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Cross-layer/multi-vendor end-to-end networking

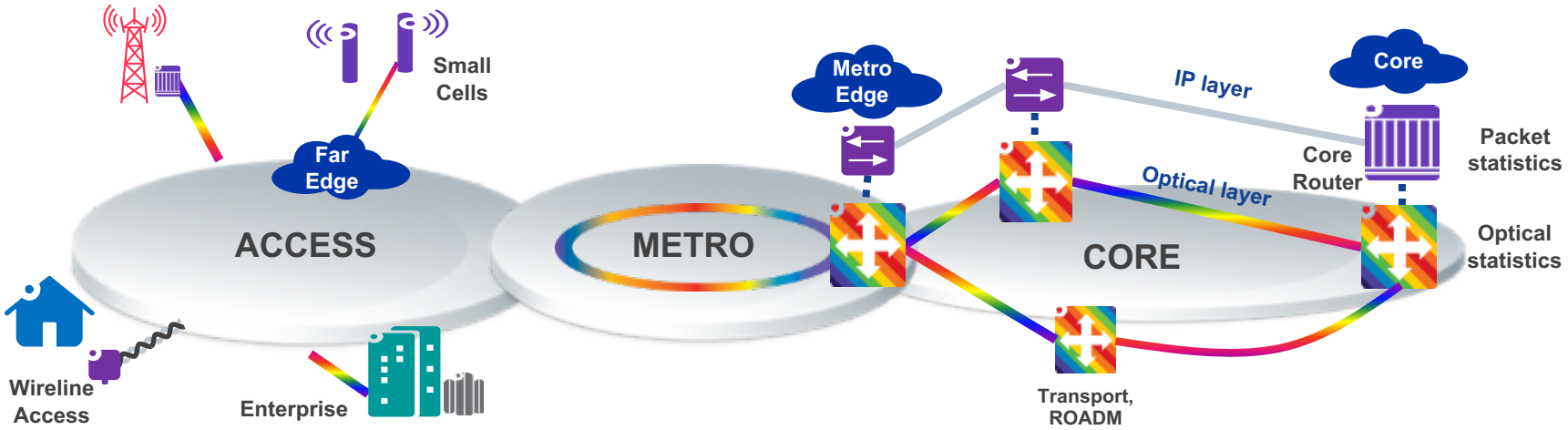
NIST Workshop on Machine Learning For Optical Communication Systems

Jesse Simsarian

Outline

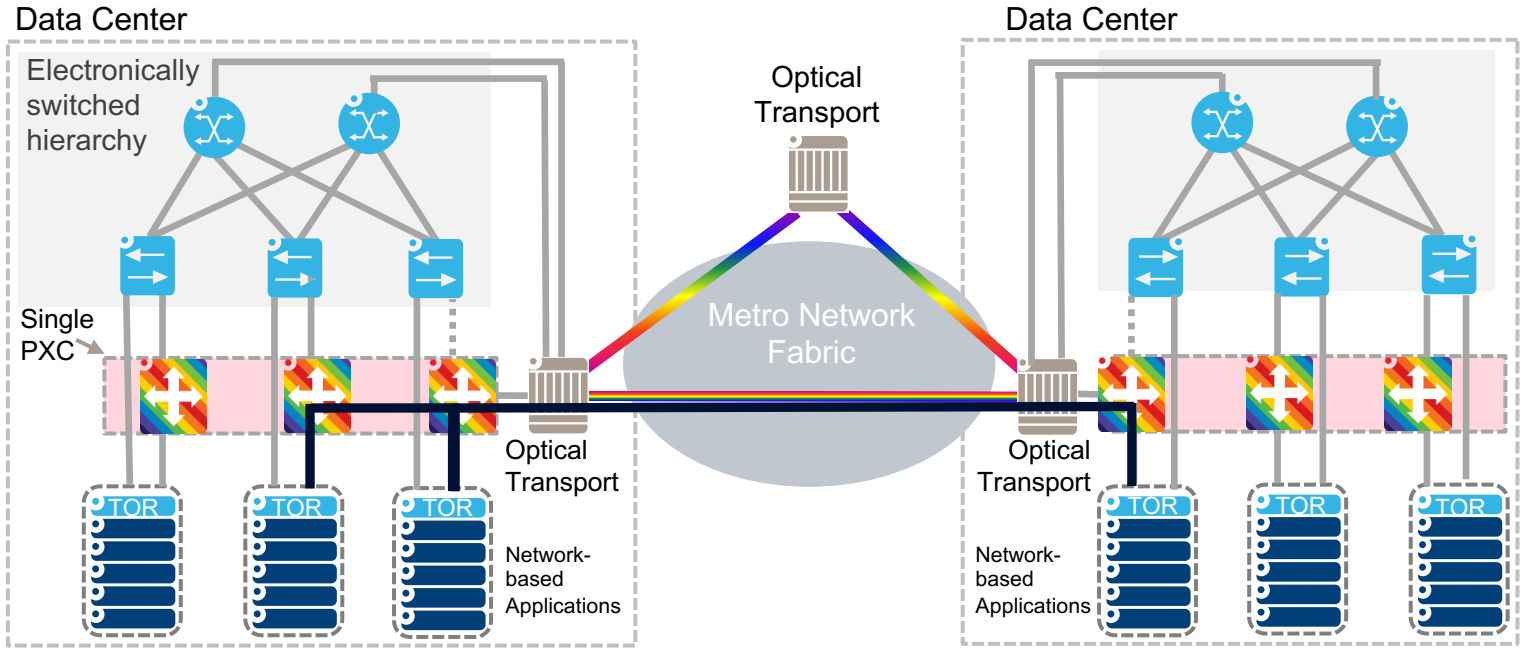
1. Use cases
   - Packet/Optical, DC/Optical, End-to-end 5G
   - Machine learning opportunities: optimization, prediction, classification, correlation, model parameter learning
2. Some example data sets
3. Multi-Vendor
   - Industry standards
   - Required metrology
4. Possible sources of data
   - Research testbeds
   - Industry
5. Conclusion and References

