CSC

ICT Solutions for Brilliant Minds

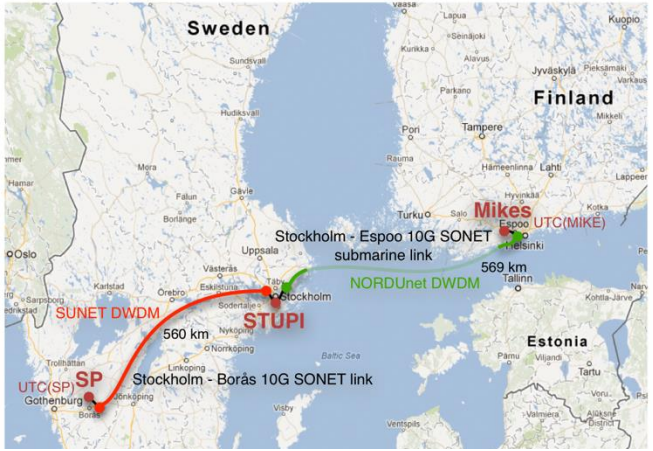
T&F update Finland (CSC/Funet and VTT)

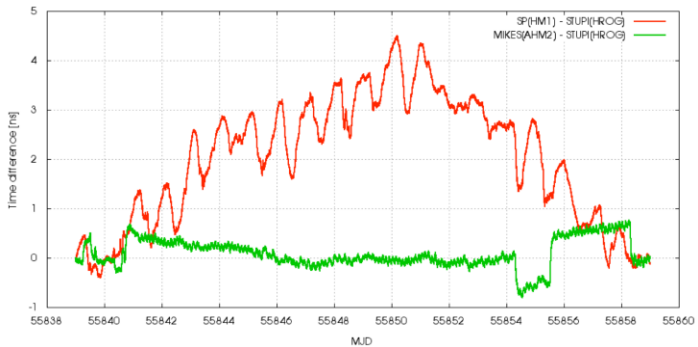
9.9.2024, GÉANT 15th SIG-NGN/TFN, Bergen, Norway

Jani Myyry, CSC/Funet

Time & Frequency transfer – the very beginning (2011)

- We got a proposal from Sweden
  - "We have a router (Cisco 12K) and one of Sven-Christers optical boxes we can lend to Mikes, I can even drive it there in my old VW bus…" (Peter Löthberg)
- The link was built
  - Used STM-64 transponders not needed anymore for our uplinks
- Survived NORDUnet's upgrade to coherent system
  - Was moved to OTN switching layer
- Decommissioned almost 10 years ago

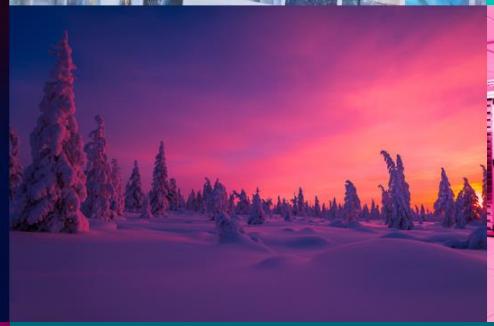




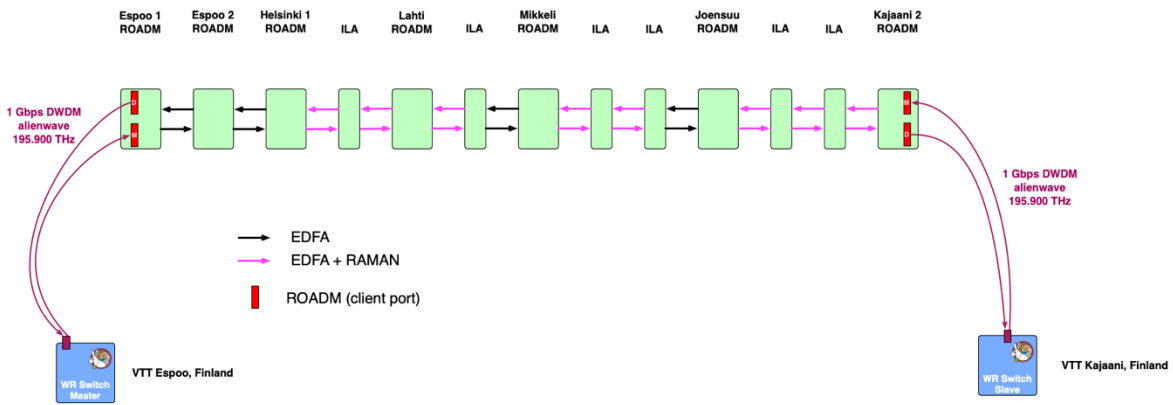
T&F fast-forward to the present day

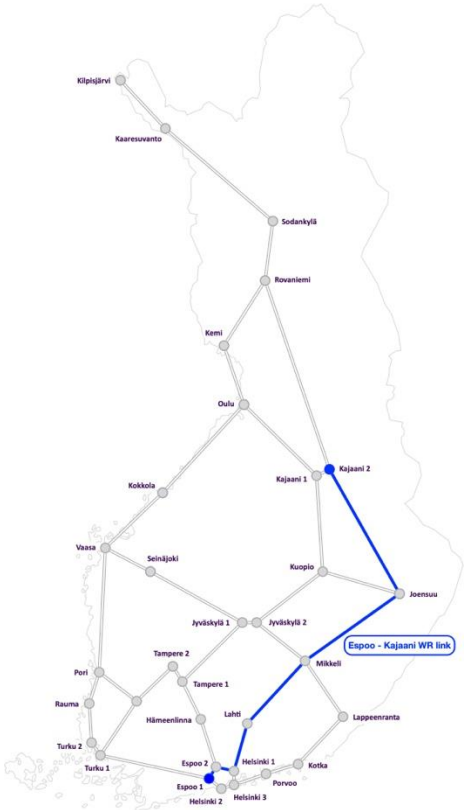
- PTP White Rabbit unidirectional (since 2013)
  - VTT/Mikes wanted to build a T&F connection with newer technology ie. PTP White Rabbit
  - Originally designed at CERN and for max 10 km but this was ~ 800 km? Required changes to White Rabbit software to support extended latency.
  - We tested it with and alienwave, 1G DWDM SFPs and it just worked!
  - As far as we know, it was the first White Rabbit based long-haul link in the world and still running
- PTP White Rabbit bidirectional
  - Later and the current approach

