About me

- **Researcher at CESNET**
  - E-infrastructure provider in Czechia, EU
    - Network, cloud infrastructure,…
    - Non-data users – *photonic services*
  - R&D

- **Software engineer at Telecom Infra Project**
  - Open Optical Packet Transport
  - **GNPy** [https://github.com/Telecominfraproject/oopt-gnpy](https://github.com/Telecominfraproject/oopt-gnpy)

**Disclaimer:** I am not speaking on behalf of TIP today
History of our OLS

- In-service since 2004
History of our OLS

- In-service since 2004
- EDFA amplifiers
  - In-line
  - Booster/Pre-amp
  - Bidirectional, single-fibre
  - No-lase for precise time & frequency
- Switches
- V-MUXes, fixed-grid legacy ROADM, WSSes
- Special equipment
Open Optical Line System
SDN ROADMs
RF system (195 THz), not a digital network

Image credit: Telecom Infra Project, Open Optical Packet Transport
Add/Drop for client signals

West East

Line Fiber
Express
Express–A/D
Client A/D

Add/Drop 1
4-degree ROADM

Add/Drop 1
West
Line 3
Line 4
East
Line Fiber
Express
Express–A/D
Client A/D

West
Add/Drop 1
East
...with redundant Add/Drop

- Line Fiber
- Express
- Express–A/D
- Client A/D

Add/Drop 1
Add/Drop M

West

East
- 1U pizza-boxes
  - **Add/Drop for client connections**

Diagram:
- Line 3
- Line 4
- Line N
- West
- Line Fiber
- Express
- Express A/D
- Client A/D
- East
- Add/Drop 1
- Add/Drop M
1U pizza-boxes

- **Add/Drop** for client connections
- **Line Degree for long-haul links**
  - Up to 8-degree ROADM
  - 25 dB reach with no additional amplification
Modular Design

- **1U pizza-boxes**
  - **Add/Drop** for client connections
  - **Line Degree** for long-haul links
    - Up to **8-degree** ROADM
    - 25 dB reach with no additional amplification
  - **Inline Amplifiers for long spans**

Note: Amplifier placement not to scale
1U scalable form-factor
cesnet

1U scalable form-factor

Line (long-haul)
cesnet

1U scalable form-factor

Express Connections
1U scalable form-factor

Client ports
A complete Open Line System
- Everything below transponders
Modern Features

- Flexgrid

Image credit: TNC 2014, Ioan Torus, Josva Kleist, Anna Manolova Fagertun
Modern Features

- Flexgrid
- Colorless
Modern Features

- Flexgrid
- Colorless
- Directionless
- Modern Features
  - Flexgrid
  - Colorless
  - Directionless
  - Contentionless

![ROADM Diagram]

- Line 3
- Line 4
- Line N
- Add/Drop 1
- Add/Drop M

Legend:
- Line Fiber
- Express
- Express–A/D
- Client A/D

West
East

Add/Drop 1
Add/Drop M
Multiple Add/Drop boxes for redundancy

- Contentionless feature
- Blocks of up to 20 client ports per Add/Drop

An MD-ROADM with a contention-less local add/drop feature is able to add or drop more than one optical channel with the same wavelength to/from different optical line ports.

Rec. ITU-T G.672 (10/2012)
- Multiple Add/Drop boxes for redundancy
  - Contentionless feature
  - Blocks of up to 20 client ports per Add/Drop
- Active and passive Add/Drop
  - WSS-based for Alien Wavelengths
Add/Drop Options

- Multiple Add/Drop boxes for redundancy
  - Contentionless feature
  - Blocks of up to 20 client ports per Add/Drop

- Active and passive Add/Drop
  - WSS-based for Alien Wavelengths
  - **Cost-optimized for coherent signals**
Add/Drop Options

- Multiple Add/Drop boxes for redundancy
  - Contentionless feature
  - Blocks of up to 20 client ports per Add/Drop

