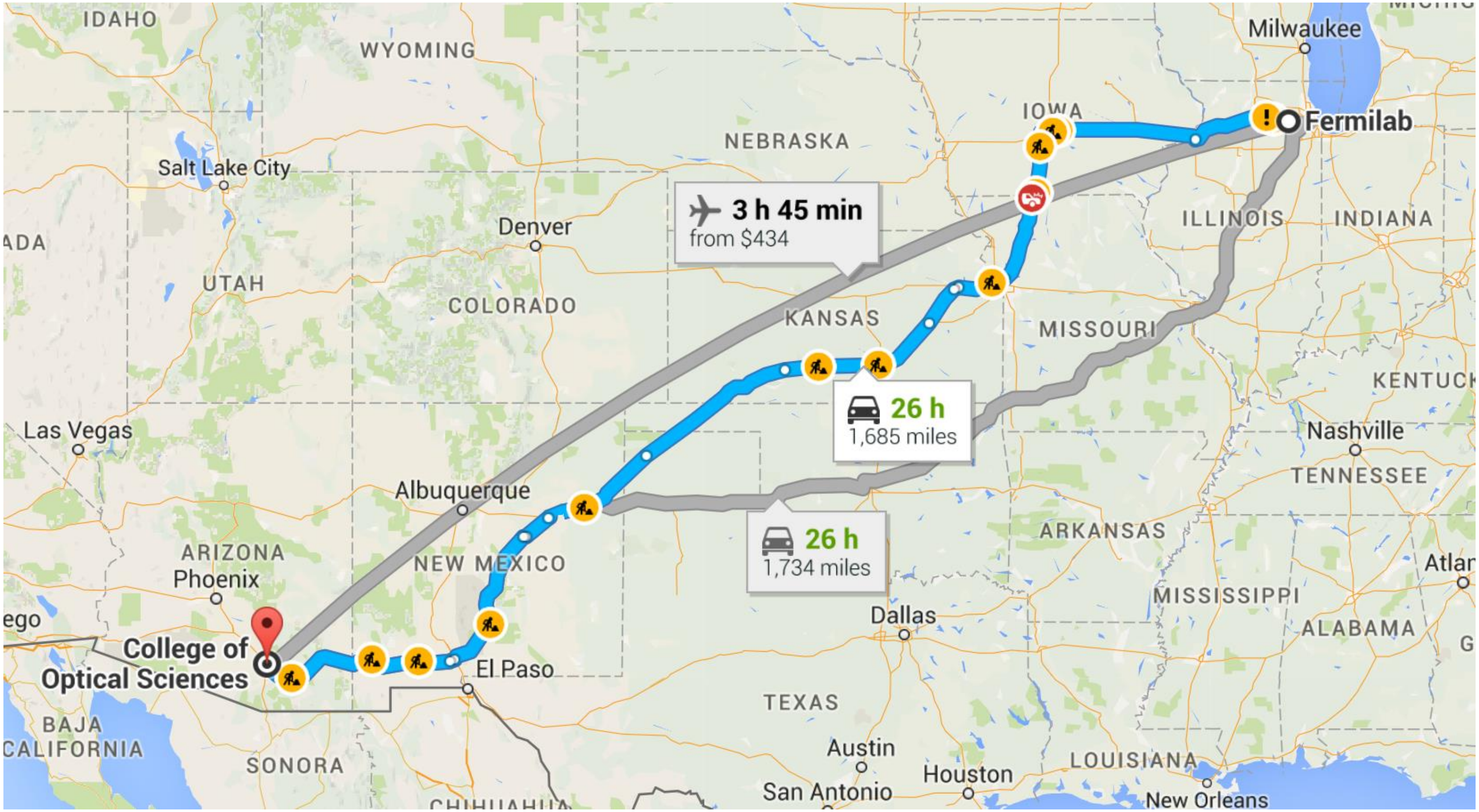
SDN: Google Map Routing for Networks? Packets = Driving, Optics = Flying



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Key Questions/Issues

- Better performance: tighten margins or eliminate margins
- Better software control: reduced complexity, improve reliability of software controls
- Reduce testing cycles, repair time
- Disaggregation: more reliable performance from disaggregated hardware
- Enable more dynamic/faster switching/DBA operation

- Can we use test or field data in order to ‘learn’ better methods to address the above issues?
- Which data is useful and where?

Long Term Question

- Can we make optical systems fully open and simple to operate?
  - Buy components from any vendor and put them together however I want without worry
  - Configure, customize, operate as you like

Scope

- Line system components:
  - WSSs, space switches, amplifiers, fiber plant, VOAs, OPM/telemetry/OTDR, multiplexers, ASE noise loading

- Line system controls:
  - RSA/RWA/PCE, steady state controls (e.g. power leveling, OA gain settings), channel provisioning (e.g. switch settings, power tuning, synchronization)

- Test, Development, Fault Management:
  - Engineering rule validation testing, interoperability testing, in-service testing, fault identification/localization, fault prediction, electrical power cycling, in-service maintenance

Signal Provisioning

Stages	Steps	Goal/Issue	AI solution
Before traffic request	Physical layer characterization	Lack of accurate optical amplifier model	DNN
	Traffic prediction	Optimize resource allocation	LSTM, DCRNN
Before channel setup	Wavelength selection	Minimize impact to existing channels	DNN
	QoT estimation	Predict signal quality (e.g. OSNR)	GP, GN, TL
During channel setup	Power tuning	Speed, avoid impact	None
	Element synchronization	Speed, stability	None
After channel setup	Adaptive control for transmission	Fluctuation of signal quality reconfiguration	Feedback Control
	Failure detection and recovery	Predict link failure, recover optical link	ML+SDN, tSDX