Unidirectional T&F transfer



Espoo – Kajaani PTP White Rabbit link





ADVA FSP3000:

- 1G alienwave 195.90 THz
- Without CD compensation
- ~ 800 km

Bidirectional T&F transfer

Oulu – Kajaani link

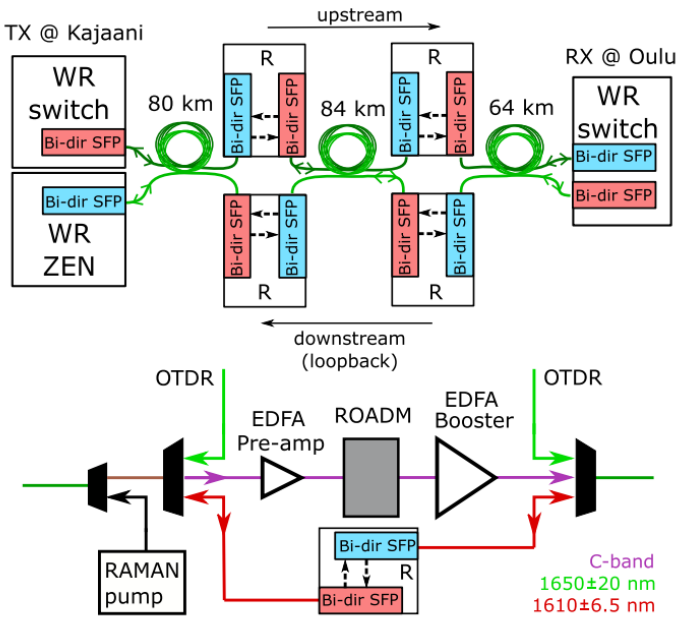


Fig. 2. Top: Schematics of the WR link with two repeater stations (R) based on bidirectional SFP transceivers (1605 and 1615 nm). Bottom: Schematics of the optical connections at a repeater station. OTDR: optical time-domain reflectometry. ROADM: reconfigurable optical add-drop multiplexer. WDM: wavelength-division multiplexer.

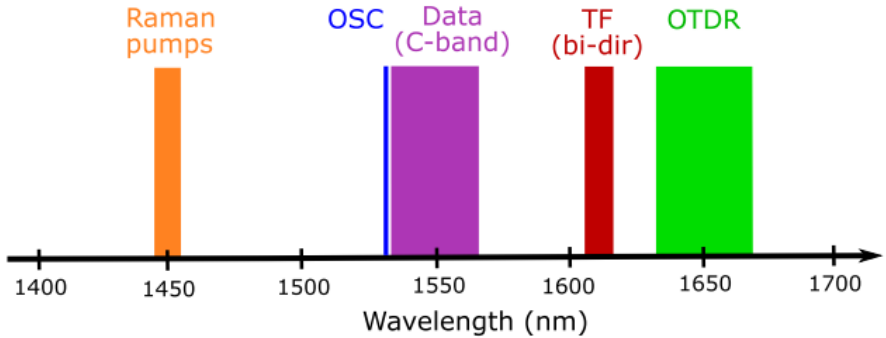
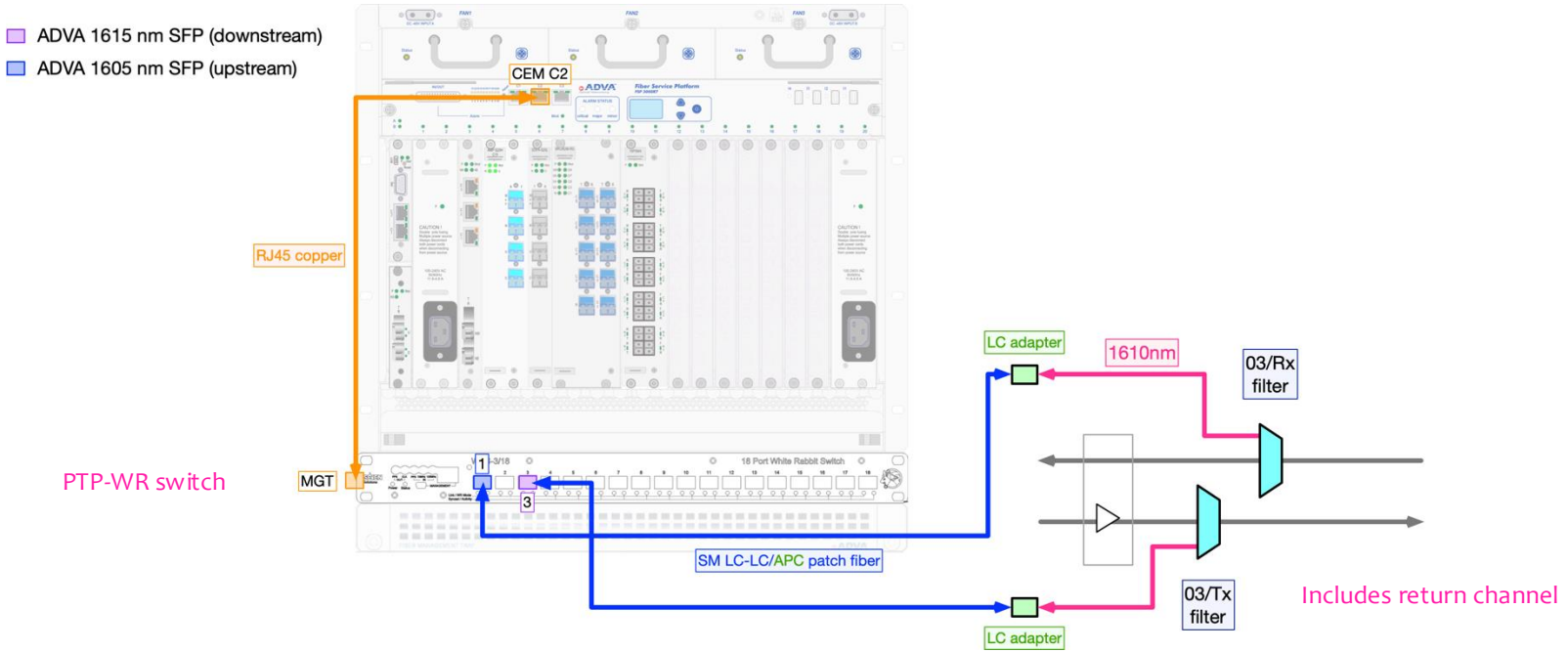


