# What Applications Can be Deployed with Software Defined Elastic Optical Networks?


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UCDAVIS

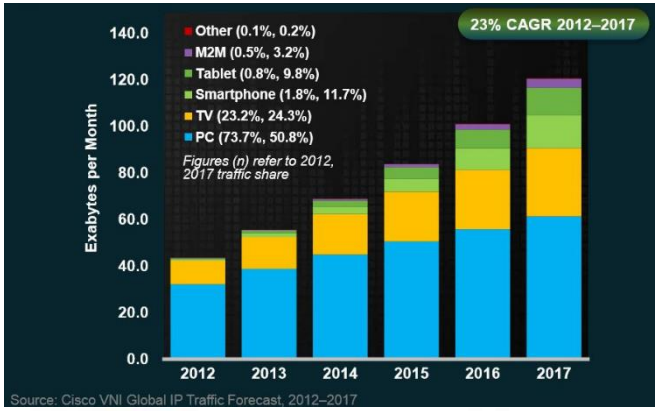
**Group Meeting, Feb. 12 2016**

# Outline

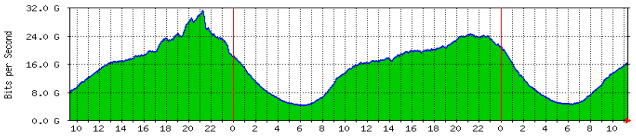
1. Background
2. Software defined elastic optical networks
3. Applications deployment with SD-EON
4. Conclusions

# Background of EON

- *New application / Large traffic*
  - High-rate applications, such as VoD, HD-TV, cloud computing, grid applications
  - Bandwidth-consuming and highly dynamic
- *Dynamic reconfigurations*
  - Fixed grids is short of the adaptability for the connection bandwidth variation
- *High speed transmission*
  - 100G and beyond/Super-channel
  - Multi-carrier modulation / OFDM
- *Cost-effective, scalable networking*








- *Flexible-grid network (EON) is regarded as a promising candidate for future transport infrastructure.*

