Orchestration of Ethernet services in software-defined and flexible heterogeneous optical networks – the EU/JP Project STRAUSS

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Outline

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* Latest Research Highlights: OFC Post-Deadline Paper
* Conclusions

http://www.ict-strauss.eu  @ICTstrauss
Project Name: Scalable and efficient orchestration of Ethernet services using software-defined and flexible optical networks.

Acronym: STRAUSS

Call identifier: FP7-ICT-2013- EU-Japan (Coordinated EU-Japan Call)

Funding scheme: STREP

EU Project Coordinator: Dr. Raul Muñoz. Centre Tecnològic de Telecomunicacions de Catalunya (CTTC)

JP Project Coordinator: Prof. Ken-ichi Kitayama. Osaka University

Duration: 36 months (1st June 2013 – 31st May 2016)

Total Cost: € 5,033,882.

EC Contribution: € 1,498,990.

JP Contribution: € 2,820,000

Project website: www.ict-strauss.eu
Organization of the consortium

EU CONSORTIUM
* CTTC (ES)
* ADVA Optical Networking (DE),
* Telefónica I+D (ES)
* University of Bristol (UK)
* Fraunhofer – HHI (DE)

JP CONSORTIUM
* Osaka University
* KDDI R&D Laboratories Inc.
* Fujitsu Ltd.

![Map of Europe and Japan showing locations of universities, research centers, and industrial partners.](image)
STRAUSS Project Objectives

Design, Integration and Development of

* **Optical Packet Switching (OPS)** nodes for aggregation networks
* **Flex-grid DWDM Optical Circuit Switching (OCS)** for metro and long haul transport
* **Virtualization layer for** dynamic and on-demand partitioning of the optical infrastructure, offering **virtual optical Ethernet transport networks** (slices)
* Legacy (e.g. GMPLS) and new (e.g. OpenFlow based) **control plane** approaches for the control and management of virtual slices
* **Service and network orchestration layer**
  * interworking and coordination of heterogeneous control plane and transport technologies to offer **end-to-end Ethernet transport services.**
The need for >100Gb/s optical Ethernet transport over EON and OPS

- An efficient transport infrastructures for > 100Gb/s Ethernet services is the adoption of Ethernet as the technology of choice in data centers
- Fixed-grid DWDM networks, EPS networks and aggregation technologies are not efficient for data rates > 100 Gb/s
- Elastic optical networks (EON) and optical packet switching (OPS) networks based on bandwidth variable transponder (BVT) are key technologies

**Challenge:** Multi-domain multi-technology network orchestration
The need for optical network virtualization

- Each data center service has its own specific QoS and SLA requirements.
- Network operators require dedicated and application-specific optical networks.
- Optical network virtualization is a key technology for addressing this issue.
The need for software defined optical network

- Each network uses a control plane (e.g. OpenFlow or GMPLS) for the provisioning of dynamic, adaptive and fault-tolerant network services.
- A physical infrastructure comprising heterogeneous optical transport and control plane technologies does not naturally interoperate.
- Software defined Networking (SDN) is a key technology for addressing this issue.
STRAUSS Architecture

SDN-based Service and Network Orchestrator

Network Control & Management
GMPLS

Virtual Transport Infrastructure 1

Virtualization Visor (Abstraction, Partitioning, Composition)

Virtual Resources Pool

OPS
OPS/OC (BVT)

Flexi-grid OCS Domain 1
Flexi-grid OCS Domain 2

Network Control & Management
OpenFlow

Virtual Transport Infrastructure n

End-to-end Orchestration

Virtual Infra. Ctrl & Mgt

Transport Virtualization

Transport Infra.
Flexible Optical Infrastructure Solutions for Ethernet Transport

- **Optical Packet Switching (OPS)**
  - Variable-length (= variable-bandwidth) electrical packets are converted to fixed-length optical packet based on multicarrier technology (OFDM/DMT)
  - VB-FL optical OFDM packet significantly eases optical buffer management while achieving the statistical multiplexing effect

- **DMT Transceiver**
  - Discrete Multi-Tone modulation (DMT)
  - Advanced modulation format realized by digital signal processing (DSP)
  - Multi-carrier modulation format maximizes spectrum utilization
Flexible Optical Circuit Switched (OCS) Transport Networks

Optical transport networks provides dynamic, high bandwidth, programmable services for Ethernet Transport
Symbol rate (SR) is an additional parameter:
- 400G leverages 100G (~30GBd)
- 1T needs 2-3x SR (~75GBd)