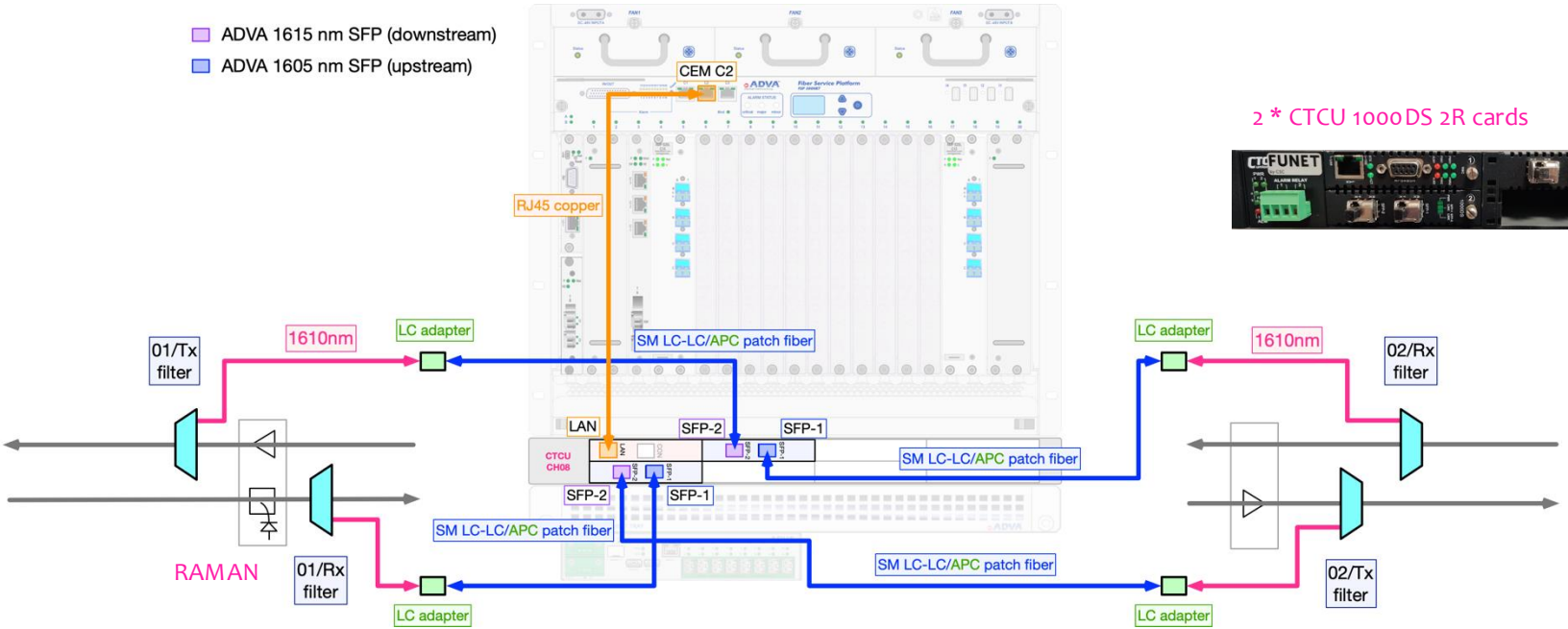
Fig. 1. Wavelength allocations in the FUNET. A similar structure is used in the SUNET [5]. OSC: optical supervisory channel. TF: time and frequency. OTDR: optical time-domain reflectometry.

