Evolution of control plane for Elastic Optical Networks GMPLS, SDN and beyond

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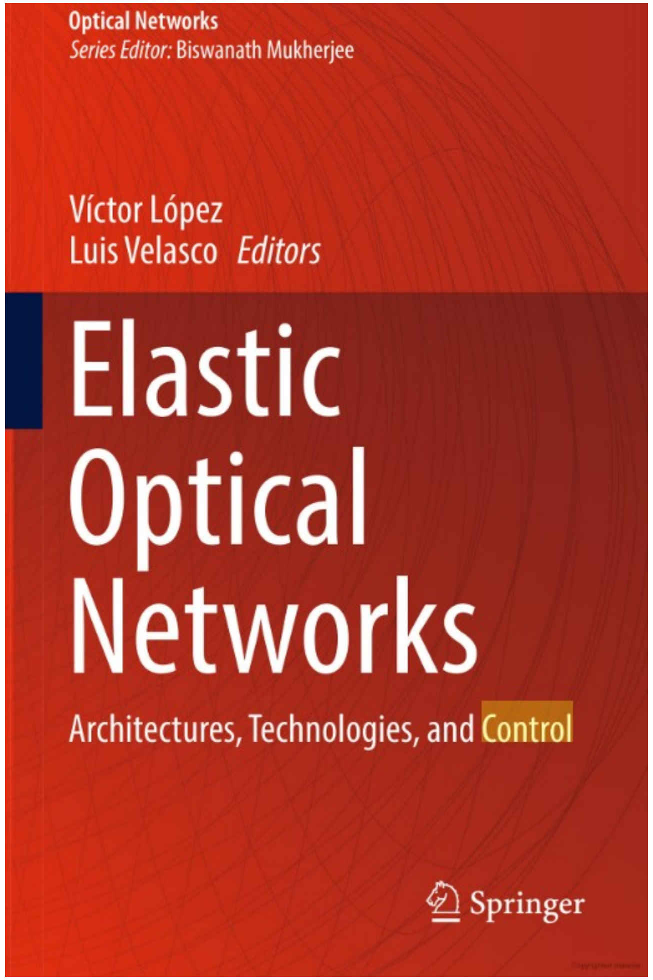
Elastic Optical network: Control plane

- 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.

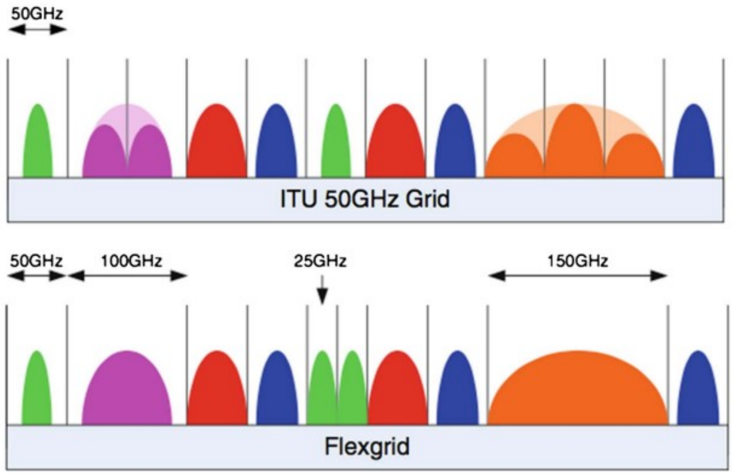


Fig. 1. Fixed and flexgrid spectrum allocation [2].

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.

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Control plane architectures for elastic optical networks : Introduction

- Control architecture is the key element to take advantage of the capabilities of flexgrid networks.
- GMPLS technologies provided a distributed control plane approach to enable the dynamic operation of optical networks.
- Advent of the SDN paradigm, abstraction is a key feature that allows easy operation of optical networks.
- This paper presents control architectures for EONs, spanning from GMPLS technologies to SDNs and how they can be combined to provide a realistic solution for network operators.

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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.

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Control Architectures: PCE-GMPLS-Based Control

- The implementation of the GMPLS architecture has been based on a distributed approach that has provided a high degree of availability and resiliency.
- However, the fully distributed nature is not able to achieve optimal allocation of resources and may lead to some inefficiencies and, in the particular case of flexgrid networks, to fragmentation of the spectrum.
- IETF proposed the path computation element (PCE) concept, "an entity (component, application, or network node) that is capable of computing a network path or route based on a network graph and applying computational constraints.
- The PCE requires information on the network state for the path computation. Information collection process is done using the link state protocols from GMPLS.

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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.