- Active and passive Add/Drop
  - WSS-based for Alien Wavelengths
  - Cost-optimized for coherent signals
  - Y-cables for 2-deg ROADM
- Optical Supervisory Channel (OSC)
  - Overlay network
  - Laser safety
  - Neighbor discovery

- Integrated line-facing bidirectional OTDR
  - Via the OSC SFP slot
  - Optional feature
Management
**SDN Operation and Management**

- Everything is remotely configurable
- Native Alien Wavelengths
- Telemetry, performance monitoring
Configuration
- NETCONF control
- YANG data model
- Interactive CLI console
  - SSH
  - microUSB port

Image credit: Randall Munroe, https://xkcd.com/927/
**Configuration**
- NETCONF control
- YANG data model
- Interactive CLI console
  - SSH
  - microUSB port

**YANG fragmentation**
- OpenROADM
- OpenConfig
- TIP OpenDevice
- T-API
- IETF TE-topology, IETF CCAMP impairment-aware
**Configuration**

- NETCONF control
- YANG data model
- Interactive CLI console
  - SSH
  - microUSB port

**YANG fragmentation**

- OpenROADM
- OpenConfig
- TIP OpenDevice
- T-API
- IETF TE-topology, IETF CCAMP impairment-aware

Image credit: Randall Munroe, https://xkcd.com/927/
YANG snippet

module: czechlight-roadm-device

---rw channel-plan
  | ---rw channel* [name]
  |   | ---rw name string
  |   | ---rw lower-frequency opendevice-types:dwdm-frequency-mhz
  |   | ---rw upper-frequency opendevice-types:dwdm-frequency-mhz
  
---rw connections* [channel]
  | ---rw channel -> /channel-plan/channel/name
  | ---rw description? string
  | ---rw add!
  |   | ---rw port device-dependent-port-type
  |   | ---rw (mode)
  |   |   | ---:(attenuation)
  |   |   |   | ---rw attenuation czechlight-roadm-common:attenuation-type
  | ---rw drop!
  |   | ---rw port device-dependent-port-type
  |   | ---rw (mode)
  |   |   | ---:(attenuation)
  |   |   |   | ---rw attenuation czechlight-roadm-common:attenuation-type

---ro channel-power* [channel]
  | ---ro channel -> /channel-plan/channel/name
  | ---ro power* [location]
  |   | ---ro location string
  |   | ---ro optical-power opendevice-types:optical-power-dBm

---ro aggregate-power* [location]
  | ---ro location string
  | ---ro optical-power opendevice-types:optical-power-dBm

List of recognized Media Channels (MCs)
module: czechlight-roadm-device
    +--rw channel-plan
    |   +--rw channel* [name]
    |   |   +--rw name string
    |   |   +--rw lower-frequency opendevice-types:dwdm-frequency-mhz
    |   |   +--rw upper-frequency opendevice-types:dwdm-frequency-mhz
    +--rw connections* [channel]
    |   +--rw channel -> /channel-plan/channel/name
    |   +--rw description? string
    |   +--rw add!
    |   |   +--rw port device-dependent-port-type
    |   |   +--rw (mode)
    |   |   +--:(attenuation)
    |   |   |   +--rw attenuation czechlight-roadm-common:attenuation-type
    |   +--rw drop!
    |   +--rw port device-dependent-port-type
    |   +--rw (mode)
    |   +--:(attenuation)
    |   |   +--rw attenuation czechlight-roadm-common:attenuation-type
    +--ro channel-power* [channel]
    |   +--ro channel -> /channel-plan/channel/name
    |   +--ro power* [location]
    |   |   +--ro location string
    |   |   +--ro optical-power opendevice-types:optical-power-dBm
    +--ro aggregate-power* [location]
    |   +--ro location string
    |   +--ro optical-power opendevice-types:optical-power-dBm
module: czechlight-roadm-device
  +++rw channel-plan
  |  +++rw channel* [name]
  |  |  +++rw name string
  |  |  +++rw lower-frequency opendevice-types:dwdm-frequency-mhz
  |  |  +++rw upper-frequency opendevice-types:dwdm-frequency-mhz
  +++rw connections* [channel]
  |  +++rw channel -> /channel-plan/channel/name
  |  +++rw description? string
  |  +++rw add!
  |  |  +++rw port device-dependent-port-type
  |  |  +++rw (mode)
  |  |  +++:(attenuation)
  |  |  |  +++rw attenuation czechlight-roadm-common:attenuation-type
  |  +++rw drop!
  |  +++rw port device-dependent-port-type
  |  +++rw (mode)
  |  +++:(attenuation)
  |  |  +++rw attenuation czechlight-roadm-common:attenuation-type
  +++ro channel-power* [channel]
  |  +++ro channel -> /channel-plan/channel/name
  |  +++ro power* [location]
  |  |  +++ro location string
  |  |  +++ro optical-power opendevice-types:optical-power-dBm
  +++ro aggregate-power* [location]
  |  +++ro location string
  |  +++ro optical-power opendevice-types:optical-power-dBm

