Rethinking Cross-Layer (IP-over-Optical) Demand-Responsive Networking

Zhizhen Zhong

Tsinghua University & UC Davis

zhongzz14@mails.tsinghua.edu.cn , zzzhong@ucdavis.edu

27 Apr. 2018

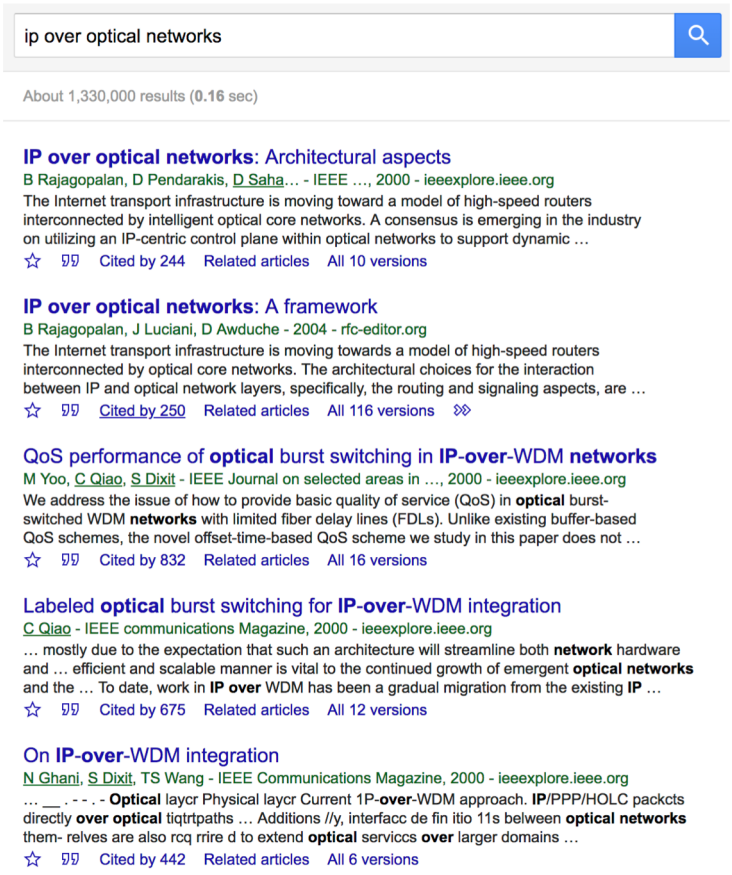
Networks Lab Group Meeting

Tsinghua University

UC DAVIS UNIVERSITY OF CALIFORNIA

Cross-layer networking is an old topic

- How old it is?



ip over optical networks

About 1,330,000 results (**0.16** sec)

