cesnet

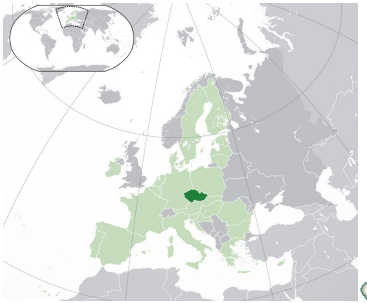
CzechLight
SDN na L0

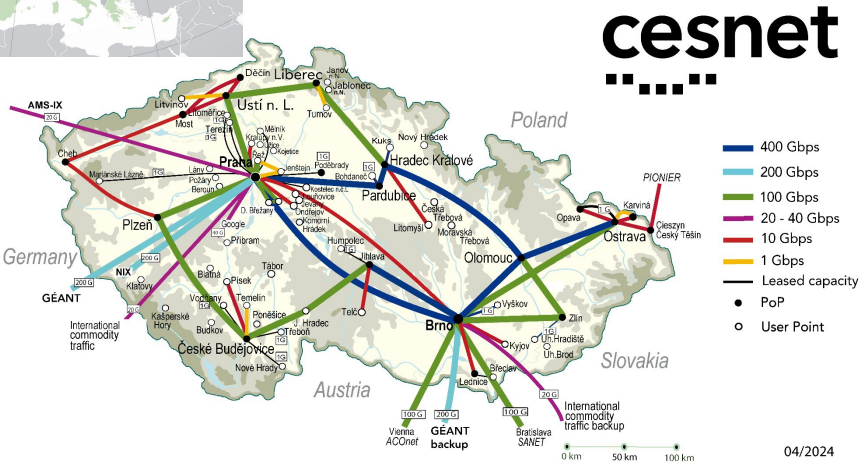
CSNOG 2025, Zlín

Michal Hažlinský

CESNET

- E-infrastructure service provider
  - Czechia, EU
  - Science, research & education
  - Services
    - Network
    - Compute
    - Storage
    - Collaborative environment
- About me
  - Researcher and Network solution architect





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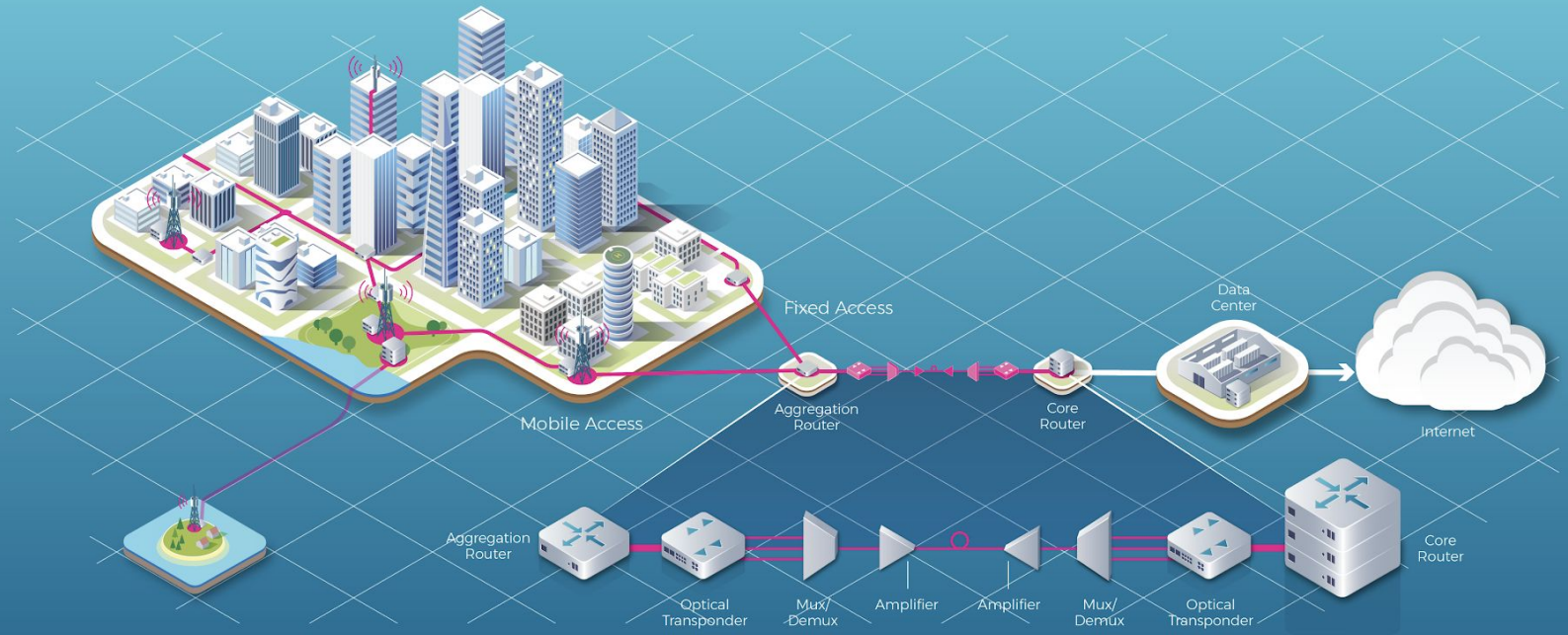
L0 - Optical Layer



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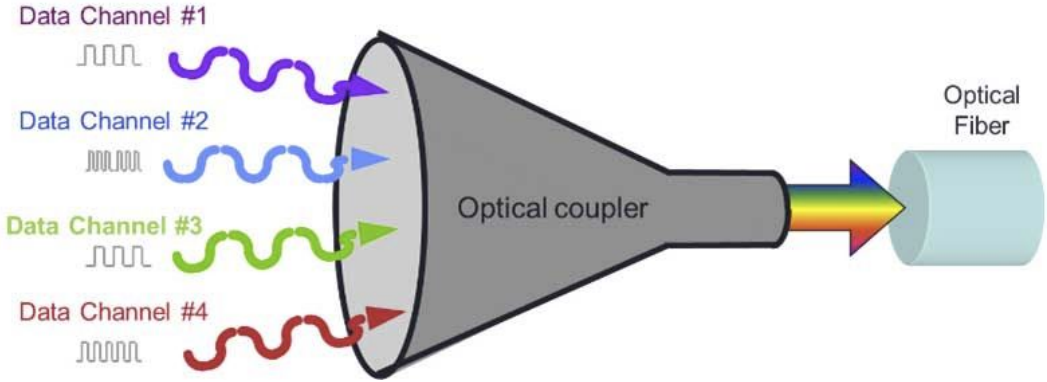
Fiber, WDM, EDFA



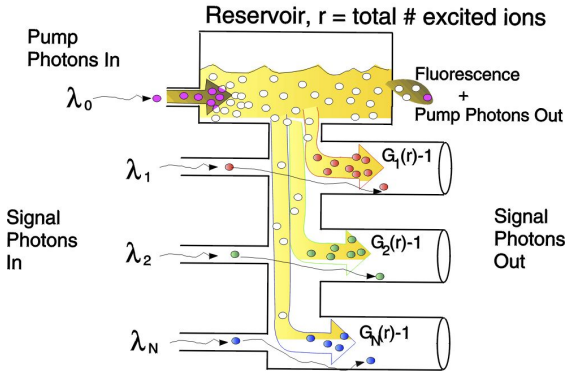


Image credits: © Corning, © A. Bononi, Universita di Parma, © Ciena

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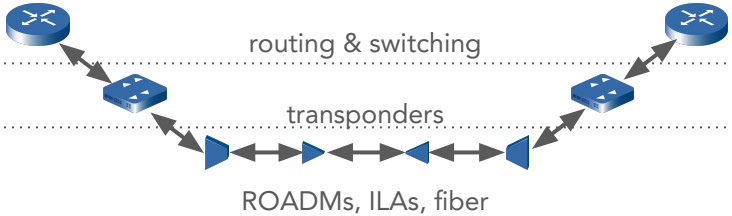
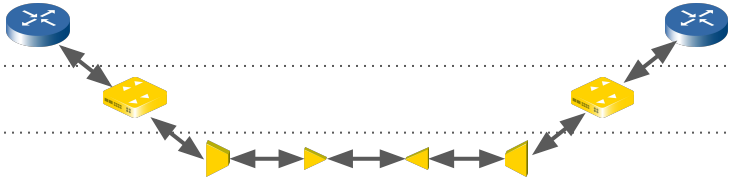
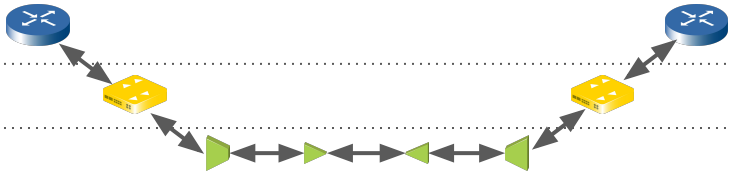
"Disaggregation"