Independent Add/Drop MC paths
module: czechlight-roadm-device
  +-rw channel-plan
    |  +-rw channel* [name]
    |    |  +-rw name string
    |    |  +-rw lower-frequency opendevice-types:dwdm-frequency-mhz
    |    |  +-rw upper-frequency opendevice-types:dwdm-frequency-mhz
    +-rw connections* [channel]
    |  +-rw channel  -> /channel-plan/channel/name
    |  +-rw description? string
    |  +-rw add!
    |    |   |  +-rw port  device-dependent-port-type
    |    |   |  +-rw (mode)
    |    |   |    |  +(attenuation)
    |    |   |    |  +-rw attenuation czechlight-roadm-common:attenuation-type
    |  +-rw drop!
    |  +-rw port  device-dependent-port-type
    |  +-rw (mode)
    |  +(attenuation)
    |    |  +-rw attenuation czechlight-roadm-common:attenuation-type
  +-ro channel-power* [channel]
    |  +-ro channel  -> /channel-plan/channel/name
    |  +-ro power* [location]
    |    |  +-ro location string
    |    |  +-ro optical-power opendevice-types:optical-power-dBm
  +-ro aggregate-power* [location]
    |  +-ro location string
    |  +-ro optical-power opendevice-types:optical-power-dBm
- Linux
  - systemd
  - glibc
  - Buildroot
  - RAUC

- NETCONF/YANG stack
  - sysrepo
  - Netopeer2-server
  - libyang
  - libnetconf2

- Interactive CLI console
  - netconf-cli

[https://gerrit.cesnet.cz/plugins/gitiles/CzechLight/netconf-cli/]
Redundancy

- Failsafe in-the-field updates
- A/B firmware slots
- HW watchdog
- Hot-swap fans + server-grade PSUs
Prototypes are ready

- **Opening up ROADM: Let’s Build a Disaggregated Open Optical Line System**

  DOI: 10.1109/JLT.2019.2906620  

- Do you want to start building this?
What’s next?

- Prototypes are ready
- **OLS Controller**
  - ODTN
  - T-API implementation
What’s next?

- Prototypes are ready
- OLS Controller
- **Looking for collaboration**
  - Telecom Infra Project
  - OpenROADM
  - IETF CCAMP
cesnet

Peek Inside the Add/Drop Box
Schematics and Optical Performance
Optics: Flex Add/Drop
Optics: Coherent Add/Drop

From Line Degrees (Express IN)

Towards Line Degrees (Express OUT)
Power Budget

- Integrated EDFA+VOA, span loss 0 — 25 dB
- Line IN: -25 dBm/channel
- Line OUT: target 0 dBm/channel
- Add: -15 — +5 dBm/channel
Performance Monitoring

- **Line Degree and WSS Add/Drop**
  - Optical Channel Monitor
  - Resolution: 6.25 GHz
  - Refresh rate: 3 Hz

- **Coherent Add/Drop**
  - Power Monitoring (no spectrum)
  - Refresh rate: 20 Hz

- **Amplifiers**
  - EDFA’s PD

- **1% Integrated Taps**
  - Line TX, RX
Q & A

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https://czechlight.cesnet.cz/