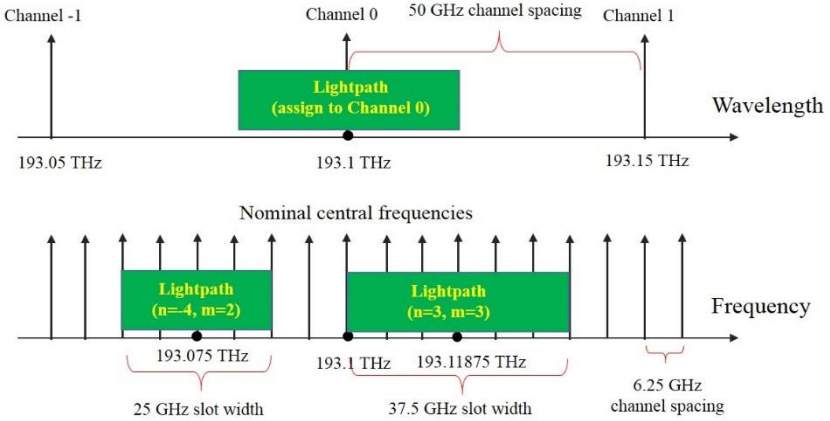
# WDM VS EON

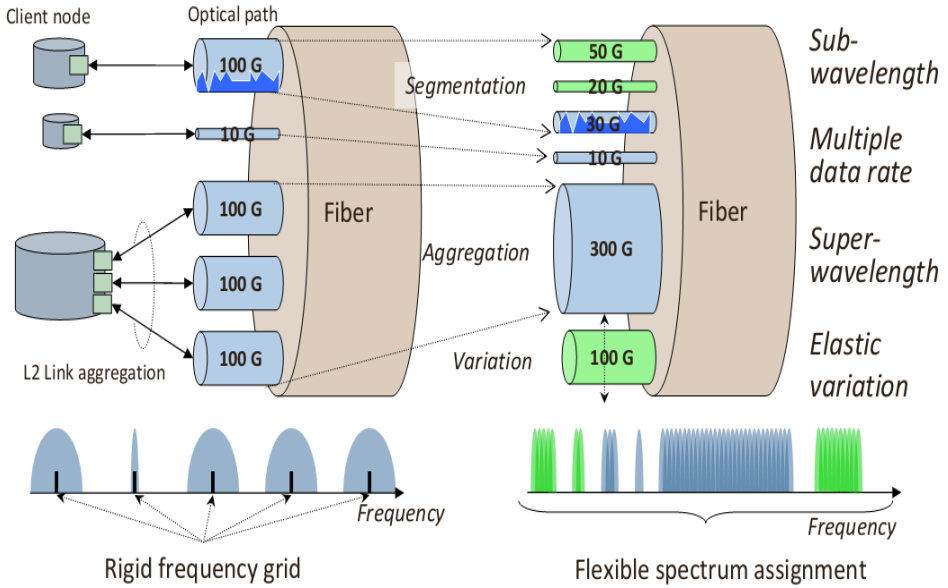
## ➢ Drawbacks of WDM

a) fixed rigid and coarse granularity

b) require full allocation of a wavelength

c) inefficient spectrum utilization



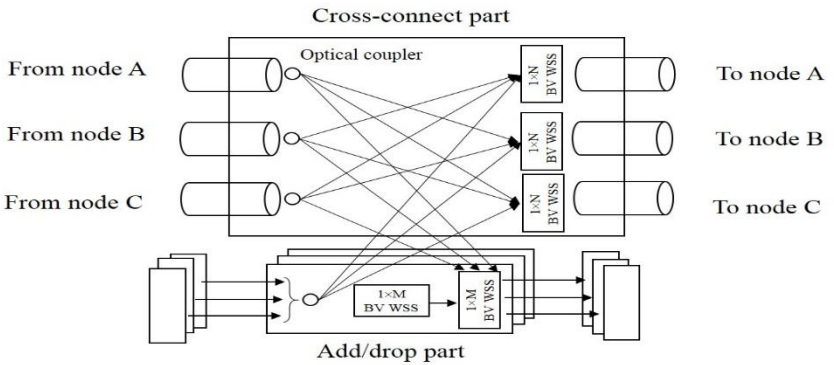

**Source:** *ECOC 2009 Symposium on "Dynamic Multi-Layer Mesh Network ... Why, How, and When?" September 23, 2009*

## ➢ EON

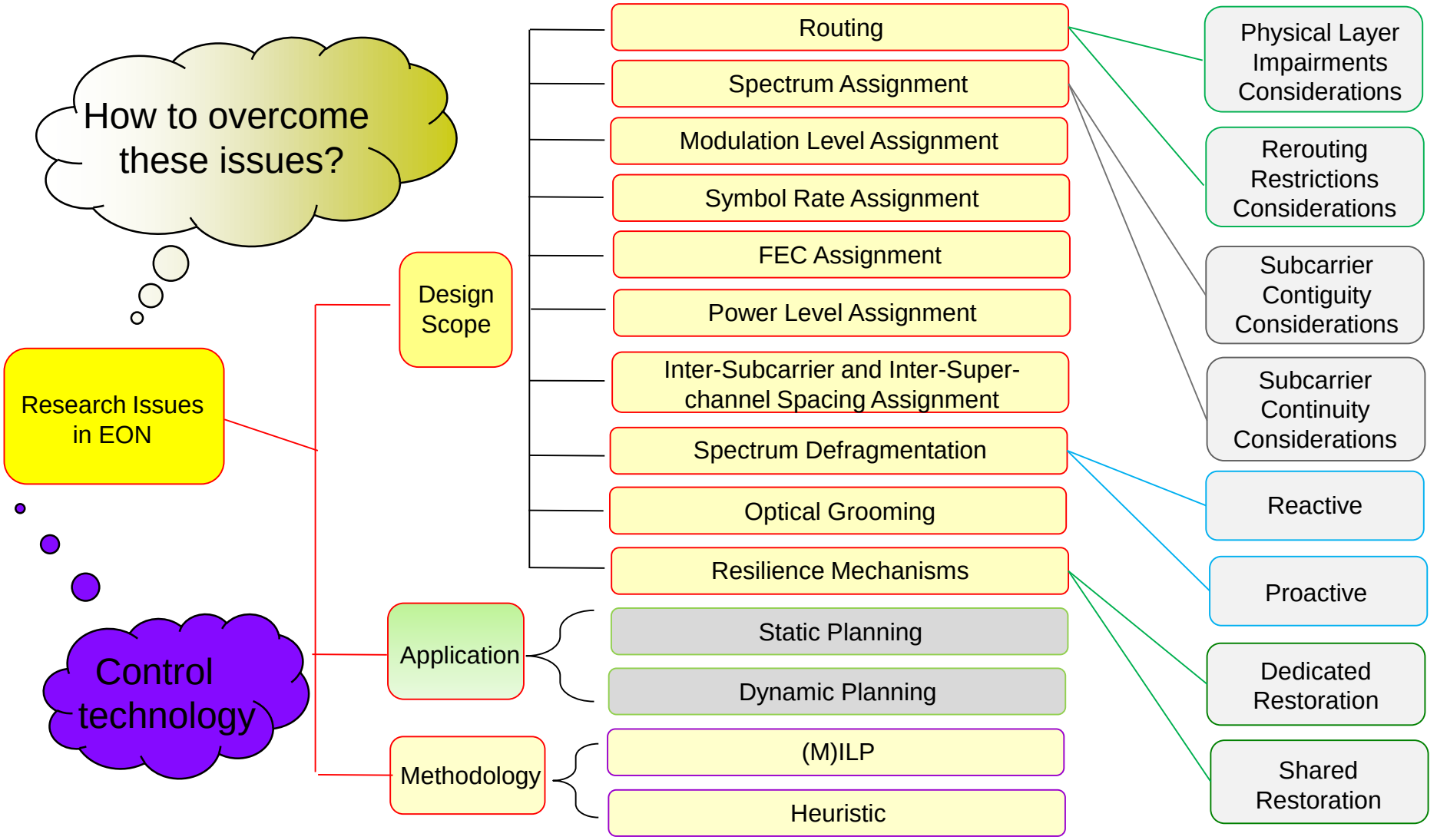
a) a flexible and fine granularity

b) adaptively provide the requirement

c) deliver high efficiency, flexibility and scalability



# Challenges and problems

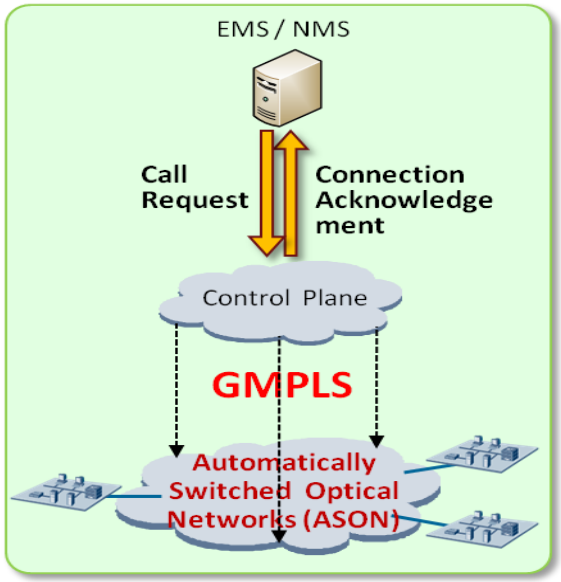



Tomkos I, et al. A tutorial on the flexible optical networking paradigm……. Proceedings of the IEEE, 2014, 102(9): 1317-1337.

# Intelligent control technology

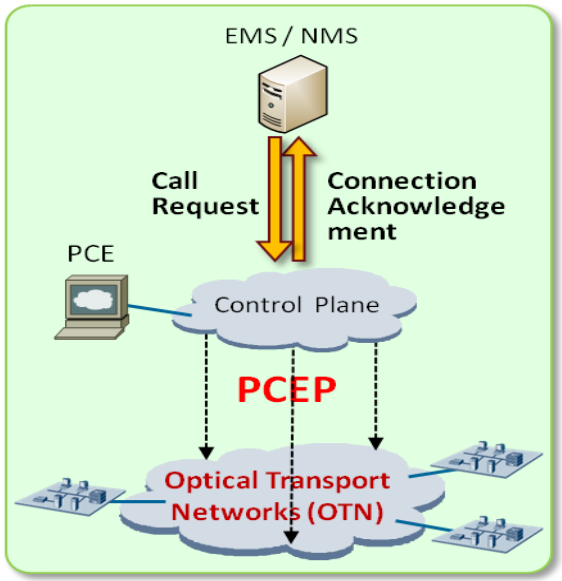
2001 → 2006 → 2011

## Automatically Switched Optical Networks (ASON)



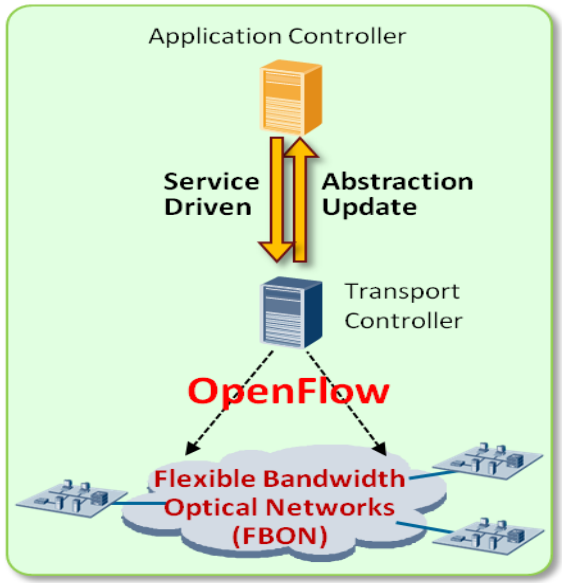

- Lightpath establishment & tear-down on demand
- Distributed signaling & routing
- Protocol: GMPLS

## Path Computing Element (PCE)




- Constraint-based path computation in multi-layer/-domain
- Centralized routing & resource assignment
- Protocol: PCEP

## Software Defined Optical networks (SDON)

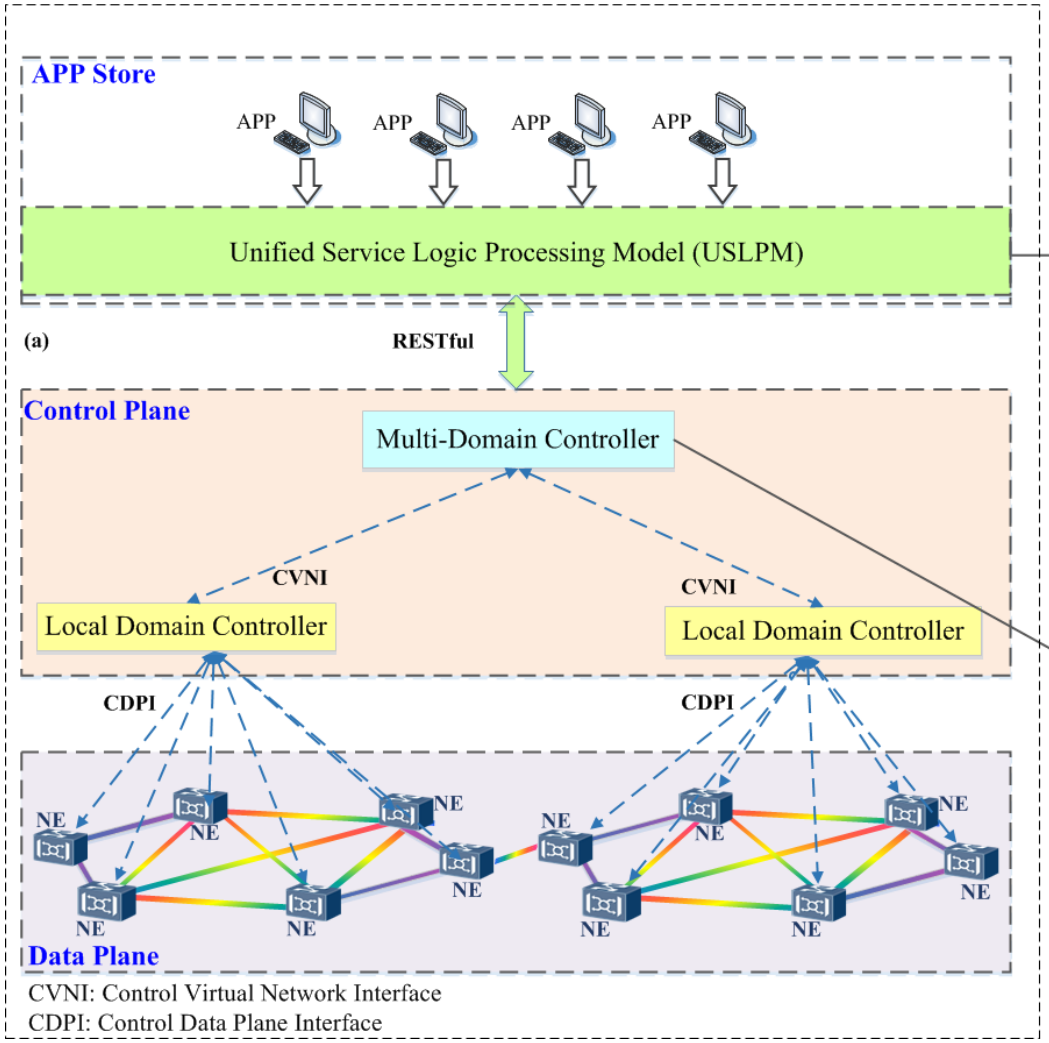


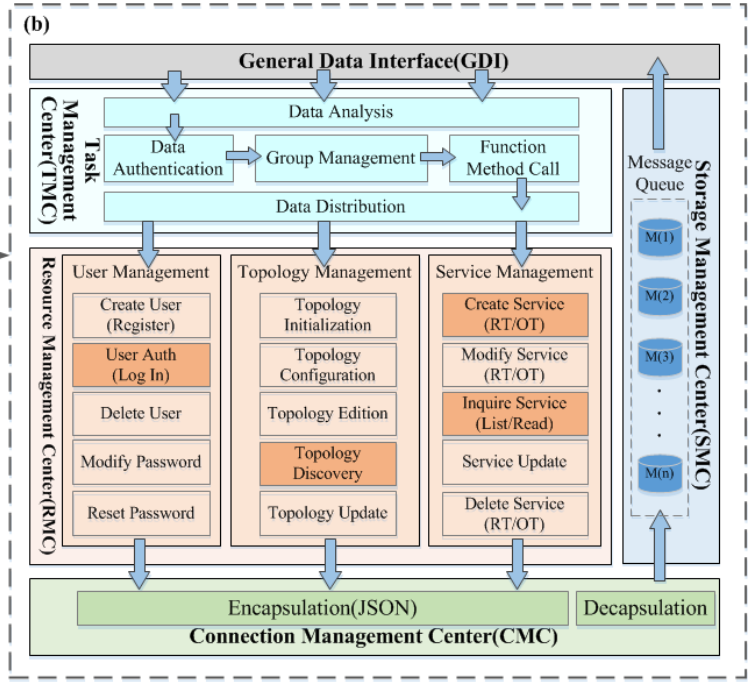

- Optical virtualization
- Unified control & Resource integration
- Protocol: OpenFlow