Cross-Layer Use Cases: Packet/Optical



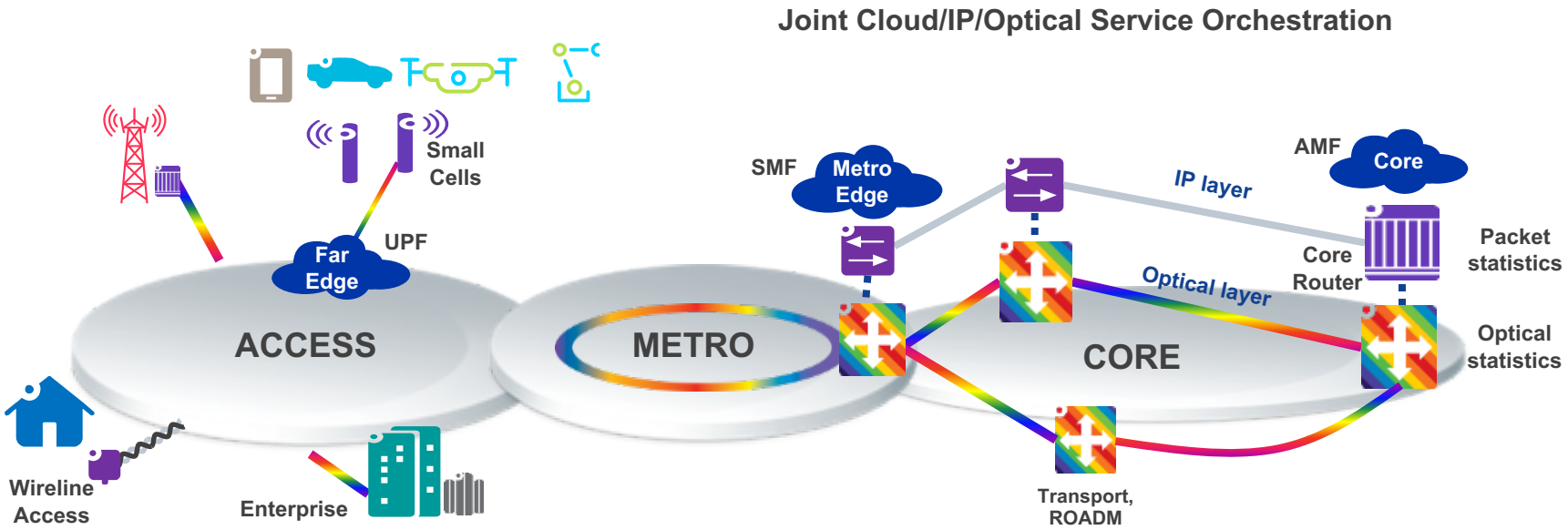
- Flexibility of optical network underutilized compared to IP and DC/cloud - virtualization of optical infrastructure [1] and increasing optical dynamicity.
- Statistics from *optical* layer & action at *packet* layer - coherent receivers: power, pre/postFEC BER, CD, DGD, polarization state, constellation, received power spectrum - Bell Labs research on postFEC BER and polarization state monitoring and action [2, 3].
- Statistics from *packet* layer and action at *optical* layer - congestion, latency, flow level statistics, routing tables - Bell Labs research on action at optical layer based on packet congestion for DC interconnection [4]
- Routing modulation and spectrum assignment (RMSA) of optical network based on *IP traffic prediction* and *packet/optical network state*

