T-SDN: Controllers for Transport Networks

Sabidur Rahman

Netlab, UC Davis.

krahman@ucdavis.edu

http://www.linkedin.com/in/kmsabidurrahman/

Agenda

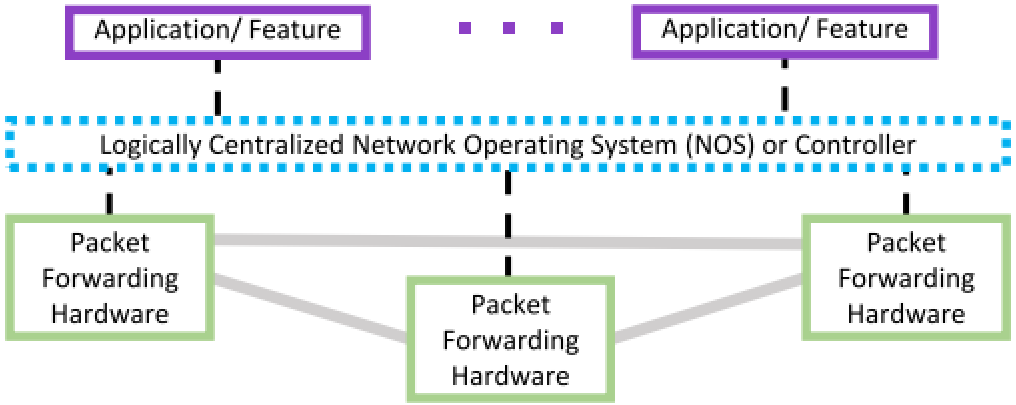
- How T-SDN is different from SDN
- How layer 0 is different from layer 1 and layer 2-3
- Control plane: Packet switched vs. Circuit Switched
- Transport network function virtualization
- Research directions

How T-SDN is different from SDN?

- Transport SDN (T-SDN) is an SDN-based architecture for control and management of transport networks, that could involve multi-layer, multi-domain, and multi-vendor scenarios
- Transport networks have features usually not present in computer networks where SDN paradigm arose, like resilience, sophisticated architectures, heterogeneous technologies (MPLS and others), and optical domain impairments
- In this sense, T-SDN is as a subset of SDN-architecture that comprises extensions to abstractions, interfaces, protocols, and control plane elements to cope with transport networks peculiarities and limitations

R. Alvizu, G. Maier, N. Kukreja, A. Pattavina, R. Morro, A. Capello, and C. Cavazzoni. “Comprehensive survey on T-SDN: Software-defined networking for transport networks,” IEEE Communications Surveys & Tutorials, vol. 19, no. 4, pp. 2232-83, 2017.

How T-SDN is different from SDN?



Basic SDN network architecture

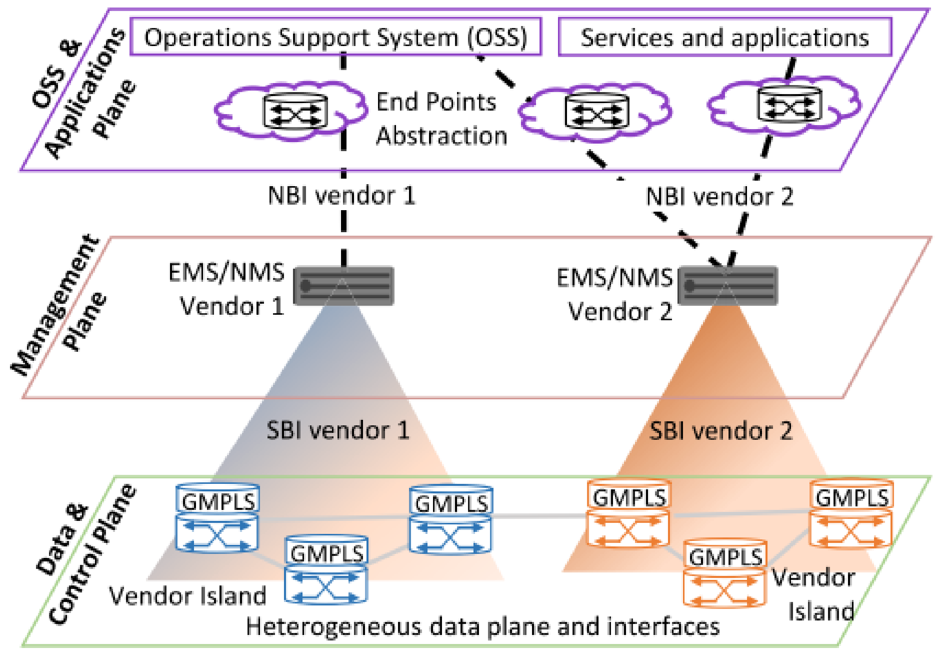


Fig. 6. Legacy transport network architecture. Notice that data and control plane are like in Fig. 1, but the management features are centralized in vendor specific EMS/NMS. SBI and NBI are both vendor specific.

