Multi-Layer Multi-Vendor Network Automation – DT’s SDN Implementation Strategy in the IP Core

Matthias Gunkel, Felix Wissel
Deutsche Telekom Technik, Fixed Mobile Engineering Deutschland, Darmstadt

10th Annual Market Focus @ European Conference on Optical Communication
September 20th, 2016, Düsseldorf
TRANSPORT SDN FOR MULTI-LAYER NETWORKS

Motivation

- single layer planning & operation
- NW design for traffic patterns relevant at a certain point in time far ago
- massive manual interventions

- tremendous capacity over-provisioning
- unacceptable end-to-end service provisioning times
- huge effort to introduce new future-proof services

- DT has already successfully achieved ML control in the IP core

DT to introduce a multi-layer multi-vendor automation environment in the IP core network following the spirit of Transport-SDN.
TRANSPORT SDN FOR MULTI-LAYER NETWORKS

Guiding Principles

- “IP & optical” transport layers considered only.
  - Optical domains remain vendor-specific.
    - Separate vendor-specific optical domains and vendor-specific SDN domain controllers
    - No optical vendor-interoperability (→ Black Link subject of other projects)
    - No “white boxes” in this context (→ subject of other projects)
  - Routers remain routers.
    - Single IP domain, single SDN controller
    - No OpenFlow-like simple packet forwarding machines

- Hierarchical control architecture.
  - Orchestrator acts on abstracted network topology. Limited insight into transport domains.
  - No logical loops in order to avoid systematic DB inconsistencies
TRANSPORT SDN FOR MULTI-LAYER NETWORKS
Hierarchical Control Architecture

Multi-Layer/Vendor/Domain Transport Orchestrator

- Orchestration & overarching coordinating instances
- Abstraction & domain specific instances
- Management
- Forwarding infrastructure

SDN-C
EMS/NMS
multi-vendor IP routers
optical vendor A
optical vendor B
optical vendor C

legacy IT, e.g. OSS

E2E service orchestrator

management E2E service orchestrator

ERLEBEN, WAS VERBINDET.
## TRANSPORT SDN FOR MULTI-LAYER NETWORKS

### Use Cases

<table>
<thead>
<tr>
<th><strong>Topology Discovery &amp; Visualization</strong></th>
<th><strong>Planning (offline) &amp; Traffic Optimization (online)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>- collects real-time L0-L3 topology information</td>
<td>- calculates optical router bypass and grooming optimization at all involved layers</td>
</tr>
<tr>
<td>- records the inter-layer mapping of IP and optical ports</td>
<td>- path optimization within the IP/MPLS layer under SRLGs and latency awareness</td>
</tr>
<tr>
<td>- builds a shared risk table; alerts when path diversity is violated</td>
<td>- highlights potential congestions and proactively recommends capacity installation based on traffic forecast</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Automated ML Resilience</strong></th>
<th><strong>Scheduled Maintenance</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>- preparation of fast autonomous failure prevention like FRR or (o)SNCP</td>
<td>- predicts the impact of maintenance activities on involved layers</td>
</tr>
<tr>
<td>- recovery from optical/OTN and IP failures and reversion to original network state</td>
<td>- coordinates ML maintenance windows in order to minimize human intervention &amp; errors</td>
</tr>
<tr>
<td>- isolation of a NE in order to enable equipment swapping</td>
<td>- initial configuration of optical and IP NEs, service creation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Configuration &amp; Provisioning</strong></th>
<th><strong>Alarming</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>- automated IP/MPLS tunnel provisioning, ODU sub喀 or wavelengths under SLA awareness</td>
<td>- gathering and monitoring of L0-L3 alarm notifications</td>
</tr>
<tr>
<td>- service dependent virtualization and network slicing</td>
<td>- runs a root cause analysis by ML/MD correlation</td>
</tr>
<tr>
<td>- support of configuration lifecycle incl. SW upgrades</td>
<td>- recommendation of appropriate reactions</td>
</tr>
</tbody>
</table>
TRANSPORT SDN FOR MULTI-LAYER NETWORKS

Hierarchical Control Architecture

- Configuration & Provisioning
- Scheduled Maintenance
- Further Multi-Layer Apps
- E2E service orchestrator

Multi-Layer/Vendor/Domain Transport Orchestrator

- Topology Discovery
- Traffic Engineering
- Capacity Planning
- Automated Recovery

Orchestration & overarching coordinating instances

Abstraction & domain specific instances

Management

Forwarding infrastructure

- Legacy IT, e.g. OSS
- SDN-C
- EMS/NMS
- Multi-vendor IP routers
- Optical vendor A
- Optical vendor B
- Optical vendor C
- IP DB
- Optic DB

Optic DB

Orchestrator Data Base
Abstraction & domain specific instances

Transport Orchestrator

Orchestration & overarching coordinating instances

Forwarding infrastructure

Management

SDN-C

EMS/NMS

Legacy IT

E2E orchestrator

Formal interface: Restconf/Netconf (IETF) or T-API (OIF/ONF) both with YANG data model

Transport orchestrator listens to the outcome of the O-SDN-C’s calculation and records all installed connections in its TED. Responsible for multi-layer path optimization.