[Fordell et al. 2023, https://ieeexplore.ieee.org/document/10110922]

Long-haul use case: Kajaani-Oulu bidi PTP-WR link (end-sites)



Long-haul use case: Kajaani-Oulu bidi PTP-WR link (ILA sites)

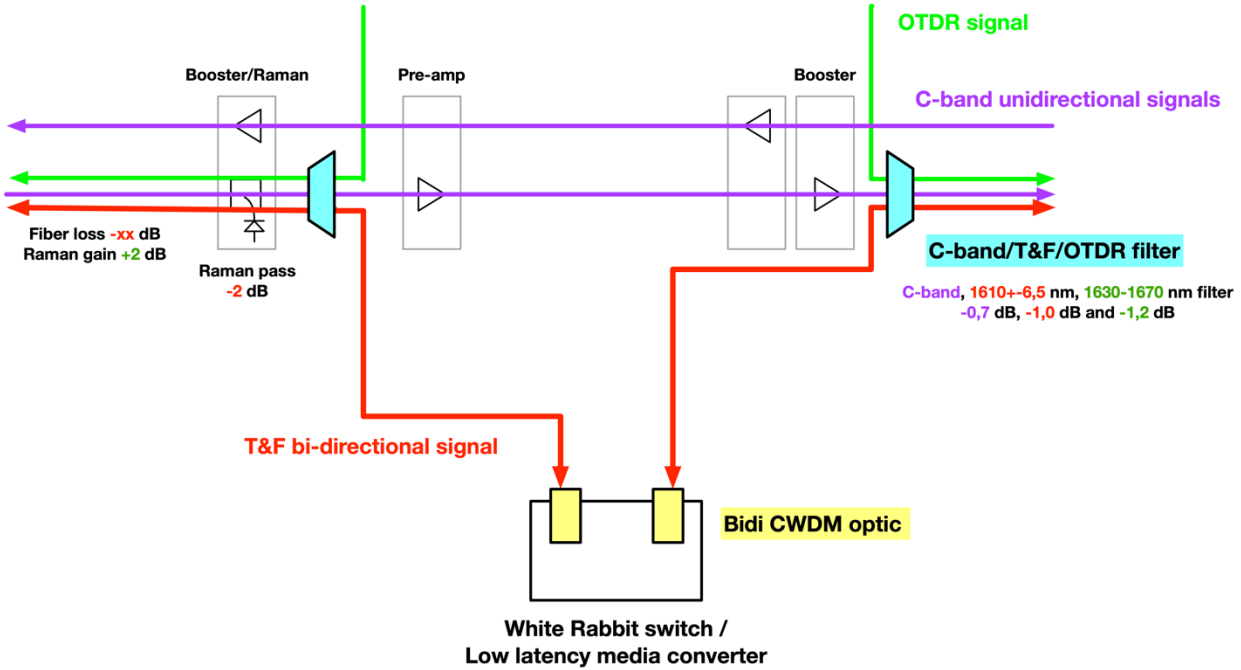


2 * CTCU 1000DS 2R cards

T&F filters used in the backbone

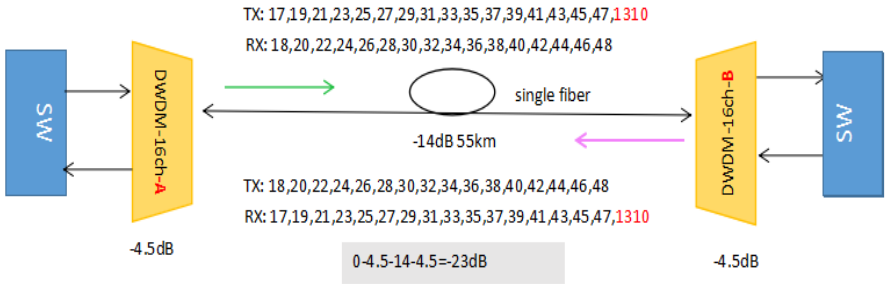
- Customized C-band (1525-1570 nm), T&F (1610 +-6,5 nm) and OTDR (1630-1670 nm) filter
  - 0,7 dB C-band loss (similar with existing OTDR filter)
  - 1,0 dB T&F loss
  - 1,2 dB OTDR loss
  - Fully bi-directional (no calibration needed)
- Very low CAPEX

T&F filters in a node (bidi Adtran optics)

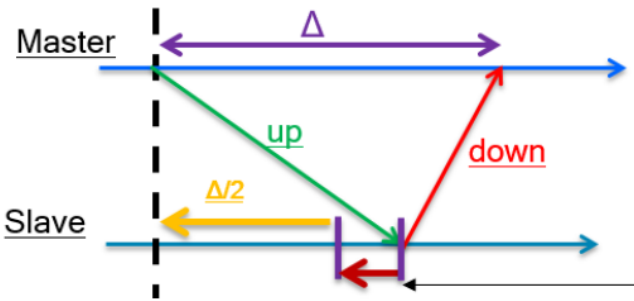


Metro use case: Espoo - Metsähovi T&F links

- A fiber pair (~55 km) splitted for two purposes:
  - One fiber for data traffic and another for T&F
- Connects VTT/Mikes and Metsähovi observatories
  - Aalto University, Finnish Geodetic Institute, National Land Survey



Asymmetry: Single fiber links are better



Correction to Δ/2

$$\frac{\propto}{2+\propto}\frac{\Delta}{2} \approx \propto \frac{\Delta}{4}$$

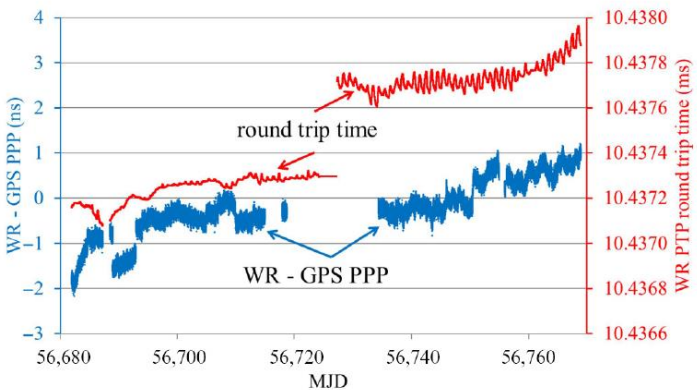
Propagation delay is taken to be half of round-trip time
Asymmetry in propagation times shows up as PPS offset
Dual fiber links: Length differences
Single fiber links: Chromatic dispersion