R. Alvizu, G. Maier, N. Kukreja, A. Pattavina, R. Morro, A. Capello, and C. Cavazzoni. “Comprehensive survey on T-SDN: Software-defined networking for transport networks,” IEEE Communications Surveys & Tutorials, vol. 19, no. 4, pp. 2232-83, 2017.

Transport SDN Characteristics

	Layer 3 and Layer 2	Layer 1 (OTN)	Layer 0 (optical)
Traffic model	Electronic packet-switching	Electronic TDM circuit-switching	Optical WDM circuit-switching
Data Plane operations	Packet header lookup, and packet operations (forwarding, encapsulation, pipeline processing, statistics collection)	Operations over time slots, signal transmission, detection and switching. Performance monitoring	Fiber switching, wavelength conversion, signal transmission (modulation format), detection, amplification and regeneration on fixed and flexi-grid technologies. Performance monitoring
Complexity	Low complexity: digital operations, based on packets headers	Relatively low complexity: digital operations, based on time slots	High complexity: analogical operations, sensitive to physical layer constraints
Data Plane implementation	Homogeneous: based on standard protocols & specifications, vendor agnostic. Suitable for COTS devices	Homogeneous: based on standard protocols & specifications	Heterogeneous: vendor-specific features & configuration, administratively independent vendor islands
Data Plane abstraction	Easy-to-define standard abstractions	Relatively easy-to-define standard abstractions	Hard-to-define low-level standard abstractions
Southbound interface	Standardized SBI (e.g., OpenFlow)	Non standard SBI, reuse of GMPLS and vendor-specific interfaces, multiple extensions proposed for OpenFlow (OpenFlow+)	
Control Plane	Standard OpenFlow-based control	Vendor-specific interface control, SDN/GMPLS and ASON, OpenFlow-based control	
Maturity	Standard commercial solutions and rollouts, based on OpenFlow	Non standard commercial solutions. Some OpenFlow standardization covered	Non standard commercial solutions

R. Alvizu, G. Maier, N. Kukreja, A. Pattavina, R. Morro, A. Capello, and C. Cavazzoni. “Comprehensive survey on T-SDN: Software-defined networking for transport networks,” IEEE Communications Surveys & Tutorials, vol. 19, no. 4, pp. 2232-83, 2017.

Control plane: Packet Switched vs. Circuit Switched

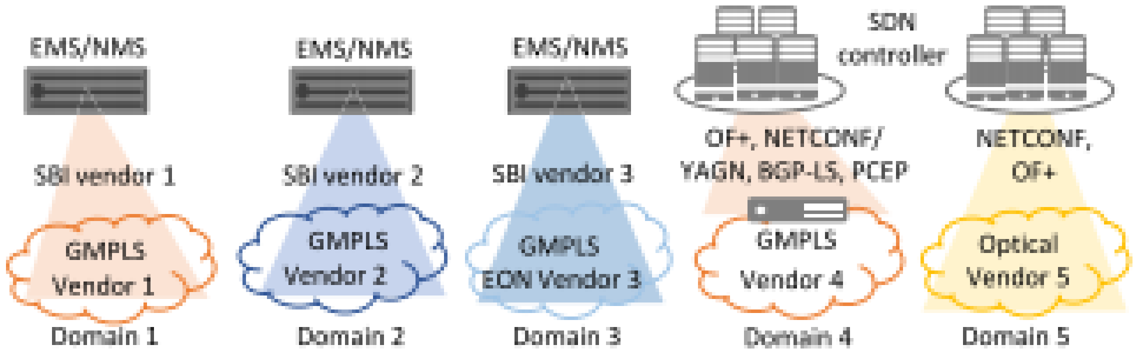


Fig. 8. Example of optical domains in a transport network.

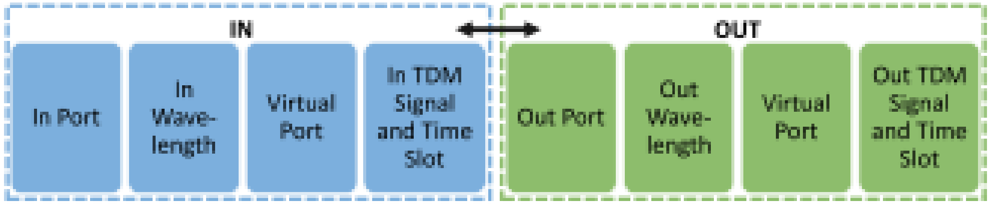


Fig. 10. Circuit flow table used to define the state of the switching matrix. It was proposed in the OpenFlow Circuit Switched Addendum v.03 [62].

