Next Challenges in Optical Networking Research: Ultra High Speed Networking, Flexibility, Programmability

High Performance Networks Group

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Optical Networks: Ultra High Speed Intelligent Network Infrastructure

- Data Plane: Flexible, Elastic Optical Layer (FP7 STRONGEST, FP7 call 8 IDEALIST
  - Architectures on Demand
- Control Plane (FP7 MAINS)
  - Targeted extensions for dynamic and data plane-aware network services
- Optical Network Infrastructure Virtualisation, Slicing and Isolation (FP7 GEYSERS)
- Software/Hardware Defined Network Programmability (FIRE OFELIA, FP7 call 8 DyNAmIC)
  - For infrastructure and service adaptation
- Optical Network Cognition (FP7 CHRON, UK EPSRC Photonics HyperHighway)

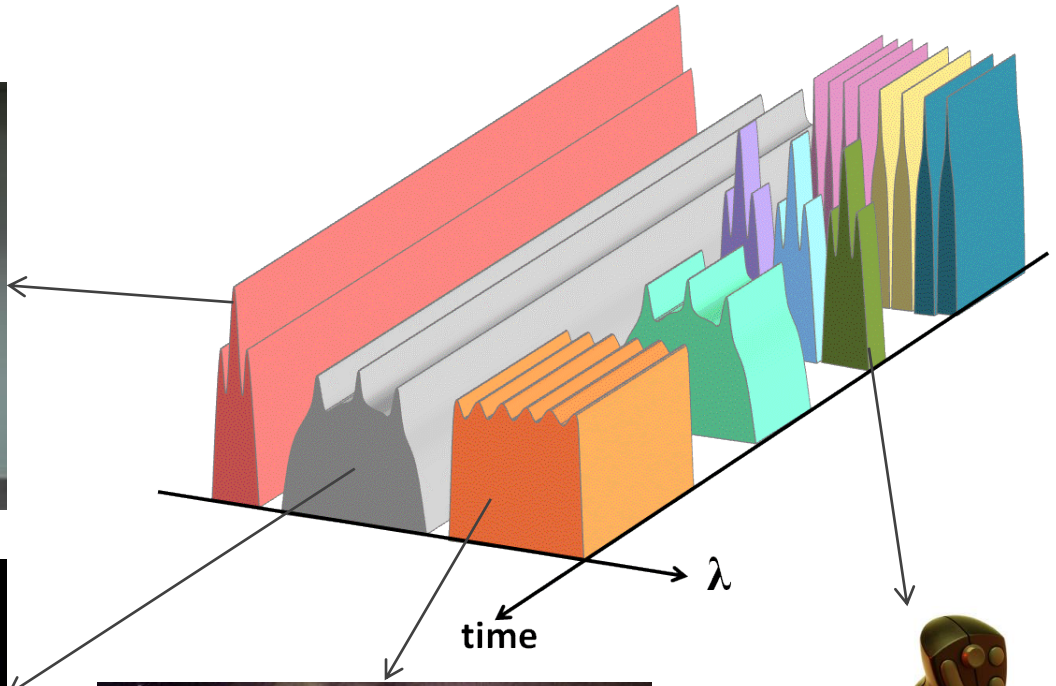
Data Plane:

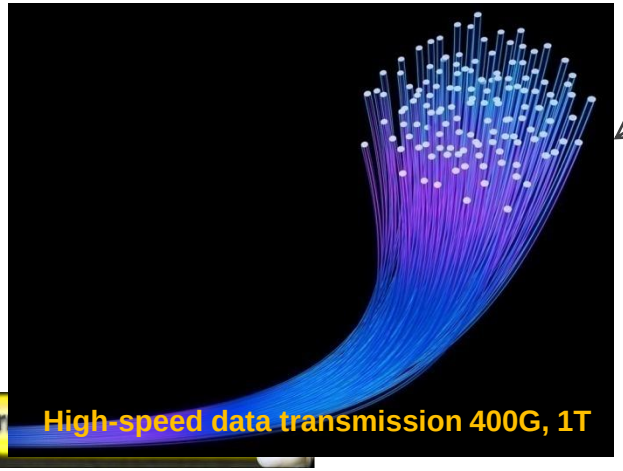
Flexible, Elastic Optical Layer

(FP7 STRONGEST)

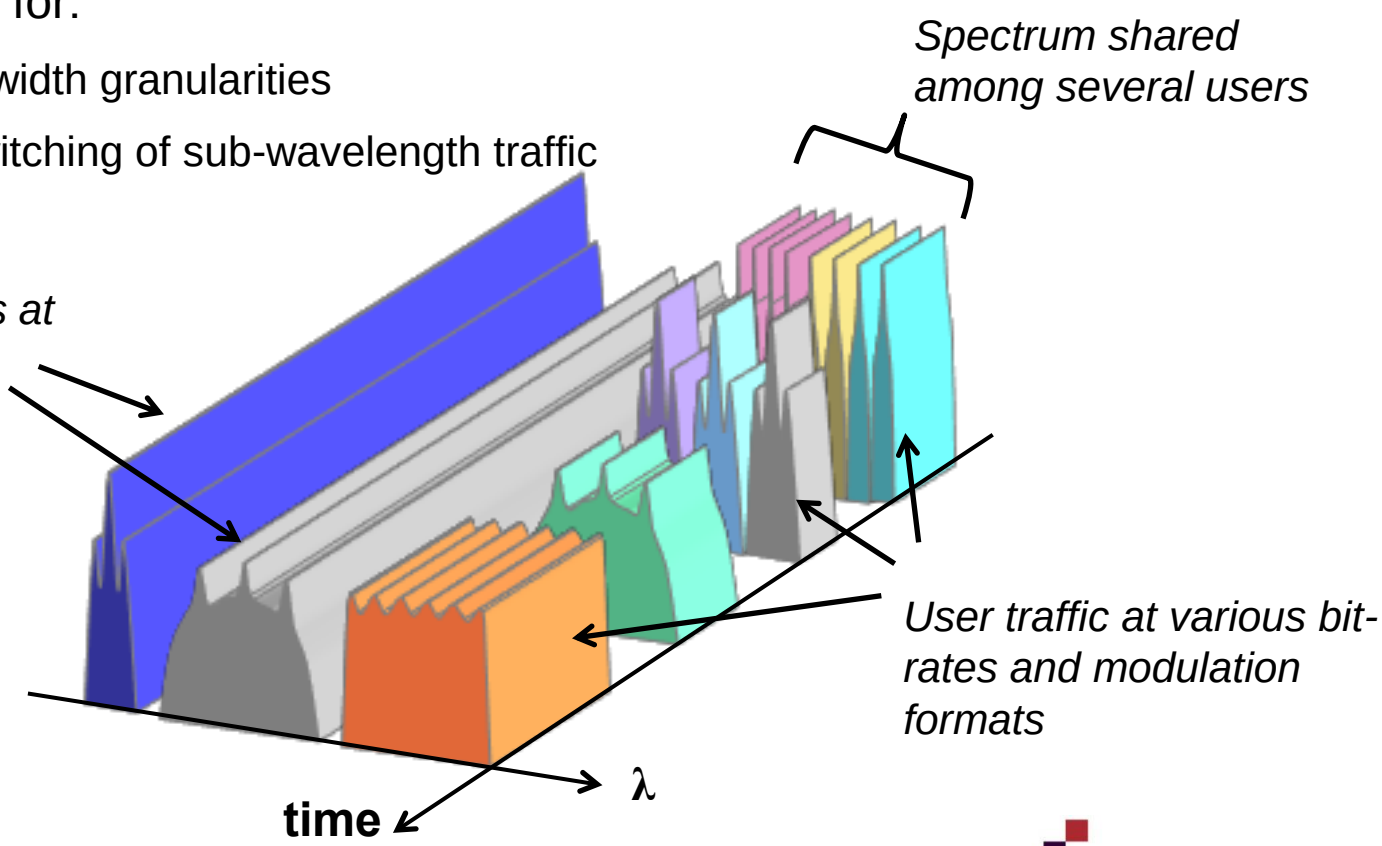
Proposed Solution: Elastic Resource Allocation

- Flexible allocation of resources in time and frequency in order to:
  - Accommodate applications with **arbitrary requirements**





- Elastic BW allocation to enable:
  - Support for high-speed channels with arbitrary bandwidth requirements (beyond 100G)
  - Better spectral efficiency for lower bit rates
- Elastic time allocation for:
  - Finer all-optical bandwidth granularities
  - Efficient all-optical switching of sub-wavelength traffic