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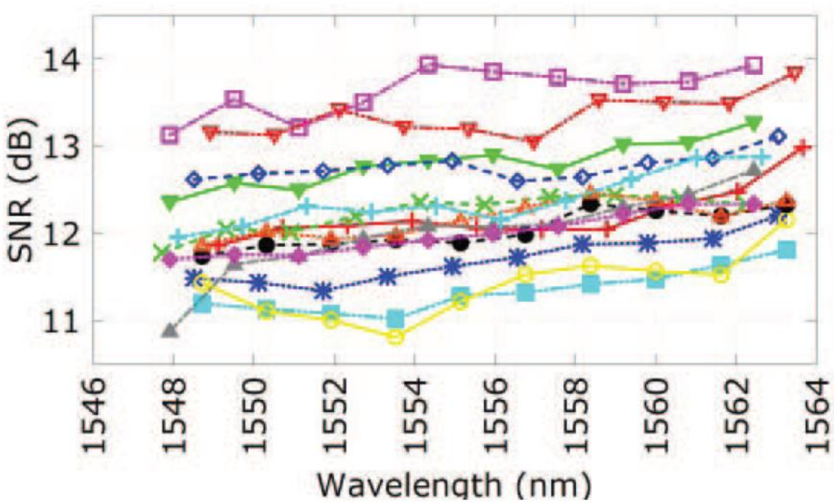
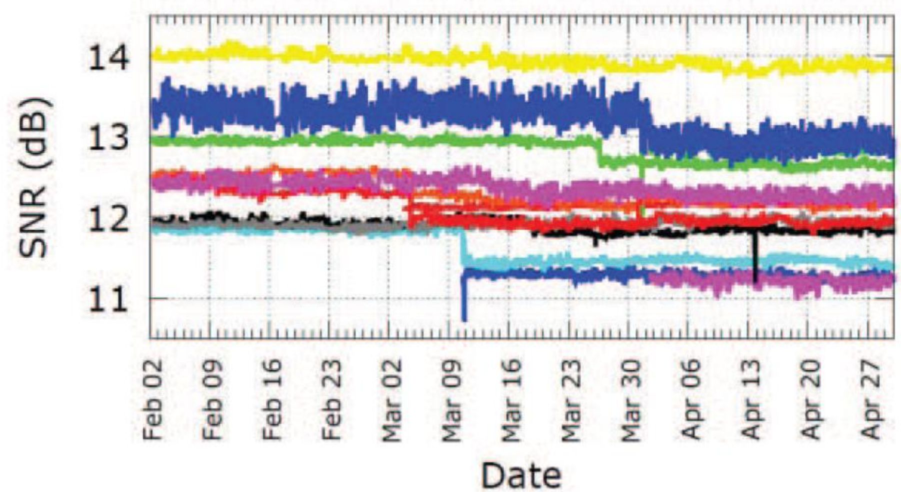
Variations in the Field

- Production system measurements (Microsoft)
- Performance varies by wavelength & route over time
- Mostly transceiver focused: what about network!

Wavelength & Route Dependence:



Time Dependence:



Ghobadi, et. al. OFC 2016

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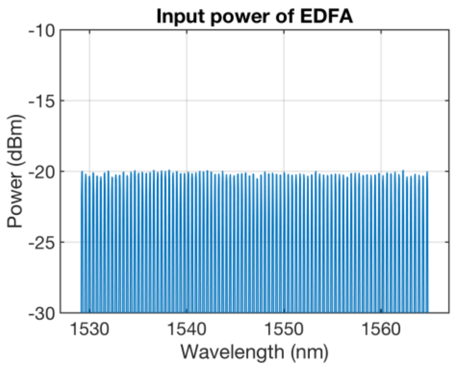
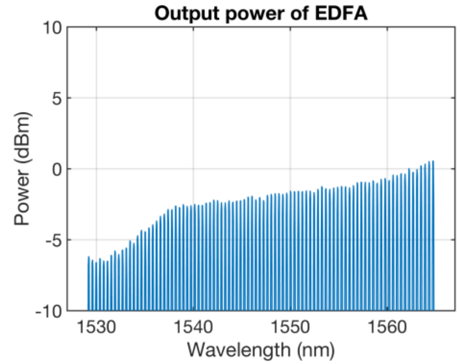
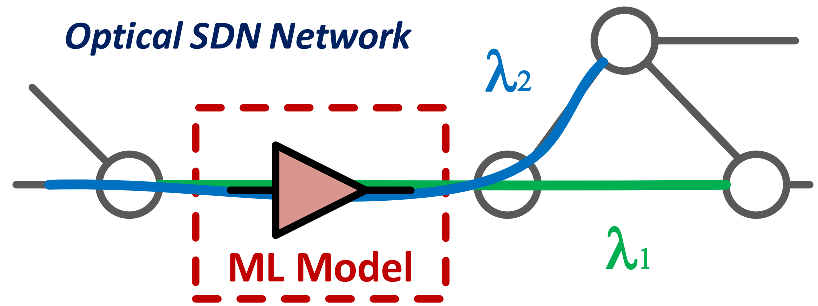
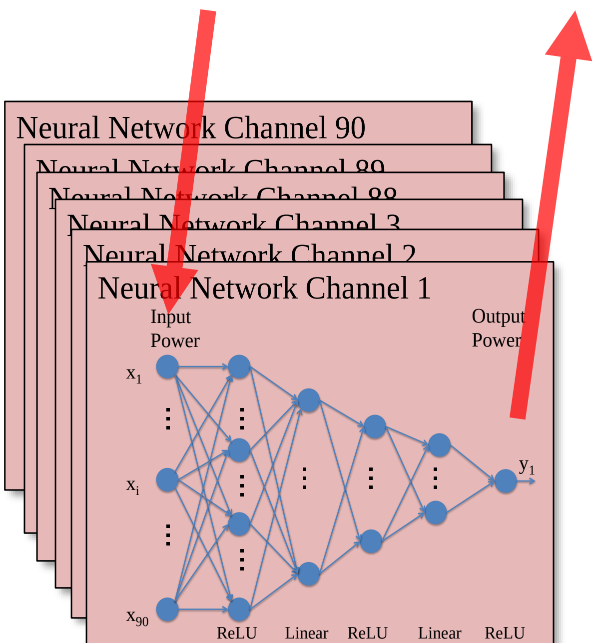
Example: OA Models