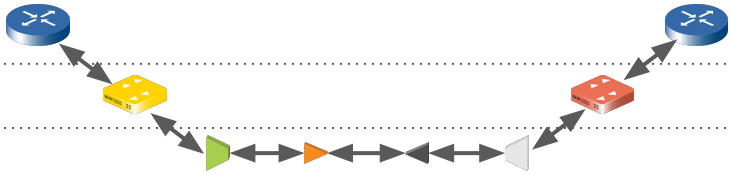
#0: monolithic



#1: turnkey DWDM

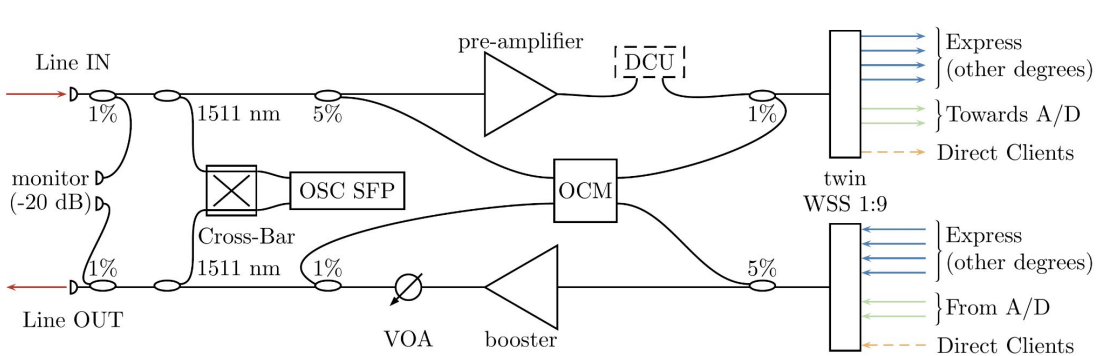


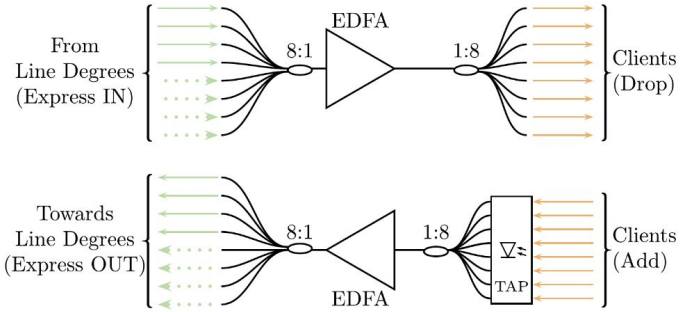
#2: transponder disaggregation



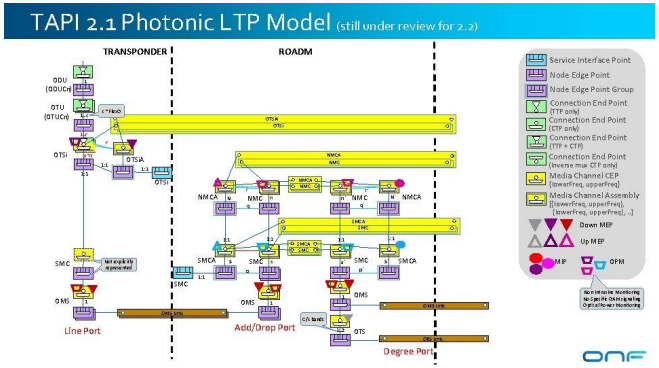
#4: full component disaggregation

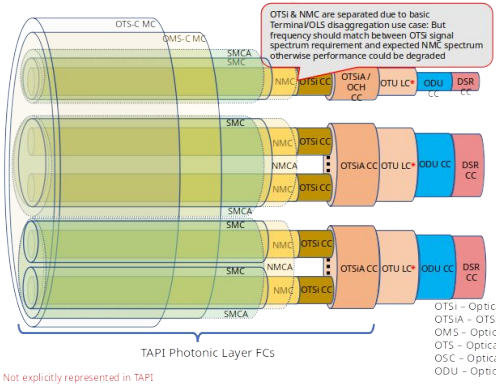
Is Optics Complex?

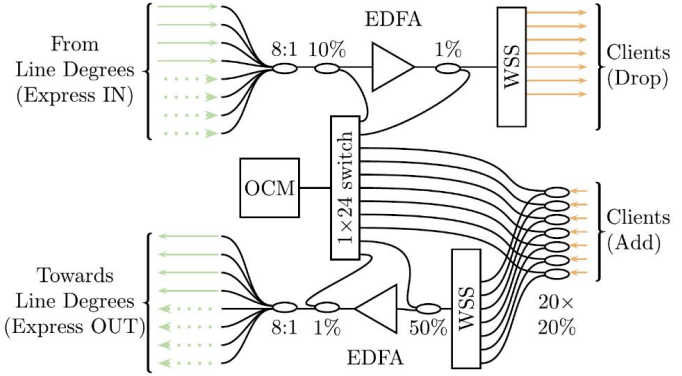




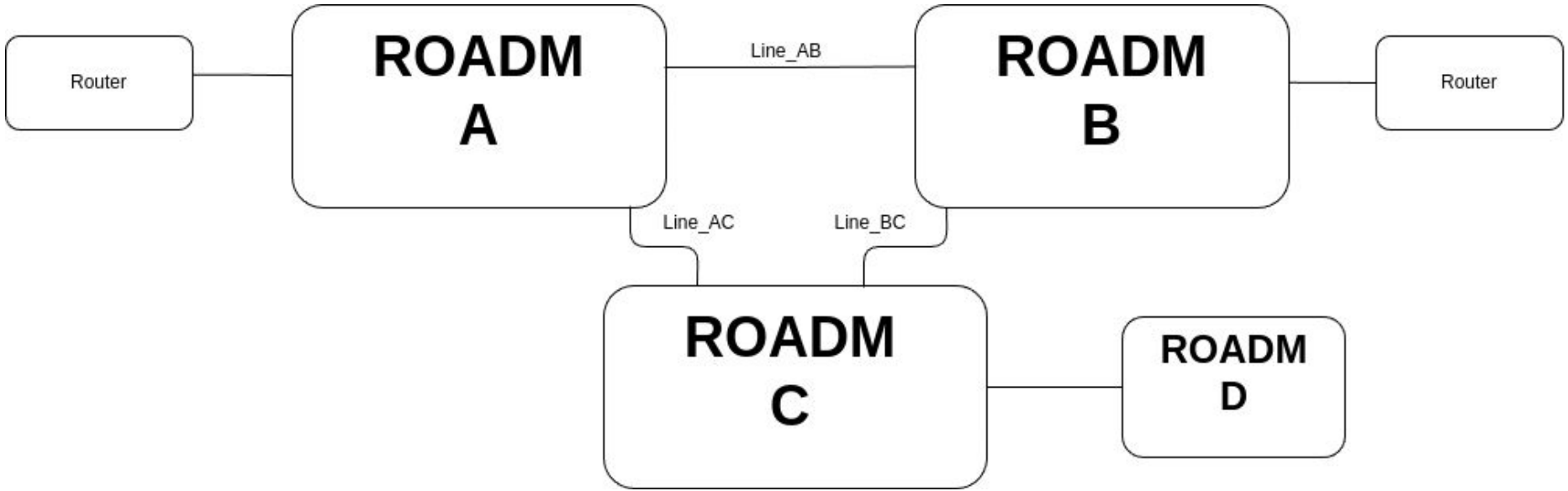
(b)