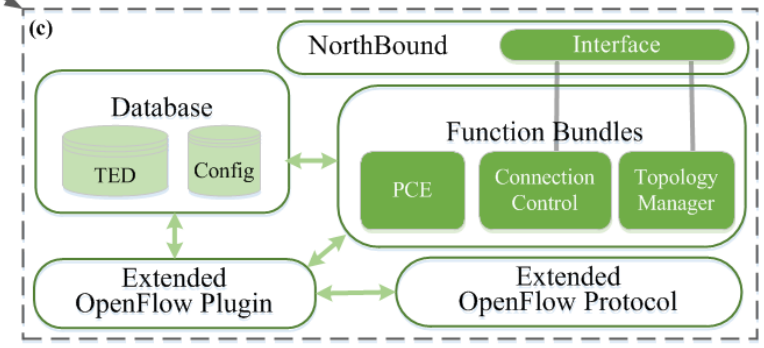
# Outline

1. Background
2. Software defined elastic optical networks
   - ✓ Control architecture
   - ✓ Testbed
3. Applications deployment with SD-EON
4. Conclusions

# Multi-controller cooperation architecture

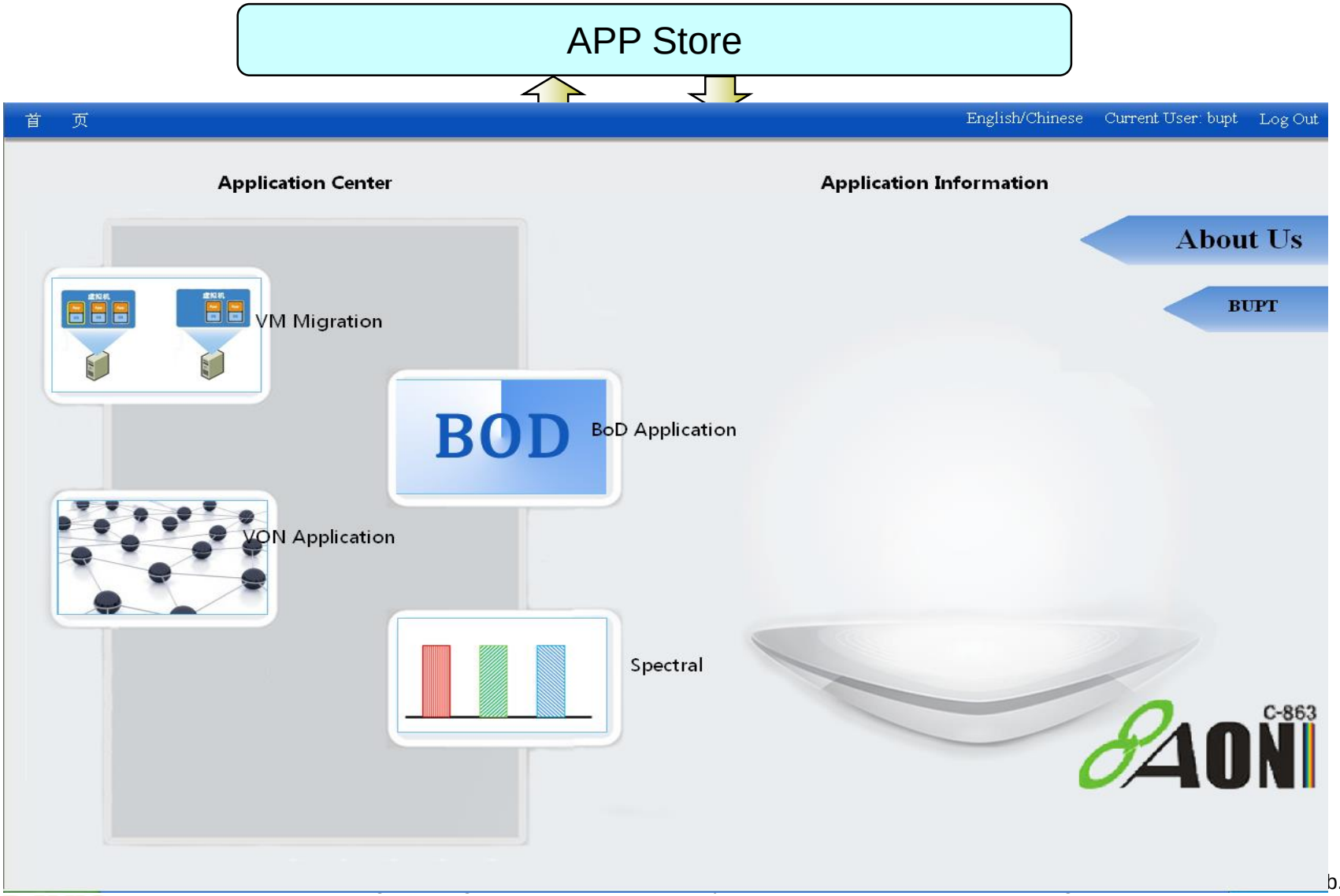



Yongli Zhao, Jie Zhang, et al. Virtual Optical Network Provisioning with Unified Service Logic Processing Model for Software Defined Multi-Domain Optical Network, Optical Engineering, 54(12), Dec. 2015.

# SDON testbed




b.2015

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# Potential applications with SD-EON