Future higher-speed channels

Maximum spectral efficiency super-channels

Optical Spectrum as a Service

Flexible Grid Optical Layer

Optical Power

λ nm

50GHz spaced channels

Future higher-speed channels

Content A

FlexGrid scalable Virtual Capacity

Content B

Virtual Private Capacity Flexible Bandwidth

Provider

Carrier

Content A

Content B
Optical Node Configuration

Optical Performance Constraints
Sequential Lightpath Setup/Teardown
Optical Power Balancing

Connectivity & Topology Discovery
Signal Mapping & Format Compatibility
In the SDN architecture,
• the control and data planes are decoupled,
• network intelligence and state are logically centralized,
• and the underlying network infrastructure is abstracted from the applications.

Facilitate optical layer virtualization & programmability based on HW abstraction
Optical transport and SDN
Direct vs. Indirect Model

- How to best extend SDN to transport layer?
- Direct control yields potential benefits at cost of complexity and latency
- Indirect control is easier to implement, and provides a migration path
- **Network Hypervisor** key element to provide network abstraction, virtualization, and multi-tenancy in abstract model and leverage existing control plane protocols

Finding the appropriate level of abstraction is key to virtualization.
Abstract Model –
Topology Virtualization Options

Virtual Node
- Hierarchical abstraction
- Presents subnetwork as a virtual switch
- Simple model, but can be deceptive
  - No easy way to advertise “limited cross-connect capabilities”

Abstract Link
- “You can reach this destination across this domain with these characteristics”
- Paths in the optical domain become links in the virtual topology
- Allows vendor independent constraint modelling

Virtual Node aggregation hides internal connectivity issues and physical constraints

Abstract Link aggregation needs compromises and frequent updates

See also: Aihua Guo, "Network Virtualization", OFC 2014, Monday, M2B.5
Optical Network Hypervisor

WAN is exposed as abstracted virtual topology
Network Virtualization Testbed
Orchestration in OpenFlow-based OPS-EON international network demonstrator

SDN Network Orchestration

Elastic Optical Network with OPS interface

OpenFlow-based OPS
Distance-adaptive-DMT-based OPS with OpenFlow control

- Fixed-length optical packet eases optical buffer scheduling
- Payload capacity is maximized based on (expected) distance to the destination
- Sophisticated NW control is required to gain statistical multiplexing effect
SDN network orchestration

- Application-Based Network Operations (ABNO)
  - ABNO controller
  - PCE, includes OF extensions
  - Topology Server
  - Provisioning Manager

OpenFlow-based OPS

- OpenFlow **OPS** Controller
  - Trema with OpenFlow OPS extensions (including OPS label)

OpenFlow **EON** Controller

- Optical OpenFlow extensions (Frequency Slot allocation)
* STRAUSS demonstrated a multi-domain multi-technology network orchestration of Variable-capacity OPS over Programable Flexi-Grid EON

* Data plane achievements:
  * 46-108Gb/s distance-adaptive DMT-based FL-VC OPS
  * Integrated OCS/EON programable node with real-time OPS-EON interface
  * Flexi-Grid Network Function Programable node

* Control plane achievements:
  * OpenFlow-based OPS Controller
  * Flexi-Grid SDN Controller
  * Application-Based Network Operations for network orchestration

* This could serve as an architecture for elastic-bandwidth slice provisioning with the finest data granularity for SDN applications.
SDN enables Optical Network Operation and Control Innovation

Datacenter Connectivity

- Tenant A cloud
- Tenant B cloud
- Tenant C cloud
- DC Site 1
- Enterprise
- DC Site N

Network Virtualization &

- OpenFlow with Extensions
- Restful API

Multilayer Optimization

Open Application Framework

- ADVA Applications
- APIs
- ADVA WAN Orchestration
- DC Orchestration
- SDN Controller
- MPLS
- Network Function Virtualization
- Network Optimization
- Network Interworking
- Ethernet
- SDN Overlay
- Inter-DC Management
- Bandwidth Management
- Optical
- Access
- Metro/ Core
- Datacenter
Network Operation Evolution with Software Defined Networking

- Abstraction & Virtualization
- Network Programmability
- End-to-End Service Orchestration

Shortened time-to-market of networking applications by optical network virtualization based upon cost/energy-efficient OPS/OCS based Ethernet transport
Thank you!

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