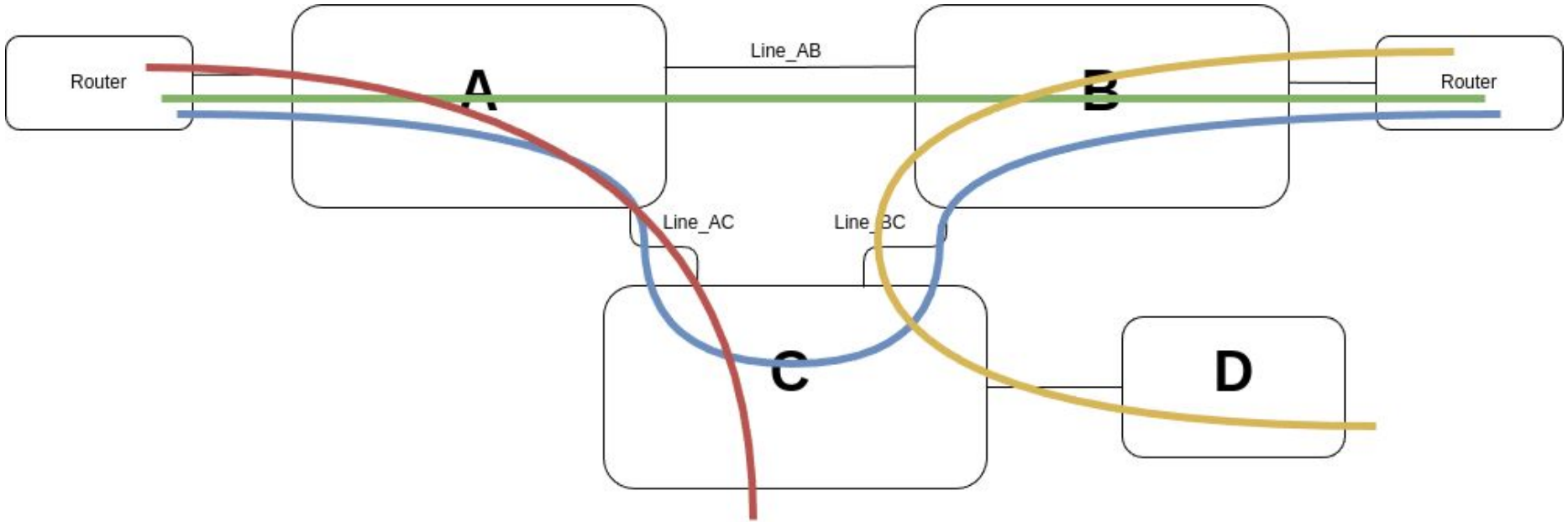




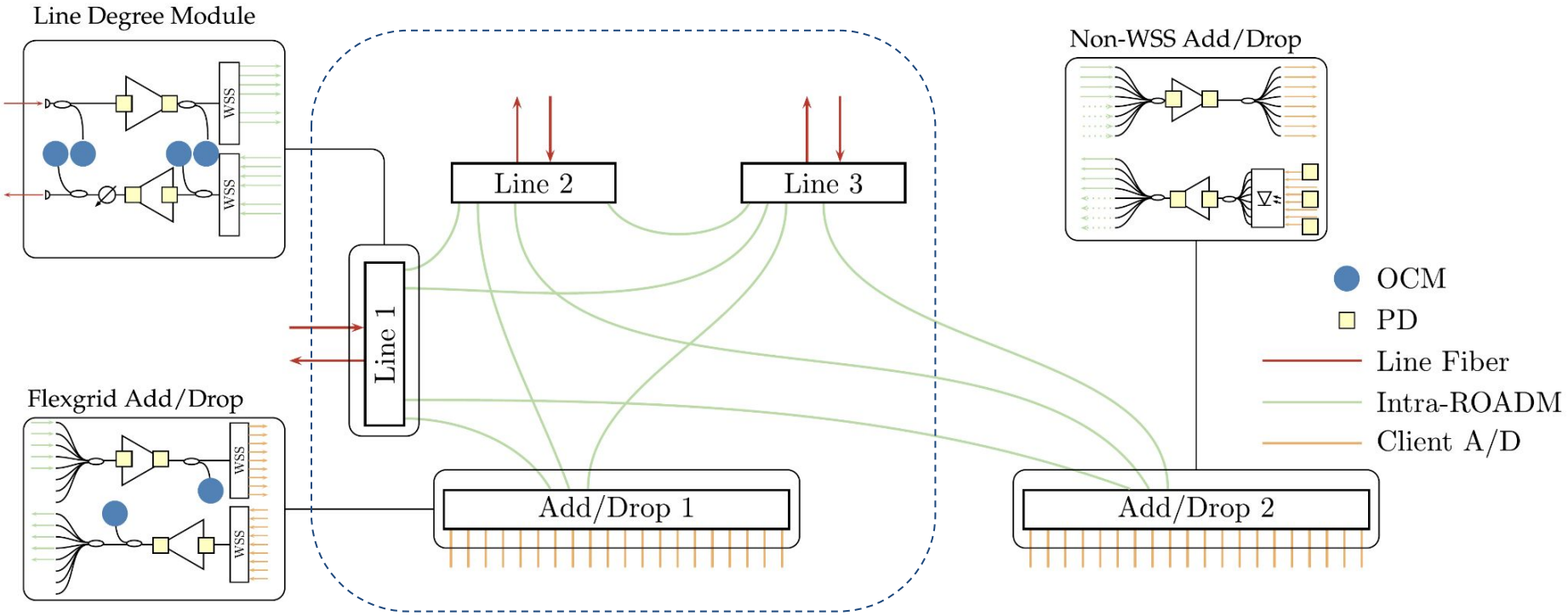
DWDM network



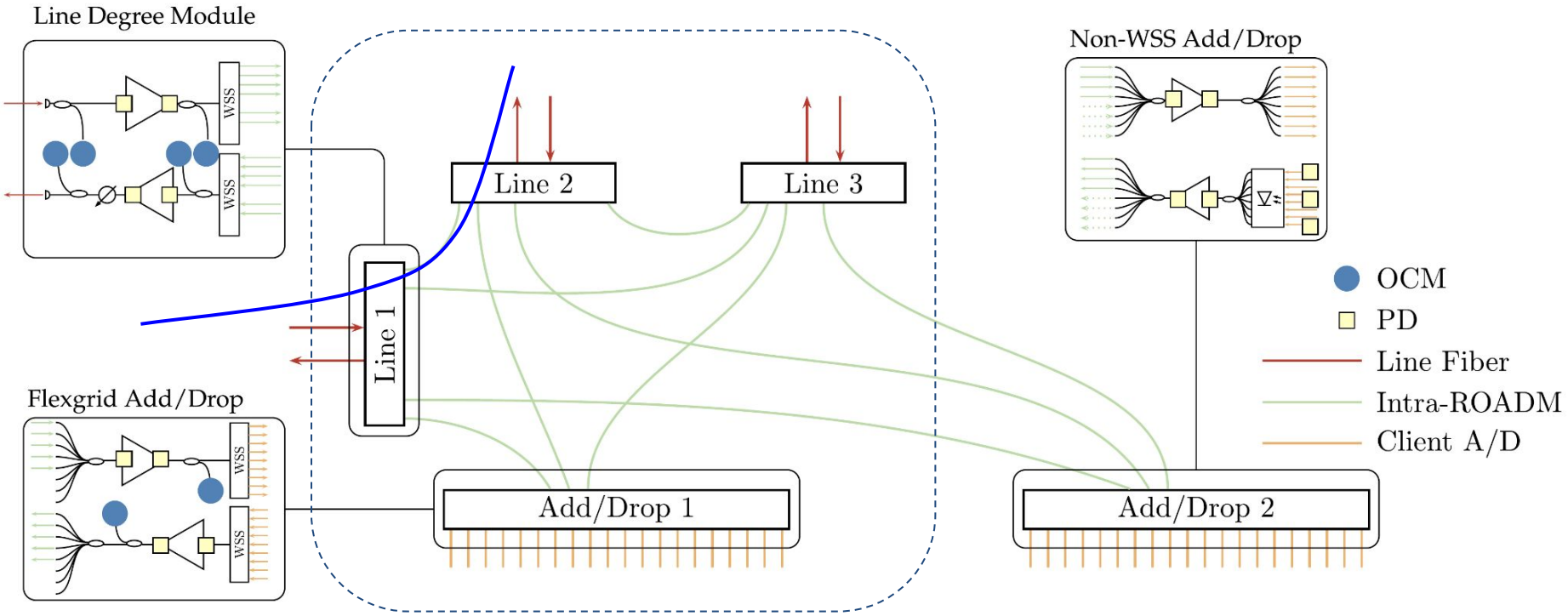
DWDM network - channel routing



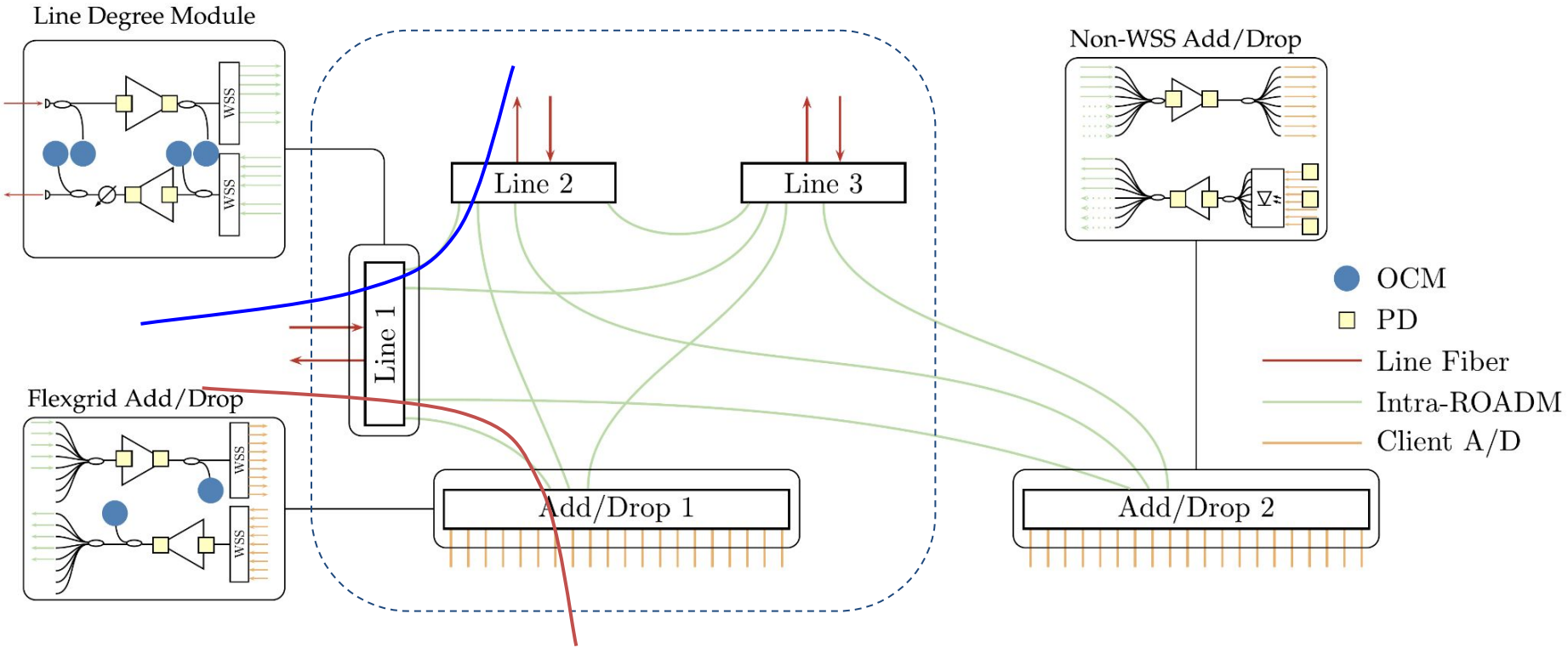
Czech Light ™ SDN ROADM



Czech Light ™ SDN ROADM

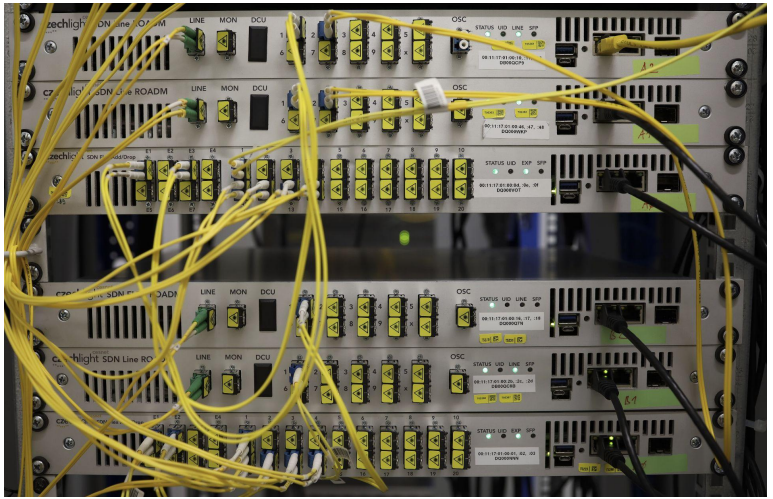


Czech Light ™ SDN ROADM



Open Line System CzechLight

- Modular 1U pizza boxes