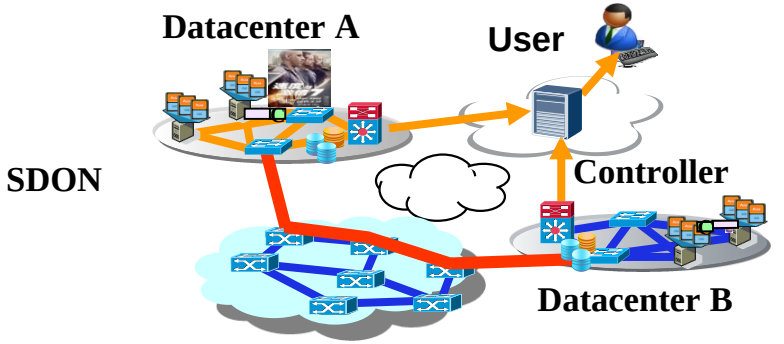
**APP innovation with SDON**

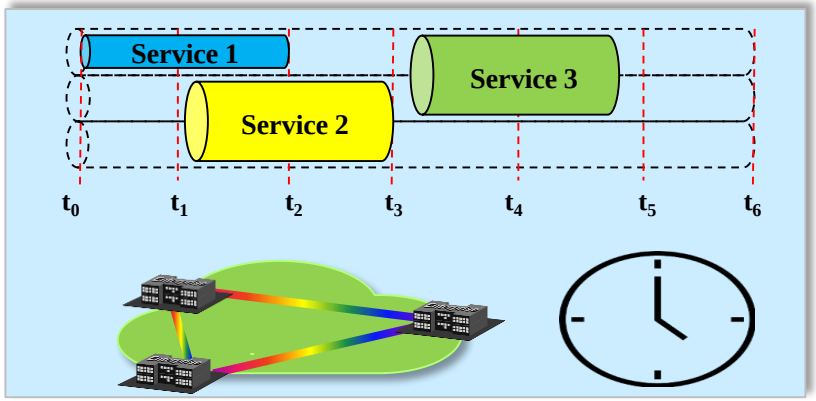
APP 4 — VM migration

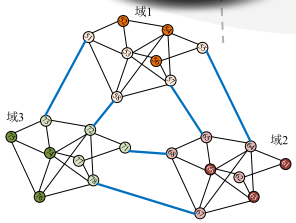
APP 3 — Service scheduling expert

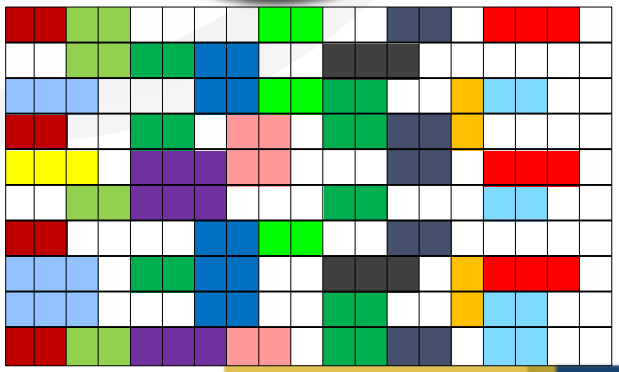
APP 2 — Virtual network provisioning

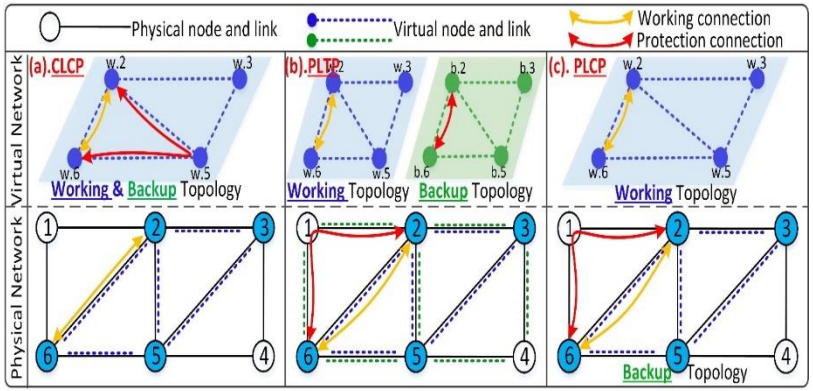
APP 1 — Spectrum defragmentation



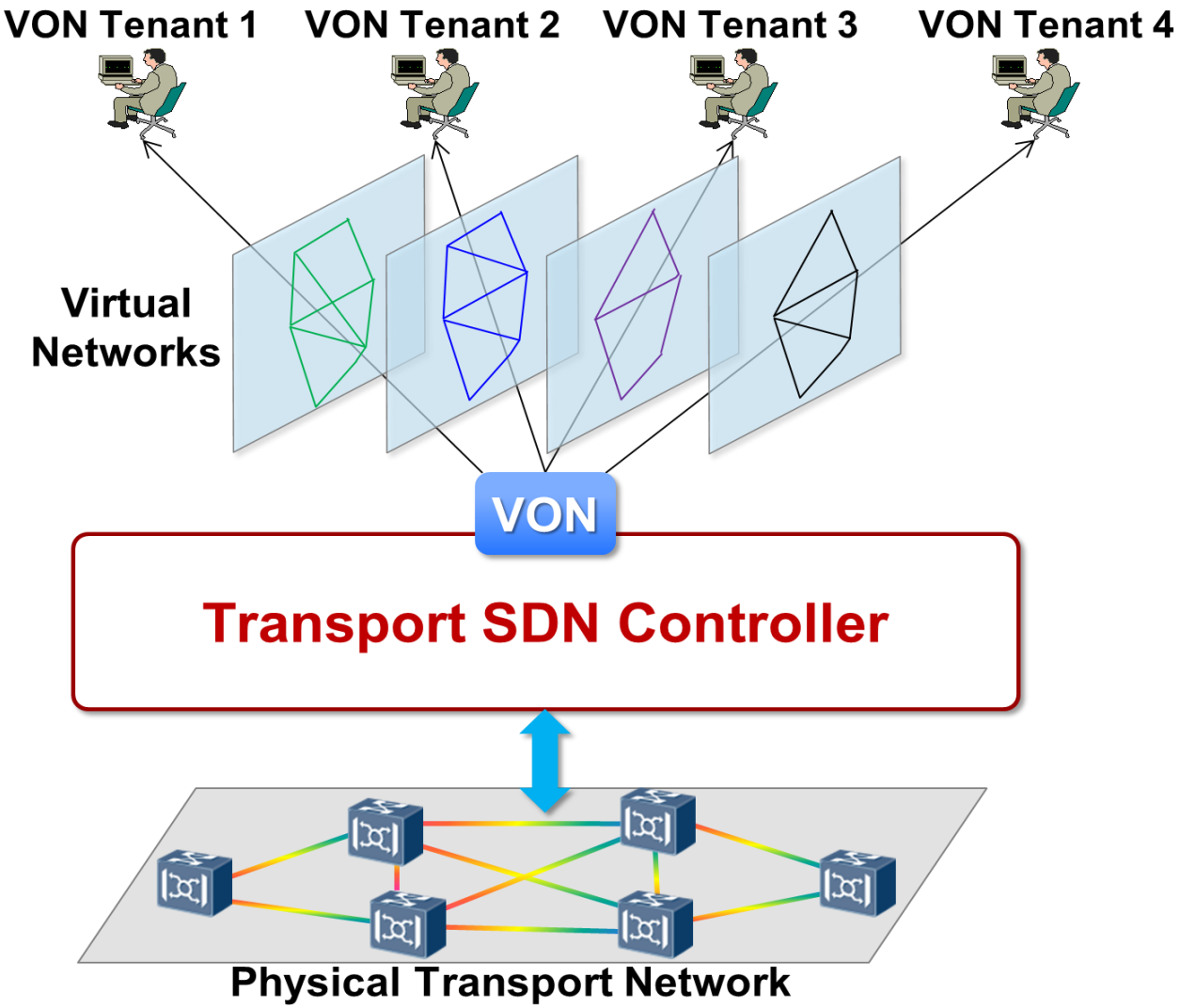







# A. Virtual network provisioning (VON)




Demonstrated on ONS2015.

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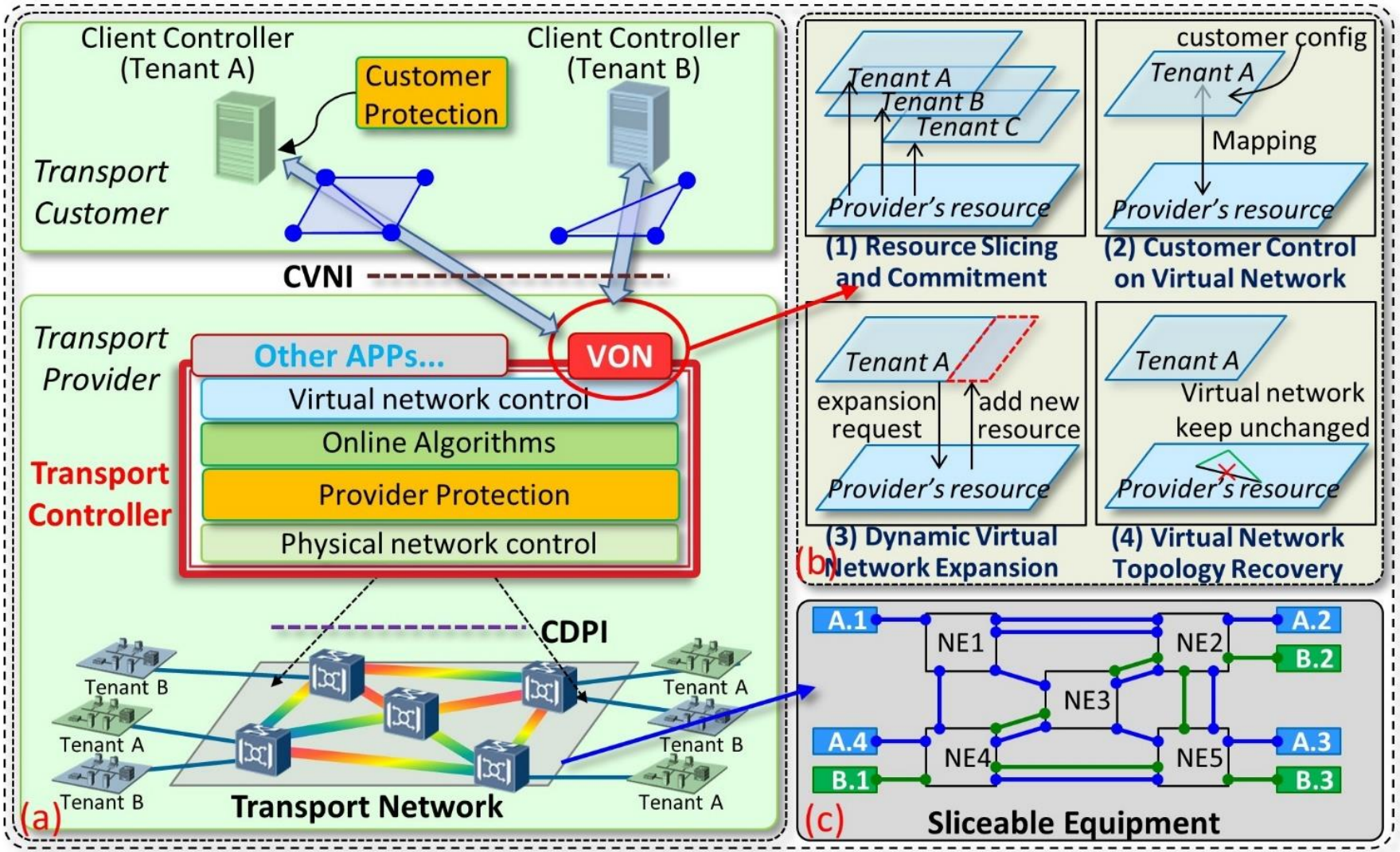
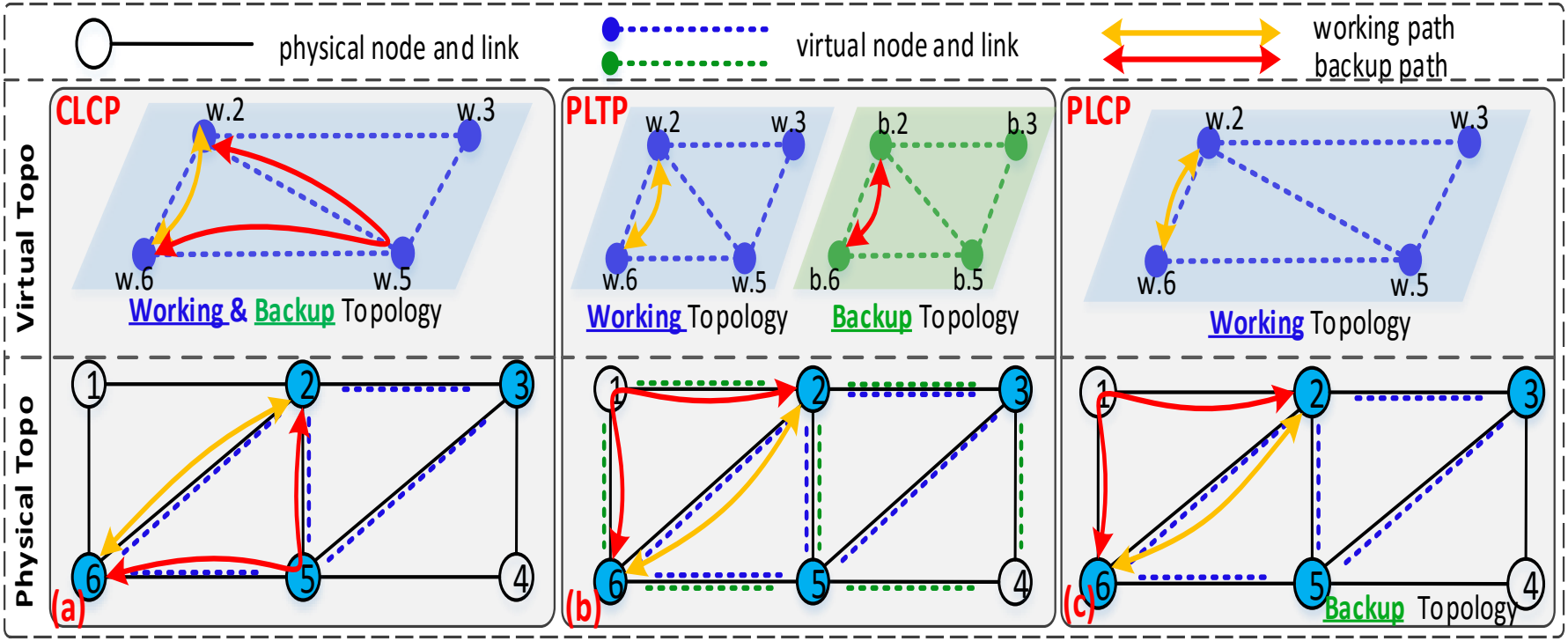