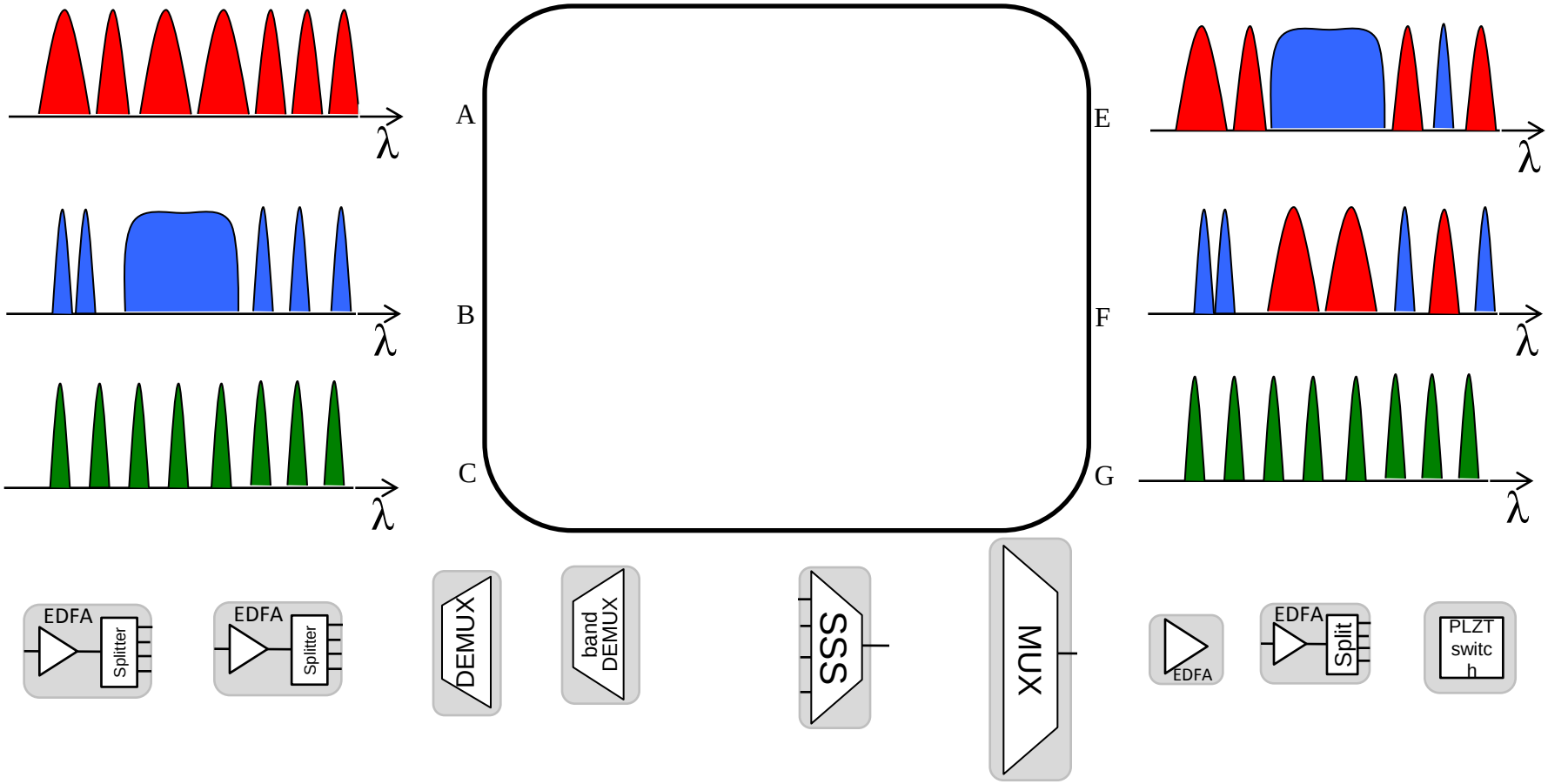


Architecture on Demand

- Adapt to traffic profile
- Support for arbitrary switching-granularity
- Dynamic architecture reconfiguration
- Fast fault recovery
  - Faulty module replacement
  - Alternative architecture
- Modular design to aid with infrastructure planning
- Easy to upgrade with new modules
  - Wavelength conversion
  - Regeneration
  - Other signal processing

Architecture on Demand (FP7 STRONGEST)

- Aimed to develop an optical node that can adapt its architecture according to the traffic profile and supports elastic allocation of resources



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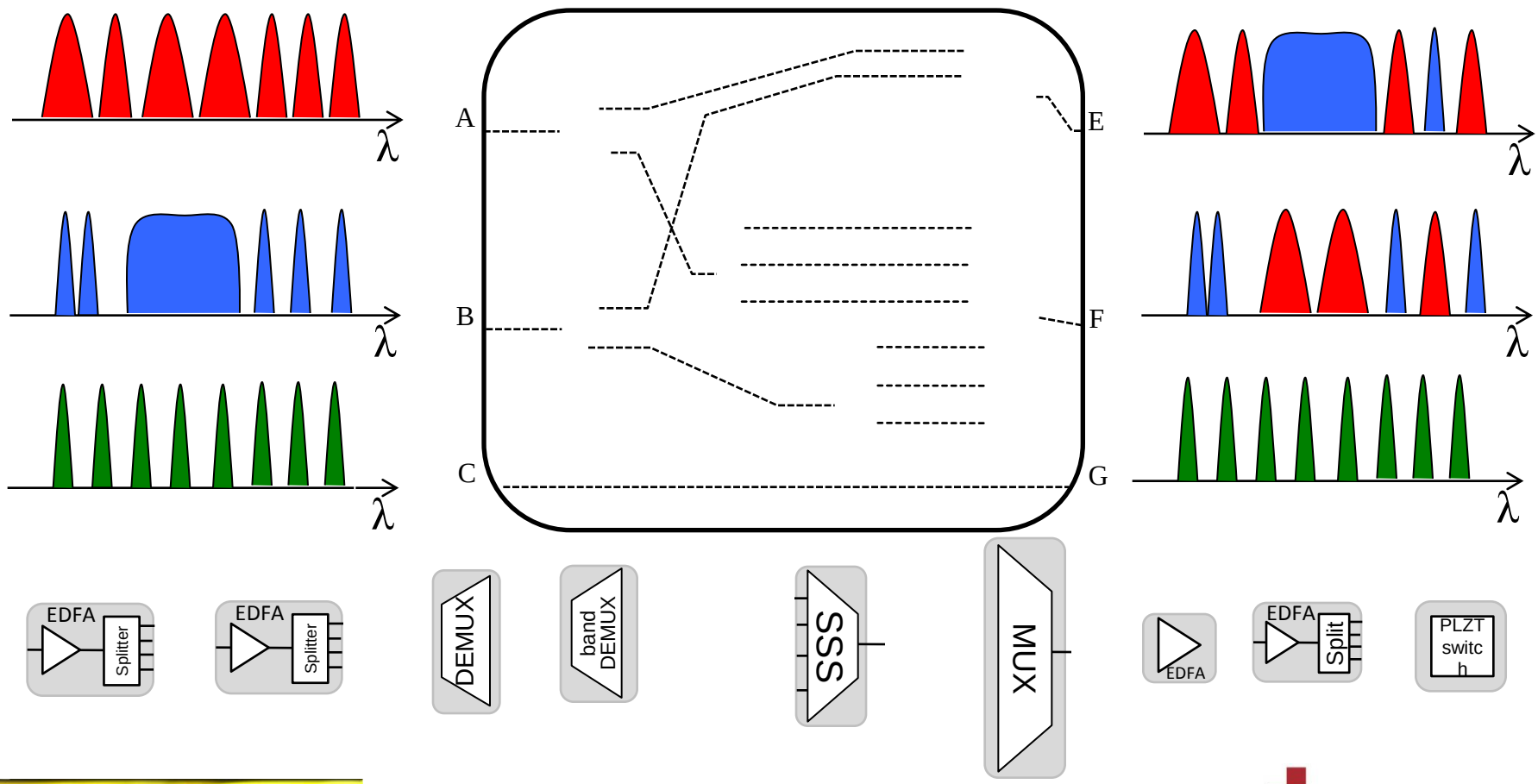