$$P_i = RG_M P_{ini} + G_M \sum_{j \neq i} (R - f g_j) P_{inj} + G_M (R - f g_I) N_I - f G_M g_R N_R$$



Parameter	Value
Input Vector	[P_{ch1}, P_{ch2}, P_{ch3}, … , P_{ch90}]
Output Vector	[P_{chi}] for *i* in [1, 90] # *i is index of the* 90 NNs
Transfer Func.	[ReLU, Linear, ReLU, Linear, ReLU]
Training Target	Min{MSE}
Training Method	Stochastic Gradient Descent (SGD)
Batch Size (m)	m = 60
Learning Rate (α)	α = 0.00025
Training Time	> 15000 iterations

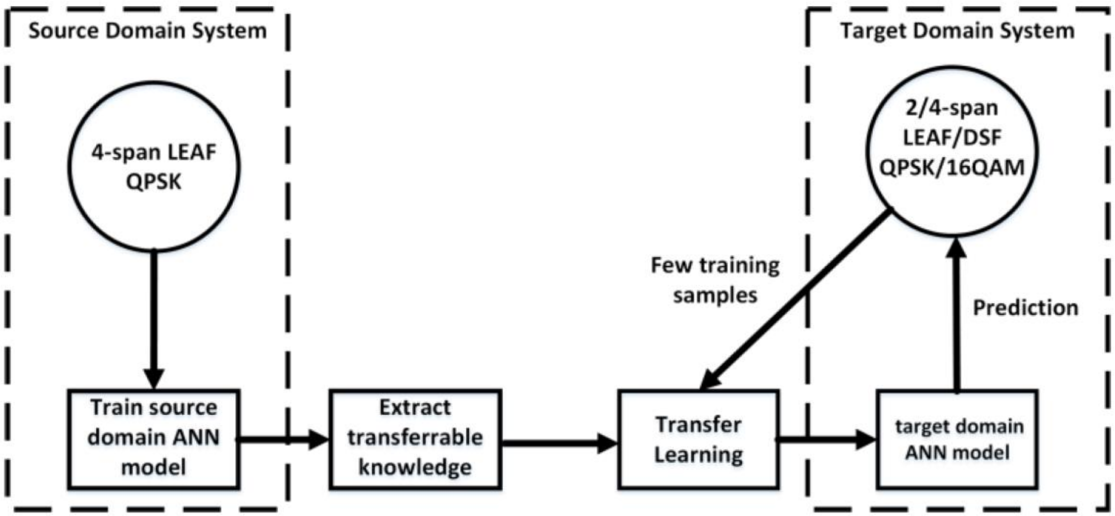
S. Zhu, et. al. ECOC 2018

Use Transfer Learning from Test Lab to Field

Y-K. Huang, E. Ip NEC & UA

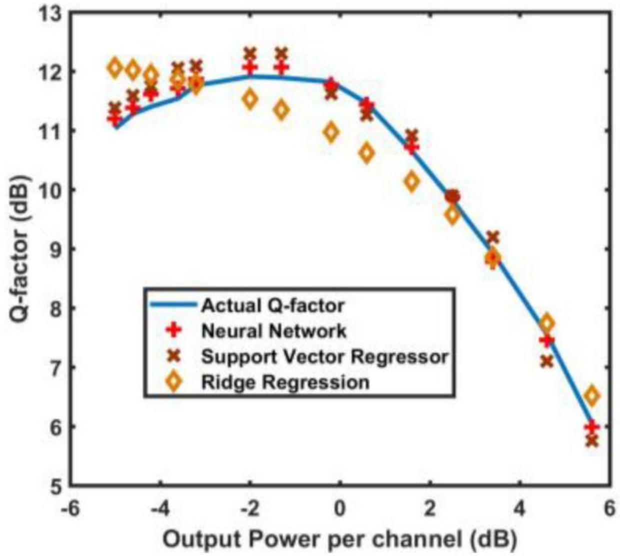
W. Mo., et. al. OFC 2018

- Improve Quality of Transmission (QoT) estimation and wavelength assignment
- Transfer learning for real time prediction

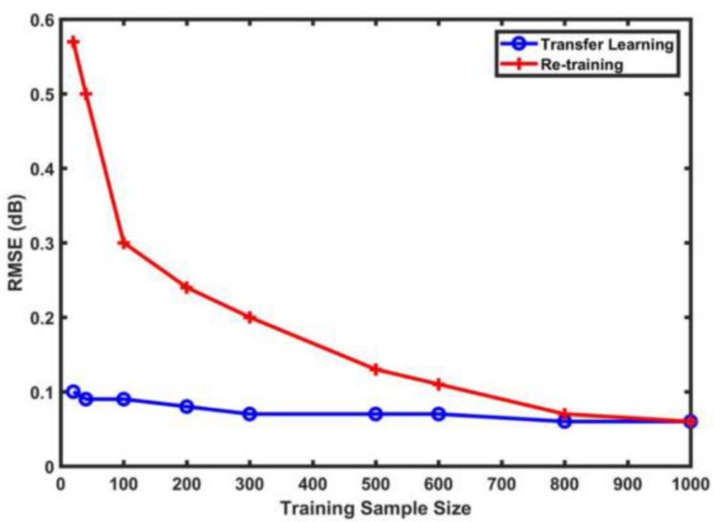


Best student paper runner-up for OFC 2018!

