Sharing optical infrastructure - from small site integration to multi-domain backbone links

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This talk is about…

SWITCHlan optical backbone

15 years of sharing & multiplexing in SWITCHlan

some general considerations about sharing
SWITCHlan “commercial”

The Swiss network for education & research

Customers
- universities
- research organizations
- hospitals
- other organizations with special networking requirements

Services
SWITCH brings together universities and research institutions from all over Switzerland and connects them with the Internet and integrated in academic networks worldwide.

Network Team
- a group of 10 engineers
- caring for infrastructure, optical transport, IP layer, peerings
- doing design, roll-out & operations
- and customer support!
SWITCHlan fiber topology
Key characteristics optical core

optical transport system
- ECI Apollo
- tendered 2013
- rolled out 2014-2016
- photonic design without OTN switching
- ROADM in most nodes
- color dispersion fully compensated

design optimizations
- nodes in 4 functionality levels
- low cost next hop links:
  - static OADMs channel 57..60
  - “aliens” lit by non-tunable optics
- regional and long-haul links
  - really need FEC → transponders!
**Channel plan**

**AS DESIGNED 2014**

- 50GHz spacing, ready for flexible grid
- split in coherent and non-coherent parts
- within non-coherent range re-use of lambdas:
  - block of 4 channels for next hop links (with fixed OADM)
  - block of 7 channels for regional links (with fixed OADM)
- 77 usable 50GHz channels

**usage 2017:**

- ~30% of lambdas used
- 2x 4 links within Zürich area
- > 40 links

**UNDER CONSIDERATION 2017:**

- 66 usable channels for dynamic lambdas
- 2-4 channels to be reserved as feeders to next ROADM node?
- 100G+ coherent waves
- 4 channels reserved for aliens to next hop routers
- 7 channels reserved for future city & regional networks
- 300GHz guard band
- 0.2 channels to be reserved as feeders to next ROADM node?
The SWITCHlan optical core

recent additions: 4 mini nodes
Mini nodes

goal
• low footprint
• low energy requirements
• low cost

typical setup
• installation in 19” rack, 25cm depth
• 3..10 rack units including cable management
• single active shelf + optional passive shelf
• dual AC power supplies integrated
• in-band management (OSC/GCC)
• ideal for single channel 10G/100G access node
• optionally complemented by amplifiers
100Gbps IP core

topology 2014: 3 Cisco ASR

topology 2016: 6 Cisco ASR

proposed topology 2018: adding 6 small next generation routers
SWITCHlan economics

challenging cost structure
- 3000km of dark fiber
- <100 customer sites

node classification
- 28 + 9 DWDM core nodes (with/without ROADM)
- ~25 in city rings
- >1/3 of all nodes are “out in the green”

dedicated fiber access links are expensive
→ we use existing fiber wherever possible!
→ we do it since we started using dark fiber
→ multiplexing technologies change, but not the concept!
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some general considerations about sharing
Sharing classification

- sharing a pair of fibers
- coarse spectrum sharing (spectral bands, CWDM channels)
- dense (“tight”) spectrum sharing

Multiplexing technology dictates how close sharing partners share their fate
Phase 1 – sharing a pair of fiber

Purpose
- completely independent express + regional networks
- sharing with a partner network

Technology
- long-haul DWDM transmission system supporting bi-directional mode
- 1310/1550nm or 1530/1550nm splitters + optics for regional links (eventually replaced by bi-directional plugins)
- easily upgrades to 10Gbps, but not further...