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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.

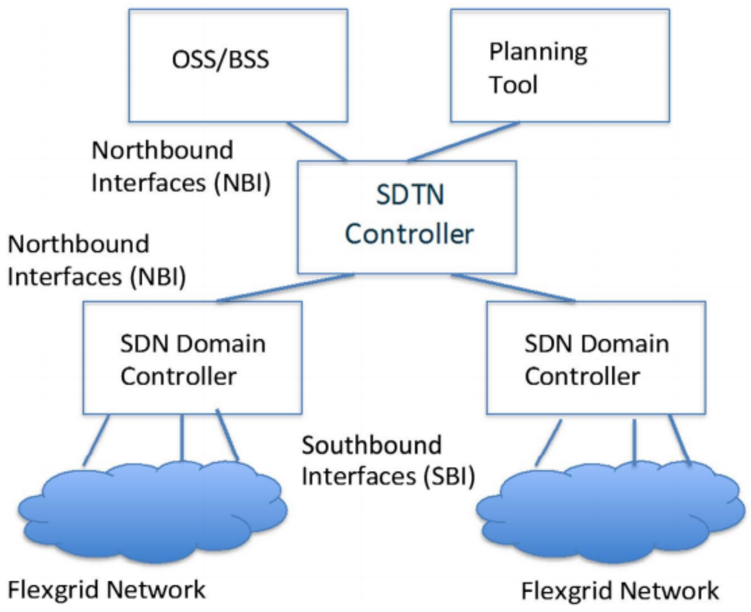

Fig. 2. Software-defined transport network (SDTN) architecture.

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Information models for elastic optical networks : Northbound Interface - Transport API

- The NBIs of the controllers do not need to capture the details of the optical networks and can operate on an abstracted level, while the SBIs need to provide enough level of detail to configure the elastic optical network.
- The TAPI abstracts five main functionalities: 1) network topology, 2) connectivity requests, 3) path computation, 4) network virtualization, and 5) monitoring to a set of service interfaces.
- For example, 'network topology' functionality requires, at a minimum, that the interface exports network topology information with unique identifiers.
- Further, the controllers can provide information about the links in the domain (physical or virtual), their utilization, or even information about physical impairments, which the orchestrator may apply to a physical impairments computation model.
- It is clear that the more information is shared, the less abstracted the network appears.

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Open Networking Foundation (ONF), "Functional requirements for transport API," ONF TR-527, 2016.

Information models for elastic optical networks : Northbound Interface - Transport API

- The connectivity requests functionality enables the setup, tear-down, and modification of connections in the network. Its most basic feature is to set up a point-to-point connection between two locations.
- The path computation function is a critical and fundamental feature because individual controllers in each domain are only able to share abstracted information that is local to their domain, while an orchestrator with its global end-to-end view can optimize end-to-end connections that individual controllers cannot configure.

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Open Networking Foundation (ONF), “Functional requirements for transport API,” ONF TR-527, 2016.

Information models for elastic optical networks : Southbound Interfaces for Elastic Optical Networks

- The southbound interfaces are responsible for configuring the network devices.
- The two main approaches are, on the one hand, using Path Computation Element Protocol (PCEP) to trigger the distributed signaling via GMPLS, or using YANG models to configure device by device.
- However, there is a gap in terms of the control of the optical interfaces. Up to now, the approach that has been used by the ITU-T defined application codes, which are a character-based abbreviation to characterize transceiver characteristics.

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Information models for elastic optical networks

MATURITY OF THE INFORMATION MODELS FOR ELASTIC OPTICAL NETWORKS

Topic	Type	Functionality	Maturity
GMPLS protocols (RSVP-TE, OSPF-TE, LMP)	Distributed control	Provisioning between NEs, routing, link maintenance	High, extensions for flexgrid in final stages
TAPI	NBI	Provisioning, topology, path computation, and virtualization	High, TAPI 2.0 released in 2017
IETF models	NBI	Provisioning, topology	Medium (technology specific models in progress—drafts)
PCEP/BGP-LS	SBI	PCE/controller to network element	Medium, flexgrid extensions depend on GMPLS
PRESCO	SBI	Configure transponders	Low (gap in current standards)

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Summary

- Elastic optical networks are controlled by a mixed GMPLS, SDN scenario which is still evolving.
- Current control plane, with multi-domain, multi-vendor is already a very complex scenario.
- Control plane becomes much more complex if we consider mixed-grid scenario where Fixed-grid and Flex-grid optical network co-exists.
- Management of such a complex architecture requires further study and improved mixed-grid-aware optimization techniques.