Q-Factor Prediction

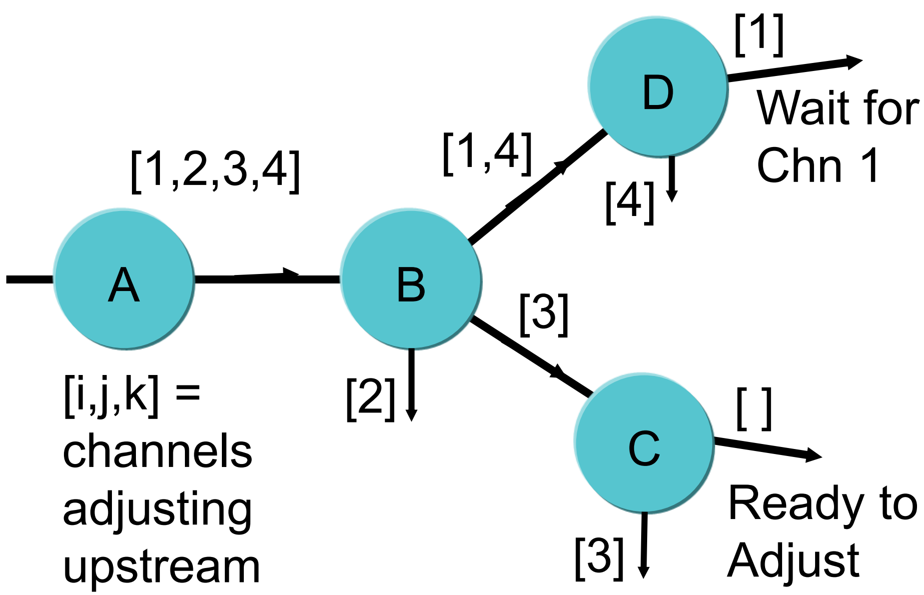


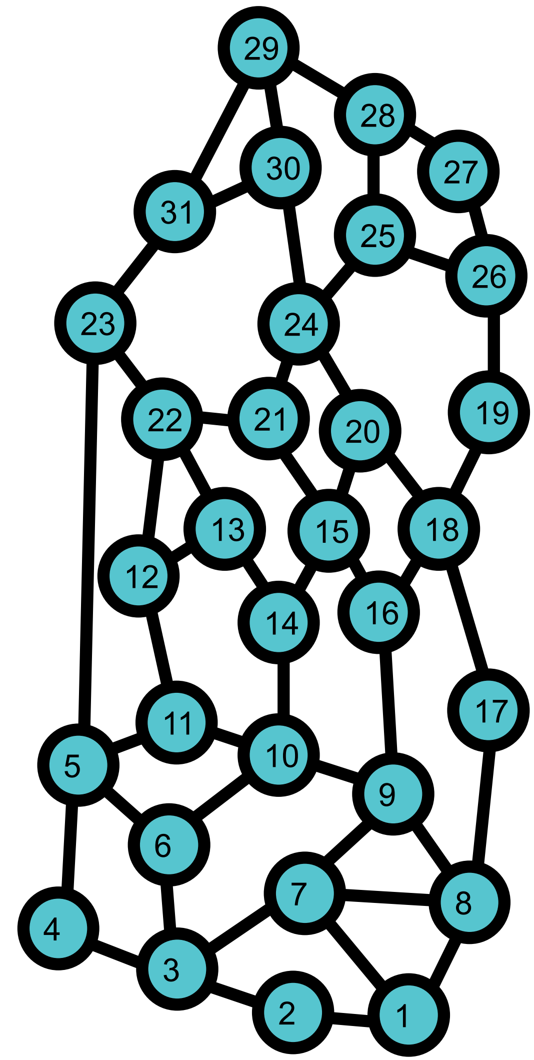
Transfer Learning



Dynamic Domain Power Control Algorithm

- Power drifts over time and new channels are provisioned: need periodic power control to stay within margins
- Adjust nodes in parallel within 'optically' isolated domains
  - Node ordering based on channel routes