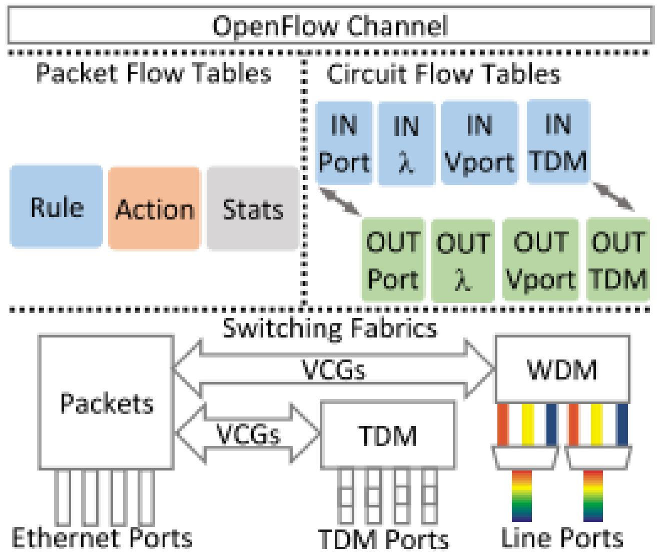


Fig. 11. Hybrid packet-circuit switch architecture. VCG: Virtual Concatenation Groups.

R. Alvizu, G. Maier, N. Kukreja, A. Pattavina, R. Morro, A. Capello, and C. Cavazzoni. “Comprehensive survey on T-SDN: Software-defined networking for transport networks,” IEEE Communications Surveys & Tutorials, vol. 19, no. 4, pp. 2232-83, 2017.

Transport Network Function Virtualization

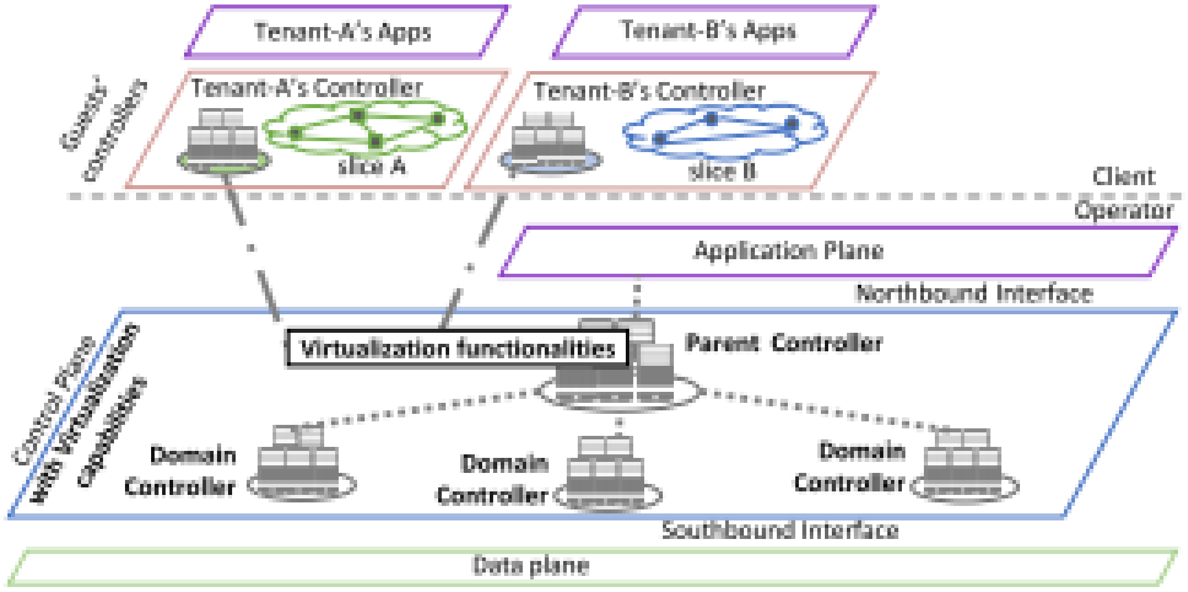


Fig. 27. Centralized virtualization architecture for the multi-domain scenario.