Cross-Layer Use Cases: DC/Optical



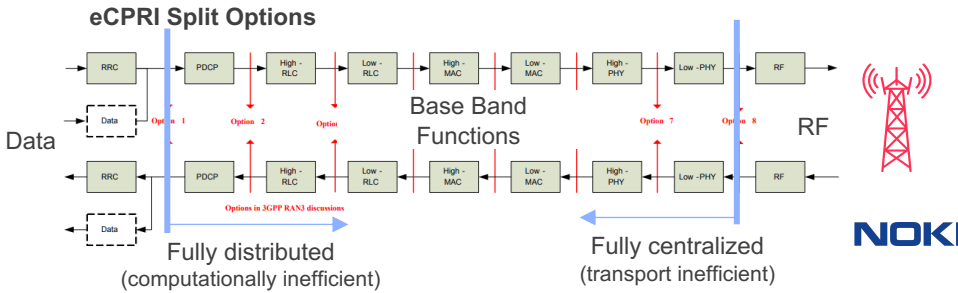
- Optical DC provisioning and reconfiguration based on traffic - elephant/mice flows and shuffle-heavy jobs [6 - 7].
- Virtual Optical Network Embedding: Consider mapping of virtual machines (VMs) to cloud infrastructure and optical network resource allocation. [5]
- Optical express DC interconnection [4]
- VM, VNF, and application performance metrics

Cross-Layer Use Cases: End-to-End 5G



- Network slice creation (logical network partitions of physical network across domains) and IoT device onboarding to network slices [8 - 9]
- IoT device authentication and security [10]

  (Not really cross-layer networking)
- Mobile fronthaul PHY split processing [11]
- 5G control and data plane service VNF placement [12]



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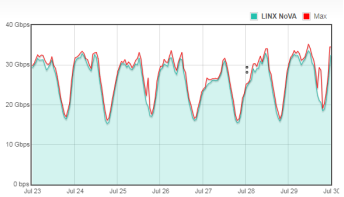
Some Data Set Examples

LINX



IP

IXPs tidal traffic: [13]: London Internet Exchange bitrate vs time at exchange sites

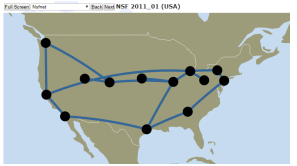
Internet2 (2003) [14]:

- Usage Statistics – the amount of traffic on network links; Flow data - data that examines individual flows across the network; Routing data; Latency data; Throughput data; Router data; Syslog data – what the routers are reporting about the network

Sprint (2002) [15]: IPMON packet trace collection (IP headers) from backbone network 10+ TB/measurement

Optical

Topology Zoo



Topology Zoo [16]: Topologies widely used in optical papers

SNDlib [17]: Topologies and demands in GML format

Internet Atlas: A Geographic Database of the Internet [18]

- Visualization and analysis portal for diverse Internet measurement data. Geographically anchored representation of the physical Internet including (i) nodes (e.g., hosting facilities and data centers), (ii) conduits/links that connect these nodes, and (iii) meta data

Microsoft Wide-Area Optical Backbone Performance [19]

- February 2015 to April 2016, taken from Microsoft's optical backbone in North America. Polled the aggregation devices every 15 minutes for their optical signal q-factor, transmit power (dBm), chromatic dispersion (ps/nm), and polarization mode dispersion. Random 4000 channels across random 115 optical paths. "This data is the first public release of a large-scale optical backbone."