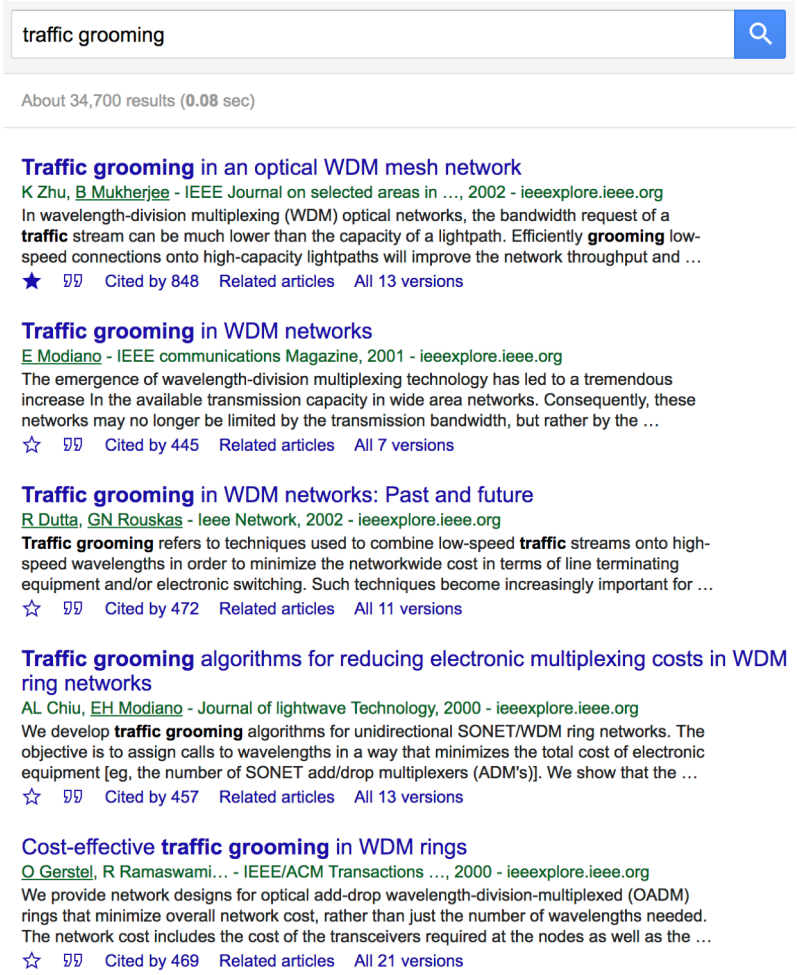
IP over optical networks: Architectural aspects
B Rajagopalan, D Pendarakis, D Saha… - IEEE …, 2000 - ieeexplore.ieee.org
The Internet transport infrastructure is moving toward a model of high-speed routers interconnected by intelligent optical core networks. A consensus is emerging in the industry on utilizing an IP-centric control plane within optical networks to support dynamic …
☆ 99 Cited by 244 Related articles All 10 versions

IP over optical networks: A framework
B Rajagopalan, J Luciani, D Awduche - 2004 - rfc-editor.org
The Internet transport infrastructure is moving towards a model of high-speed routers interconnected by optical core networks. The architectural choices for the interaction between IP and optical network layers, specifically, the routing and signaling aspects, are …
☆ 99 Cited by 250 Related articles All 116 versions »

QoS performance of **optical** burst switching in **IP-over**-WDM **networks**
M Yoo, C Qiao, S Dixit - IEEE Journal on selected areas in …, 2000 - ieeexplore.ieee.org
We address the issue of how to provide basic quality of service (QoS) in **optical** burst-switched WDM **networks** with limited fiber delay lines (FDLs). Unlike existing buffer-based QoS schemes, the novel offset-time-based QoS scheme we study in this paper does not …
☆ 99 Cited by 832 Related articles All 16 versions

Labeled **optical** burst switching for **IP-over**-WDM integration
C Qiao - IEEE communications Magazine, 2000 - ieeexplore.ieee.org
… mostly due to the expectation that such an architecture will streamline both **network** hardware and … efficient and scalable manner is vital to the continued growth of emergent **optical networks** and the … To date, work in **IP over** WDM has been a gradual migration from the existing **IP** …
☆ 99 Cited by 675 Related articles All 12 versions

On **IP-over**-WDM integration
N Ghani, S Dixit, TS Wang - IEEE Communications Magazine, 2000 - ieeexplore.ieee.org
… __ . - - - . - **Optical** laycr Physical laycr Current 1P-**over**-WDM approach. **IP**/PPP/HOLC packcts directly **over optical** tiqtrtpaths … Additions //y, interfacc de fin itio 11s belween **optical networks** them- relves are also rcq rrire d to extend **optical** serviccs **over** larger domains …
☆ 99 Cited by 442 Related articles All 6 versions



traffic grooming

About 34,700 results (**0.08** sec)

Traffic grooming in an optical WDM mesh network
K Zhu, B Mukherjee - IEEE Journal on selected areas in …, 2002 - ieeexplore.ieee.org
In wavelength-division multiplexing (WDM) optical networks, the bandwidth request of a **traffic** stream can be much lower than the capacity of a lightpath. Efficiently **grooming** low-speed connections onto high-capacity lightpaths will improve the network throughput and …
★ 99 Cited by 848 Related articles All 13 versions