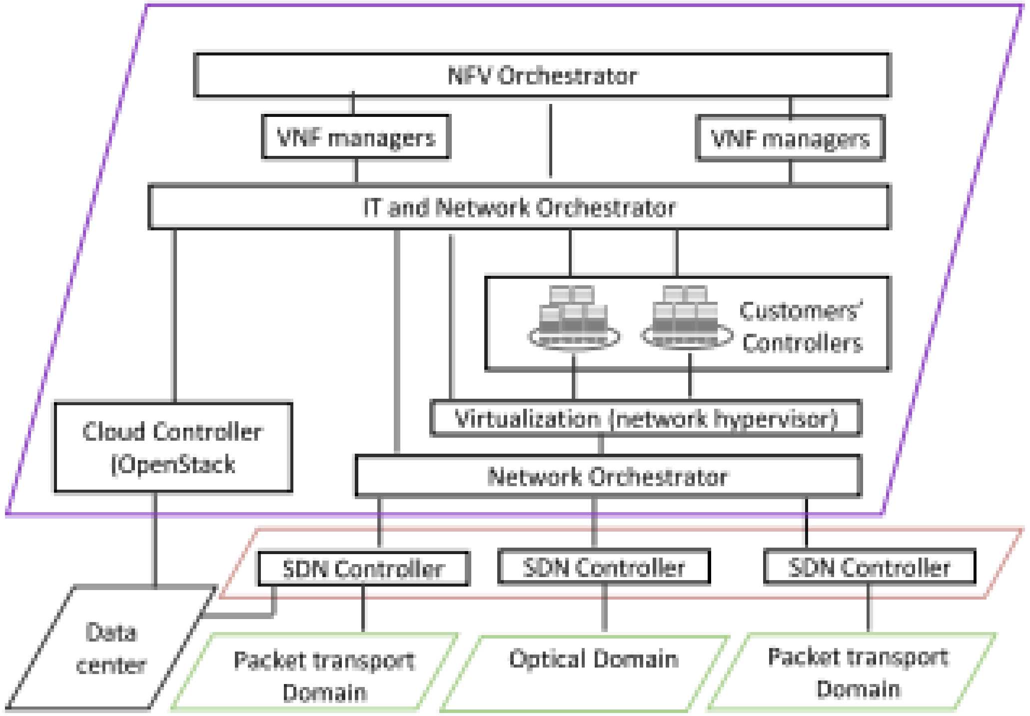


Fig. 30. Transport Network Function Virtualization architecture proposed in [115].

R. Alvizu, G. Maier, N. Kukreja, A. Pattavina, R. Morro, A. Capello, and C. Cavazzoni. "Comprehensive survey on T-SDN: Software-defined networking for transport networks," IEEE Communications Surveys & Tutorials, vol. 19, no. 4, pp. 2232-83, 2017.

Defining the controller placement problem

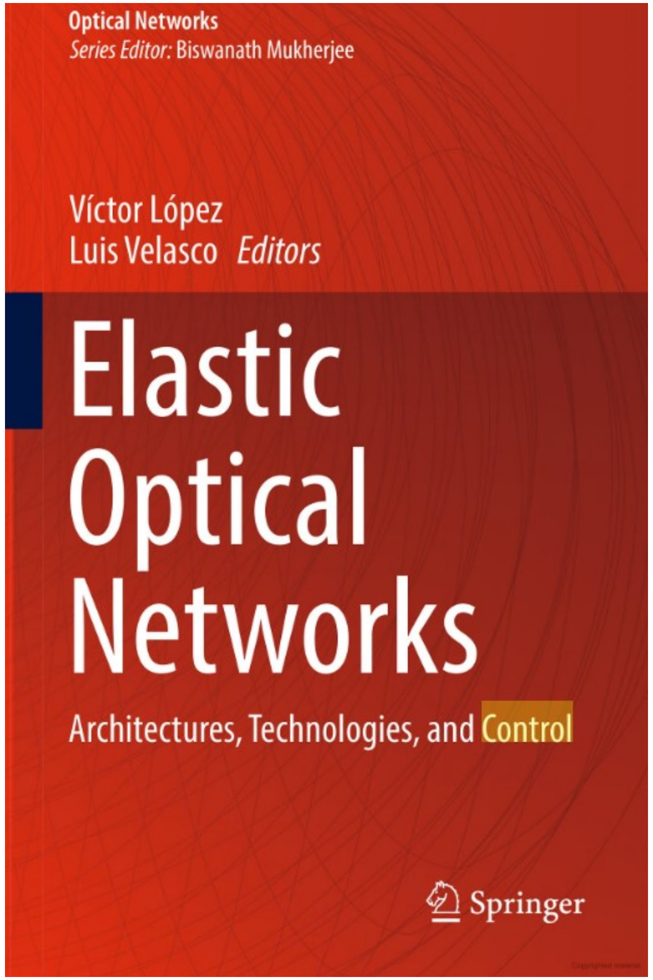
- Virtualized controller placement for a mixed-grid scenario
- Controller components
- Virtualized controller instances
- Mixed-grid
- Dynamic deployment (turn on/off based on load)
- Tenant wants to keep the controllers closer to active users

1. V. López, R. Jiménez, O. G. de Dios, J. P. Fernández-Palacios, "Control plane architectures for elastic optical networks." *Journal of Optical Communications and Networking*. vol.10, no. 2, pp. 241-249, Feb. 2018

2. R. Munoz, R. Vilalta, R. Casellas, R. Martínez, T. Szyrkowiec, A. Autenrieth, V. López, and D. López. "SDN/NFV orchestration for dynamic deployment of virtual SDN controllers as VNF for multi-tenant optical networks," *In Proc. Optical Fiber Communications Conference and Exhibition (OFC),* 2015.

Elastic Optical network: Controller components

- Generalized Multi-Protocol Label Switching (GMPLS).
- Software Defined Network (SDN) control plane for optical network with OpenFlow.



Control plane architectures for elastic optical networks : Introduction

- Elastic optical networks (EONs) are based on a flexible allocation of the spectrum and configurable transponders.
- To take advantage of such flexibility and unlock the potential of EONs, the control architecture plays a key role.
- This paper presents the architectural choices, including generalized multiprotocol label switching, path computation element, and software-defined networking using a transport application programming interface.

