BTFS network Technical status

Belnet

Royal Observatory of Belgium

Belnet

Connecting communities

.be

Belnet

Connecting communities

ROB & BELNET: an ideal partnership

Royal Observatory of Belgium

ROB

- Supplier of Belgian UTC
- R&E community
- European NMI's

Belnet

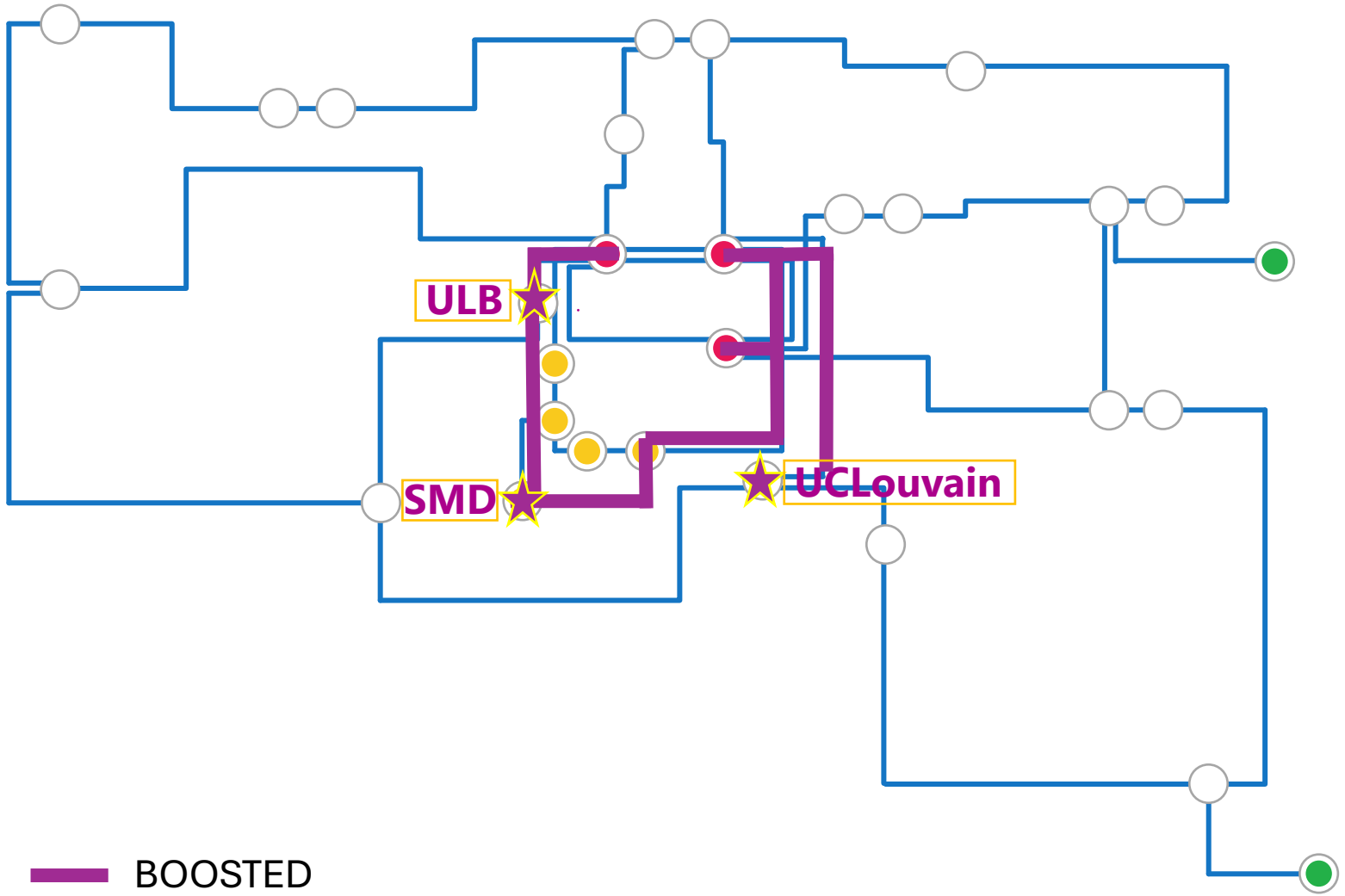
- Neutral service provider
- NREN
- Geant

Belnet

Connecting communities

The BOOSTED network

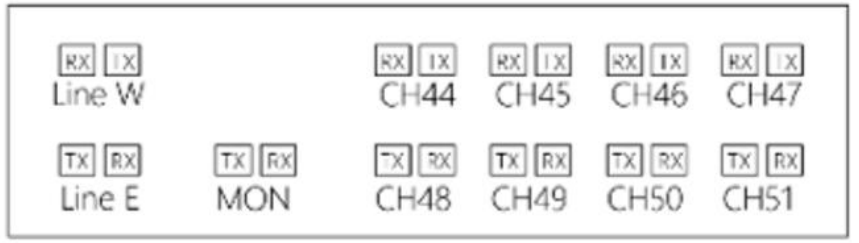
Royal Observatory of Belgium

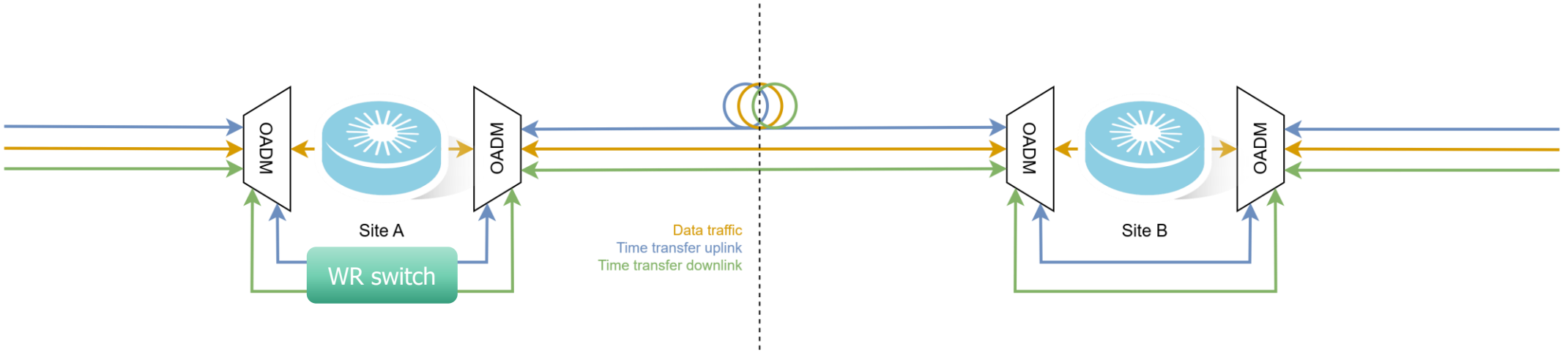


High level architecture

- Channels used:
  - Frequency service: CH44
  - Timing service: CH45 / CH46 / CH47 / CH48 / CH49 / CH50

OADM module





Belnet
Connecting communities

C-band or L-band?