- ROADMs
  - Scalability
    - Up to 8-degree ROADM
    - Redundant Add/Drop
  - Element-level control
    - SDN northbound APIs
    - One NETCONF server per box
- InLine Amplifiers
- BiDi Amplifiers



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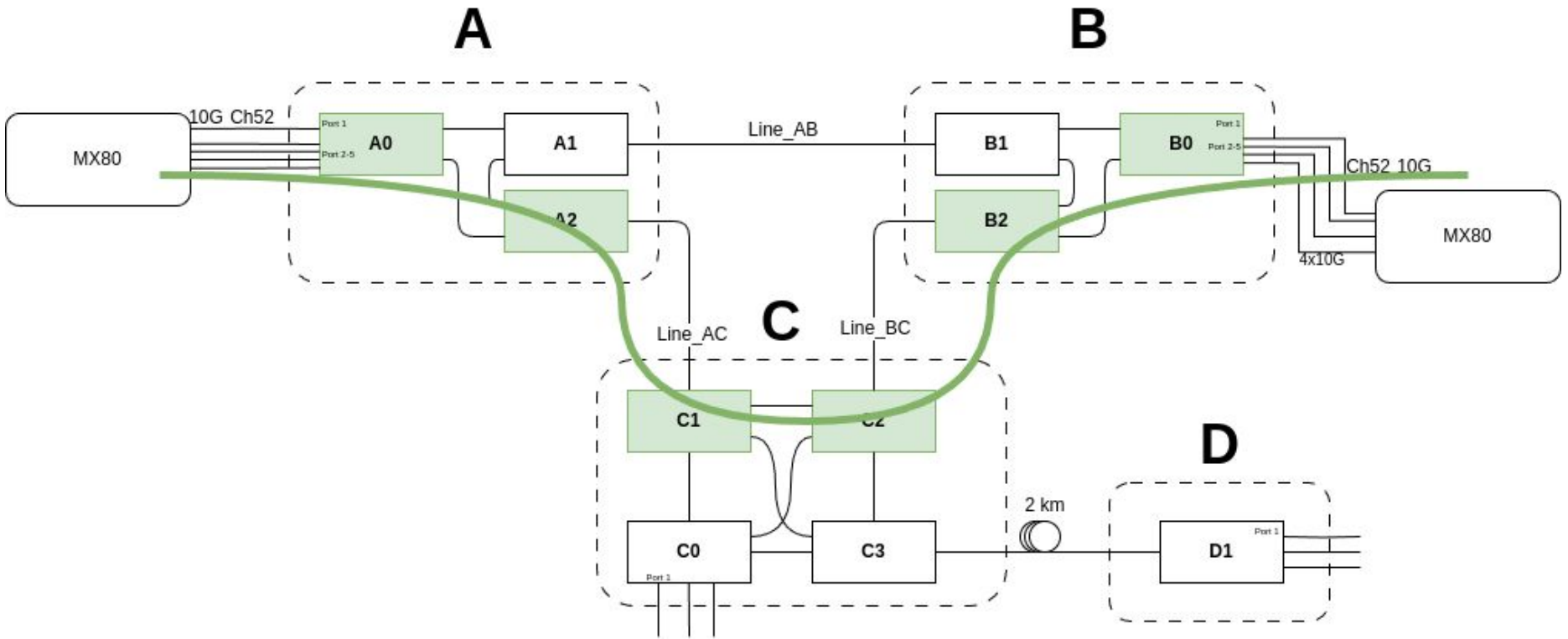
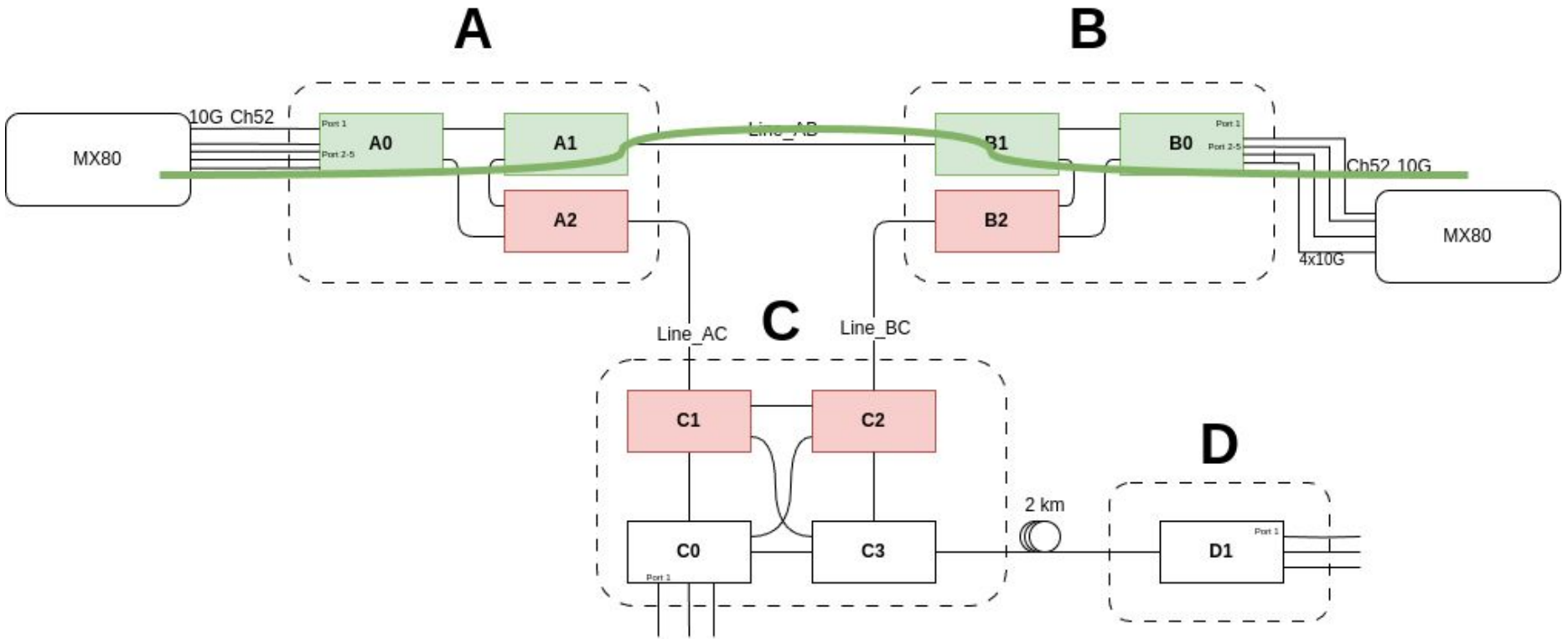
- YANG
- NETCONF
- RESTCONF
- CLI