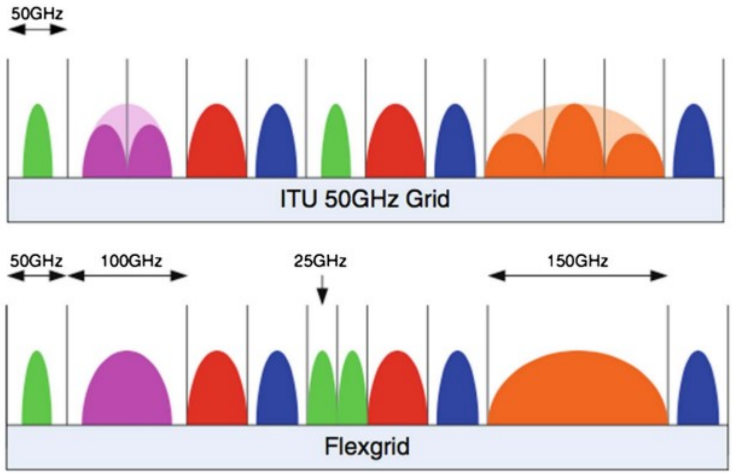


Fig. 1. Fixed and flexgrid spectrum allocation [2].

V. López, R. Jiménez, O. G. de Dios, J. P. Fernández-Palacios, "Control plane architectures for elastic optical networks." *Journal of Optical Communications and Networking*. vol.10, no. 2, pp. 241-249, Feb. 2018

Control plane architectures for elastic optical networks : Introduction

- 2013: a half million users with fiber access.
- 2014: 1,590,990 users.
- 2015: 3,161,302 users.
- This massive increase in fiber access justifies the high pressure in the metro/backbone networks.
- We need to squeeze resources efficiently to maintain network costs.
- Elastic optical networks (EONs) provide flexibility by enabling the use of transponders that use a wide variety of modulation formats, are reconfigurable by software, and are even capable of slicing the spectrum.

V. López, R. Jiménez, O. G. de Dios, J. P. Fernández-Palacios, “Control plane architectures for elastic optical networks.” *Journal of Optical Communications and Networking*. vol.10, no. 2, pp. 241-249, Feb. 2018

Control Architectures: Distributed GMPLS Control

- The majority of the commercial deployments of optical core and transport networks with an automated control plane have been based on the protocol suite defined by GMPLS architecture.
- GMPLS was standardized by the Common Control and Measurement Plane (CCAMP) working group of the Internet Engineering Task Force (IETF).
- **Resource reSerVation Protocol** - Traffic Engineering (RSVP-TE): responsible for setting up end-to-end quality-enabled connections.
- **Open Shortest Path First** - **Traffic Engineering** (OSPF-TE): responsible for the dissemination of information about the topology and the traffic engineering (TE) and for constructing a TE database (TEDB), enabling the routing at each node in the network.
- **Link Management Protocol** (LMP): responsible for the link management. It monitors the proper functioning of the links and control channels and checks the connectivity between adjacent nodes, helping to locate failures.

V. López, R. Jiménez, O. G. de Dios, J. P. Fernández-Palacios, “Control plane architectures for elastic optical networks.” *Journal of Optical Communications and Networking*. vol.10, no. 2, pp. 241-249, Feb. 2018
O. Gonzalez de Dios, V. López, and J. P. Fernandez Palacios, “Control plane architectures for flexi-grid networks,” in Optical Fiber Communication Conf. (OFC), Mar. 2017.

Control Architectures: SDN-Based Control

- Most of the solutions nowadays on the market for SDNs are based on single-domain and vendor-specific solutions.
- However, real networks are based on a combination of multiple technologies, provided by different vendors, and divided into multiple domains to cope with administrative and regional organizations.
- It is not feasible that a single SDN controller is able to configure/manage the whole network of an operator due to scalability and reliability issues.

V. López, R. Jiménez, O. G. de Dios, J. P. Fernández-Palacios, "Control plane architectures for elastic optical networks." *Journal of Optical Communications and Networking*. vol.10, no. 2, pp. 241-249, Feb. 2018

Control Architectures: SDN-Based Control

- The Open Networking Foundation (ONF) proposed a hierarchical architecture that fits with the multivendor/multidomain scenario.
- In this approach, there are multiple SDN controllers interacting with an SDN orchestrator hierarchically placed on top of them.
- The SDTN controller is in charge of providing services through several domains. In the SDN literature, this element is also known as the SDN orchestrator.
- SDTN controller is connected to SDN domain controllers.
- The SDN domain controllers are in charge of a set of network elements. It has SBIs that depend on the technology, but not in the equipment vendor, to communicate with the network elements.
- SDN domain controller also has a northbound interface (NBI) to communicate with the SDN orchestrator. We can consider the SDN domain controller as a controller of flexgrid technologies.
- The implementation of the controller depends on the vendor, but there are open source approaches such as ONOS or Netphony. Even though there is debate among the operators whether to use open source implementations, there is wide agreement that the interfaces to the controllers and orchestrator, southbound and northbound, must be standard.