SFP standard/description	TX	RX	Asymmetry coefficient 'alpha' / PPM
1000BASE-BX10-D/U	1490 nm 1000BASEBX10-D	1310 nm 1000BASEBX10-U	250
	1550 nm	1490 nm	192
L-band BiDir optics from ADVA	1605 nm	1615 nm	37
10GBASE-BX, SFP+	1330 nm	1270 nm	14
L-band DWDM optics, spacing 100 GHz	1611.8 nm	1610.93 nm	3.9
C-band DWDM channels at 100 GHz spacing, 1000BASE-DWDM	ITU channels CH17-61 on Wavelength 1528.77-1563.86 nm	adjacent channel	~3
'below' C-band DWDM optics, spacing 100 GHz	1511.8 nm	1511.05 nm	2.2

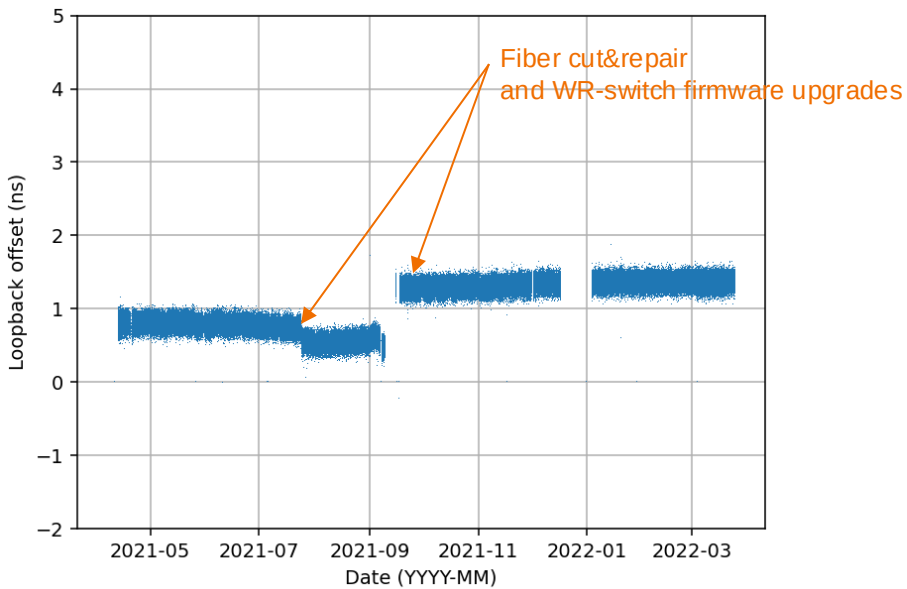
Source: Anders Wallin, VTT

Actual performance on VTT testbeds

950 km **dual-fiber** link: Espoo – Kajaani
asymmetries several microseconds, changing with fiber-cuts and repairs



Round-trip performance on **single-fiber** 200 km link:
Kajaani – Oulu (200+200 km with loopback)

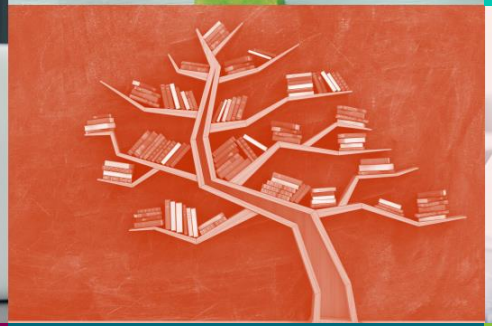


timing drift is about −80 ps during the first 102 days
and +140 ps during the last 16 months

E. F. Dierikx *et al.*, "White Rabbit Precision Time Protocol on Long-Distance Fiber Links," in *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control*, vol. 63, no. 7, pp. 945-952, July 2016, doi: 10.1109/TUFFC.2016.2518122. https://ieeexplore.ieee.org/document/7383303

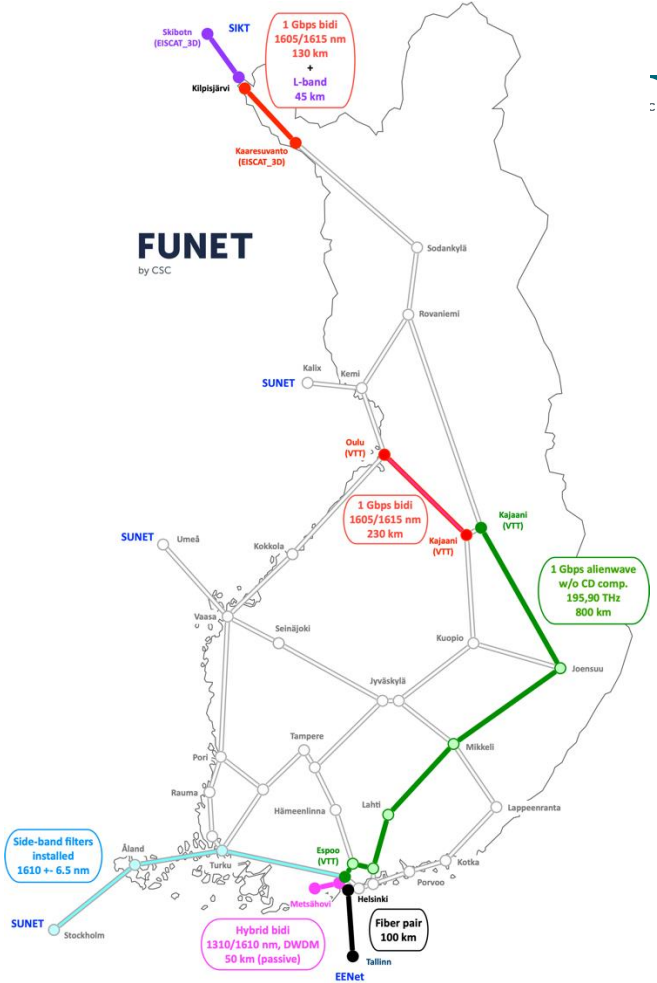
[Fordell et al. 2023, https://ieeexplore.ieee.org/document/10110922]