-> DevOps on L0

Example: Channel rerouting



Example: Channel rerouting



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Standard tools for automation

```yaml
- hosts: roadm-deg3-foo.bar.example.org
  # Ansible's built-in NETCONF support
  connection: ansible.netcommon.netconf
  tasks:

  # Spectrum Definition
  - CzL_channel_plan:
    name: ciena
    state: present
    lower_frequency: '193950000'
    upper_frequency: '194150000'

  # Spectrum Routing
  - CzL_media_channel:
    name: ciena
    state: present
    leaf_port: 1
    attenuation_add: 0
    attenuation_drop: 10
    description: Ciena
```

Configuration via Ansible

```
---
- hosts: roadm-a0
strategy: free
connection: ansible.netcommon.netconf
tasks:
  - name: "ch 52 C"
    CzL_media_channel:
      name: "52 (100GHz)"
      leaf_port: "12"
      state: present
      attenuation_add: 10.0
      attenuation_drop: 10.0
```

```
- hosts: roadm-a2
strategy: free
connection: ansible.netcommon.netconf
tasks:
  - name: "ch52 AD-C"
    CzL_media_channel:
      name: "52 (100GHz)"
      leaf_port: E1
      state: absent
```

```
- hosts: roadm-c2
strategy: free
connection: ansible.netcommon.netconf
tasks:
  - name: "ch52 A-B"
    CzL_media_channel:
      name: "52 (100GHz)"
      leaf_port: E3
      state: absent
      attenuation_add: 10.0
      attenuation_drop: 10.0
```

```
- hosts: roadm-b1
strategy: free
connection: ansible.netcommon.netconf
tasks:
  - name: "ch52 AD-A"
    CzL_media_channel:
      name: "52 (100GHz)"
      leaf_port: E1
      state: present
      attenuation_add: 10.0
      attenuation_drop: 10.0
```

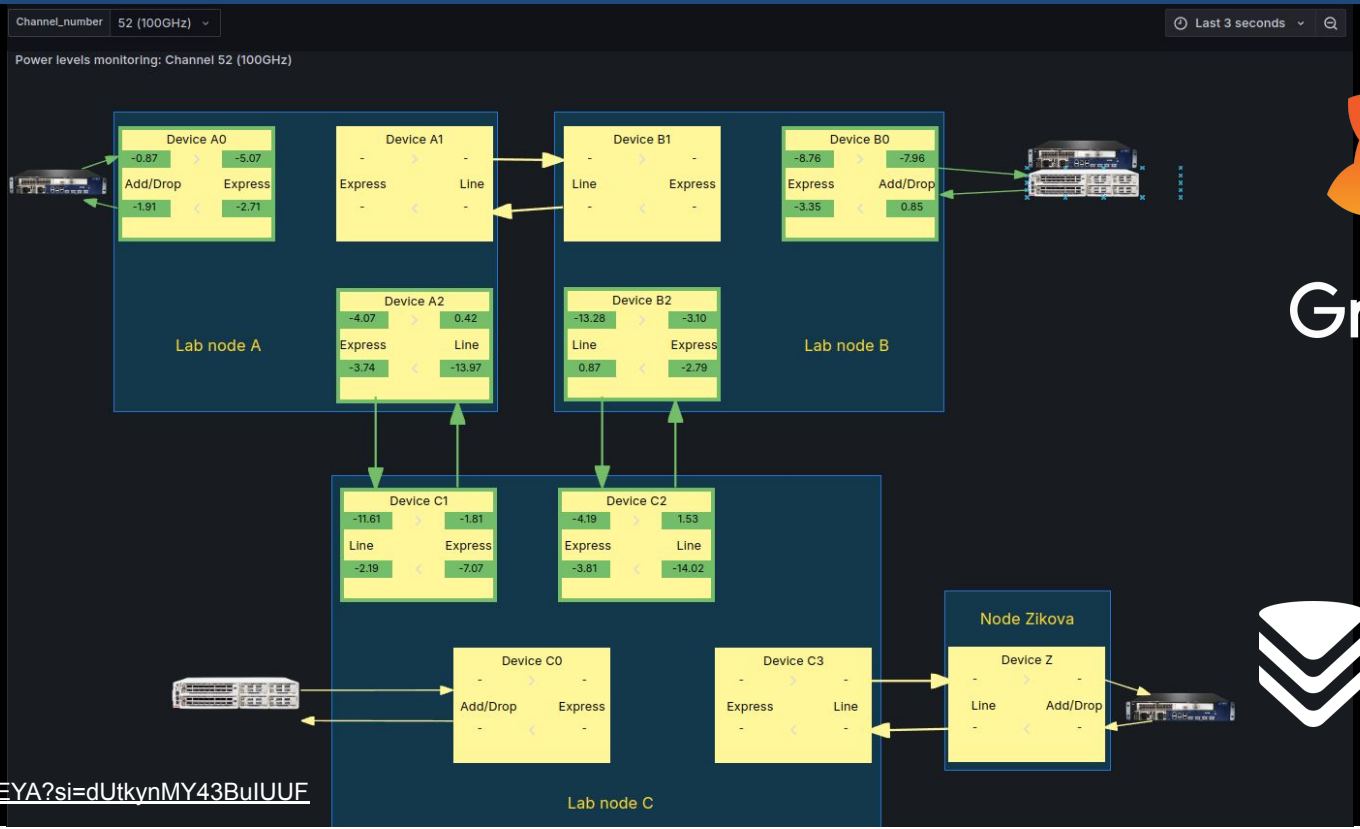
```
- hosts: roadm-a1
strategy: free
connection: ansible.netcommon.netconf
tasks:
  - name: "ch52 AD-B"
    CzL_media_channel:
      name: "52 (100GHz)"
      leaf_port: E1
      state: present
      attenuation_add: 10.0
      attenuation_drop: 10.0
```

```
- hosts: roadm-c1
strategy: free
connection: ansible.netcommon.netconf
tasks:
  - name: "ch52 A-B"
    CzL_media_channel:
      name: "52 (100GHz)"
      leaf_port: E3
      state: absent
      attenuation_add: 10.0
      attenuation_drop: 10.0
```

```
- hosts: roadm-b2
strategy: free
connection: ansible.netcommon.netconf
tasks:
  - name: "ch52 C-AD"
    CzL_media_channel:
      name: "52 (100GHz)"
      leaf_port: E1
      state: absent
```

```
- hosts: roadm-b0
strategy: free
connection: ansible.netcommon.netconf
tasks:
  - name: "ch52 C"
    CzL_media_channel:
      name: "52 (100GHz)"
      leaf_port: "12"
      state: present
      attenuation_add: 10.0
      attenuation_drop: 10.0
```