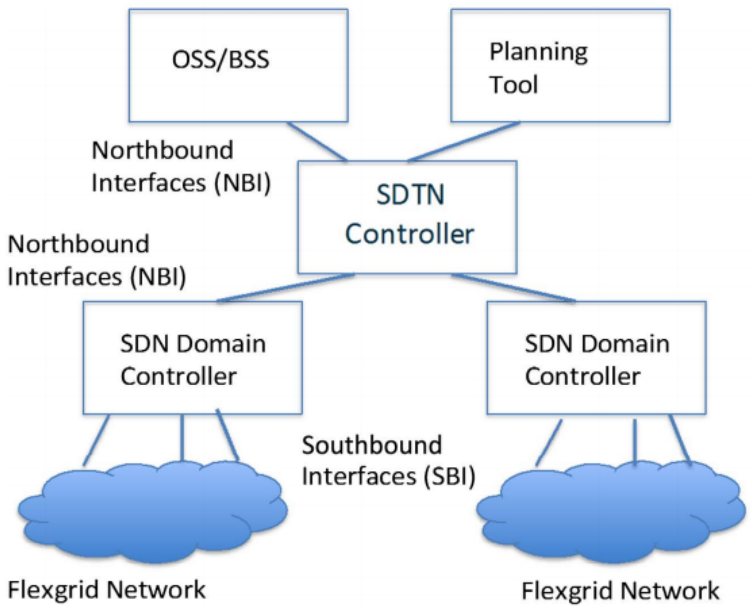


Fig. 2. Software-defined transport network (SDTN) architecture.

V. López, R. Jiménez, O. G. de Dios, J. P. Fernández-Palacios, “Control plane architectures for elastic optical networks.” *Journal of Optical Communications and Networking*. vol.10, no. 2, pp. 241-249, Feb. 2018
Open Networking Foundation (ONF), “SDN architecture,” ONF TR-502, 2014.
D. Ceccarelli and Y. Lee, “Framework for abstraction and control of traffic engineered networks,” IETF draft-ietf-teas-actnframework, 2017.

Defining the research problem

- Virtualized controller placement for a mixed-grid scenario.
- Controller components
- Virtualized controller instances
- Mixed-grid
- Dynamic deployment (turn on/off based on load)
- Tenant wants to keep the controllers closer to active users?

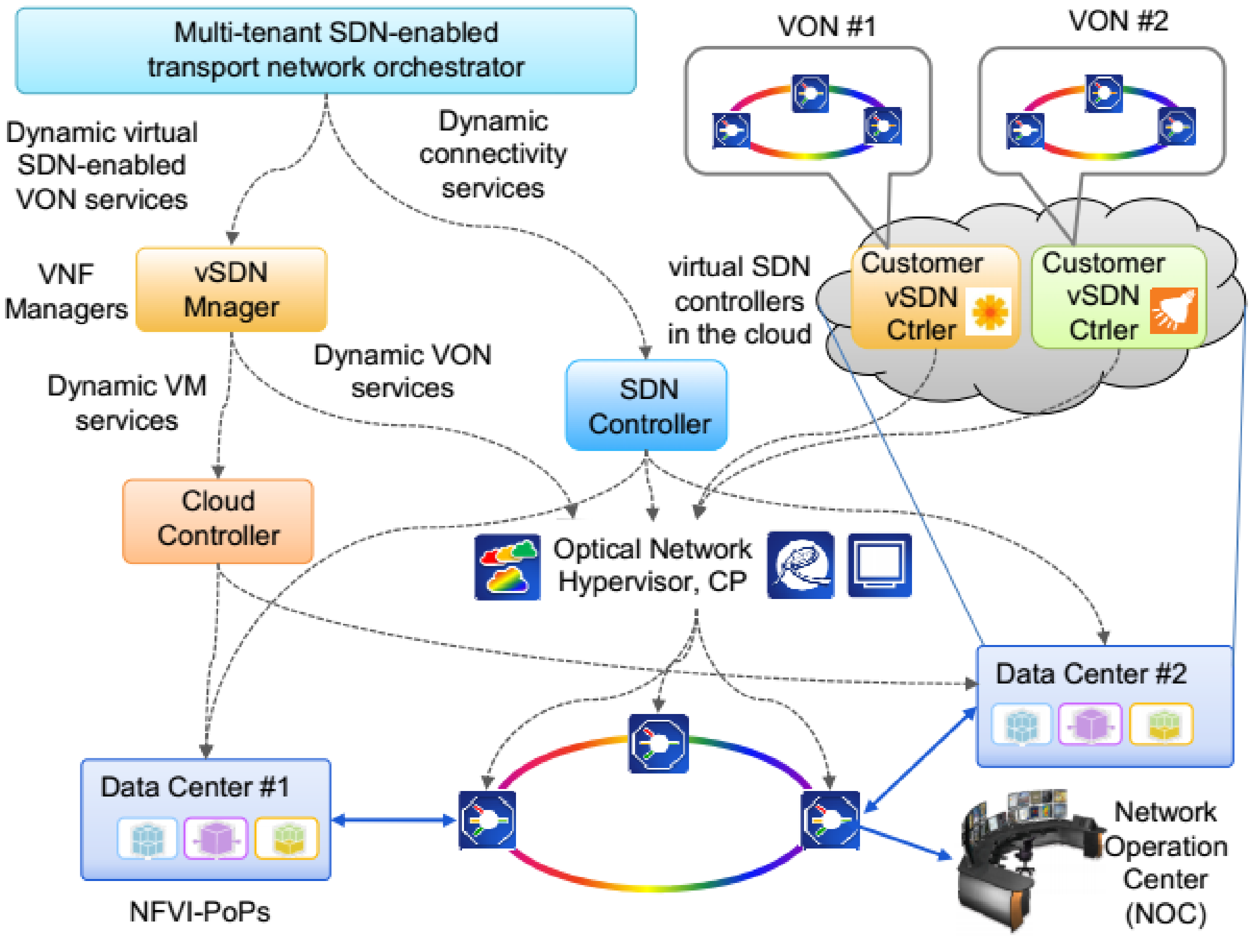
1. V. López, R. Jiménez, O. G. de Dios, J. P. Fernández-Palacios, "Control plane architectures for elastic optical networks." *Journal of Optical Communications and Networking*. vol.10, no. 2, pp. 241-249, Feb. 2018
2. R. Munoz, R. Vilalta, R. Casellas, R. Martínez, T. Szyrkowiec, A. Autenrieth, V. López, and D. López. "SDN/NFV orchestration for dynamic deployment of virtual SDN controllers as VNF for multi-tenant optical networks," *In Proc. Optical Fiber Communications Conference and Exhibition (OFC),* 2015.