Wei Wang, Yongli Zhao, Jie Zhang, et al., First Demonstration of Virtual Transport Network Services with Multi-Layer Protection Schemes over Flexi-Grid Optical Networks, Communications Letter, vol.13, no.9, 2015.

# Differentiated protection schemes for VON

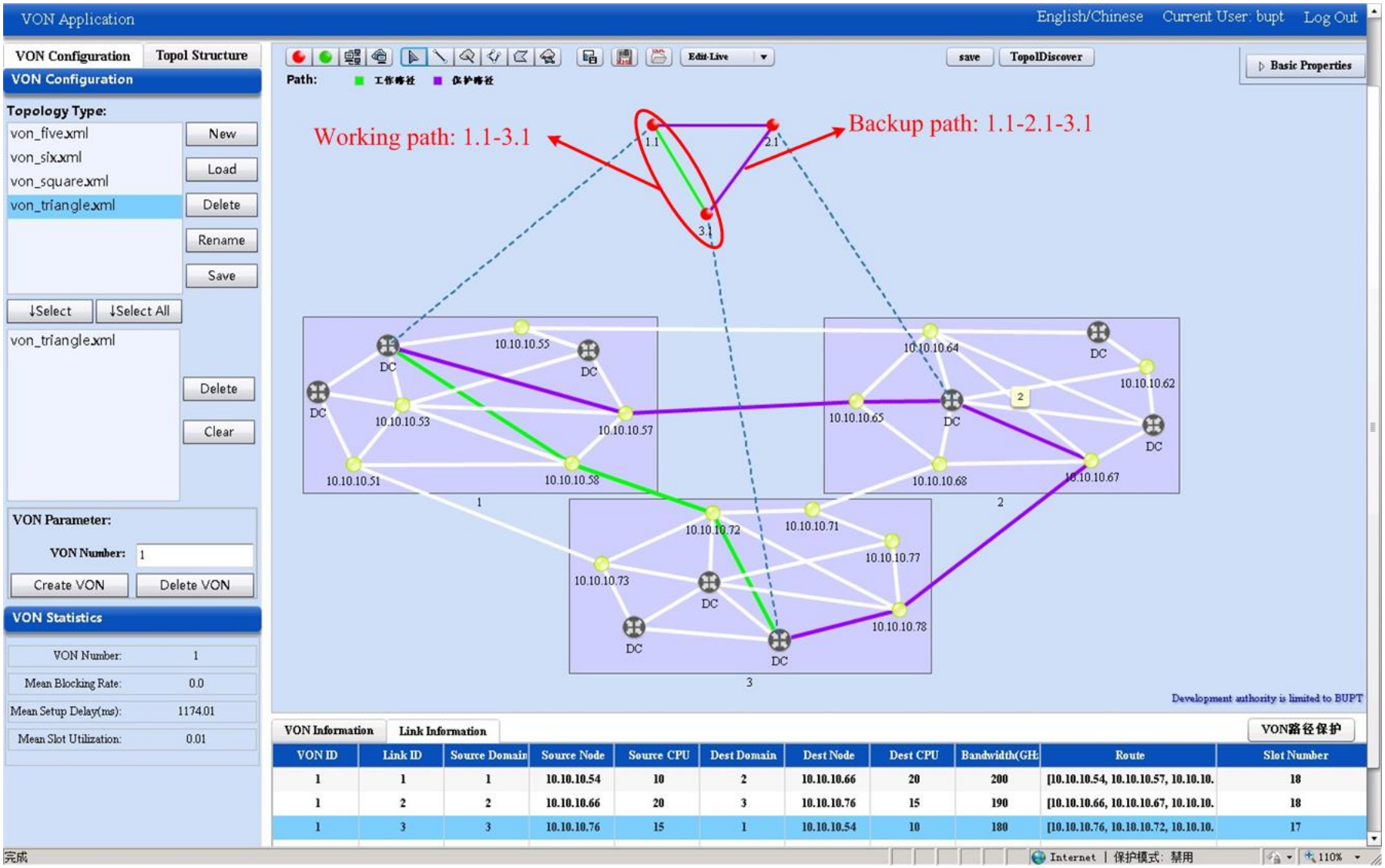
Three protection schemes for VON

1. CLCP: Customer Layer Connection Protection.
2. PLTP: Provider Layer Topology Protection.
3. PLCP: Provider Layer Connection Protection.




Wei Wang, Yongli Zhao, Jie Zhang, et al., First Demonstration of Virtual Transport Network Services with Multi-Layer Protection Schemes over Flexi-Grid Optical Networks, Communications Letter, vol.13, no.9, 2015.

# Experimental results



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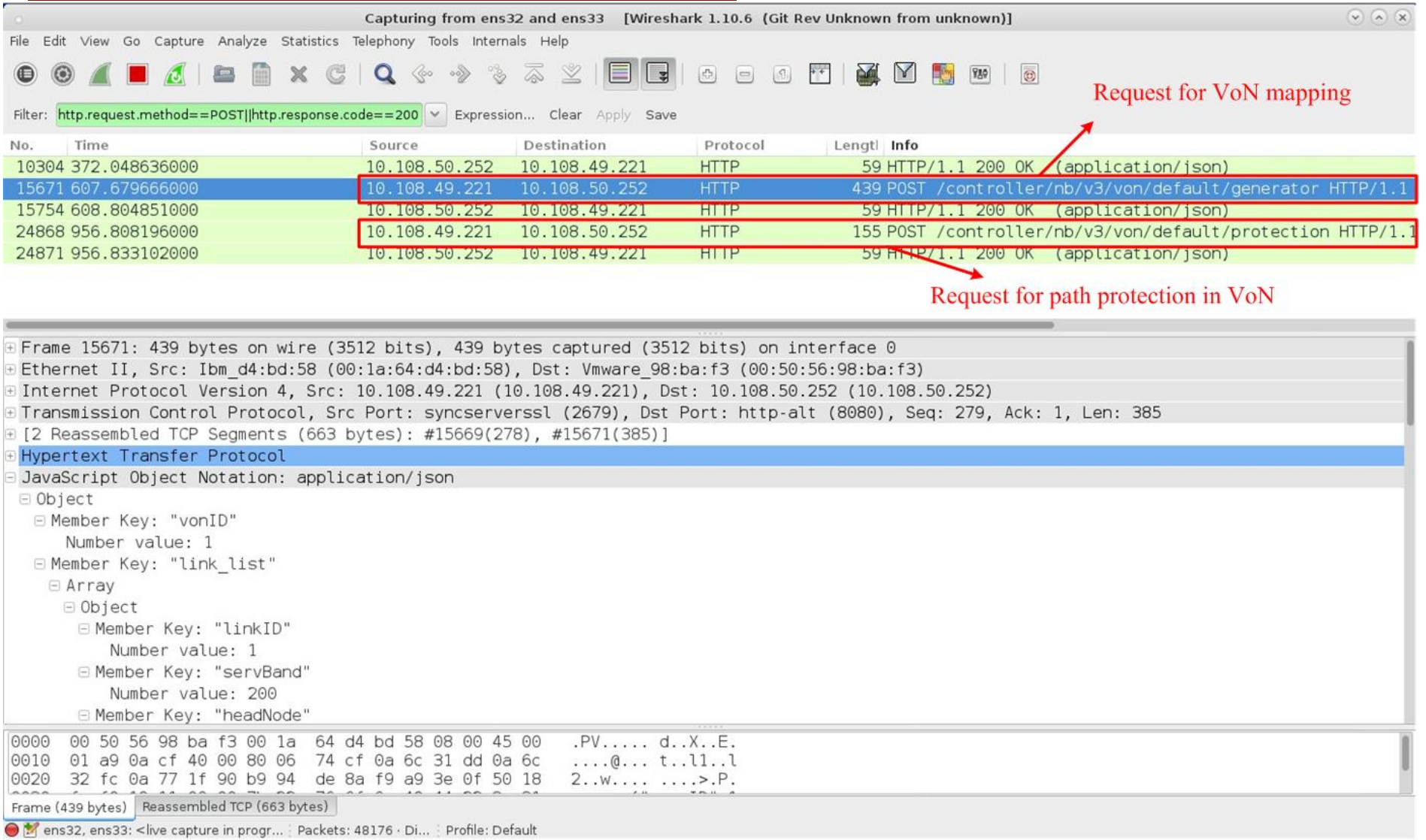