Royal Observatory of Belgium

- Channels used: 6 (WR) + 1 (FQ) = **7 reserved for T&F**
- Add guard-band (50-200Ghz)
    - Even more on high-capacity links!
- Q: what are other NREN's doing about this?

Scenario	Main Pros	Main Cons
C-band	Architecture will work day 1 Respect Ciena recommendations No extra delays No extra work/investigation needed Optimizations are possible	c-band usage (40-54% used of currently deployed) Need to deploy full c-band (red+blue) => 27-40% reserved for timing Might require extra fiber (medium - long term) (extra cost)
L-band	c-band usage (only Ch44) No technical disadvantage	Project delay (6 - 12 months) Requires investigation (architecture & providers,...) Risk that the attenuation is higher than in the c band.

Belnet

Connecting communities

First results: Belnet backbone

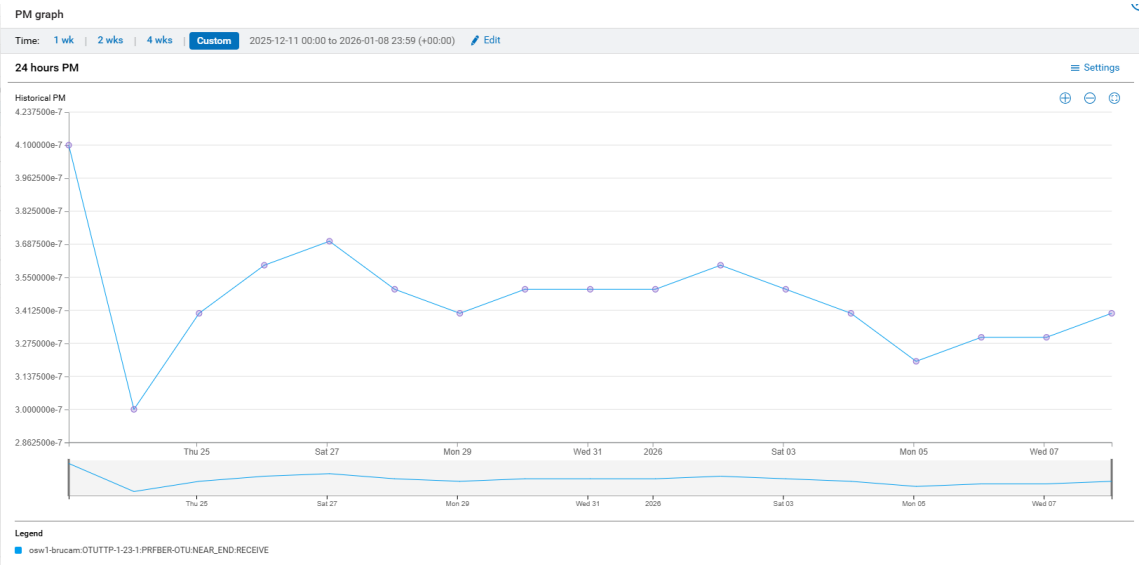
Royal Observatory of Belgium

Effect on backbone traffic (BER)

- Basically invisible

Added attenuation

- +1.7-2.9db (more than expected)



Royal Observatory of Belgium

BTFS network : technical status

Workshop ROB 2026

Guillaume Le Portz

10/03/2026

Pre-Deployment Calibration strategy

Royal Observatory of Belgium

1. Hardware delay characterization

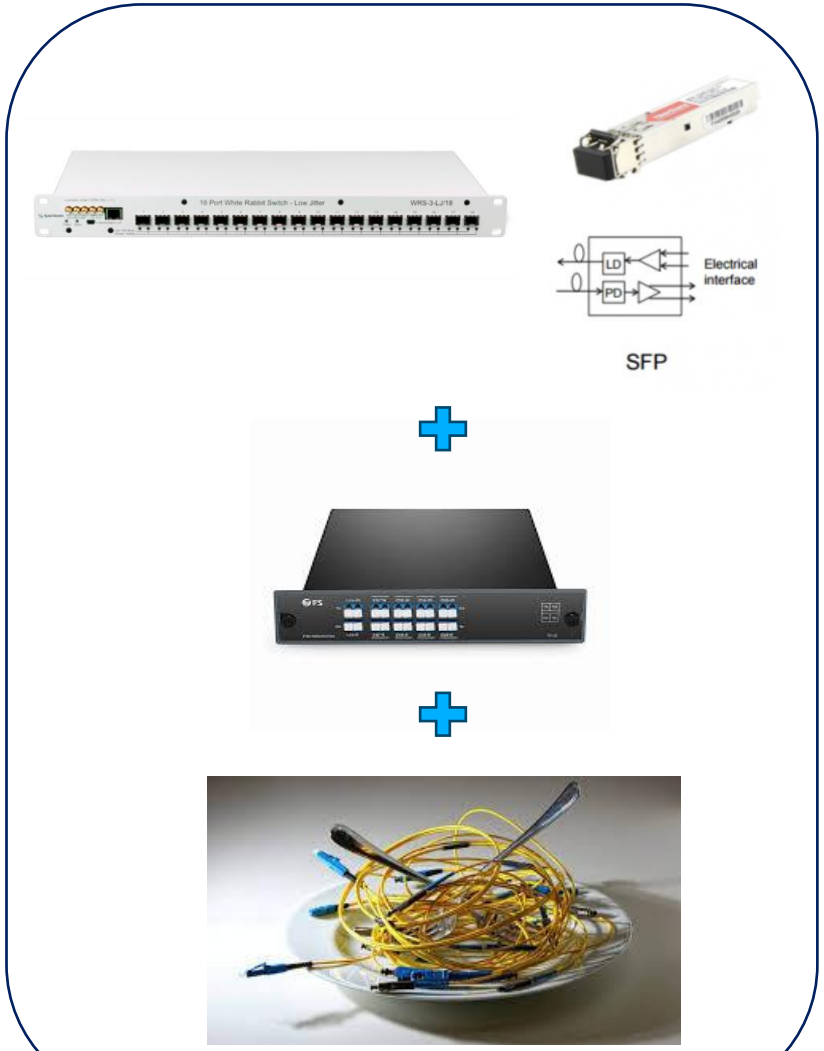
- SFP Tx/Rx delays measured
- The asymmetry delays of OADMs are measured.

2. Parameter registration

- All delays stored in a calibration database
- Equipment-specific configuration prepared before deployment
- Fibre asymmetry coefficient (α) due to chromatic dispersion in a single fiber.