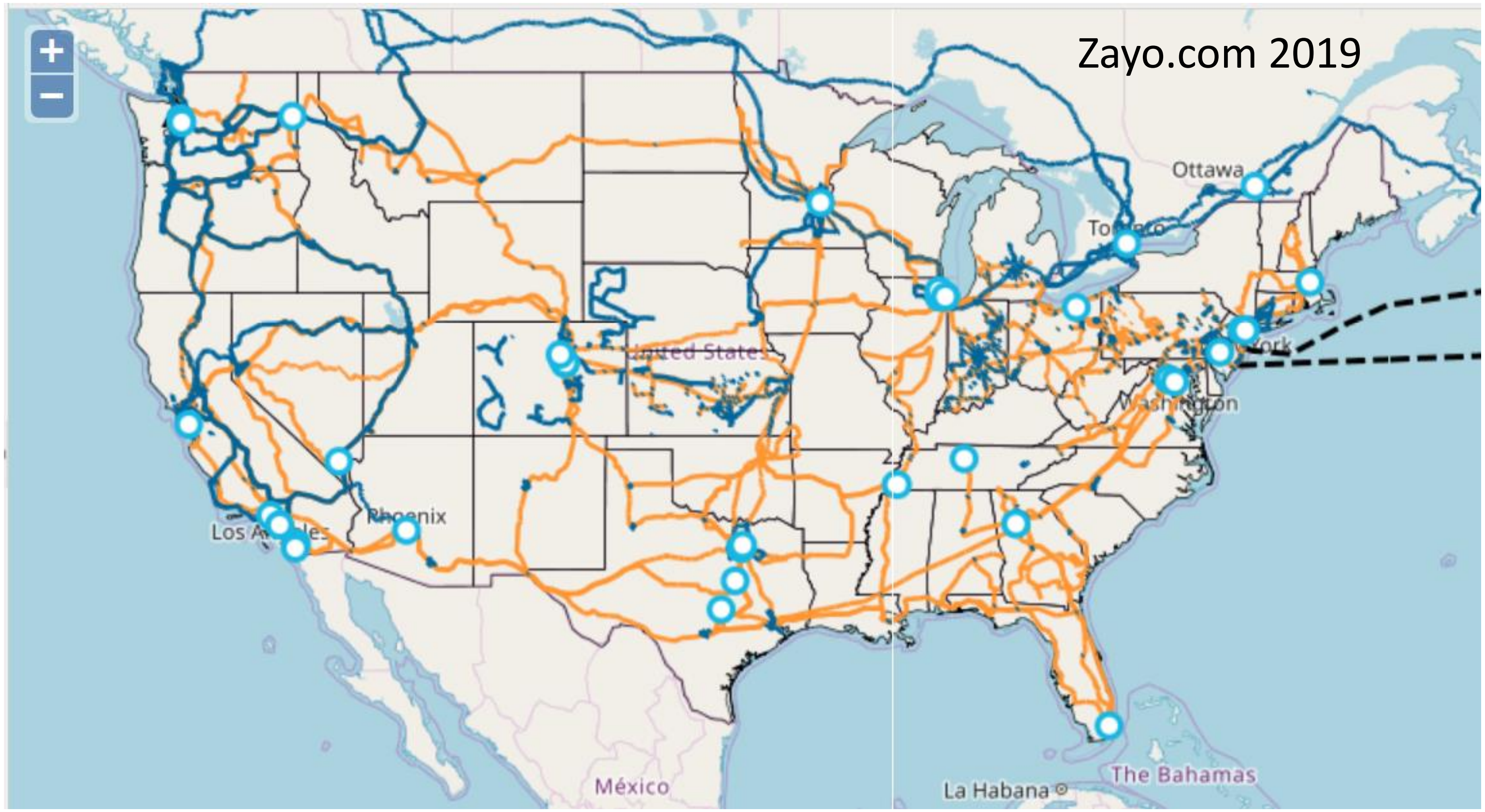




Kilper & White OFC 2007

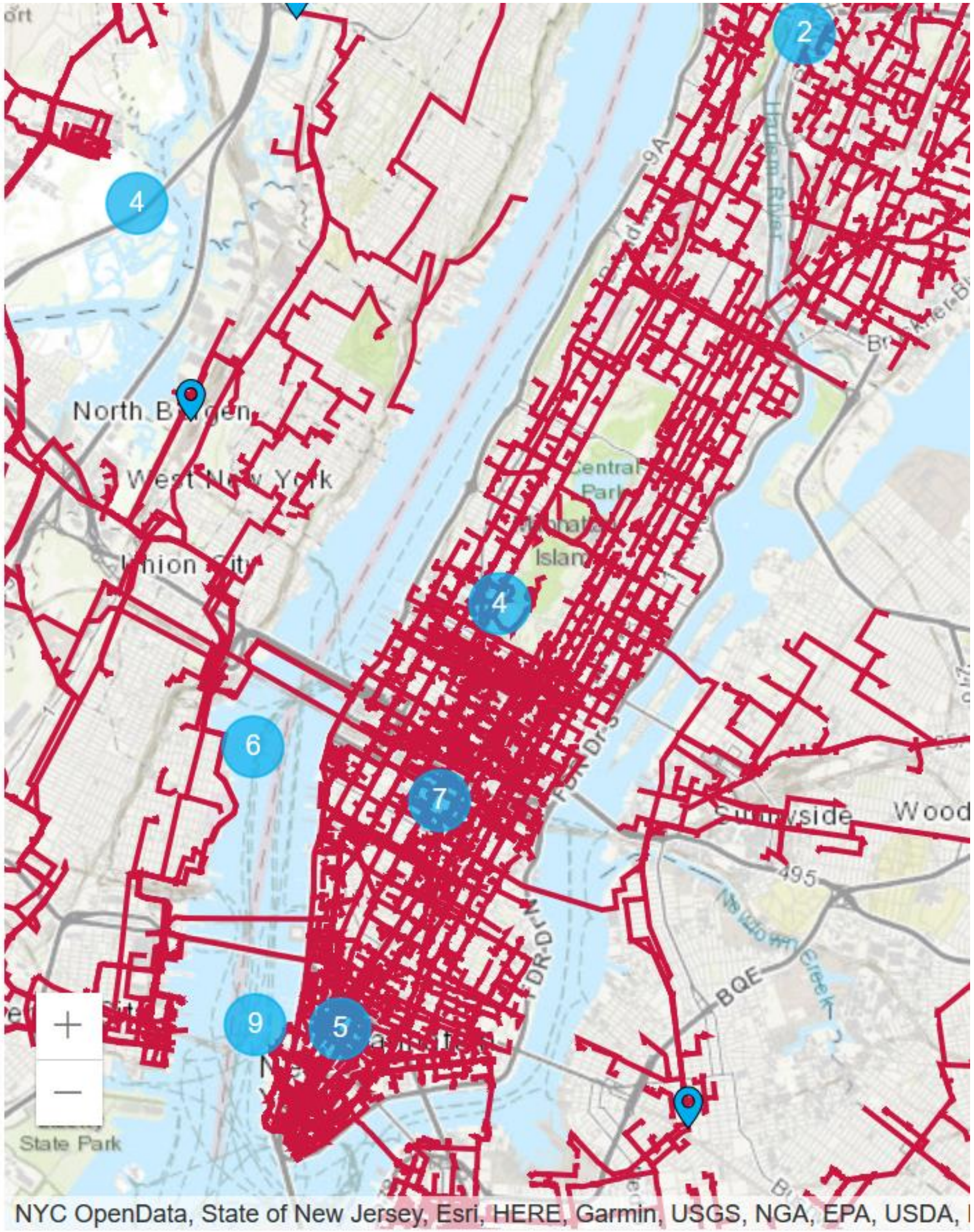
The Network Today: Long Haul/Regional

- No point to point trans-continental links
- Large, continental scale transparent network