Traffic grooming in WDM networks
E Modiano - IEEE communications Magazine, 2001 - ieeexplore.ieee.org
The emergence of wavelength-division multiplexing technology has led to a tremendous increase In the available transmission capacity in wide area networks. Consequently, these networks may no longer be limited by the transmission bandwidth, but rather by the …
☆ 99 Cited by 445 Related articles All 7 versions

Traffic grooming in WDM networks: Past and future
R Dutta, GN Rouskas - Ieee Network, 2002 - ieeexplore.ieee.org
Traffic grooming refers to techniques used to combine low-speed **traffic** streams onto high-speed wavelengths in order to minimize the networkwide cost in terms of line terminating equipment and/or electronic switching. Such techniques become increasingly important for …
☆ 99 Cited by 472 Related articles All 11 versions

Traffic grooming algorithms for reducing electronic multiplexing costs in WDM ring networks
AL Chiu, EH Modiano - Journal of lightwave Technology, 2000 - ieeexplore.ieee.org
We develop **traffic grooming** algorithms for unidirectional SONET/WDM ring networks. The objective is to assign calls to wavelengths in a way that minimizes the total cost of electronic equipment [eg, the number of SONET add/drop multiplexers (ADM's)]. We show that the …
☆ 99 Cited by 457 Related articles All 13 versions

Cost-effective **traffic grooming** in WDM rings
O Gerstel, R Ramaswami… - IEEE/ACM Transactions …, 2000 - ieeexplore.ieee.org
We provide network designs for optical add-drop wavelength-division-multiplexed (OADM) rings that minimize overall network cost, rather than just the number of wavelengths needed. The network cost includes the cost of the transceivers required at the nodes as well as the …
☆ 99 Cited by 469 Related articles All 21 versions

Tsinghua University

UC DAVIS
UNIVERSITY OF CALIFORNIA

2

Cross-layer networking is an old topic

- How old it is?

ip over optical network optimization

About 385,000 results (**0.17** sec)

Energy-minimized design for IP over WDM networks
G Shen, RS Tucker - … of **Optical** Communications and **Networking**, 2009 - osapublishing.org
… and cost-minimized design. II. **IP OVER** WDM BACKBONE TRANSPORT **NETWORKS** The **IP over** WDM **network** [10,11] is made up of two layers as shown in Fig. 1, including the **IP** layer and the **optical** layer. In the **IP** layer …
★ Cited by 515 Related articles All 14 versions

Integrated dynamic IP and wavelength routing in IP over WDM networks
M Kodialam, TV Lakshman - INFOCOM 2001. Twentieth Annual …, 2001 - ieeexplore.ieee.org
… 1 1 1 1 1 1 0.8 Fig. 7. Graph (with residual capacities) after routing 4 —3 to the egress **over** the **network** where the capacity of a link is the current residual capacity. The maximum flow is computed on the **network** with both the logical **IP** links and the **optical** links …
☆ Cited by 268 Related articles All 8 versions

Traffic grooming in an optical WDM mesh network
K Zhu, B Mukherjee - IEEE Journal on selected areas in …, 2002 - ieeexplore.ieee.org
… A low-speed traffic stream on one wavelength can be either dropped to the local client (**IP** router, ATM switch, etc.) or switched to another … 2) Route the lightpaths **over** the physical topology … ZHU AND MUKHERJEE: TRAFFIC GROOMING IN AN **OPTICAL** WDM MESH **NETWORK** …
★ Cited by 848 Related articles All 13 versions

IP over optical networks: A framework
B Rajagopalan, J Luciani, D Awduche - 2004 - rfc-editor.org
… 4.4.1. **Optical** Virtual Private **Networks** (OVPNs) Given that the data plane links between **IP** routers **over** an **optical network** amounts to a virtual topology which is an overlay **over** the fiber **optic network**, it is easy to envision a virtual private **network** of lightpaths that …
☆ Cited by 250 Related articles All 116 versions »

Saving energy in IP-over-WDM networks by switching off line cards in low-demand scenarios
F Idzikowski, S Orlowski, C Raack… - **Optical Network** …, 2010 - ieeexplore.ieee.org
… and calculate a minimum-cost **IP-over**-WDM **network** which satisfies this maximum demand matrix … It comprises all relevant sources of installation cost both in the **IP** and the WDM layer … Parameters Assuming all **network** elements to be bidirec- tional, we model the **optical** layer by …
☆ Cited by 150 Related articles All 19 versions

optical multi layer survivable

About 20,500 results (**0.11** sec)