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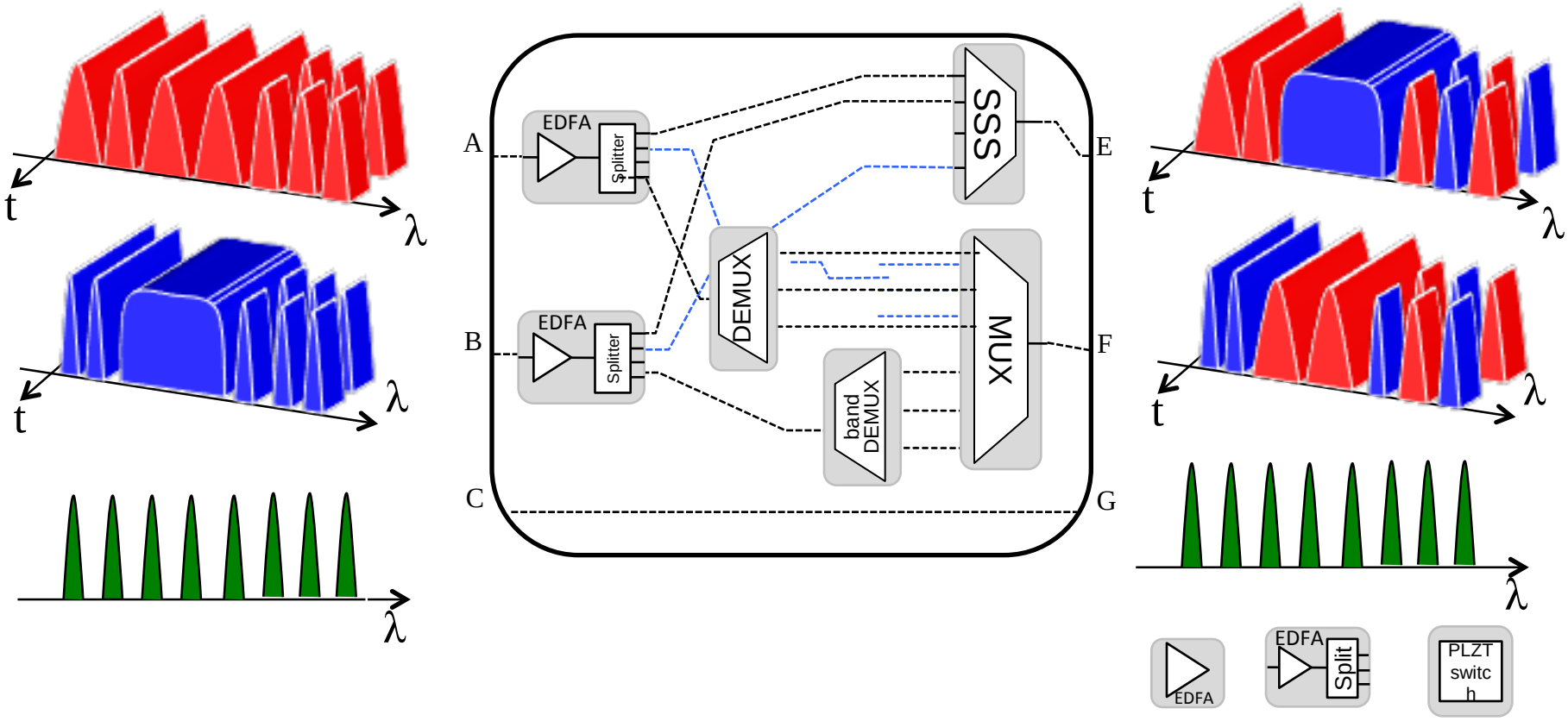
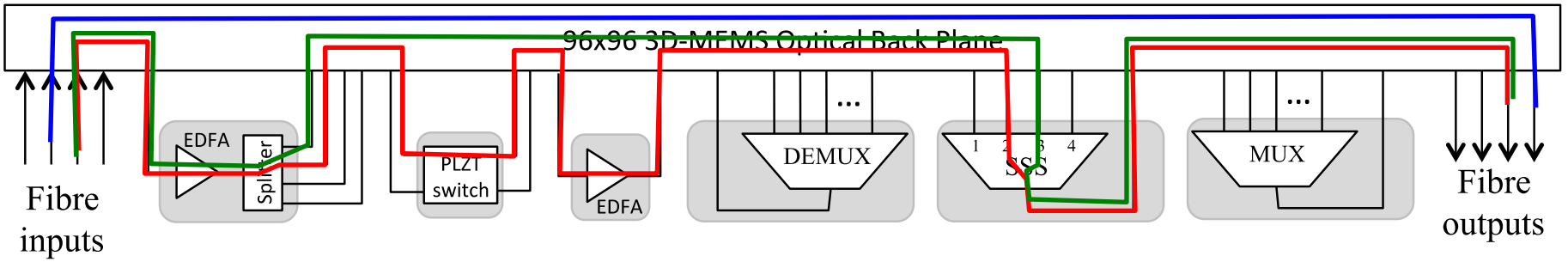
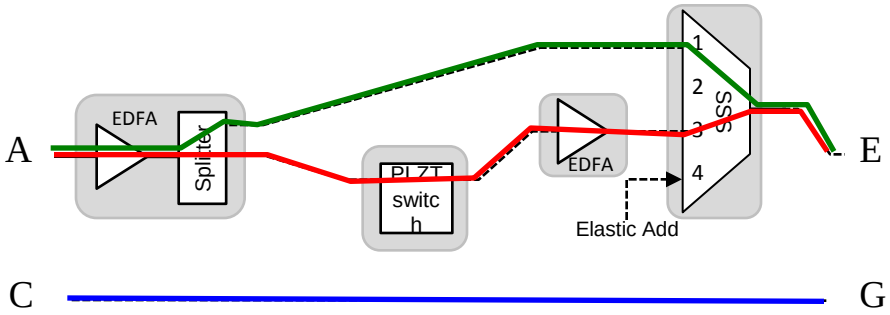


Flexible OXC Configuration

- Backplane implemented with 96x96 3D-MEMS
- Asymmetric configuration per port
- Flexibility to implement and test several switch architectures on-the-fly
- Switching time 20ms





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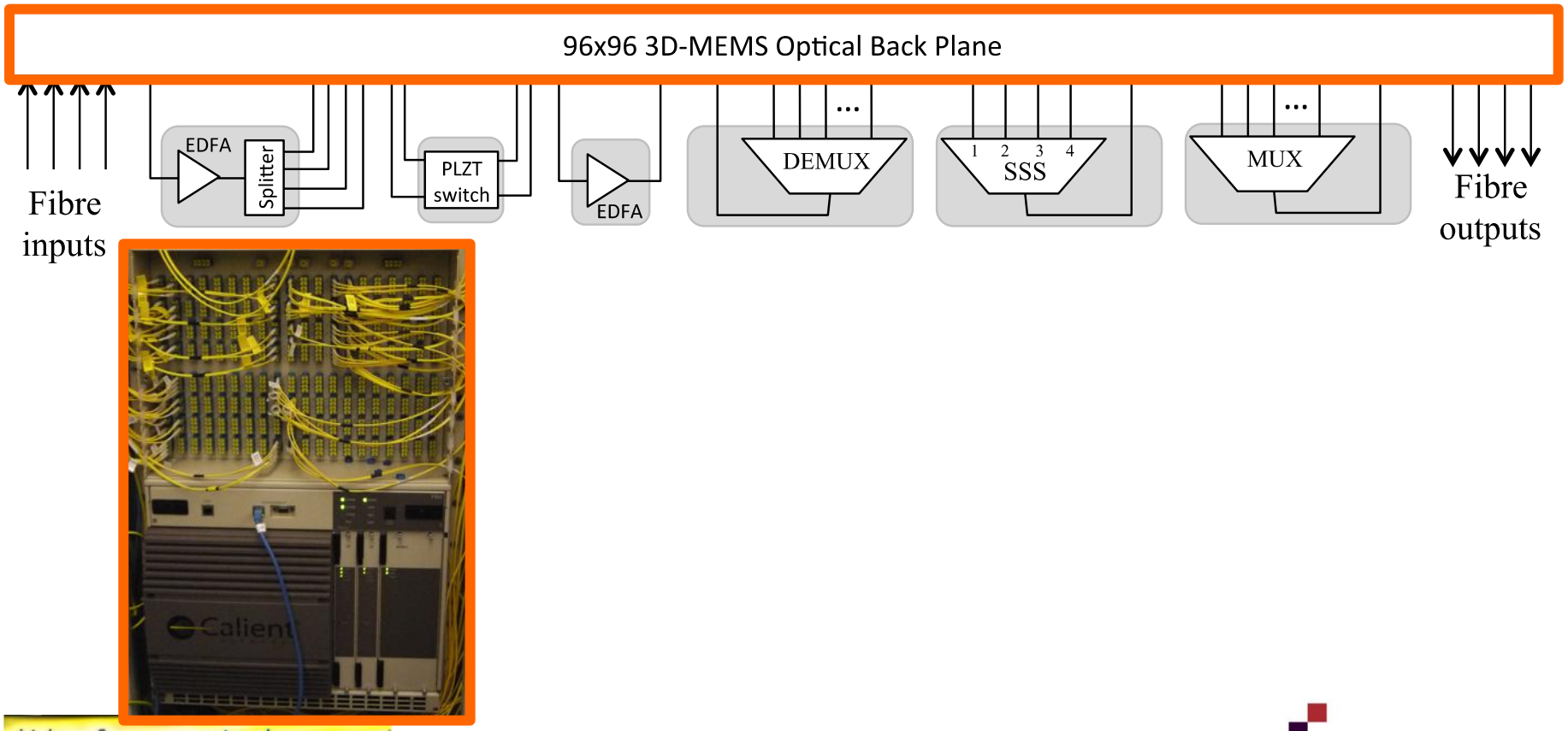

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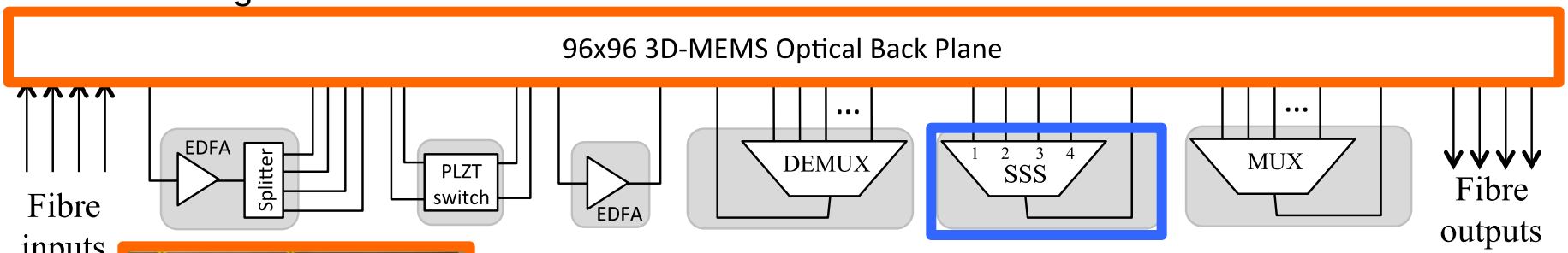