Example: Channel rerouting

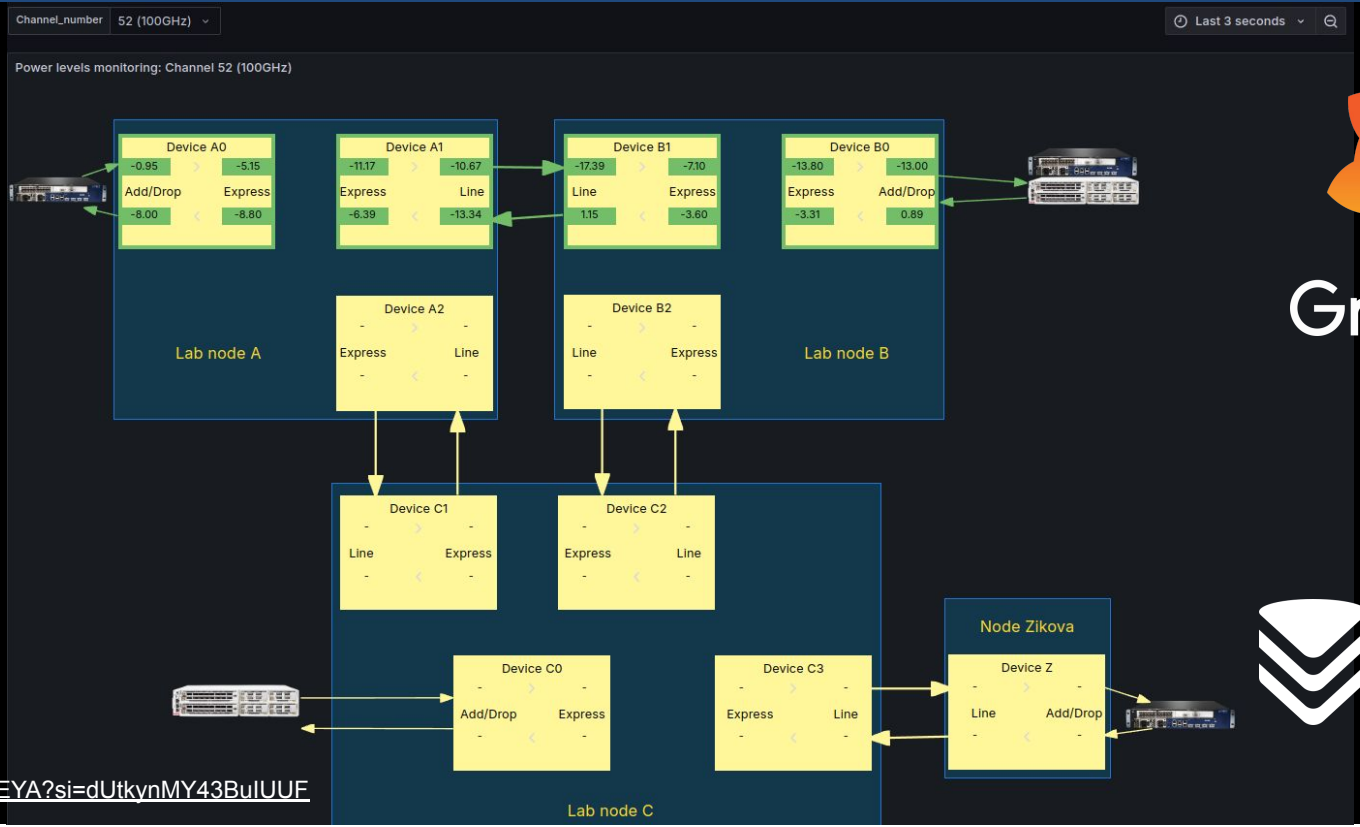


Grafana

VICTORIA METRICS

https://youtu.be/lviKYIL0EYA?si=dUtkynMY43BuIUUF

Example: Channel rerouting



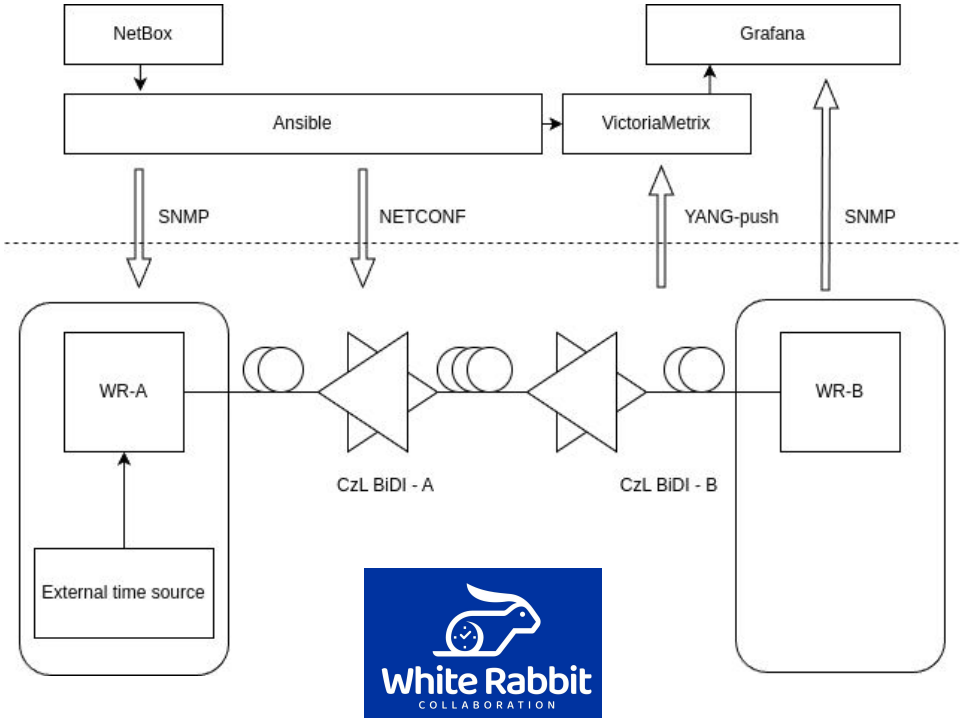
Grafana

VICTORIA METRICS

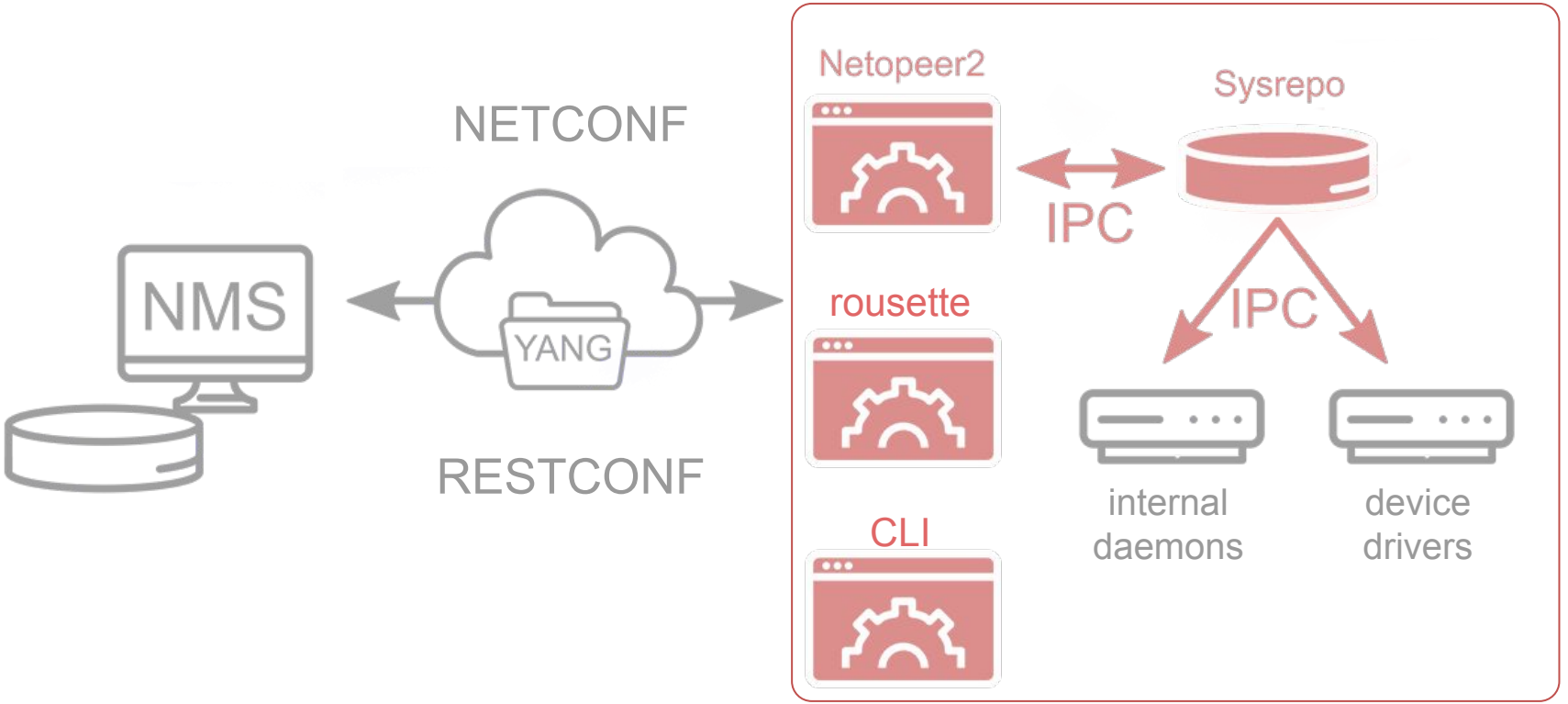
https://youtu.be/lviKYIL0EYA?si=dUtkynMY43BuIUUF