  - Add and drop traffic many times along route from NY to LA



The Network Today: Metro/Wireless/ Access

Manhattan Crown Castle (Wireless) Fiber



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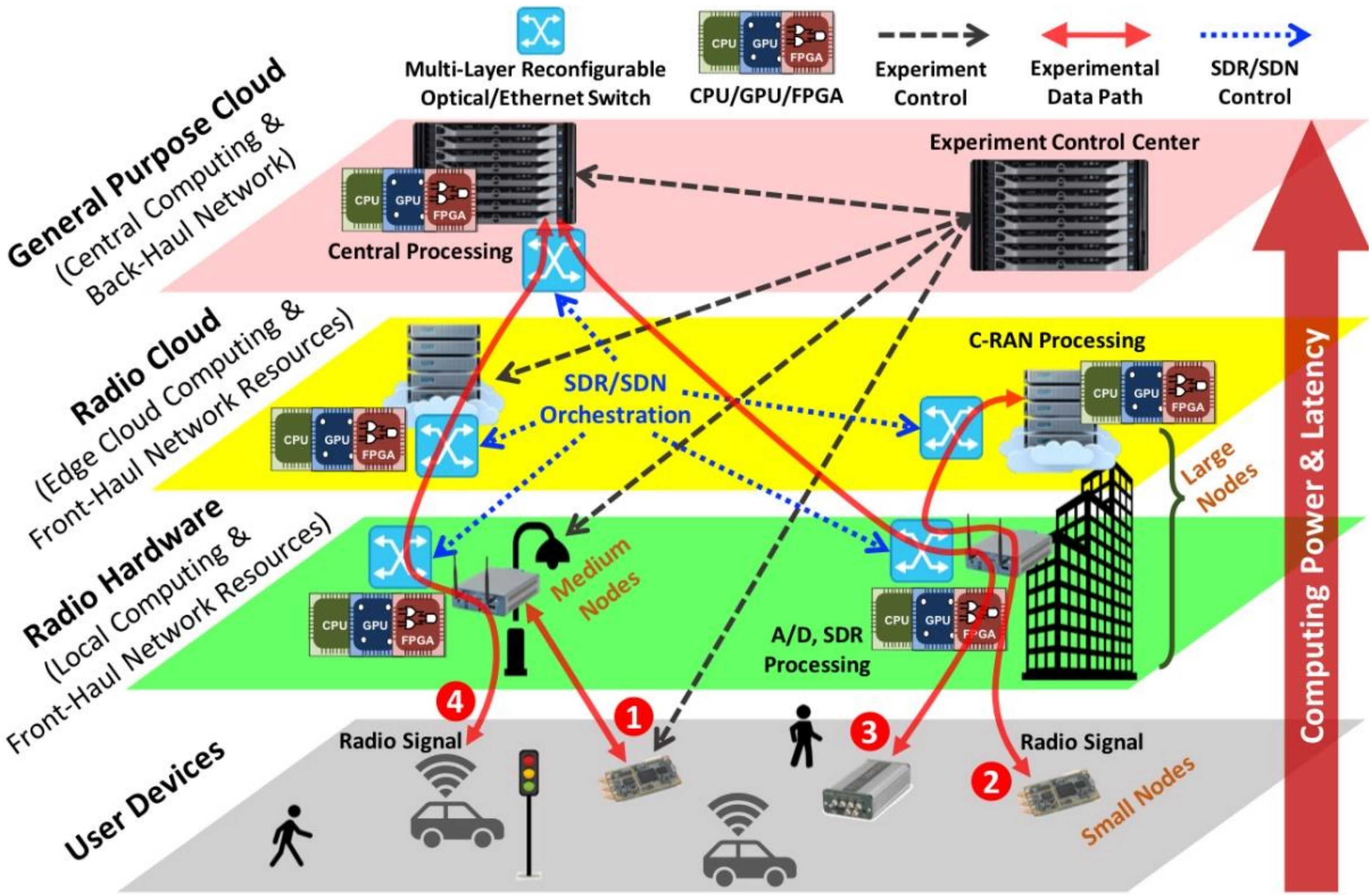
COSMOS: Multi-Layer Wireless Optical Testbed