Did you mean: optical ***multilayer*** survivable

Intelligent optical networking for multilayer survivability
S De Maesschalck, D Colle… - IEEE …, 2002 - ieeexplore.ieee.org
… ie, using switched connection flexibili- ty, typical for intelligent **optical** networks) **multi- layer** recovery schemes … in advance, but capacity is provisioned as needed and always **optically** protected … **Optical** link or node failures are recovered in the **optical layer** using an appropriate …
☆ Cited by 137 Related articles All 9 versions

Resilience in multilayer networks
P Demeester, M Gryseels, A Autenrieth… - IEEE …, 1999 - ieeexplore.ieee.org
… **Survivability** issues encountered in a **multi- layer** environment include, among others: how to … result in adding new **survivable layers** to the existing ones (eg, **optical layer survivability**) … As explained before, **multilayer** survivabil- ity implies providing multiple spare capacity pools …
☆ Cited by 311 Related articles All 14 versions

Differentiated multi-layer survivability in IP/WDM networks
H Zhang, A Durresi - … , 2002. NOMS 2002. 2002 IEEE/IFIP, 2002 - ieeexplore.ieee.org
… It is shown in [20] that the cost reduction in 10 Gb/s **optics** would make the **optical** mesh … Consequently we only consider **optical** mesh network in this paper … Before exploring the differentiated and **multi-layer survivability** issues in IP/WDM network, we first summarize the …
☆ Cited by 57 Related articles All 11 versions

Survivability in optical networks
D Zhou, S Subramaniam - IEEE network, 2000 - ieeexplore.ieee.org
… Due to the large traffic carried in fiber **optic** systems, recovery time is a very … **Multilayer** Protection in WDM Networks WDM systems are being widely deployed in the backbone net- work … and all-**optical** components introduces a new network **layer**, called the **optical layer** or WDM …
☆ Cited by 481 Related articles All 13 versions

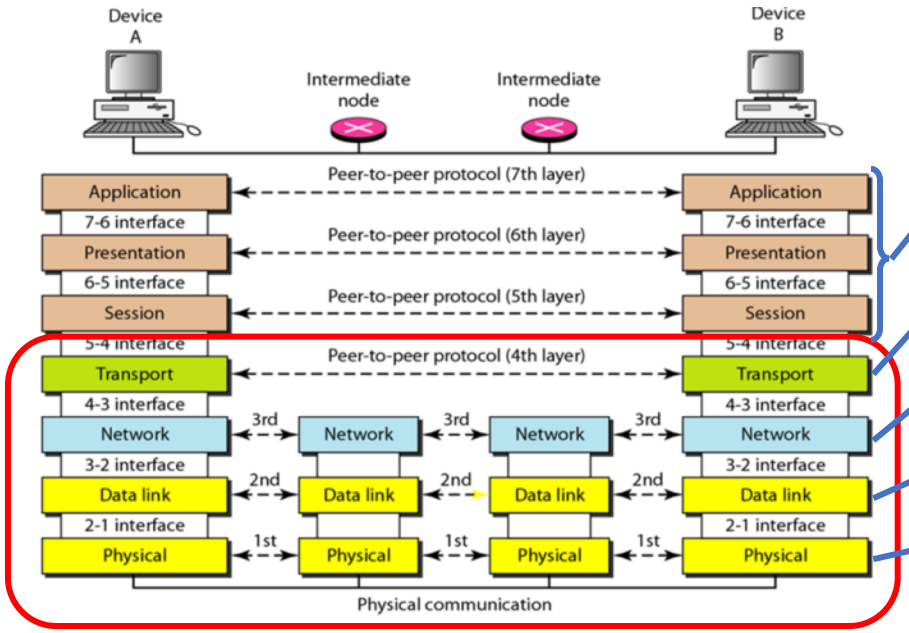
Data-centric optical networks and their survivability
D Colle, S De Maesschalck, C Develder… - IEEE Journal on …, 2002 - ieeexplore.ieee.org
… Two solutions are described here. Page 8. COLLE et al.: DATA-CENTRIC **OPTICAL** NETWORKS 13 Fig. 13. The bottom-up approach … Note that the previous sections, on generic **multilayer survivability** strategies, remain true for IP-MPLS/OTN-MP S **multi-layer** networks: this …
☆ Cited by 171 Related articles All 15 versions