Precise Time Distribution

- SDN is not just about data
- Precise time distribution in CESNET production network
  - About 20 White Rabbit switches and 50 BiDi amplifiers to be deployed
  - Integration into standard management and monitoring tools



SW Architecture with Sysrepo



YANG: API Which Fits on One Slide

```
module: czechlight-roadm-device
  +--rw channel-plan
  |  +--rw channel* [name]
  |     +--rw name                    string
  |     +--rw lower-frequency         opendevice-t:dwdm-frequency-mhz
  |     +--rw upper-frequency         opendevice-t:dwdm-frequency-mhz
  +--rw media-channels* [channel]
  |  +--rw channel                    -> /channel-plan/channel/name
  |  +--rw description?               string
  |  +--rw add!
  |  |  +--rw port                    device-dependent-port-type
  |  |  +--rw (mode)
  |  |  +--:(attenuation)
  |  |  |  +--rw attenuation          attenuation-type
  |  |  +--:(power)
  |  |     +--rw power                opendevice-t:optical-power-dBm
  |  +--rw drop!
  |  |  ...
  |  +--ro power
  |     +--ro common-in               opendevice-t:optical-power-dBm
  |     +--ro common-out              opendevice-t:optical-power-dBm
  |     +--ro leaf-in                 opendevice-t:optical-power-dBm
  |     +--ro leaf-out                opendevice-t:optical-power-dBm
  +--ro aggregate-power
  |  +--ro common-in                  opendevice-t:optical-power-dBm
  |  +--ro common-out                 opendevice-t:optical-power-dBm
  +--rw leaf-ports* [port]
  |  +--rw port                       device-dependent-port-type
  |  +--rw description?               string
  +--rw line {hw-line-9}?
  |  +--rw output-voa?                attenuation-type <0.0>
  |  +--ro osc
  |     +--ro tx-power?               opendevice-t:optical-power-dBm
  |     +--ro rx-power?               opendevice-t:optical-power-dBm
  +--rw spectrum-scan!
        +--rw period                  union
        +--rw pin-source?             union {pre-wss-ocm}?
        +--ro common-in
        |  +--ro lowest-frequency     frequency-ghz
        |  +--ro step                 frequency-ghz
        |  +--ro p?                   anydata
        +--ro common-out
           +--ro lowest-frequency     frequency-ghz
           +--ro step                 frequency-ghz
           +--ro p?                   anydata
```

https://github.com/CESNET/CzechLight-yang

#1: Define Spectrum

```
module: czechlight-roadm-device
  +--rw channel-plan
  |  +--rw channel* [name]
  |    +--rw name                    string
  |    +--rw lower-frequency         opendevice-t:dwdm-frequency-mhz
  |    +--rw upper-frequency         opendevice-t:dwdm-frequency-mhz
  +--rw media-channels* [channel]
  |  +--rw channel                   -> /channel-plan/channel/name
  |  +--rw description?              string
  |  +--rw add!
  |  |  +--rw port                   device-dependent-port-type
  |  |  +--rw (mode)
  |  |  +--:(attenuation)
  |  |  |  +--rw attenuation         attenuation-type
  |  |  +--:(power)
  |  |     +--rw power               opendevice-t:optical-power-dBm
  |  +--rw drop!
  |  |  ...
  |  +--ro power
  |    +--ro common-in               opendevice-t:optical-power-dBm
  |    +--ro common-out              opendevice-t:optical-power-dBm
  |    +--ro leaf-in                 opendevice-t:optical-power-dBm
  |    +--ro leaf-out                opendevice-t:optical-power-dBm
  +--ro aggregate-power
  |  +--ro common-in                 opendevice-t:optical-power-dBm
  |  +--ro common-out                opendevice-t:optical-power-dBm
  +--rw leaf-ports* [port]
  |  +--rw port                      device-dependent-port-type
  |  +--rw description?              string
  +--rw line {hw-line-9}?
  |  +--rw output-voa?               attenuation-type <0.0>
  |  +--ro osc
  |     +--ro tx-power?              opendevice-t:optical-power-dBm
  |     +--ro rx-power?              opendevice-t:optical-power-dBm
  +--rw spectrum-scan!
     +--rw period                    union
     +--rw pin-source?               union {pre-wss-ocm}?
     +--ro common-in
     |  +--ro lowest-frequency       frequency-ghz
     |  +--ro step                   frequency-ghz
     |  +--ro p?                     anydata
     +--ro common-out
        +--ro lowest-frequency       frequency-ghz
        +--ro step                   frequency-ghz
        +--ro p?                     anydata
```

#2: Activate Channels

```
module: czechlight-roadm-device
  +--rw channel-plan
  |  +--rw channel* [name]
  |     +--rw name                    string
  |     +--rw lower-frequency         opendevice-t:dwdm-frequency-mhz
  |     +--rw upper-frequency         opendevice-t:dwdm-frequency-mhz
  +--rw media-channels* [channel]
  |  +--rw channel                    -> /channel-plan/channel/name
  |  +--rw description?               string
  |  +--rw add!
  |  |  +--rw port                    device-dependent-port-type
  |  |  +--rw (mode)
  |  |  +--:(attenuation)
  |  |  |  +--rw attenuation          attenuation-type
  |  |  +--:(power)
  |  |     +--rw power                opendevice-t:optical-power-dBm
  |  +--rw drop!
  |  |  ...
  |  +--ro power
  |     +--ro common-in               opendevice-t:optical-power-dBm
  |     +--ro common-out              opendevice-t:optical-power-dBm
  |     +--ro leaf-in                 opendevice-t:optical-power-dBm
  |     +--ro leaf-out                opendevice-t:optical-power-dBm
  +--ro aggregate-power
  |  +--ro common-in                  opendevice-t:optical-power-dBm
  |  +--ro common-out                 opendevice-t:optical-power-dBm
  +--rw leaf-ports* [port]
  |  +--rw port                       device-dependent-port-type
  |  +--rw description?               string
  +--rw line {hw-line-9}?
  |  +--rw output-voa?                attenuation-type <0.0>
  |  +--ro osc
  |     +--ro tx-power?               opendevice-t:optical-power-dBm
  |     +--ro rx-power?               opendevice-t:optical-power-dBm
  +--rw spectrum-scan!
        +--rw period                  union
        +--rw pin-source?             union {pre-wss-ocm}?
        +--ro common-in
        |  +--ro lowest-frequency     frequency-ghz
        |  +--ro step                 frequency-ghz
        |  +--ro p?                   anydata
        +--ro common-out
           +--ro lowest-frequency     frequency-ghz
           +--ro step                 frequency-ghz
           +--ro p?                   anydata
```

