Photonic SDN Models for Disaggregated Optical Networks – Insights and Results from the SENDATE Multivendor Field Trial

Achim Autenrieth, Anders Lindgren, Jonas Mårtensson, Martin Skorupski, Hanif Kukkalli, Mohit Chamania, Filipe Caetano, Dmitry Khomchenko, Stefan Melin, Roope Tanner, Anders Gavler, Herbert Eiselt, Jörg-Peter Elbers, Antonio Felix, Thomas Luipold, Rainer H. Derksen, Ulrich Häbel, Stefanos Dris, André Richter

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Outline

1. Trends in optical networking
2. SDN models for disaggregated photonic networks
3. SENDATE multi-vendor field trial & interop events
4. Results and Outlook
Major trends in optical networking

Network architecture

• Open optical networking
• Disaggregation

“Hard facts”

• Compact, high-density HW
• 400G+ per wavelength
• High-order modulation
• Flexible grid spectrum

“Soft facts”

• Programmability on network, device and port level
• Network automation during set up and operation

From “fix and forget” to programmable flexibility and scalability
Openness drives disaggregation
Disaggregation models and benefits

**Full disaggregation**
All devices as separate managed elements

**Partial disaggregation**
Terminal and Open Line System (OLS) as separate elements

**Benefits**
- Enables flexibility to deploy best-in-class equipment
- Facilitates multi-vendor environments
- Avoids implementation lock-ins
- Triggers innovation and evolution
- Accommodates different lifecycles

Separation of terminal and OLS is most common
Advances in technology: Ultra-flexible terminals

Software defined interfaces

Channel rate – flexible wavelengths

Modulation – with interleaving (hybrid)

Symbol rate – tunable Baud rate

Shaping – channel adaption

Superchannel capacity – multiple lambdas

FEC – ultimate gain and options

Flexibility is key for disaggregated networks – and cost efficiency
Programmability and automation via open APIs

Variety of legacy and SDN APIs
Configuration & monitoring in disaggregated networks

High flexibility and OLS complexity requires abstraction and open APIs

Disaggregated Transponder
- OTSi - Optical tributary signals
- Channel rate
- Frequency
- Spectral width
- Modulation
- Symbol rate
- Roll-off
- FEC
- Transmit power

Client counters (RMON)
- client vs network

Frequency offset equipment

PDL & PMD polarization effects

SOP
- e.g. lightning strikes

CD link length

TX / RX power connection

Terminal

LLDP peer device

ODUk subnets

FEC BER & Q factor
- general events

SNR & OSNR
- loss and amplification

CD

EVM* vs SNR
- nonlinearity and filters

Terminal

Service connectivity
- Client → Network

Network connectivity
- WSS, EDFA, ...

EVM* vs SNR *Error Vector Magnitude

*High frequency offset equipment

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The challenge ahead ...

**Standardize control of Transponders**
- Configuration of multiple layers like Photonic Media, OTN, and Ethernet
- Effectively describe and configure relationship between Client and Network ports
- Monitoring capabilities for ensuring valid operation

Path computation and provisioning in (multiple) Open Line Systems
- Evaluate optical performance of paths in optical networks
- Establish optical paths in the network using an SDN controller
- Potentially extend this to a multi-vendor multi-domain configuration

Ensure interoperability through proof of concept and interop events
- SENDATE field trial
- ONF Wireless Transport PoC 5.0
- ONF Open Disaggregated Transport Network Project
Overview SDN standard bodies and data models

Standards Defining Organizations (SDOs)

- IETF TE Tunnels
- IETF Network
- IETF Network-Topology
- IETF TE Topology
- IETF Flexi-Grid TED
- IETF Flexi-Grid media channel
- IETF WSON Technology

ONF Transport-API

ONF Core Model

ONF Transport-Effects:
- Topology
- Connectivity
- Path
- Computation
- Virtual
- Network
- Notification

Industry Alliances

- Lead: Google
  - Telemetry

- Lead: AT&T
  - Services
  - Network
  - Device

Opening LSO
Lifecycle Service Orchestration

MEF

OPENCONFIG

OPENROADM
ONF Core Model

ONF TR-512 Core Information Model v1.4

Core Model simplified

Network Control Domain

Forwarding Domain

Link

Logical Termination Point

Forwarding Construct

Scope of Control

Forwarding element

Adjacency between FDs

Termination and adaptation

Potential for forwarding

Model of data plane resources in an SDN-enabled network

- Technology agnostic
- Recursive (Forwarding Domain may contain FDs)
- Models static and dynamic elements
- **Extensible** to different technologies and environments

TR-512.A.4 applies the Core Model for photonic networks (**Photonic Media Model**).

This work has been used extensively by MEF and Facebook TIP

Open Transport Configuration & Control Lyndon Ong (Ciena), 12 Dec 2017
ONF Core Model

- Can be applied to a wide range of application scenarios. Demonstrated applications include:
  - Ethernet switching configuration
  - OTN switching/multiplexing configurations
  - Precision Timing Protocol propagation
  - **Photonic media configuration and monitoring**

- Conditional package definitions improve extensibility:
  - Network element definition remains unchanged and does not require frequent updates
  - Conditional packages can be introduced and updated incrementally
ONF Core Information Model

Designed for extensible network element presentation

Layer specific information presented using conditional packages

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- 
- 

Conditional Packages

- 
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Conditional Packages

- 
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Conditional Packages

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Interconnections presented using forwarding constructs

Port Presentation with logical termination points
## ONF Photonic Media Model for Open Terminal APIs