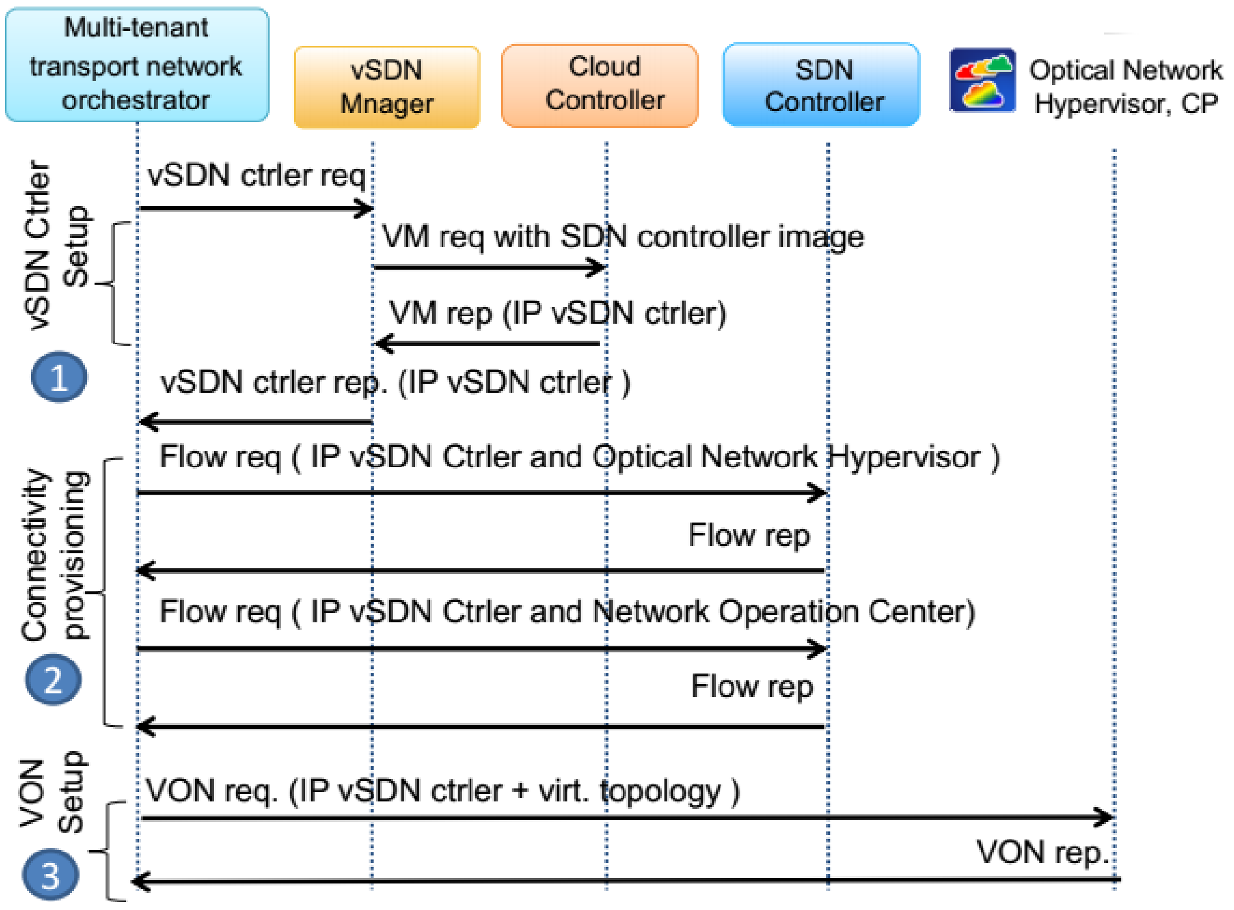
SDN/NFV orchestration for dynamic deployment of virtual SDN controllers

- Virtualize SDN control functions and move them to cloud.
- Dynamically deploy independent SDN controller instances for each deployed virtual optical network.
- Application-specific optical network services to support specific quality of service (QoS) and Service Level Agreement (SLA) requirements.
- Virtual optical networks (VONs) are created by first partitioning and/or aggregating the physical resources into virtual resources .
- The users of the VON can dynamically create, modify and delete virtual network slices in response of application demands.
- Customer SDN controller and Optical Network controller (Optical Network Hypervisor (ONH)) makes this possible.
- VNFs of SDN controller, Optical Network controller, and virtualized PCE.