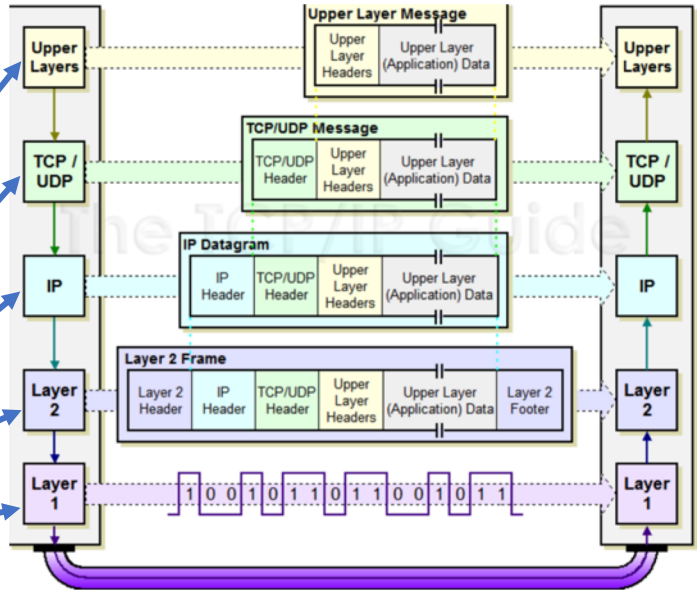
Tsinghua University

UC DAVIS UNIVERSITY OF CALIFORNIA

3

Internet on OSI 7 layer model





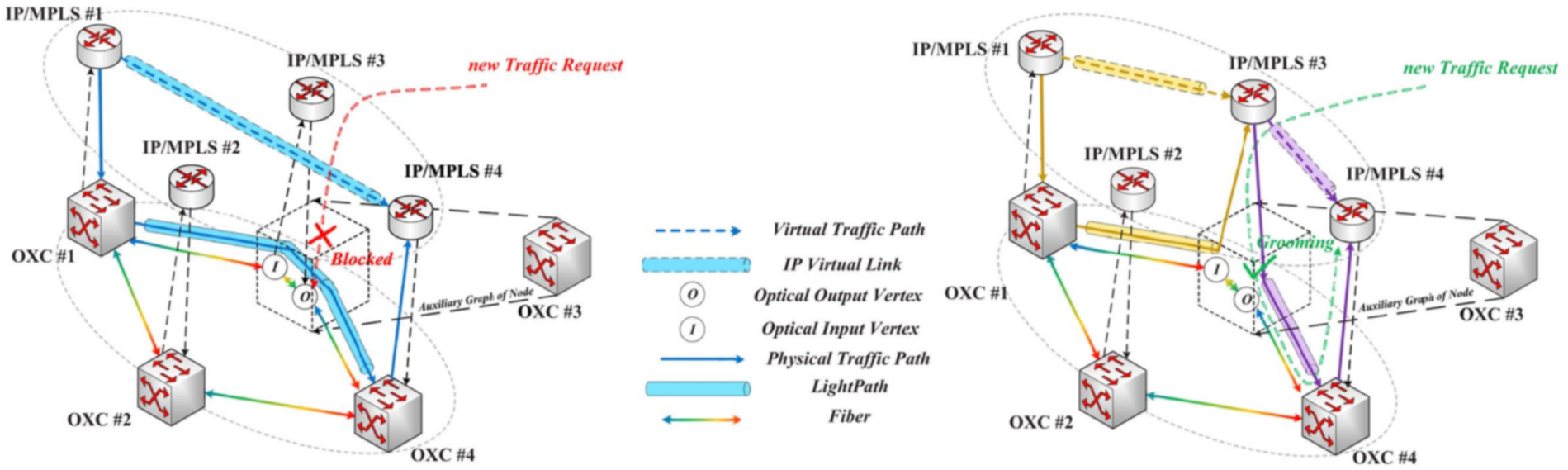
OSI 7 layer model in networks

Where I have been working on

7 layer model protocol stack

- **Network: transmission and switching**
- For **information transmission** (L0/L1), user data (L7) from clients needs to go through 7 layer protocol stack to be encapsulated.
- For **information switching** (L3), information go through 3 layer protocol stack to perform routing based on packet IP address.

Research paradigms in cross-layer networking



- Basic problem: resource mapping, optical bypass