3. Validation

- Full end-to-end test before field installation
- Synchronisation verified in controlled conditions

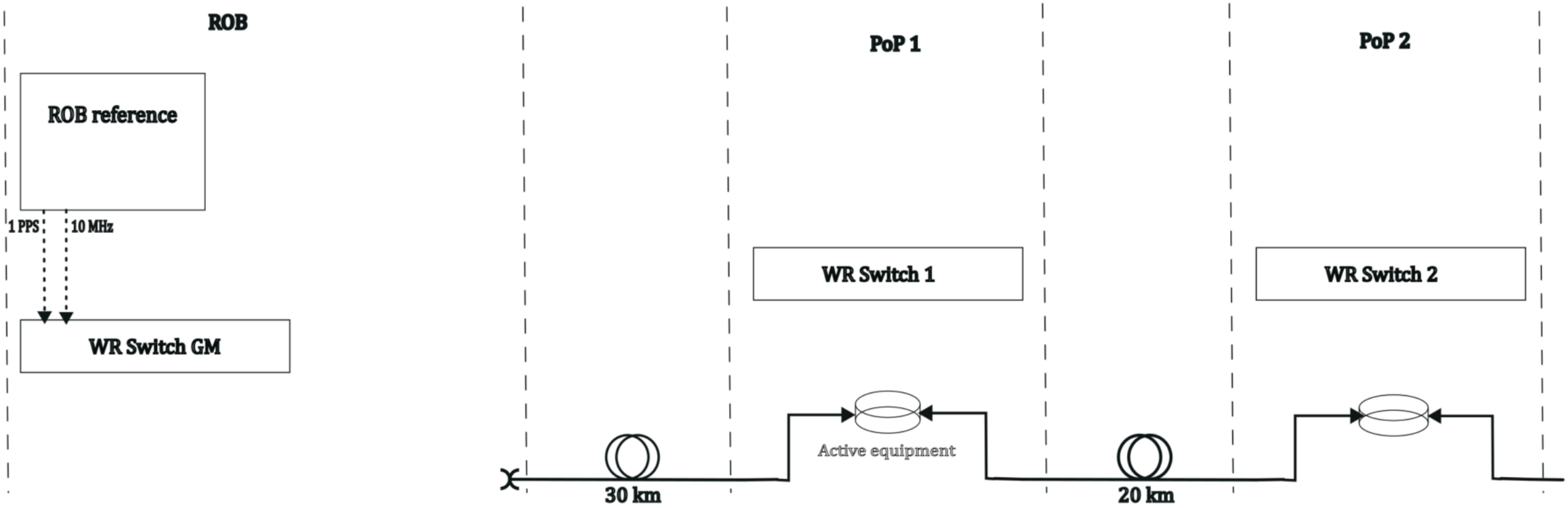


$$\alpha = \frac{\delta_{MS} - \delta_{SM}}{\delta_{SM}}$$

The entire calibration procedure is detailed here :
https://gitlab.com/ohwr/project/white-rabbit/-/wikis/calibration