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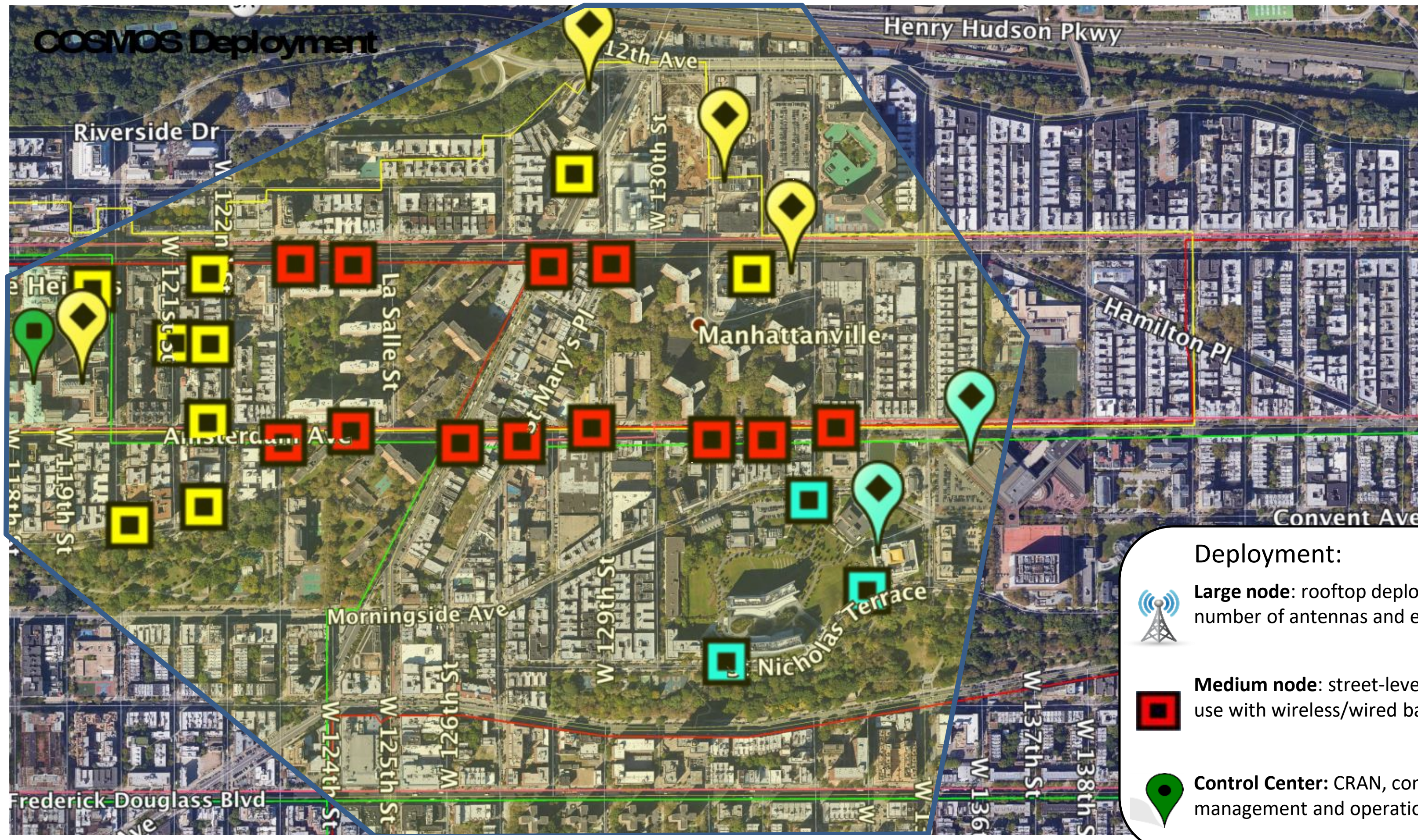
New York City Deployment Area



Deployment:

Large node: rooftop deployments with number of antennas and edge cloud

Medium node: street-level devices dual use with wireless/wired backhaul

Control Center: CRAN, control, management and operations center

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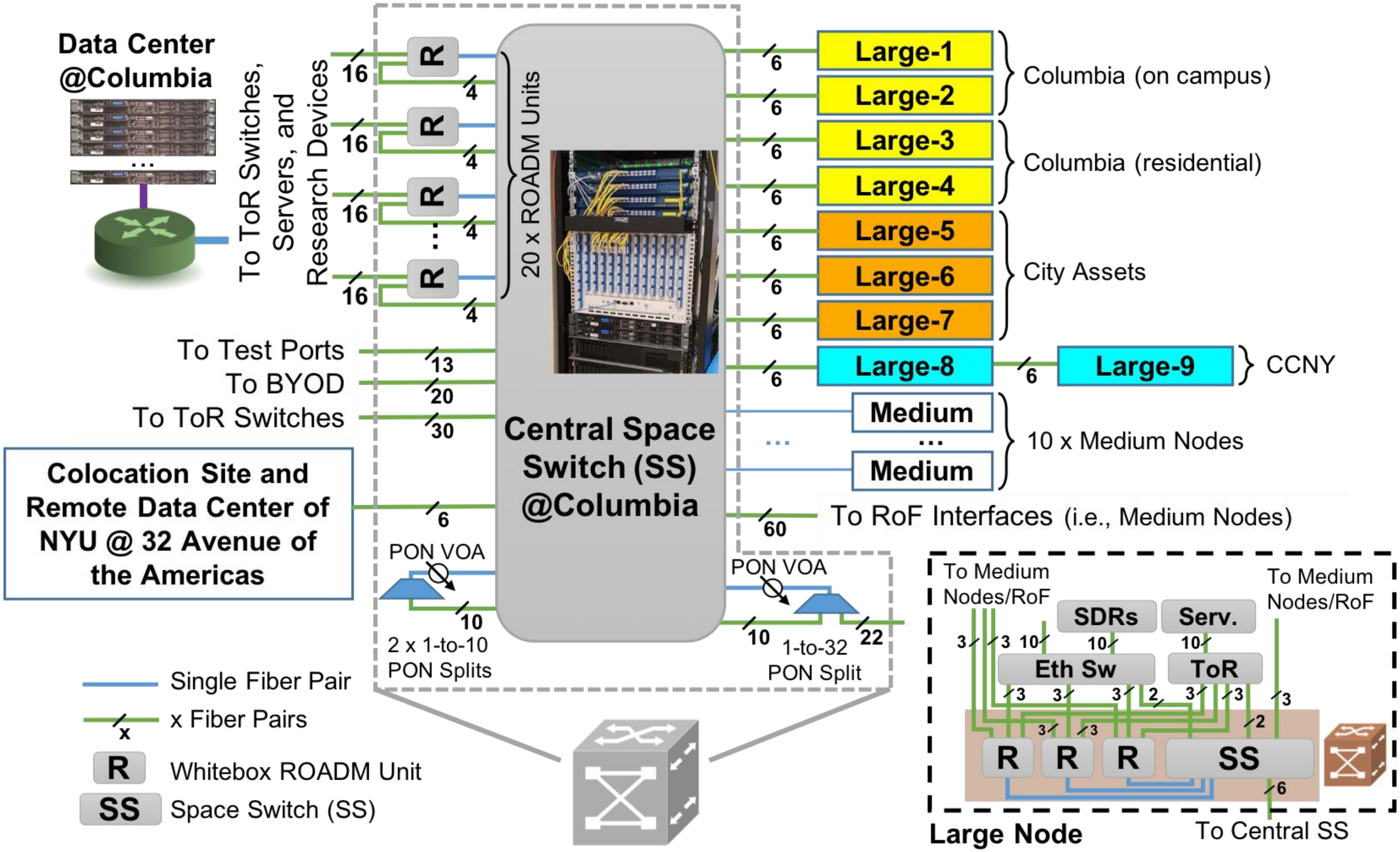
COSMOS: Optical Networking