DC/Cloud

U. Wisconsin and Microsoft "Network Traffic Characteristics of Data Centers in the Wild" [20]

- SNMP link statistics, fine-grained packet traces, and detailed topology

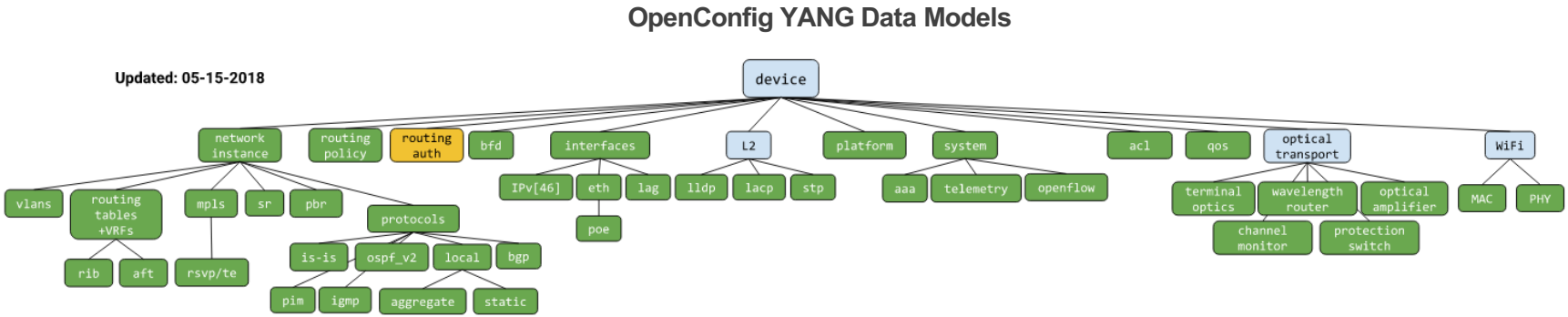
Google cluster server usage data [21].

Virtual Network Functions (VNFs) [22]: Traffic features + CPU consumption: knowledgedefinednetworking.org

E2E 5G

TBD, see 5G network testbeds COSMOS and Berlin

Multi-Vendor and Metrology



Open source data models

- IP/Optical data models from OpenConfig [23]
- Data models from OpenROADM [24]
- Is there a need to expand the data models?

Required standards?

- ITU-T Q6/15 new definition of OSNR in dB/0.1nm referenced to 193.6 THz
- Packet trace capture definition - IPFIX from IETF [25]
- VM resource usage definition/data model?

Possible Sources of Data

Internet2, ESNet or other government-sponsored networks

- More detailed data, e.g., flow level, latency, router data?
- Cross-layer IP/optical?

5G Testbeds

- Make link between VNF placement, network slice creation, device onboarding, traffic generated, and end-to-end performance

COSMOS

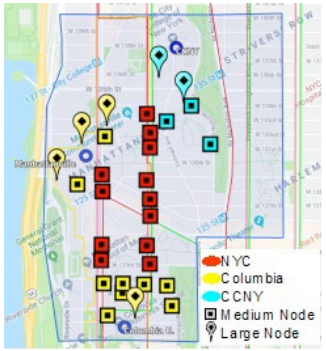
- NSF funded 5G testbed in Manhattan [26]
- Dark fiber based optical ROADM network
- C-RAN with distributed x-haul processing

Open Testbed Berlin for 5G and Beyond

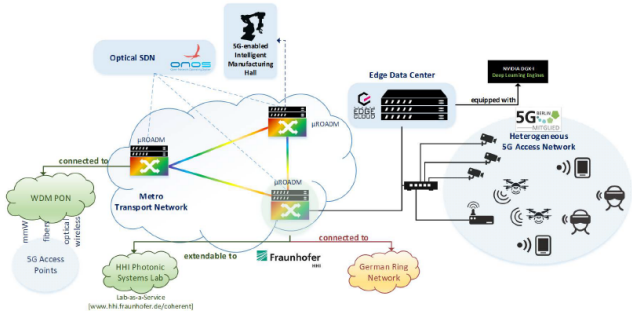
- Fraunhofer HHI [27]
- 3-node ROADM metro network testbed
- 5G-ready RAN infrastructure and edge compute capability
- Could offer NFV services and will eventually support network slicing

ADRENALINE in Spain [28] and RISE/JGN-X in Japan [29]

COSMOS



Berlin Testbed



Conclusions

- End-to-end covers many possible applications and diverse data sets
- Fully service-based 5G deployment involves optimization across access/IP/optical/cloud
- NIST could be the go-to place for networking data sets crossing network layers
- Contribute to the cross-layer E2E breakout group
  - Refine use cases and target some of them
  - Define desired data sets to support use cases
  - Define data formats? How much structure do we impose on data sets?
  - Target potential data sources and collaborate with them

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