Boosted network overview for the first link

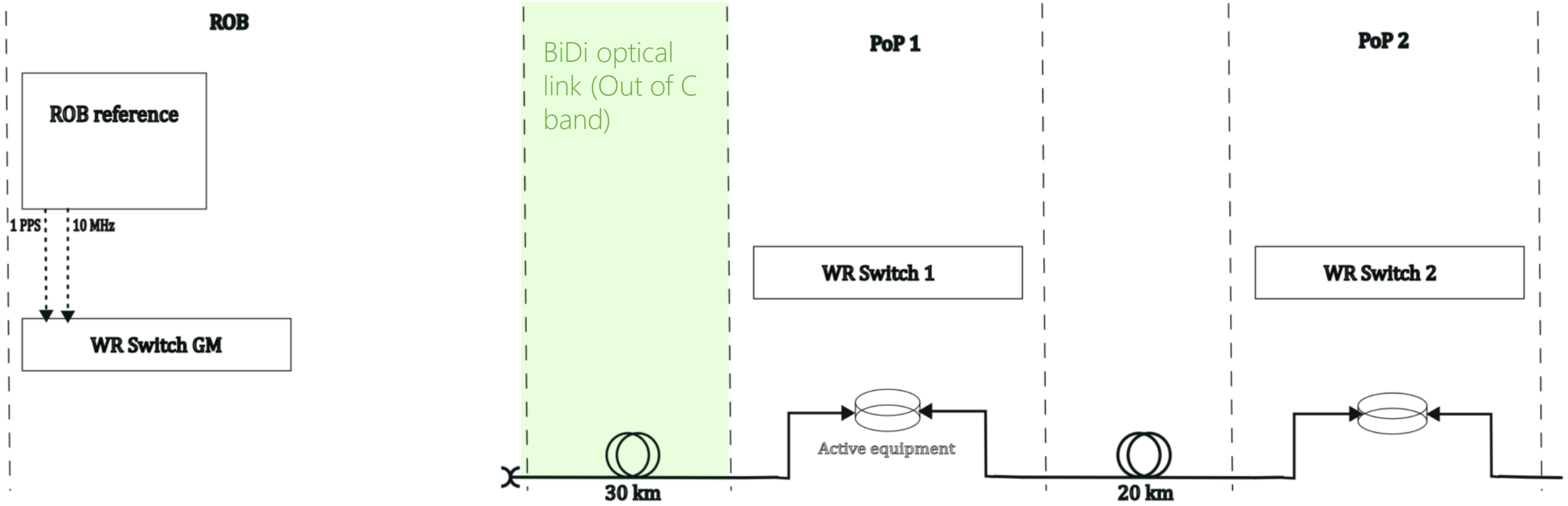
Royal Observatory of Belgium



- G.652.D fiber used on the network

Boosted network overview for the first link

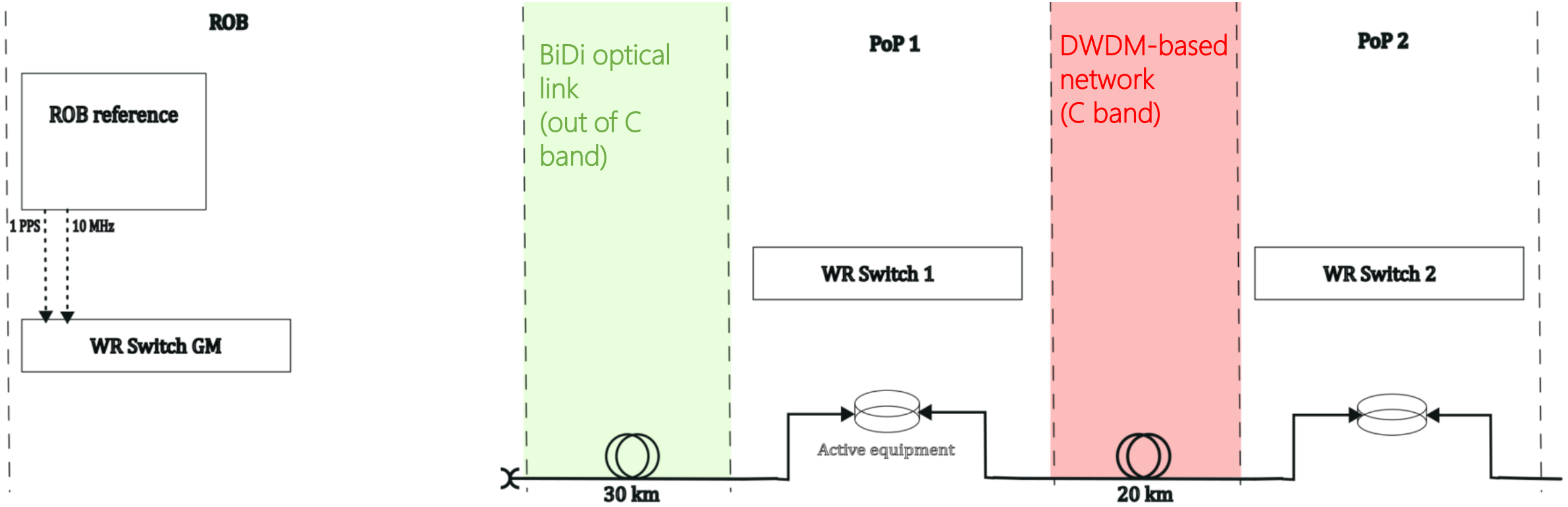
Royal Observatory of Belgium



- G.652.D fiber used on the network
- First link uses bidirectional optical SFPs for data (1310/1490)

Boosted network overview for the first link

Royal Observatory of Belgium

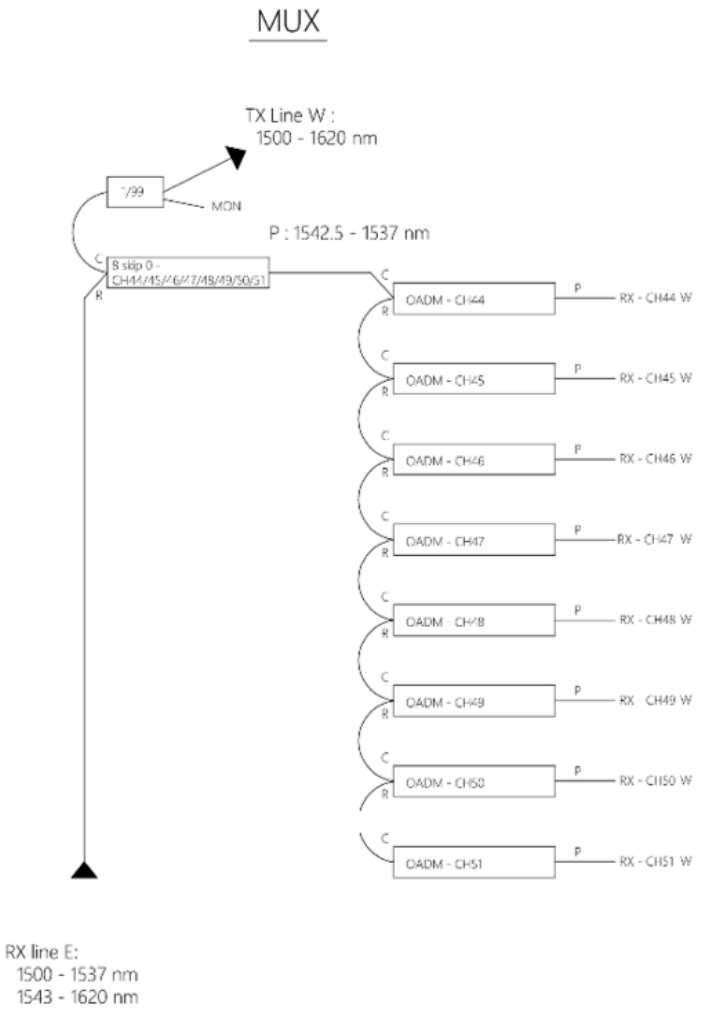


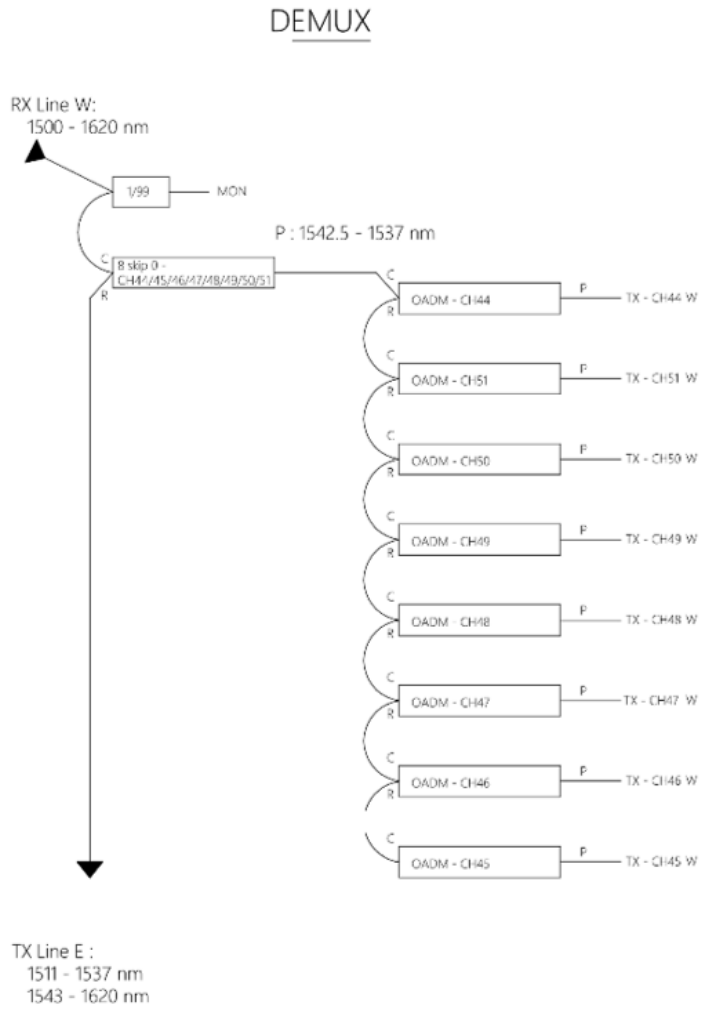
- G.652.D fiber used on the network
- First link uses bidirectional optical SFPs for data (1310/1490)
- Second link uses DWDM based network for data (like the rest of the network)

Implementation of OADMs

Optimized architecture for the DWDM network

- 8-skip-1 filter extracts a block of 8 channels
- Individual filtering of channels **CH44–CH51**