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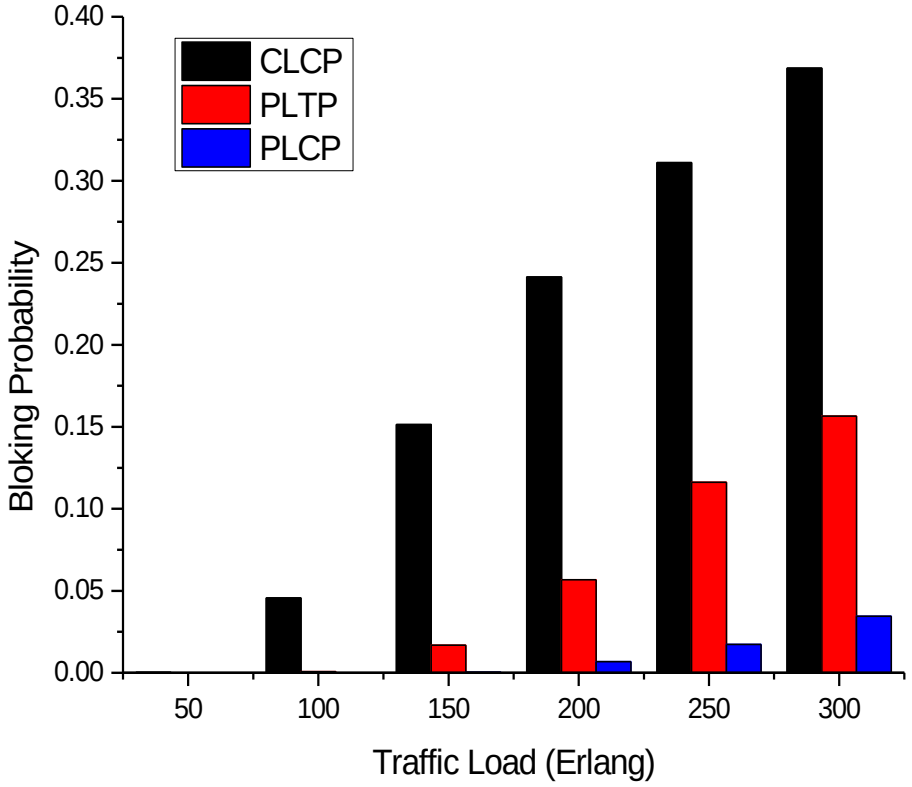
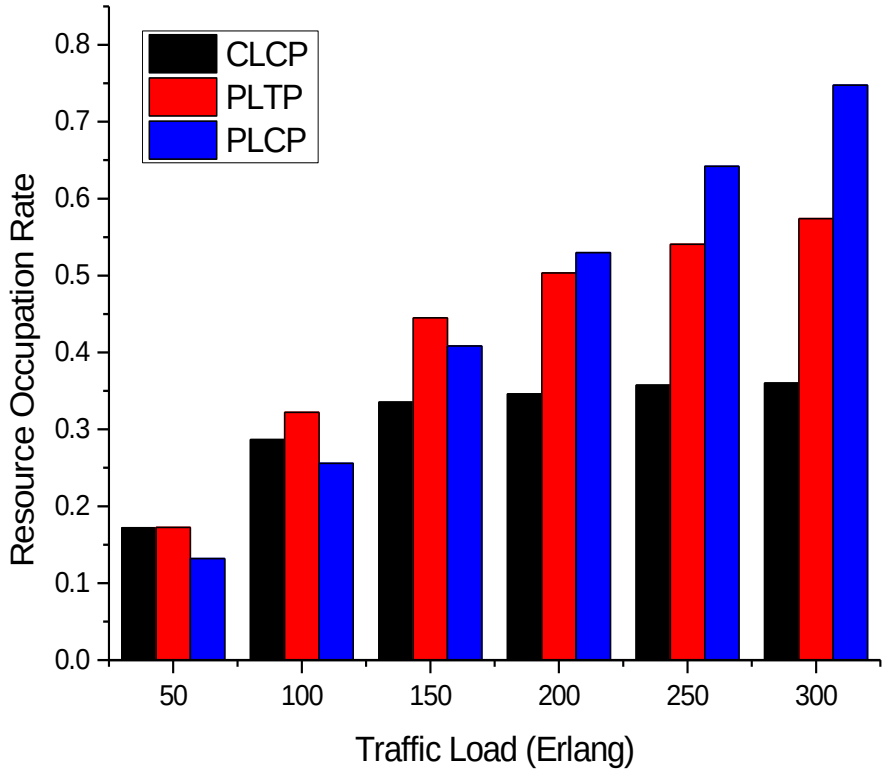
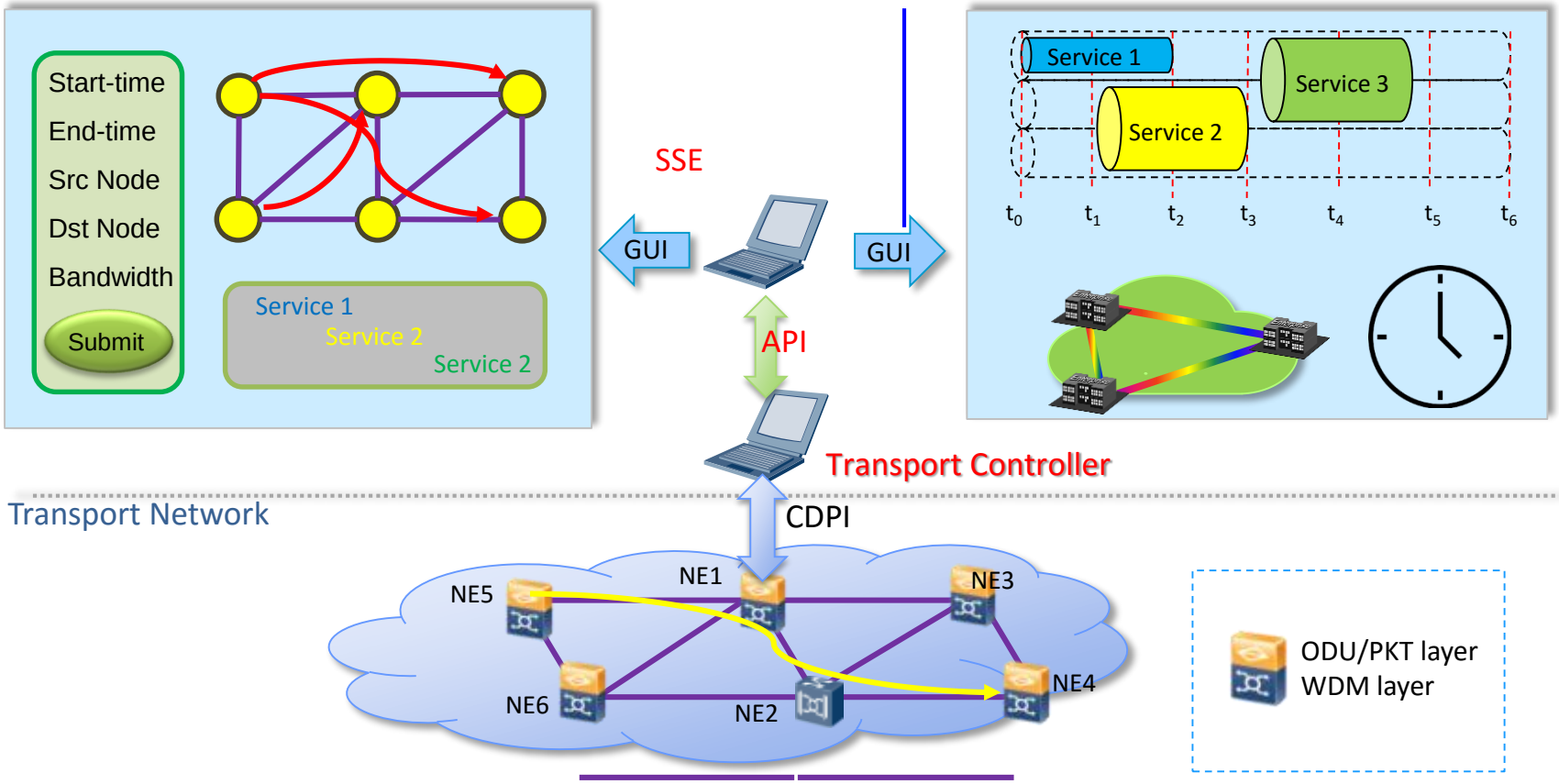



PLTP and PLCP performs better than CLCP, for the reason that the network tenant has only one work topology to deploy both work connection and backup connection under CLCP. PLCP can protect VON most efficiently.