Pros & Cons
- complete isolation between the 2 fibers
- bi-directional mode is “cumbersome” for lambda muxing
- does not really work with ROADMs

Installations:
- since 2003, only few left
- approx. 30 chassis with 50 filters
Phase 2 – coarse spectrum sharing

**purpose**
- running multiple services on a fiber pair (your own, partner’s or client’s services)
- guarantee low mutual influence
- allow individual management

**technology**
- CWDM: 8..16 channels with static filters
- “HMUX” spectral band filters:
  - separate O/S/C/L-bands
  - bands suitable for different applications
  - very low attenuation

**pros & cons**
- high isolation between lambdas/spectral bands ➔ allows to run services independently
- not a viable option to share long-haul links
Phase 2: Spectrum sharing with HMUX’s

HMUX key characteristics
- very low attenuation
- precise crossover frequencies
- dual monitoring taps

4-Band Hybrid WDM wavelength allocation scheme

- local and regional links
- extended O-Band
- regional CWDM links
- S-Band
- long distance DWDM links
- extended C-Band
- regional CWDM or long distance DWDM links
- L-Band

Water peak

- potentially free spectral ranges for use by SWITCH or community
- always reserved for SWITCH

DWDM system
- 88 channels
- @50GHz spacing
Phase 3 – dense spectrum sharing

**purpose**
- sharing a **big** number of lambdas
- sharing over long-haul distances
- share not only fibers, but amplifiers, compensators and active optical switches as well

**technology**
- DWDM
- 80+ channels of 50GHz (“flexible” channel width in future)
- reach >1000 km, depending on modulation, FEC, quality of optical channels etc
- transceiver technology is progressing fast
- trend to disaggregate transceivers and managed channels ?

**pros & cons**
- weak isolation between lambdas → good power management mandatory
- coherent designs can get rid of “colored” filters → less protection against human errors
- complexity asks for a good NMS

2 use cases to be discuss:
- small coherent site integration
- multi-domain backbone links
small coherent site integration (1)

existing environment: fully compensated network design with post-compensation in mid-stage of pre-amps

direct access through splitters
- simple (no ROADMs, no colored filters)
- passive
- highly flexible - access to all lambdas!

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small coherent site integration (2)

unamplified design

specs stolen from Optosun:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Grade P</th>
<th>Grade A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating wavelength (nm)</td>
<td>1260–1620</td>
<td></td>
</tr>
<tr>
<td>Operating bandwidth (nm)</td>
<td>±80</td>
<td></td>
</tr>
<tr>
<td>Typical excess loss (dB)</td>
<td>0.07</td>
<td>6.10</td>
</tr>
<tr>
<td>Insertion loss (dB)</td>
<td>0.15</td>
<td>0.20</td>
</tr>
<tr>
<td>PDL (dB)</td>
<td>±0.15</td>
<td>±0.20</td>
</tr>
<tr>
<td>Directivity (%)</td>
<td>±50</td>
<td>±50</td>
</tr>
<tr>
<td>Operating temperature (°C)</td>
<td>40 ~ 85</td>
<td></td>
</tr>
</tbody>
</table>

avg fiber attenuation: 0.22 dB/km

span length: 100 km

max range from far end

max range from far end: 64 59 52 44 29 15

add/drop [dB]:
- 50:50: 3.8
- 40:60: 5.0
- 30:70: 6.4
- 20:80: 8.3
- 10:90: 11.5
- 5:95: 14.6

passthrough [dB]:
- 50:50: 3.8
- 40:60: 2.8
- 30:70: 2.0
- 20:80: 1.3
- 10:90: 0.70
- 5:95: 0.45

min safe rx power TM100: -18 dBm

design launch power/ch: 0 dBm
small coherent site integration (3)

amplified design

- fixed splitters with
  - high add/drop attenuation
  - low trunk insertion loss
- amplifiers at node C
- minimal impact on trunk
- access to all lambdas
- easier and much more flexible design!
Is over-compensation a problem?