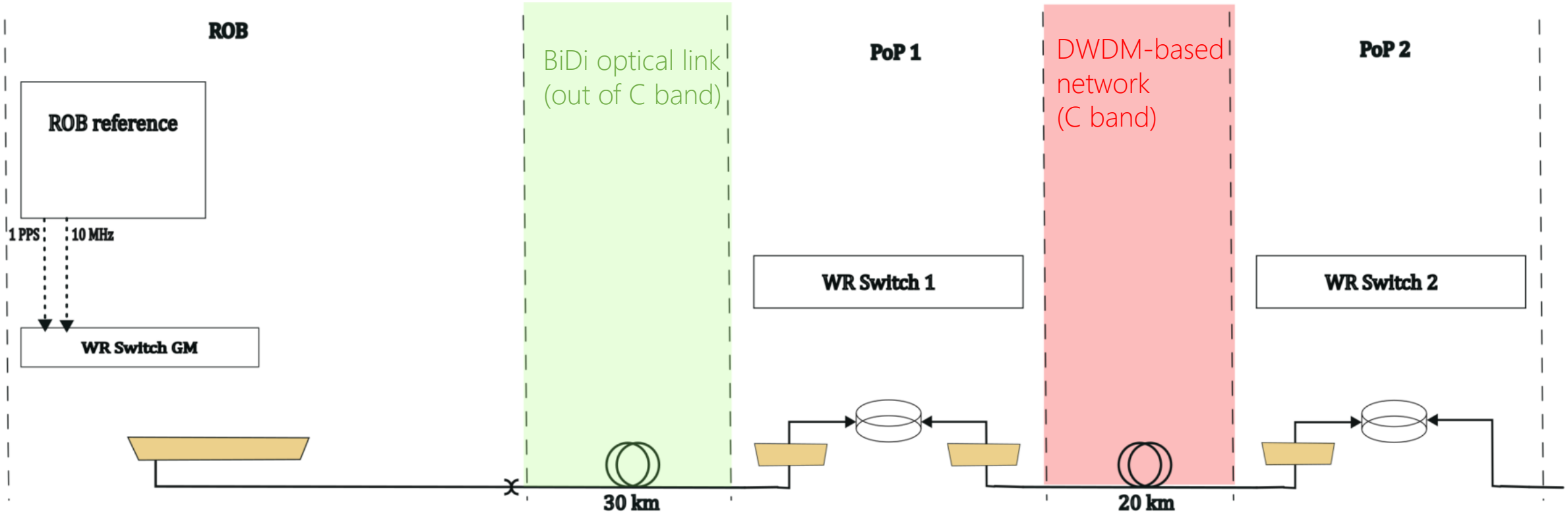




Insertion loss < 1 dB for the data traffic

Implementation of OADMs

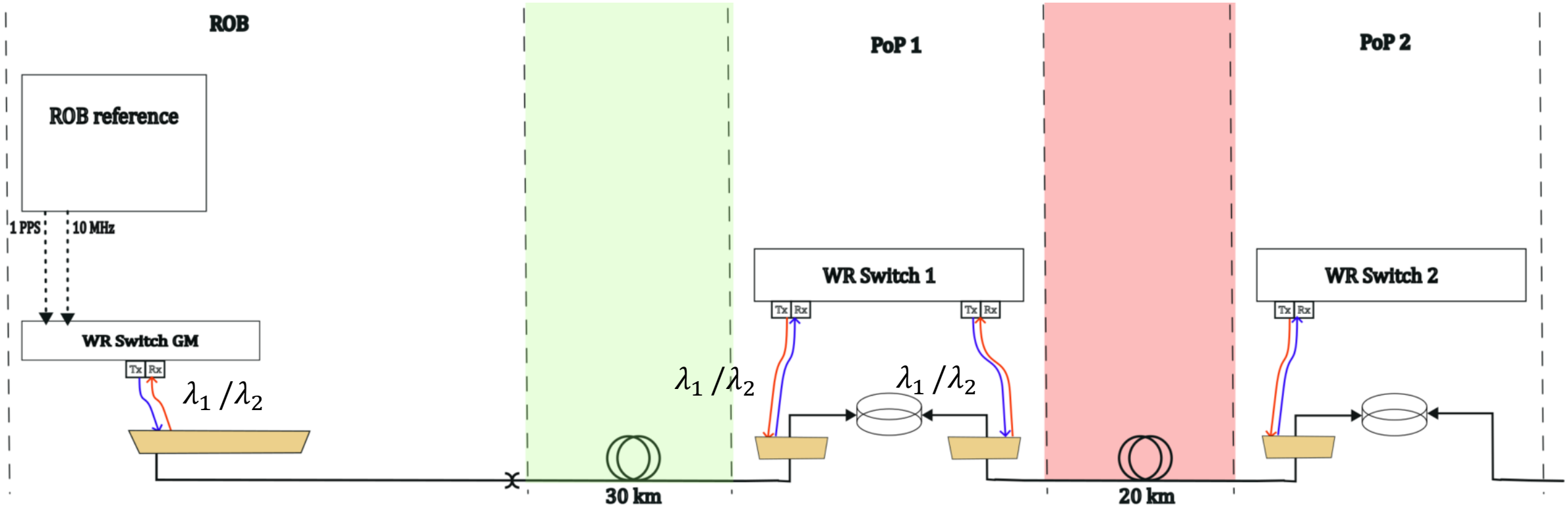
Royal Observatory of Belgium



- OADMs are used to inject and extract signals.