Wei Wang, Yongli Zhao, Jie Zhang, et al., First Demonstration of Virtual Transport Network Services with Multi-Layer Protection Schemes over Flexi-Grid Optical Networks, Communications Letter, vol.13, no.9, 2015.

# B. Service scheduling expert (SSE)




Costumer submit deadline driven services to Transport Controller.

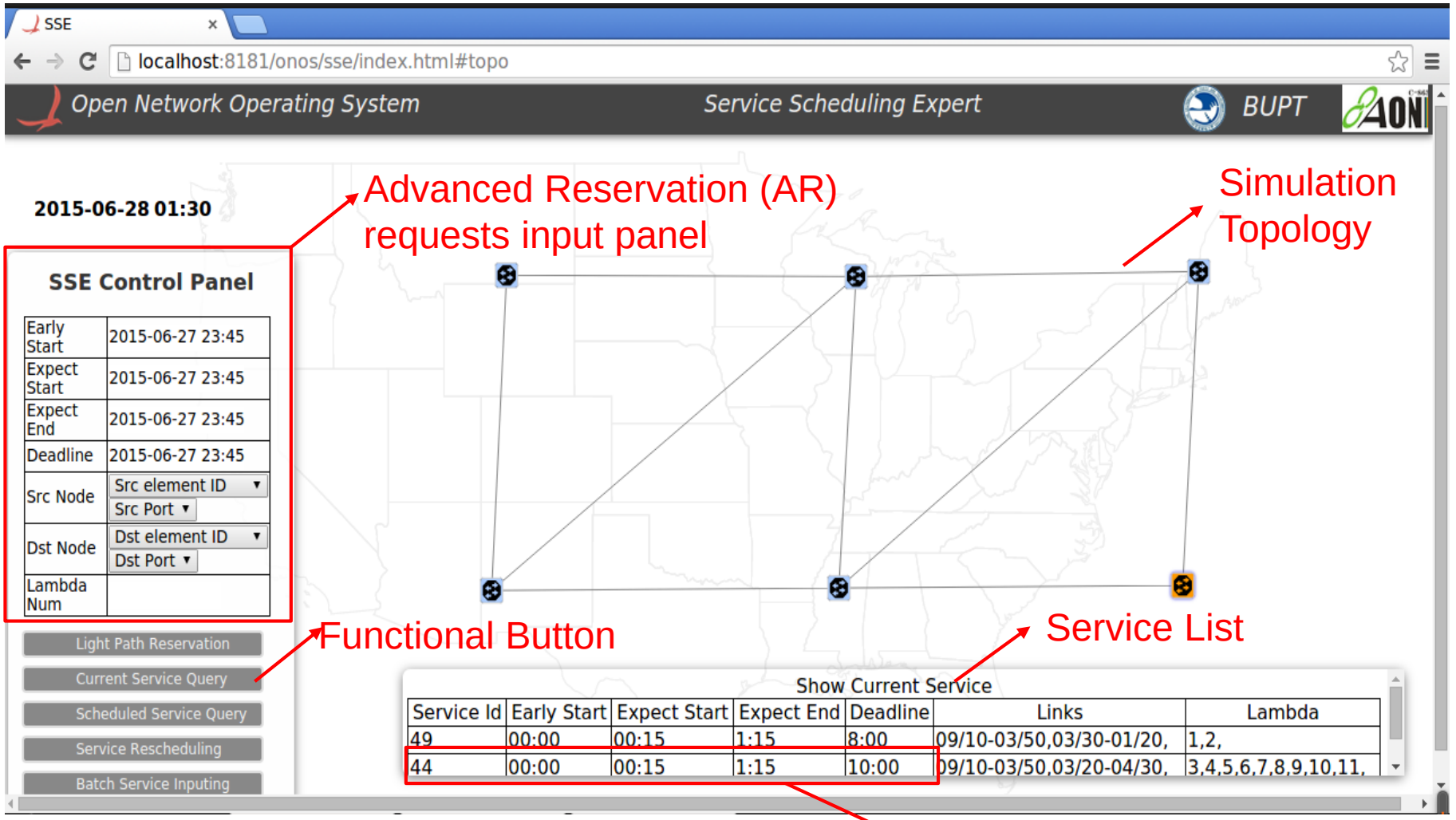
Transport Controller reserve required resource during working time.

SSE reschedule the services by modifying their working time.

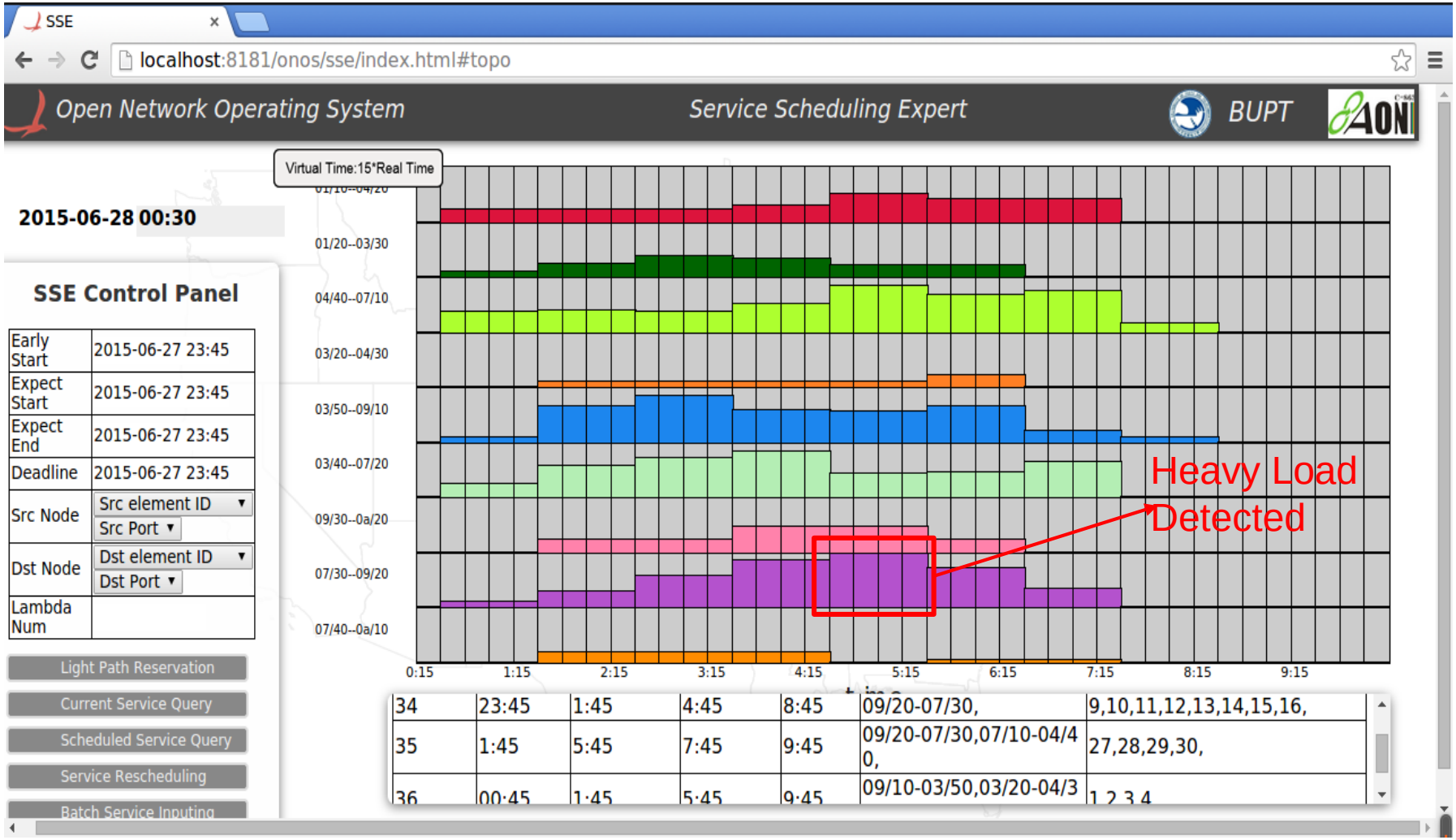
Start time arrive, and Transport Controller setup lightpath for corresponding service.

Demonstrated on ONS2015.

# Overall GUI of SSE



# Load Migrate via Rescheduling




Wei Wang, Yongli Zhao, Jie Zhang, et al., Demonstration of Parallel Service Re-Provisioning over Advanced Reservation enabled Software Defined Optical Transport Networks, OFC2016, Anaheim, CA, USA, March 2016.