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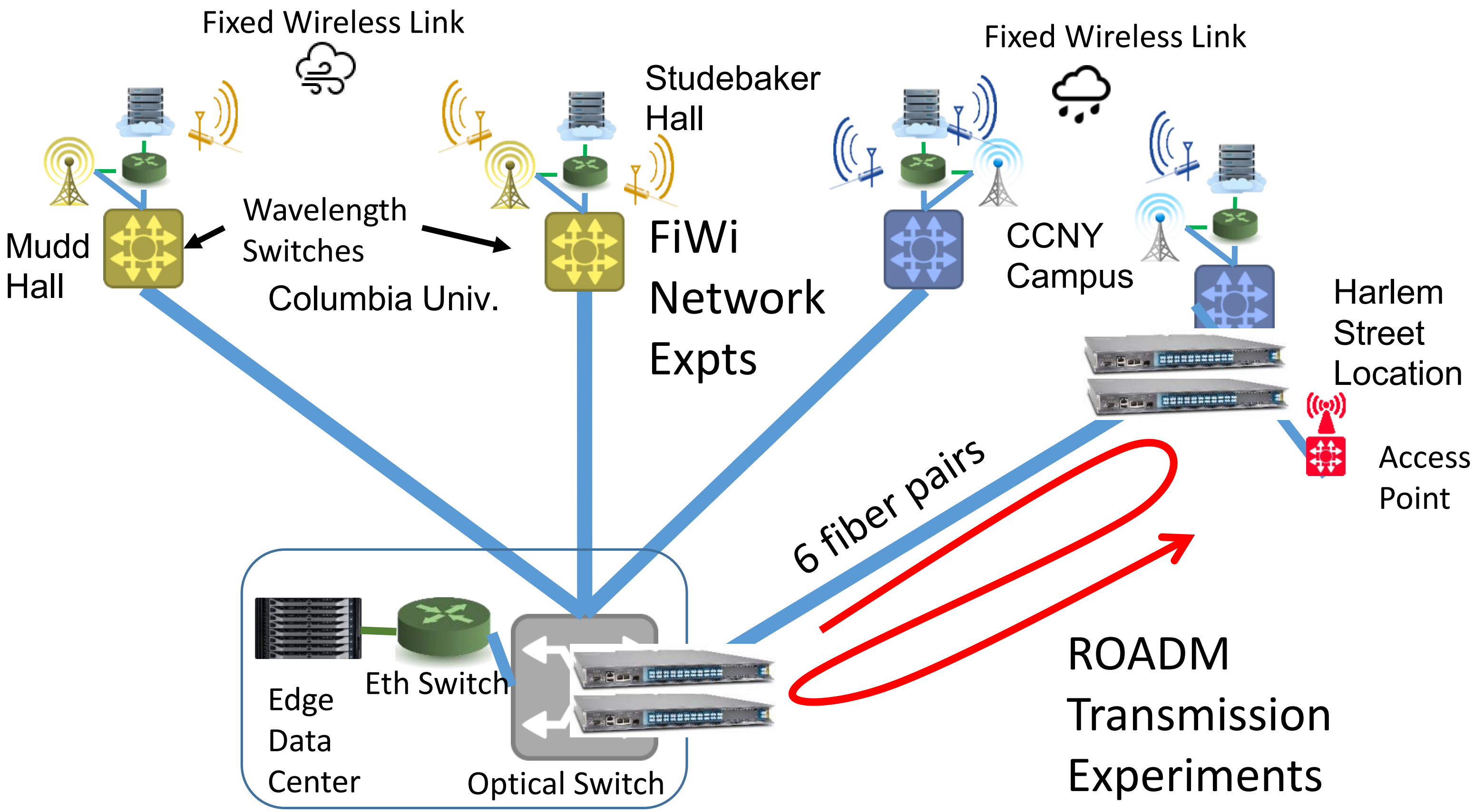
COSMOS: Optical Platform for Data Collection



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