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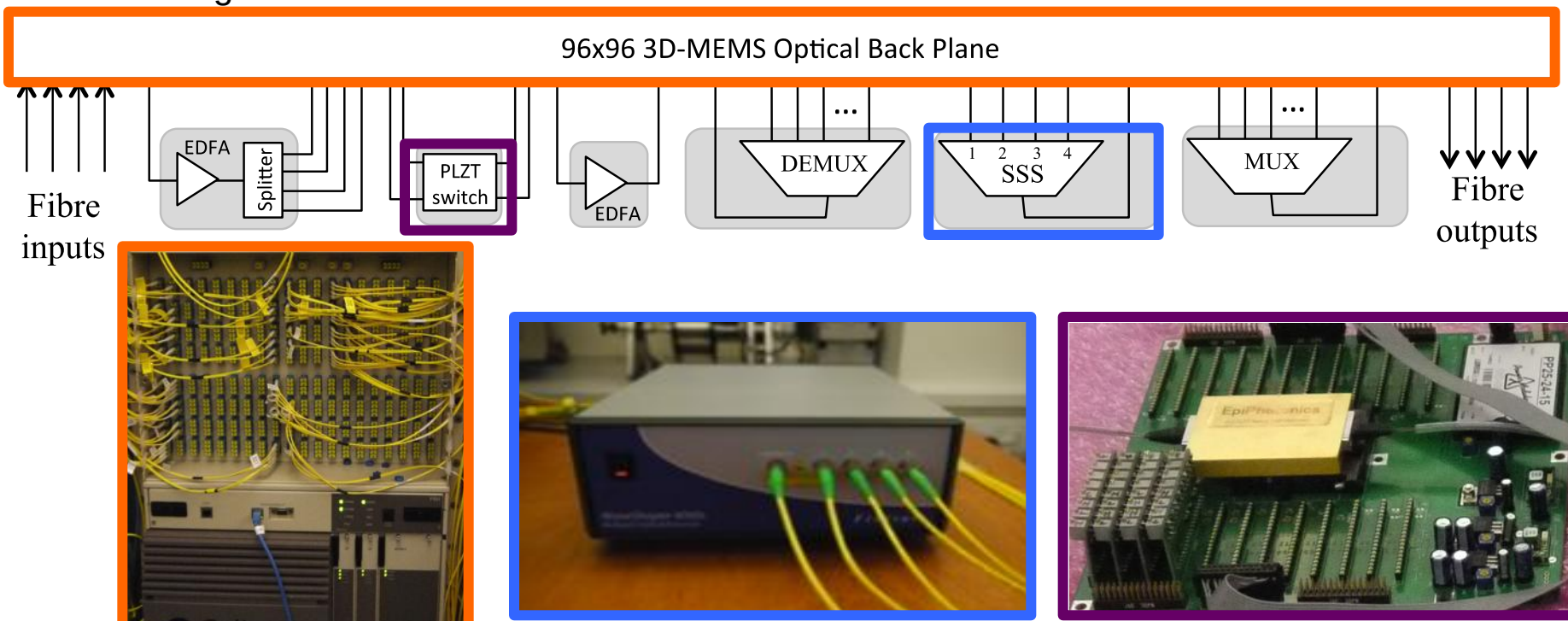

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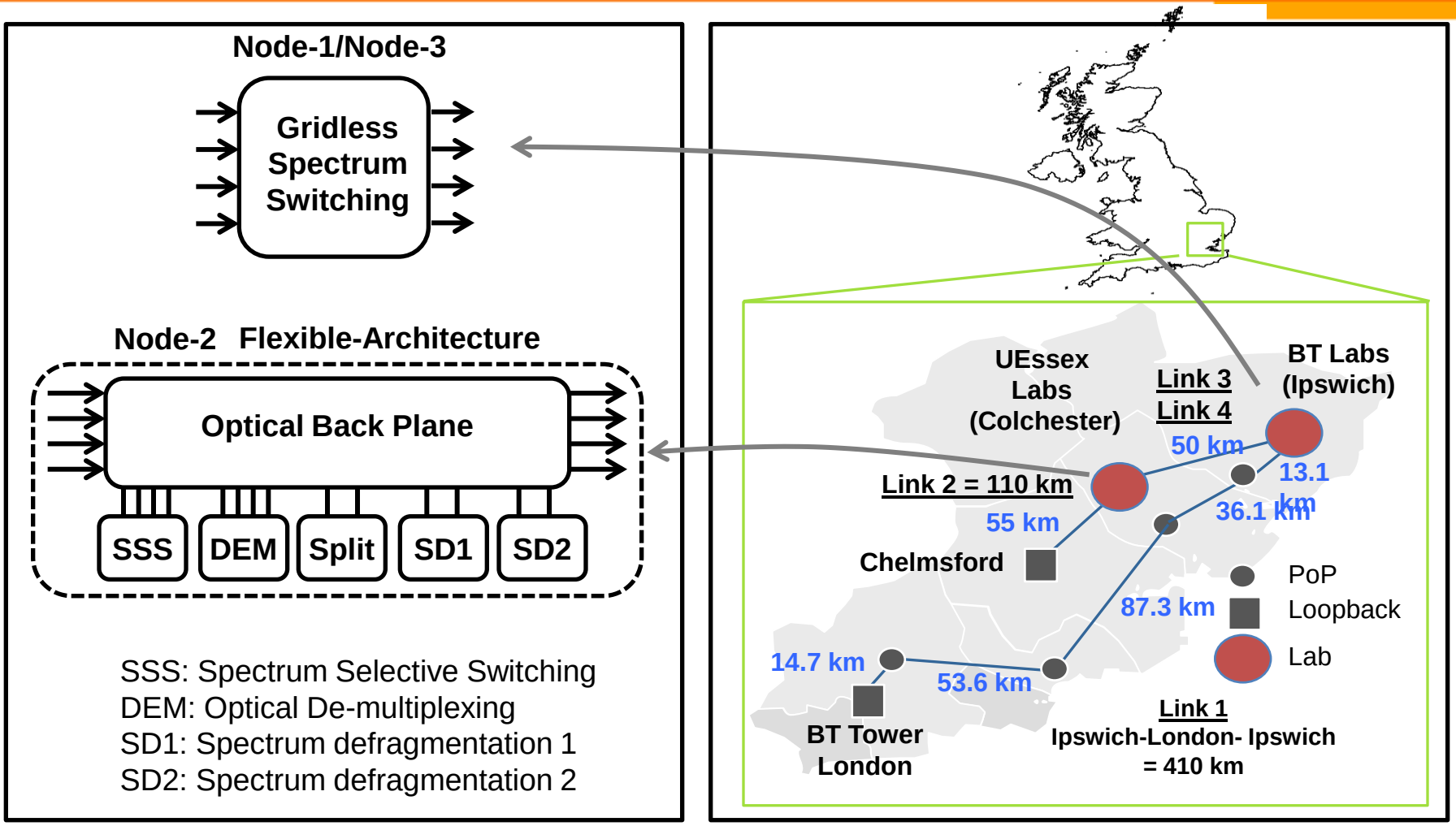
Gridless Optical Networking Field Trial



*N.Amaya, et. al. "Gridless optical networking field trial: flexible spectrum switching, defragmentation and transport of 10G/40G/100G/555G over 620-km field fiber," **ECOC 2011 Postdeadline Paper**,*

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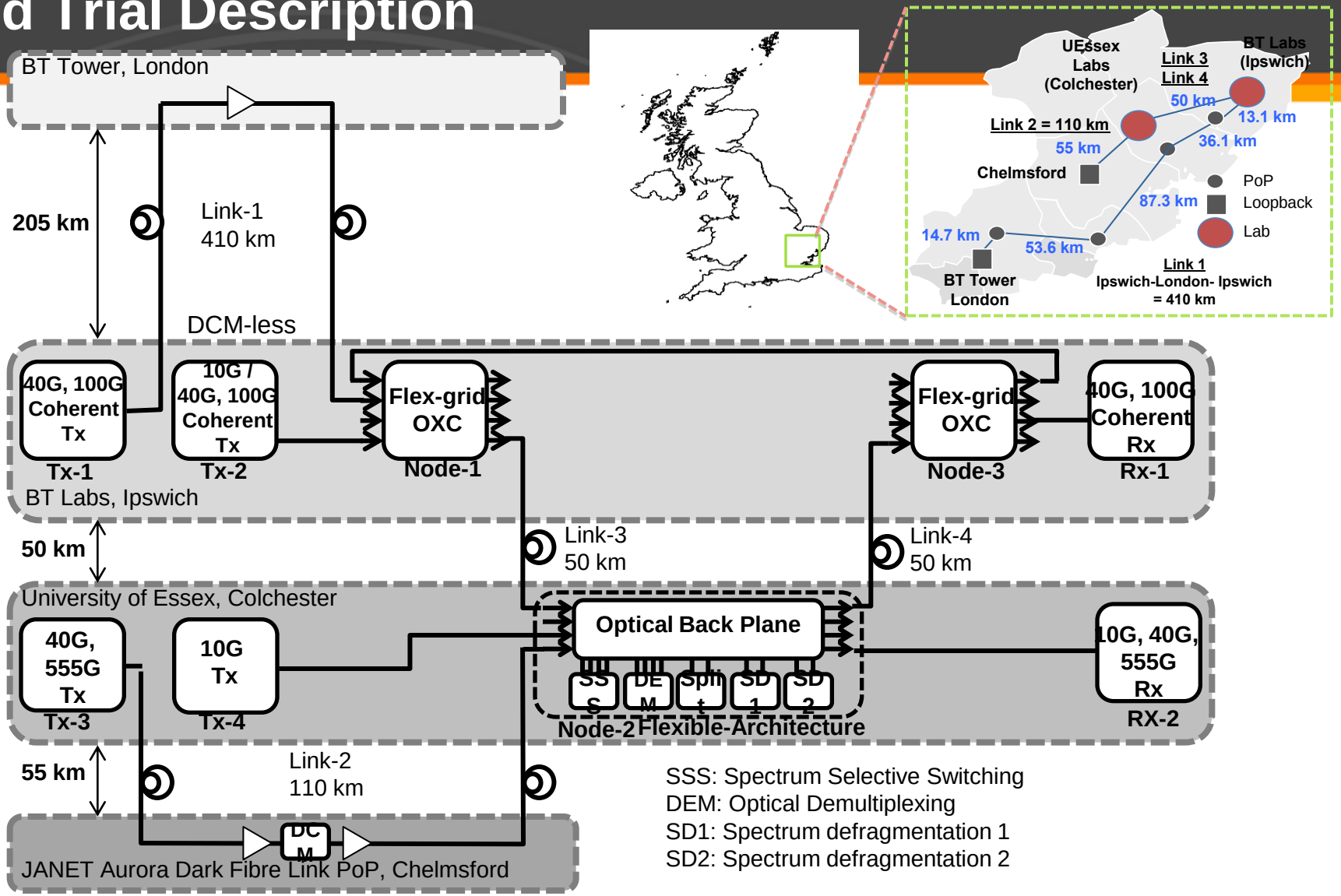
Field Trial Description