#3: Routing

```
module: czechlight-roadm-device
  +--rw channel-plan
  |  +--rw channel* [name]
  |     +--rw name                    string
  |     +--rw lower-frequency         opendevice-t:dwdm-frequency-mhz
  |     +--rw upper-frequency         opendevice-t:dwdm-frequency-mhz
  +--rw media-channels* [channel]
  |  +--rw channel                    -> /channel-plan/channel/name
  |  +--rw description?               string
  |  +--rw add!
  |  |  +--rw port                    device-dependent-port-type
  |  |  +--rw (mode)
  |  |  +--:(attenuation)
  |  |  |  +--rw attenuation          attenuation-type
  |  |  +--:(power)
  |  |     +--rw power                opendevice-t:optical-power-dBm
  |  +--rw drop!
  |  |  ...
  |  +--ro power
  |     +--ro common-in               opendevice-t:optical-power-dBm
  |     +--ro common-out              opendevice-t:optical-power-dBm
  |     +--ro leaf-in                 opendevice-t:optical-power-dBm
  |     +--ro leaf-out                opendevice-t:optical-power-dBm
  +--ro aggregate-power
  |  +--ro common-in                  opendevice-t:optical-power-dBm
  |  +--ro common-out                 opendevice-t:optical-power-dBm
  +--rw leaf-ports* [port]
  |  +--rw port                       device-dependent-port-type
  |  +--rw description?               string
  +--rw line {hw-line-9}?
  |  +--rw output-voa?                attenuation-type <0.0>
  |  +--ro osc
  |     +--ro tx-power?               opendevice-t:optical-power-dBm
  |     +--ro rx-power?               opendevice-t:optical-power-dBm
  +--rw spectrum-scan!
     +--rw period                     union
     +--rw pin-source?                union {pre-wss-ocm}?
     +--ro common-in
     |  +--ro lowest-frequency        frequency-ghz
     |  +--ro step                    frequency-ghz
     |  +--ro p?                      anydata
     +--ro common-out
        +--ro lowest-frequency        frequency-ghz
        +--ro step                    frequency-ghz
        +--ro p?                      anydata
```

#4: Monitoring

```
module: czechlight-roadm-device
  +--rw channel-plan
  |  +--rw channel* [name]
  |     +--rw name                    string
  |     +--rw lower-frequency         opendevice-t:dwdm-frequency-mhz
  |     +--rw upper-frequency         opendevice-t:dwdm-frequency-mhz
  +--rw media-channels* [channel]
  |  +--rw channel                    -> /channel-plan/channel/name
  |  +--rw description?               string
  |  +--rw add!
  |  |  +--rw port                    device-dependent-port-type
  |  |  +--rw (mode)
  |  |  +--:(attenuation)
  |  |  |  +--rw attenuation          attenuation-type
  |  |  +--:(power)
  |  |     +--rw power                opendevice-t:optical-power-dBm
  |  +--rw drop!
  |  |  ...
  |  +--ro power
  |     +--ro common-in               opendevice-t:optical-power-dBm
  |     +--ro common-out              opendevice-t:optical-power-dBm
  |     +--ro leaf-in                 opendevice-t:optical-power-dBm
  |     +--ro leaf-out                opendevice-t:optical-power-dBm
```

```
+--ro aggregate-power
|  +--ro common-in                   opendevice-t:optical-power-dBm
|  +--ro common-out                  opendevice-t:optical-power-dBm
+--rw leaf-ports* [port]
|  +--rw port                        device-dependent-port-type
|  +--rw description?                string
+--rw line {hw-line-9}?
|  +--rw output-voa?                 attenuation-type <0.0>
|  +--ro osc
|     +--ro tx-power?                opendevice-t:optical-power-dBm
|     +--ro rx-power?                opendevice-t:optical-power-dBm
+--rw spectrum-scan!
     +--rw period                    union
     +--rw pin-source?               union {pre-wss-ocm}?
     +--ro common-in
     |  +--ro lowest-frequency       frequency-ghz
     |  +--ro step                   frequency-ghz
     |  +--ro p?                     anydata
     +--ro common-out
        +--ro lowest-frequency       frequency-ghz
        +--ro step                   frequency-ghz
        +--ro p?                     anydata
```

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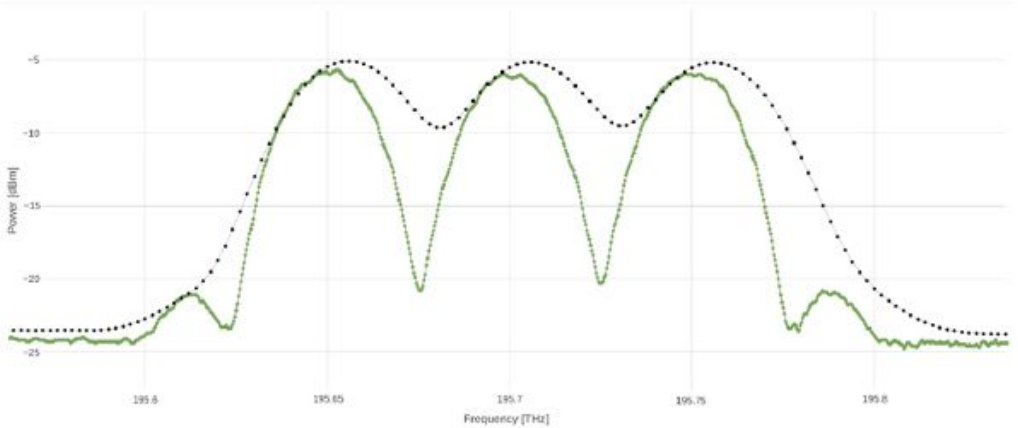
Monitoring & Telemetry

- Streaming Telemetry
  - All the metrics
  - Sub-second latencies
- I/O Formats
  - IETF YANG-push
  - OpenMetrics (Prometheus)
  - Grafana



VICTORIA METRICS

Grafana

Live Monitoring with Grafana

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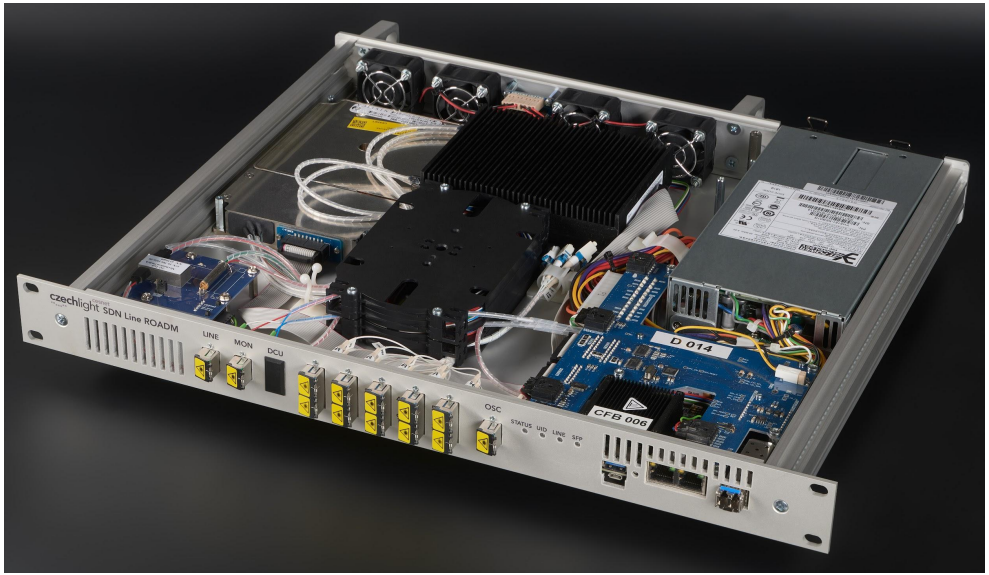
Summary

- Optical networks don't have to be complex
- The SDN concept can be applied to optical networks
- Standard DevOps tools can be effectively leveraged



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Thank you

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HW: SolidRun Clearfog Base

- Marvell Armada A38x SoC
  - Dual core 32-bit ARM
  - 1GB RAM, 4 GB eMMC
- SFP built-in
  - Native I^2C access
  - No need to route SGMII or PCIe
- Well-supported upstream
  - Same SoC as Turris Omnia
- Not that many GPIOs

Image source: © SolidRun

System Image and Bootloader

- Atomic system updates
  - System built as a single image: http://buildroot.org/
- A/B software slots
  - http://rauc.io/
  - Integrated with HW watchdog

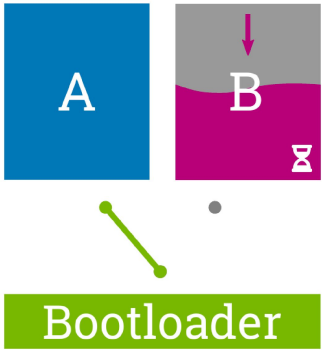

Image source: © Enrico Jörns, Pengutronix. © Open Compute Project

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Open Source Software

- sysrepo and libyang
  - YANG software stack
  - config/ops database
- libnetconf2 and Netopeer2
  - NETCONF server
- rousette
  - RESTCONF server
  - telemetry
- netconf-cli
  - <Tab>-driven interactive console
- velia: system management
  - health tracking
  - system management
  - firewall
  - hardware
  - network (L2/L3)
- sysrepo-ietf-alarms
  - alarm management
- cla-sysrepo
  - drivers for optical modules
  - ROADM logic