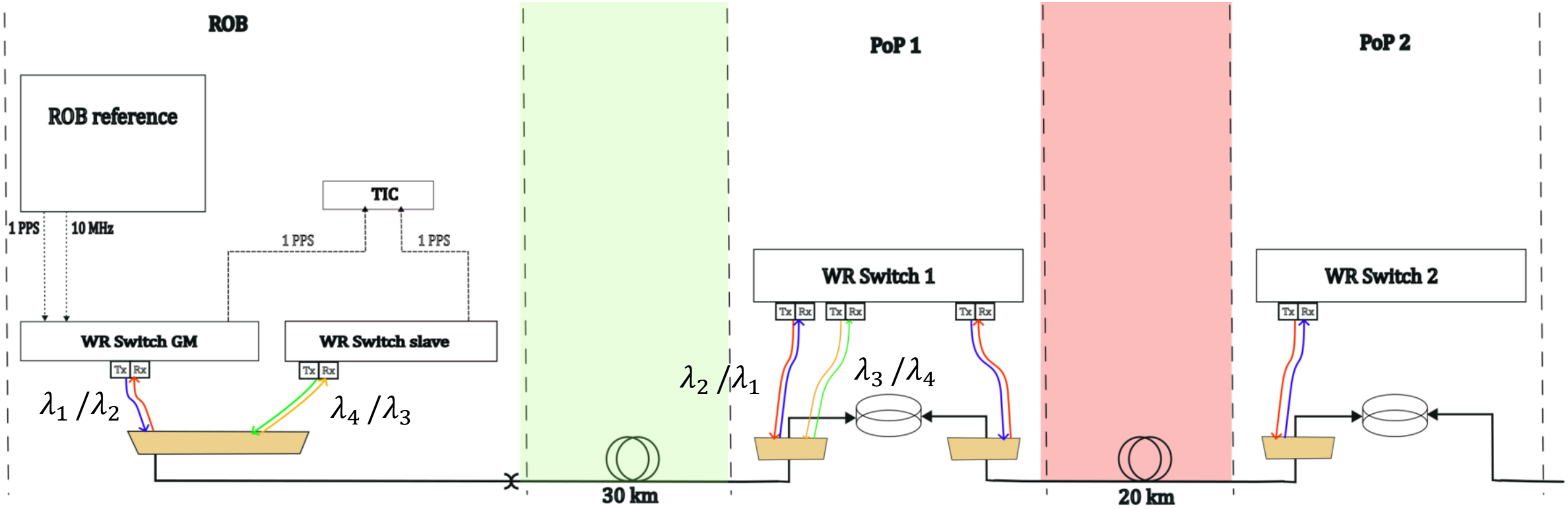
WR signal injection

Royal Observatory of Belgium



- White Rabbit uplink uses **two adjacent wavelengths from the ITU grid 100 GHz : λ_1 /λ_2**

Monitoring of the link

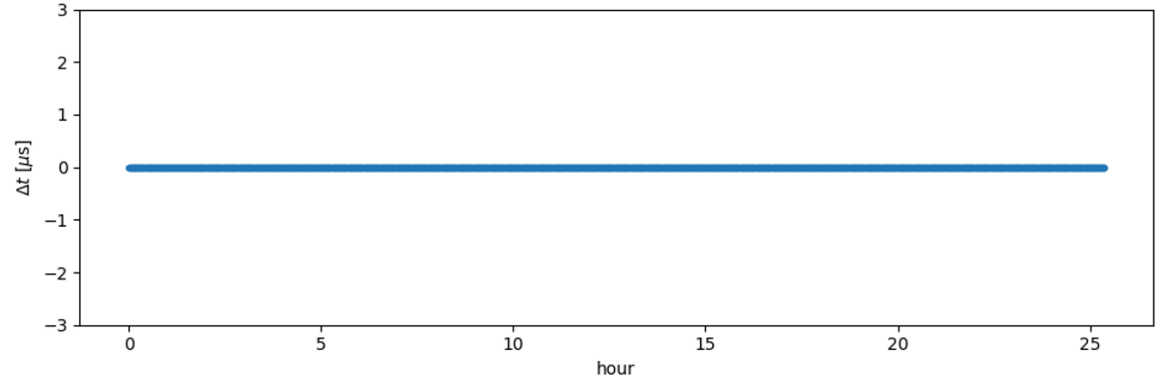


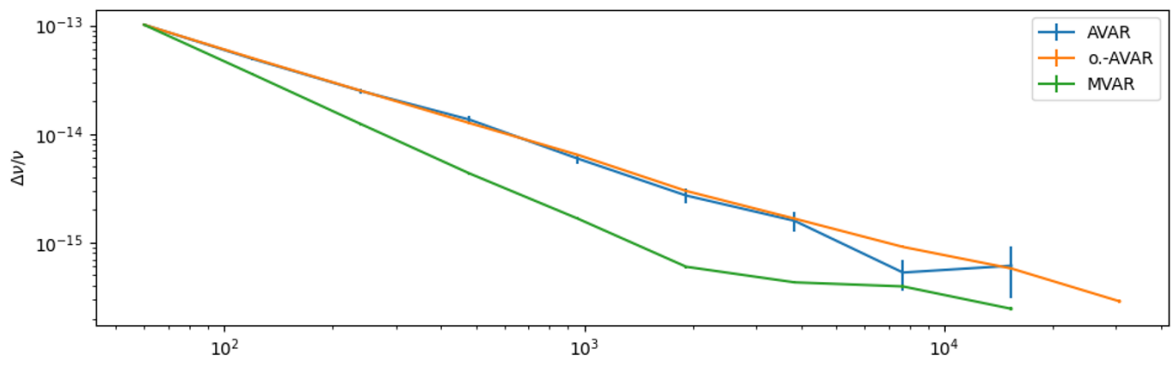
- Establishment of a downlink with another pair of adjacent channels from the ITU grid 100 GHz.
- A White Rabbit slave switch is placed next to the Grandmaster.
- A Time Interval Counter is used to measure the time difference between the PPS signals (TIC offset).

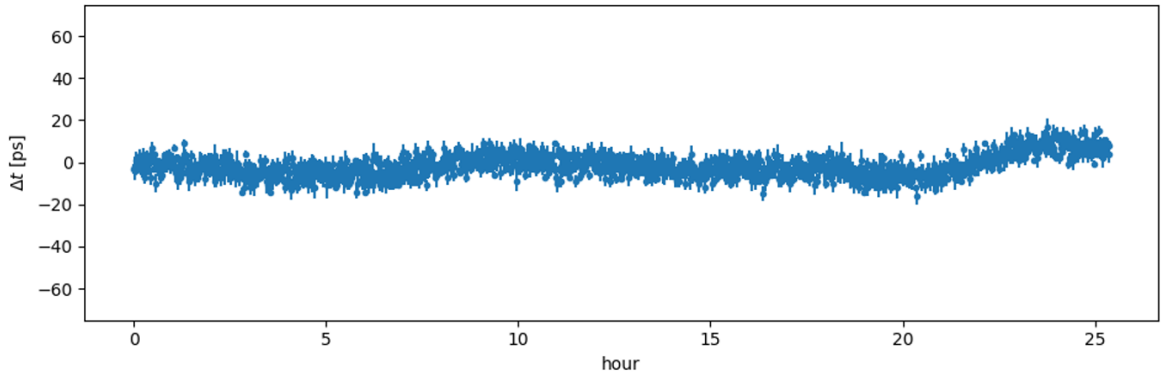
$$\lambda_1 - \lambda_2 \approx \lambda_3 - \lambda_4 \quad \Rightarrow \quad TIC\ offset \approx 2\Delta_{Switch\ GM-Switch\ 1}$$