SSS: Spectrum Selective Switching
DEM: Optical Demultiplexing
SD1: Spectrum defragmentation 1
SD2: Spectrum defragmentation 2

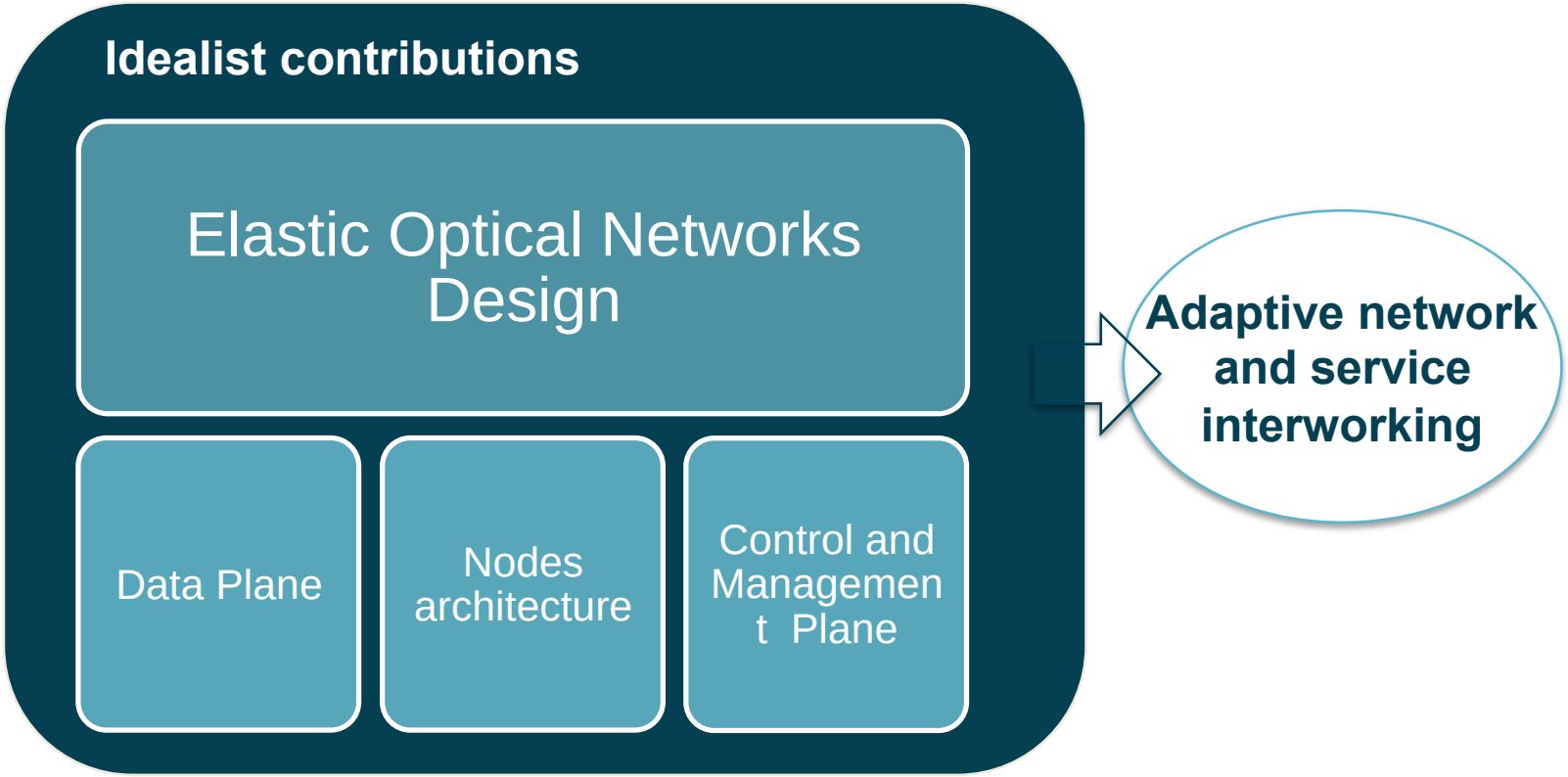
IDEALIST in summary

- Funding scheme: **IP** - Call: **ICT Call 8**
- Duration: **3 years**
- Target budget: **8 M€**
- **Consortium :**

Operators	Telefonica I+D (Spain),	British Telecom (UK),	
	Telecom Italia (Italy),	Telekom Deutschland (Germany)	
Equipment Vendors	Alcatel-Lucent Bell Labs (France)	Ericsson (Italy)	CISCO (Italy)
	Alcatel Lucent (Italy)	Nokia Siemens Networks (Germany)	Nokia Siemens Networks (Portugal)
SMEs	Naudit (Spain)	Old Dog (UK)	Lexden (UK)
Research Centers	CTTC (Spain)	Coritel (Italy)	
Universities	UPC (Spain)	UEssex (UK)	TUE (Netherlands)
	CNIT (Italy)	HHI (Germany)	UoPa (Greece)
	UoP (Greece)	WUT (Poland)	

IDEALIST Overall Objective

- IDEALIST aims at developing pre-commercial data and control plane solutions based on elastic networks enabling adaptive network and service interworking



IDEALIST Specific Objectives

Idealist contributions

Elastic Optical Networks design

Data Plane

- Transmission beyond 400G
- Bandwidth Variable Transponders
- Gridless Switching technologies
- Grooming technologies for elastic networks (e.g IP, OTN, etc)

Nodes architecture

- Core nodes based on bandwidth variable transmission over gridless optical networks
- Metro-Core border nodes enabling metro and core data, control and OAM interworking
- Interconnection between multiple vendors

Control and Management Plane

- GMPLS and PCEP extensions for multivendor elastic networks including multidomain and multilayer aspects
- Dynamic network resources allocation (e.g spectrum) according to traffic patterns behavior

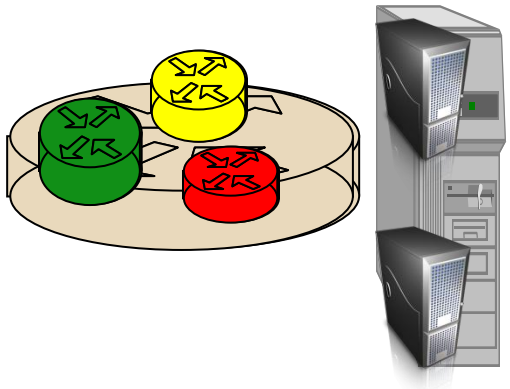
Implementation and demonstration of prototypes
Standardization

Optical Network Virtualisation

(FP7 GEYSERS project)

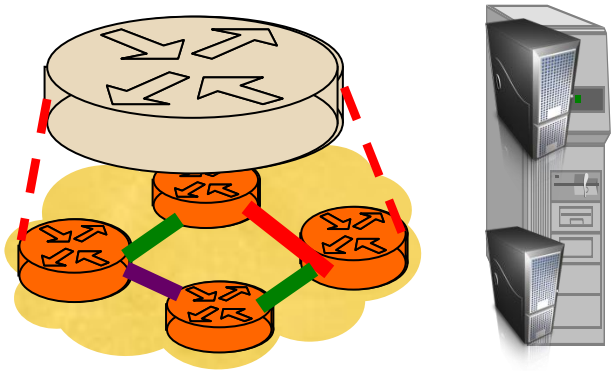
What Is Resource (Infrastructure) Virtualization?