Each optical SDN Controller owns sovereignty over single-layer path optimization (incl. spectrum management) inside its domain. It calculates feasible optical light-paths under vendor-specific physical constraints using its child-PCE.

E2E service orchestrator responsible for service assignment & requests onto platforms.
TRANSPORT SDN FOR MULTI-LAYER NETWORKS
Hierarchical Control Architecture – information flow downward

1. Orchestrator requests to the optical SDN-C
   - traffic demand between end nodes inside the domain
   - path optimization policy (requirements incl. significance)
     - bandwidth
     - disjointness
     - latency
     - availability/target SLA (e.g. in case of multiple failures)
     - most uniform load distribution on all links/fibers
     - least impact of shared risk within a selected set of other IP links in case of a failure
   - maximum number of to be advertised paths (e.g. all feasible)
   - set-up time
   - scheduled tear-down time (if applicable)
TRANSPORT SDN FOR MULTI-LAYER NETWORKS
Hierarchical Control Architecture – encapsulated information

Abstraction & domain specific instances
Forwarding infrastructure
Management

Information remaining encapsulated inside the optical domain
- power levels
- OSNR (actual, required)
- fiber parameters (dispersion, PMD)
- line-sided capacity and deployed transceiver modules
- spectrum, i.e. central frequency & bandwidth
- wavelength number
TRANSPORT SDN FOR MULTI-LAYER NETWORKS
Hierarchical Control Architecture – information flow upward

2. General network state information being exposed by the optical SDN-C to the orchestrator
   - optical nodes (location, address)
     - optical switching capabilities (?)
     - ROADM degree
     - actual status/utilization, ...
   - optional: electrical switching capabilities (in case of muxponder or ODU-XCs)
     - capacity
     - granularity matrix
     - blocking behavior
     - actual status/utilization, ...
   - client ports
     - max. capacity
     - color (grey, PWDM,...)
     - actual status: bandwidth, utilization, spare...
   - optical fiber links/edges
     - general reachability/paths inside the optical domain
     - actual feasible bandwidth [Gbit/s] btw. opt. nodes
     - latency per fiber
   - hypothetic optical connectivity
     - total latency conditions
     - L0/1 induced intrinsic SRLGs with existing demands
Abstraction & domain specific instances

Forwarding infrastructure

Management

Orchestration & overarching coordinating instances

Transport Orchestrator

Formal interface: Restconf/Netconf (IETF) or T-API (OIF/ONF) both with YANG data model

SDN-C

EMS/NMS

1. **Abstraction & domain specific instances**

2. **Forwarding infrastructure**

3. **Information being exposed by the optical SDN-C in reaction to a specific orchestrator’s connectivity request**

   - specific feasible optical paths
   - optical end nodes & optical transit nodes
   - feasible capacity
   - total latency conditions
   - L0/1 induced SRLGs, i.e. jointly utilized resources like, e.g. common line cards/muxponders, common ROADM ports, common fibers
   - informative: wavelength number, central frequency & bandwidth, FEC etc. (reserved for later use in case of alien wavelength or black link applications)

4. **Notifications autonomously triggered by the optical SDN-C**

   - deployed hardware status
     - client port up/down
     - ROADM degree up/down
     - optical connectivity provisioned
   - alarms
     - LoF
     - LoS
     - AIS
     - equipment aging (optional)
     - further...
TRANSPORT SDN FOR MULTI-LAYER NETWORKS
Flow chart - example

- **Multi Layer/Domain Transport Orchestrator**
  - Parent PCE
  - e.g. E2E orchestrator

- **IP SDN-C**
  - General poll
  - PCReq (N paths)
  - Provide state of domain
  - PCResp (N paths)

- **Opt. SDN-C**
  - Child PCE
  - Encapsulated computation
  - Feasible capacity, transit nodes, ports, L0/1 SRLGs, total latency, (informative: spectrum)

- **Flow chart**
  - Discovery
  - Provisioning

- **Path Provisioning**
  - Specific path

- **Provisioning response**
  - Domain provisioning accomplished

- **Encapsulated path provisioning**

**Notes:**
- E2E orchestrator
- Multi Layer/Domain Transport Orchestrator
- IP SDN-C
- Opt. SDN-C
- Child PCE
subordinate question!
use cases are guiding
interfaces should be as close to standards as possible
- Transport-API
- NetConf/RestConf
- PCEP
- BGP-LS
- YANG-based data models

Looking into the T-API’s eyes...
TRANSPORT SDN FOR MULTI-LAYER NETWORKS

Summary

- Successful implementation of multi-layer control (especially ML resilience) recently accomplished
- Next step: fully automated core network following the spirit of Transport-SDN
  - Use cases
  - Hierarchical control architecture
    - Orchestrator
    - SDN controllers
  - Clear responsibilities
  - Information flow
  - Standardized APIs/protocols

It’s time for full automation of our network, now!
Questions?

Matthias Gunkel, Felix Wissel
Deutsche Telekom Technik
Fixed Mobile Engineering Deutschland
GunkelM@telekom.de