Overview of current and future links



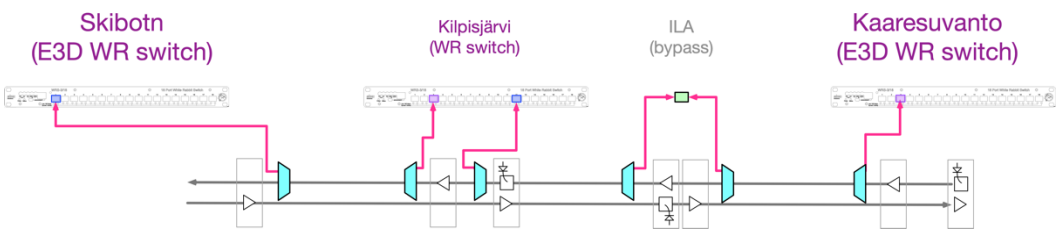
Current T&F services in Finland

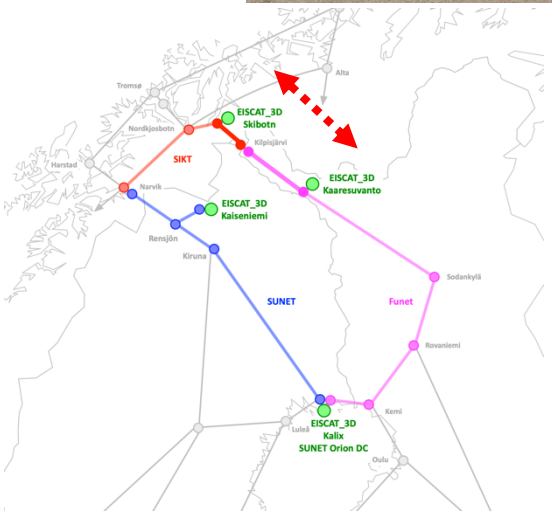
- Espoo - Kajaani PTP-WR unidirectional alienwave
  - 1 GbE DWDM pluggables
  - Connect VTT time labs
- Kajaani - Oulu PTP-WR bidirectional
  - Adtran 1605/1615nm bidi pluggables
  - Connect VTT sites
- Espoo - Metsähovi PTP-WR bidirectional
  - 1 GbE DWDM pluggables and single-fiber DWDM filters
  - Connect Metsähovi observatory to VTT time labs



Cross-border EISCAT_3D T&F pilot

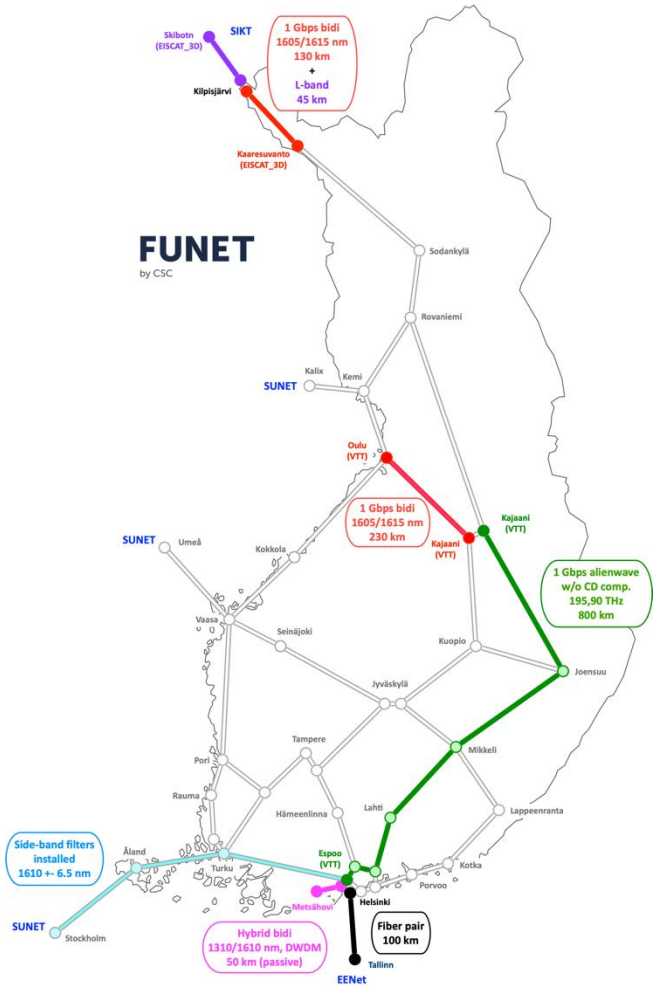
- Will connect EISCAT_3D sites in Kaaresuvanto, Finland and in Skibotn, Norway
  - Easiest and shortest span within the 1700+ km ring
  - Only single regeneration in a manned research station (Biological station in Kilpisjärvi)
- Will base on bidirectional signals on side-band filters at ~ 1600 nm
  - In Finland (Adtran OLS): Adtran bidi 1605/1615nm
  - In Norway (Nokia OLS): L-band DWDM or Adtran bidi 1605/1615nm (TBD)
- To be installed soon, equipment is ready