Slicing



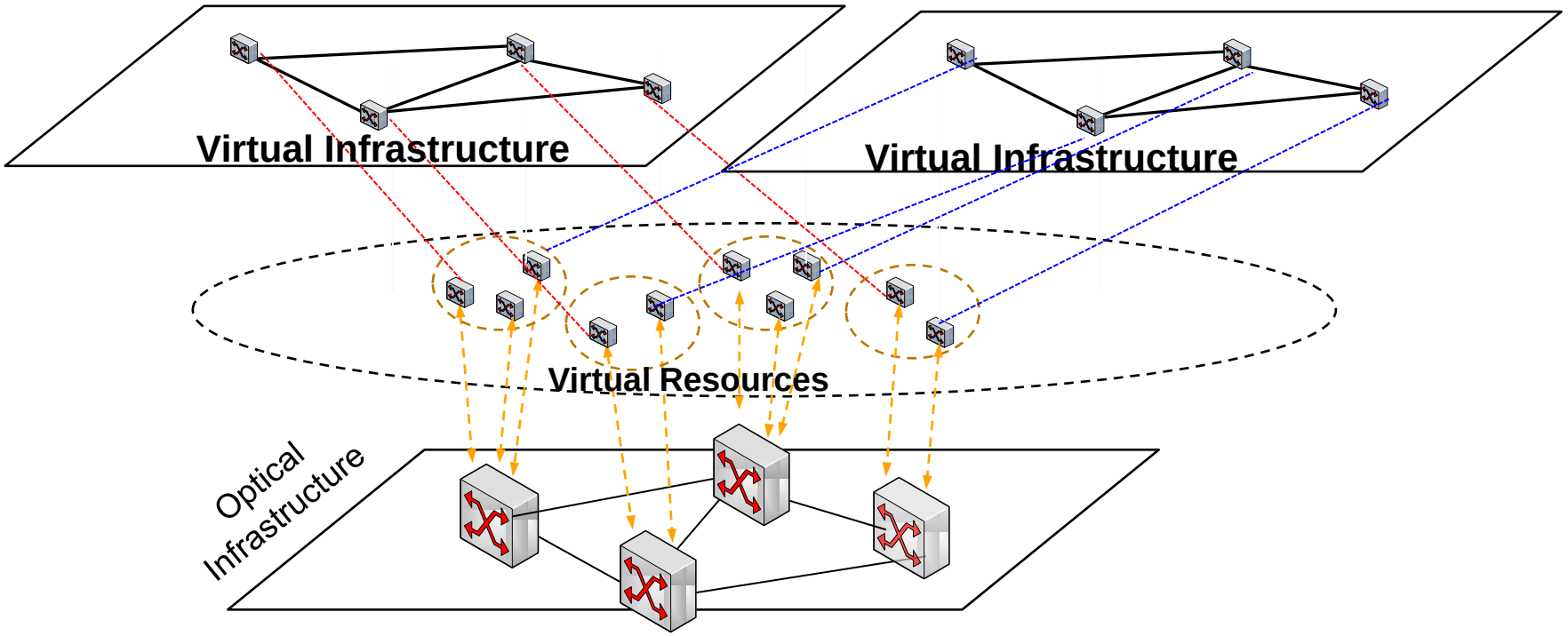
- Network virtualization
  - Router/switch virtualization
  - Bandwidth and connectivity virtualization
  - Layered based Virtualization
    - **Layer1 Photonic**, Layer II CG-Ethernet, Layer III IP

Aggregating



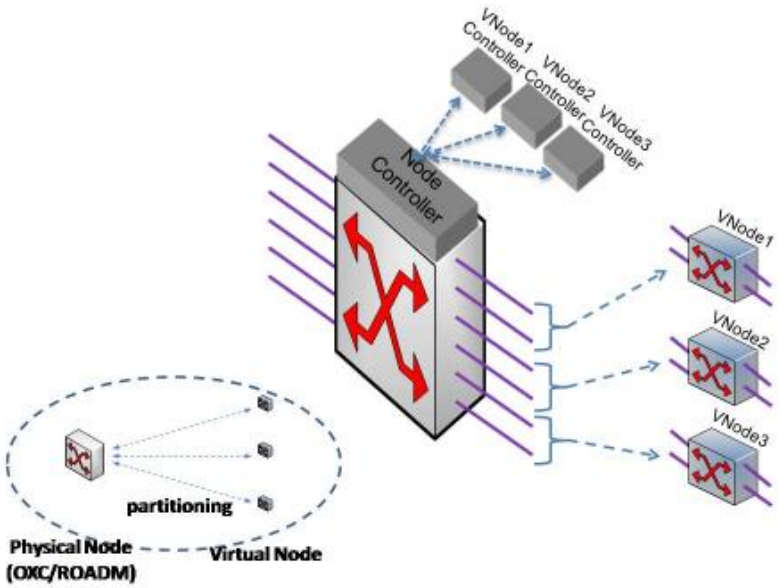
- IT virtualization
  - Hardware virtualization
  - Local computing/storage virtualization
  - Networked computing/storage virtualization