R. Munoz, R. Vilalta, R. Casellas, R. Martínez, T. Szyrkowiec, A. Autenrieth, V. López, and D. López. “SDN/NFV orchestration for dynamic deployment of virtual SDN controllers as VNF for multi-tenant optical networks,” In Proc. Optical Fiber Communications Conference and Exhibition (OFC), 2015.

SDN/NFV architecture





R. Munoz, R. Vilalta, R. Casellas, R. Martínez, T. Szyrkowiec, A. Autenrieth, V. López, and D. López. “SDN/NFV orchestration for dynamic deployment of virtual SDN controllers as VNF for multi-tenant optical networks,” In Proc. Optical Fiber Communications Conference and Exhibition (OFC), 2015.

Things not considered

- Which NFV-PoP is the optimal location?
- How many controllers are optimal solution?
- Latency constraints?
- Load?
- Can we turn some of them off when load is low?

Defining the research problem

- Virtualized controller placement for a mixed-grid scenario.
- Controller components
- Virtualized controller instances
- Mixed-grid
- Dynamic deployment (turn on/off based on load)
- Tenant wants to keep the controllers closer to active users?

T. Ahmed, S. Rahman, M. Tornatore, X. Yu, K. Kim, and B. Mukherjee, "Dynamic Routing and Spectrum Assignment in Co-Existing Fixed/Flex Grid Optical Networks,“ *submitted to IEEE Advanced Networks and Telecom Systems (ANTS*), 2018.

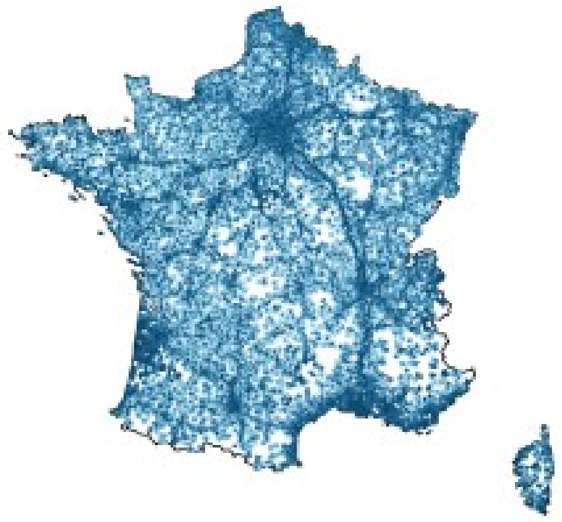
Defining the problem

- Virtualized controller placement for a mixed-grid multi-tenant scenario.
- Controller components [1]
- Virtualized controller instances [2]
- Mixed-grid
- Dynamic deployment (turn on/off based on load)
- Tenant (Netflix) = Keep the controller closer to active users?

1. V. López, R. Jiménez, O. G. de Dios, J. P. Fernández-Palacios, "Control plane architectures for elastic optical networks." *Journal of Optical Communications and Networking*. vol.10, no. 2, pp. 241-249, Feb. 2018
2. R. Munoz, R. Vilalta, R. Casellas, R. Martínez, T. Szyrkowiec, A. Autenrieth, V. López, and D. López. "SDN/NFV orchestration for dynamic deployment of virtual SDN controllers as VNF for multi-tenant optical networks," *In Proc. Optical Fiber Communications Conference and Exhibition (OFC),* 2015.

Virtualization enabled dynamic deployment

- Can we use active user information (arrival, location, departure, etc.) for dynamic controller deployment?



Maps of the average per-subscriber activity for downlink for Netflix

- Motivation: saving operational cost, moving controllers closer to users

C. Marquez, M. Gramaglia, M. Fiore, A. Banchs, C. Ziemlicki, Z. Smoreda. "Not All Apps Are Created Equal: Analysis of Spatiotemporal Heterogeneity in Nationwide Mobile Service Usage." CoNEXT, 2017.

Problem statement

Input:

- Optical mixed-grid network
- NFV-PoP locations
- Controller component requirements
- Latency and other constrains for controllers
- Dynamic user information (arrival, departure, location, required bandwidth, etc.)
- SLA requirements for users

Output:

- How many controllers required?
- Where to deploy?
- When to turn on/off/migrate?

Summary

- Elastic optical networks are controlled by a mixed controller scenario with multiple domains, multiple tenants, multiple vendors and so on.
- Control plane becomes much more complex if we consider mixed-grid scenario where Fixed-grid and Flex-grid optical network co-exists.
- Introducing virtualized controllers enable dynamic deployment of these controllers.
- Exploring the problem statement in this direction will solve an important problem.
- Define: Input, output, simulation set up

Thanks!