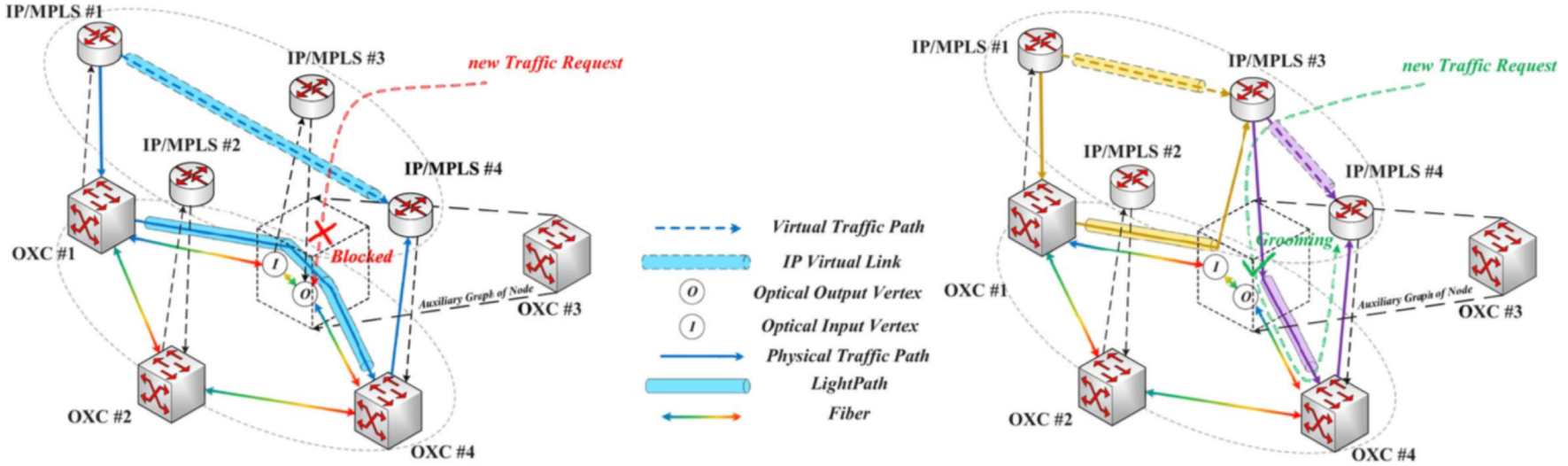
Research paradigms in cross-layer networking

- Solid paradigms, well received.
- Static one-shot optimization.
  - Can be solved by operation-research methods (ILP), fine!
  - If ILP is too complex, we have heuristics.
  - Already adopted in industry.
- Dynamic event-driven simulation
  - Dynamically setup or tear down lightpaths
  - Question: how to define “dynamic”?
  - Monthly? Daily? Hourly? Minute?

Dynamic cross-layer networking: demand responsive?

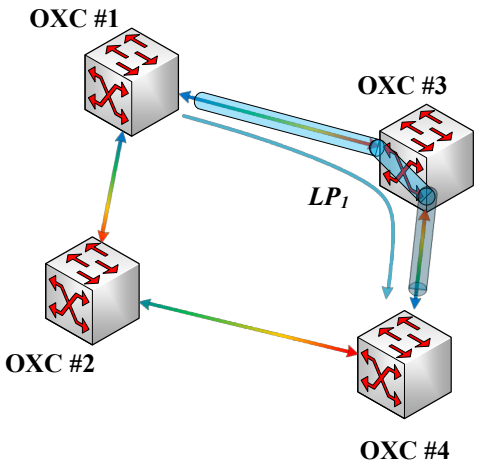
- Basic assumption for dynamic traffic grooming: "when a new traffic arrives, we should decide whether to groom it onto existing lightpaths, or setup a new lightpath."