typical minimum dispersion for DP-QPSK optics
  – according to specs: -1000ps/nm (~60km) – split DCFs?
  – according to ECI R&D, this limit is deliberate, in reality, dispersion limits are symmetrical!
  – no splitting of DCFs required!
small coherent site integration (5 – summary)

existing environment: fully compensated network design with post-compensation in mid-stage of pre-amps

link length $L = 100$km

A

DCF L km

unamplified setup

amplified setup

passive splitter module

coherent add/drop

C

B

DCF L km

direct access through splitters

- good flexibility, easy access to all lambdas
- unamplified design needs careful planning
- **amplified design gives much more freedom**
- over-compensation should not pose problems

a word of caution:
- design approved by vendor
- but not yet tested!
redundant coherent site integration (1)

redundant version of amplified design – first proposal

link length $L = 100\text{km}$

- good flexibility, easy access to all lambdas
- protection switch
  - a color-insensitive mini-ROADM
  - distributes local signals
  - selects one of incoming trunk signals
- depends on availability of wavelength blocker (active device)
- also: difficult power management

lambda blocker

new devices required
redundant coherent site integration (2)

pragmatic approach using 2 different lambdas

link length $L = 100\text{km}$

feeder channel + lambda conversion
- 2 independent transponders in node C
- not really a neat design
- only reasonable when lambda conversion gets really cheap

static filter module: O-band or ch17/18

coherent add/drop

passive splitter module

static filter channels 17/18 to be reserved for next hop “feeder” links

access to all lambdas

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some general considerations about sharing
“New” multi-domain sharing

Current operational 10Gbps CBF links are likely to be either terminated or upgraded.

Expectations
• only 100Gbps+ channels
• scaling to Tbps desired
• long-haul distance range
• photonic domain crossings (no OEO-conversions)
• decoupling between lambda termination equipment and photonic infrastructure

Implications
• „massive“ sharing allocates a considerable part of available spectrum
• dense (“tight”) multiplexing only  \(\rightarrow\) joint use of C-band
• sharing of managed spectrum instead of managed lambdas
Sharing as an opportunity

**economics**
- jointly use expensive, scarcely used infrastructures
- divide the cost
- and ideally
  - still get all the resources you need
  - with minimal added complexity

**cooperation & collaboration**
- leads to more interaction with partners
- more human communication
- more exchange of know-how
- might lead to further joint projects…
Sharing challenges

design & operational issues

safety & privacy

economy & fairness
Sharing – design & operational issues

**design**

- establish fiber connectivity unless existing already!
- interoperability of optical transport systems
  - coordinate channel plans
  - agree on power levels
  - characterization of the optical paths
- doing so
  - adds additional prerequisites
  - limits freedom for design & modifications

**daily operations**

- to be studied:
  - interoperability of monitoring
  - “interoperability” of NOCs (tickets, work processes, “mind sets”…)
- consider partner’s operational requirements and rules
- likely to add administrative overhead for your daily work
- likely to diminish freedom of action for instant interventions

- „tight“ multiplexing
  - joint use of DWDM in C-band
  - photonic approach
  - no OEO-conversion at domain boundaries

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Sharing – safety & privacy issues

privacy → data protection
• avoid leaking internal traffic to neighbors
  ➢ use ROADMs to block all but intended lambdas on output

reliability → network protection
• protect ingress against malfunction or operator error
  ➢ take measures to block all but expected incoming lambdas
  ➢ take measure to block incoming waves exceeding agreed power limits
Sharing – economy and fairness

“massive” sharing
• limits the scalability of your own services
• asks for a reasonably fair cost sharing model
  • but what exactly is “fair” anyway?
  • openly discuss the cost sharing models among NRENs, do not only compare the “numbers”!
• honor the considerable regional differences in Europe, namely

different local cost for
• fiber leases
• housing
• manpower

different NREN organizational structures
• direct government funding versus funding by users
• freedom of action given to NREN’s by its constituency
Summary – and some personal remarks

Technology
• coherent hardware is getting cheaper, faster, smaller, cooler...
• coherent lambdas permit slimmer designs, let us try it out
• study, test and improve interoperability – learn!

Multi-domain sharing
• more than technology - economy, cost sharing models, trust and mindsets…
• implies reasonable NOC interoperation processes
  • some changes will inevitably be needed
  • let us not subdue to overly formal processes and formalisms
  • keep the successful (if informal) way NREN manage their networks so many years!
  • minimize the loss of operational freedom