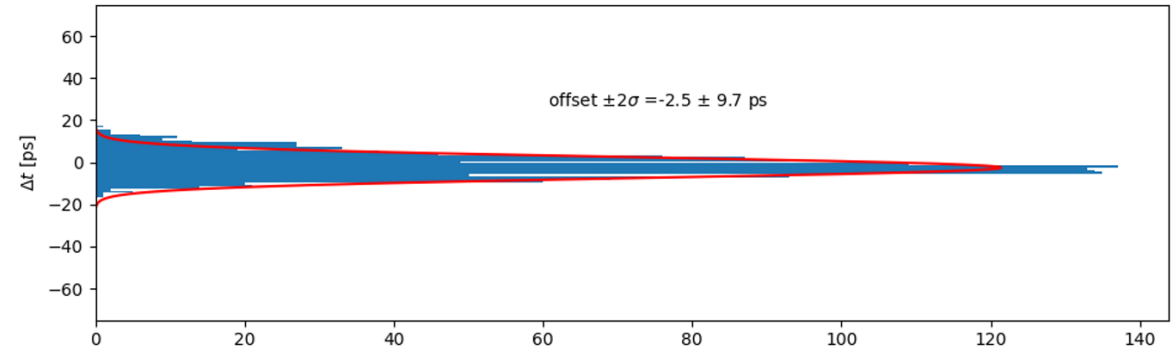
Results for the first link

Short-term performance





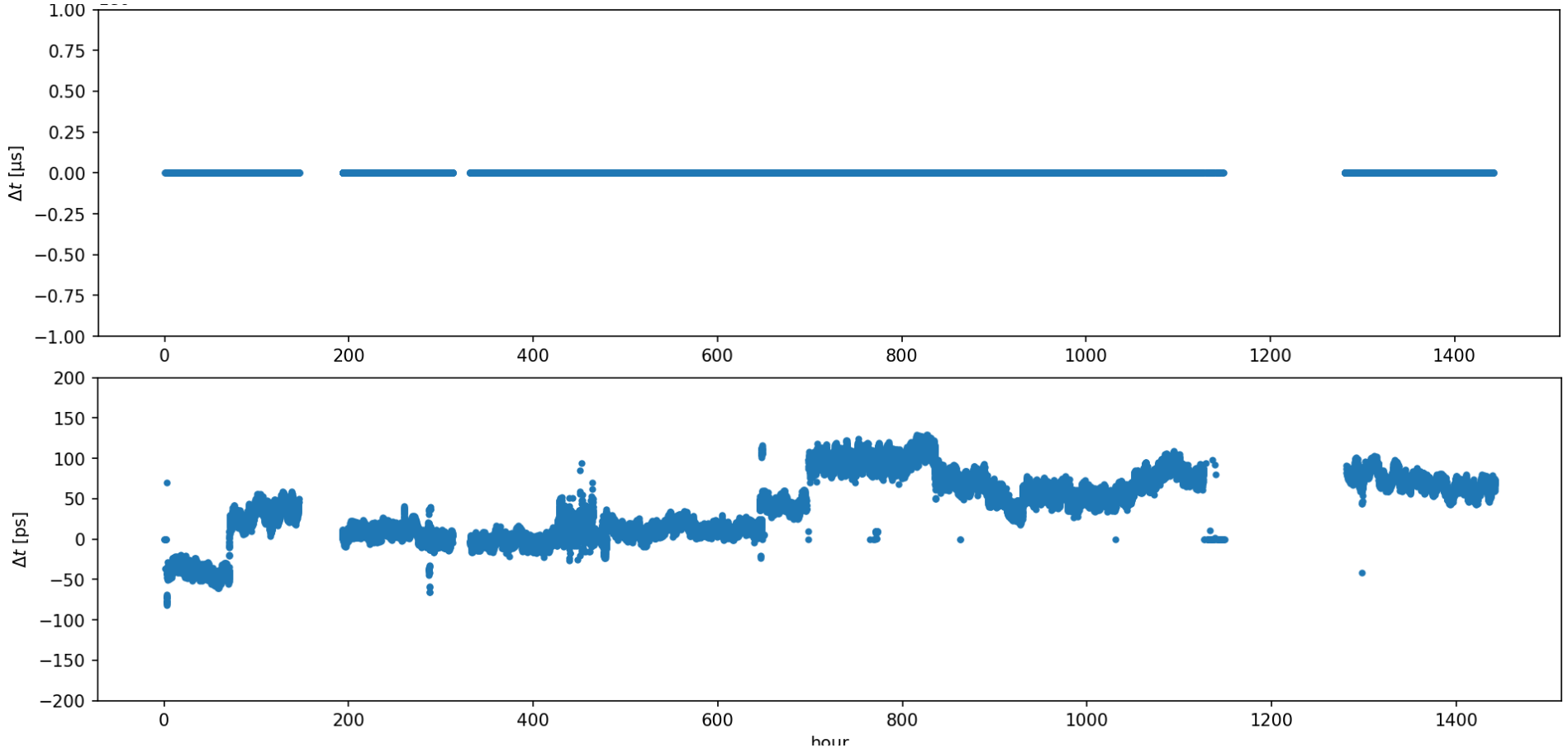




- Synchronisation within 10 ps over 24 hours

Results for the first link

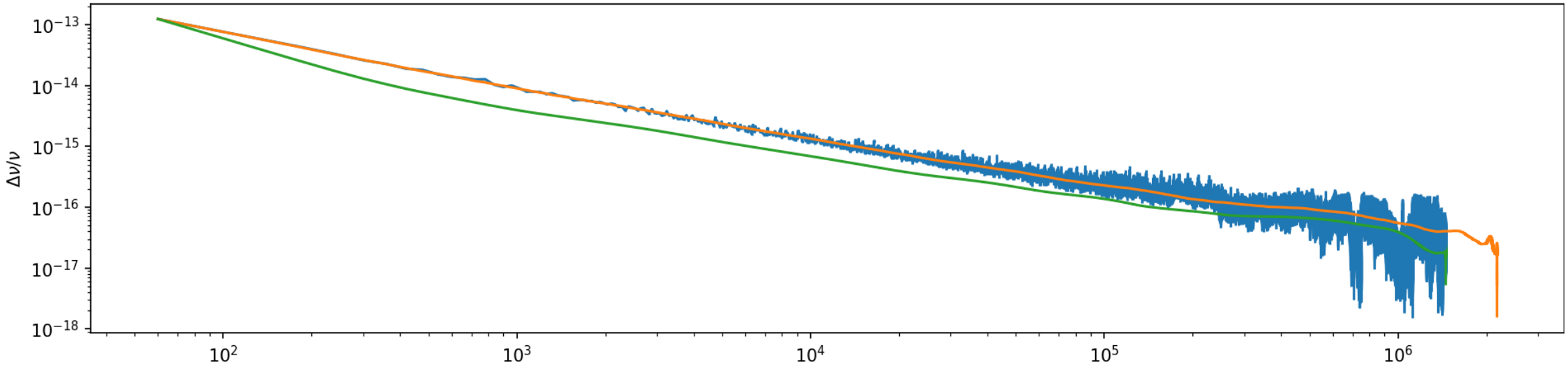
Long-term performance



- Synchronisation over 1400 hours (60 days)
- In the long term, we have jumps that can exceed 100 ps.