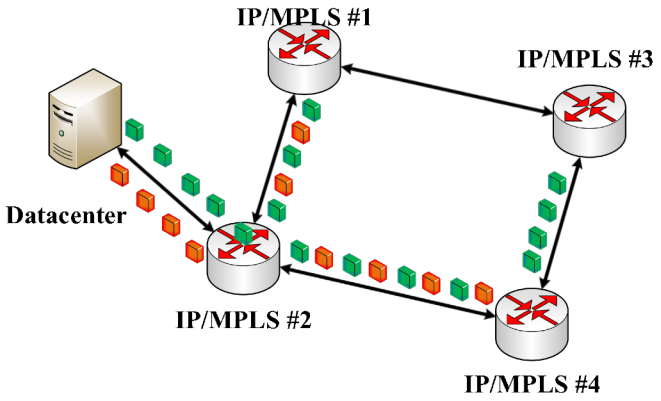
Setting a new lightpath requires some time, does the arriving traffic has to wait?
The problem is more severe if we want to achieve agile cross-layer networking.



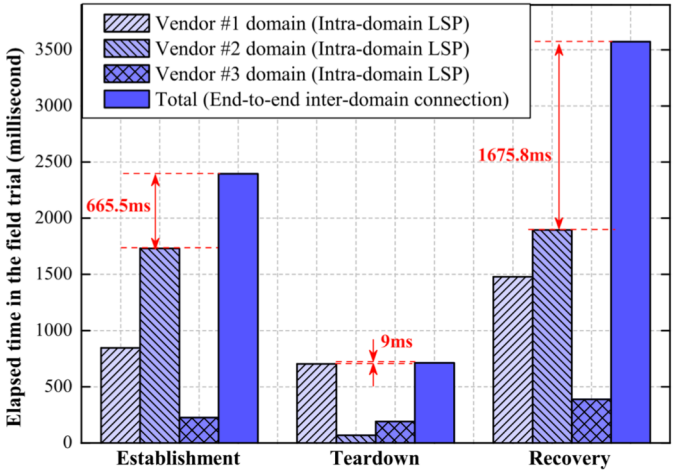
Dynamic cross-layer networking

- When a traffic arrives：
  - IP layer packet: immediate serve
  - Optical layer circuit: 100 ms setup a lightpaths
  - For a 10Gb/s traffic flow, waiting 100 ms means 1Gbit!
  - We cannot wait for lightapth to setup.