Other potential cross-border T&F links

- Finland - Estonia
  - Separate research fiber pair secured between Helsinki/Espoo and Tallinn, available soon
  - Greater extend of freedom to choose appropriate part of spectrum
  - Use cases: T&F, QKD and fiber sensing
- Finland - Sweden
  - Build-in sideband filters available (1610 nm) for T&F
- Getting sustainable funding probably the most difficult issue for cross-border links…



Optical T&F Network in National Research and Education Network

4.mars.2024

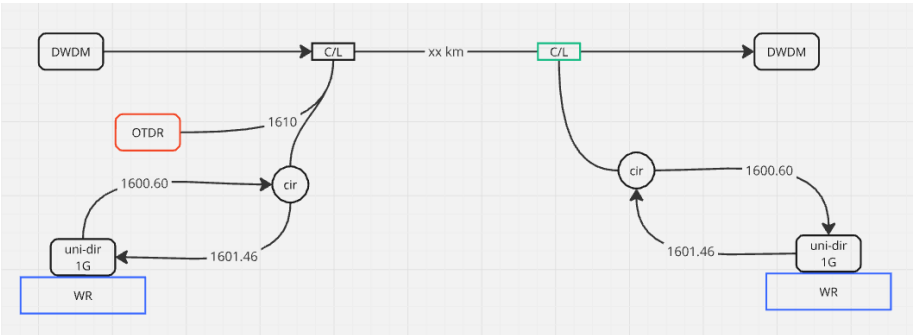
Teknisk møte om tid og frekvens 4. mars

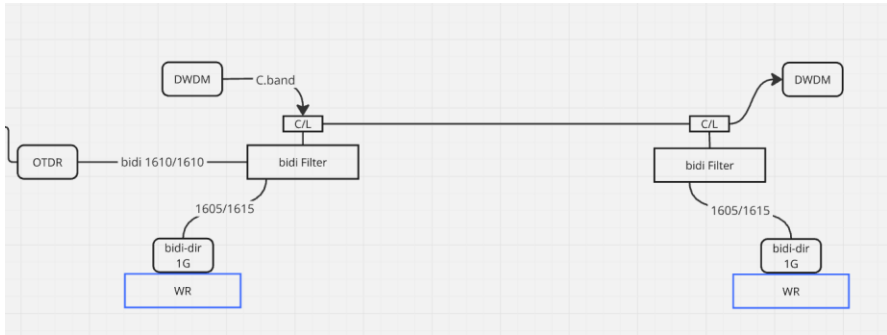