Results for the first link

Long-term transfert stability



- The Allan deviation shows a stability improving from about $\mathbf{10^{-13}}$ at short times to $\mathbf{10^{-17}}$ for long averaging times.

Outlook and improvement

Royal Observatory of Belgium

Continuous monitoring

- Implementation of continuous monitoring of: WR switch temperature, SFP temperature, SFP optical power, etc…
- Identify correlations with synchronization fluctuations

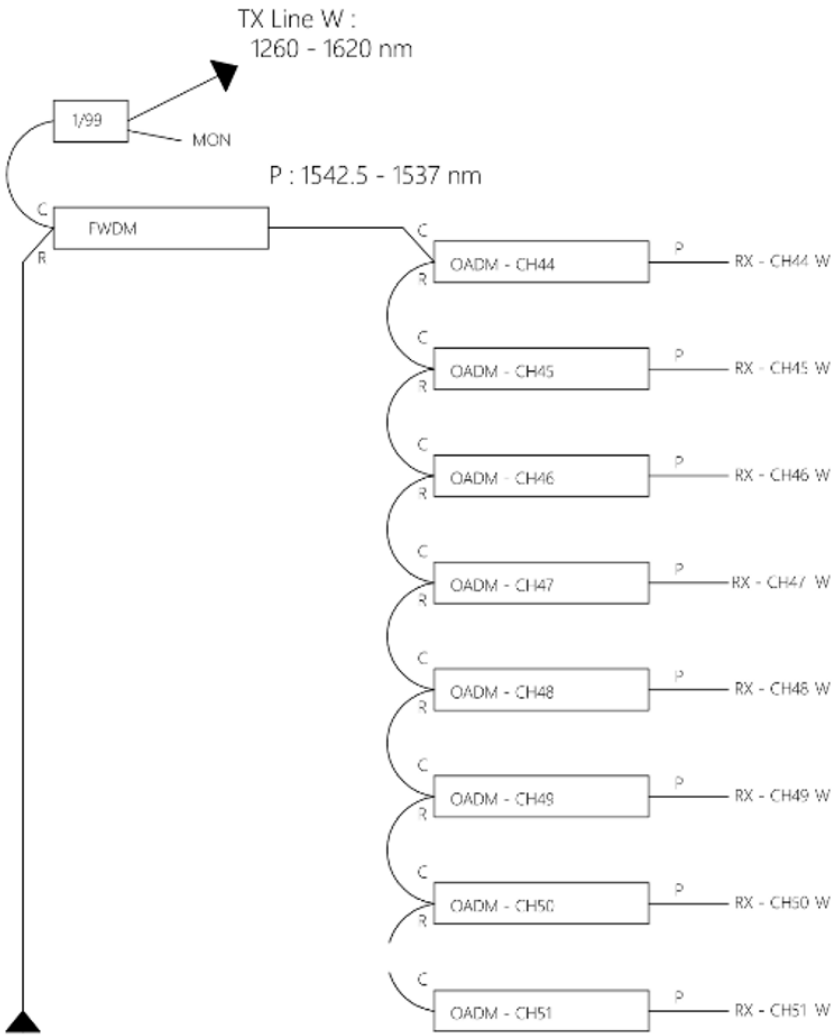
Performance analysis

- Use monitoring data to better understand **synchronization fluctuations**
- Improve calibration parameters and long-term stability

Network expansion

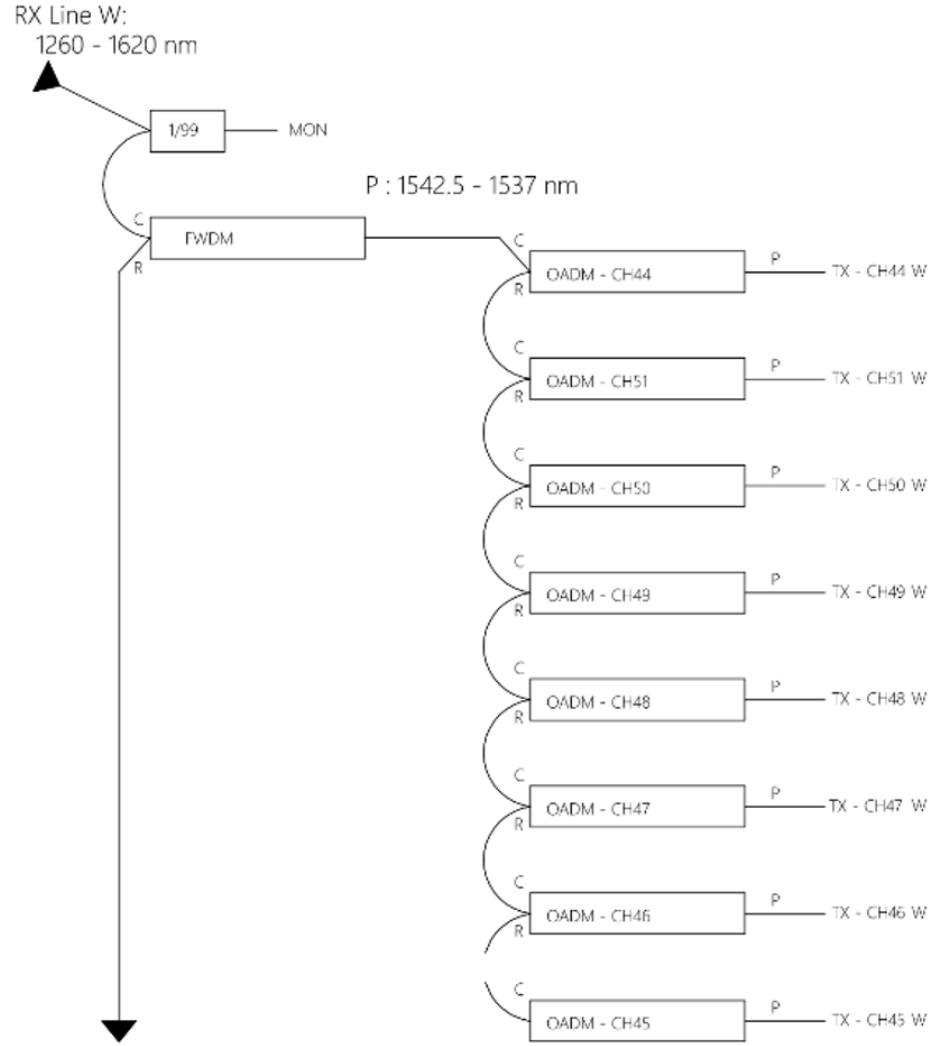
- Deployment and calibration of **additional White Rabbit links**
- Progressive extension of the **BOOSTED network**

MUX



RX line E:
1260 - 1537 nm
1543 - 1620 nm

DEMUX



TX Line E :
1260 - 1537 nm
1543 - 1620 nm