Optical Network Virtualization

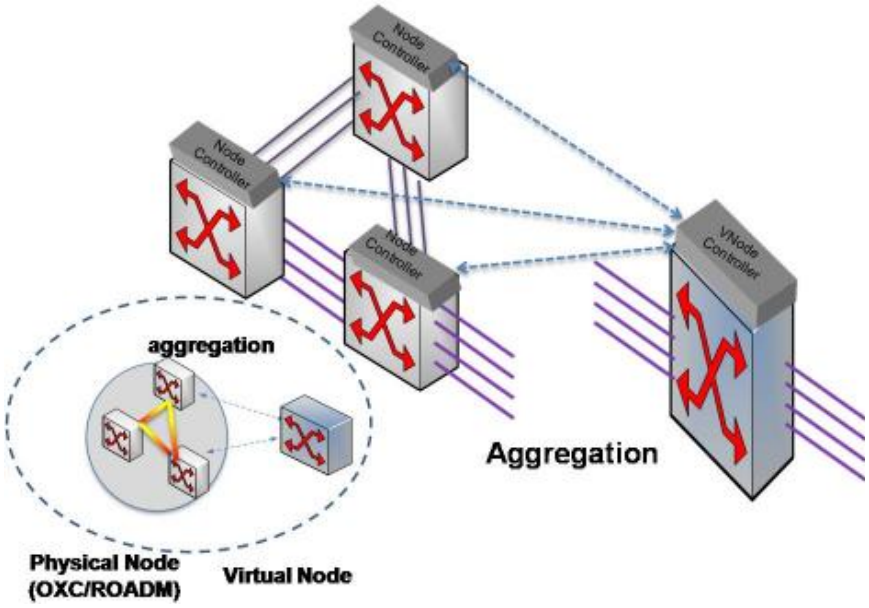


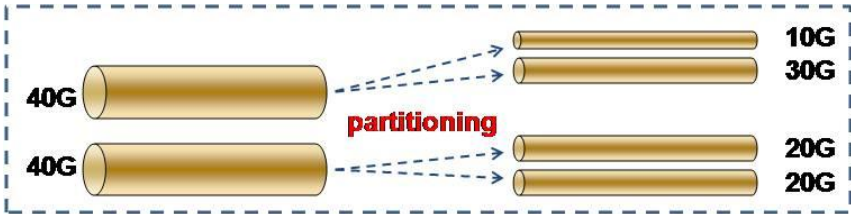
Virtualization of Optical Resources

Optical Resource partitioning



Optical Resource Aggregation





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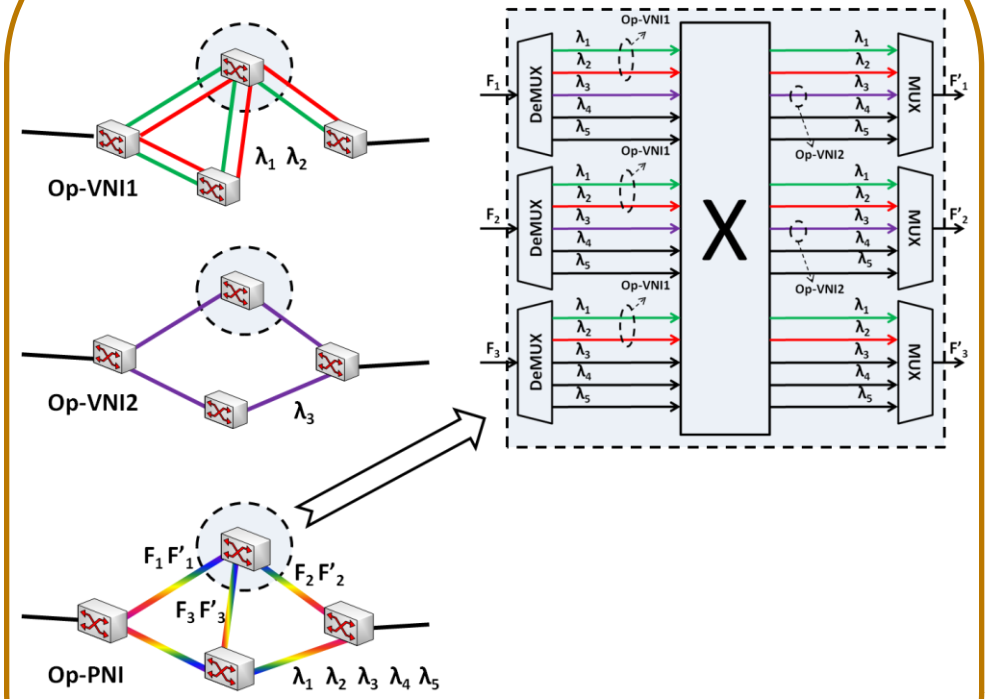
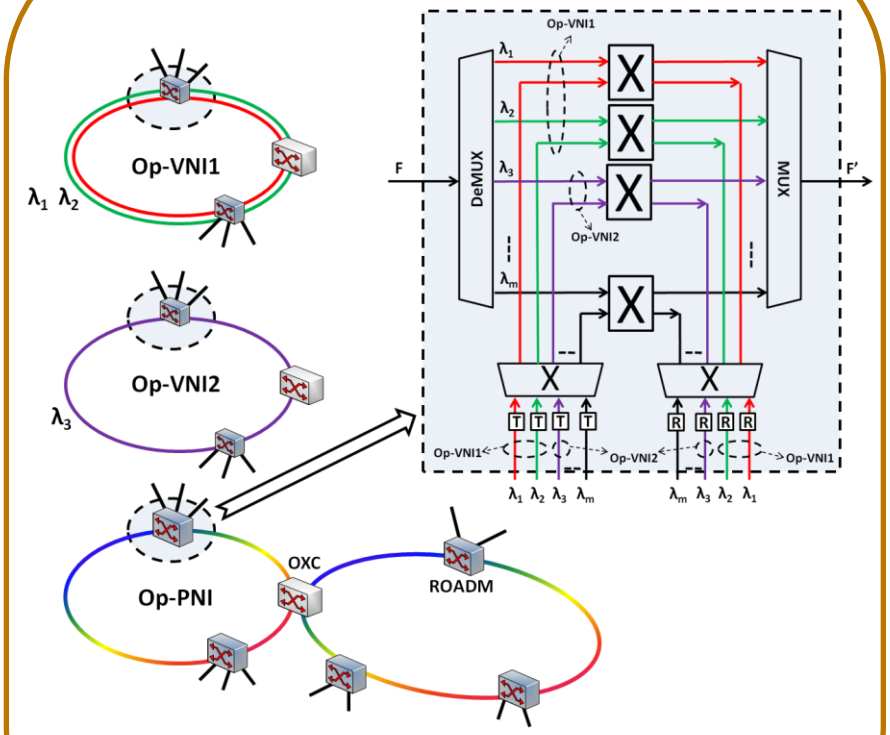
Virtualization of Optical Resources



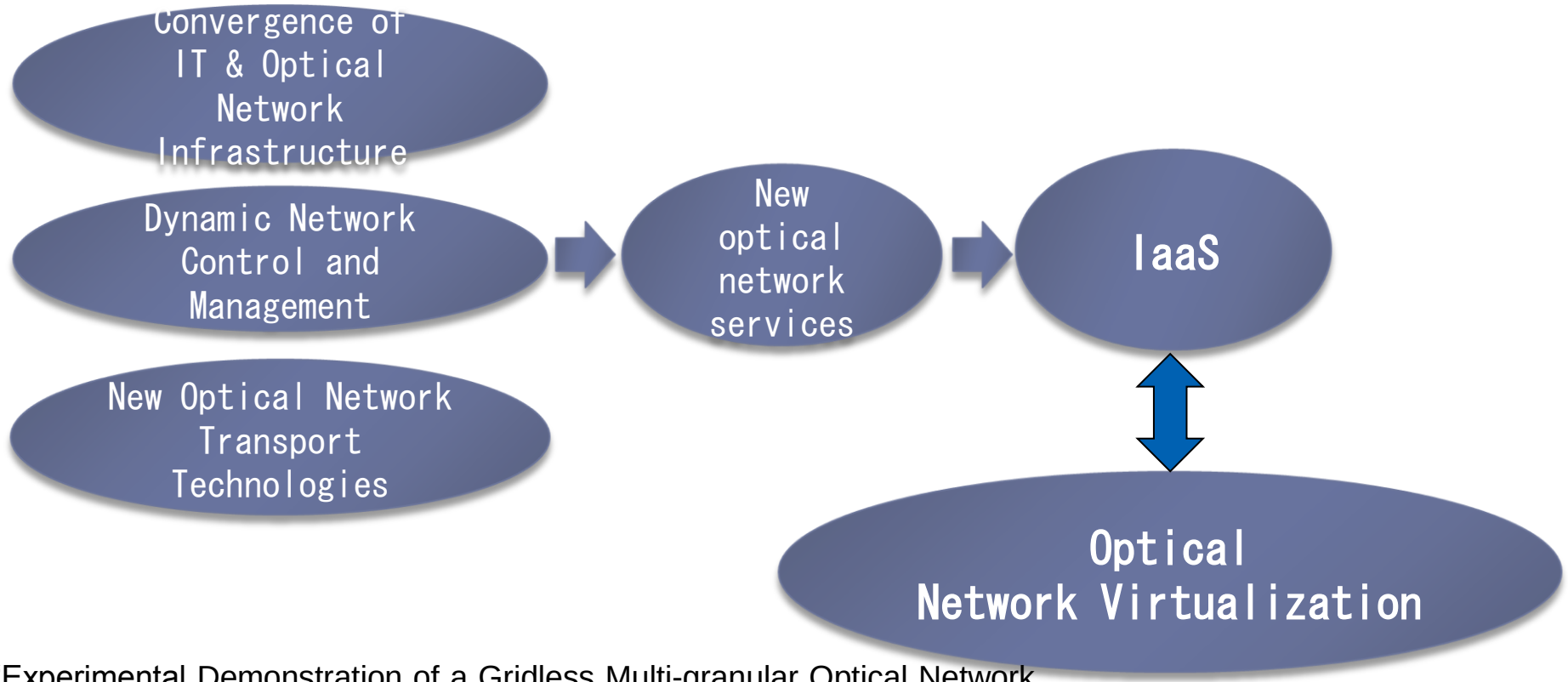
Virtualization of OXC



Virtualization of ROADM

Enablers for Optical Network Virtualization

FP6 PHOSPHORUS and FP7 GEYSERS projects



"Experimental Demonstration of a Gridless Multi-granular Optical Network Supporting Flexible Spectrum Switching", OFC'11

"Field Trial of a 1.5 Tb/s Adaptive and Gridless OXC Supporting Elastic 1000-Fold Bandwidth Granularity", ECOC'11

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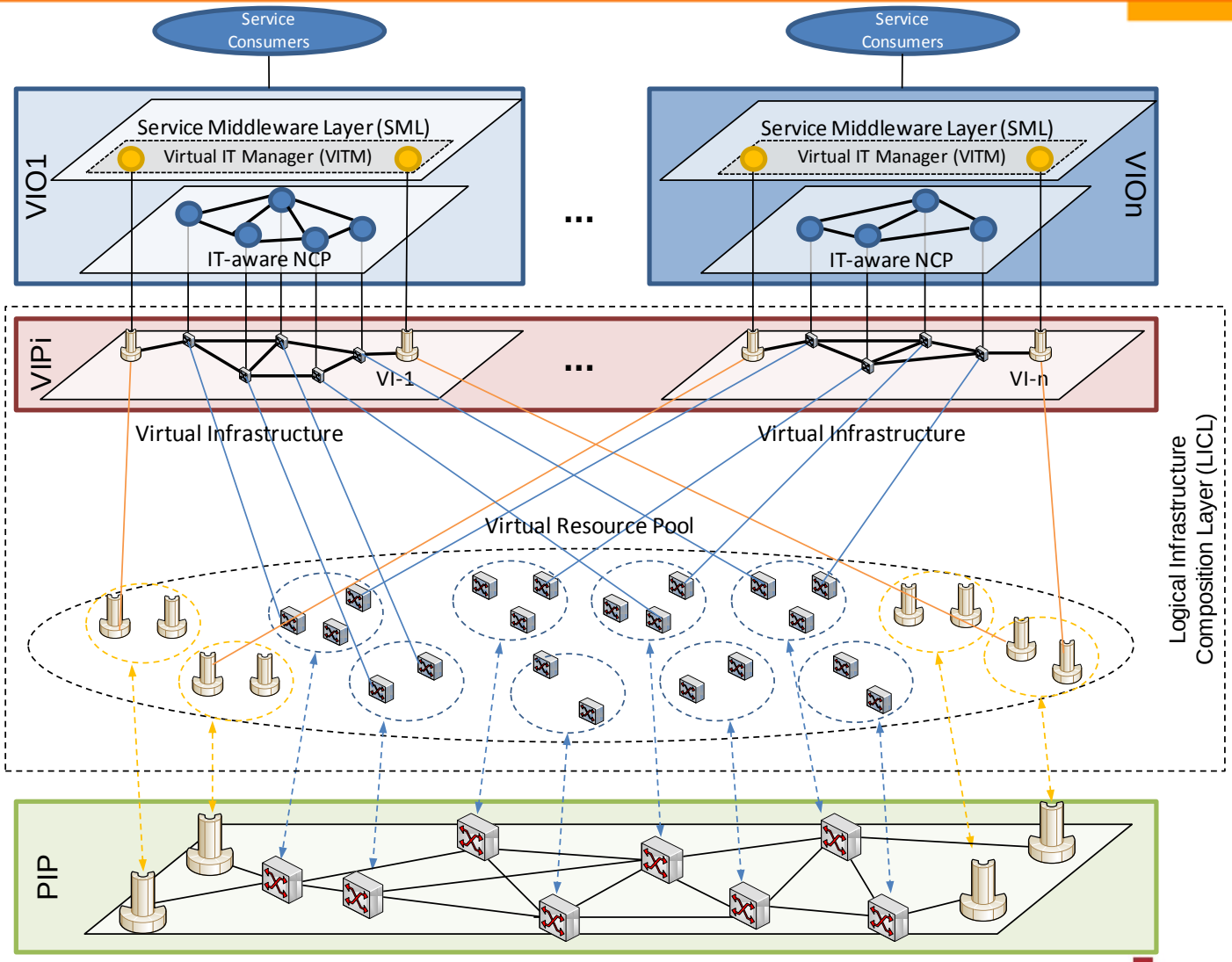
GEYSERS Architecture
Enabled by Optical Network Virtualization