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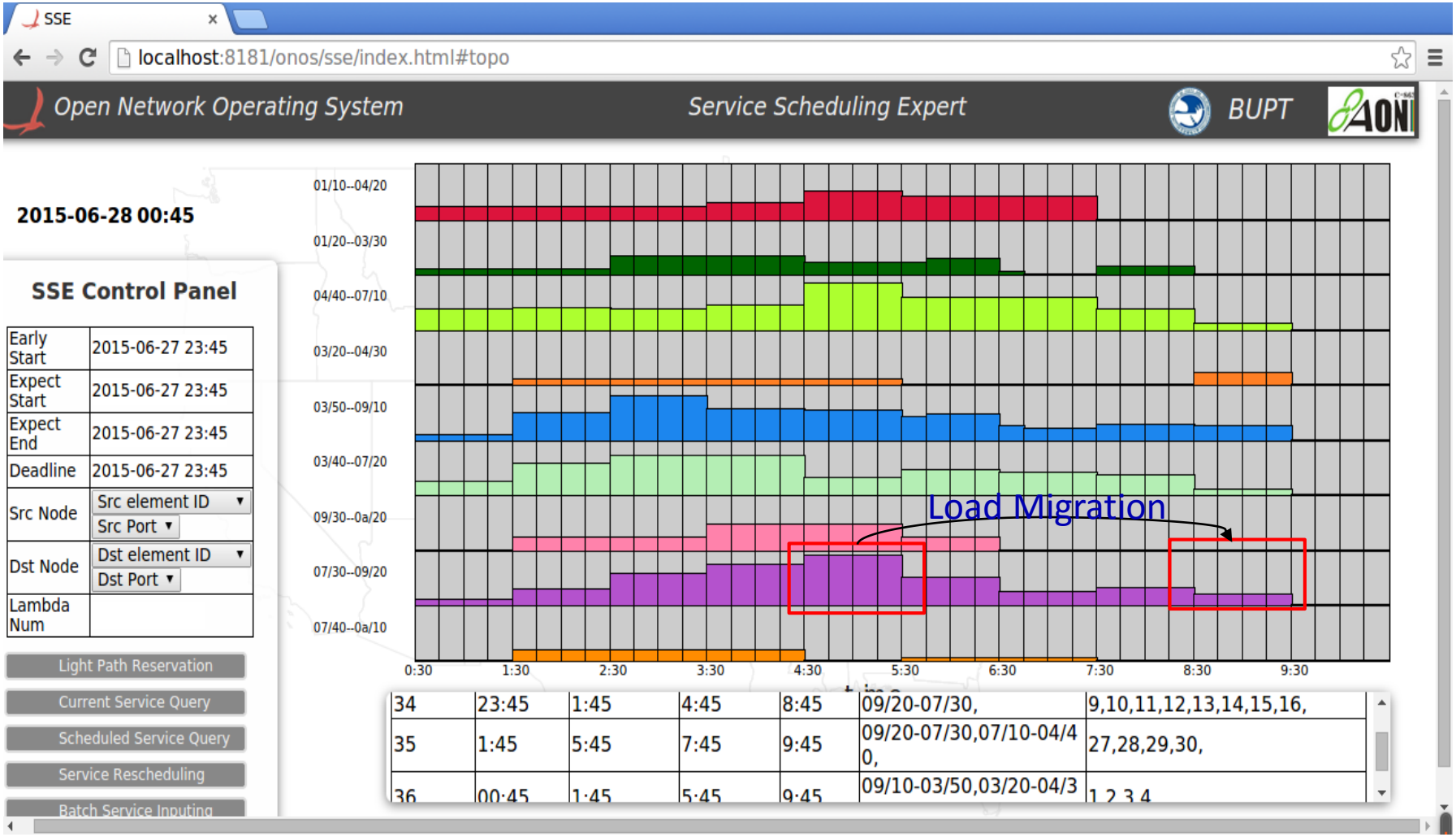



Wei Wang, Yongli Zhao, Jie Zhang, et al., Demonstration of Parallel Service Re-Provisioning over Advanced Reservation enabled Software Defined Optical Transport Networks, OFC2016, Anaheim, CA, USA, March 2016.

# APP demonstrated on ONS2015


ONS2015 at Silicon Valley

DanPitt

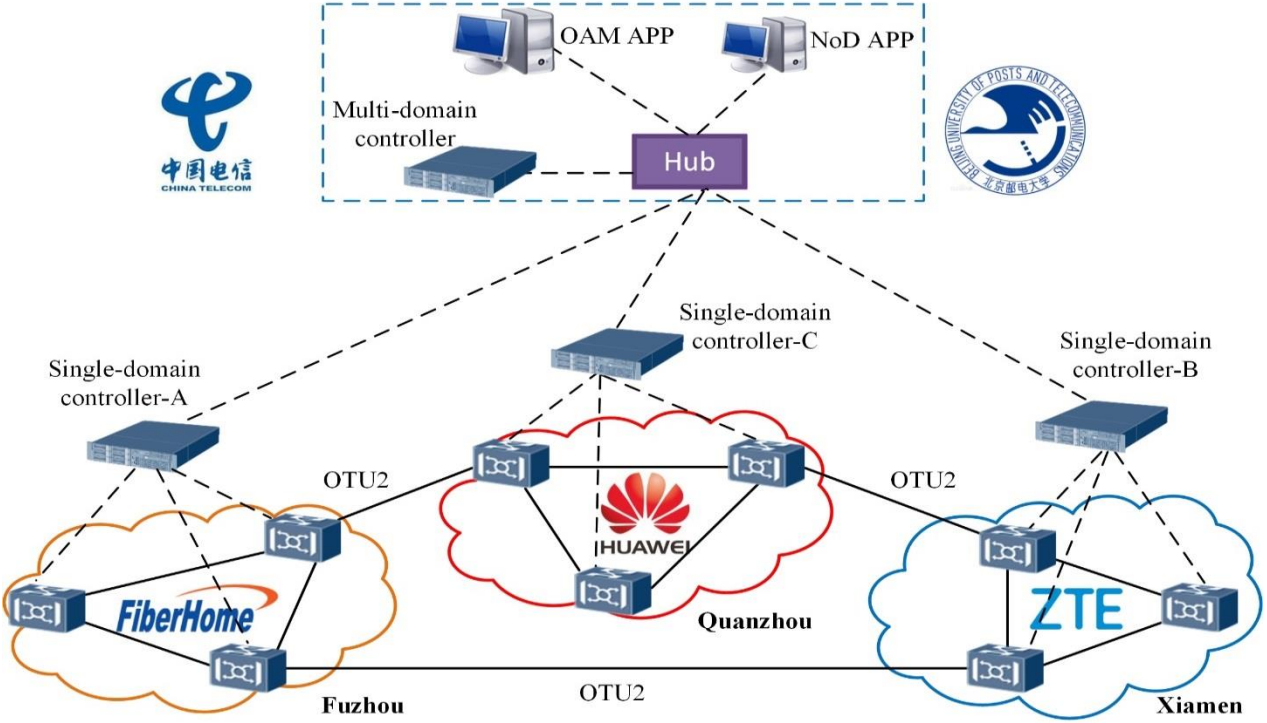

Guru Parulkar

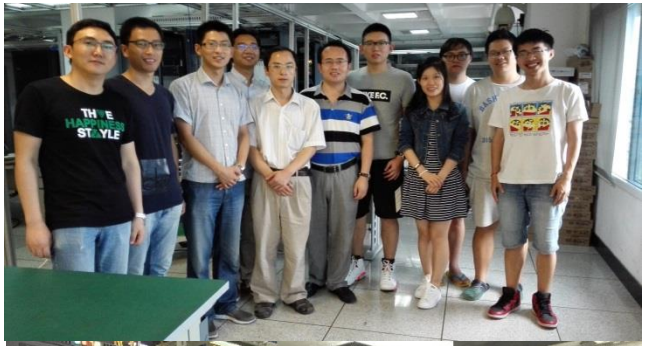

Jennifer Rexford

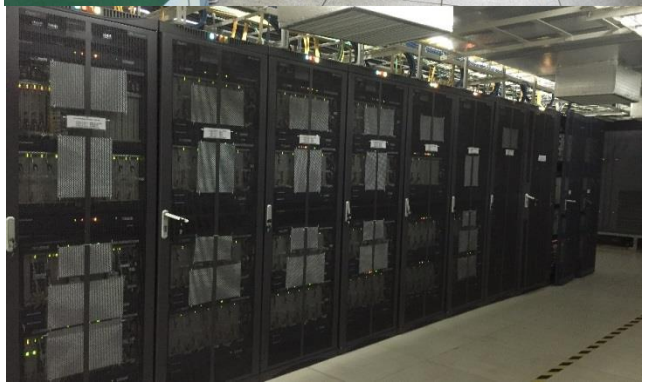
# APP deployment in field trial

- **Locations of three domains**: Quanzhou, Xiamen and Fuzhou in Fujian province.
- **5 cooperating organizations:** China Telecom, BUPT, Huawei, ZTE and FiberHome
- **Customers:**
- **Data plane property:**

- **Inter-domain links** are 10Gbit/s, and i**ntra-domain links** are 10Gbit/s.
- Supported client interfaces include **GE and 10 GE interfaces**.





Yajie Li, Yongli Zhao, Jie Zhang, et al., First Field Trial of Virtual Network Operator Oriented Network on Demand (NoD) Service Provisioning over Software Defined Multi-Domain Optical Networks with Multi-Vendor OTN Equipment, ACP2015, Hongkong, China, Nov. 2015, Postdeadline paper

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# Conclusions

- Programmability and virtualization are keys to SD-EON
- Series of technologies of SD-EON are moving fast to mature
- Various applications have been developed in APP store, such as BoD, VON, SSE, SRD, VM.
- Different potential applications are to be developed to drive the deployment of SD-EON

# Thank you for your attention!

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