Kurosh Bozorgebrahimi
Raimena Veisllari

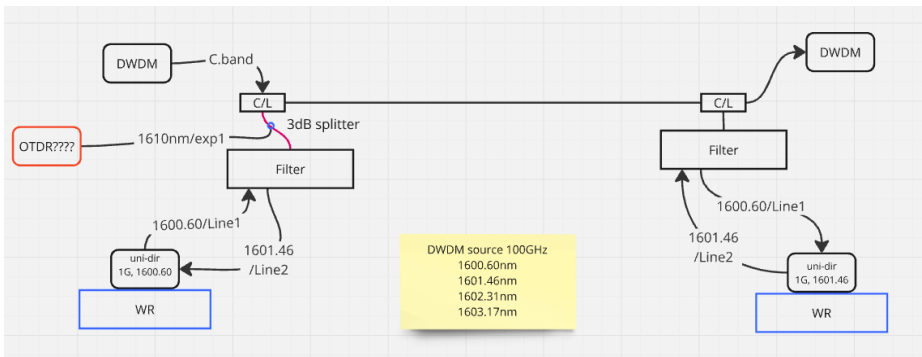
Sikt

Sikt and the current T/F activities

EISCAT challenges and possible solutions

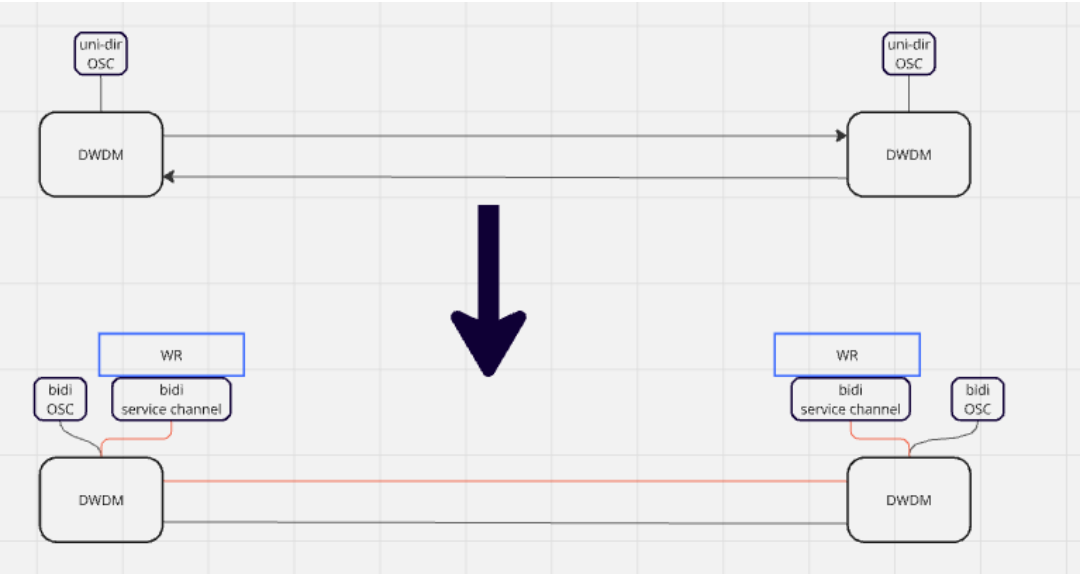






Sikt

EISCAT challenges and possible solutions



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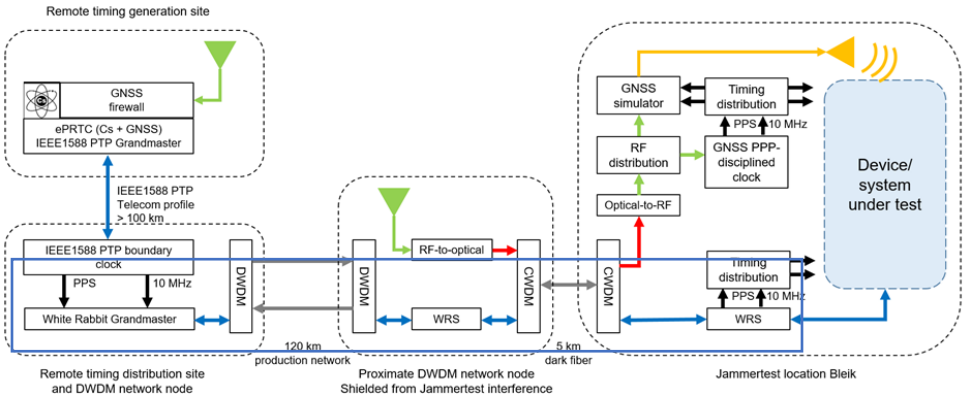
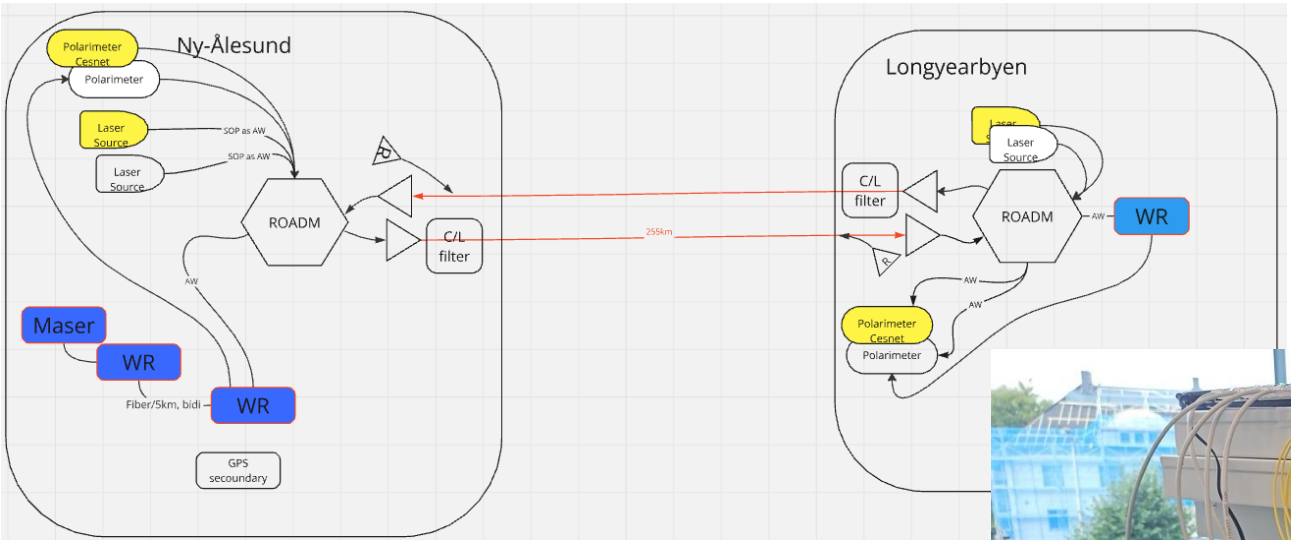
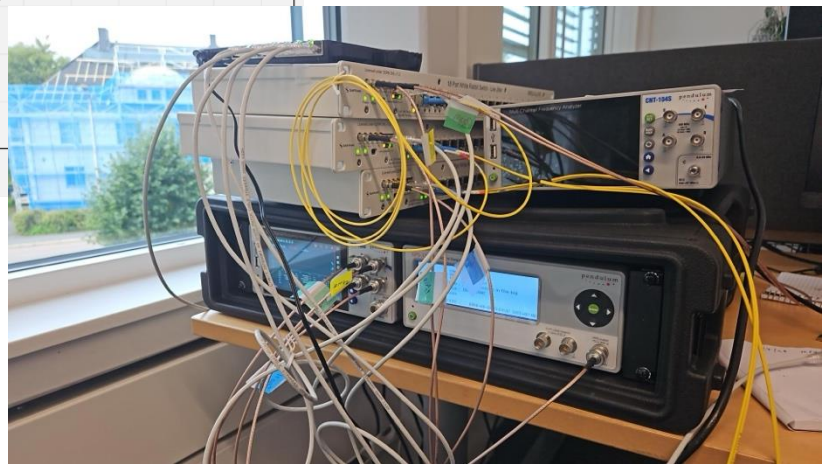
GNSS Attack Tests Andøya



Sikt WDM network with 3 white rabbit nodes

White Rabbit Field Trials in Svalbard





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