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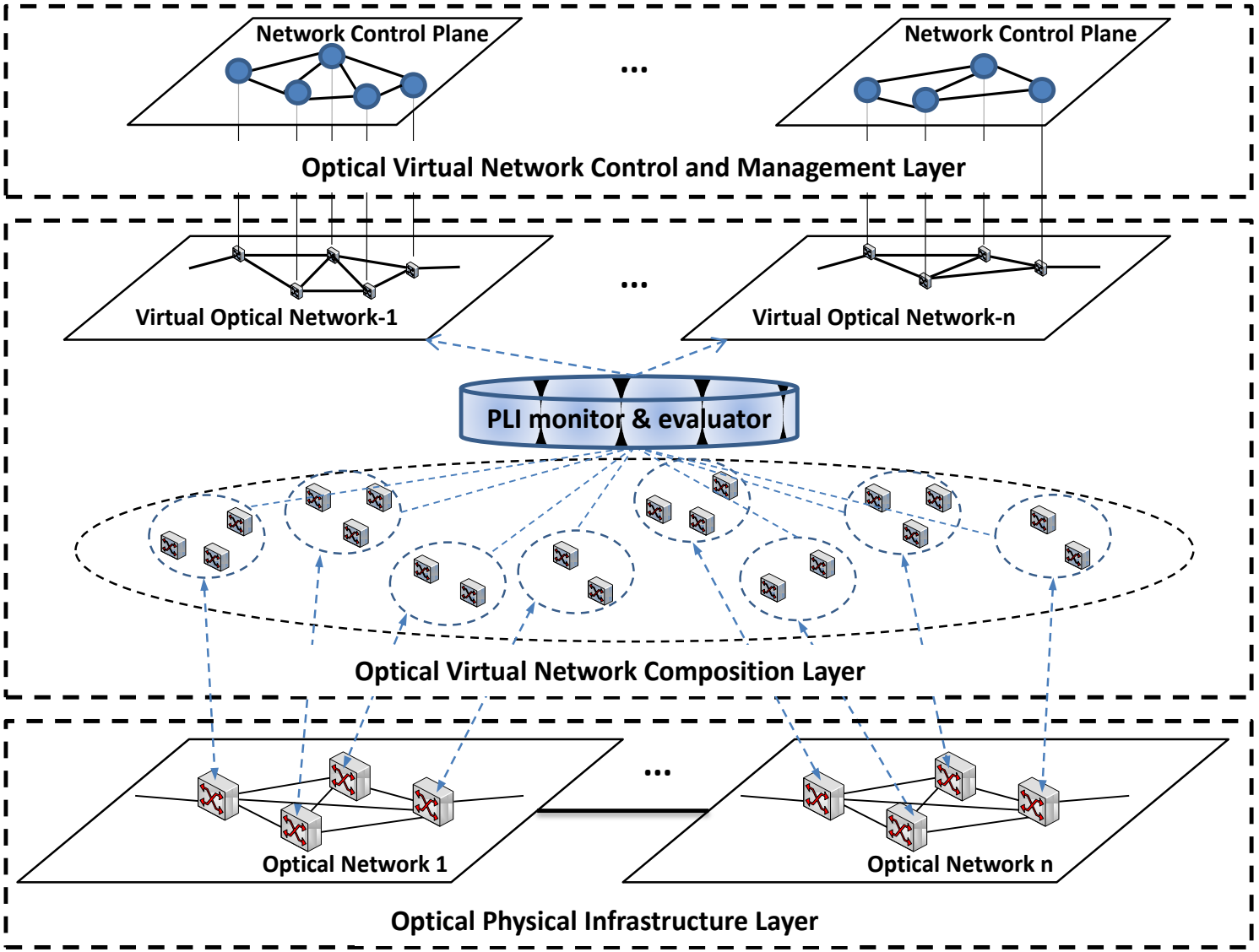
Specific Issues in Optical Network Virtualization

- Optical networks are analogue in nature
  - More complexity than L2/L3 (digital domain) virtualization as a result of physical layer impairments and constraints
  - Slice isolation is a challenge in optical networks
- Physical layer impairments
  - Affect the isolation between VIs
  - Newly composed VIs will affect the existing ones
  - Affect the ultimate feasibility of VIs
- Wavelength continuity constraint
  - Affect the network resource utilization

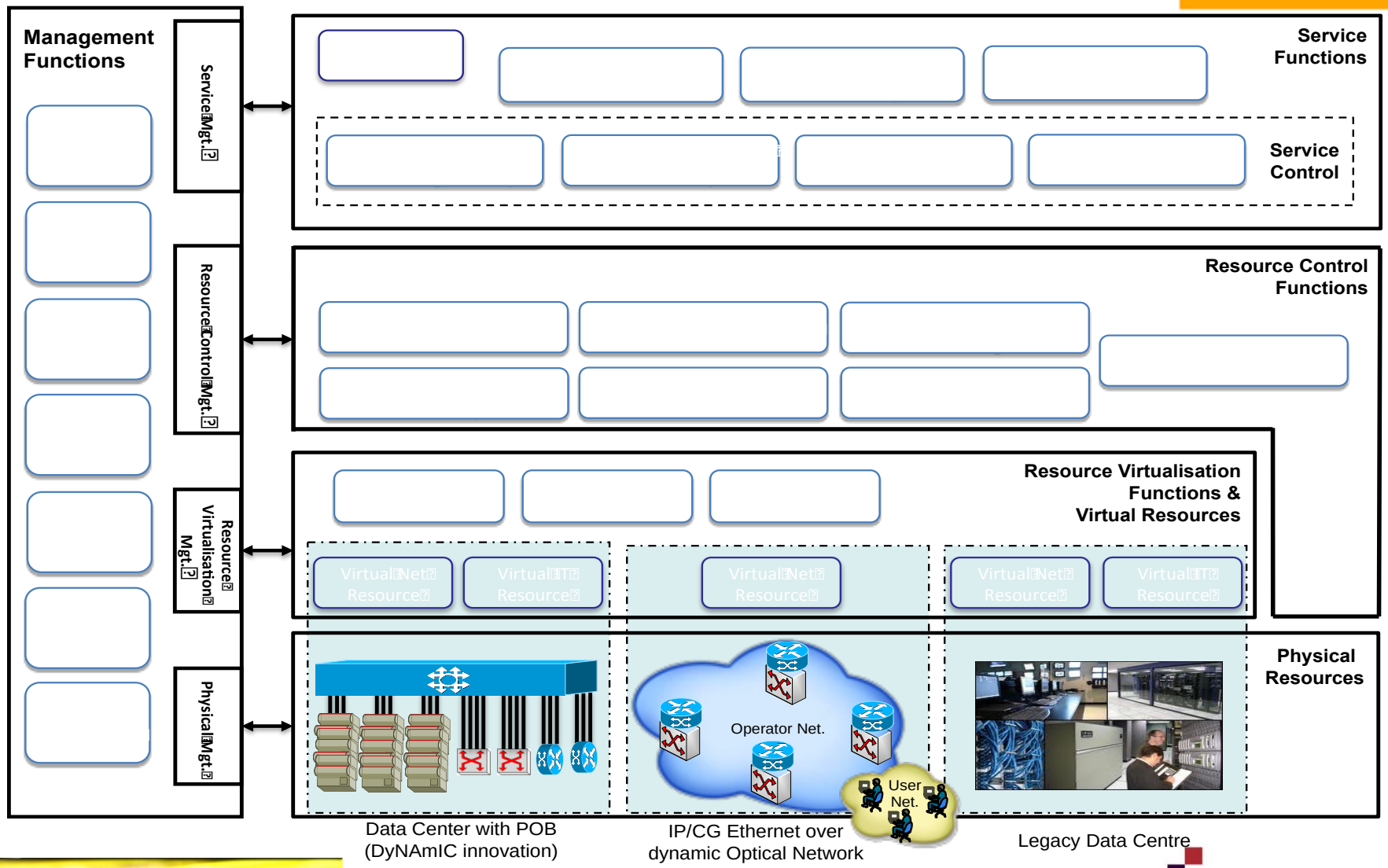
Relevant Contributions from GEYSERS

- Optical network virtualization aware of PLIs
- PLI-aware virtual optical network composition
  - Q tool to assess the PLIs
  - PLI-aware wavelength assignment
- Virtual optical network mapping
  - Direct mapping
  - Indirect mapping
    - Shortest path routing algorithm
    - Mixed ILP
- Energy efficiency in integrated IT and optical network infrastructures

IaaS Architecture Enabled by Optical Network Virtualization Aware of PLIs



DyNAmIC: Datacenters and Network infrAstructures coordInation for Cloud service delivery (FP7 Call 8)



Thank you