Conditional Package developed using ONF T-API constructs

<table>
<thead>
<tr>
<th>Interface Capability</th>
<th>Interface Configuration</th>
<th>Interface Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Supported Channels / Grids</td>
<td>- Configured Channel/Grid</td>
<td>- Current Channel/Grid</td>
</tr>
<tr>
<td>- Supported Modulation Formats</td>
<td>- Modulation configured</td>
<td>- Current Modulation</td>
</tr>
<tr>
<td>- Supported Applications</td>
<td>- Laser Control</td>
<td>- Received/Transmitted Power</td>
</tr>
<tr>
<td>- Optical Power Threshold limits</td>
<td>- Receive Power Threshold Configuration</td>
<td>- Current Laser Status and PMs</td>
</tr>
<tr>
<td></td>
<td>- Transmit Power configuration</td>
<td>- Bias Current</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Temperature</td>
</tr>
</tbody>
</table>

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<tr>
<th>Current Problems</th>
<th>Current Performance</th>
<th>Historical Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Alarm list with severity and description</td>
<td>- Optical Transport Performance data</td>
<td>- List of historical Optical Transport Performance data</td>
</tr>
<tr>
<td></td>
<td>- Pre-FEC BER</td>
<td>- Pre-Post FEC BER</td>
</tr>
<tr>
<td></td>
<td>- Post-FEC BER</td>
<td>- Corrected/Uncorrected bits/bytes</td>
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</tr>
</tbody>
</table>

- Current Problems
- Current Performance
- Historical Performance

- List of historical Optical Transport Performance data
  - Pre-Post FEC BER
  - Corrected/Uncorrected bits/bytes
Industry Progress on Info Models & API Alignment

- **TELECOM INFRA PROJECT**
  - OpenOLS, OpenDevice

- **OPENCONFIG**
  - Transponder Control

- **ONF**
  - CIM
    - TAPI 2.0, 2.1, ...

- **OIF**
  - TAPI 2.0 Interop Demo

- **ODTN**
  - 1.0, 1.5, 2.0...

- **OpenROADM**
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Disaggregated single-domain SDN control

Integration with SDN Orchestators
- Interact with domain controllers using standard protocols
- ONF T-API with extensions to report optical path characteristics used to request and configure lightpaths

Single Vendor Open Line System
- Capability to add/drop and route channels
- Control of individual equipment via vendor domain controllers using custom protocols
Disaggregated multi-domain SDN control

Challenges
- End-to-end path calculation by orchestrating domain specific path computation
- Optical reach validation using optical impairment parameters exposed by domains.
- Orchestrating provisioning across multiple domain controllers
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SENDATE Multi-vendor Field Trial (Sep. 2018)

Open, Disaggregated Network Control

- 2 vendor domains
- Coherent 100G interfaces
- Transparent optical interconnect
- ONF Transport API 2.0 with optical extensions (photonic media model)
**SENDATE trial - Multi-domain provisioning**

**Lightpath provisioning workflow**

1. Planning app receives topologies and wavelength occupancy from domain controllers + inter-domain links from a database.
2. It receives request for a new connection from user of the northbound rest client.
3. It then computes a number of possible paths and assigns available wavelengths.
4. Computed paths are split into one segment per domain and planning app requests OSNR for all segments using a TAPI extension.
5. Planning app calculates end-to-end OSNR.
6. It reports all feasible paths along with OSNR to the northbound rest client.
7. User selects one of the paths which is activated by the planning app via domain controllers using TAPI including extension for wavelength configuration.
SENDATE trial - Test case examples

1. Single-domain disaggregated path provisioning
2. Multi-domain disaggregated path provisioning

... with various combinations of transponder and OLS domains
SENDATE trial - Graphical user interface
OpenDaylight multi-domain optical planning & provisioning GUI
Summary - Results of the trial

Successful proof of concept that routing and reach planning of optical circuits can be managed by a multi-domain controller and generic planning tool for simplified network operation across disaggregated, multi-domain optical network

**Highlights**

- Generic multidomain reach planning.
  - Necessity for introduction of Open Optical Line Systems.
- Transparent interdomain links on the ROADM line side
- Interdomain connections – Transponder circuits passing both vendor domains.

**Open Challenges** (not covered in the trial)

- Routing: Explicit routing
- Flexible modulation format assignment
- Custom wavelength assignment
- Detailed reach validation
ONF PoC 5 (Nov. 2018, Telefonica, Munich)
SDN controlled open disaggregated optical transport

- **ONF T-API** based SDN control
- **NETCONF protocol and YANG information model**
- **ADVA open terminals and open line system**
  - Open terminals for 1 and 10G services
  - Open line system (OLS) as infrastructure
Open Disaggregated Transport Network (ODTN)
OFC 2019, Mar. 2019 and ongoing ...

1. Intent-based service provisioning
2. Service request translated into OLS intent and TX configuration
3. Provisioning through ONF T-API on OLS via Ensemble Controller and OpenConfig on TX
Conclusion

Partially disaggregated Open Line Systems provide an ideal trade-off for application in operator networks

- Ease of management of optical line systems
- Easy integration of third-party transponders

ONF Core Model provides a path towards incremental standardization

- Based on best-practice management information models (ITU-T, TMF, ...)
- Separation of capabilities in conditional packages ideal for differentiating applications, e.g. *Photonic Media model* as conditional package

**ONF Transport-API** for OLS and **OpenConfig** for Transponder is most supported

Interoperability requires further alignment of standards and open source initiatives
Thank you

aautenrieth@advaoptical.com