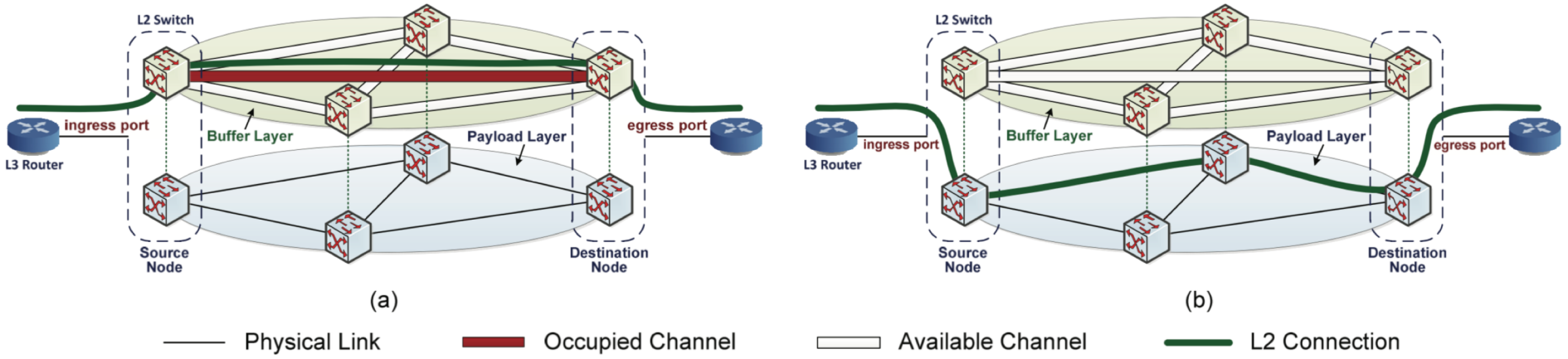
Real equipment data



- Three vendor equipments from: Huawei, ZTE, fiberhome
- lightpath setup/teardown/recover time measurement

[1] Liu, Wangyang, Nan Hua, Xiaoping Zheng, and Bingkun Zhou. "Intelligent inter-domain connection provisioning for multi-domain multi-vendor optical networks." *Journal of Optical Communications and Networking* 7, no. 3 (2015): 176-192.

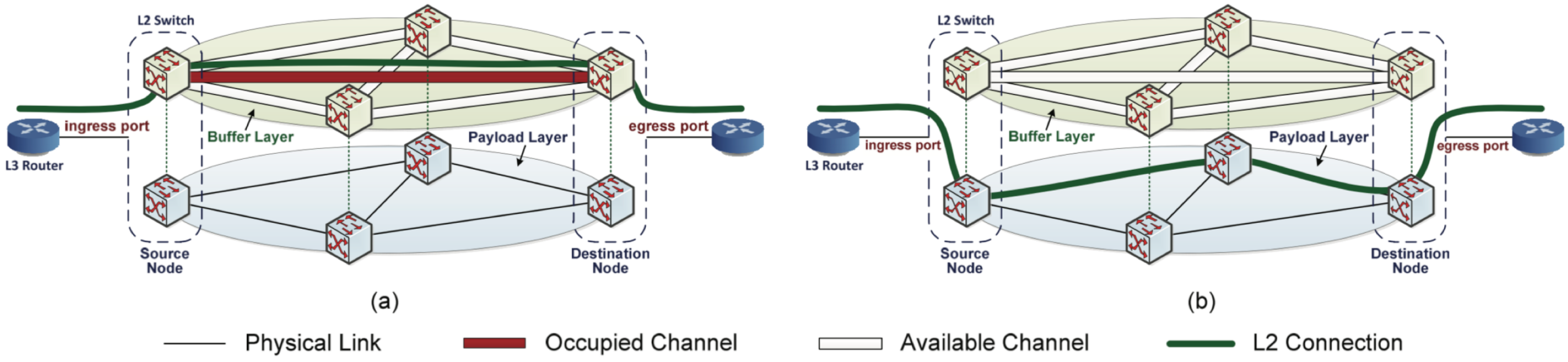
Optical resource buffer



- Basic idea: We have some pre-established lightpaths. When a new request comes, it will be immediately served by these lightpaths, at the same time, we setup new dedicated lightpath. When new lightpath is done, we switch the traffic to the new lightpath.

[2] Chen, Xiaohui, Nan Hua, and Xiaoping Zheng. "A Unified Control Architecture for Software Defined Packet over Optical Networks Using Resource Buffering." In Photonic Networks and Devices, pp. NeT2F-4. 2015.
[3] Zheng, Xiaoping, Nan Hua, and Zhizhen Zhong. “Achieving heterogeneous packet-optical networks inter-connection with a software-defined unified control architecture.” In International Conference on Optical Communications and Networks (ICOCN), 2015.

Problems to answer



- How do we design the resource buffer layer under dynamic traffic?
- Do we need to setup resource buffer lightpath for all node pairs?
  - Topology, capacity for resource buffer layer
- Tradeoff: how much we buffer, better access delay, worse throughput.

Thank you for attention!

Zhizhen Zhong

Tsinghua University & UC Davis

zhongzz14@mails.tsinghua.edu.cn , zzzhong@ucdavis.edu

27 Apr. 2018

Networks Lab Group Meeting

Tsinghua University

UC DAVIS
UNIVERSITY OF CALIFORNIA